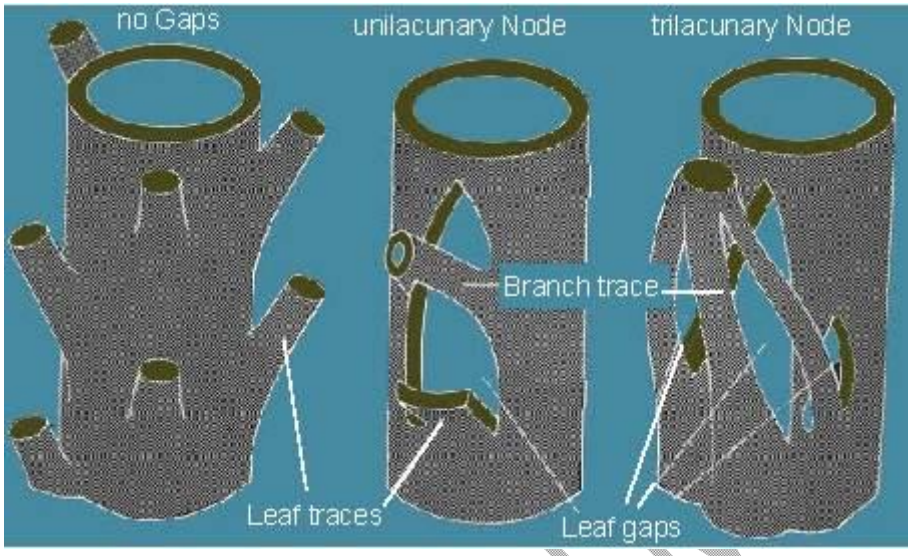
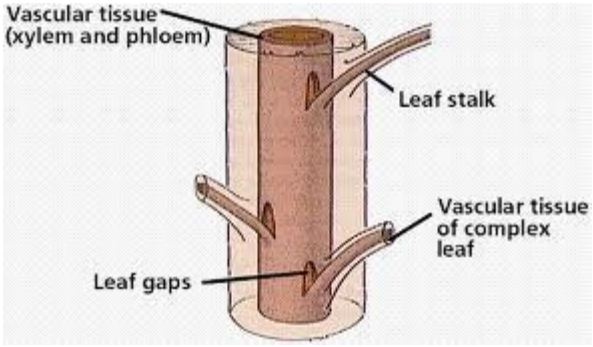
Type of Stelar System in Pteridophytes

All part inside endodermis are called stele. Endodermis is the boundary between cortex and stele. Therefore the pericycle xylem and phloem together is called stele. In Pteridophytes the stele is divided in to different type on the basis of arrangement of **xylem and phloem**. The stele of the stem remains connected with leaf and branch by a vascular connection known as the **leaf and branch supply**. Due to this region leaf and branch trace found in the cortical region and some time also found leaf and branch gape also found. The leaf trace is surrounded by endodermis. The gap is filled with parenchymatous tissue. The steles may be following two types:





Stele

Nonmedullated	Medullated
Pith is absent.	**Pith is present.**
Most primitive stele. 1.Protostele .	1. Siphonostele 2. Solenostele 3. Dictyostele

Protostele :

The xylem is completely surrounded by a layer of phloem. There are several forms of the protostele which are as follows:

a. Haplostele:
This is the most primitive type of protostele. Here the circular cylindrical xylem is surrounded by a layer of phloem, e.g., Salaginella sp.

b. Actinostele:
This is the modification of the haplostele. The central xylem core with star shaped appearance surrounded by the phloem, e.g., Lycopodium serratum, L. phlegmaria and Psilotum.

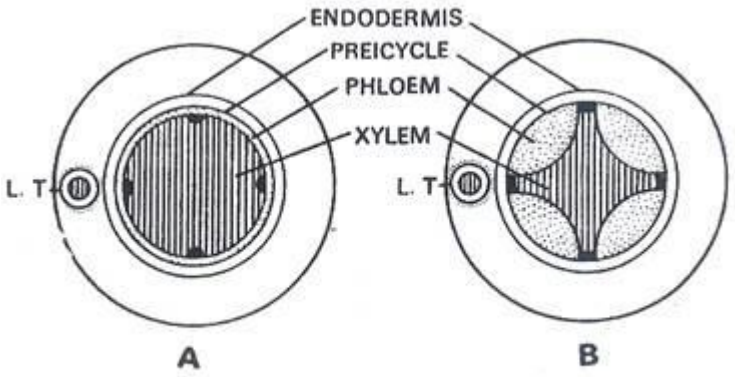


Fig. 32.2. Stelar system in ferns. A, haplostele; B, Actinostele.

c. Plectostele:

This is the most advanced type of protostele. Here the central xylem core is divided into a number of separate plates arranged parallel to each other surrounded by the phloem. e.g., Lycopodium clavatum

d. Mixed-protostele:

In this case xylum and phloem are uniformly distributed. The xylem is break up in to a small group and all surrounded by phloem. Most advanced among Protostele. This type is found in primitive fossils and living ferns. e.g.,L. cernuum and Osmunda sp.

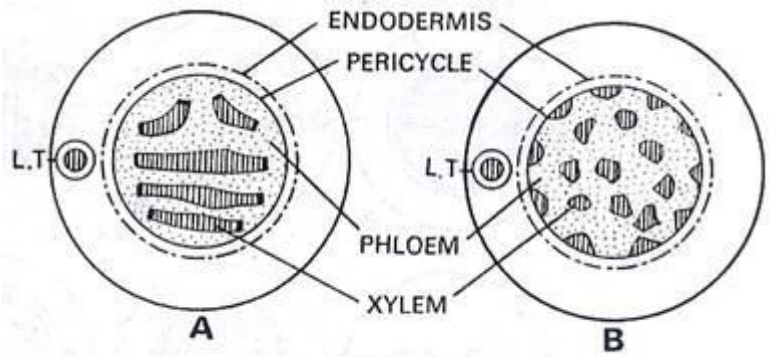


Fig. 32.3. Stelar system in ferns. A, plectostele; B, mixed

e. Polystele

Generally in a Protostele, the stem has a single stele in the center. But in **Selaginella**, the stem axis has several steles (di – stelic or polystelic). Each stele is a protostele with xylem core surrounded by phloem with pericycle and endodermis.

Siphonostele:

This is the modification of protostele. A stele in which the protostele contains parenchymatous pith in the center is known as siphonostele. In siphonostele leaf gap is absent. A siphonostele may be of the following types:

(i). Ectophloic: In this type of siphonostele, the pith is surrounded by xylem cylinder and xylem surrounded only on the outer side by phloem cylinder.

(ii). Amphiphloic: In this type of Siphonostele has central pith. Xylem is surrounded on both outer and inner side by ring of phloem e.g., Marsilea rhizome

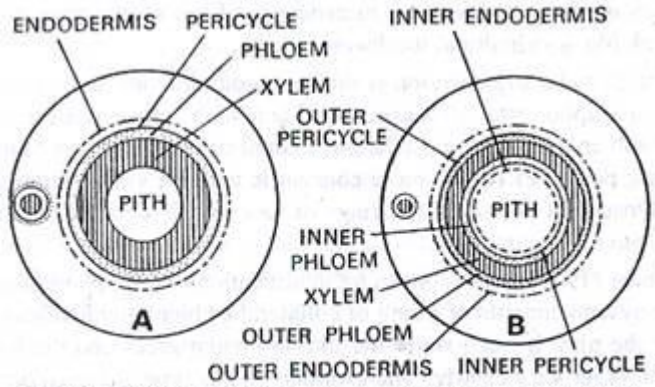


Fig. 32.5. Stelar system in ferns. A, ectophloic siphonostele; B, amphiphloic siphonostele.

Solenostele:

In Solenostele found pith and one leaf gape. It may be ectophloic or amphiphloic solenostele.

(i) Ectophloic solenostele- Xylum is surrounded by only on the outer side by phloem.e.g. In Osmunda

(ii) Amphiphloic solenostele- In center found a pith. Xylum is surrounded on both sides by phloem.e.g. Marselia rhozome

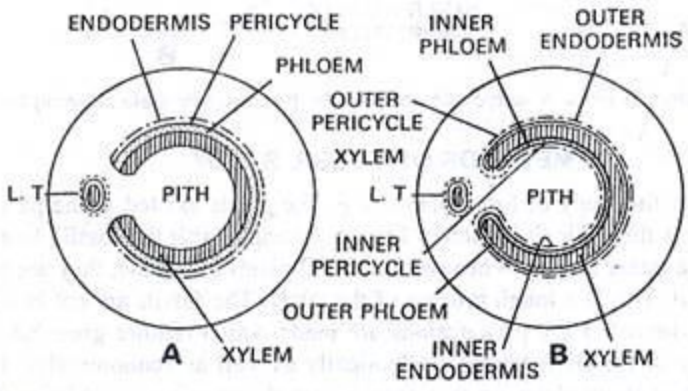


Fig 32.6. Stelar system in ferns. A, ectophloic solenostele; B, amphiphloic solenostele.

D. Dictyostele:

It is the more advanced stele. It contains overlapping leaf gaps. The portion of vascular tissue which lies in between two gaps is termed as Meristele. Each meristele is protostelic in nature.

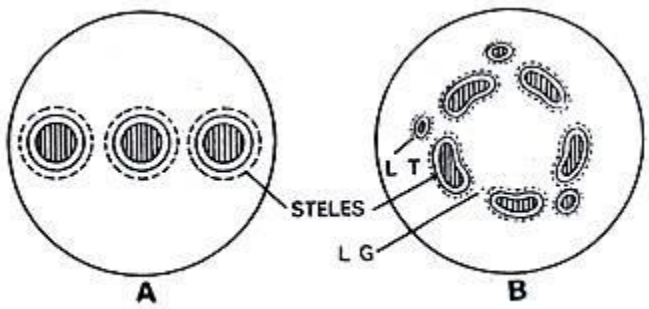


Fig. 32.7. Stelar system in ferns. A, polystelic stem; B,

Primary and secondary xylem

Primary xylem is the xylem that is formed during primary growth from procambium. It is two type protoxylem and metaxylem. Metaxylem develops after the protoxylem. Metaxylem has large vessels and tracheids than protoxylem.

Secondary xylem is the xylem that is formed during secondary growth from vascular cambium. Secondary xylem is found in members of the "gymnosperm"and "Angyosperm".

Arrangement of protoxylem and metaxylem

In a young vascular plant the primary xylem found one or more strands in stems and roots. There are four main patterns to the arrangement of protoxylem and metaxylem in stems and roots.

- *Centrarch* refers to the case in which only one strand of primary xylem, present in the center of the stem and develops from the center. Thus protoxylem is found toward central core and the metaxylem toward the periphery.

The other three terms are used where there is more than one strand of primary xylem.

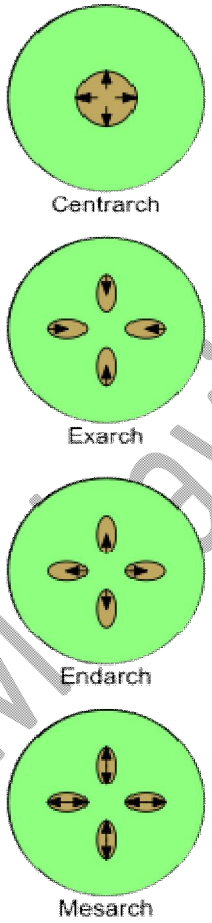
- ***Exarch*** is used when there is more than one strand of primary xylem in a stem or root, and the xylem develops from the outside inwards towards the center, i.e. centripetally. The metaxylem is thus toward the center of the stem or root and the protoxylem toward the periphery. The roots of vascular plants are normally considered to have exarch development.

- *Endarch* is used when there is more than one strand of primary xylem in a stem or root, and the xylem develops from the inside outwards towards the periphery, i.e. centrifugally. The protoxylem is thus closest to the center of the stem or root and the metaxylem closest to the periphery. The stems of seed plants typically have endarch development.

- *Mesarch* is used when there is more than one strand of primary xylem in a stem or root, and the xylem develops from the middle of a strand in both directions. The metaxylem is thus on both the peripheral and central sides of the strand with the protoxylem between the metaxylem. The leaves and stems of many ferns have mesarch development.

On basis of number of group of protoxylem the primary xylem is following type

1. **Monarch-** When protoxylem present only one group.
2. **Diarch-** When protoxylem present in two groups.
3. **Triarch-** When protoxylem present in three groups.
4. **Polyarch-** When protoxylem present in mor then six group.



Pteridophyta

The word cryptogams means that the plant produce by spore and do not produce by seed. The algae fungi bryophytes and pteridophytes are all cryptogams. The Pteridophytes are vascular cryptogams because they have well developed conducting system. The lower cryptogams (algae, fungi and bryophytes) have no conducting system. The term Pteridophyta also has a Greek origin. Pteron means a "feather" that is they have pinnate or feather - like fronds (leaf containing mega or micro spore and contain unbranched midrib called fronds or foliage leaf). Late Paleozoic regarded as the **"age of Pteridophyta".**

Characteristic Features:

A. Sporophytes (Diploid phase)–

- The main plant body is a sporophyte which is differentiated in to root, stem, rhizome (underground stem) and leaves.
- Pteridophytes are herbaceous except a few tree fern. They have dichotomously (the type of branching in plant in which the growing point or apical bud divided in to two equal branched which in turn dived in a similar manner after a period of growth) branched stem.

- The plant may be **homosporous** (only one type of spore) like Lycopodium and Equisetum or **heterosporous** (produce two type of spore megaspore and microspore) like Selaginella and Marsilea.
- The haploid spore is produce in special type of structure called sporangia. The leaf contains sporangia called sporophylls. When sporophylls compacted in distinct region then they called **cone or strobius** (Selaginella and Equisetum). In some cases the sporangia produce in special structure called **sporocarps** (Marsilea).
- The development of sporangia may be **eusporangiate** (sporangium develop from agroup of cell), e.g. Lycopodium, Selaginella, Equisetum. Or **leptosporangiate** (sporangium develop by a single cell) type, e.g. Marsilea.

B. Gametophyte –

- The haploid spores germinate and produce **prothalli** (gametophytes stage). It is independent from sporophyte. It is may be autotrophic, saprophytic, partialy autotrophic or partial saprophytic. The time period of the gametophyte is comparatively smaller then sporophyte.
- The sex organ develops on the prothalli. The male sex organ is called **antheridium** and female sex organ is calle **archegonium**.
- The male gamete is called **antherozoid** and female sex organ is called **egg**.
- The homosporous Pteridophytes have monoecious (that is male and female sex organ separate on the same prothalli) prothalli. They may be protandrous (male sex organ mature before female sex organ) or protogynous (female sex organ mature before male sex organ). The heterosporous Pteridophytes have dioecious (that is male and female sex organ on the separate prothalli).
- The archegonia have four longitudinal row of **neck cell** whose height varies from two to six cells and it has one to fourteen **neck canal cells**.
- The water is always needed for fertilization. The antherozoid and egg fuse to form diploid oospore which act as mother cell of the sporophytic generation.

Alternation of Generations

In Bryophyte and Pteridophytes there are two type of morphologically distinct individuals found in the life cycle. Both individual come alternate in the life cycle. Some event shows that one generation produce to other generation. Strasburger discovered the process of meiosis in pteridophytes. He says that pteridophytes plant produced a new individual after reduction in chromosome number. This new individual has haploid number of chromosome. It bears sex organs and produces gametes and related with sexual reproduction. He gives the name gametophyte generation. The haploid gametes fertilized and form diploid cell called zygote. Zygote is a pioneer structure of diploid individual or sporophyte individual. Zygote germinates and form sporophyte individual. This generation is known as sporophyte generation. The sporophyte individual contains sporangia which produced spore after meiosis. The spores are the pioneer structure of the haploid individual or gametophyte individual. The spores germinate and produce gametophyte individual known as prothallus. Therefore two generation come in alternate in their life cycle therefore the meiosis and syngamy is the “switch on” in the life cycle from one generation to the other.

Rhynia

The genus rhynia has only two species R. gwynne vaughanii and R. major discovered by Kidston and Lang from the village of Rhynie of Northern Scotland which occur as fossils. They are as petrified

fossil (dead and decay and become hard stone after a long period). The age of fossil is about 315 million year (middle Devonian era). This plant is known as primitive vascular plant.

Habit and Habitat:

The fossil evidences suggested that these plant were found in swampy (very wet covered with water and plant) and marshes (low land area) near the volcanoes. Where the atmosphere surrounded by sulphur vapour and the soil is saturated with acid water.

External Features of sporophyte

- The sporophyte is differentiated in to rhizome and erects aerial branches.
- The aerisl branch of R. gwynne were 20cm long and R. major were 50cm long
- Root is absent and at the place of root rhizoid is found in group or patches.
- The aerial shoot was erect dichotomously **without leaf**. The apex of most branches change into sporangia.

T.S. of Aerial Shoot and Rhizome

The internal structure of aerial shoot and rhizome were generally similar.

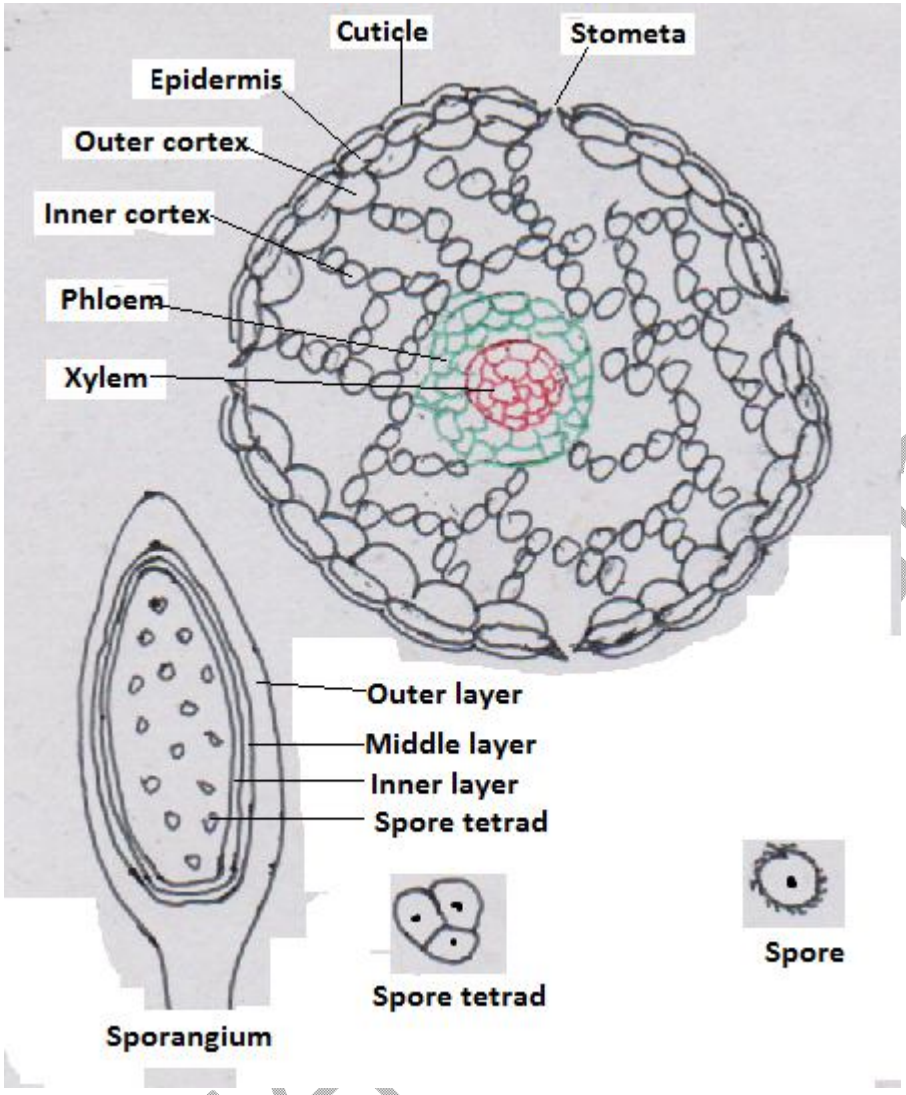
- Internally it is differentiated into **epidermis, outer cortex, inner cortex and stele.**
- **Epidermis** is a single layered and stomata present at several place. It is surrounded by cuticle.
- **Cortex** is differentiated in to outer and inner cortex.
- **Outer cortex** is made up of angular parenchymatous cell. Intercellular spaces are absent. It is also known as hypodermis.
- **Inner cortex** made up of round parenchymatous cell. Intercellular space is present. This region is green and photosynthetic.
- **Endodermis and pericycle** is absent.
- **The stele** is protostele (haplostele) i.e. Xylem is surrounded by phloem.

Reproductive Structures:

The terminal part of aerial shoot is modified in to sporangium which meant for spore production. The sporangium was born singly on the apex of some aerial branches. The sporangium may be oval or cylindrical.

L.S of sporangium

- The sporangium was broad in middle and conical at tip.
- The wall of sporangia contain three layer the cell of outer layer (epidermis) was thick-walled and cutinized. The cell of middle layer was thin-walled. The cell of inner most layer was thin-walled and rounded called tapetum.
- The columella was absent.
- In central portion found a cavity filled with numerous spores in tetrads form.
- All the spores were only one type showing homosporous condition.
- The sporangium lacked any special device for dehiscence.



Gametophyte

The gametophyte of Rhynia is unknown. Some are suggested that the sporophytic axes were gametophyte. But Spore did not favor because these structure were without archegonia and antheridia. According to Merker rhizome of Rhynia represent gametophyte it contain both sex organ male and female. Pant says that R. gwynne- vaughani was gamitophytic phase of R. major and suggested that some stomata of rhizome work as archegonia.

Genus - LYCOPODIUM (Club moss)

The genus is represented by about 180 species. L. cernuum, L. clavatum, L. phegmaria etc are reported in India.

Habitat:

- Most of the tropical specie are epiphyte and grow hanging from tree trunk e.g. L. phlegmaria.
- The temperate species grow in moist and acid soil L. reflexum. This is erect and shrubby form.
- L. clavatum and L. cernuum are creeping form. The creeping forms give out erect branches at intervals. The creeping stem may be above or underground (rhizomes).

External features (Sporophyte) of Lycopodium:

- The plant body is differentiated in to stem, roots and leaves.
- The stem is creeping underground rhizome with aerial branchs. It gives dichotomously branch.
- Leaves are simple sessile with entire margin and single median vein.
- Root is adventitious and arises from the creeping rhizomes. It gives dichotomously branch.
- The leaves are dense and spirally arranged.
- The tip of apical part of branches terminates in to strobili or cone. The strobili contain leaf like structure called sporophylls with serrate margin. It is smaller than foliage leaf.
- The sporophylls found on the cone axis and contain sporangia.

Internal structure of sporophyte:

T.S. of stem of L. clavatum- The outline of cross section contain ridge. The T.S of L. clavatum stem differentiated into following part.

Epidermis:

- It is a single layered and surrounded by cuticle.
- It is interrupted by stomata.

Hypodermis (Exodermis):

- It is present bellow the ridge only. It is made up chlorenchymatous tissue.

