Pteridophytes
Psilotum
Selaginella

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Psilotum (Whisk fern)

Div: Psilophyta
Class:Psilotopsida
Order: Psilotales
Family: Psilotaceae
Genus: Psilotum

sporophytes are dichotomously branched with an underground rhizome and upright leafless branches. Rhizoids present instead of roots. Stem have a relatively simple vascular cylinder (Protostele). The sporangia are borne in groups (trilocular) and form synangia. Spores produced are all alike (homosporous). The development of gametophyte is exosporic and form monoecious subterranian gametophyte. The development of embryo is exoscopic.

Plant body (Sporophyte)

The plant body of Psilotum is sporophytic branched rhizome system and dichotomously branched, slender, upright, green aerial systems that bears small appendages and synangia (singular: synangium).

Aerial Stem:

Any one of the rhizome tips may turn upward and undergo several dichotomies to give rise to a green aerial shoot. The aerial shoots are slender, generally erect but may be pendent in epiphytes .They are perennial and become shrubby by repeated dichotomies and sometimes attain a height up to one meter.

Rhizome

The basal subterranean branched rhizome is generally hidden beneath the soil or humus. It bears numerous rhizoids, instead of roots, which perform the functions of absorption and ancho- rage.

Appendages:

These are small scale-like structures helically arranged on the upper part of the aerialsystem. Internally, the appendage is composed of parenchymatous photosynthetic cells, bounded by a single-layered cutinised epidermis. There is no stomata in the appendages. There is no vascular trace in the appendages.

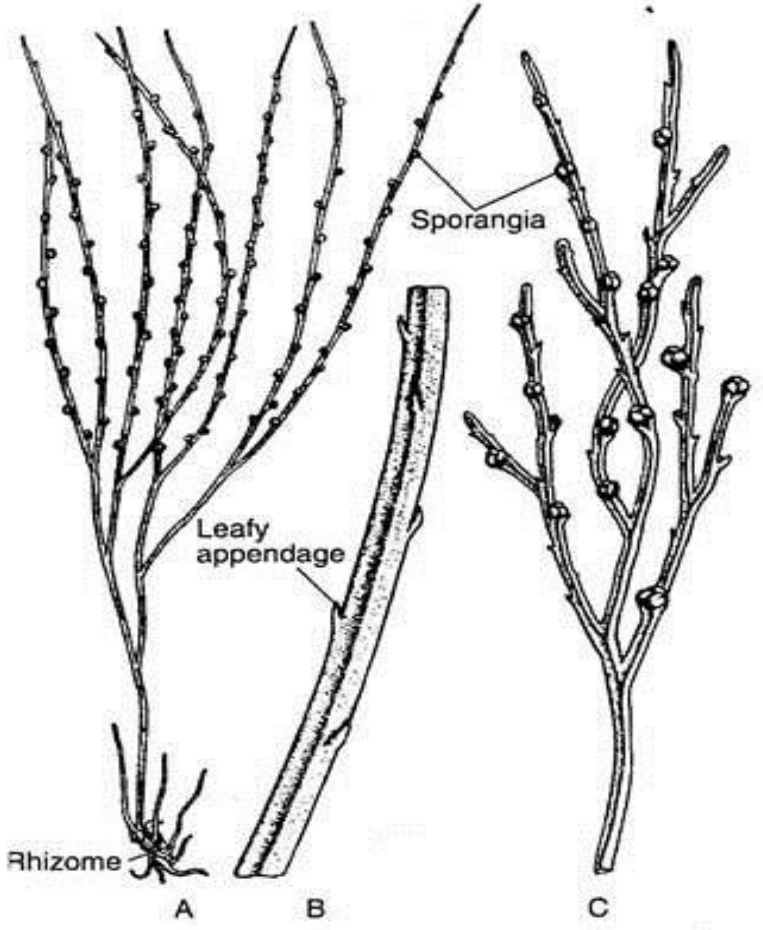


Fig. 7.11 : *Psilotum nudum* : A. A sporophyte plant, B. An enlarged part of stem showing scaly appendage, C. A fertile twig

Reproduction in Psilotum:

Psilotum reproduces vegetatively as well as by spores.

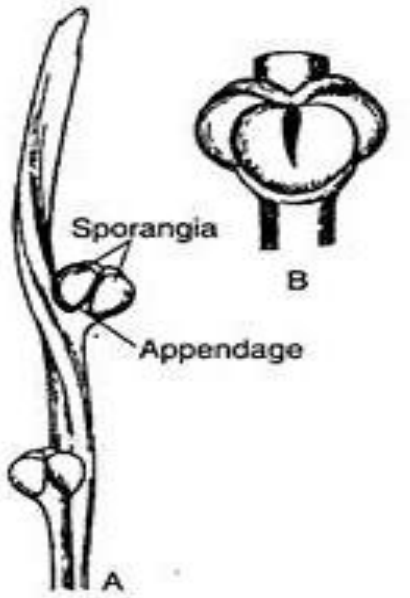
Vegetative Reproduction:

- The sporophyte as well as gametophyte of Psilotum (e.g., P. nudum) propagate vegetatively through the production of Gemmae. They are small, multicellular and ovoid structures developing on surface of rhizome (in sporophytic plant body) or prothallus (in the gametophyte).
- After detachment from the parent body, gemmae of sporophyte may germinate to form a subterranean shoot, while the gemmae of prothallus, on germination, form a new prothallus.

by Spores:

Spore-Producing Structure: At maturity, many of the dichotomously branched aerial shoots become fertile and produce trilocular sporangia known as synangia. The mature synangium is generally a three-lobed structure and each lobe of the synangium corresponds to a sporangium.

- The synangia located at the tip of very short axis, measuring 1-2 mm in diameter and closely associated with a forked, foliar appendage. At maturity, the synangium exhibits loculicidal dehiscence.



