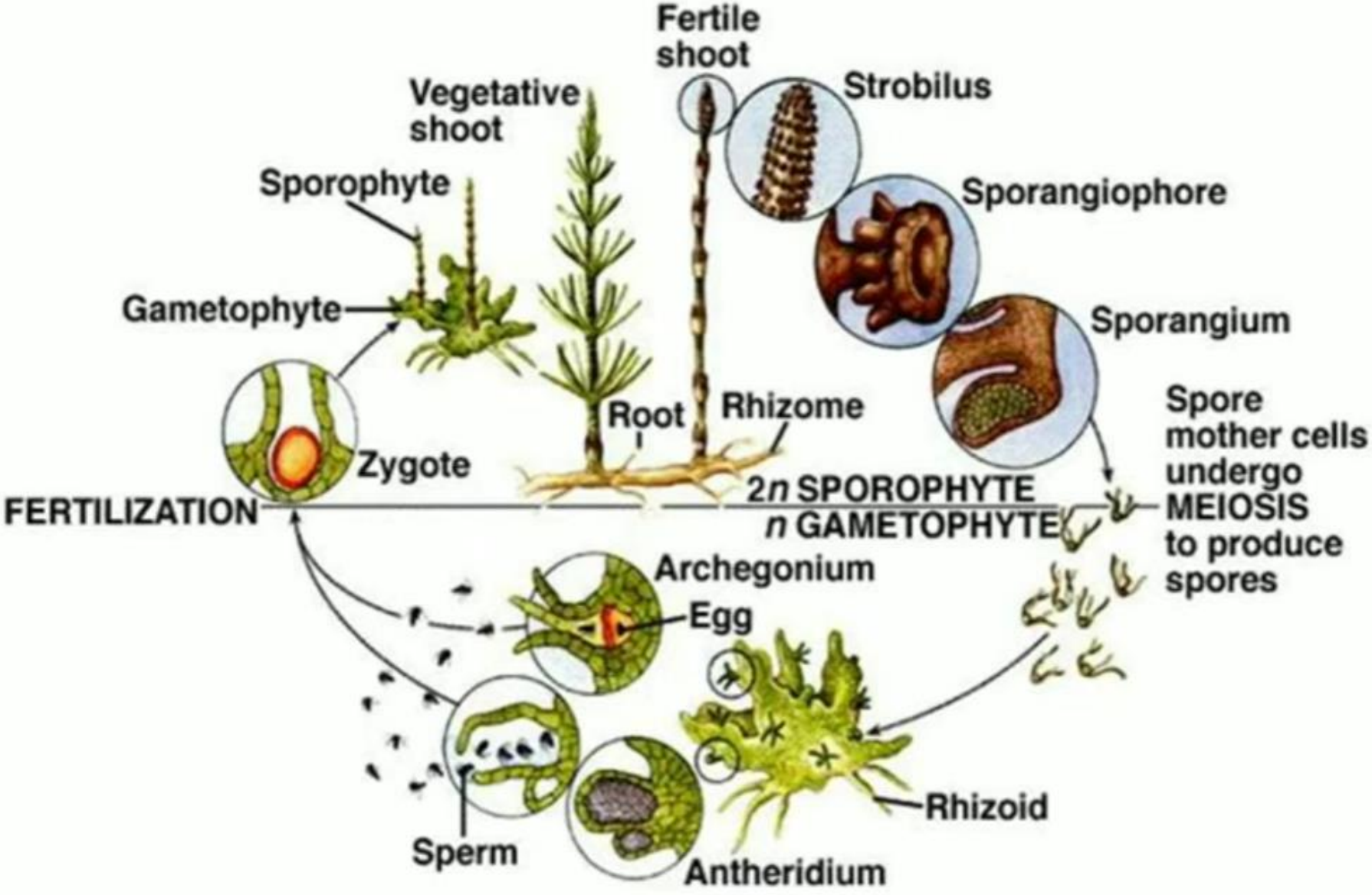
Equisetum

(Horsetail)

Life Cycle of *Equisetum*




Systematic position
Kingdom Plantae
Division Pteridophyta
Sub-division Sphenopsida
Class Filicophyta
Order Equisetales
Family Equisetaceae

OCCURRENCE

Number: *Equisetum* is represented by some **30 species** and are distributed all over the world. Some common Indian species are *E. arvense, E. debile, E. diffusum, E. ramosissimum.*

Habitat: *Equisetum* generally grows in **wet or damp habitats** and are particularly common along the banks of streams or irrigation canals. However, some species are adapted to xeric condition (*Equisetum arvense*).

- Some species of *Equisetum* are **indicators** of the **mineral** content of the soil in which they grow. Few species accumulate **gold**, thus they are considered as **gold indicator plants**.
- There is deposition of **silica** on the outer wall of the epidermal cells due to which plants become rough in texture and are used as abrasive. Silica provides a **protective covering** to these plants against predators and pathogens.

Habit and Habitat of Equisetum:

The plant body of Equisetum has an aerial part and an underground rhizome part (Fig. 7.83). The rhizome is perennial, horizontal, branched and creeping in nature. The aerial part is herbaceous and usually annual. Majority of the species are small with a size range in between 15 and 60 cm in height and 2.0 cm in diameter.

However some species grow up in higher heights [e.g., E. giganteum (13 m), E. telmateia (2 m); E. ramosissimum (4 m), though their stem are relatively thin (0.5-2.0 cm in diam.)] showing vine-like habit and climb over adjacent forest trees.

Equisetums generally grow in wet or damp habitats and are particularly common along the banks of streams or irrigation canals (E. debile, E. palustre). However, some species are adapted to xeric condition (e.g., Equisetum arvense). Some common Indian species are : E. arvense, E. debile, E. diffusum, E. ramosissimum.

Some species of Equisetum are indicators of the mineral content of the soil in which they grow. Some species accumulate gold (about 4.5 ounce per ton of dry wt.), thus they are considered as 'gold indicator plants.

Hence these plants help in prospection/exploration for new ore deposits. In Equisetum, silica is deposited on the outer wall of the epidermal cells giving the characteristic rough feeling, thus it provides a protective covering against predators and pathogens.

Structure of Equisetum:

The Sporophyte:

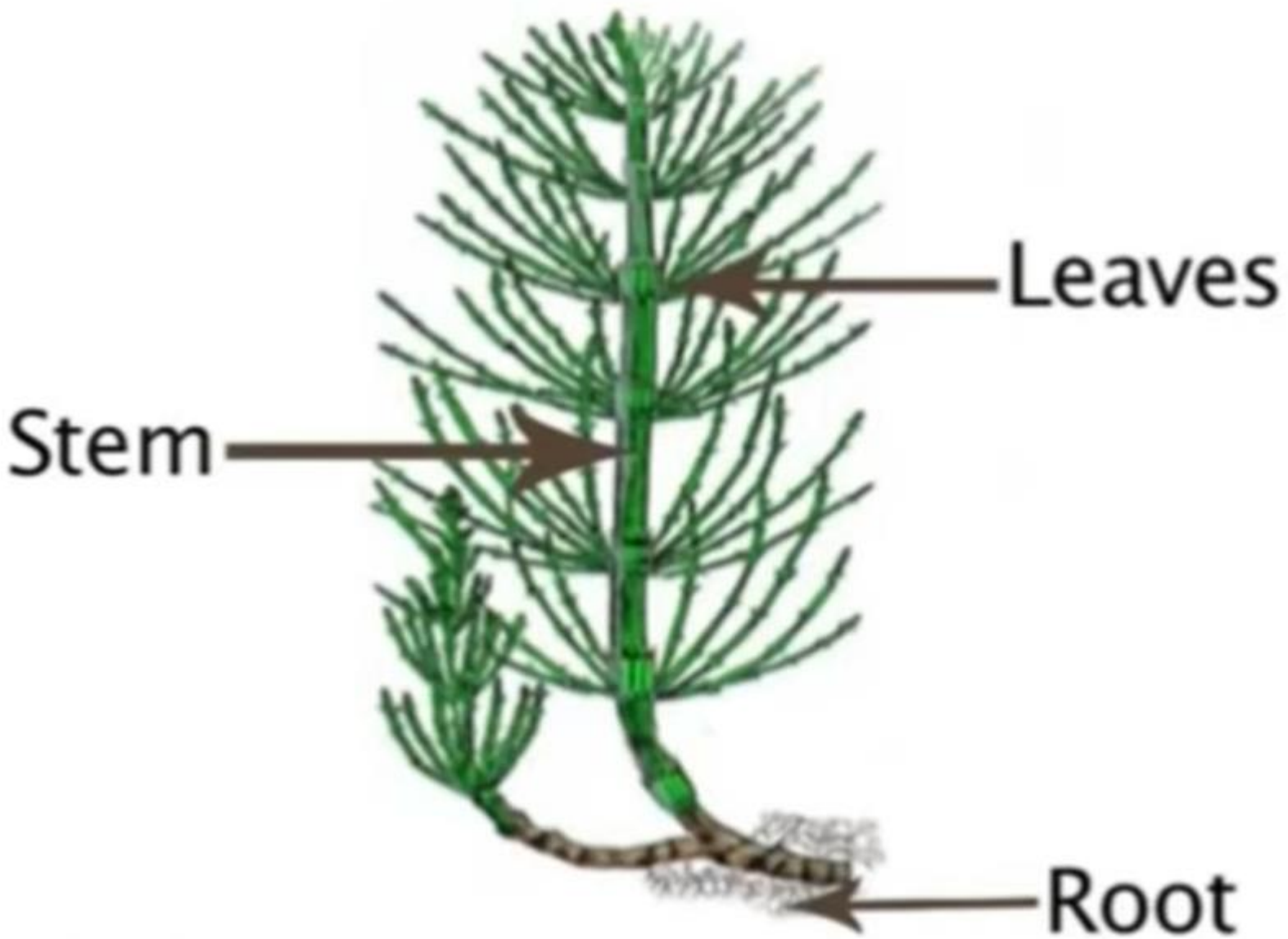
The sporophytic plant body of Equisetum is differentiated into stem, roots and leaves (Fig. 7.83).

Stem:

The stem of Equisetum has two parts: perennial, underground, much-branched rhizome and an erect, usually annual aerial shoot. The branching is monopodial, shoots are differentiated into nodes and internodes.