Cortex:

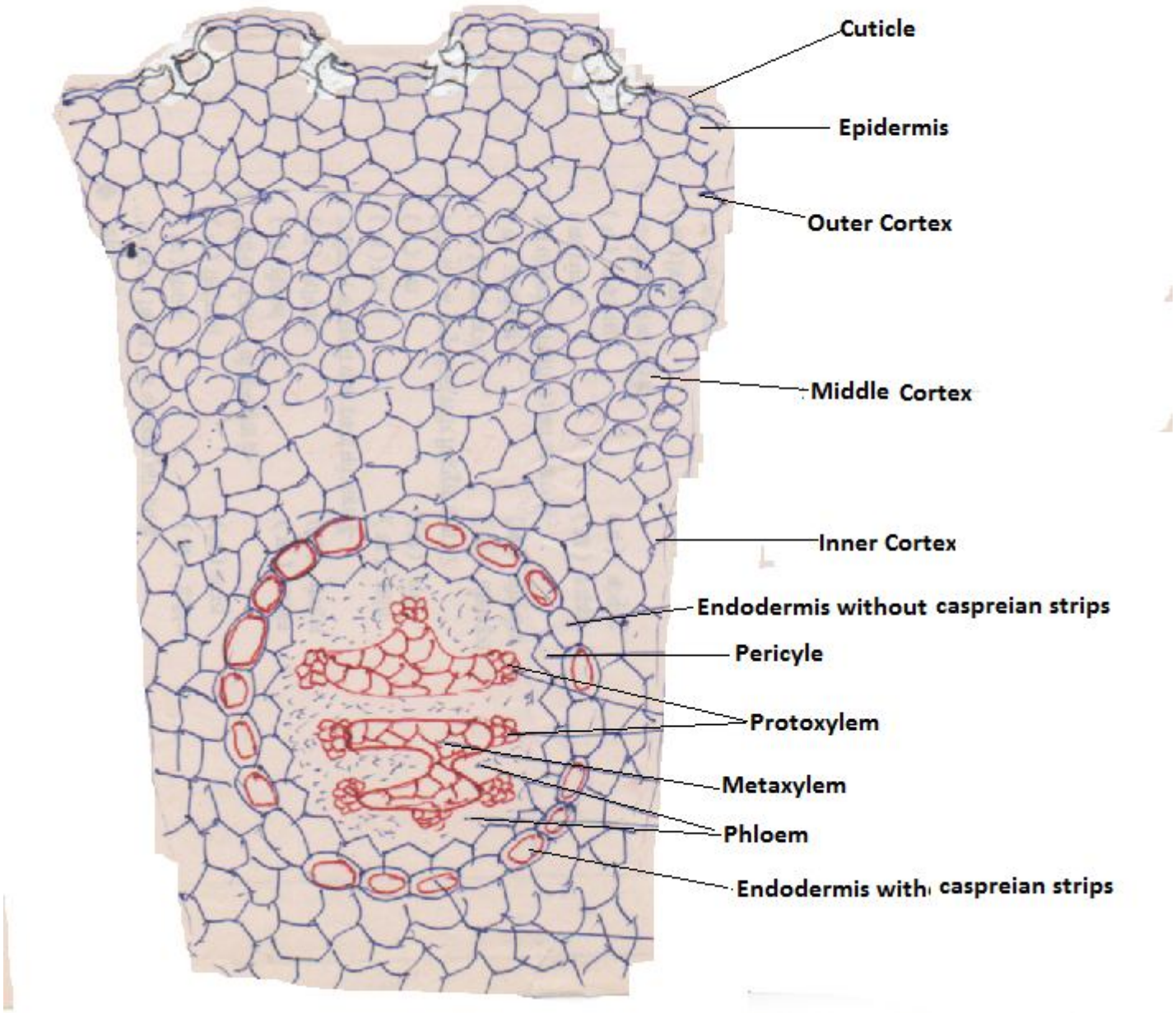
- It is differentiated in to outer, middle and inner cortex.
- The outer and inner cortex is thick wall sclerenchymatous and without intercellular space.
- The middle cortex is thin wall parenchymatous.

Endodermis:

- The cortex is followed by endodermis. The cell of endodermis contains casparian strips (casperian strips is a band of suberin an impermeable substance found in the endodermal cell).

Stele:

- Stele is surrounded by pericycle. The stele is protostele i.e. xylem is surrounded by phloem without pith.
- The xylem is exarch i.e. metaxylem present in center and protoxylem towards periphery.
- Xylem is plate like i.e. stele is plectostele.



T.S of root of Lycopodium- The outline of cross section is circular. The T.S. of L. cavatum is differentiated in to following part.

Epiblema:

- It is outermost layer of root.
- Some cell of epiblema divided by oblique walls and give rise to unicellular root hair. Thus the root hair arises in pair.

Cortex:

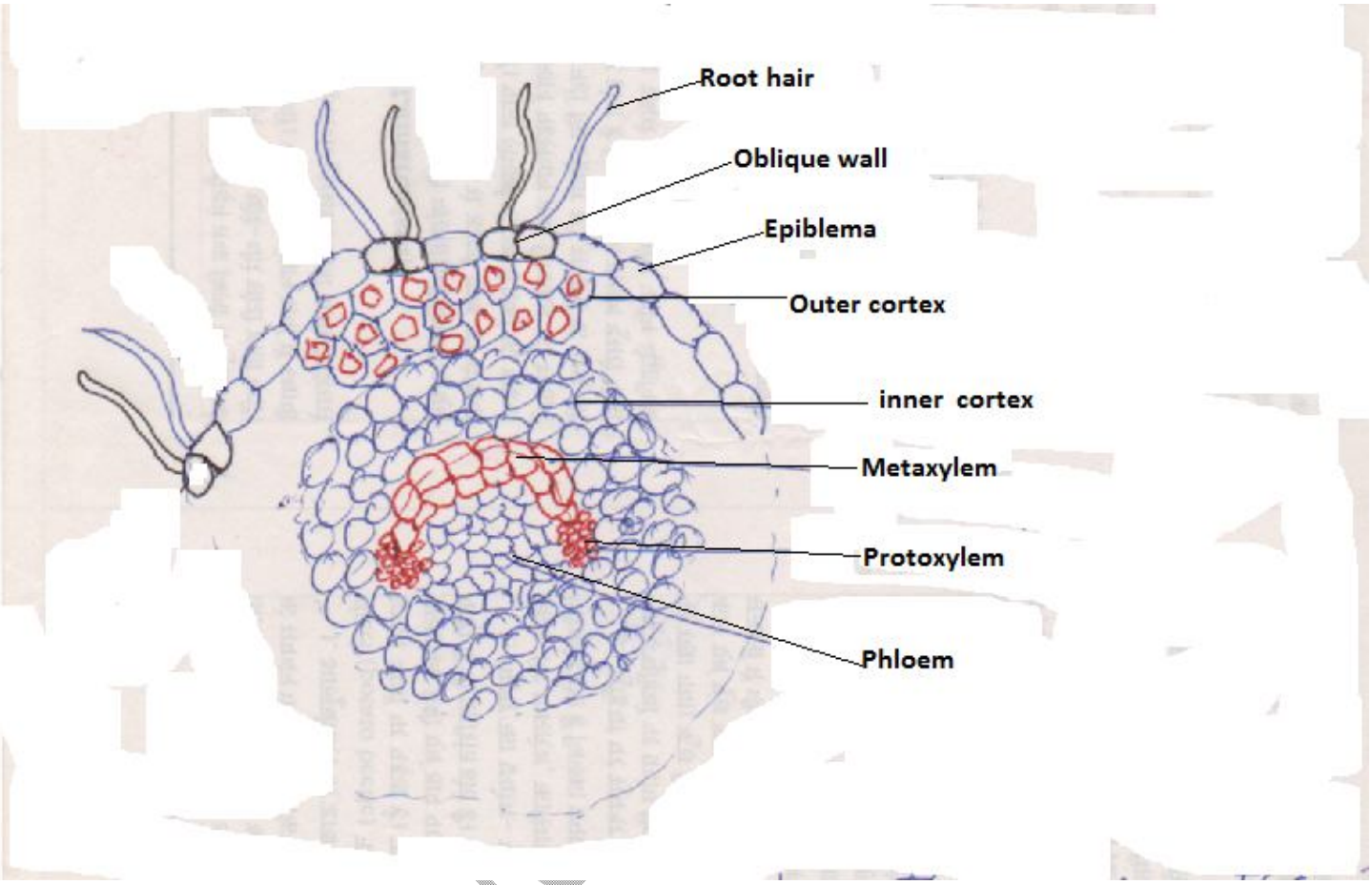
- The cortex is differentiated in to outré and inner cortex.
- The outer cortex is parenchymatous and the inner cortex is sclerenchymatous. In L. selago the outer cortex is sclerenchymatous and the inner cortex is parenchymatous.

Endodermis & Pericycle:

- Endodermis and peericycle is not clear.

Stele:

- The stele is protostele i.e. xylem is surrounded by xylem.
- Xylem is diarch and exarch i.e. metaxylem in center and protoxylem toward periphery.

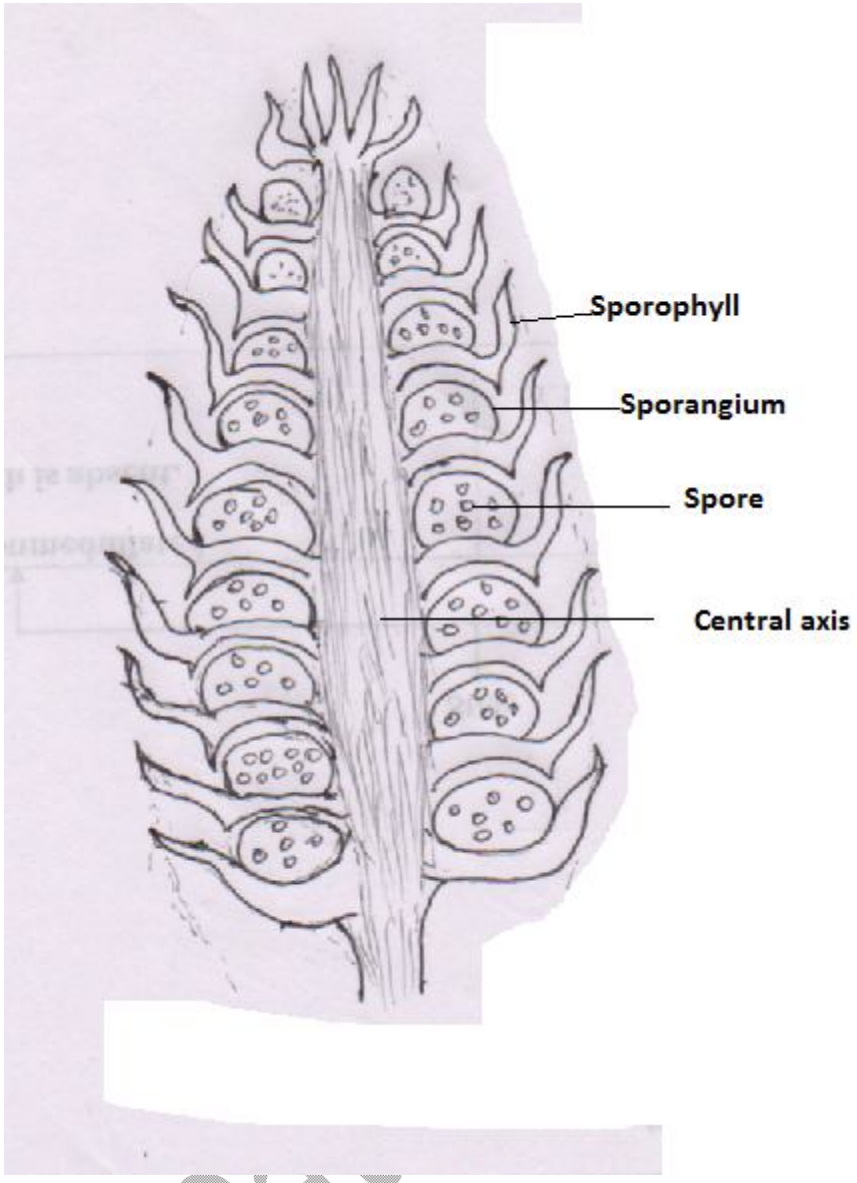


L.S. of strobilus of Lycopodium:

- The cross section shows a long central axis on which sporophylls arranged.
- The position of sporangium may be axillary, i.e. in the angle between the sporophyll and cetral axis but in L. clavatum and L. cernuum sporangia present on the adaxial (ventral) surface of sporophylls.
- Each sporangium is bean or kidney shaped, non septate, short stalked and brown to black or orange to yellow in coloured.
- The sporangium wall is multilayered and the inner layer is called tapetum. Tapetu provide nutrition to sporangia.
- Sporangium contains many spores. The spore is same i.e. homosporous condition.

Dehiscence of sporangium:

- The central axis elongated then sporsngum exposed.
- The sporangial wall contain thin wall cell called stomium.
- The exposed sporangial wall loss water then the sporangial wall split from stomium and the spore scatters from air current.
- The spore is the first stage of gametophyte.



Structure of Gametophyte:

- The spore is the first stage of gametophyte.
- The inner wall of spores contains fat and oil as reserve food material and use in development.
- The spore wall rupture and two celled prothallus projected out. Now symbiotic fungal hyphae (member of phycomycetese) inter into prothallus cell. It supplies certain nutrient for development of prothallus.
- Later mature multicellular prothllus develop.

Structure of mature prothllus:

- In Lycopodium prothallus is bisexual.
- It contains many unicellular rhizoids.
- The sex organs (antheridia and archegonia) are produce on the upper surface of prothalii.

Type of prothallus:

- Three type of prothallus are found in Lycopodium species.
  (1) Cernuum type (2) Clavatum type (3) Phlegmaria type

Cernuum type (First type):

- It is erect cylindrical body about 2-3mm long and grows on the surface of the ground.
- The cylindrical prothallus divided in to upper crown and lower base.
- The lower base contains rhizoid and also contains endophytic fungus.
- On the crown found many lobes. In between lobed found sex organ at base.
- The cells of crown contain chlorophyll and lower base is colourless.
- The sex organ develops from the meristem.
- The portion of prothallus bearing sex organs is called generative zone. This zone lacks of fungal hyphae.

Clavatum type (Second type):

The proyhalli are the **saprophytic** nature because it is yellow brown or colourless.

- They are may be top-shaped, carrot shaped or conical.
- They have two distinct region:- (1) lower conical region (2) upper broad generative region

(1) Lower conical region- it is divided in to four layers.

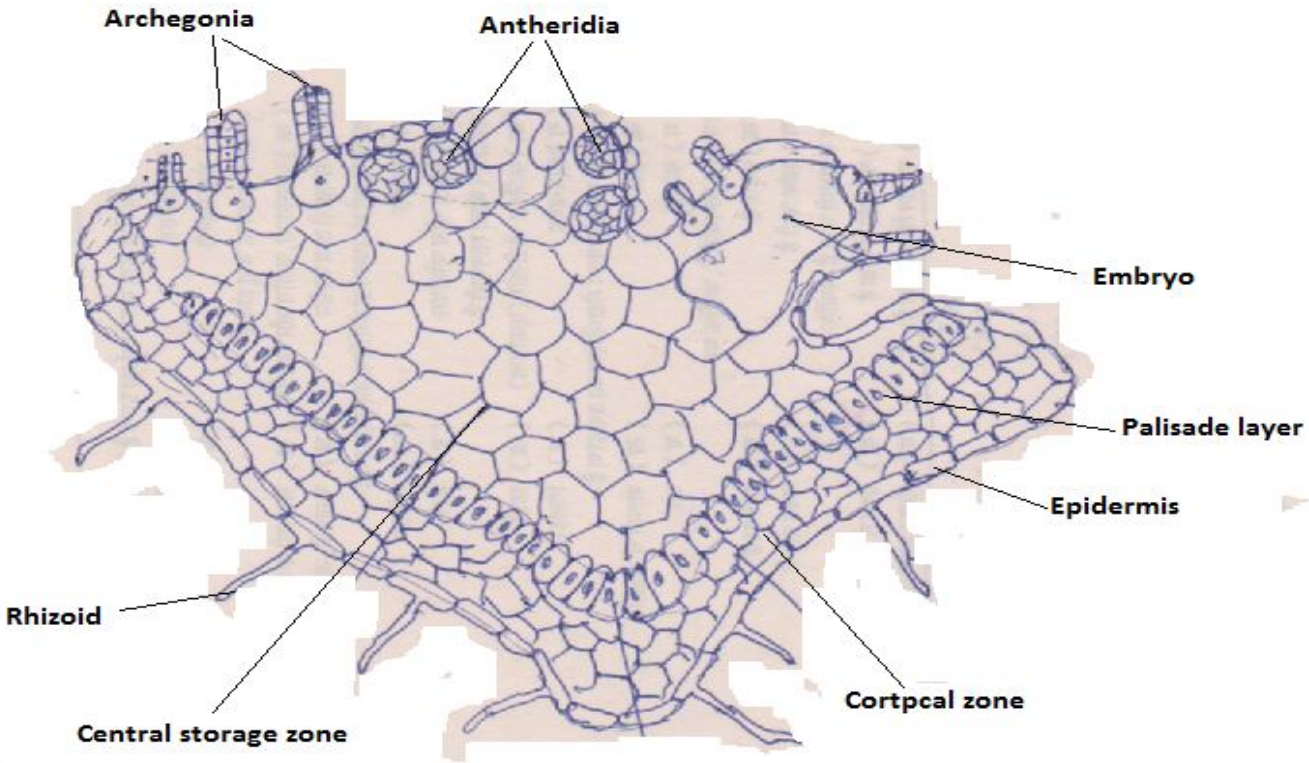
(a) Outer epidermis- It contain many rhizoids.

(b) Cortical zone- It is made up of parenchymatous cell and filled with endophytic fungal hyphae.

(c) Pallisade zone- It is also contain fungal hyphae.

(d) Cortical storage zone- It's call is filled with storage food.

(2) Upper broad generative cell- It bears sex organs on it flattened surface. The archegonia are found near the margins and the antheridia are located centrally.



L. clavatum

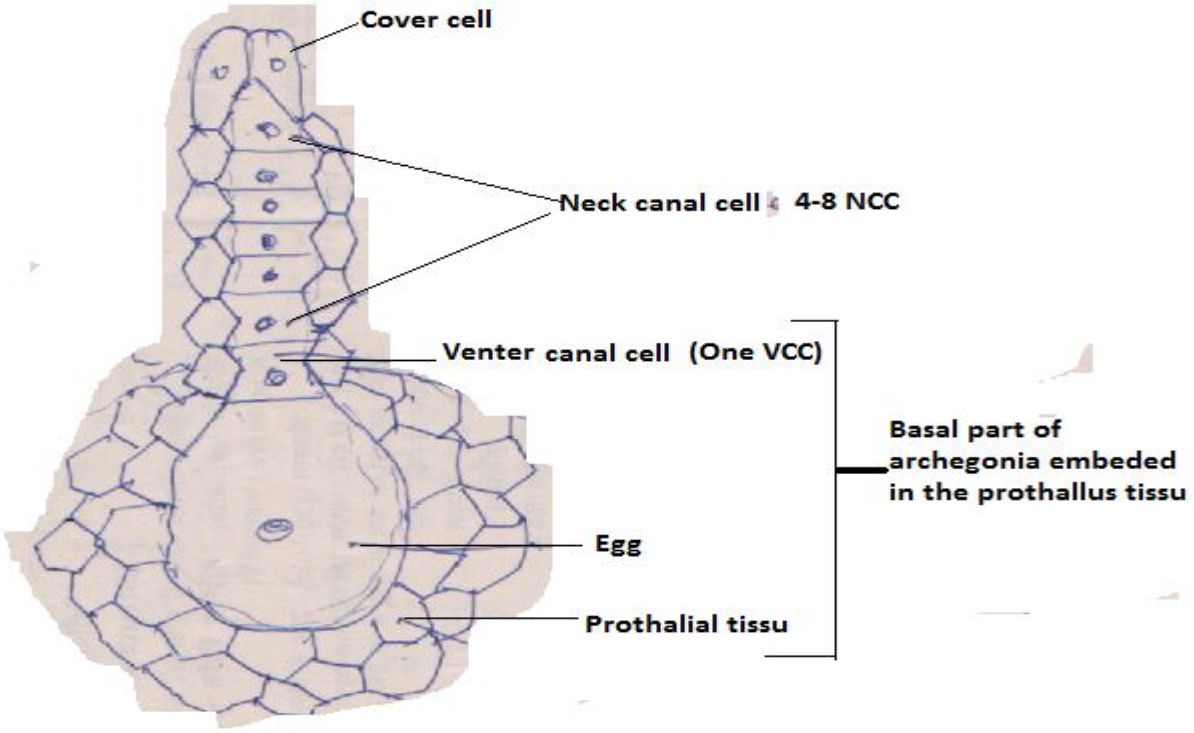
Sex organs:

- Prothallus of Lycopodium is monoecious.
- The sex organ is protandrous.

Antheridia:

- The antheridia present near the marginal and embedded in tissue of prothallus.
- Antheridial wall contain **opercular cell**.
- Antheridia contain many biflagellate anthrozoids.
- Antheridia swell after absorb water and rupture from opercular cell. Therefore antherozoid liberated.

Archegonia:



Fertilization: When archegonia mature then neck canal cell and venter canal cell degenerate & change in to mucilaginous substances which attract antrozoid fused to egg cell & form oospore. The oospore act as mother cell of next sporophytic generation.

Protocorm:

- The morphological nature of protocorm is controversy.
- Treub say that protocorm is a ancestral structure present in some Lycopodium for some time. It must have been present in ancestral vascular plant.
- Bwer say that it grow in a particular environmental condition in some species of Lycopodium. It serves only to establish the young sporophytes in soil.
- According to Holloway protocorm is a specialized structure that help the sporophyte to carry the plant over the dry season.
- Browne says that the protocorm is a modification of reduced stem.

- According to Wardlaw protocorm is a modification of shoot. He say that development of protocom depend on metabolic condition of young sporophyte. In case embryo received a balanced nutrition and C/N ratio is normal then the embryo produce no swelling and produce normal leafy shoot. In case embryo received unbalanced nutrition and C/N ratio is high then the young sporophyte produce protocorm.

SELAGINELLA

- The genus is represented by about 700 species. Out of which about 70 species have been reported in India. Some common species are S. kraussiana, S. trachyphylla, S. selaginoides, S. rupestris and S. lepidophylla etc.

External features of Sporophyte:

- On the basis of sporophytic structure genus is divided in to two sub genera (1) Homoeophyllum (2) Heterophyllum.
- The genera which contain only one type of leaf is called homoeophyllum e.g. S. rupestris. In this genera stem is radially and dichotomously. The leaves are spirally arranged.
- The genera which contain two type of leaf (dimorphic) are called heterophyllum e.g. S. lepidophyllum. In this genera the stem is dorsiventral and dichotomously. The leaves are present in two rows on ventral side and two rows on dorsal side of stem. In alternate arrangement. The ventral leaves are large then dorsal leaves.