Psilotum nudum : A. A part of fertile axis bearing sporangia with bifid appendages, B. A trilocular synangia showing dehiscence

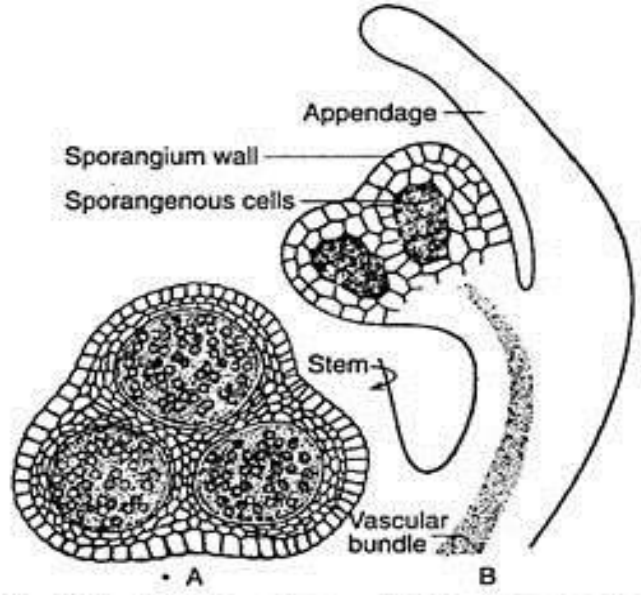


Fig. 7.17 : *Psilotum nudum* : A. T.S. of synangium, B. V.S. of fertile axis through a synangium

Gametophyte: The mature gametophyte shows a striking similarity with a piece of sporophytic rhizome . It grows as saprophyte with an associated fungus.

Spores germinate exosporically to form the gametophyte. The mature gametophytes are brown, cylindrical, subterranean, radially symmetrical and usually dichotomously branched, but may sometimes become irregular. The surface of the gametophyte is covered by long unicellular, brownish rhizoids. The gametophyte grows by means of apical meristem .

Sex Organs: Psilotum is monoecious (i.e., homothallic). Sex organs i.e., antheridia and archegania, are superficial and scattered over the surface of the gametophyte.

Antheridium:

The antheridium develops from a single superficial cell (antheridial initial) of the prothallus. The periclinal division of the superficial cell produces an outer jacket initial and an inner primary androgonial cell.

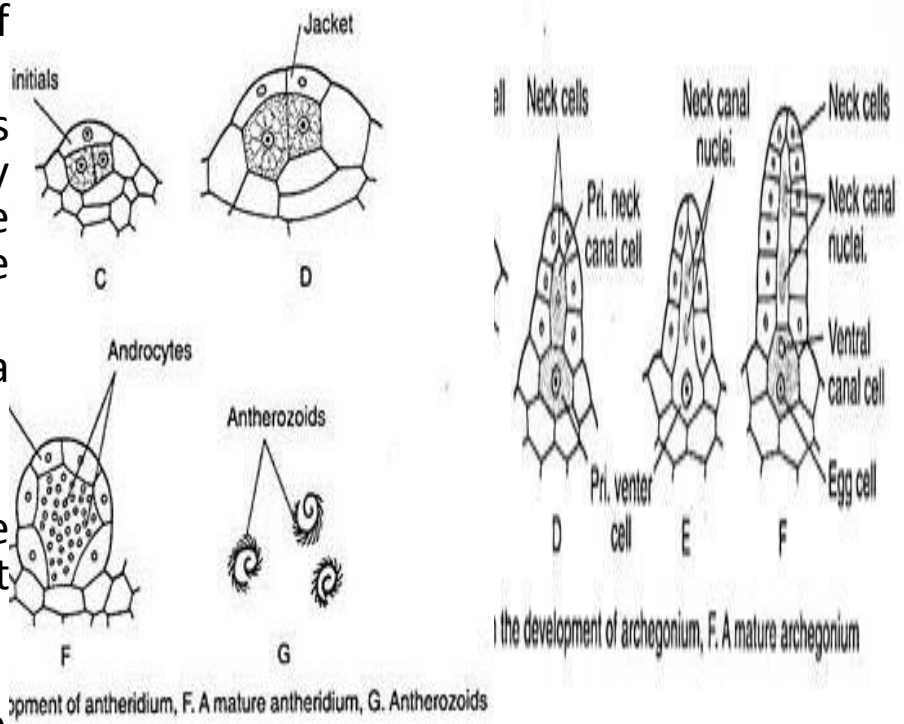
Archegonium:

The archegonium is also developed from a single superficial cell (archegonial initial) of the prothallus. The initial cell undergoes periclinal division to form an outer primary cover cell and an inner central cell . The anticlinal divisions followed by periclinal divisions of the outer cover cell produces a long projecting neck arranged in four vertical rows of cells with four to six cells in each row.

Fertilization:

At maturity, the cell wall of the lower tier of neck cells becomes thick walled and cutinized. The apical tier, however, breaks away in presence of water and the mucilagenous contents of the neck cells are released. Thus, a free passage is formed for the entry of the antherozoids.

Fertilization is accomplished by the union of a multiflagellate sperm and egg, resulting in the formation of a diploid zygote.



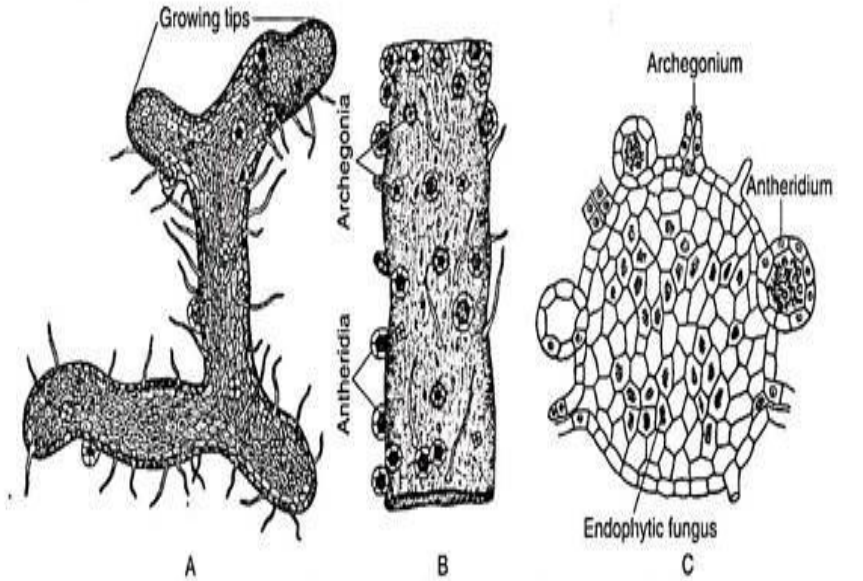


Fig. 7.18 : *Psilotum nudum* : A. A gametophyte, B. An enlarged portion of the gametophyte showing sex organs and rhizoids, C. T.S. of gametophyte

- **Embryo (New Sporophyte):**
- The diploid zygote is the mother cell of the sporophytic generation. The first division of the zygote is transverse, forming an outer epibasal cell (directed towards the neck of the archegonium) and an inner hypobasal cell (directed towards the base of the archegonium).
- The apical epibasal cell ultimately gives rise to the sporophytic branch system (aerial and underground), while the lower hypobasal cell produces the foot. This type of embryogeny where the shoot forming apical cell is directed outward (towards the neck of the archegonium) is called exoscopic mode of embryo development.
- The foot anchors the young sporophyte securely to the gametophyte and absorbs nutrients until the sporophyte becomes physiologically independent.