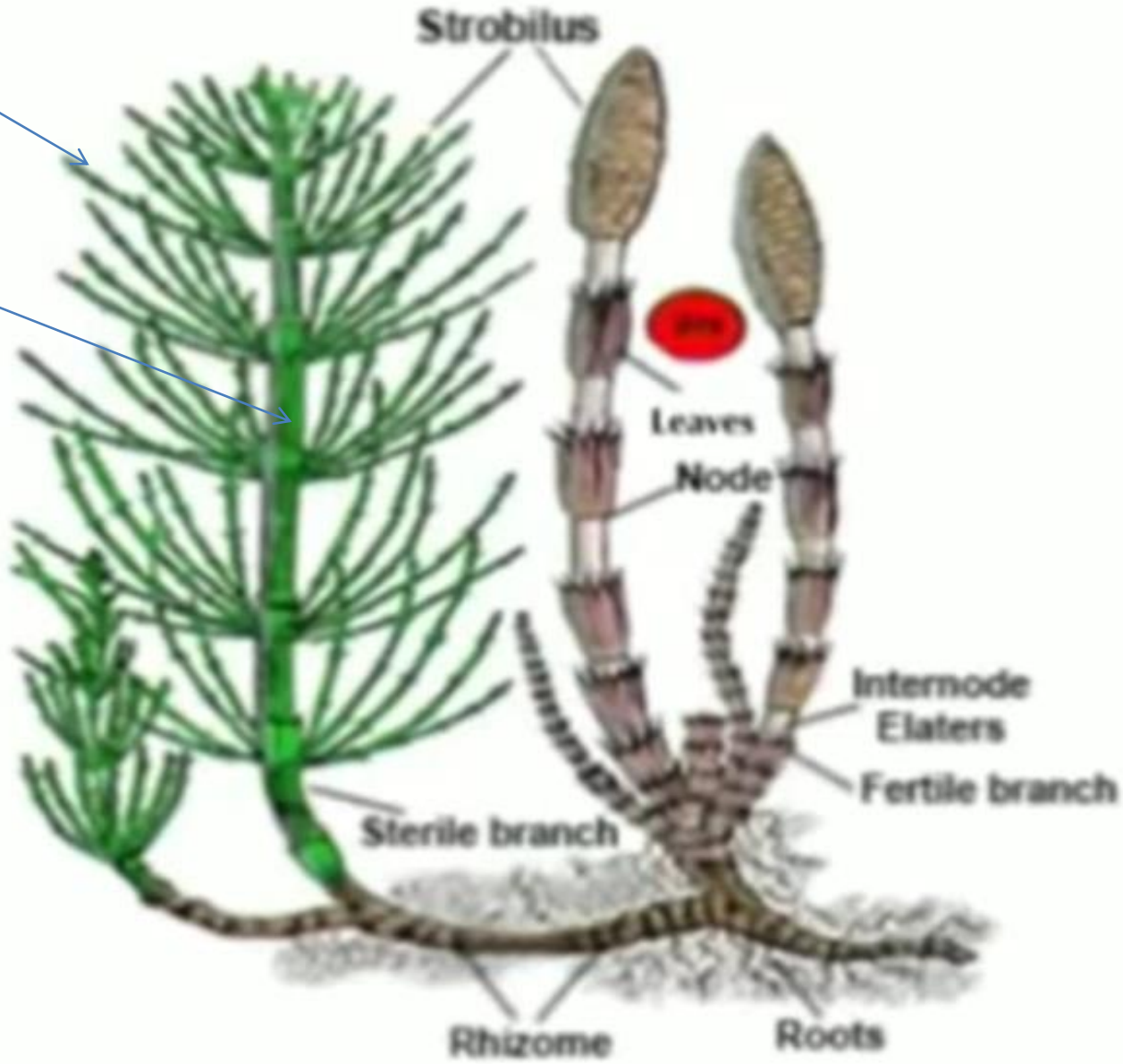
In majority of the species, all the shoots are alike and chlorophyllous and some of them bear strobili at their apices (e.g., E. ramosissimum, E. debile). Sometimes shoot shows dimorphism (two types of shoots i.e., vegetative and fertile) e.g., E. arvense.

Some shoots are profusely branched, green (chlorophyllous) and purely vegetative. The others are fertile, unbranched, brownish in colour (achlorophyllous) and have terminal strobili.


Leaves
Stem
Root

Branch with limited growth

Branch with unlimited growth



Equisetum (Horsetail)

Plant body is sporophyte consisting of;

a) Rhizome

- Horizontal, underground
- Penetrate deep into the soil
- It gives off aerial branches
- It has nodes/inter nodes
- Lateral branches arise from nodes
- A whorl of small brown leaves is present at each node

b) Aerial Branches

- Green
- These have nodes and internodes
- Internodes have ridges and furrows those alternates with each other
- Aerial branches have lateral branches and lateral branches have tertiary branches

i. Fertile branches

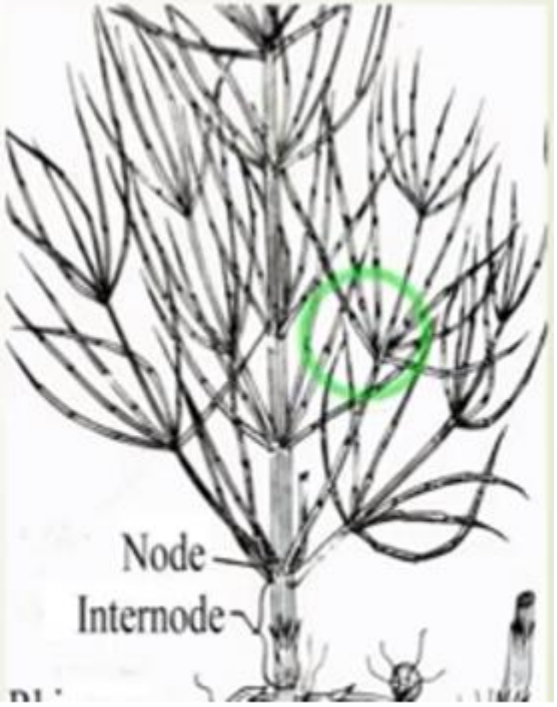
- Short and brown in colour
- These have no lateral branches
- These produces a cone/strobilus at apex
- They die after the production of cones

ii. Sterile branches

- Long and green in colour
- These have lateral branches
- These don't produce cones
- These persist throughout the year

c) Scale leaves

- A whorl of small scale leaves at each node
- They form sheath at each node
- They perform very little photosynthesis



d) Roots

- First root is primary but short lived.
- Primary root give rise to adventitious root
- These arise from nodes of rhizome
- Anchoring and water and mineral absorbing

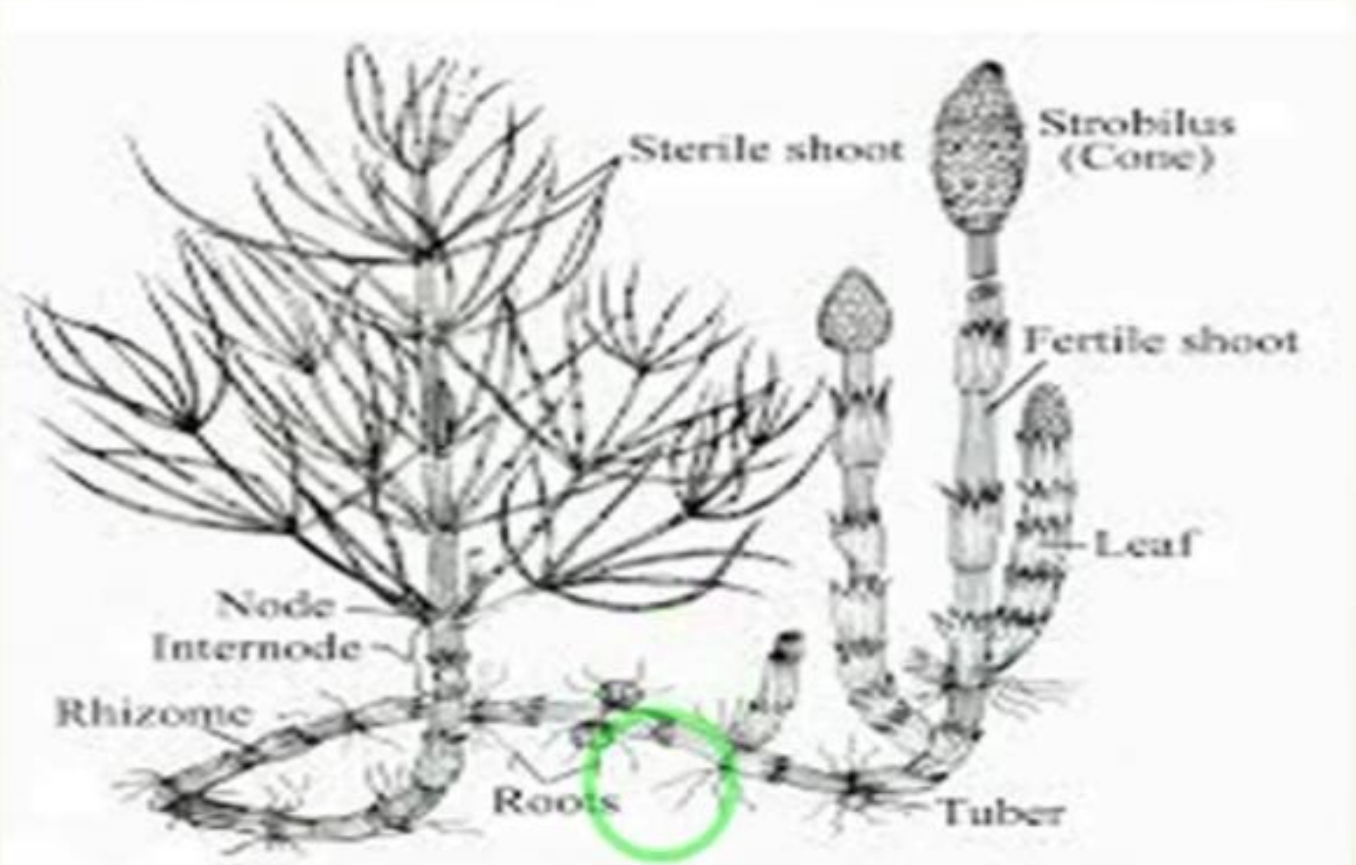


Fig: *Equisetum spp.* Sporophytic plant body showing habit.

ANATOMY

Root

- TS of the root shows epiblema, cortex and stele
- The epidermis consists of elongated cells, with or without root hairs.
- The cortex is wider and consist of sclerenchymatous cell followed by inner parenchymatous cortex.
- A characteristic feature of the root of *Equisetum* is the presence of a **two layered endodermis.**
- The cells of the outer layer of endodermis are larger and have casparian bands but inner layer has smaller cells and without casparian bands.
- The stele is protostelic where the xylem is triarch or tetrarch in mature roots and in smaller roots, the xylem may be diarch.

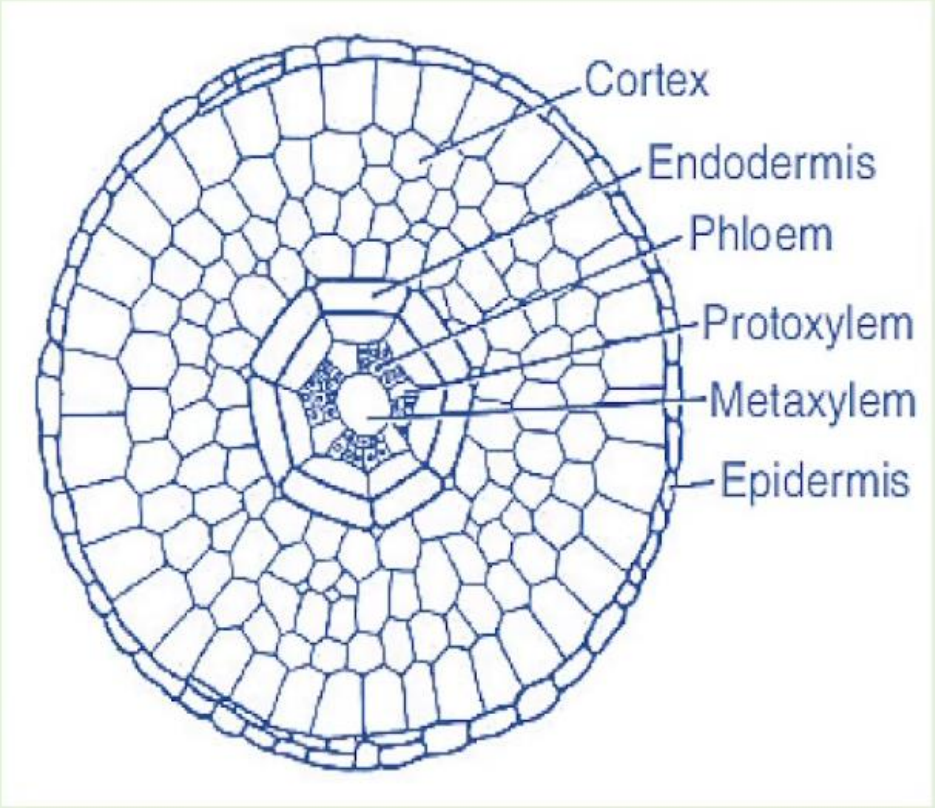


Fig. 2: *Equisetum*, T.S. of root near the growing apex.