Figure

- All leaves are containing ligule attached at base toward ventral (adaxial) side.
- The plant body is differentiated in to root, rhizophore, stem and leaves.
- Root is adventitious and arises from the terminal end of rhizophore.

Structure of ligule:

- The ligule is characteristic feature of genus Selaginella and class ligulopsida.
- The ligule is a membranous toungue-like structure present at base toward ventral (adaxial) side.
- It is internally differentiated into two part (i) glossopodium and (ii) the body.
- Glossopodium surrounded by glossopodium sheath at base. The sheath is embedded in the tissue of leaf.
- The body of ligule is made up of polygonal parenchymatous cell.
- The function of ligule is unknown but it is believed that it secret mucilage.

Rhizophore:

- It is present in most of the dorsiventral Selaginella. It's morphological nature is controversial.
- It is arise from meristematic tissue present between the two branches of stem.
- The number of rhizophore at each branch may be one in S.kraussiana or two in S.martensil.
- It grows down word toward ground and produces a small tuft of adventitious root at their tip.

Morphological Nature of Rhizophore:

The morphological nature of rhizophore is controversial. There are three views given on morphological nature of rhizophore:

1. Rhizophore is capless roots

- They are positively geotropic.
- They are leafless and do not bear root.
- The anatomical organization is similar to root.
- It contains monostelic even if the stem is polystelic.

2. Rhizophore is stem

- They lack root cap and hairs.
- They develop from special meristem called angle meristem that is present between the two branches of stem.
- Under experimental experiment rhizophre grow into a shoot.

Internal structure:

T.S. of Stem:

The outline of section may be wavy or flat. It shows following structure-

Epidermis:

- It is single layer and covered by a thin layer of cuticle.
- Stomata absent.

Hypodermis:

- It is parenchymatous or sclerenchymatous.

Cortex:

- It contain parenchymatous cell without intercellular space.
- In xerophytic species like S. rupestris the cortex is sclerenchymatous.

Trabeculae:

- It is a modification of endodermis.
- During the course of development the endodermal cell elongated and separate from each other therefore form a large space between cells.
- The large space between trabeculae is called lacunae.
- It is possess casparian strips.

Stele:

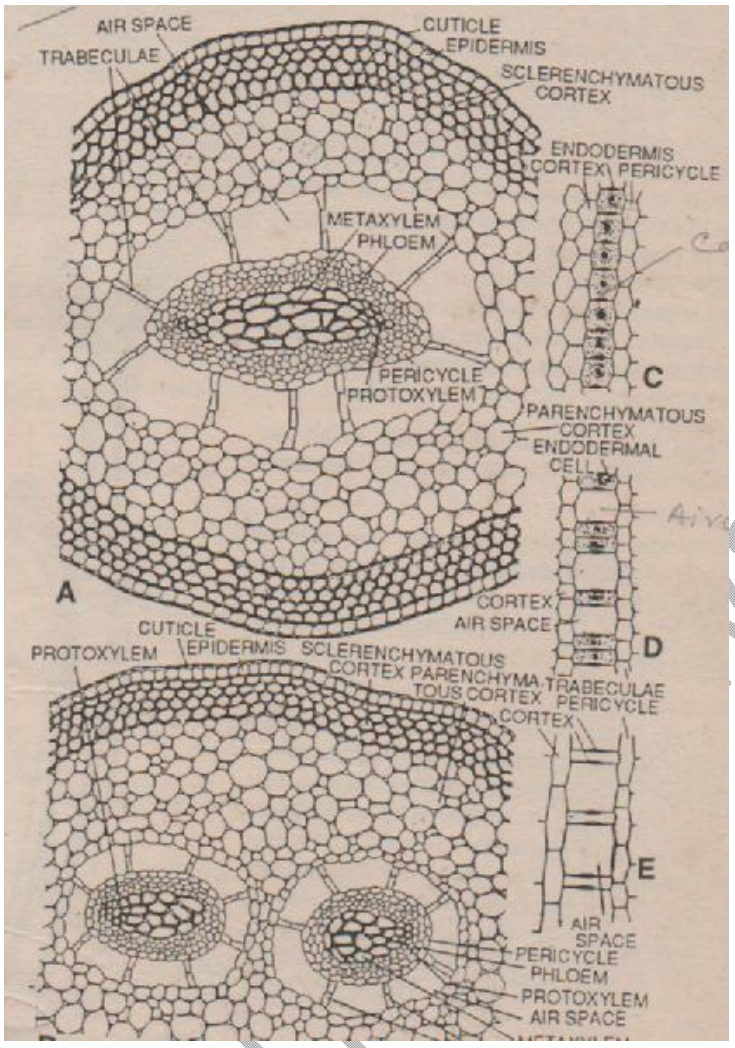
- The stele is suspended the air space by trabeculae.
- The stele ranges from protostele (monostele to polystele) to siphonostele. The stem of S. kraussiana contains two stele i.e. distelic conditions.

Pericycle:

Each stele shows own pericycle. The pericycle encloses vascular tissue.

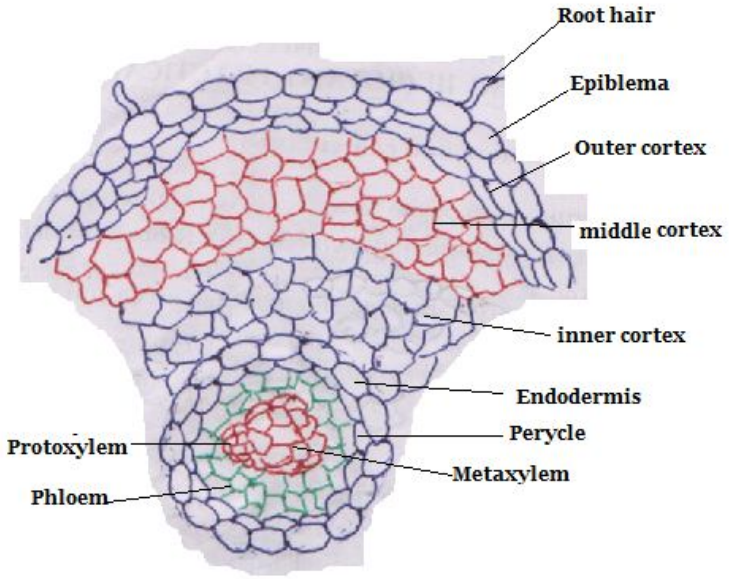
Vascular tissue:

- The xylem in **monostelic** condition is **diarch** and **exarch**. Xylem may be plate like or bifurcation on both the lateral side.
- The xylem in distelic condition will be **monoarch** and **exarch**.
- The xylem in **polystelic** condition 4 or more plate like xylem found.



T.S. of Root:

- The outer most layers is epiblema without cuticle. The cortex is differentiated in to outer parenchymatous, middle sclerenchymatous, inner parenchymatous. Endodermis single layer. Pericycle is 1-3 layers.
- Stele is protostele i.e. xylem is surrounded by phloem. Xylem is exarch and monoarch.



T.S. of Rhizophore:

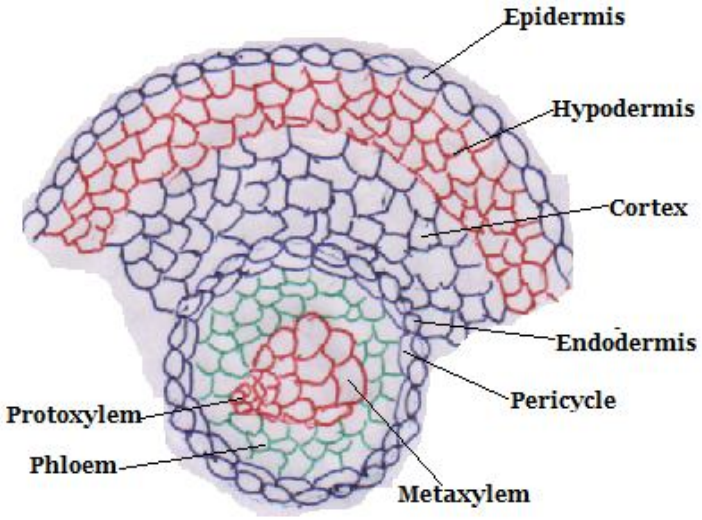
If cross section of rhizophore is compared with stem and root. It epidermis and cortex resembles with stem but its stele portion resembles with root.

Resembles with root:

- Distinct endodermis and pericycle present. (trabeculated endodermis and airspace absent).
- Protostele and monostelic condition. Xylem monoarch and exarch.

Resembles with stem:

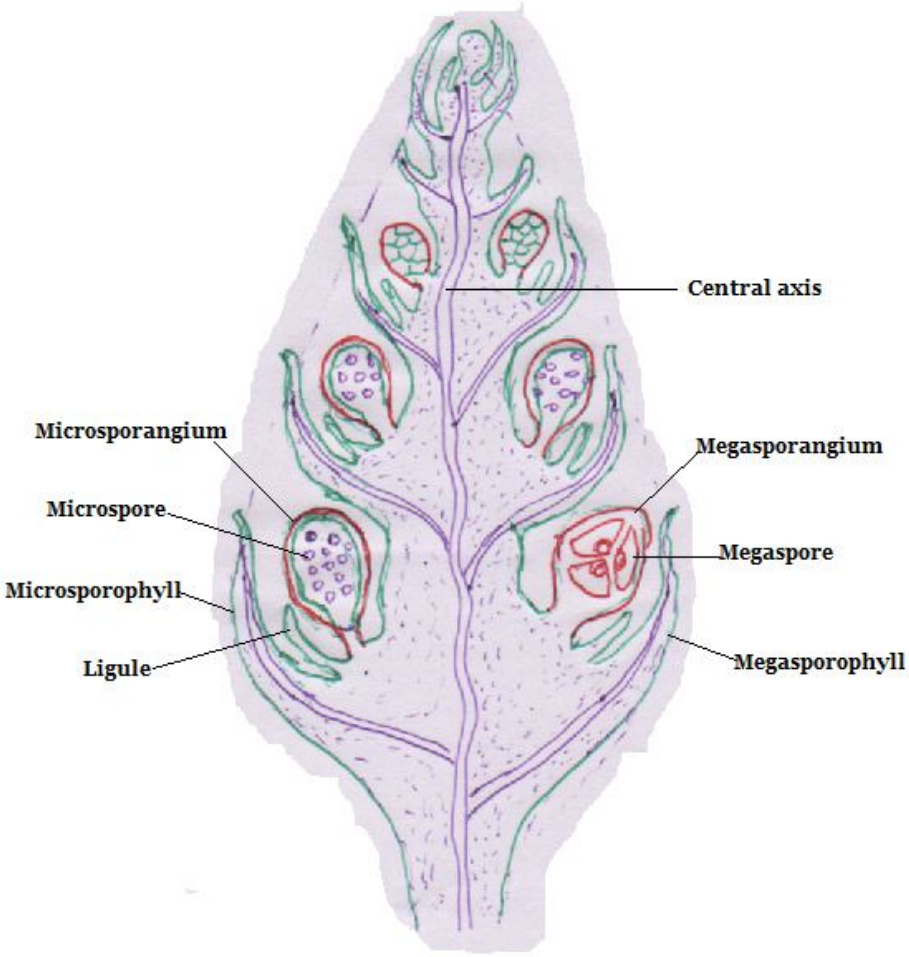
- Cortex is divided in to outer sclerenchymatous and inner parenchymatous. Root hair absent.



Sexual Reproduction:

L.S / Structure of Strobilus or Cone or Spike

- It is the reproductive structure of selaginella. Produce on the apex of branch.
- It is usually cylindrical but sometime it may be dorsiventral.
- The cross section shows a long central axis on which sporophylls spirally arranged.
- Each sporophyll bears a ligule at its base.
- The sporophylls are of two type microsporophylls and megasporophylls.
- The megasporophyll contains megasporangium and microsporophyll contains microsporangium at base.
- Each megasporangium contains 4 large megaspore and microsporangium contains many small microspores.
- Thus two type of spore are produced in the same strobilus. It is called **heterospory**.
- Sporangium consist two wall inner wall called tapetum contain chloroplast.
- The microspore on germination give rise to male gametophyte (microgametophyte) and megaspore on germination give rise to female gametophyte (megagametophyte).
- Each spore consists of outer exine and inner intine.



Gametophyte:

The spore is mother cell of gametophytic generation. In selaginella the spore start germinating inside sporangium i.e. they show *in situ* germination. After germination the microspore produce male gametophyte and megaspore produce female gametophyte.

Male gametophyte:

The mature male gametophyte contain antheridial cell. It divides and forms 128-256 androcytes. It converts into biflagellate antherozoid after metamorphosis.

Female gametophyte:

The exposed part of female gametophyte contains chlorophyll. It gives nutrition to developing embryo. Archegonia develop on apical part of gametophyte. The mature archegonia contain 4 neck cell, one neck canal cell, one venter canal cell and one egg cell.

Fertilization:

At the time of fertilization the neck canal cell and venter canal cell are degenerate and form passage. The antherozoid swims in to the archegonia with the help of dew or rain water. After fusion to egg cell they form zygote (first stage of sporophyte).

Equisetum (Horsetails)

The genus equisetum consists of 30 species. E. ramosissimum is found in India grow abundantly near the rivers in sandy soil or along the shady and swampy soil.

Sporophyte:

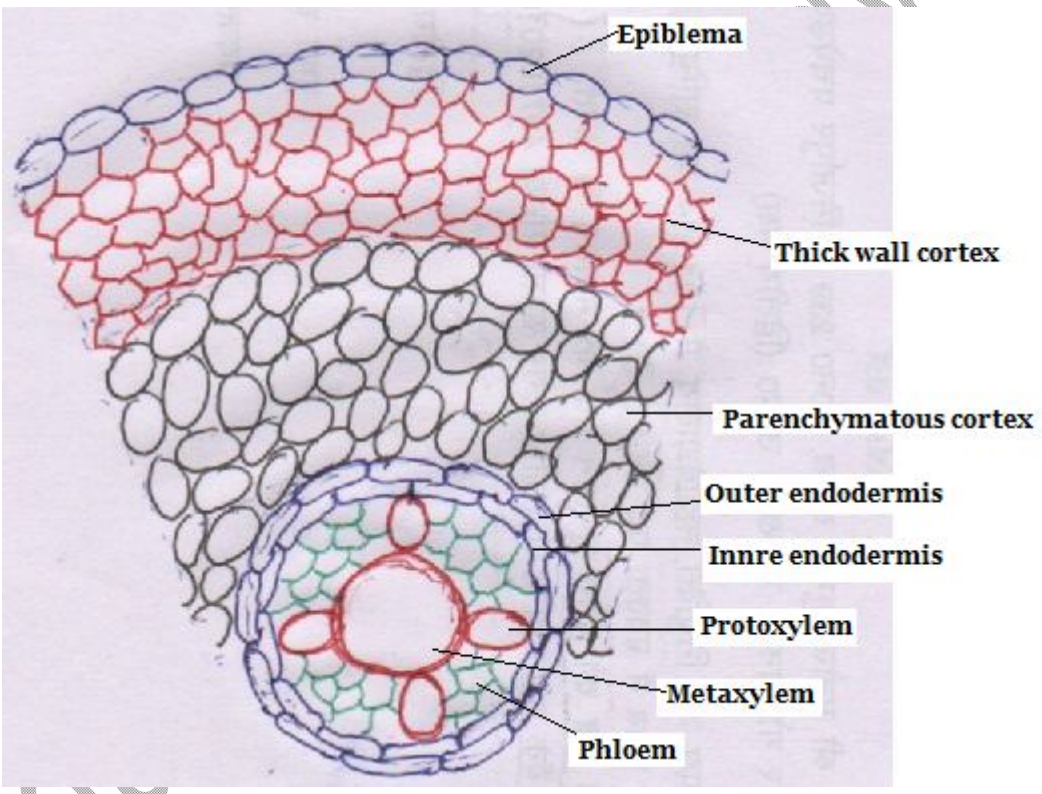
- The main stem is rhizome. It grows underground. Rhizome gives aerial branch.
- The branch is differentiated into nodes and internodes.
- The aerial shout and root arise from the node of rhizome.

- The aerial shout are two type sterile shout (branched and green) and fertile shout (unbranched and nongreen).
- Scale or teeth like leaves arise from node in whorl.
- The stem and branch contain ridges and furrows.
- The number of leaves in each whorl is equal to the number of ribs in the internodes.
- The outer surface of stem and branch is rough due to deposition of silica crystals.

Internal structure:

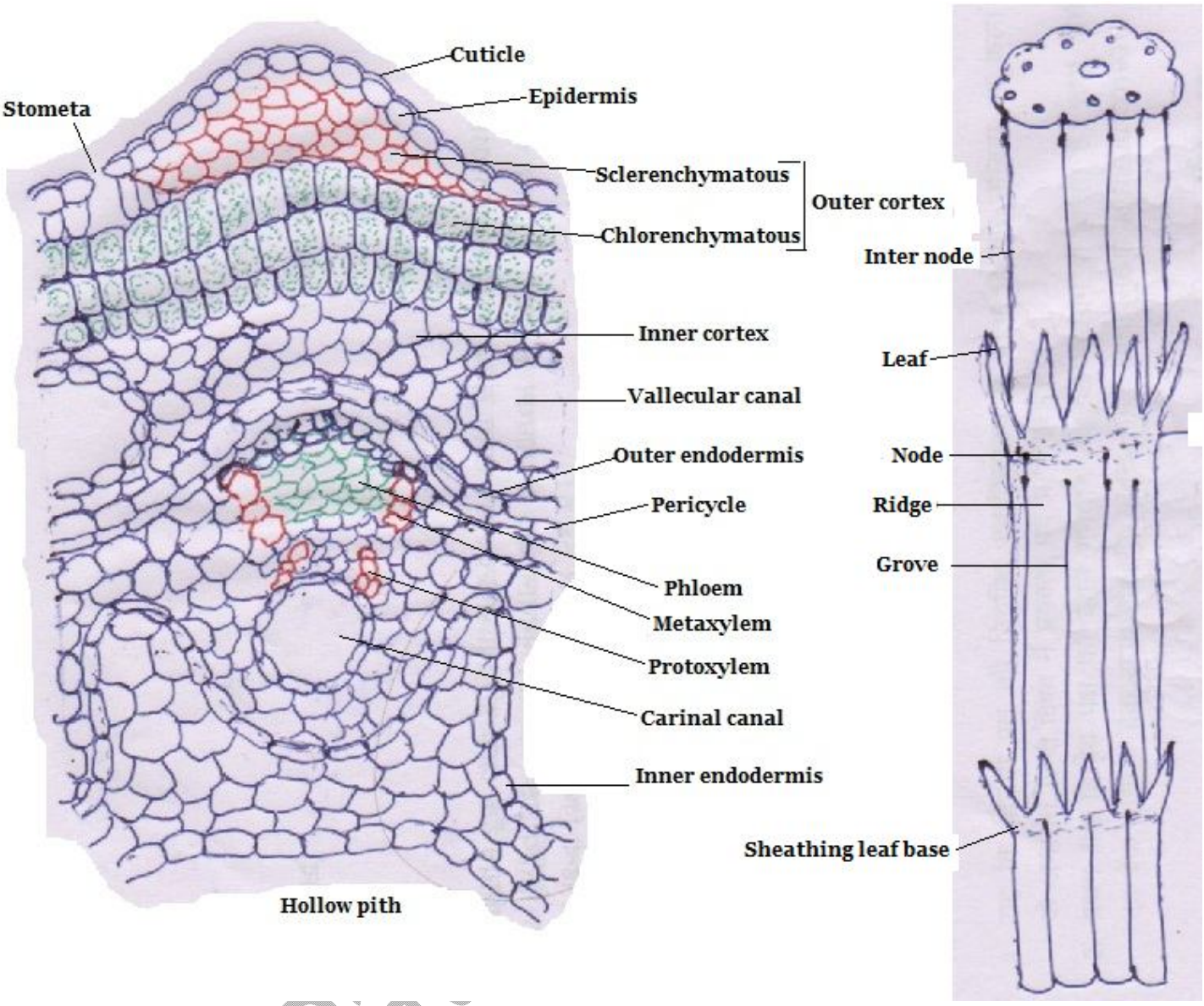
T.S. of Root:

- Outer most layers are epiblema.
- The cortex is differentiated in to outer cortex and inner cortex.
- The outer cortex is lignified and thick called exodermis.
- The inner cortex is parenchymatous with or without intercellular space.
- Endodermis is double layered. The pericycle is absent.
- Stele is protostele. The xylem is exarch and tetrarch.
- Single large size metaxylem present in the center and 4 protoxylem present in 4 different side of metaxylem.



T.S. of Stem through internode:

- Epidermis is outer most single layer covered by cuticle. Cuticle is coated by silica crystals which make rough surface.
- Stomata present in the grooves in between epidermal.
- Cortex is divided in to two layer outer and inner cortex.
- Outer cortex called hypodermis made up of two types of cells. The outer side **sclerenchymatous cell** present bellows the ridge and inner side chlorenchymatous cell. The **chlorenchymatous cell** contains large number of chloroplast.



- The inner cortex contains **vallecular canal** (filled with air) bellow the groove. It is hydrophytic character of plant.
- Stele is surrounded by endodermal cell contain **casparian thicking.**
- Stele is **siphonostele** it may be **ectophloic or endophloic**. Stele contain ring of vascular bundles around the pith.
- Vascular bundles present beneath the ridge.
- The vascular bundles are **conjoint, collateral and closed**. The xylem is **endarch** i.e. protoxylem towards center and metaxylem towards periphery.
- Each vascular bundle consists of two group of metaxylem toward periphery and two group of protoxylem towards the center.
- In between two group of metaxylem phloem present.
- Protoxylem in each bundle disintegrates to form a cavity called **carinal cavity**. It is filled with water. It is **hydrophytic character** of plant.
- Pith cavity filled with water.

<u>The internodal portion show both xerophytic and hydrophytic character.</u>

Xerophytic characters:

- Presence of ridge and grooves.
- Stomata are situated in the grooves only.
- Presence of thick cuticle.

- Deposition of silica crystals on cuticle.
- Well develop sclerenchymatous tissue.

Hydrophytic character:

- Presence of vallecular canal in the cortex bellow the grooves.
- Presence of carinal cavity bellow the ridge in vascular region.
- Presence of pith cavity filled with water.
- Presence of reduced xylem.