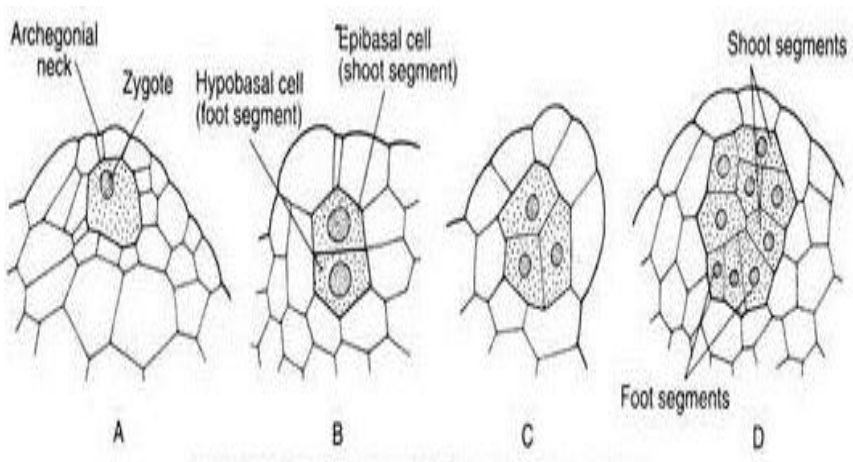


Fig. 7.21 : *Psilotum nudum* : A–D. Stages in early embryogeny

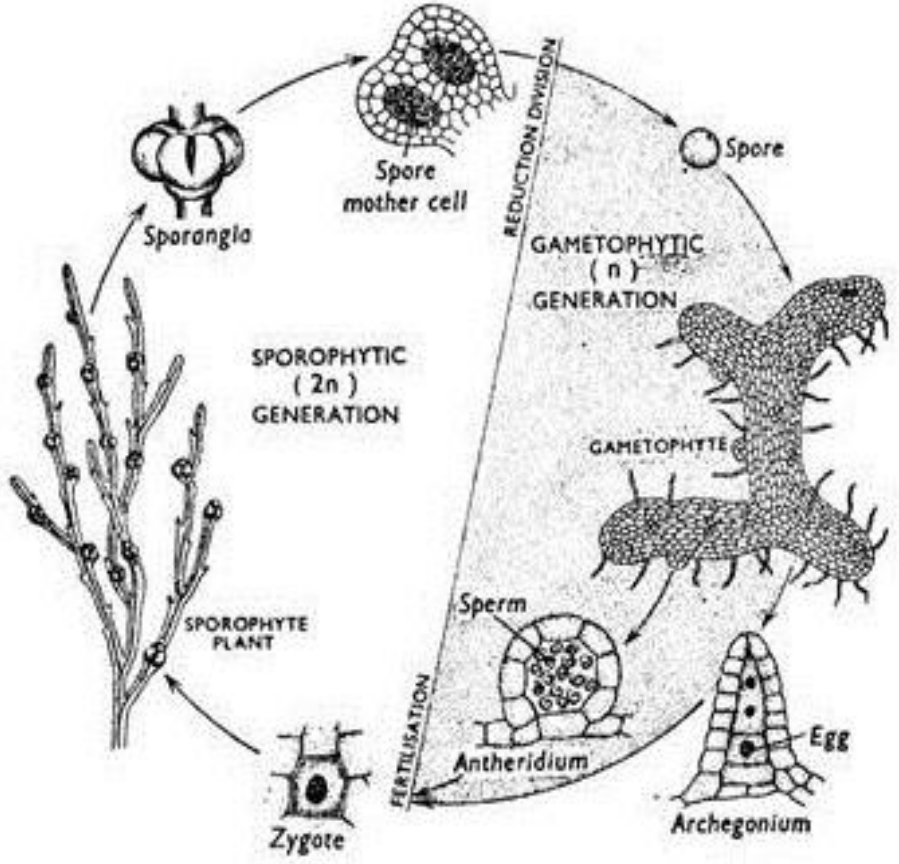


Fig. 7.22 : Life cycle of *Psilotum*

Selaginella (Spike/Club moss)

Div: Lycophyta
Class: Lycopsida
Order: Selaginellales
Family: Selaginellaceae
Genus:Selaginella

- *Selaginella* is a genus of lycophytes commonly known as spike mosses. The genus includes around 700 species of primitive vascular plants that are found in a wide range of habitats in most regions of the world.
- Spike mosses are spore producing plants and are most closely related to quillworts. *Selaginella* is the single remaining genus from the order of plants known as Selaginellales. One species, *Selaginella lepidophylla*, has a remarkable ability to tolerate drought and has earned the name 'resurrection plant'.

Stem:

- It is usually profusely branched, delicate and evergreen. The branching is of monopodial type. The growing apex of the stem consists of either meristematic tissue or a single apical cell. In the sub-genus homoeophyllum the stem is erect and somewhat cylindrical and in the sub-genus heterophyllum it is prostrate with stout erect branches and is somewhat dorsiventral.