(a) Internode.

- A TS of the internode is wavy due to presence of ridges and grooves (Fig. 3).
- It has a single layer of epidermis interrupted by stomata and with a heavy incrustation of silica.
- The cortex is differentiated into two regions.
  - The outer cortex consists of sclerenchymatous and chlorenchymatous cells. It is many layered below the ridges but in the region of the grooves it is few layered.
  - The inner cortex is composed of thin-walled parenchymatous cells. There is a large air cavity in the inner cortex corresponding to each furrow and alternating with the ridges, known as **vallecular canal**. These are **schizolysigenous canals** extending the entire length of internodes and form a distinct aerating system.

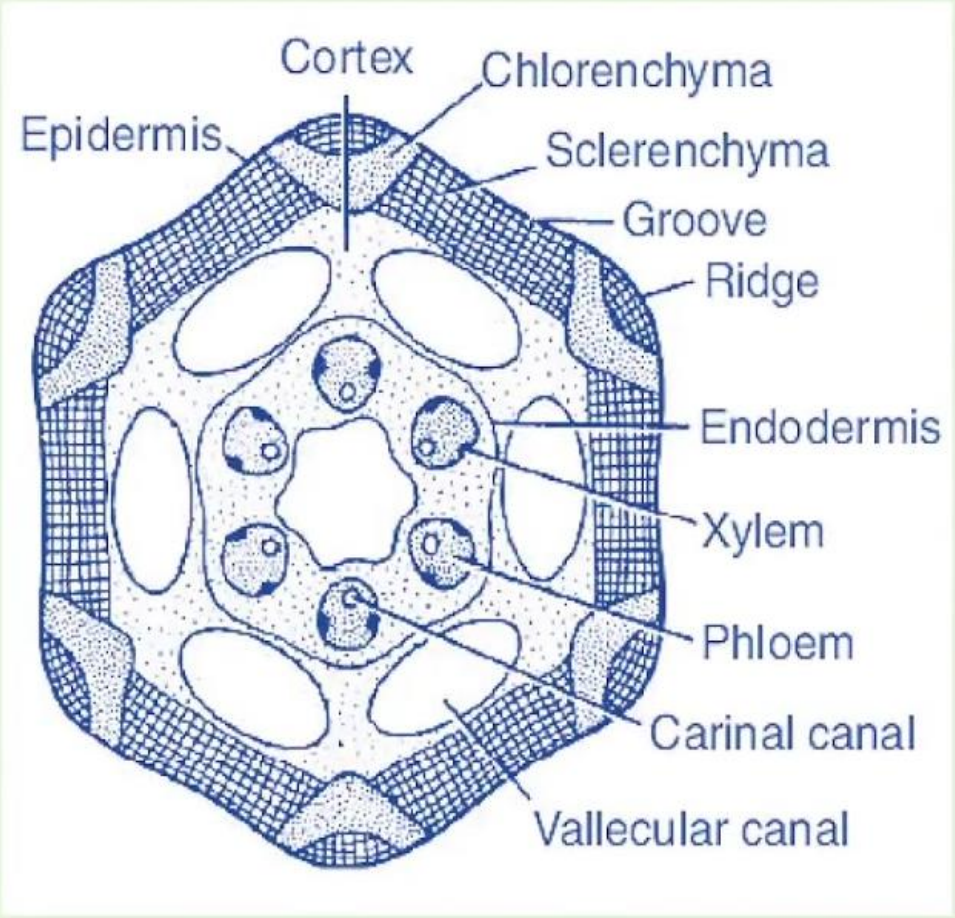


Fig.3. *Equisetum.* T.S. of internode of aerial shoot

- The stele is ectophloic siphonestele which is surrounded by an outer endodermal layer.

- The vascular bundles lie opposite to the ridges in positions alternate to the vallecular canals. Thus, the number of vascular bundles corresponds with the number of ridges. The vascular bundles are conjoint, collateral and endarch.
- In the mature bundle the protoxylem elements disintegrate to form a conspicuous protoxylem lacuna, called **carinal canal**. The carinal canals are filled with water and help in conduction of water.
- The central part of the internode of the aerial shoot is occupied by a large pith cavity. The internode shows the xerophytic and hydrophytic features

(b) Node

The internal structure of the node shows following features.

- The pith is not hollow and instead a solid diaphragm, called **nodal diaphragm** (resist wall) is present.
- Vallecular canals are absent.
- Vascular bundles fuse together and form vascular cylinder around a nodal diaphragm.
- Carinal canals are absent in the nodal region.
- Leaf and branch traces arise from the vascular cylinder of the node.

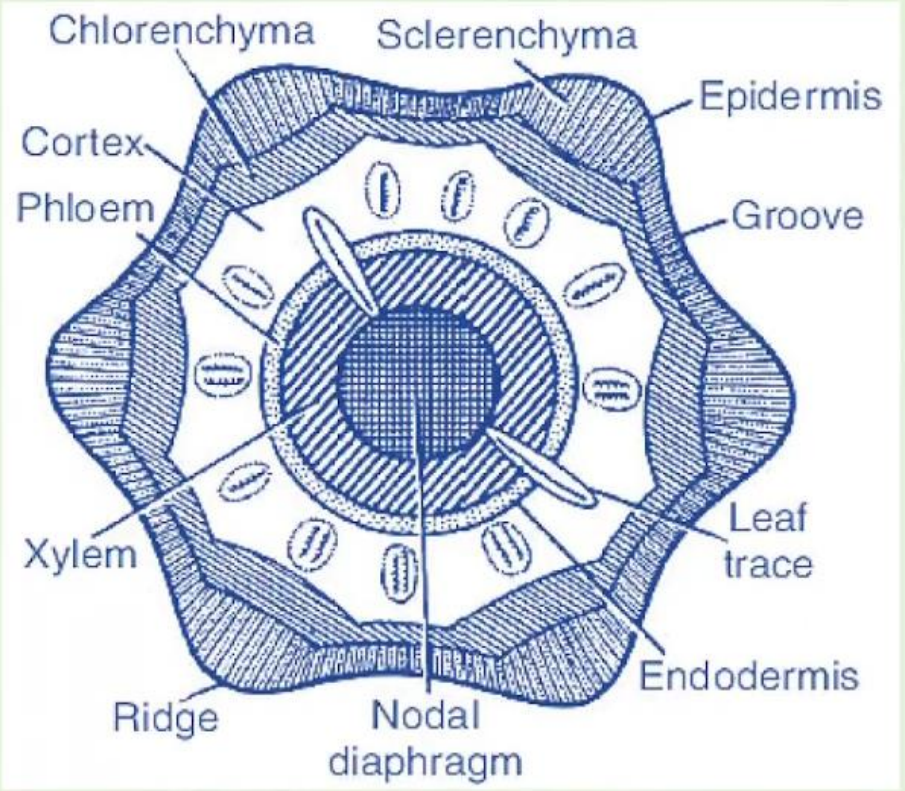


Fig. 4: T.S. of node of aerial sterile shoot of *Equisetum*.

The internal structures of the shoot of Equisetum is peculiar because it shows xerophytic as well as hydrophytic features.

The xerophytic features are:

(i) Ridges and furrows in the stem,

(ii) Deposition of silica in the epidermal cells,

(iii) Sunken stomata,

(iv) sclerenchymatous hypodermis,

(v) Reduced and scaly leaves, and

(vi) photosynthetic tissue in the stem.

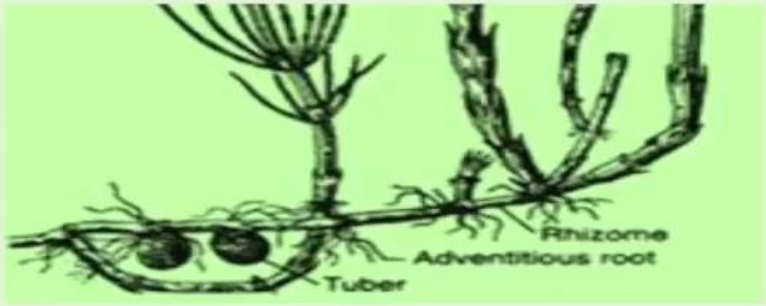
The hydrophytic characteristics on the other hand are (i) we 11-developed aerating system like carinal canal, vallecular canal and central pith cavity, and (ii) reduced vascular elements.

REPRODUCTION

Equisetum reproduces by vegetative and by spores.

Vegetative reproduction

The subterranean rhizomes of some species form tubers which on separation from the parent plant germinate to produce new sporophytic plants.

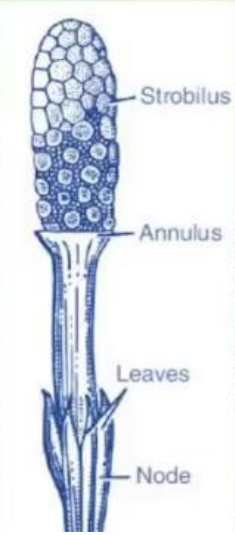


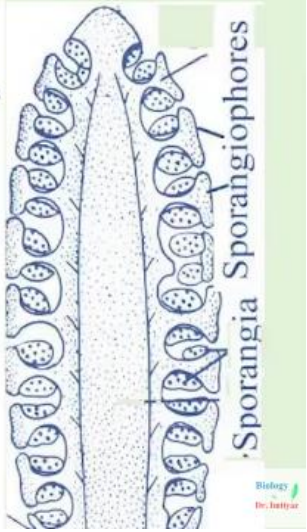
Reproduction by spores

- *Equisetum* is a homosporous pteridophyte.
- The spores develop within sporangia borne on sporangiophores.
- The sporangiophores are aggregated into a compact cone or strobilus, which born terminally on the fertile shoots.

Development of sporangium

- The development of sporangium is eusporangiate, i.e., a sporangium develops from a group of initials.





Spores

- The spores are spherical with numerous chloroplasts. The spore has four concentric layers, the outermost perispore or epispore, the second middle layer, the third exospore and the innermost endospore.
- At maturity, the epispore splits to produce four ribbon like bands or strips with flat spoon-like tips. These bands are known as **elaters** which are hygroscopic (Fig.7).
- Elaters help in the dehiscence process and also the dispersal of spores in large groups from the sporangium.
- The elaters of *Equisetum* are different from those of the bryophytes.