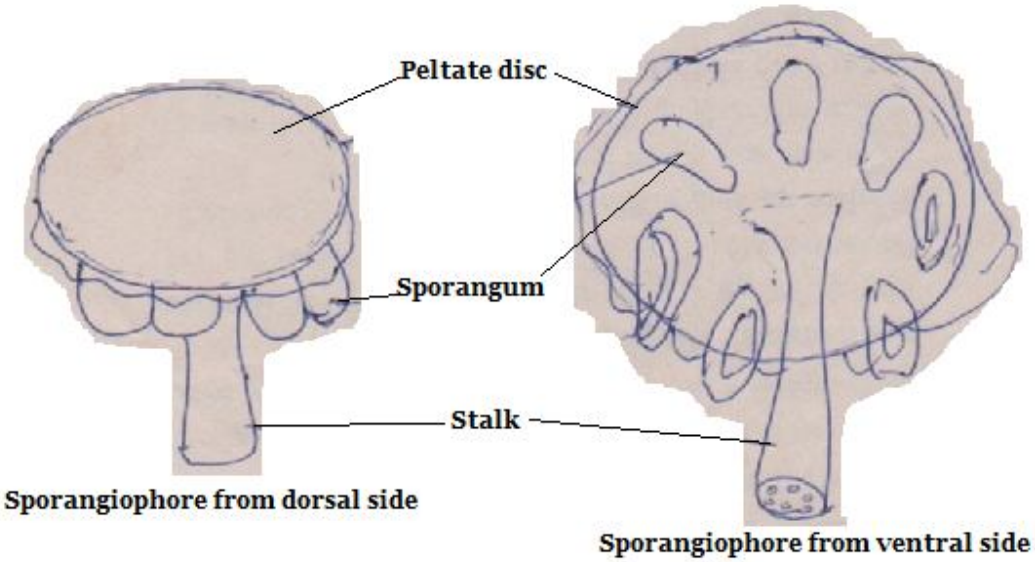
Reproductive structure:

<u>All mater for Strobilus:</u>

- Strobilus arises on the apex of the fertile branch. It is unbranched and colourless.
- It consist a thick central axis.
- At the base of cone found ring like toothed **annulus**. It is reduced leaf whorl.

Only for sporangiophore:

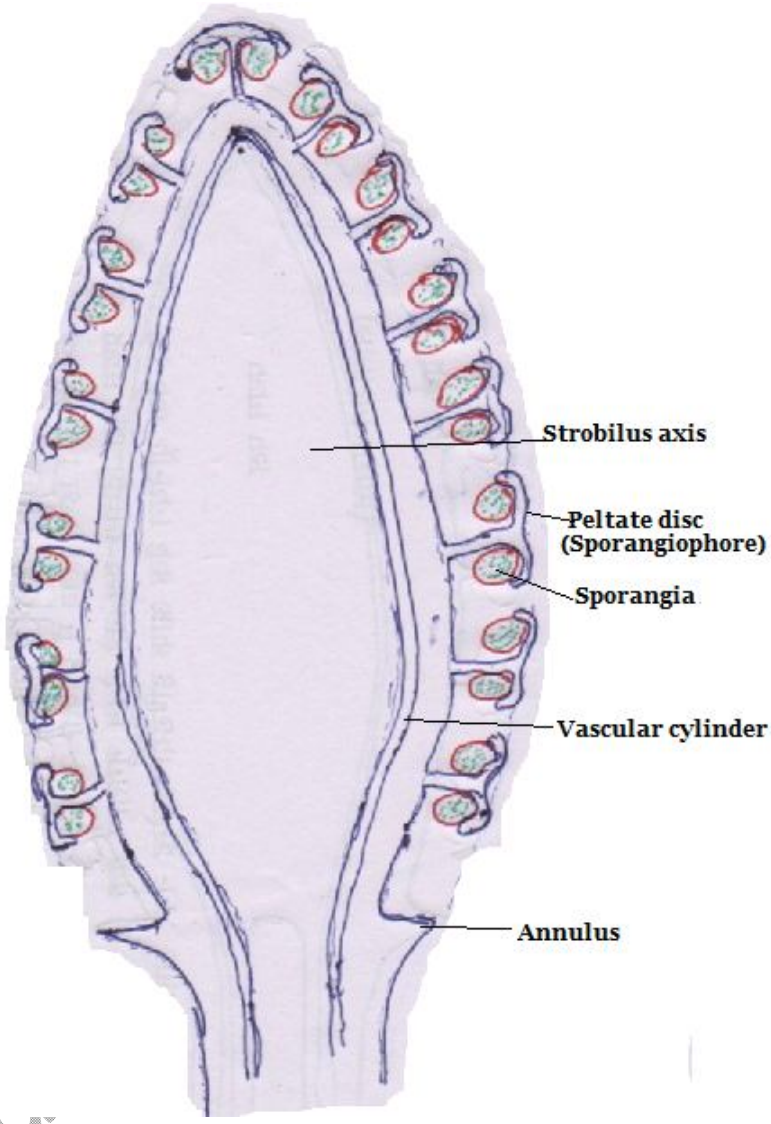
- Many **sporangiophore** present on the central axis arranged in whorls.
- Sporangiophore contains a **peltate disc and a stalk**. It's stalk attached with central maxis.
- Due to mutual pressure of peltate disc it becomes hexagonal in out line.
- The peltate disc and stalk attached each other at 90^{o}.
- Peltate disc contain 5-10 sac-like **sporangia** on the under-surface. The sporangia are extending inward toward cone axis.
- The morphology of sporangiophores uncertain. Some botanist say that it is modification of leaf and some are say that it is a specialized related to stem.
- The mature sporangia sac-like structure. It contains only one type of spore called **homosporous**.
- The inner most layer of sporangium is called **tapetum**.

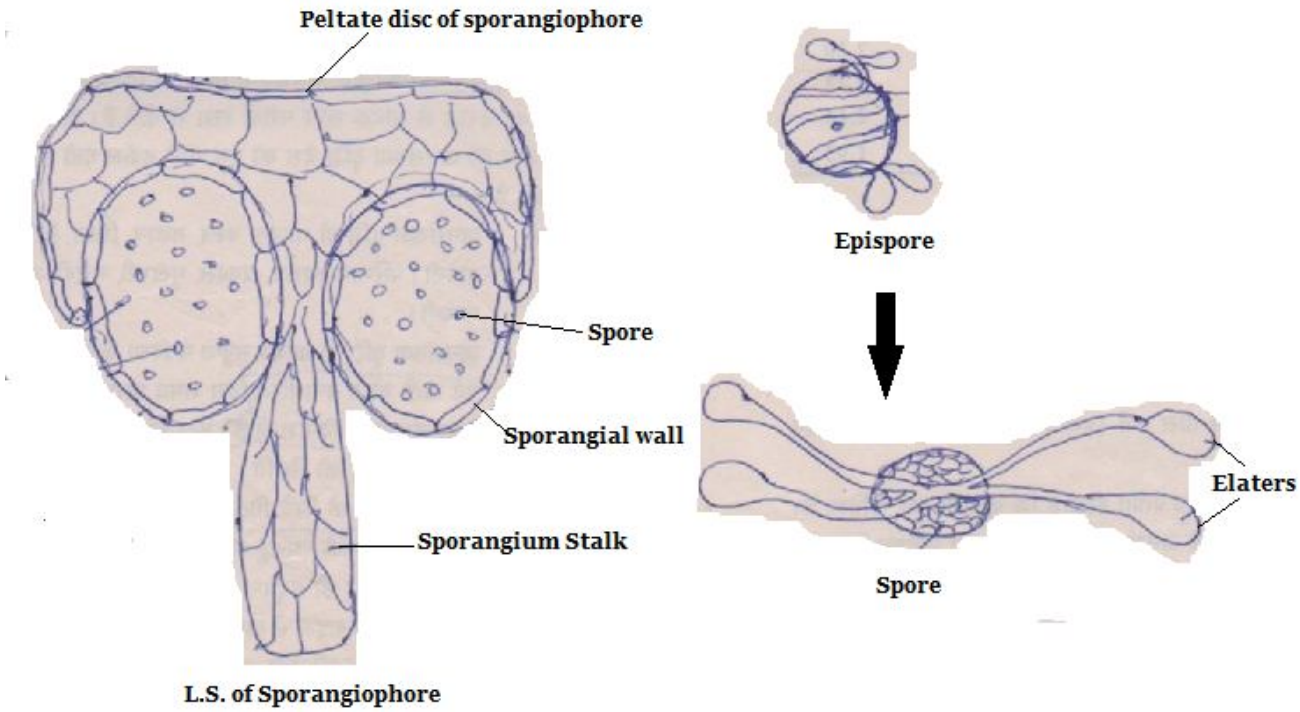


Differ from strobilus of Lycopodium / Seleginela:

	Strobilus of Lycopodium	**Strobilus of Equisetum**
1.	It is arise on the any aerial branch	It arise only on the fertile branch
2.	The sporophyll are spiraly arranged on cone axis	The sporangiophore are arranged in whorls
3.	Annulus does not found at base of strobilus	At the base of strobilus found annulus in whorl
4.	The sporophyll is a modification of leaf	The morphology of sporangiophores uncertain
5.	The shape of sporophyll is leaf like	The sporangiophore is disc like
6.	Its sporophyll contain sporangia on ventral surface at base	Its sporangiophore contain sporangia under surface of peltate disc and extending inward toward cone axis

7.	The sporophyll contain only one sporangia	The sporangiophore contain 5-10 sporangia
	Seleginela	
8.	It contain two type of sporophyll micosporophyll and megasporophyll	It contain only one type of sporangiophore
9.	It contain two type of spore microspore and megaspore i.e. heterosporous	It contain only one type of spore i.e. homosporous





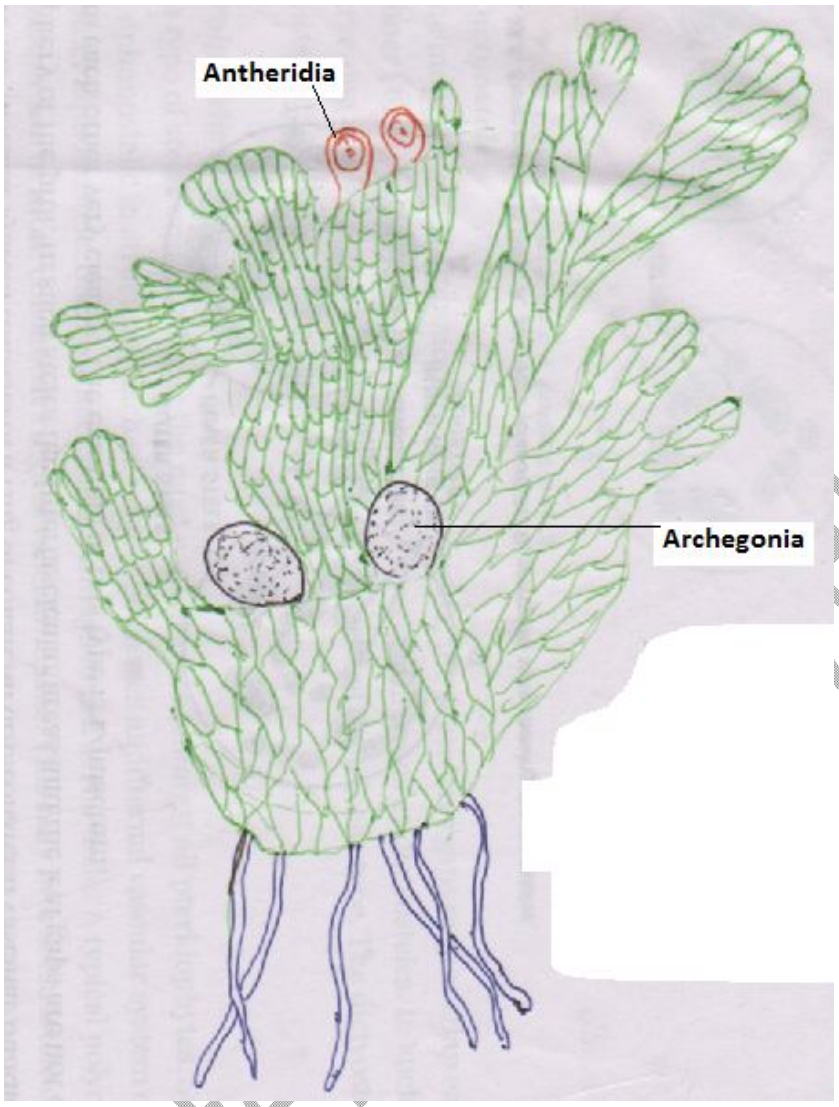
Gametophyte:

- The spore is first cell of the gametophyte.
- The spore is found in side of the sporangium. All spore is same i.e. homosporous.
- Spore filled with chloroplast and surrounded by four layers. Epispore, cuticular, exine and intine layer present from outer to inside respectively.

Elaters: - It produced inside sporangium. The epispore splits in to two spiral bands which always attached to the wall of spore. The end of spiral band is spoon-shaped. These spiral structures with spoon shaped ends are called elaters. It is hygroscopic in nature. At moist condition they coil around the spore and at dry condition they uncoil. The elater helps in the dispersal of spore and dehiscence of sporangium. At maturity the sporangia loss water. Therefore spore become dry and uncoil their elater. All spores make pressure on sporangium wall by elater.

Prothalus:

- Spore germinates after 10-12 hours and gives rise to prothalus.
- The prothalus is differentiated in to two regions. The basal massive cushion like and upper lobes.
- The basal massive region lack chlorophyll and contain starch because chloroplast change in to leucoplast (store starch grain).
- The upper lobed region is green and contains chloroplast.
- Many rhizoids arise from the basal region.
- The margin of basal cushion region formed by meristematic cell.
- The antherida mature before archegonia. The antheridia present on the margin of lobe and the archegonia are present in the tissue of basal cushion portion of prothalus.



GENUS - MARSILEA

This order includes a single family, Marsileaceae. The family includes the living genera-**Marsilea**. They are **heterosporous ferns**.

The sporangia of these are produced within special structures known as sporocarps. Each sporocarp possesses many sori which bear microsporangia and megasporangia

There are about 65 species of Marsilea distributed all over the world. They are more commonly found in tropical regions, such as, Africa and Australia. Gupta and Bhardwaja (1957) have recorded about ten species of Marsilea in our country.

They are hydrophytic (aquatic) or amphibious plants. They grow rooted in the mud of marshes and shallow pools. Marsilea vestita and some other species grow in shallow ponds. The Indian species recorded by Gupta and Bhardwaj (1957) are as follows-

1. M. quadrifolia; 2. M, minuta; 3. M. rajasthanensis; 4. M. brachycarpa; 5. M. condensata

External Morphology:

Rhizome (Stem):

The species of Marsilea possess a rhizome which creeps on just below the surface of the soil. The rhizome is slender, branched and possesses **nodes and internodes**. The leaves arise from nodes of rhizome. One or more adventitious roots come out from each node of the rhizome. The rhizome is dichotomously branched and is capable of indefinite growth in all directions and covers area more than twenty-five metres in diameter.

Internal Structure Of Rhizome:

- Epidermis is single-layered, thickwalled cells without any stomata.
- The cortex is differentiated into outer, middle and inner cortical regions.
    A. The outer cortical region consists of parenchymatous tissue. This region may be one to several celled in thickness.
    B. Just beneath the outer cortical region contains large lacunae or air spaces (aerenchyma). The lacunae are separated from each other by one layered parenchymatous septa. This region may be considered the middle cortex.
    C. Beneath the middle cortex the inner cortex is found. The cells of this region are thick-walled sclerenchymatous cells. Beneath this region the cortex again consists of compact parenchymatous tissue act as storage tissue store starch. Some of the tannin cells may be found in this innermost region.
- The vascular cylinder is siphonostele; limited externally and internally by endodermis, hence called outer endodermis and inner endodermis, respectively.
- The siphonostele is medullated i.e. central pith. The xylem is in the form of ring. Phloem is present on both sides of xylem. Such a stele is called amphiphloic siphonostele.
- Outside the pith there is a single-layered inner pericycle, inner endodermis and then inner phloem in a continuous succession. Thereafter, there is a ring of xylem which is surrounded by the successive rings of outer phloem, outer pericycle and outer endodermis.

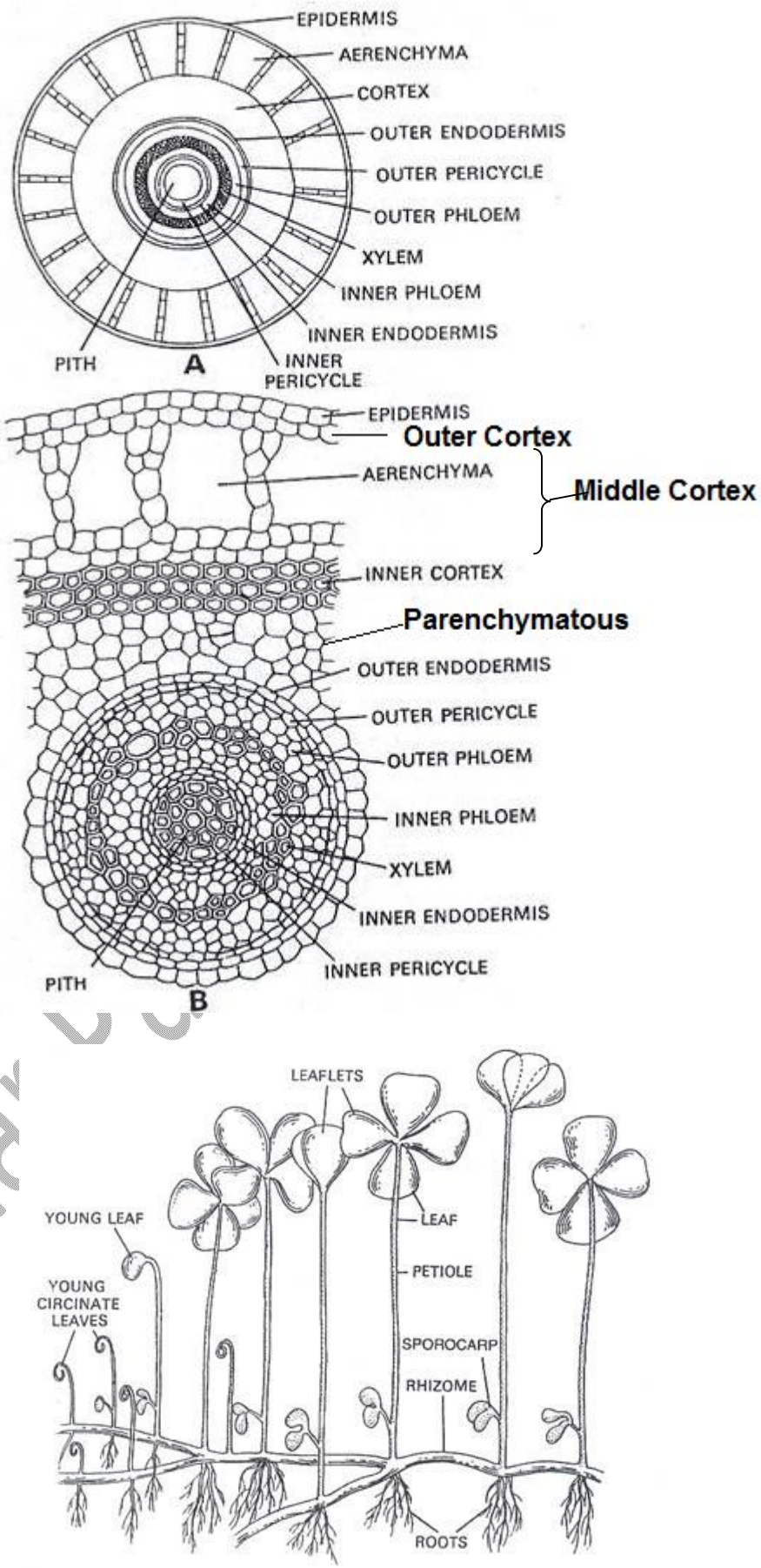


Fig. 30.1. *Marsilea quadrifolia*. A sporophyte with sporocarps, rhizome, leaves and roots.

Leaves:
The leaves are borne alternately along the upper side of the rhizome at the nodes. The leaves possess **circinate vernation**.

The leaves of submerged plants contain long flexible **petioles** and leaf lamina that float on the water surface. When the plants grow on mud or marshy places the leaves have got shorter and the petioles erect which spread the leaves in the air.

The leaves are compound. The **lamina** of each leaf is divided into four **leaflets or pinnae** arising from the apex of the petiole.The veins of each pinna are dichotomously branched.

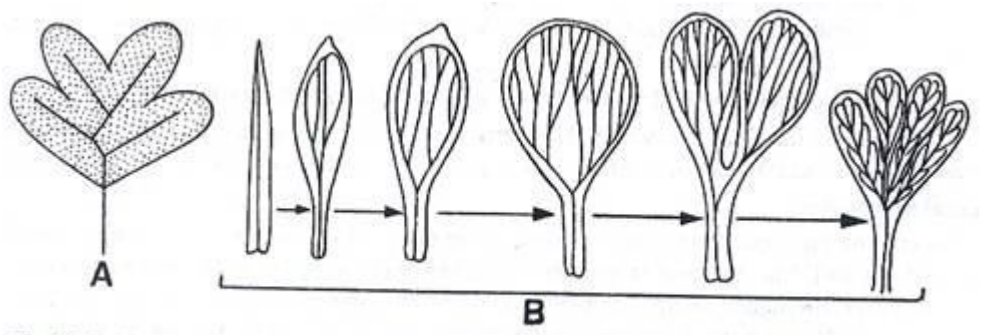


Fig. 30.2. *Marsilea* sp. A, leaf showing arrangement of leaflets as a result of three dichotomies; B, successive types of juvenile leaves of *Marsilea*. (A, after Bower; B, after Braun).

The sporocarps are borne on short peduncles near the base of the petiole. In majority of cases the peduncle or stalk of the sporocarp is unbranched and bears a single sporocarp at its apex.

Roots:
One or more adventitious roots are borne at each node of the rhizome. The adventitious roots may arise from internodes.

Sexual reproduction:
The plant is a sporophyte. It bears the special structures known as sporocarps which contain micro and megasporangia in them. It is heterosporous. The sporocarps are borne on short peduncles above the base of the petiole. The peduncle is unbranched and bears a single sporocarp at its apex. In M. quadrifolia the peduncle is dichotomously branched and bears 2 to 5 sporocarps.

The sporocarps may be oval or bean-shaped. In the earlier stages it is soft and green but later on it becomes hard and brown in colour. Near the point of attachment of the stalk or peduncle there are usually one protuberances in the median plane. Such protuberances consist of one or two teeth called raphe.

The vascular supply in the sporocarp by a dorsal bundle (main vein) present in the peduncle. Numerous lateral veins arise from the dorsal bundle and enter in to right and left sporocarp.

Internal Structure of the Sporocarp:

To study the internal structure of the sporocarp the sections cut in longitudinal and transverse planes. The internal structure of the sporocarp in transverse, longitudinal and dorsiventral sections is as follows:

Vertical transverse section (V.T.S.) or Transverse section:

In the transverse section there are found three layers outside the sporocarp. One layer is epidermis and two layers of hypodermis. The outermost layer is known as epidermis. The epidermis is interrupted by a number of stomata. Below the epidermis there are two hypodermal layers.

The outer hypodermal layer consists of elongated palisade like cells. In transverse section of sporocarp seen only two chambers of sori. Each sori surrounded by separate indusium which is double layer. Each sorus possesses a **receptacle** which bears either micro or megasporangia. The sporangia are attached on the placenta. The gelatinous ring also present on the upper and lower side of the receptecls.