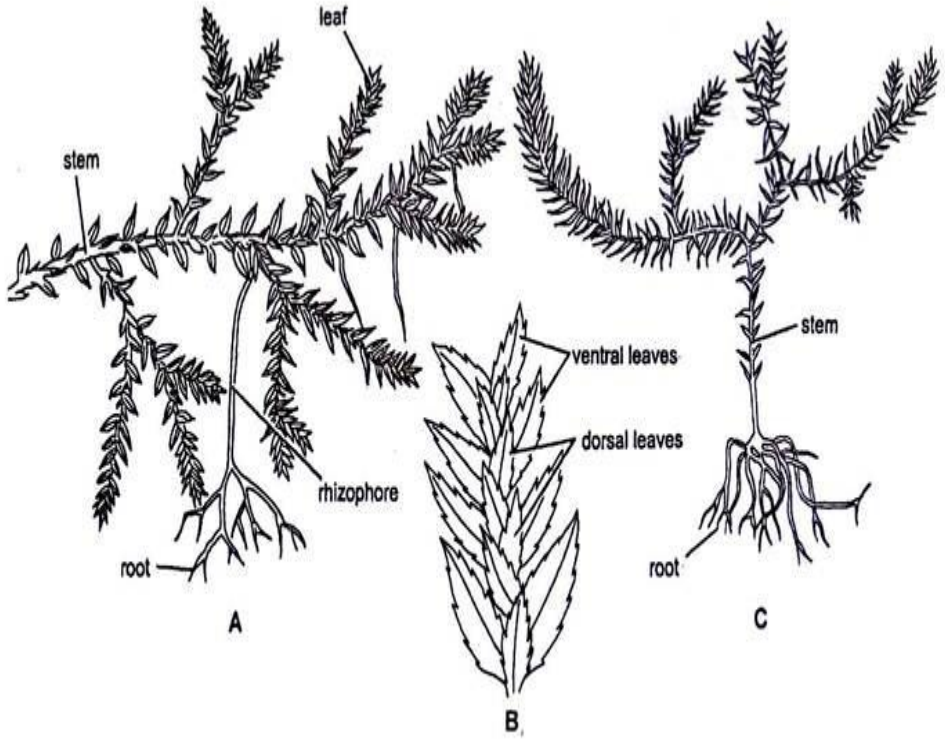


Fig. 1 (A–C). *Selaginella*. External features : A. *S. kraussiana*, B. Leaf arrangement in a branch of *S. kraussiana*, C. *S. spinulosa*

Leaves:

- They are usually small, simple and lanceolate with a pointed apex. Each leaf is provided with a single unbranched midrib. In the sub-genus homoeophyllum all the leaves are of same size and are spirally arranged forming a dense covering.
- In the sub-genus heterophyllum the leaves are dimorphic i.e., of two size (small and big) and are arranged in pairs. Small leaves are present on the dorsal side of the stem and bigger ones on the ventral side of the stem. The bigger leaves alternate with bigger ones and smaller leaves alternate with smaller ones.
- Usually the leaves near the apical portion of the branch, bear sporangia (micro-or mega) and are called as sporophylls (micro-or mega) respectively. The sporophylls are usually aggregated into a condense structure which is known as strobilus.

Ligules

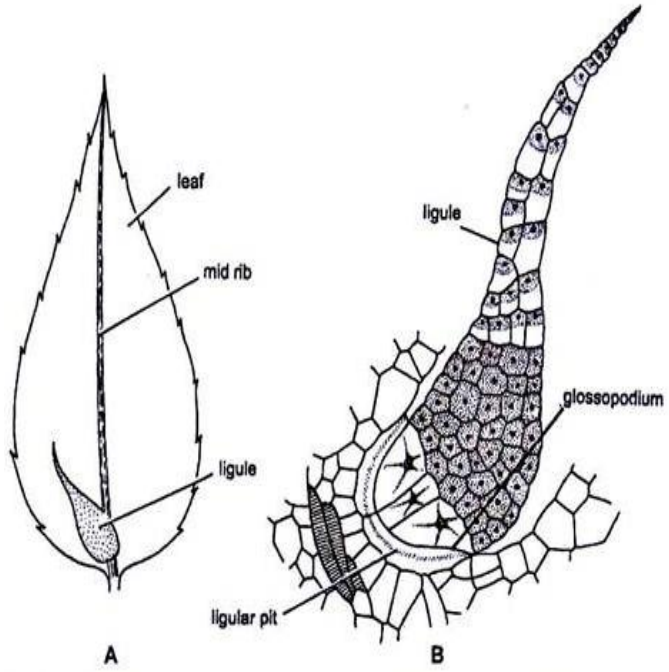
- On the adaxial side of the leaf, near the base is present a small membranous out-growth known as ligule. It is embedded at the base of a leaf in a pit like structure known as ligule pit.
- It may be tongue shaped, fan shaped, fringed, or lobed. It is more than one cell in thickness except at the apex. The structure of the ligule can be differentiated into two parts, glossopodium and the body of the ligule .

Rhizophore:

- This structure arises from the prostrate axis at the point of dichotomy and elongates downward. It is a colourless, leafless, unbranched and cylindrical structure.
- As soon as the free end of rhizophore touches the soil it develops a tuft of adventitious roots at its free end. In few species the rhizophore is present e.g., S. krciussiana while in others it is absent e.g., S. cuspidata. It differs from root in having no root cap and from stem in having no leaves.

Roots:

- They originate either from the tips of rhizophores or directly from the stem or from the swollen base of hypocotyl. Their origin is endogenous. They are usually dichotomously branched structures. The roots are provided with root caps and root hairs.



B). *Selaginella*. Structure of ligule : A. Leaf with ligule, B. Longitudinal section of ligule

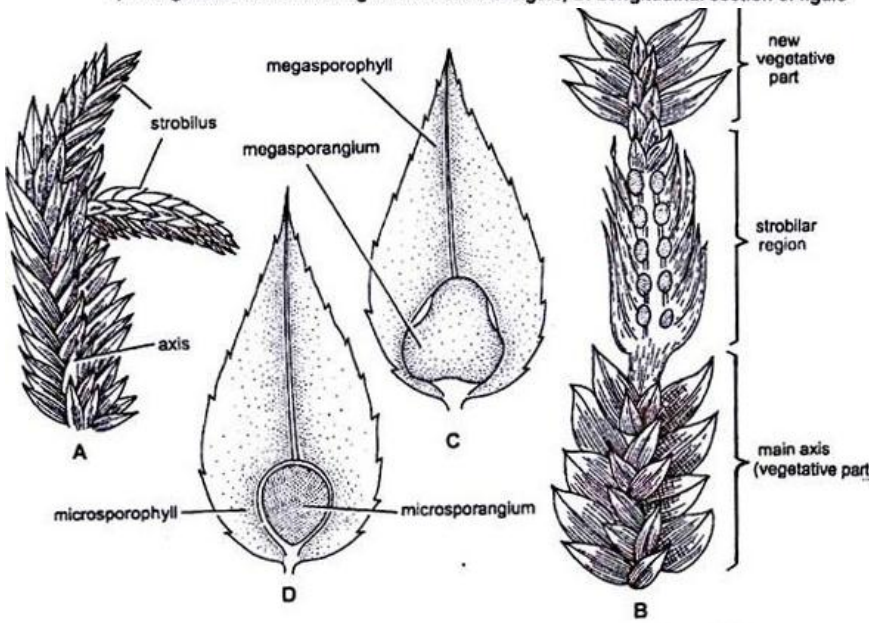


Fig. 8 (A–D). *Selaginella* : Structure of strobilus. A. A branch bearing strobilus, B. A branch after formation of strobilus region again changing into vegetative region, C. A megasporophyll, D. A microsporopyll

Reproduction

Vegetative reproduction: Fragmentation: Under humid conditions trailing branches of the stem develop adventitious branches that later disjoin from the parent plant and develop into separate individual plants.