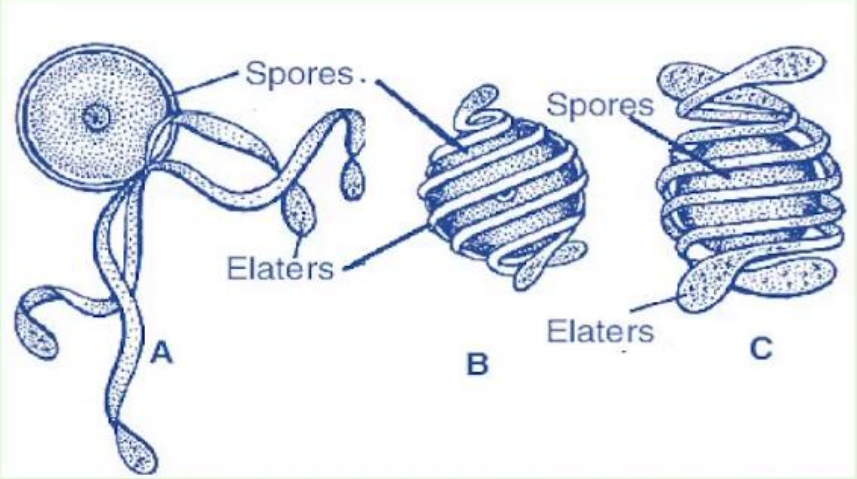


Fig. 7. *Equisetum* mature spores, a spore with uncoiled elaters (A), with coiled elaters (B,C)

- The spores germinate on a substratun absorbing water and divide asymmetric produces a small rhizoidal cell and a la cell (Fig. 8 A-B).
- The former develops into the first rhizoid, whereas the latter eventually gives rise to prothallus.
- Spores usually form thick and cushion-shaped prothalli which first bear archegonia and then antheridia.
- Both, antheridia and archegonia develop by superficial meristematic cells of the prothallus (Fig 9)

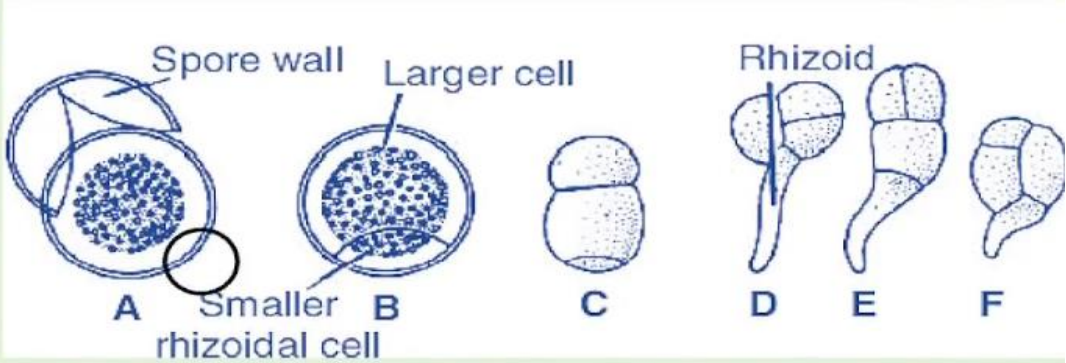


Fig.8. *Equisetum* showing germination of spore and early stages of gametophyte developme

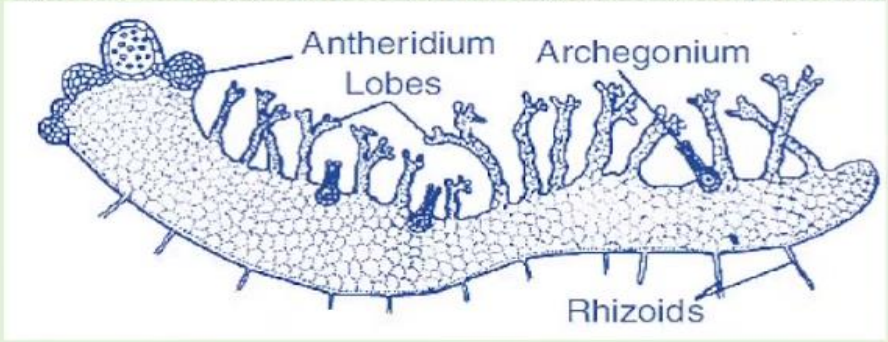
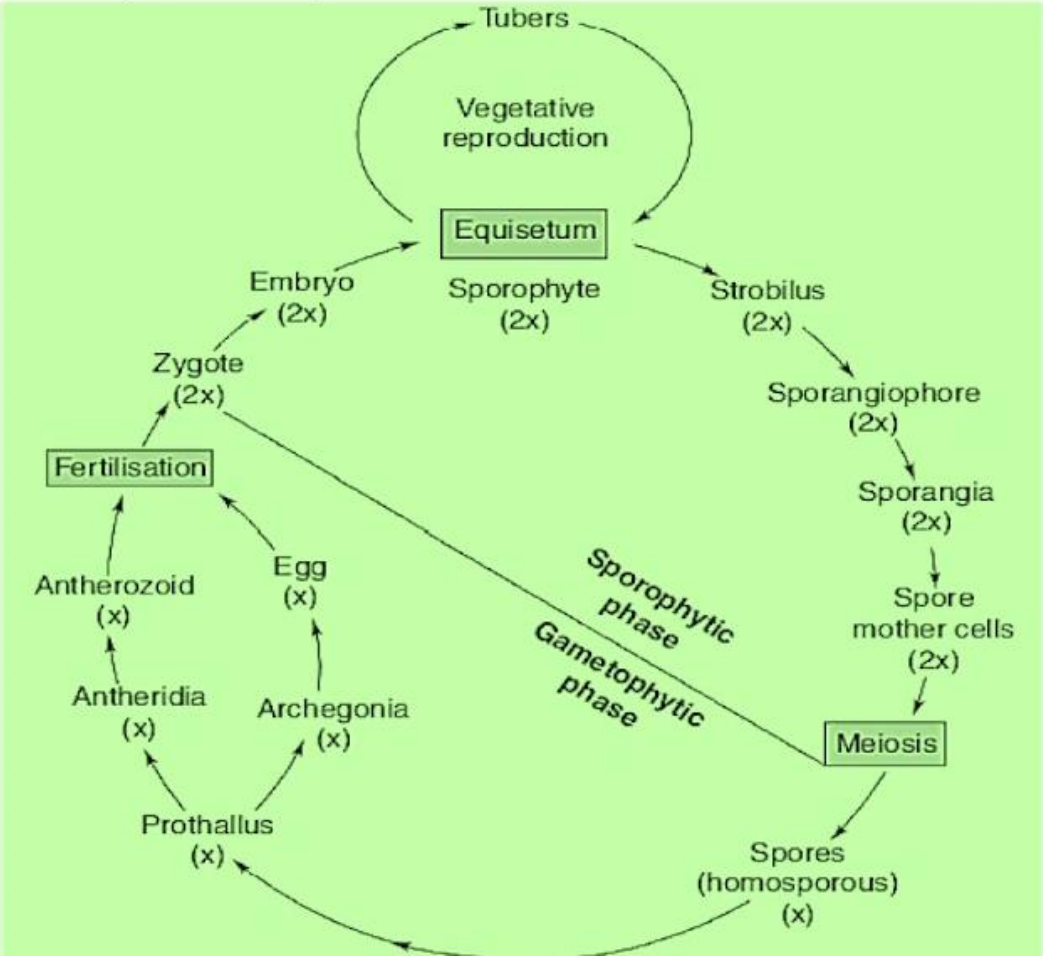
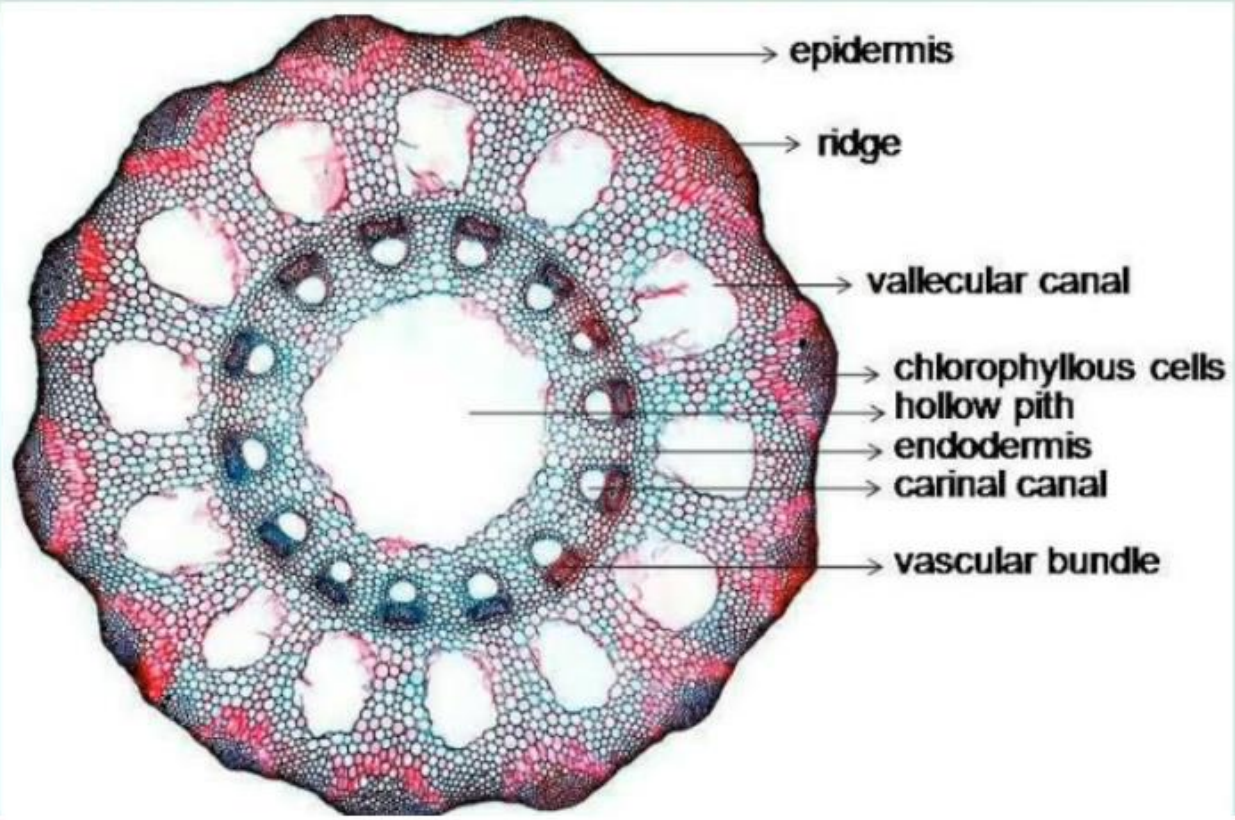


Fig.9. Gametophytes of *E. arvense* showing antheridia and archegonia.

LIFE CYCLE: The life cycle of *Equisetum has* summarized in below figures.