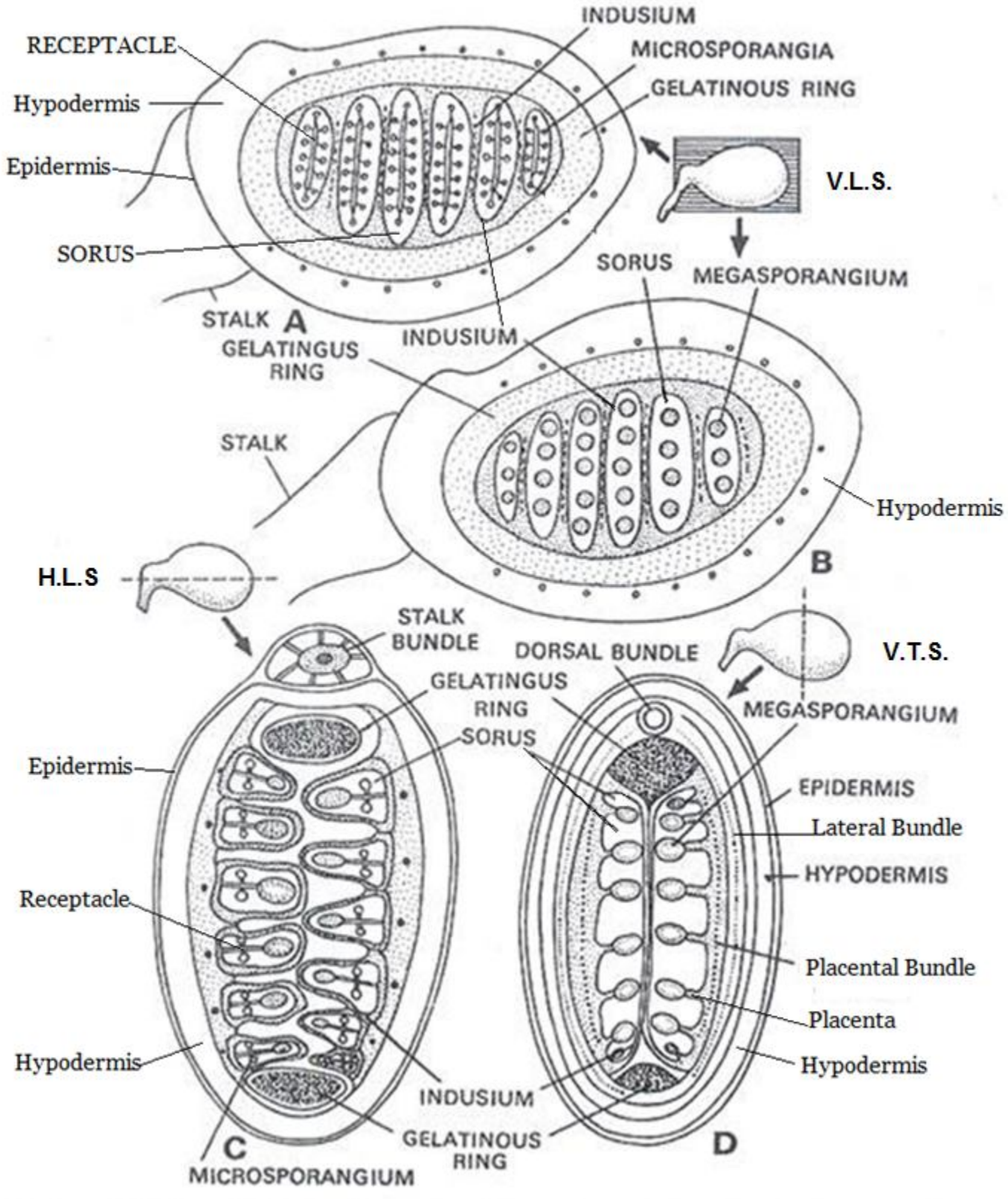
Horizontal longitudinal section (H.L.S.) or Longitudinal section:

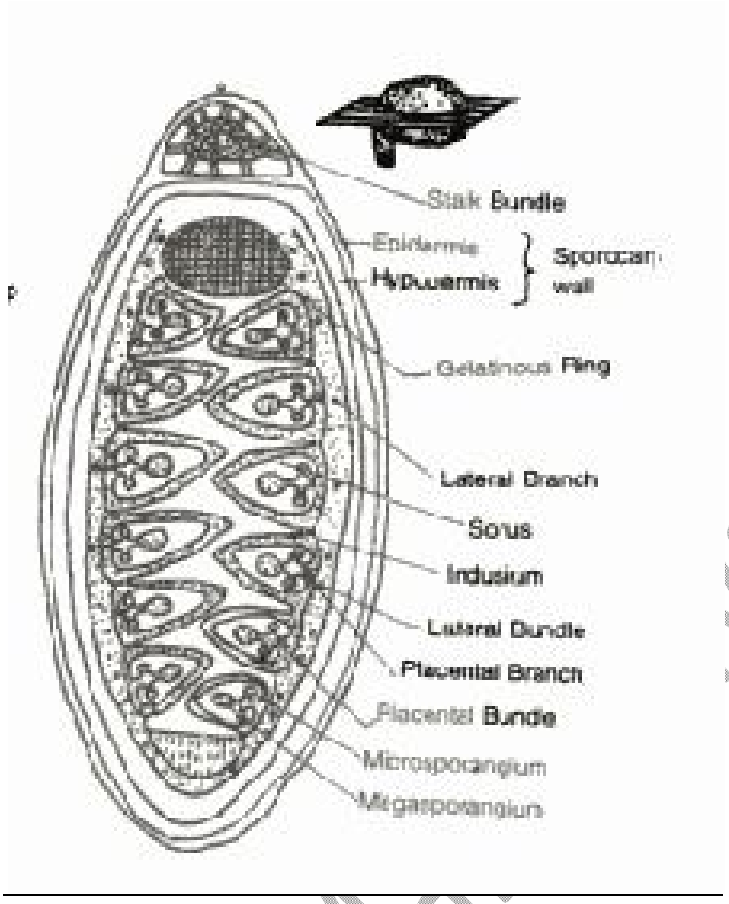
The structure of the wall of sporocarp and the gelatinous ring is the same as in transverse section. In the longitudinal section of the sporocarp there are two rows of sori found. Each sori surrounded by a two layered indusium. A placental bundle goes to each sorus from the lateral bundles. The receptacle bears a single megasporangium at the tip and the two microsporangia on the lateral sides. Each megasporangium contains a large single megaspore while the microsporangium contains many small rounded microspores.

Vertical longitudinal section (V.L.S.) or dorsiventral section:

The structure of the outer wall of the sporocarp is the same as seen in transverse and longitudinal sections. Below the outer wall a continuous gelatinous ring is found. Within the sporocarp there is a group of sori. Each sorus is surrounded by indusium. In V.L.S. the half of the total number of the sori are cut longitudinally and are arranged in a single row.

The sorus contains micro and megasporangia. The megasporangia may easily be seen if the sporocarp is cut slightly away from the median line. Microsporangia may be easily seen if the sporocarp is cut in the same plane but slightly farther away than previous one.


INDUSIUM
RECEPTACLE
MICROSPORANGIA
Hypodermis
GELATINOUS RING
Epidermis
V.L.S.
SORUS
SORUS
MEGASPORANGIUM
STALK
A
INDUSIUM
GELATINGUS RING
STALK
Hypodermis
B
H.L.S
STALK BUNDLE
DORSAL BUNDLE
V.T.S.
GELATINGUS RING
SORUS
MEGASPORANGIUM
Epidermis
EPIDERMIS
Lateral Bundle
HYPODERMIS
Receptacle
Placental Bundle
Placenta
Hypodermis
Hypodermis
INDUSIUM
GELATINOUS RING
C
D
MICROSPORANGIUM



GYMNOSPERMS

Gymnosperms (**gymnos=naked**; **sperma=seed**) and angiosperms (**angios=closed**; **sperma=seed**) are two subdivision of division **Spermatophyta** of plant kingdom. Spermatophyta includes all those plant which bear seed. The lower gymnosperms resemblances with the higher pteridophyta (cryptogams) whereas the higher gymnosperms resemble with member of angyosperms. Gymnosperm thus form a bridge between the pteridophytes and angiosperms therefore it hase been referred as **"Phanerogams without ovary"**. The tallest living tree is about 112 meter e.g. ***Sequoia sempervirens***. The smallest gymnosperm is ***Zamia pygmaea. Cycas revoluta*** is a living focial.

Order – Cycadales(Genus- Cycas)

The genus cycas is an example of order cycadales. During the Mesozoic era especially in Jurassic and lower cretaceous, the cycadales were world- wide in distribution. Six species of cycas are found in India ***C.revoluta, C.circinalis, C.rumphii, C.pectinata.***
The plant of cycas is palm like tree. They grow in xerophytic habitat but grow in Indian gardens also. The plant body is divided in to root, stem and leafs.

Root: - Root in cycas is two types.

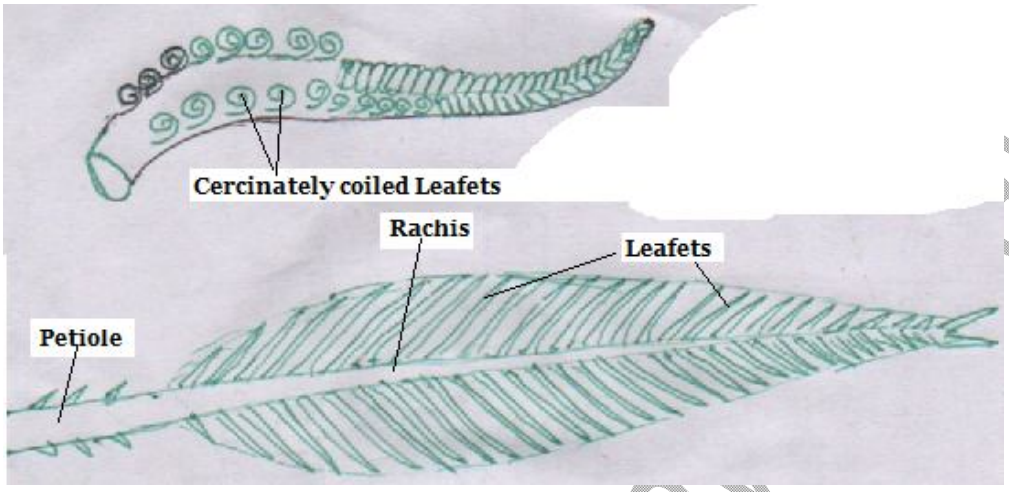
(1) Normal tap root – It grow deep into the soil. Their function is to fix the plant in the soil and to absorb water and minerals.

(2) **Coralloid root** – It is arise from the normal tap root. It comes out from the surface of soil. The bacteria, algae and fungi also live in this root in symbiotic association. They are dichotomously branched. They are photosynthetic in nature. The algae help in nitrogen fixation.

Leafs:- The leaves of cycas show **dimorphism** i.e. the plant contain two types of leaves.

(1) Foliage Leaves – It found at the apex of stem in the form of crown. These are green **pinnately compound**. The petiole has spine (modification of leaflet) at base and is modified in to a **rachis** toward upper side. Several **leaflet or pinnae** present on the rachis. Each leaflet has a thick midrib in center and lateral veins are absent. The young leaves show **circinate vernation.**

(2) Scale leaves – They are dry, rough, brown in colour and triangular in shape and always covered with **rementa** (hair). They are present on the apex of stem. Protection in fuction.



Stem: - The stem is woody cylindrical unbranched. The stem covered by leaf base. At the apex of stem a crown of foliage leaf is present. Stem also has bulbils for vegetative propagation.

Anatomy of Normal Root-

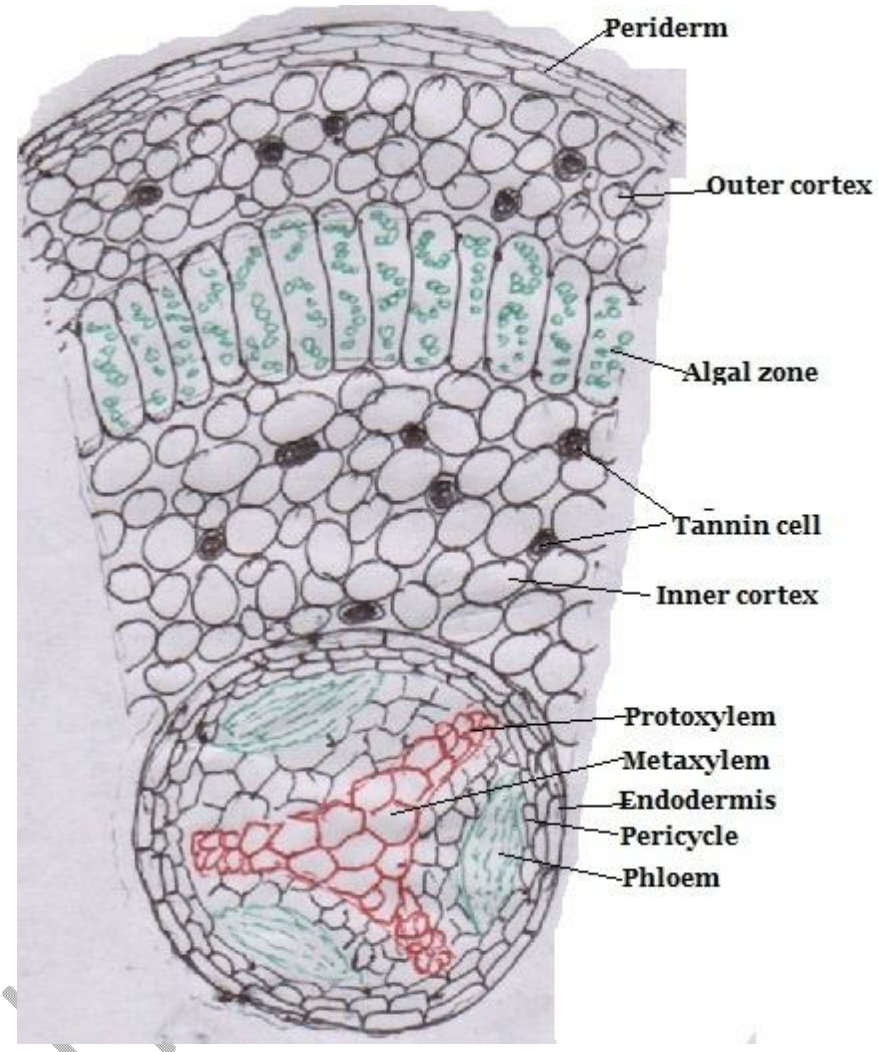
- It is resembles with root of dicotyledons plant. The outer most layers are epiblema or exodermis. Some cell of epiblema form root hair.
- The cortex is multilayered, parenchymatous cell. **Tannian** cells are scattered in the cortex.
- Stele is surrounded by single layer of endodermis. The cell of endodermis contains casparian strips.
- Next to endodermis 2-3 layer pericycle is present.
- The stele is protostele. Xylem and phloem bundles present in different radii.
- Cambium present in stele so secondary growth found in normal root. Secondary growth also found in cortex therefore **Cork cambium (periderm)** develops in the cortex. It forms **cork (phellem)** toward outer side and **secondary cortex (phelloderm)** toward inner side.
- Xylem exarch. Protoxylem may be diarch, triarch, tetrarch or polyarch.
- Pith are absent.

Anatomy of Coralloid Root-

The internal structure of coralloid root is similar to that of normal root. The only difference is that of coralloid root contain algal zoon in the cortex and the secondary growth in stellar region absent or poorly develops.

- Epiblema is similar to normal root.
- Cortex contain **tannin cell** cortex is differentiated in to three regions.
- **Outer cortex** lie bellow the epidermis.
- It is mead up of parenchymatous cell.
- Secondary growth found in cortex therefore **Cork cambium (phellogen)** develops in the cortex. It forms **cork (phellem)** toward outer side and **secondary cortex (phelloderm)** toward inner side. Cork, cork cambium and secondary cortex together make up **periderm**.
- **Middle cortex** is single layer and contain elongated cell. Each cell contain blue green algae e.g. *Nostoc* and *Anabaena.*
- Blue green live symbiotically with root and help in nitrogen fixation.
- **Inner cortex** are parenchymatous and resemble with outer cortex.
- The stele is protostele. Xylem and phloem bundles present in different radii.
- Xylem exarch. Protoxylem may be diarch, triarch, tetrarch or polyarch.

- Pith is absent.



Anatomy of Stem –

The stem of cycas also resembles with stem of dicotyledonous stem.

- Epidermis is the outer most layers.
- The cortex is parenchymatous. Its cell is filled with starch grain. This starch is the source of **"Sago"**.
- The cortex is cross by many simple and **girdle-shaped leaftrace**.
- Many **mucilage ducts** are found in cortex.
- Endodermis and pericycle are not present.
- The stele is ectophloic siphonostele. It contains vascular bundles in a ring.
- Each vascular bundle is conjoint, collateral and open. Xylem is endarch.
- **Xylem vessels in xylem and companion cell in phloem are absent.**
- Cambium present in between xylem and phloem.
- Pith are well develop contain mucilage duct and starch grain cell.

Secondary Growth in Stem:-

The **interfascicular and intrafascicular cambium** unites to form **cambium ring**. This cambium ring form secondary phloem toward outside and secondary xylem toward inside. After some time the cambium ring inactive and second cambium ring develop in the region of pericycle. This cambium ring also behaves similar manner and the third cambium ring may develop in cortex region and it also behave like the first two cambium ring. In this fashion about 14-22 cambium ring develop in cycse. Many medullary rays develop in the secondary vascular tissue. The **cork cambium** also develops in the outer most region of cortex. They form **cork** toward outer side and form **secondary cortex** toward inner side. In the beginning cycas is **monoxylic** i.e. it contain single ring of vascular bundles but in older stem many ring of vascular bundles appear outside the primary vascular ring i.e. **polyxylic** condition. The wood of cycas is manoxylic (soft wood).

Wood of Gymnosperms is classified into manoxylic or pycnoylic. This classification is based on the amount of xylem cells in the wood.

Manoxylic wood:

It is the non-compact wood with large amount of parenchyma, large pith and cortex mixed with less amount of xylem tracheids or wood.

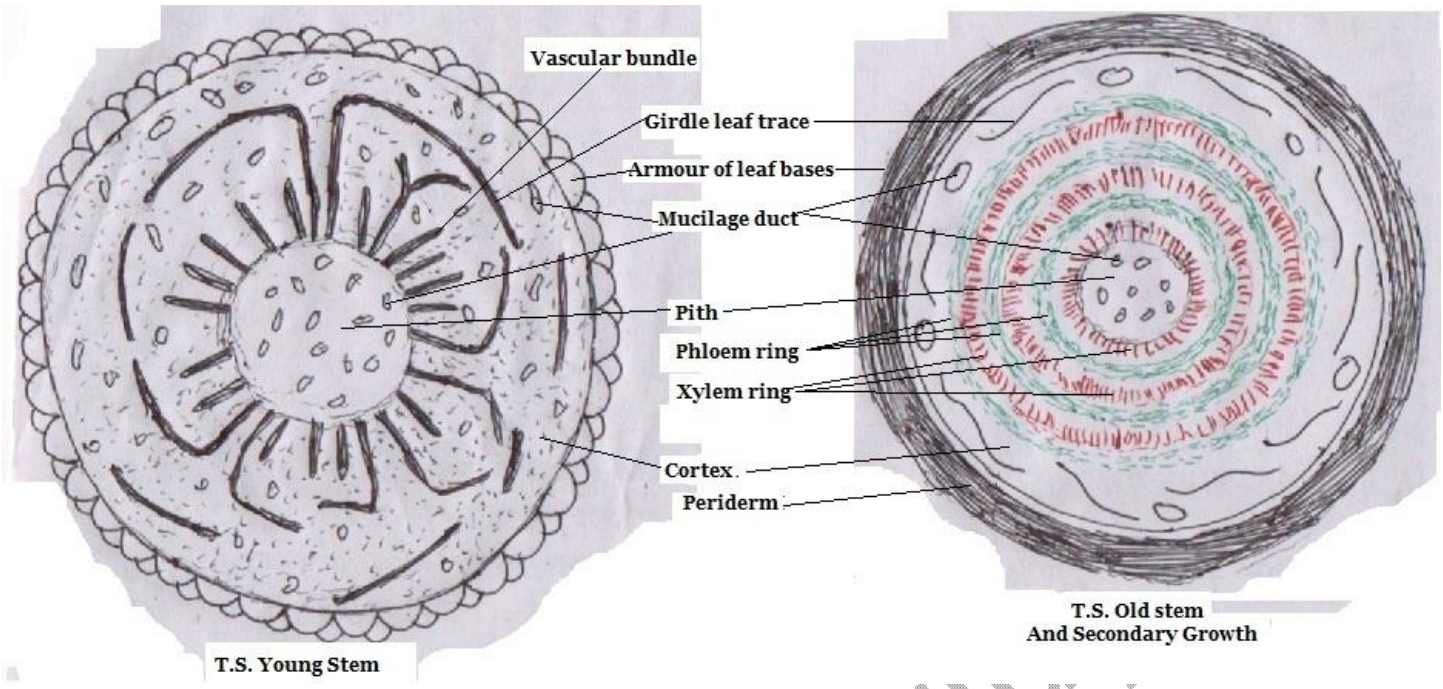
-Parenchyma cells are filled with starch grains

-Not important commercially as wood is not durable e.g. In Cycas

Pycnoxylic wood:

It is the compact strong wood with large amount of xylem tracheids or wood and small amount of cortex and pith with little Parenchyma.

-Durable and yields timber e.g. In Pinus

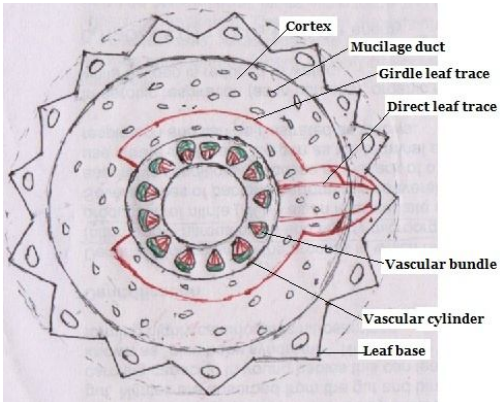


Leaf Traces:

- The leaf trace remains scattered in the cortical region of stem. It supply vascular to leaf.
- Normally four leaf trace found for each leaf. Two of this direct leaf trace and two girdle leaf trace.
- Both leaf trace arise from the main vascular bundle.
- The direct leaf trace lying in front of leaf base while the girdle leaf trace arises from opposite to the direct leaf trace.
- The girdle leaf trace curve soon in opposite direction around the vascular ring and enter in the leaf base.
- In cortical region the girdle leaf trace connected with another leaf trace.
- **At the time of their entrance in the petiole of leaf the leaf trace divided into many bundle. Each bundle arranged in to inverted omega (ʊ) shape in petiole and rachis.**

Rachis:-

- In transverse section it looks like biconvex.
- **Epidermis** is the outer most layers covered by cuticle. The lower and upper surface contains sunken stomata.
- **Hypodermis** present bellows the epidermis. It is also divided in to outer **chlorenchyma** and inner **schlerenchyma**.
- Bellow the hypodermis parenchymatous **ground tissue** is present. Many mucilage canals and many vascular bundles are present.
- Each vascular bundle are oval shape and arranged in **inverted omega** (ʊ) shape.
- Each vascular bundle is **conjoint, collateral and open** and surrounded by bundle sheath.
- Each vascular bundle is made up of xylem, phloem and cambium.
- The xylem in each vascular bundle present toward inner side (ventral surface) and phloem present toward outer side (dorsal surface).
- Vascular bundle are ***diploxylic*** i.e. it consist two type of xylem one is **centripetal xylem** means xylem in **exarch** (protoxylem toward periphery and metaxylem toward center) condition and other is **centrifugal xylem** means xylem in **endarch** (protoxylem toward center and metaxylem toward periphery) condition.
- There are three type of vascular bundle are found in rachis basal to top.