Tubers: appear towards the end of the growing season. They may be aerial, developing at the apical end of aerial branches or subterranean. Under favorable conditions tubers germinate into a new plant.

Resting buds: are the compact structures which develop at the apical end of some aerial branches. The leaves are closely arranged and overlap the growing points. These resting buds are capable to pass on the unfavorable conditions. Under favorable conditions these buds give off rhizophore that bear roots at their tips

Sexual Reproduction: Spore producing organs: Selaginella is a sporophytic plant (2x) and reproduces sexually. The plants are heterosporous i.e., produce megaspores and microspores in megasporangia and microsporangia, respectively which, in turn, are produced on fertile leaves known as megasporophylls and microsporophylls respectively. Usually both these structures are grouped together to form a compact structure known as strobilus. **Strobilus:** a reproductive structure formed by the aggregation of ligulate sporophylls at the apex of the branches of stem. The length of the strobilus varies in different species. Strobili are usually bisporangiate but the arrangement of microsporophylls and megasporophylls differ in different species.

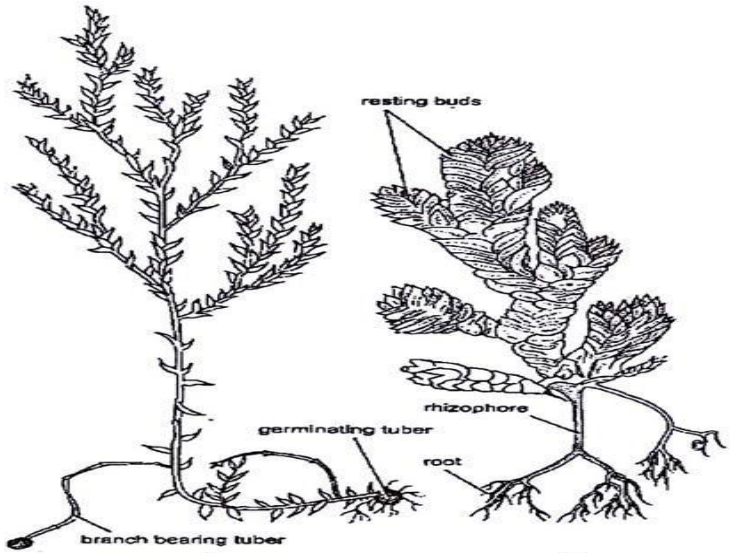


Fig. 7 (A–B). *Selaginella*. Vegetative reproduction, A. Tubers, B. Resting buds

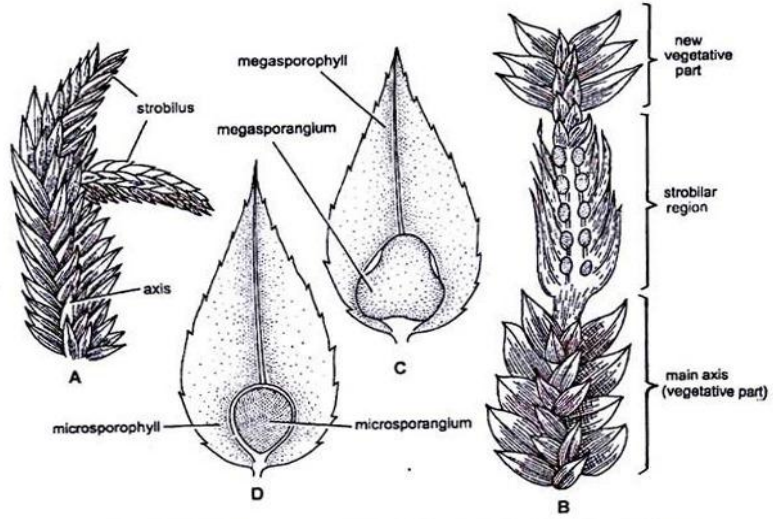


Fig. 8 (A–D). *Selaginella* : Structure of strobilus. A. A branch bearing strobilus, B. A branch after formation of strobilus region again changing into vegetative region, C. A megasporophyll, D. A microsporopyll

Microsporangium:

- Each microsporangium is a stalked, globular or elongated structure . Its color varies from red, yellow to brown in different species. The wall is 2 layered thick which is followed by a conspicuous tapetum . In the young sporangium inside the wall is present a mass of sporogenous cells which in due course of development separate into microspore mother cells and later on by meiotic divisions produce numerous haploid tetrads of microspores.
- The microspores at maturity separate from each other. At maturity the tapetal cells as well as the inner wall of the microsporangium disorganizes i.e., wall of the sporangium is usually one layered at maturity. Microspores are smaller in size.

Megasporangium:

- Each megasporangium is also a stalked but lobed structure and somewhat bigger than the microsporangium. Its colour varies from whitish yellow to red. Its wall is also 2 layered thick and followed by a single layered tapetum . In the young sporangium inside the wall is present a mass of sporogenous cells which in due course of development separate into megaspore mother cells. All the megaspore mother cells accept one degenerate.
- The remaining one later on by meiotic division produces only 4 haploid megaspores. Sometimes less than 4 megaspores are produced inside each megasporangium. At maturity the tapetal cells usually along with inner wall of the sporangium disorganise. Megaspores are larger in size than microspores .
- The sporangia usually dehisce by a vertical slit formed in apical region of the sporangia and the spores are disseminated in the air.

Gametophytic Generation:

- The development of male and female gametophytes (prothalli) takes place from the haploid microspores and megaspores respectively i.e., microspores and megaspores are the unit of male and female gemetophytes, respectively.