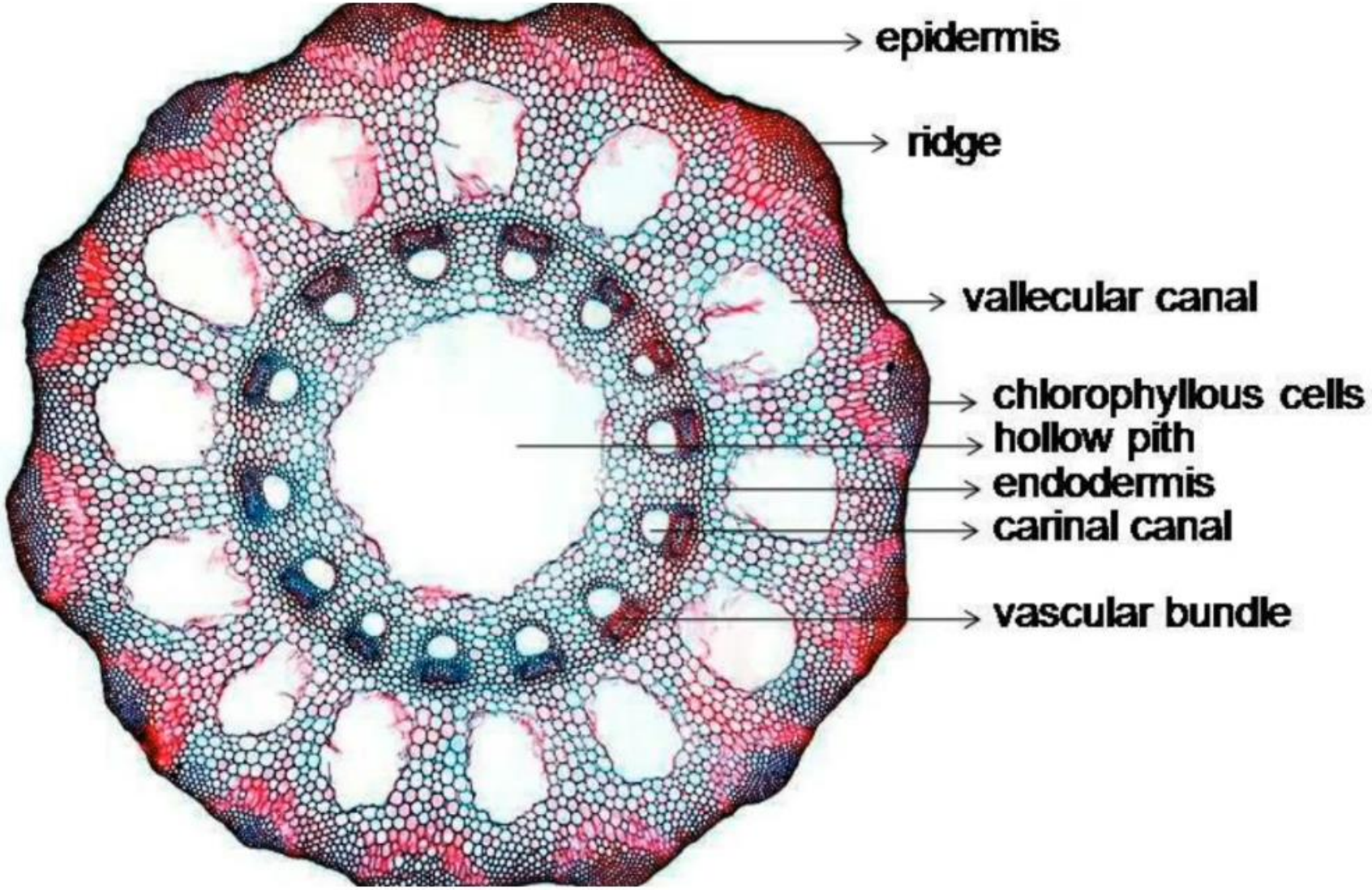


The underground rhizome and the aerial axis appear to be articulated or jointed due to the presence of distinct nodes and internodes. Externally, the internodes have longitudinal ridges and furrows and, internally, they are hollow, tube-like structures. The ridges of the successive internodes alternate with each other and the leaves are normally of the same number as the ridges on the stem.



Anatomy

Aerial shoot shows a combination of Xerophytic and Hydrophytic characters



Selaginella

SYSTEMATIC POSITION

Sub-division: Lycopsida

Order: Selaginellales

Family: Selaginellaceae

Genus: *Selaginella*

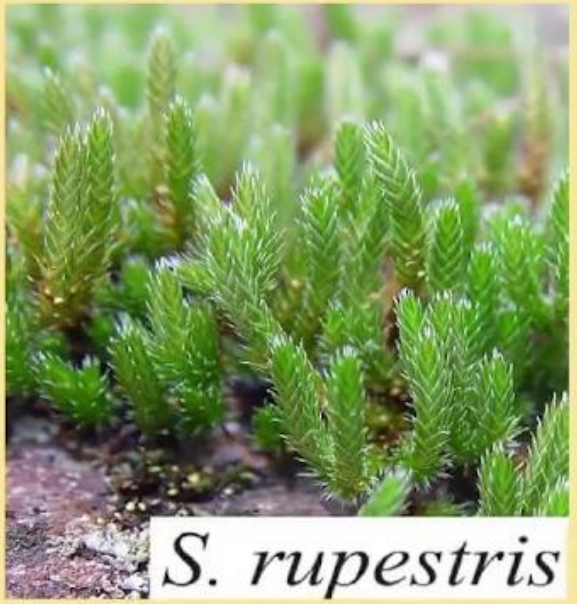
Only living genus of the order Selaginellales and is commonly known as **spike moss**.

OCCURRENCE

- It is a large genus comprising of about **700 species**, distributed all over the world and about **70 species** of *Selaginella* have been reported from India. Abundantly it is found in tropical rain forests.
- Mostly the species prefer **moist and shady places** to grow.
  - Few species are also found growing in **xerophytic conditions** i.e., on dry sandy soil or rocks e.g., *S. lepidophylla, S. rupestris* etc.
  - A very few species are epiphytes e.g., *S. oregena*. It is found growing on tree trunks.
- *S. lepidophylla*, *S. pilifera* show **cespitose habit**, they roll/curl and become ball like during dry season and again unroll and become green and fresh when moisture is available and called **resurrection plant.**

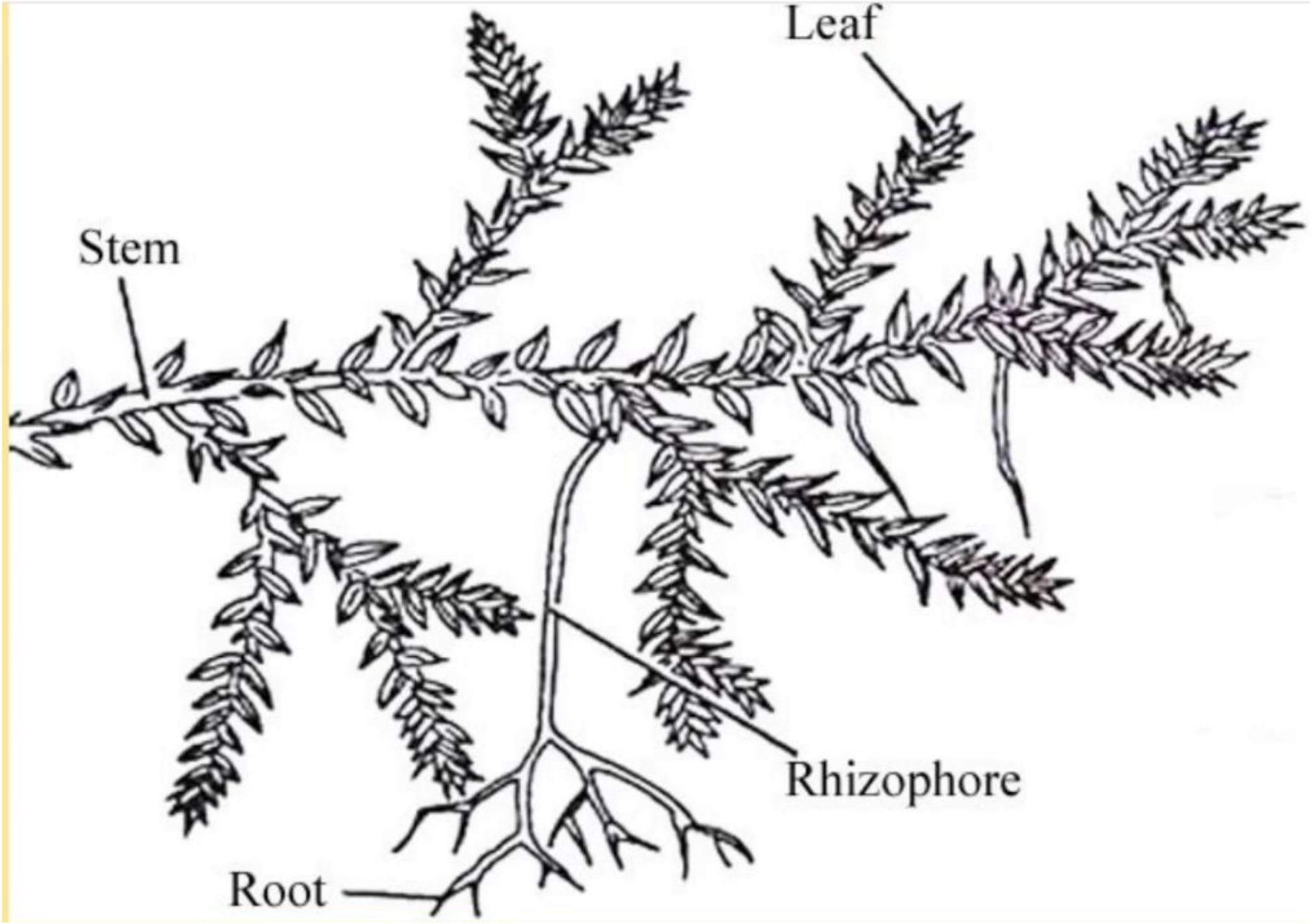
MORPHOLOGY

- The main plant body is **sporophytic, evergreen delicate herb**. Its size varies greatly from species to species (cm-m).
- They may be **erect or prostrate** depending upon the sub-genus.
- In the sub-genus **homoeophyllum** the plants are **erect** and the leaves are isophyllous.
- In the sub-genus **heterophyllum** the plants are prostrate and bearing small leaves and large leaves.
- The sporophytic plant body of *Selaginella* is differentiated into **root, stem and leaves**, whereas some species also have **rhizophores (organ sui-generis.)**



S. rupestris

S. lepidophylla


Leaf
Stem
Rhizophore
Root

Stem

- In the sub-genus **Homoeophyllum, stem is erect** and dichotomously branched and in the sub-genus **Heterophyllum, stem is prostrate** or sub-erect with lateral branching.
- The growing apex of the stem consists of either meristematic tissue or a single apical cell.