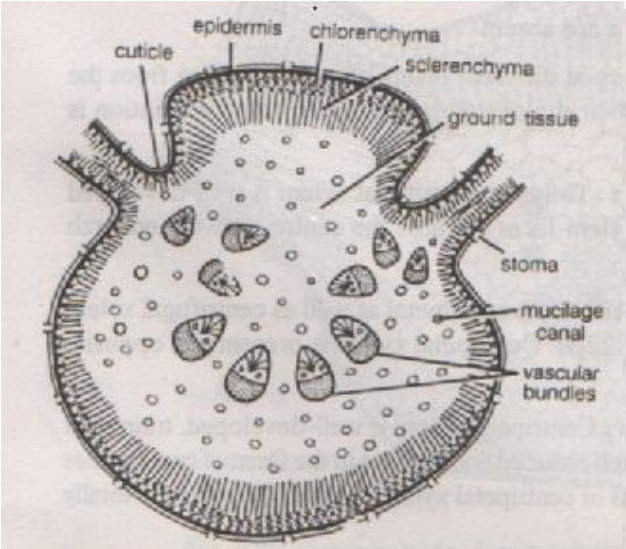


Fig. 8.25. *Cycas*. T.S. rachis (diagrammatic).

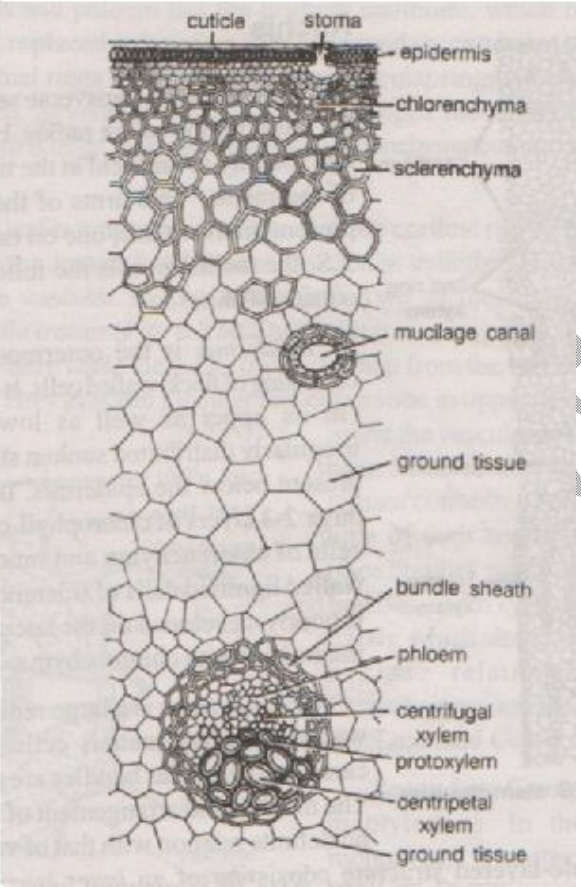


Fig. 8.26. *Cycas revoluta*. A part of T.S. of rachis.

Vascular Bundle at the Base of Rachis- In this region the vascular bundle contain triangular centrifugal xylem i.e. xylem in endarch condition.

Vascular Bundle in the Middle of Rachis- In this region vascular bundle contains both centripetal and triangular centrifugal xylem. Showing **diploxylic** condition. Centripetal xylem is present just opposite to the protoxylem of the centrifugal xylem.

Vascular Bundle in the Apex of Rachis- Vascular bundle contains triangular centripetal xylem. Centrifugal xylem reduced and present in the form of two patches.

Leaflet:

- The vertical section of leaflet show central biconvex midrib region and two lateral wings. In C.revoluta the wing are curved downward (revoluted) at the margins but in C.circinalis, C.rumphii and C.pectinata the margin are flat.
- The outermost layer of leaflet is epidermis covered by cuticle. Sunken stomata present on the lower epidermis.
- Below the upper epidermis sclerenchymatous hypodermis are present. Below the lower epidermis it is present only midrib region and in the part of wing it is absent.
- Below the hypodermis mesophyll are present and it is differentiated into palisade parenchyma and spongy parenchyma.
- **Palisade parenchyma** is continuous layer below the upper hypodermis form one end of wing to another end of wing e.g. C. revolute but in C. circinalis it is absent in midrib region.
- Palisade parenchyma is absent bellow the lower epidermis but the **spongy parenchyma** present bellow the lower epidermis except midrib region.
- The cell of palisade parenchyma is elongated and cell of spongy parenchyma is rounded or oval in shape. Both cell is contains chloroplast.
- **Transfusion tissue** is two types **(1) primary transfusion tissue (2) secondary transfusion tissue**.
- The primary transfusion tissue present on the lateral side of the vascular bundle. The secondary transfusion tissue **(accessory transfusion tissue)** present both wing in between the palisade and spongy parenchyma.
- Transfusion tissue helps in the lateral conduction of water in the wing.
- The middle midrib portion contains vascular bundle. It is surrounded by a bundle sheath.

- The vascular bundle of leaflet resembles the vascular bundle of the upper part of the rachis. It is conjoint, collateral, open and diploxylic.
- Vascular bundle contains triangular centripetal xylem. Centrifugal xylem reduced and present in the form of two patches.

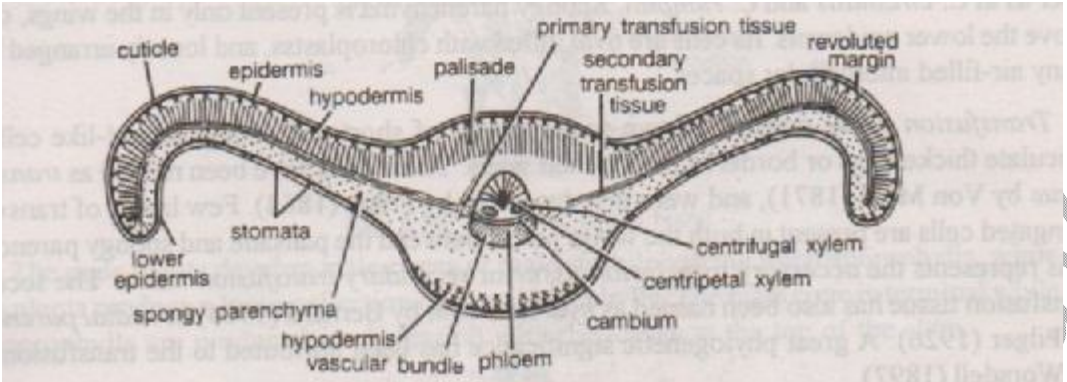


Fig. 8.28. *Cycas revoluta*. T.S. leaflet (diagrammatic).

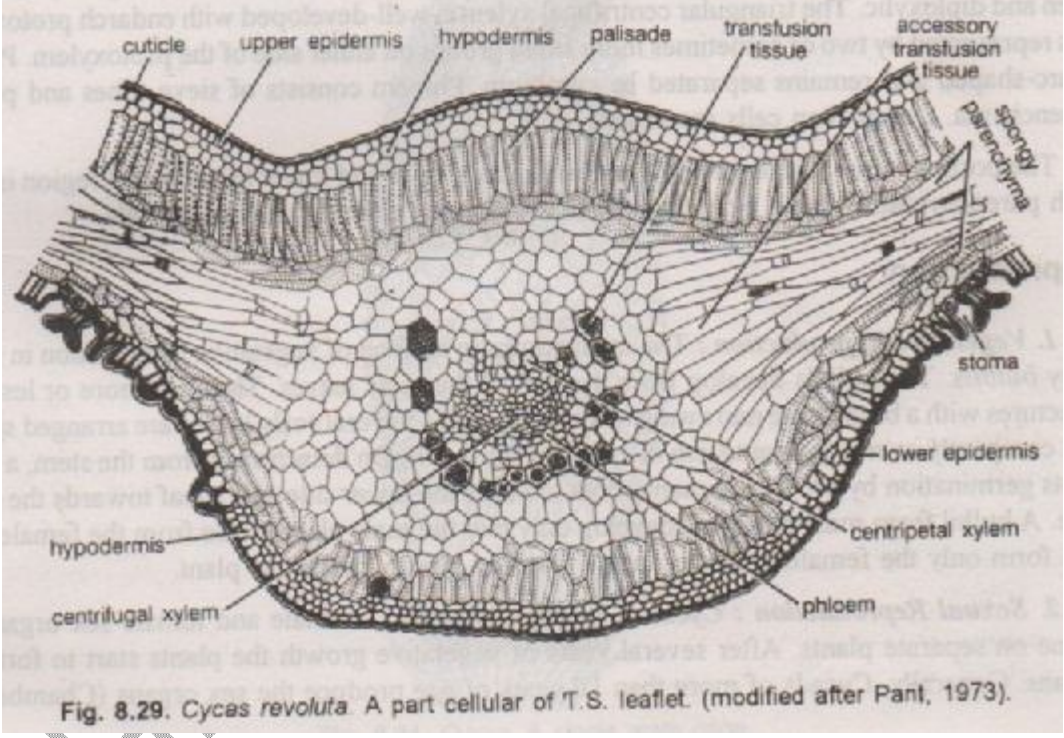


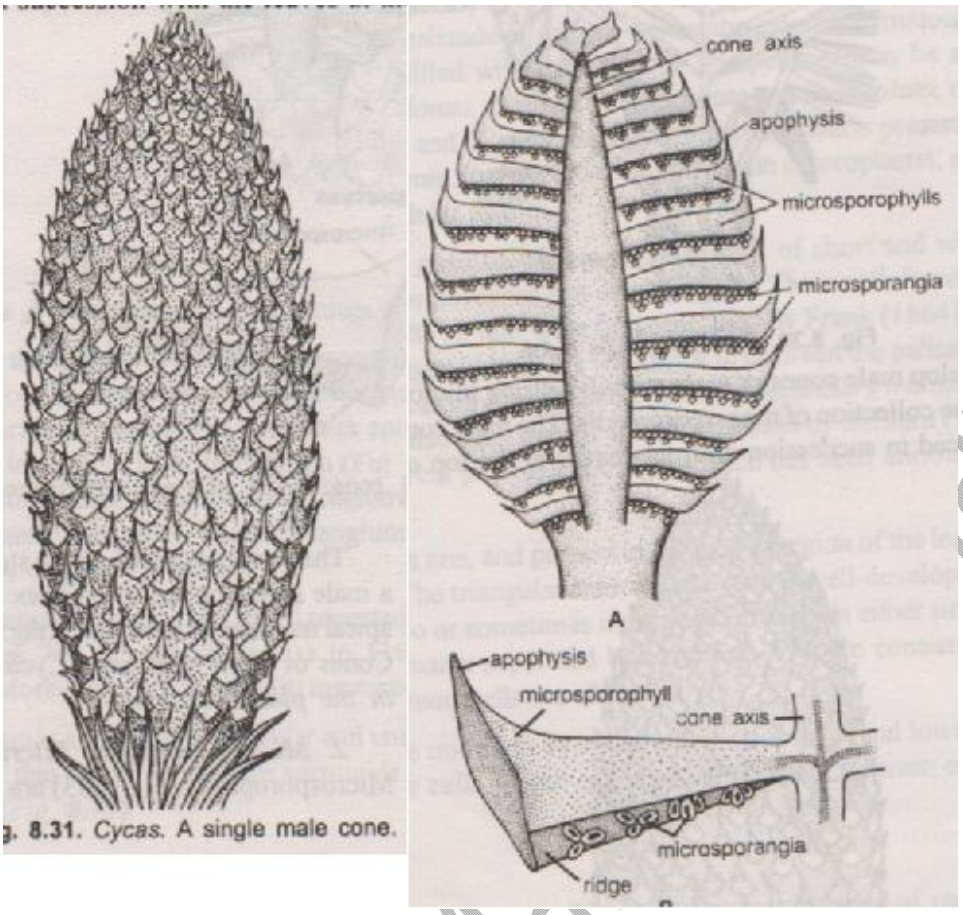
Fig. 8.29. *Cycas revoluta*. A part cellular of T.S. leaflet. (modified after Pant, 1973).

Reproduction

Cycas is dioecious plant i.e. male and female sex organ found on separate plant. Male plant **develop male cone or male strobillus** contain microsporophyll while female plant produce megasporophyll and **do not form female cone**.

Male cone:

- First time male cone is produce in between crown of foliage leaf which stops the growth of main plant. Further the growth of main plant occurs by the lateral bud. Now the other cone is produce on lateral side on the stem.
- Each cone is conical, stalk and about 40-60cm long.
- It contains a central cone axis on which many microsporophylls are arranged spirally.
- All microsporophyll except few terminal and few basal are fertile.



g. 8.31. *Cycas*. A single male cone.

Microsporophyll (Stamen):

- It is flat, leaf like, woody and brown in coloured.
- It is narrow at base and expended on upper portion.
- The upper expended portion become pointed is called **apophysis**.
- The narrow base is attached to cone axis with a short stalk.
- It contains two surface i.e. **upper surfaces** (ventral or adaxial) and **lower surface** (dorsal or abaxial).
- The lower surface median longitudinal ridge. It contains many **sori (sing: sorus)** on either side of ridge.
- The upper side is sterile and bears no sori.
- Each sorus contains **2-4 microsporangia** containing **spore (pollen grain)**.
- Several soft unicellular or bicellular hairs are present on microsporangia called **soral or inducial hair**.
- A lining of dehiscence present in each microsporangia which help in the dispersal of spore.
- The wall of microsporangia is made up of three layer outer exothecium, middle endothecium and inner tapetum.
- Tapetum is nutritive in function.
- Microspore is boat in shape and covered by outer exine and inner intine.

L.S. of Male Cone:

- It contains a central axis or cone axis in center.
- It contain stalk on base.
- Many microsporophylls are arranged on both side of the central axis.
- Many microsporangia found on the lower surface of micerosporophyll.
- The few terminal and basal are sterile.
- The apophysis of microsporophyll is curved upward.
- Sporangia contain many spores (pollen grain).

Female reproductive structure:

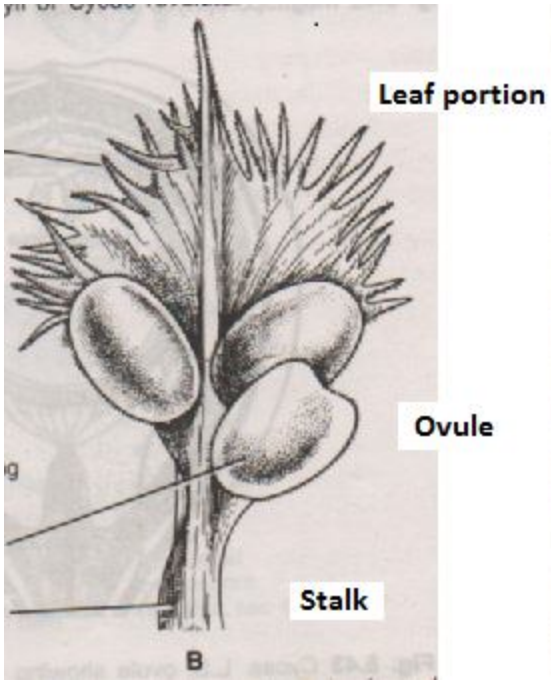
The female reproductive structure is megasporophyll. It is spirally arranged on the apex of stem. **Megasporophyll do not form cone like structure.**

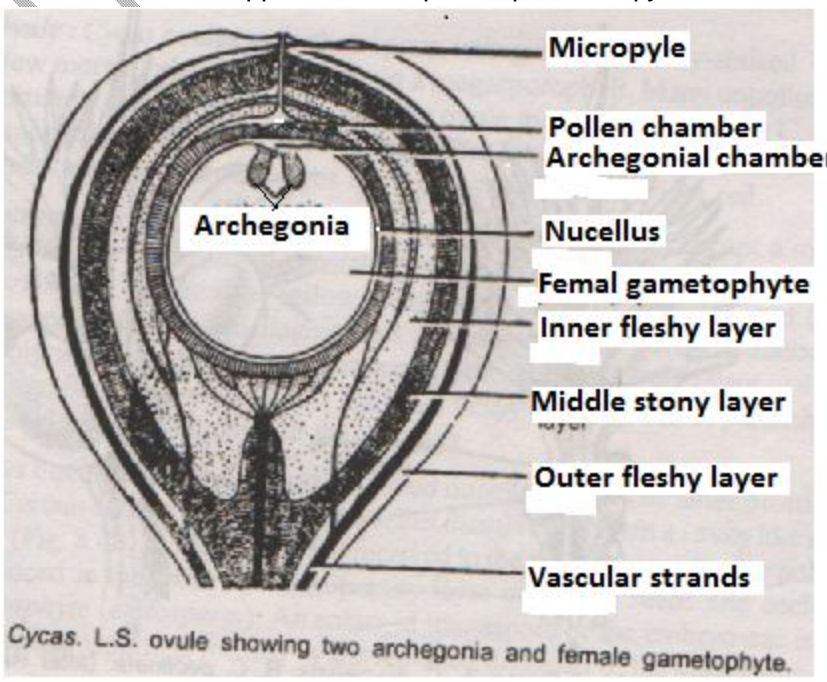
Structure of megasporophyll:

- Megasporophyll is a modified structure of foliage leaf.
- It is a flat body, consisting upper leaflet (pinnate leaf) portion, middle ovule bearing portion and basal petiol.
- The middle part is comparatively wider then basal and upper portion.
- The middle portion bears ovule between leaflets (pinnate). The number of ovule varies from 2-12 in different species.
- The ovule is green when young but at maturity they become orange or red coloured.

Structure of Ovule (megasporangium) / L.S. of mature Ovule:

- The ovule is **orthotropous, unitegmic** (one integument) **and short stalked.**
- It is covered by single thick integument from all side except a mouth like opening called micropyle.
- The integument consist of three layers; (i) outer green or orange **fleshy layer** called **outer sarcotesta** (ii) middle yellow **stony layer** called **middle sarcotesta** (iii) inner **fleshy layer** called **inner sarcotesta.**
- The inner part of inner integument is made up of parenchymatous cell called **nucellus**.
- At beginning the nucellus grow toward micropyle through beak like portion called **nucellar beak**. Latter the cell of nucellar beak is dissolved now called **micropylar canal**.
- At the top of nucellus some cell dissolve and form a cavity called **pollen chamber or micropylar chamber**.
- The micropyle opens inside in to the pollen chamber. Pollen chamber received many pollen grains after pollination.
- Inside nucellus massive **female gametophyte (endosperm)** are present formed by **megaspore mother cell** present in nucellus.
- Just below the pollen chamber is present an **archegonial** chamber.
- There are 3-6 archegonia are present in the female gametophyte below the archegonial chamber.
- The vascular strand enters into the base of ovule and help in the vascular supply through outer and inner layer of integument. The vascular supply become branched toward upper side and spread up to micropyle.





Cycas. L.S. ovule showing two archegonia and female gametophyte.

Gametophyte:

- The plant of cycas is heterosporous because it is produce microspore (pollen grain) and megaspore.
- The microspore and megaspore both represent to gametophytic generation. Both are develop by meiosis division in microspore mother cell and megaspore mother cell respectively.

Male gametophyte:

- Microspore is the first cell of the male gametophyte.

- The microspore starts germination in the microsporangium i.e. in situ.
- Microspore dived into two unequal cells. The smaller one is called prothalial cell and the large antheridial cell.
- Prothalial cell does not divide while antheridial cell divide into generative cell and large tube cell with large nucleus.
- At this three celled stage (prothalial cell, generative cell and tube cell) the microspore or pollen grain is liberated from microsporangium.
- The rest development of pollen grain is completed in pollen chamber of ovule.

Pollination:

- Dehiscence of microsporangium by longitudinal slit and the three celled microspore blown away by wind. Therefore the pollination in Cycas is anemophyllous.
- On the other hand the cell of nucellar beak is dissolve to form a drop of mucilage called **mucilage drop.** It is also secreted by some cell of nucellus and integument.
- Mucilage drop come out from micropyle now called pollination drop.
- Certain pollen grain or microspore present in the air is caught in this pollination drop.
- Now microspore withdrawn into pollen chamber through micropylar canal.
- The pollination drop start drying then the micropylar canal sealed up. Thus pollination process completes.

Female gametophyte:

The central part of nucellus contains megaspore mother cell. It under go meiosis division and form four haploid cell. Three cell of them degenerate and one is called functional haploid megaspore. The functional megaspore is called female gametophyte. Later it formed massive endosperm and 3-6 archegonia. The cell of endosperm later provides nutrition to the developing embryo.

Archegonia:

Each archegonium is made up of 2-neck cell, 1-venter canal cell, and one large egg cell. **The egg of Cycas is the largest among all living plant.**

Fertilization:

The pollen grain in pollen chamber form pollen tube. The pollen tube act as an **absorbing organ or haustoriua**. The generative cell soon divides into **stalk cell and body cell.** Further development of male gametophyte take place after a gap of 4 month. Now become ciliated and divide in to two sperm (spermatozoid). Now the pollen tube penetrates to pollen chamber and reaches into archegonial chamber. Therefore the pollen tube hangs in between pollen chamber and archegonial chamber. Now the end of pollen tube bursts and the sperm move freely in to archegonial chamber by cilia. The sperm enter into archegonia through neck and reaches up to the egg. Therefore the nucleus of sperm fuses with egg nucleus to form zygote (oospore). In Cycas the fertilization take place with the help of motile ciliated sperm, therefore it is called **zoodogamy.** On the other hand the pollen grain act as a sperm carrier therefore it is called **siphonogamy**.