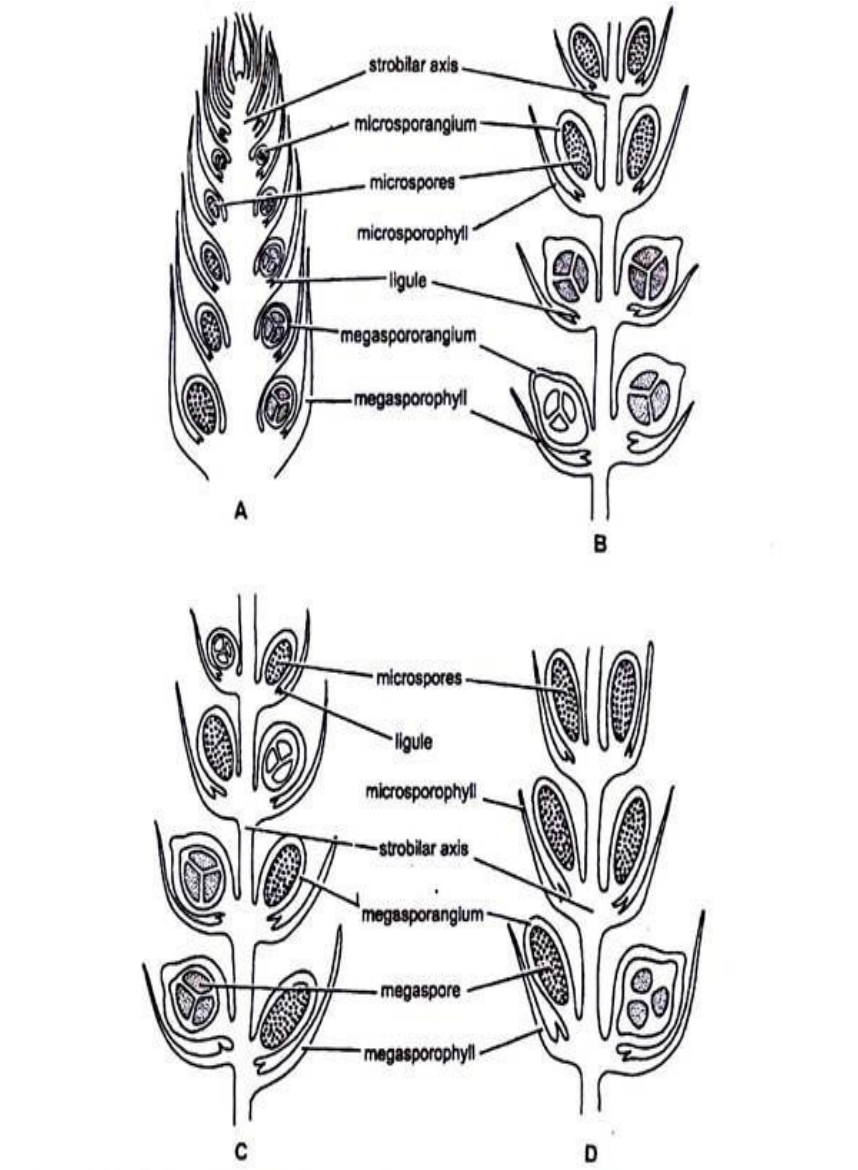


Fig. 9. (A–D). *Selaginella*. Longitudinal sections of strobili of different species showing position of microsporangia and megasporangia A. *S. inaequalifolia*, B. *S. rupestris*, C. *S. martensii*, D. *S. kraussiana*

Spore

- The microspores are small, 0 015 to 0 05 millimeter in diameter, spherical or round in shape and double layered structures. The outer wall is thick and known as exospore (exine). While inner wall is thin and is called endospore (intine).
- The megaspores are much larger than microspores, 1.5 to 5 millimeter in diameter, tetrahedral in shape and show triradiate ridge. The megaspore has three wall layers namely exospore, mesospore and endospore. The microspores on germination give rise to male prothalli and megaspores to the female prothalli.

Development of male gametophyte: Each microspore is a unicellular, uninucleate, rounded or spherical, haploid structure with outer spiny thick exosporium and inner thin endosporium. The first division is in such a way that 2 unequal cells are formed, smaller prothallial cell and a larger antheridial cell. Each antherozoid mother cell finally metamorphosis into a single antherozoid which is a spirally coiled, uninucleate and biflagellate structure. The two flagella are unequal in size. The antherozoids are liberated by the rupturing of endosporium and swim in water till they reach the neck of archegonium.

Development of female gametophyte:

The megaspore is the initial stage in the development of female gametophyte. The development of female gametophyte starts while the megaspore is still inside megasporangium. The megaspores are liberated from the megasporangium either at the time of first archegonium formation or just after fertilization.

At this stage usually the female gametophyte is liberated from the gametangium. If it falls on suitable substratum, it germinates. The exine and mesine ruptures. The cellular tissue protrudes out and a few rhizoids develop which fixes the gametophyte to the substratum and absorbs water.

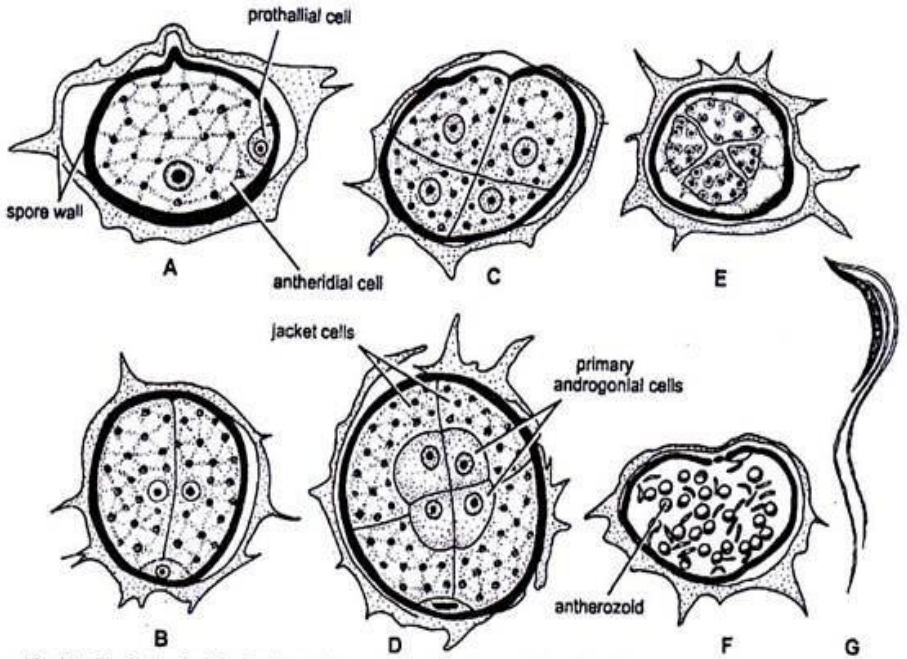


Fig. 13. (A–G) *Selaginella*. Schematic representation of the development of male gametophyte