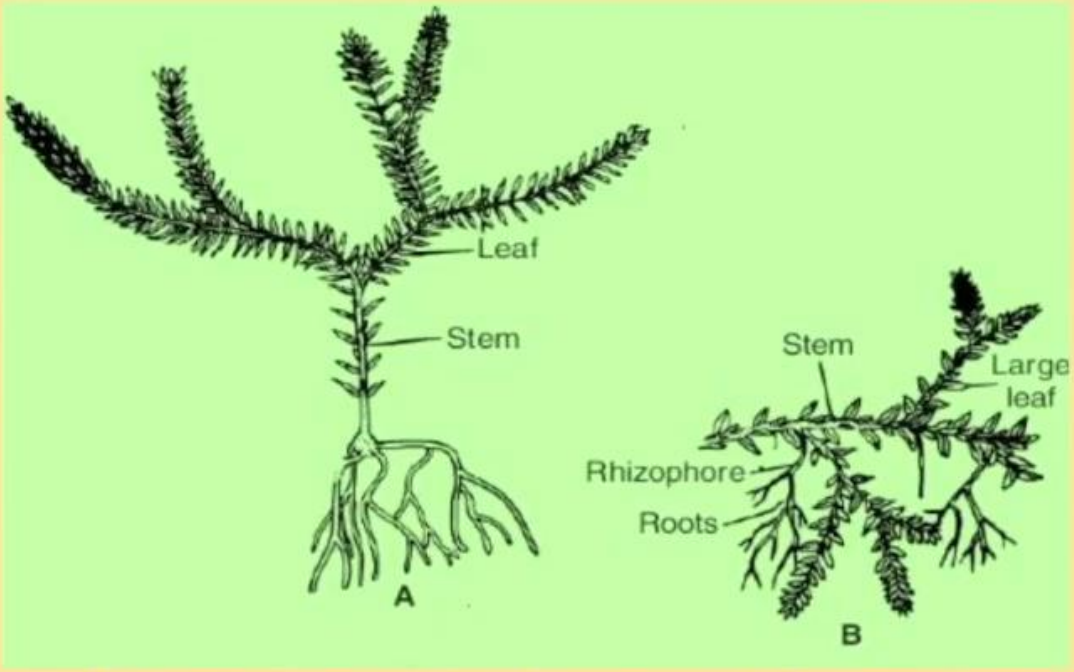


Fig 1. *Selaginella* external features, *S. seiaginoides (A), S. kraussiana (B)*

Leaves:

- Leaves are usually **small, simple** and lanceolate with a pointed apex. The leaf has a **single midvein** that remains unbranched throughout its course.
- The vegetative leaf as well as **sporophylls** possess a membranal projection on the adaxial side close to the base called as **ligule** (Fig 2A).
- The base of the ligule has a foot-like structure, called **glossopodium**, which is a highly vacuolated thin-walled tubular cell.

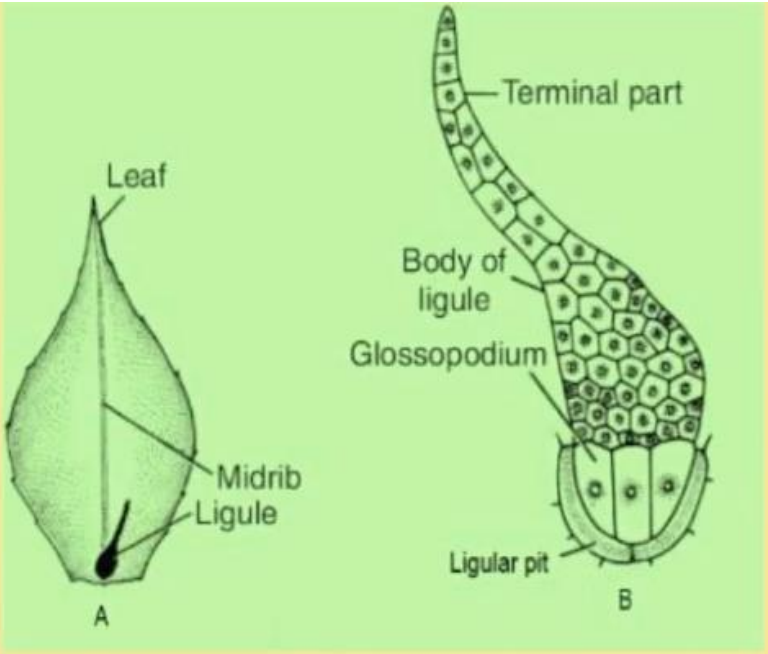


Fig 2. *Selaginella* structure of ligule, leaf with ligule (A), longitudinal section of ligule (B).

ANATOMY

Root

T.S. of the root is somewhat circular in outline and shows the following internal structures:

Epidermis one cell in thickness and unicellular root hairs arise from them.

Cortex is made up of a wide zone of parenchymatous cell. Is some species there may be 3-5 layered sclerenchymatous hypodermis in the form of outer cortex.

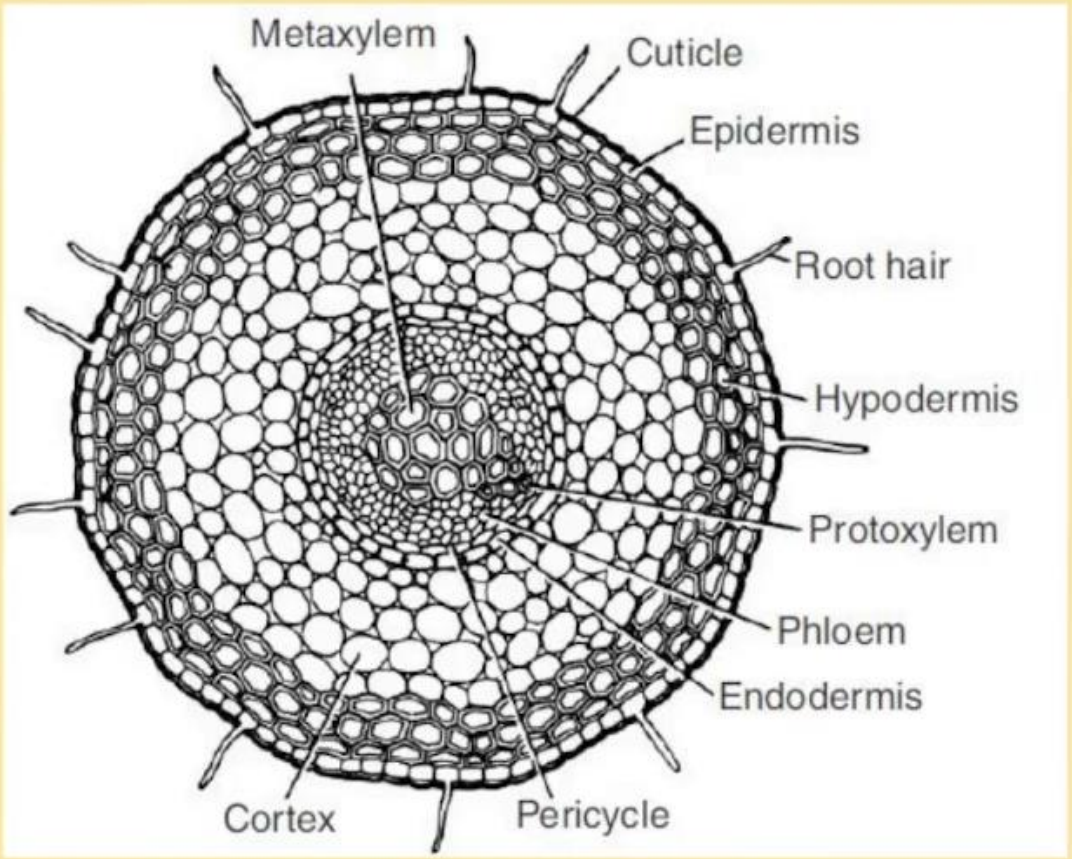


Fig. 3. T.S. of root of *Selaginella*

Endodermis is indistinct but, in some species it is present e.g., *S. densa. It* is followed by one to three layered parenchymatous **pericycle.**

Stele is protostele. The **xylem is exarch** and surrounded by phloem on all sides.

Rhizophore

The internal structure of rhizophore is almost **similar to that of root**. It is also circular in outline

Epidermis is single layered, root hairs and stomata are absent.

Cortex is differentiated into outer sclerenchymatous and inner parenchymatous zones.

Endodermis it is made up of single layered structure.

Pericycle is present inside the endodermis and formed of single layered parenchymatous cells.

Stele is typically a protostele.

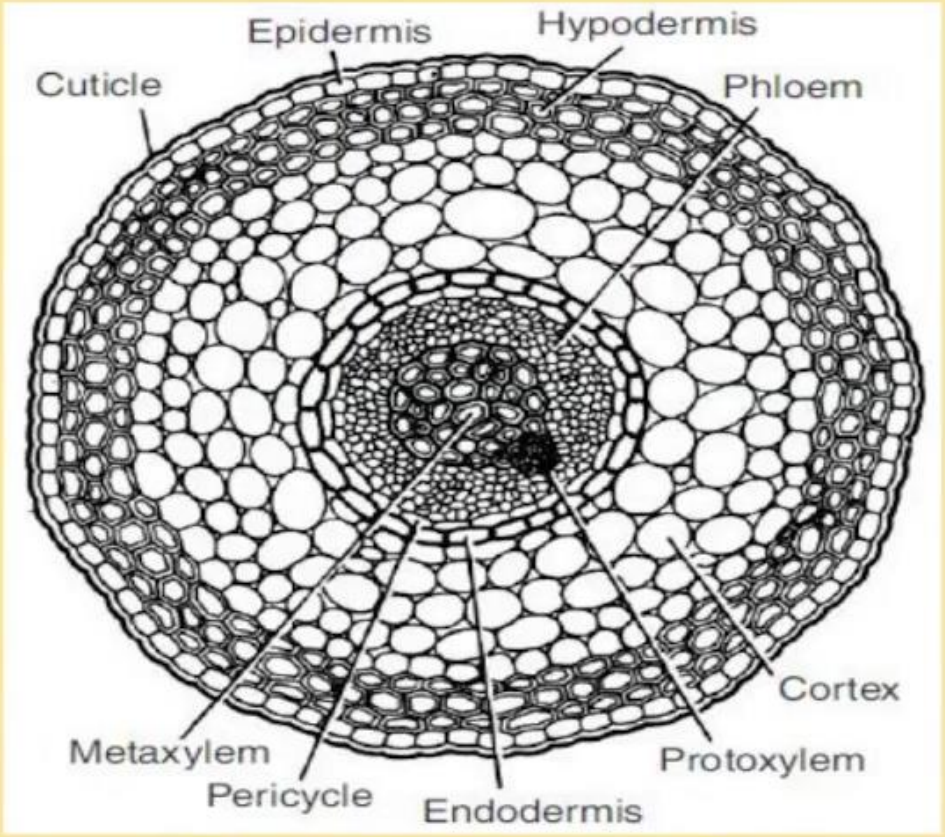


Fig.4. T.S. of rhizophore of *Selaginella martensii*

Stem

The anatomy of the stem **shows variations** not only in different species but also within the same species depending on stem diameter. Anatomy of the stem shows epidermis, cortex and central cylinder (Fig. 5)

Epidermis:

It is the outer most covering layer comprising of a single cell in thickness and devoid of hairs and stomata.

Cortex:

Inner to the epidermis is present a well-defined zone of cortex. The cortex is usually composed of compactly arranged parenchymatous tissue with no intercellular spaces.