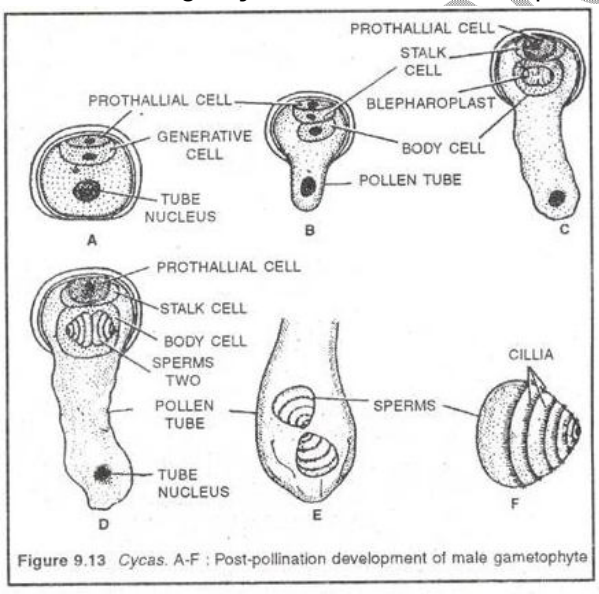
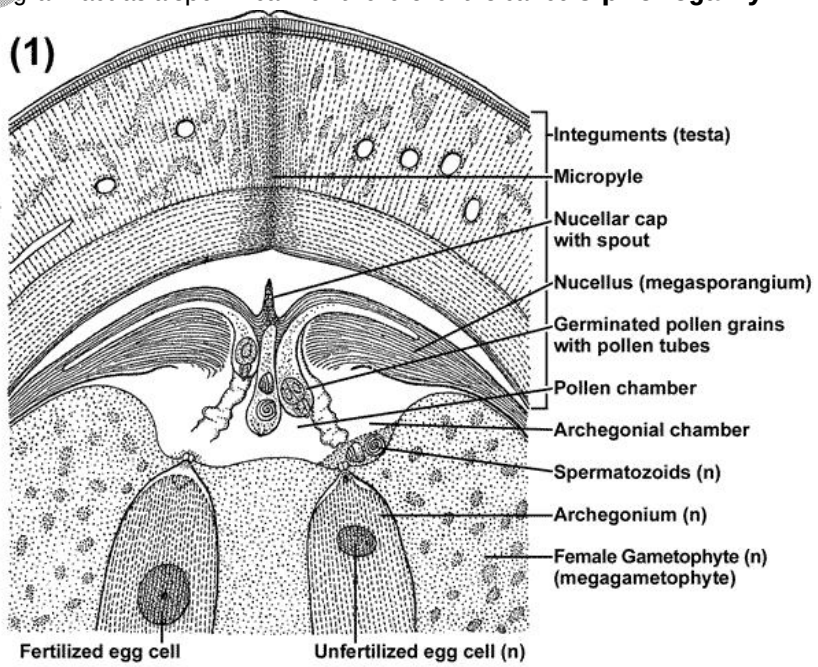
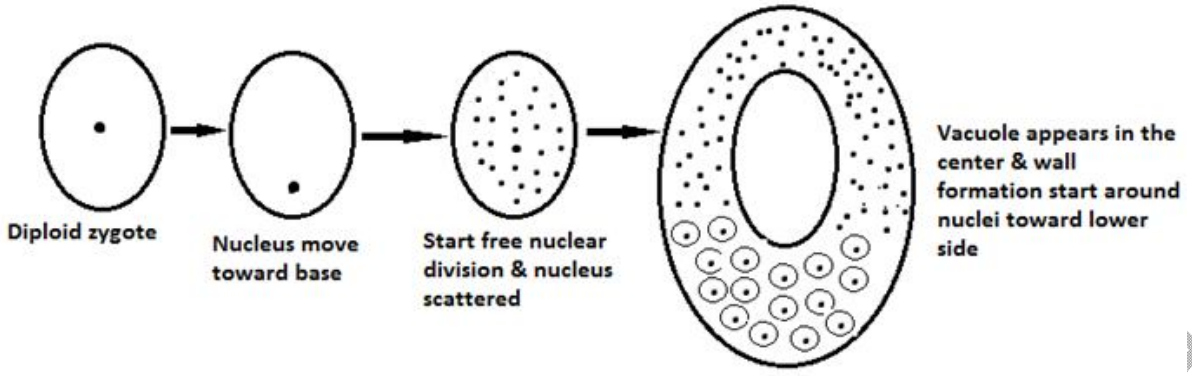


Figure 9.13 *Cycas*. A-F : Post-pollination development of male gametophyte



Sporophyte:

<u>Development of embryo or Oospore or sporophyte</u>



- After some time wall formation proceeds to the nuclei present toward upper side.
- Some of the nuclei in the upper most regions always free.
- Thus developing zygote (oospore) now consists of a cellular region toward the lower side and free nuclear region toward the upper side. Such structure of zygote is called proembryo.
- Proembryo differentiated in to three region

(a) Free nuclear region (Haustorial region):- It is the upper part of the proembryo. It always attached with female gametophyte (endosperm). It works as a haustoria and absorb nutrition from endosperm for developing embryo.

(b) Suspensor region: - It is middle region of proembryo. It is long coiled region. It push the embryo in to the endosperm.

(c) Embryonal region:- It is basal part of proembryo. The embryo is formed by division in the cell of proembryo. The complete develop embryo divided in to three regions. (1) Lower most large two cotyledons (2) central plumul and (3) the upper most redicle. The part between plumul and redicle are called hypocotyls. Some hard cell are found at the tip of redicle which are called coleorrhiza.

Order – Coniferales (Genus- Pinus)

They grow in xerophytic habitat. The plant body is divided in to root, stem and leafs. Common Indian species are ***P.gerardiana and P.raxburghii.*** They are found in temperate to subalpine region of North hemisphere especially in **Himalayas**. Generally the genus forms dense forest in the hills. The plant body is pyramidal look. It is evergreen and about 50-200 feet.

Root:

In the primary stage the root is tap root for very short period. Later it forms adventitious roots. The root is covered by fungal hyphae which represent ectotrophic mycorrhiza. Some worker says that they show mutual benefit relationship and some say that fungus remains parasite on this root.

Stem:

The stem is cylindrical and branched. It has two type of branch one is long shoot and other is short shoot.

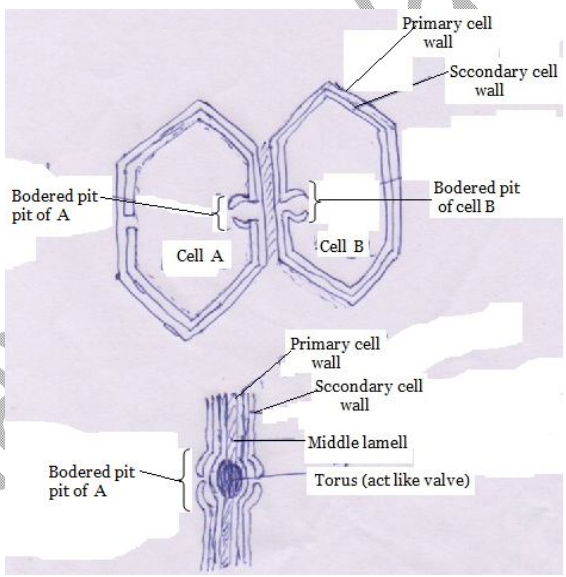
Long shoot: - In this branch found unlimited growth. They arise from the axil of scale leaves on the main stem. **They become shorter toward the apex and provide a pyramidal look to the entire plant**. Several short shoot are present on each long shoot. The older part of long shoot is always covered by spot of fallen dwarf shoot.

Dwarf shoot: - In this branch found limited growth. It also develops from axil of scale leaves on the long shoot. On the dwarf shoot found two scale leaves called **prophylls** arranged in opposite manner. Above the prophylls found 5-13 cataphylls. Finally the dwarf shoot contains 1-5 needles like leaves at the tip. The dwarf shoot with needle like leaves are called **foliar spurs**. If foliar spurs contain one needle like leaf called unifoliar, if two needle called bifoliar (P.gerardiana).

Leaves: - Pinus contain five types of leaves. These are **cotyledon, juvenile, prophyll, cataphyll and acicular.** Initially develop cotyledon leaves. After some time juvenile leaves develop at the place of cotyledon leaves for 1-3 year. Prophyll and cataphyll is a scaly leaves born on dwarf shoot. **Acicular leaves are foliage leaves called needles. They also develop only on the dwarf shoot. Needles in Pinus show xerophytic characters.** The outline of needles may be circular, semicircular or triangular (P.gerardiana).

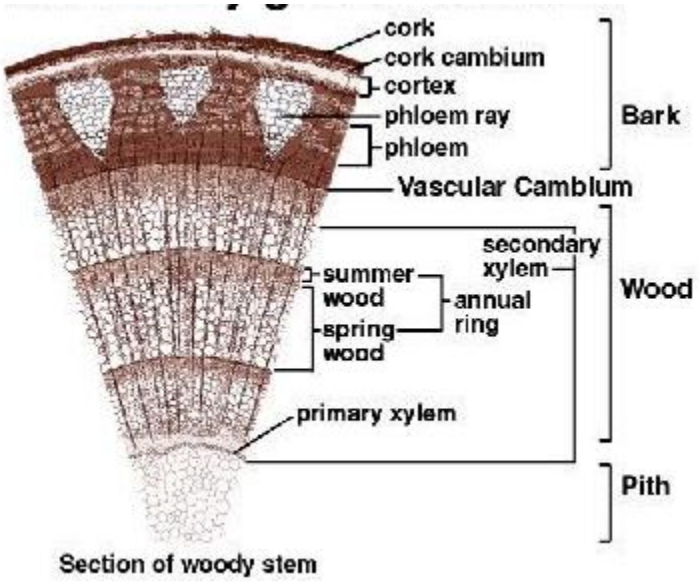
T.S. of young stem (Long-shoot)

- The outline of stem is wavy due to presence of scale leaves and dwarf shoot. It is identical to the dicot stem.
- **Epidermis** is the outer most layers covered by cuticle.
- **Cortex** is divided in to outer cortex and inner cortex. The outer cortex is made up of sclerenchymatous and 1-3 layer thick. The inner cortex parenchymatous and multilayered. Few cells are containing chloroplasts. **Resin canal and leaf trace** also found in cortex. Resin canal is the chief source of **turpentine.**
- **Endodermis** is present bellow cortex. It is single layered.
- **Pericycle** is multilayered but not distinguishable from other part.
- **The stele** is ectophloic siphonostele, made up of 5-8 or more vascular bundles arranged in ring like in dicot stem.
- **The vascular bundle** is conjoint, collateral and open. The xylem is endarch. In between two vascular bundle found primary medullary rays. It connects the pith with cortex.
- Primary xylem consists of xylem tracheids and xylem parenchyma. On the wall of the xylem tracheid found **bordered pits. Xylem vessels and xylem wood are absent.**
- Primary phloem consists of sieve tube and phloem parenchyma. **Companion cell is absent.**
- **Pith** is central and parenchymatous.



T.S. of old stems (Long stem) showing secondary growth:

The secondary growth in old stem of Pinus is same like dicotyledonous stem. The **interfascicular and intrafascicular cambium** unites to form **cambium ring**. The cambium ring form secondary phloem toward outside and secondary xylem toward inside. After some time the cambium ring inactive and second cambium ring develop in the region of pericycle. This cambium ring also behaves similar manner. The secondary **medullary ray** present in between secondary xylem. **Due to presence of secondary medullary ray the wood become soft.** A band of secondary phloem and secondary xylem is formed each year. Each secondary xylem divided in to two zones called **autumn wood (summer wood) and spring wood.** The autumn wood is formed in autumn (summer) secession and spring wood is formed in spring (winter) secession. The wall of tracheid of autumn wood is thick then spring wood. The wall of tracheid of autumn wood contains small **bordered pit** then spring wood. The tree shows a layer of spring (early) wood and a layer of autumn (late) wood which form the **annual rings** in each year. **Therefore secondary xylem band is called annual ring**. Springwood is usually light in colour and of low density. Autumn wood is usually dark in colour and of high density. A torus is present in the pit. **Resin canals** are present in



Section of woody stem

both primary and secondary wood. **The wood is dense, massive and compact. The wood of pinus is pycnoxylic (hard wood).** The age of the tree and any branches are determined by counting the number of the annual ring. Some of the cortex cell forms cork cambium. It forms cork toward outer side and secondary cortex toward inner side.

Wood of Gymnosperms is classified into manoxylic or pycnoylic. This classification is based on the amount of xylem cells in the wood.

Manoxylic wood:

It is the non-compact wood with large amount of parenchyma, large pith and cortex mixed with less amount of xylem tracheids or wood.

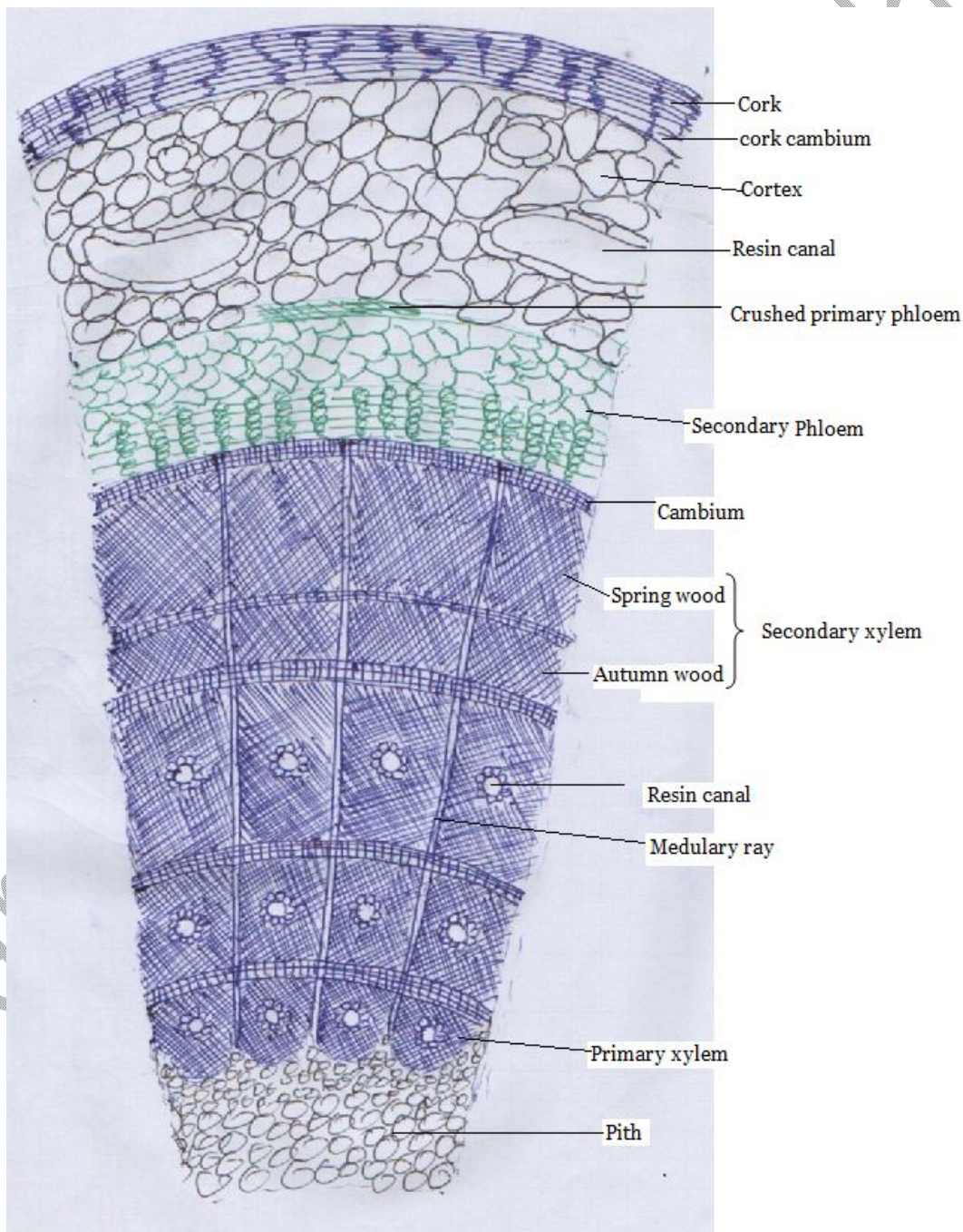
-Parenchyma cells are filled with starch grains

-Not important commercially as wood is not durable e.g. In Cycas

Pycnoxylic wood:

It is the compact strong wood with large amount of xylem tracheids or wood and small amount of cortex and pith with little Parenchyma.

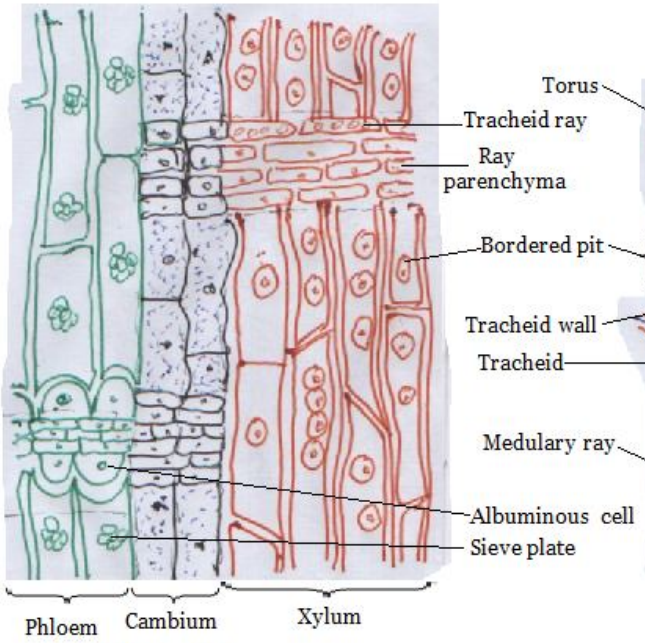
-Durable and yields timber e.g. In Pinus



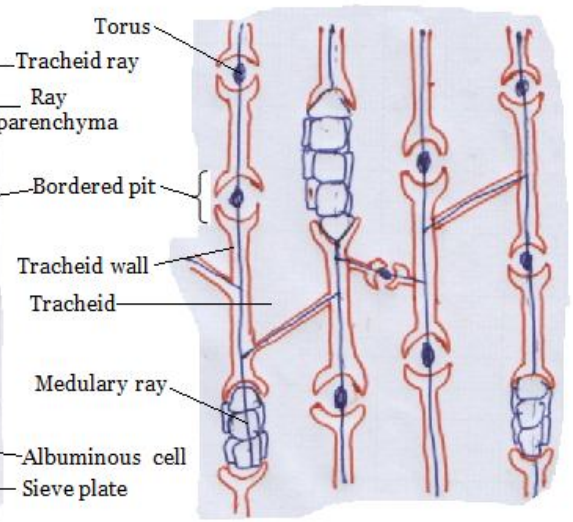
T.L.S. (Tangential Longitudinal Section of Wood):- The longitudinal section passing away from the center is called T.L.S. In this plane tracheids and medullary rays are cut transversely.

R.L.S. (Radial Longitudinal Section of Wood):- The longitudinal section passing from the center is called R.L.S. In this plane the tangential wall of tracheids are cut.

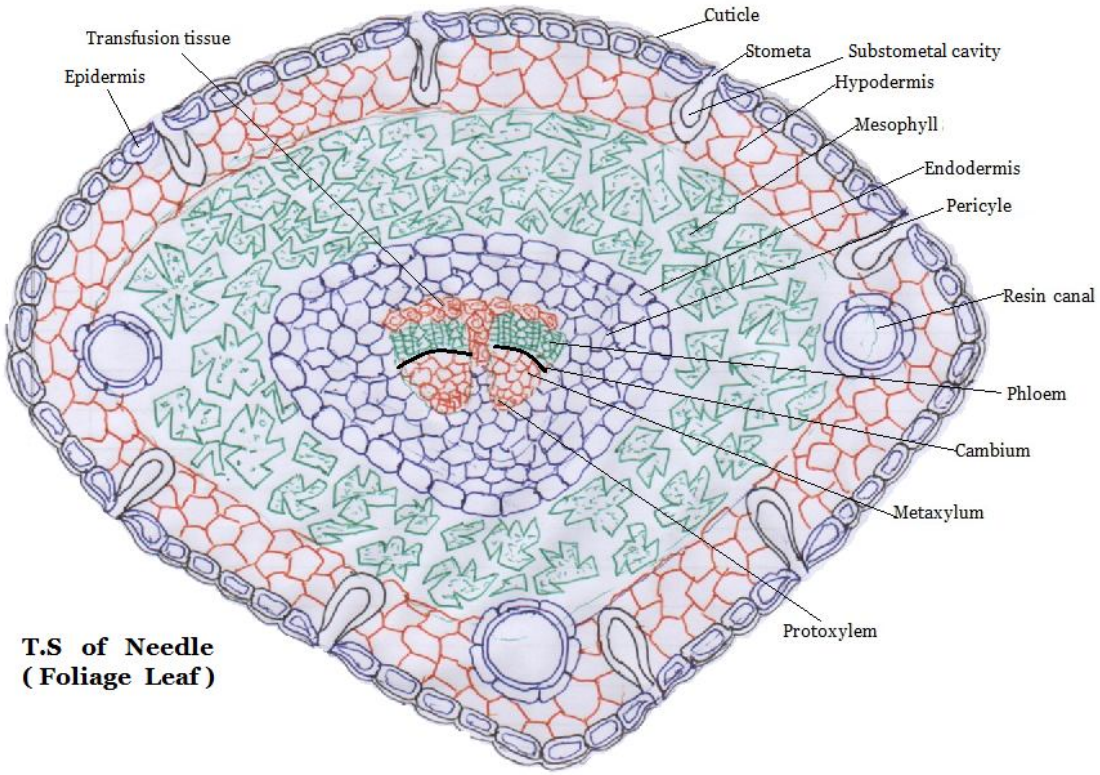
T.S. of Dwarf Shoot:- secondary growth like long shoot. Only Fig Of T.S. of dwarf Shoot



R.L.S of Stem



T.L.S. of Stem



T.S of Needle (Foliage Leaf)

Anatomy of Needle or Foliage Leaf:

- The outline of foliage leaf or needle in ***P.roxburghi*** is triangular.
- The outer most layers are **epidermis** and covered by cuticle. Epidermis is broken by many sunken stomata. Each stomata internally open in to **substomatal cavity**.
- **Hypodermis** is 2-3 layer and sclerechymatous. The region of hypodermis is interrupted by the stomata.

- **Mesophyll** is present in between hypodermis and endodermis. Its cell contains chloroplast. Many peg - like infolding also found in the wall of mesophyll cell.
- Generally three resin canal present in the mesophyll cell. Each canal is surrounded by the epithelial cell.
- **Endodermis** is single layer contain casparian strips.
- **Pericycle** is multilayered and consist many **parenchymatous cells** and some **sclernchymatous cell** in T-shaped. Two vascular bundle remain separated by these T-shape cells. This T-shape cell represents the **transfusion tissue**.
- The **vascular bundle** is two in number. They are conjoint, collateral and open.
- The xylem present toward lower side and phloem present toward upper side.
- Xylem and phloem separated by cambium.

Xerophytic characters of Needle:

- Needle like leaf.
- Presence of thick cuticle.
- Presence of stomata on all side i.e. amphistomatic nature.
- Presence of sunken stomata.
- Presence of peg-like projection in the mesophyll cells.
- Presence of resin canals.
- Multilayered pericycle.
- Presence of transfusion tissue.
- Presence of T-shape sclerenchymatous patch in between vascular bundle.

Reproduction: Pinus is a monoecious plant i.e. male and female cone present on the separate branch on the same plant.