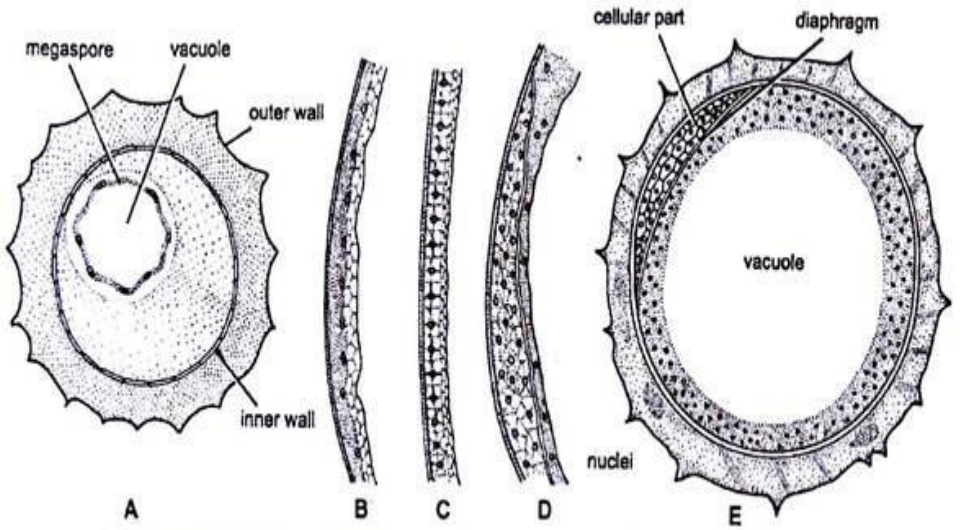


Fig. 14 (A–E). *Selaginella*. Stages in the development of female gametophyte

Structure of Mature Archegonium:

- The archegonium is a short flask shaped structure embedded in female gametophytic tissue. Only the upper tier of neck cells projects out. Each archegonium consists of a short neck of 2 tiers of 4 cells each and a broad venter. The four cells of the upper tier of neck function as cover cells.
- The neck encloses a single neck canal cell and the venter consists of a ventral canal cell and an egg. There is no definite wall of venter. At maturity the neck canal cell and the ventral canal cell disorganize and absorb water which creates a pressure to separate apart the cover cells through which the antherozoids enter the archegonium and reach the egg.

Fertilization:

- Water is necessary to carry out the process of fertilization. The swimming antherozoids reach the egg through the neck of archegonium and the nucleus of antherozoid fuses with the egg nucleus thus forming a zygotic nucleus. The fertilized egg secretes a wall around it forming a diploid structure known as zygote or oospore (2x). Thus the gametophytic generation ends and the initial stage of sporophytic generation is formed.

Development of embryo:

- Oospore is the initial stage of sporophytic generation. During development of the embryo, the oospore first divides by a transverse division into an upper suspensor initial (epibasal) and a lower embryo initial (hypobasal).

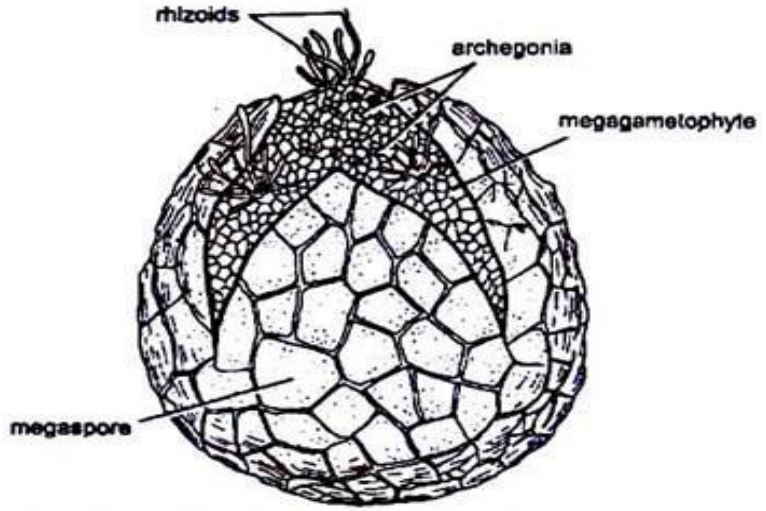
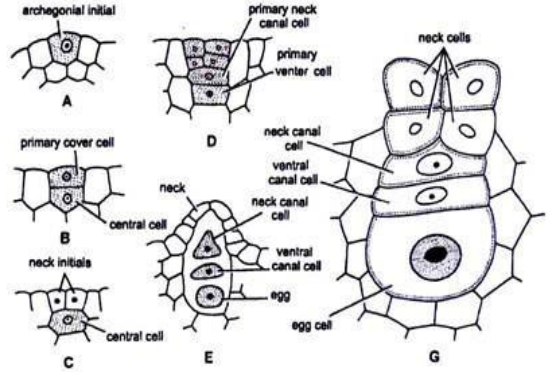


Fig. 15. *Selaginella*. Female gametophyte. A. Dehiscent megaspore and rhizoids in *S. kraussiana*



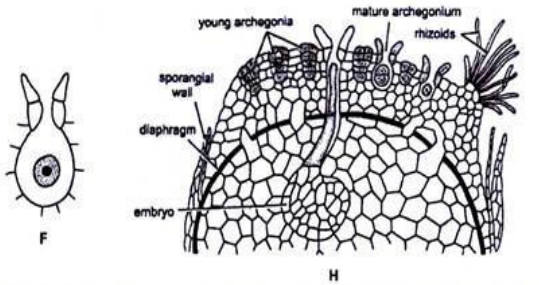


Fig. 16 (A–G). *Selaginella* : Development of archegonium. A–F. Various stages in the development, G. A mature archegonium before fertilization, H. A nearly median section of a mature prothallus showing various stages in the development of archegonium.