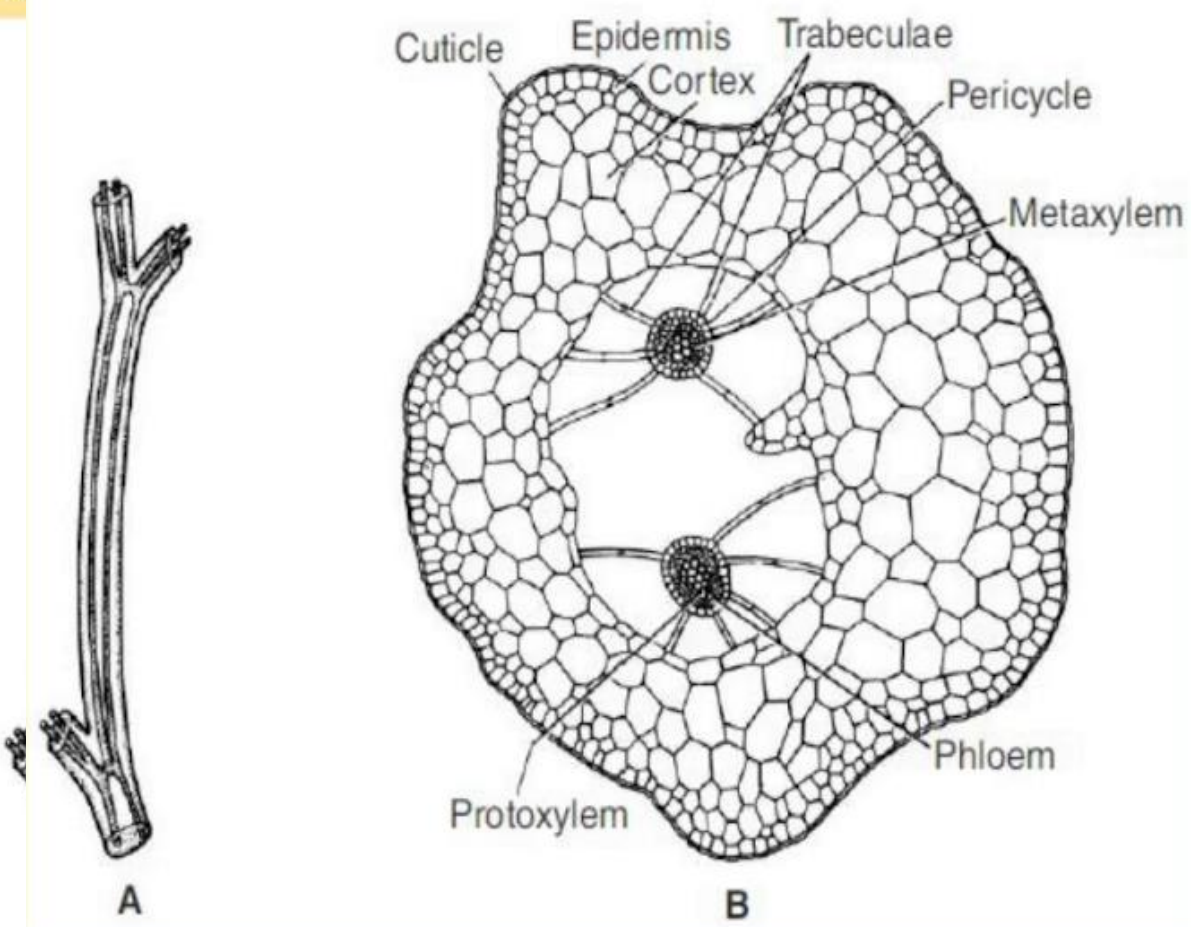


Fig.5: *Selaginella kraussina*, a part of cleared distelic stem showing vascular tissue, T.S of stem

STELE

- The central portion of the stem is occupied by a well-developed stele. The stele is of **protostelic type** i.e., xylem is present in the centre and surrounded by phloem on all sides. The stele is surrounded by a single layered pericycle made of parenchymatous cells. **Pith is absent.**
- The number of steles is variable in different species of *Selaginella*. It is 1 i.e., **monostelic** e.g., *S. spinulosa*, **2 i.e., distelic e.g., *S. kraussiana***, 12-16 i.e., **polystelic** e.g., *S. laevigata*.
- The stele remains suspended in the centre by **radially elongated tubular**, unicellular structures known as **trabeculae.** These are formed by the radial elongation of the **endodermal cells**. Trabeculae are provided with conspicuous casparian strips. In between the trabeculae, there are large spaces present, known as **air spaces.**
- Xylem is usually made of **tracheids** which is surrounded on all sides by phloem which consists of **sieve cells and phloem parenchyma.**

Leaf

- A T.S. of the leaf shows epidermis, mesophyll and a single median vascular bundle.
- Both, the upper and lower epidermis of the leaf are **unistratose**. The cells of the epidermis are provided with chloroplasts.
- The leaves are mostly **amphistomatic** but sometimes they are hypostomatic as in *S.martensii*..

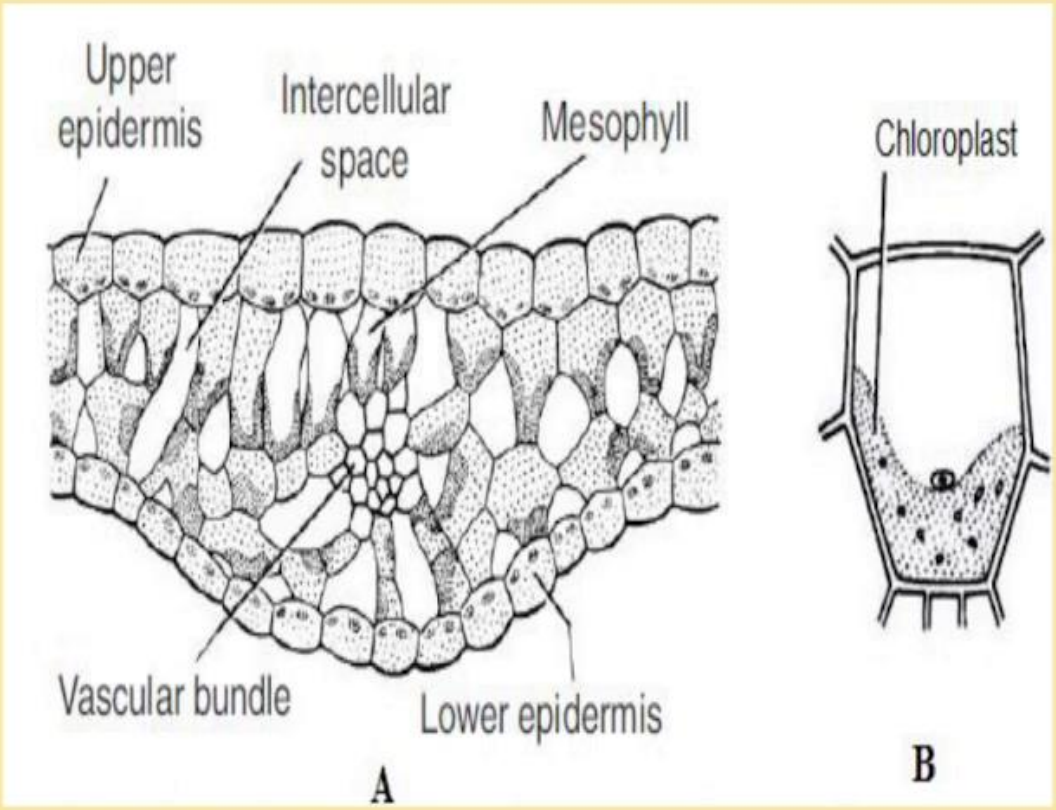


Fig.6: *S. kraussiana,* T.S. of a part leaf (A), a mesophyll cell showing chloroplast (B).

- The mesophyll is usually made up of parenchymatous cells which have conspicuous intercellular spaces and chloroplasts (Fig 6B).
- The leaf has a median **vascular bundle** surrounded by a distinct bundle sheath. The xylem, which occupies the central part of the bundle consists of only tracheids with annular or spiral thickenings. It is surrounded by phloem.

REPRODUCTION

- *Selaginella* reproduces by two methods: Vegetatively and by formation of spores.
- Vegetative reproduction takes place by **fragmentation, tubers and resting buds** (Fig.7).

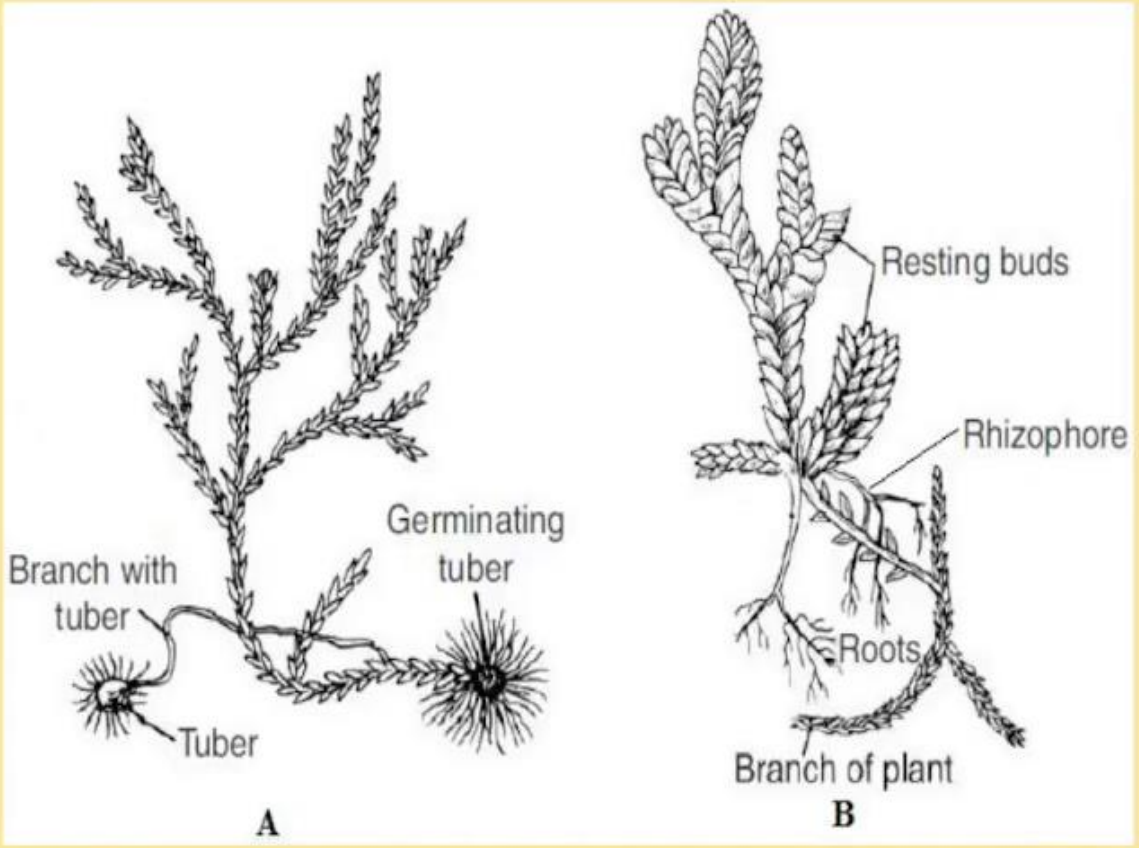


Fig.7. *S. chrysorrhizos* showing germination of tuber (A) and a part of plant with resting buds (B).