Male cone/L.S OF Male cone:

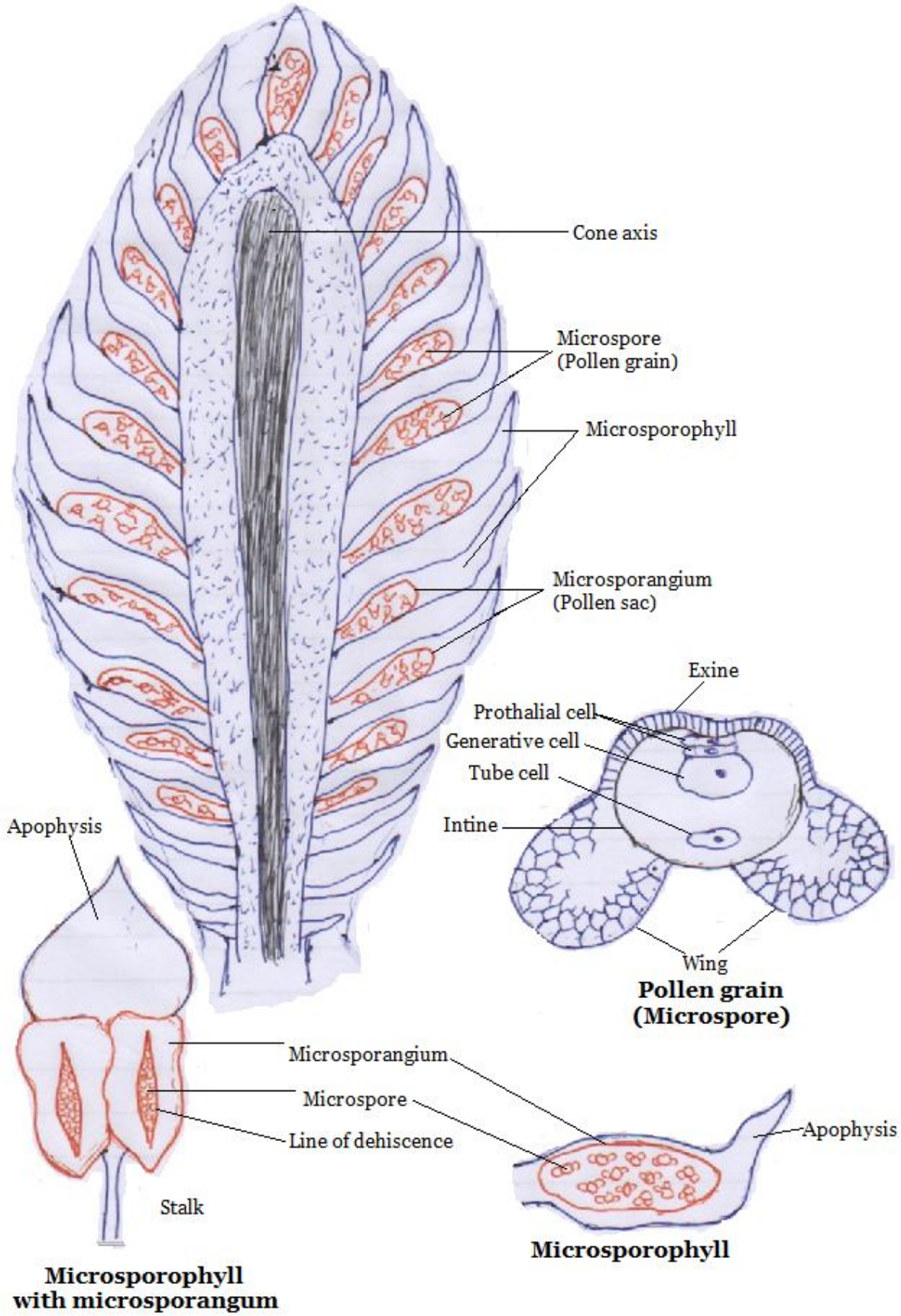
- The male cone develops in a cluster in the axil of scaly leaves on long shoot. **They arise by replace dwarf shoot.** Therefore the growth of the long shoot is contentious.
- It contains a large number of microsporophyll arranged in spirally on cone axis.
- Each microsporophyll is a small membranous structure. Compared with **stamen**.
- The tip of microsporophyll is projected upward called **apophysis.**
- Two pouch like **microsporangia (pollen sack)** present on the lower surface of microsporophyll.
- Several **microspores (pollen grain)** are present in the microsporangia.
- A **longitudinal line of dehiscence** is present on each microsporangia.

Structure of Microspore (Pollen Grain):

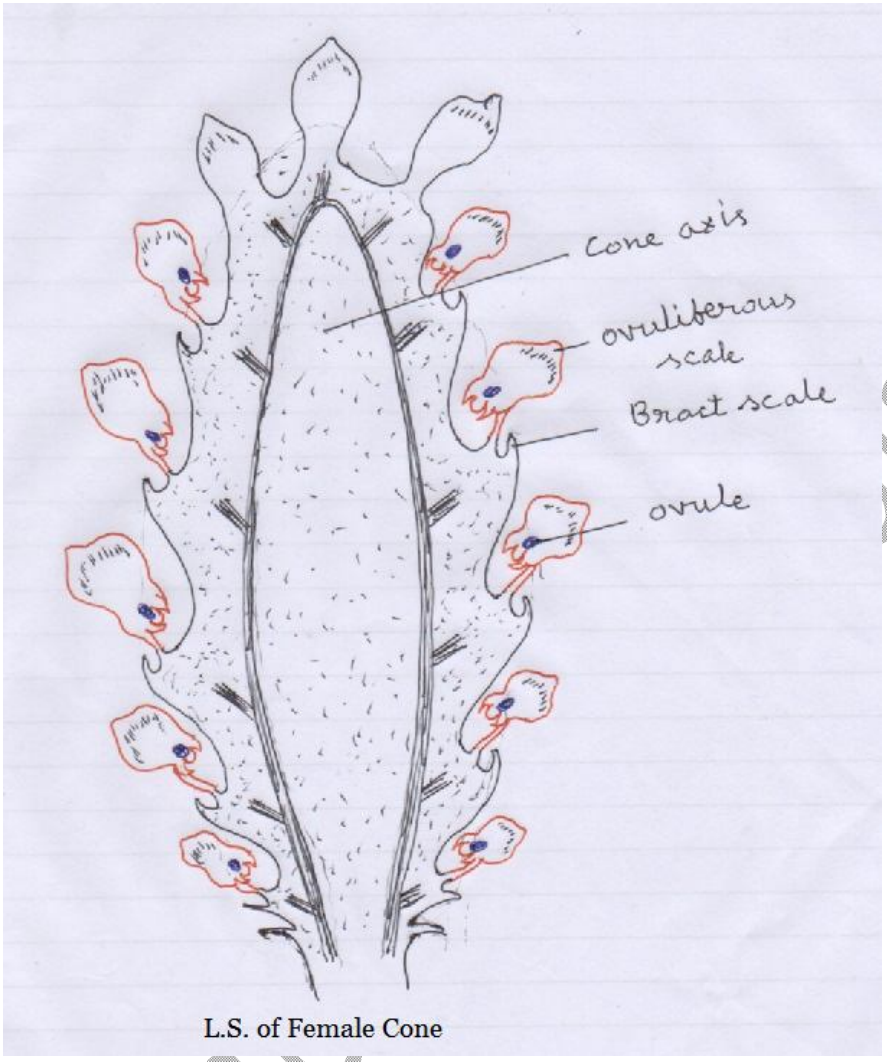
- The pollen grain is found inside the microsporangium.
- It is surrounded by double layered outer exine and inner intine.
- Exine expended and form balloon structure on the lateral sides called **wings or air-sacs**.
- The wings help in the flotation and dispersal of pollen grain.
- The exine and entine are thick toward upper side and form a cape like structure.
- It contains a large amount of cytoplasm and a nucleus.
- A mature pollen grain contain four nuclease two prothallial cell, one generative cell and one large tube cell.
- At the time of dehiscence the microspore is four celled stage.

Female Cone / L.S. of Female cone:

- The female cone develops in group of 2-4.
- It born in the axil of scaly leaves on the apex of long shoot. Therefore the growth of long shoot is cheek. Therefore female cone is formed at the place of long shoot.
- The mature female cone is hard, woody and larger then male cone.
- Cone axis is present in the center of the cone.
- Megasporophyll arranged spirally on the cone axis.
- Each megasporophyll consists of two types of scale leaves (1) bract scale and (2) ovuliferous scale.
- The bract scale is small and arises from the cone axis. It lies below the ovuliferous scale.
- The ovuliferous scale arises from the axil of bract scale.



- Ovuliferous scale is woody and large. The upper sterile and triangular portion is called apophysis.
- Ovuliferous scale bear two ovule on the upper surface near the base.
- The micropyle of ovule face toward cone axis.



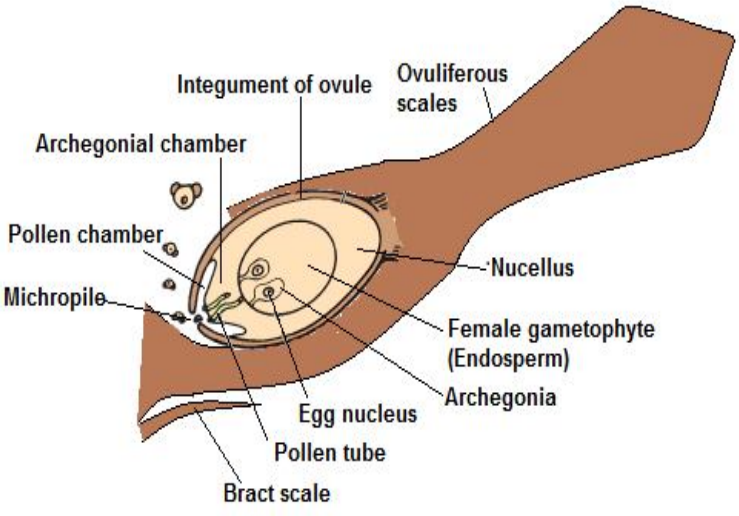
L.S. of Female Cone

Nature of Ovuliferous Scale:

- The nature of ovuliferous scale is not cleared. Some botanist says that it is a *free carpel* while other believed that it is a placenta.
- According to some other workers it is an axillary shoot.
- It is also considered as fused outer integument or ligule.
- Florin says that it is a seed- scale-complex.

Structure 0f Ovule / L.S. of Ovule:

- Each ovule is anatropous and surrounded by integument from all side except micropyle opening.
- The integument is differentiated into outer flashy layer, middle stony layer and inner flashy layer. But it is not clear as in Cycas.
- The opening of ovule is called micropyle. Micropyle opened in side in to pollen chamber.



- Near the pollen chamber found free portion of nucellus while remaining part is fused with the inner fleshy layer.
- Nucellus surrounded to female gametophyte (endosperm) in which 2-5 archegonia present toward micropylar region.
- In between female gametophyte and free portion of nucellus found archegonial chamber.

Pillition:

- Pollution takes place in the month of May or Jun in hills and in February to March in the plains.
- After few days nucellus of ovule secrete a **pollination drop** at mid night under high humidity.
- The pollen grain liberated from microsporangia by longitudinal slit and blown by **wind (animophyllous)**.
- The winged yellow pollen grain is caught by **pollination drop**.
- In the pollination period the yellow colour pollen grain produce in large number therefore during pollination period **small clouds of yellow colour** are seen in Pine forest.
- The pollen grain is very light and contain balloon like wings therefore they easily blown away by wind.

Post –pollination development of the pollen grain:

OR Development of pollen after pollination:

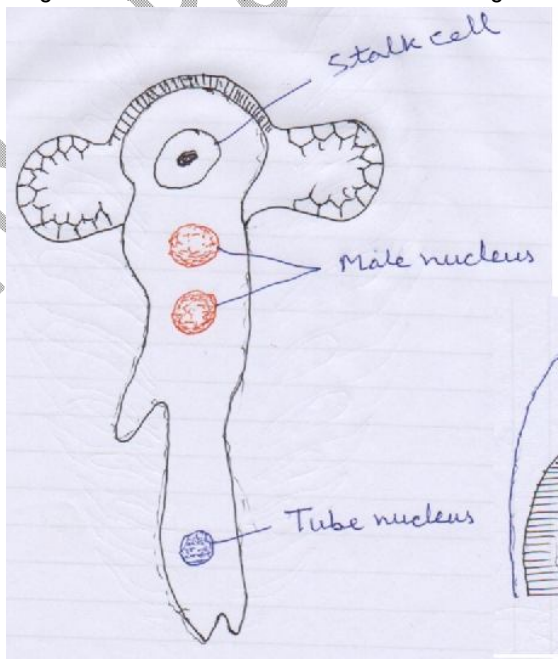
- After pollination the pollen grain is in four celled stage two prothalial cell, one generative cell and one large tube cell.
- On the nucellar tip the intine of pollen grain form pollen tube. The tube nucleus comes in pollen tube.
- After penetrating the nucellar tissue the pollen tube rest throughout winter.
- After one year the **generative cell** dived in to **stalk cell and body cell**.
- After some time the stalk cell degenerate and body cell divided into **two unequal non motile male gamete**.
- In this time the pollen tube reaches near the neck of archegonium. And archegonia ready to receive male gamete

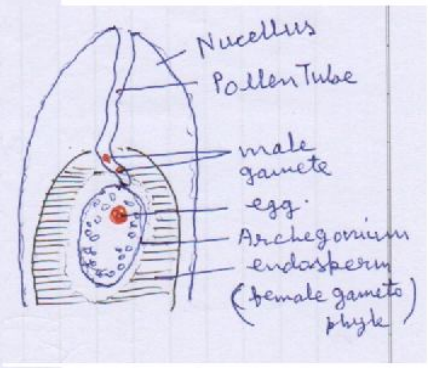
Archegonia:

- Each archegonium is made up of 8-neck cell, 1-venter canal cell, and one large egg cell.

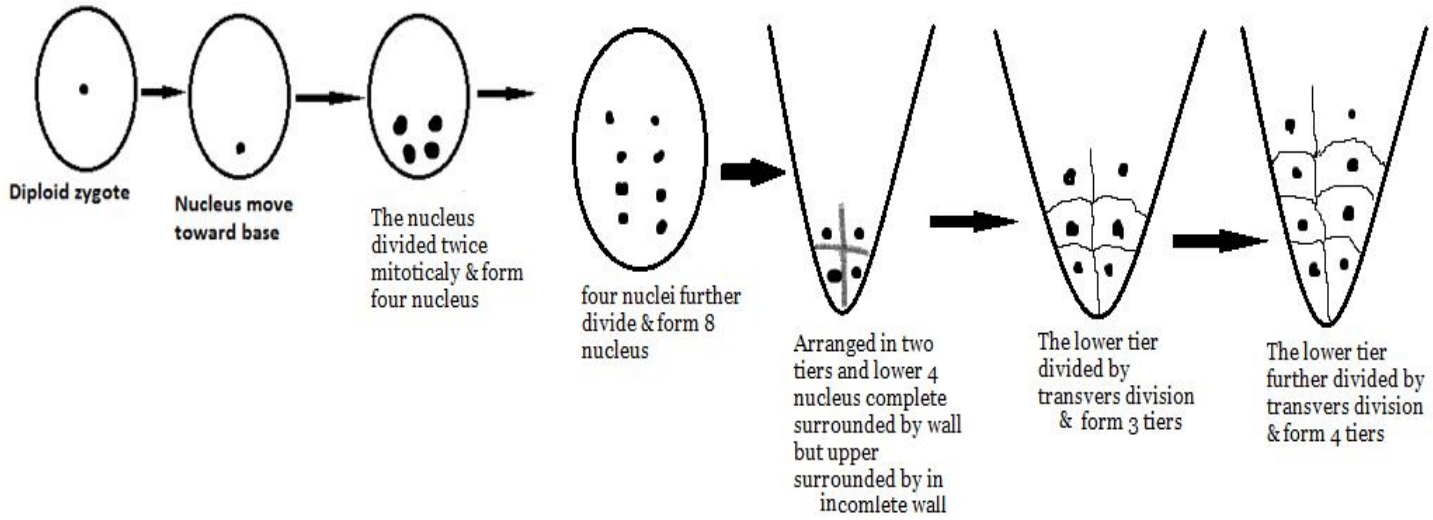
Fertilization:

- Pollen tube enters into neck canal cell of archegonium through nucellus.
- In this stage the pollen tube contain stalk cell, tube nucleus and two male nucleus.
- The pollen tube burst in side archegonium and only one male nucleus move toward the egg cell.
- The membrane of male nucleus fuses with membrane of egg nucleus and form zygote or oospore.
- The other male gamete, stalk cell, and tube nucleus degenerate soon.





Development of Embryo:



Each tiers contain 4 cell therefore total 4 tiers contain 16 cells. The upper one tier are called nutritive tier. It does not part of embryo. This group of 16 cells is called pro-embryo. The 4 tiers from the lower side are known as Embryonal tier, suspensor tier, rosette tier and open or upper tier. **The lower most embryonal tier with 4 cells gives rise to embryo. Each cell of these tier form embryo. Thus Pinus show phenomenon of *polyembryony*.** The embryo is differentiated into the cotyledons, plumule, radical and hypocotyls.

Seed:

The seed of *P.gerardiana* commonly called chigoza are used as a dry fruit. As the development of embryo completed then following changes found in ovule.

- The outer fleshy layer disappears.
- The middle stony layer become hard, brown in colour called **seed coat or testa**.
- The inner layer survives in a thin brown in colour called **tegmen**.
- Nucellus and endosperm is used up by developing embryo and present as a thin membrane called **perisperm.**

Polyembryony in Pinus:

In pro-embryo the each tiers contain 4 cell therefore total 4 tiers contain 16 cells. The upper one tier are called nutritive tier. This group of 16 cells is called pro-embryo. The 4 tiers from the lower side are known as **Embryonal tier, suspensor tier, rosette tier and open or upper tier**. **The lower most embryonal tier with 4 cells gives rise to embryo. Each cell of these tier form embryo. Thus Pinus show phenomenon of *polyembryony*.** Therefore each suspensor cell contain embryonal cell at it tip. Thus four embryos are formed by one fertilized egg. Such type of embryo is called ***cleavage polyembryony.*** In the later stage one embryo develops and other three are degenerate. Some time more than one archegonia are fertilized and develop more than one embryo. This is called simple polyembryony. Some time rosette tire also develops in to embryo. Such type of polyembryony is called rosette polyembryony.

Fossils

The word fossil was derived from Latin word fossilum means something dug up. Therefore fossil are dug out from the earth. **Any remaining material or sing of plant which are extinct now is known as fossils**. Slowly and slowly sediment deposited over the dead organisms therefore the organisms will go deeper in earth's surface. The process of preservation of living being or their part in the form of fossils is known as fossilization.

The process of fossilization and kind of fossils:

The following two theories proposed for fossilization process in plant.

1. Molecule and Molecule replacement theory- According to this theory the original substance of plant body are replaced by minerals present in soil solution. This replacement takes place by the hydrolysis of organic substance except the cell wall material (particular lignin and cellulose). The replacement process is the slow process.

2. Infiltration theory – According to this theory infiltration and precipitation of mineral matter take place in the cell. Therefore the partial disintegration takes place of the plant or plant part and

release free carbon. The free carbon reacting with calcium, magnesium and iron present in mineral mater and form carbonate. Finally silica and other compound reach in the cell and deposited.

Type of fossil:

1. Compression – They are most common type of fossil. The complete plant or part of plant becomes compressed due to continuous overlapping presser of sediment. The plant part becomes flat due to high pressure of sediment. The organic matter preserved in the form of carbonaceous film. This fossil is used only in the study of **external morphology**. Coal and Peat contain such type of fossil.

2. Impression – These fossils found in the form print or impression of plant or plant part on sediment like clay or silt. The organic matter fall in clay and clay change into stone. Therefore such fossil do not contain any organic matter. They used in the **study of external feature** of plant or plant part like stem, leaves and flower.

3. Petrifications – These fossil preserved both external and internal features of plant. In this fossil all cell of the fossil preserved in the original form. It is very rare. The process of their formation is not clear. Some are say that about twenty type of mineral like silicate, carbonate, sulphate etc. infiltrate in the cell and form salt after precipitation. Some time plant tissue degenerated and form carbon carboxylic acid and humic acid. It is also precipitate in to insoluble form like pyrites. This fossil is suitable for study of anatomical structure of plant.

4. Incrustation or Cast – In the process of formation of cast the plant or plant part is covered by sand or mud. After some time the plant material decompose and formed hollow space inside the plant. The hollow space is filled with rock forming material. After the long time the material change in to stone. They provide three dimensional information of plant. They only preserved seed or woody stem e.g. coal ball. Coal ball are found in broken piece of coal. It is made up of calcium and magnesium carbonate. It is petrified remains of plant fragment.

5. Amber - It is a resin. It is come out from fossil coniferous plant due to injuries by insect or from decaying branch. The resin comes out in the form of drop. After some time it becomes hard clear yellowish brown substance called **amber**. Amber may contain small plant, insect and animal. Amber is considered as type of fossil.

6. Pseudo fossil – Sometime certain minerals or rock take the shape of some plant or animal. When they are studied they indicate neither plant nor animal but simply stone in the shape of plant or animal. Such specimen are called pseudo fossils.

Nomenclature of Fossils:

Normally complete organism does not form fossil there soft part already disintegrate after preservation. Therefore fossilization is better for hard part like skeleton then soft part. Therefore complete plant is rarely preserved like stem, root, fruits, sporangiophore etc. These fossils of plant part are found at different time at different place. **Each fossil part of plant is given by a different name and the name is considered as a genus**. Opposite to living plant the generic

name in fossil applied only for a plant part, without actually indicating to what plant it belong. **Each part of plant representing a genus is called form genus or artificial genus e.g.** phylum for a leaf, Dendron for a stem, pteris for a fern like stem.

Rules for naming form genera:

In naming a form genus a particular suffix is applied which indicate the part of plant. Following suffix are used to represent the different part of plant.

1. Phylum is used for leaf e.g. *Lepidophyllum, Ptolophyllum, Nipaniophyllum* etc.

2. Dendron is used for stem e.g. *Lepidodendron,* and *Lyginodendron* etc.

3. Pteris is used for fern like stem e.g. *Lyginopteris.*

4. Xylon is used for woody part of plant e.g. *Mycoxylon, Cladoxylon, Dictyoxylon.*

5. Spermum or corpon is used for seed e.g. *Lpidocorpon,*

Reconstruction:

Formation of the complete plant by the arrangement of different form genera. The different form genera are arranged on the basis of their similarity and period in which they belonging in such a manner as it present in its original form. Thus the different form genera give rise to a **complete plant** called **reconstruction.** For e.g. the fossil plant *Calymmatotheca hoeninghausi* has been reconstruction by putting together stem called *Lyginopteris,* root called *Kaloxylon,* leaves called *Sphenopteris,* rachis called *Rhacoptaris* and seed called *lagenostoma.*

Geological Time Scale:

Before 4.6 billion ago the earth was in the form of gaseous stat. Before 4 billion ago the earth has been changed into solid state called earth's crust. Therefore the .6 billon life period of earth was gaseous state called **Azoic era** (era of no life).The life of earth before 4 billion ago to now days are divided in to five eras (eras of life) called **geological time scale.** The five eras are called (1) Archaeozoic (2) Proterozoic (3) Palaeozoic (4) Mesozoic (5) Coenozoic. The eras also divided into many period and each period also divided into epoch. The Archaeozoic and Proterozoic eras together called **Precambian era**.