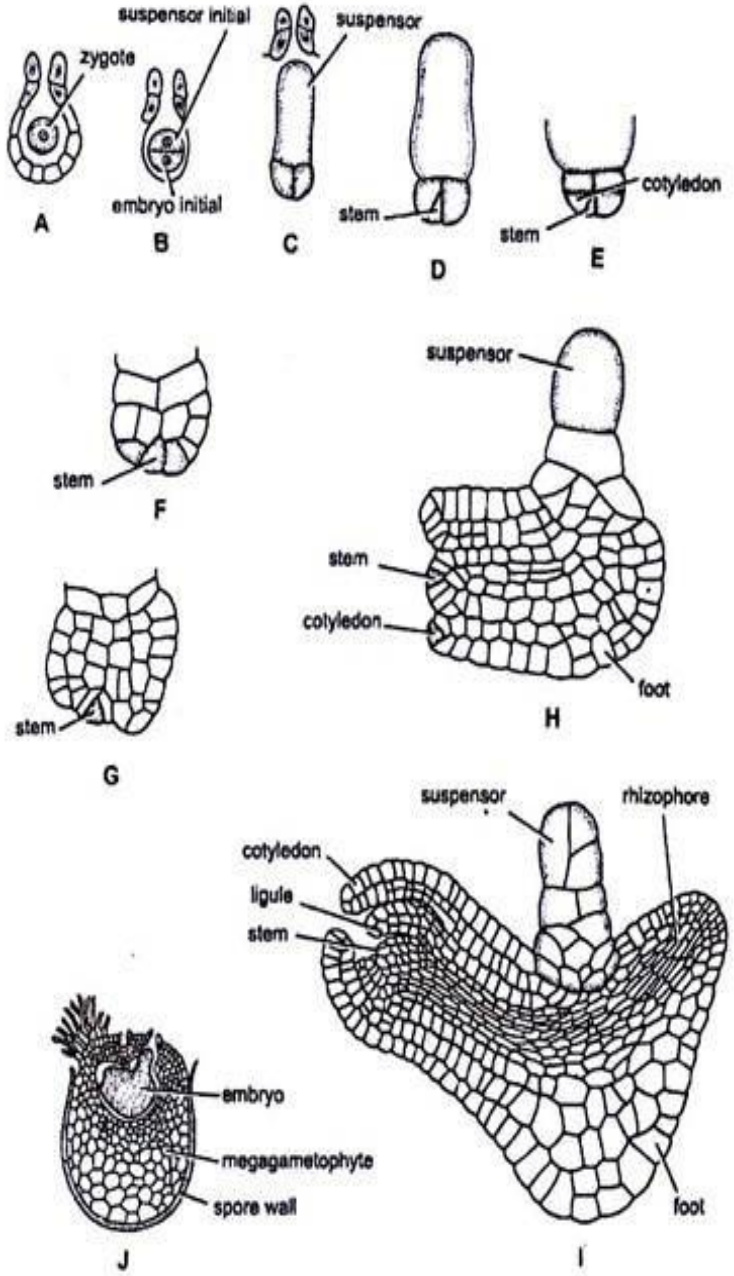


Fig 17 (A–J). *Selaginella* : Development of embryo.

A–I various stages in the development J. Longitudinal section of female gametophyte bearing embryo.

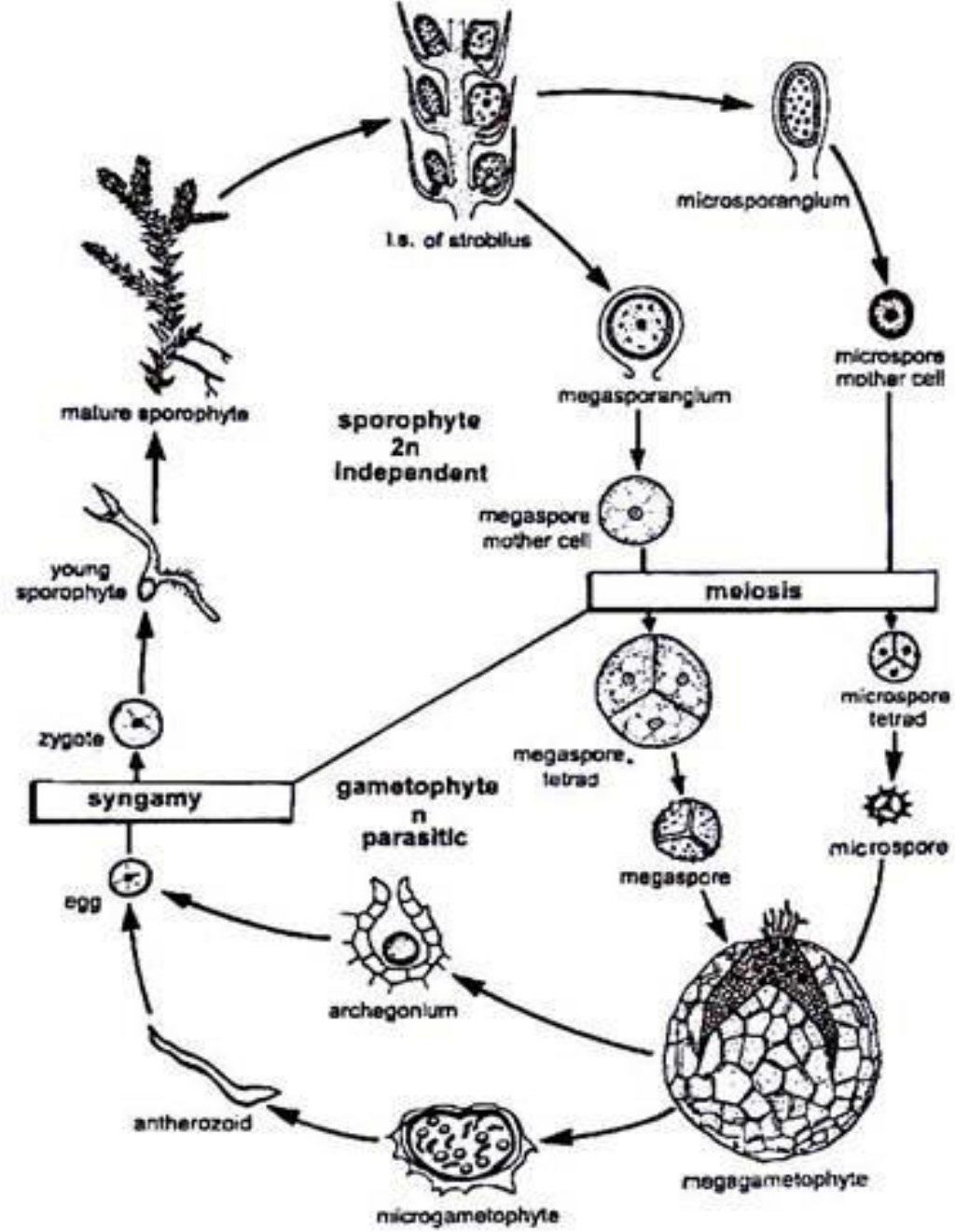


Fig. 19. Diagrammatic life cycle of *Selaginella*