Sexual Reproduction

Spore producing organs

- *Selaginella* is a **heterosporous pteridophyte**, produces two different types of spores—**megaspores and microspores**. The dimorphic condition of the spores is known as heterospory.
- Megaspore and microspores produced in **megasporangia and microsporangia respectively**. These mega and microsporangia are produced on fertile leaves known as **megasporophylls and microsporophylls** respectively (Fig. 8).
- The leaves bearing sporangia are called **sporophylls**. In most of the species of *Selaginella* sporophylls are aggregated at the apex of the main stem and its branches in definite loose **compact cones**, called **strobili** (Fig. 8).

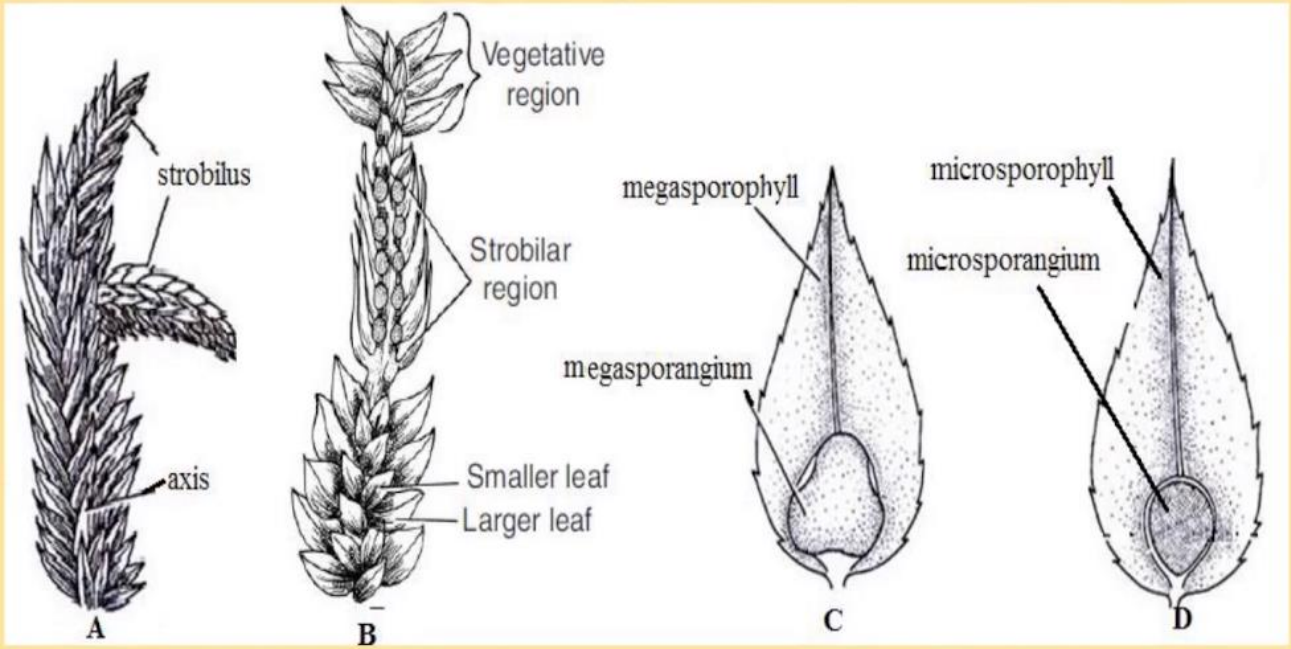


Fig.8: *Selaginella* a branch bearing strobilus (A), a branch after formation of strobilus region again changing into vegetative region (B), a megasporophyll (C), a microsporophyll (D).

- The Longitudinal section (L.S.) of strobilus shows a **central axis** covered with spirally and densely arranged ligulate sporophylls. Each sporophyll **adaxially** bears a single **stalked sporangium** in its axis (Fig. 9).
- The microsporangium produces **large number of microspores** whereas megasporangium produces usually **4 megaspores**.
- Both **spores** are produced by **meiosis** and thus are **haploid** in nature.

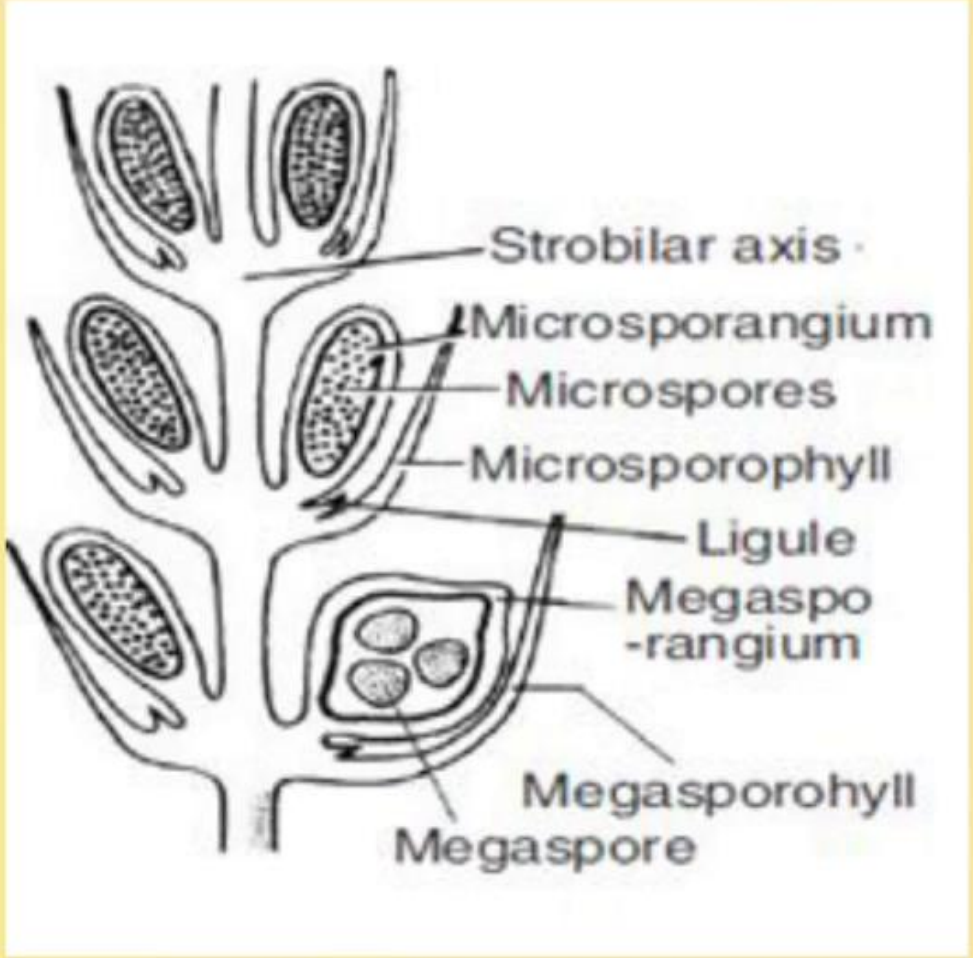
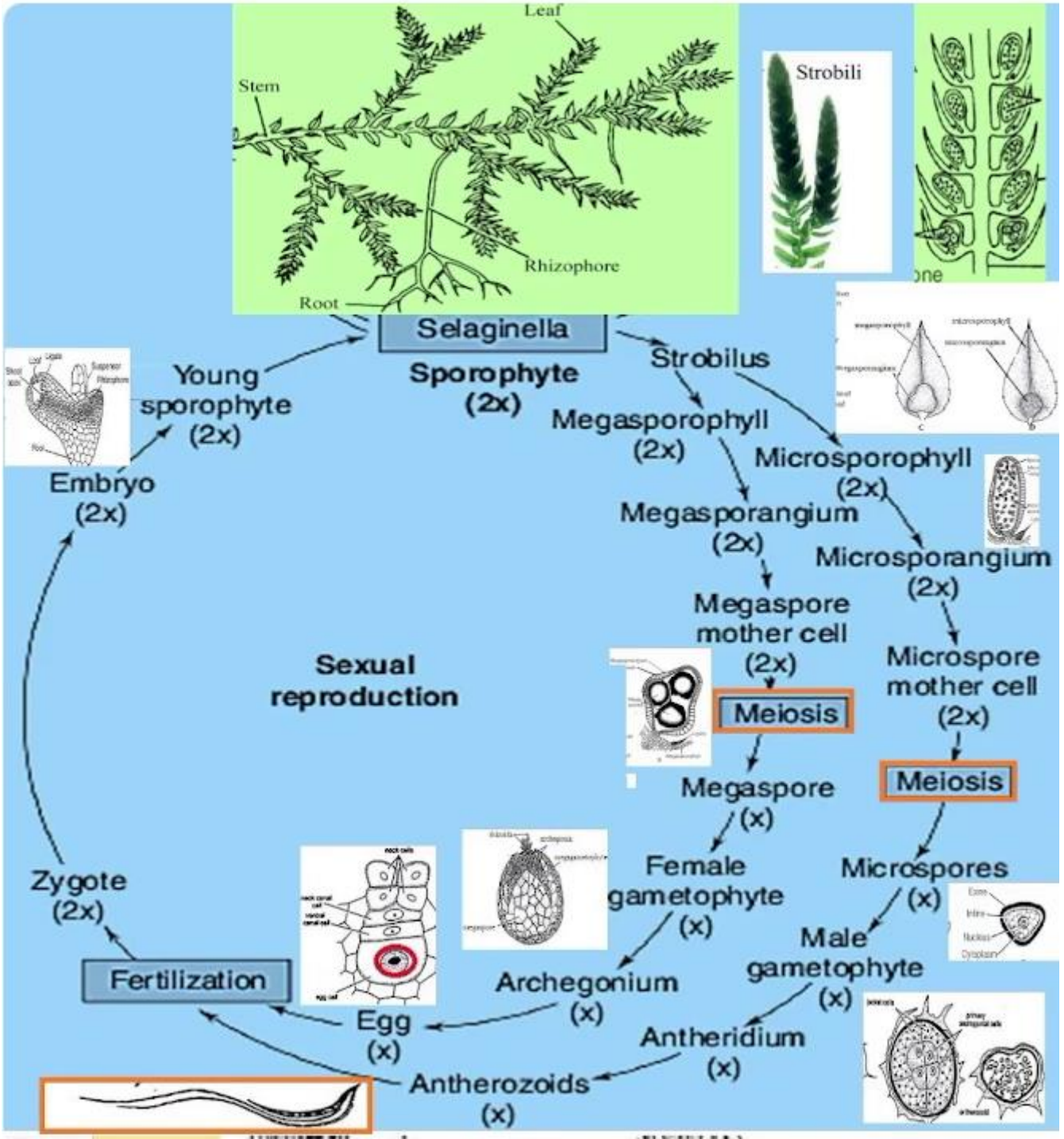


Fig.9 : *Selaginella* LS of strobili showing arrangement of megasporangia and microsporangia.


Leaf
Stem
Rhizophore
Root
Strobili
Selaginella
Sporophyte
(2x)
Strobilus
Young
sporophyte
(2x)
Embryo
(2x)
Megasporophyll
(2x)
Microsporophyll
(2x)
Megasporangium
(2x)
Microsporangium
(2x)
Megaspore
mother cell
(2x)
Microspore
mother cell
(2x)
Sexual
reproduction
Meiosis
Meiosis
Megaspore
(x)
Female
gametophyte
(x)
Microspores
(x)
Male
gametophyte
(x)
Archegonium
(x)
Egg
(x)
Antheridium
(x)
Antherozoids
(x)
Fertilization
Zygote
(2x)

THANK YOU