3rd SEM B.Sc. Botany

CALICUT UNIVERSITY

Bryophytes and Pteridophytes

2019 ADMISSION

Prepared by

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Syllabus
BOT3B03T: BRYOLOGY AND PTERIDOLOGY
Lectures Hours per week: 5, Credit – 3, Internal: 15,
External: 60, Examination 2 Hours
Objectives:

- Appreciate the diversity and evolutionary significance of lower plant groups.
- Classify algae, bryophytes and pteridophytes.
- Understand the economic and ecological importance of lower plant groups.

BRYOLOGY

1. Introduction, general characters and classification by Stotler & Stotler (2008)
2. Study the distribution, morphology, anatomy, reproduction, life cycle and affinities of the following types (Developmental details not required)

a. Riccia (Marchantiophyta)
b. Anthoceros (Anthocerotophyta)
c. Funaria (Bryophyta)

Reference Books:

1. Smith G.M. (1938) Cryptogamic Botany Vol.II. Bryophytes and pteridophytes. McGraw Hill Book Company, London.
2. Sporne K.R. (1967) The Morphology of Bryophytes. Hutchinson University Library, London.
3. Vasishta B.R. Bryophyta. Revised edition. (2011). S. Chand and Co. New Delhi.
4. Watson E.V. (1971) The structure and life of Bryophytes. Hutchinson University Library, London.

PTERIDOLOGY

1. Introduction, general characters and classification (Smith et al., 2008 – brief outline only).
2. Study the distribution, morphology, anatomy, reproduction, life cycle and affinities of the following types (Developmental details are not required)

a. Psilotum (Psilotopsida)
b. Selaginella (Lycopsida)
c. Equisetum (Equisetopsida)
d. Pteris (Polypodiopsida)

3. Apogamy and apospory in Pteridophytes; Stelar evolution in Pteridophytes; Heterospory and seed habit; Affinities of Pteridophytes; Economic importance of Pteridophytes

Reference Books:

1. Chandra S. & Srivastava M. (2003) Pteridology in New Millenium, Khuwer Academic Publishers.
2. Rashid, A. (1976) An Introduction to Pteridopyta, Vikas publ. Co. New Delhi.
3. Vasishta B.R. (1993) Pteridophyta – S. Chand and Co., New Delhi.

BRYOLOGY

- Bryophytes (bryon= moss, phyton= plants) –group of non-vascular plants
- Commonly called amphibians of plant kingdom
- Simplest and most primitive group of plants, in between thallophytes (algae) and pteridophytes.
- Comprises mosses, liverworts and hornworts with 960 genera and 24,000 species.
- Occur in humid and shady localities at higher altitudes
- Submerged- *Riccia fluitans, Ricciocarpus natans.*
- On dry rock with little moisture- *Porella platyphylla*
- As epiphytes on trees of tropical rain forest- Dendroceros

General features

- Life cycle with morphologically distinct (heteromorphic) gametophytic and sporophytic phases
- Gametophytic phase is haploid, represent the prominent adult plant. Green coloured, branching non-living, independent and autotrophic
- Sporophytic phase is diploid, short living and completely dependent on the gametophyte.
- In Riccia and Marchantia – gametophyte is prostrate and thalloid, without differentiated to root stem and leaf
- In mosses like Funaria – plant body erect, differentiated to stem(axis), lateral appendages(leaves)
- Roots absent, fixation and absorption by root like and filamentous rhizoids.
- Rhizoids unicellular and unbranched in hepaticopsida & anthocerotopsida , multicellular and branched in bryopsida
- Order Marchantiales possess multicellular scales to protect the growing regions of thallus and also for water absorption.
- Plant body made up of parenchymatous cells, xylem and phloem altogether absent.
- Reproduction by vegetative and sexual methods
- Vegetative multiplication involves the death and decay of older parts. it takes place by formation of formation of adventitious branches, gemmae, protonema, bulbils, tubers etc. in addition to these fragments of stem and leaves may develop to new plants.
- Sexual reproduction oogamous, sex organs multicellular and complex.
- Male sex organ –stalked,globose or elliptical antheridia
- Antheridia possess one-cell thick sterile jacket, surrounding an inner solid mass of fertile cells called androcytes. Androcytes gives rise to biflagellate and motile antherozooids or sperms.
- Female sex organ –flask shaped archegonia, with a swollen basal portion called venter, and a slender and elongated distal part called neck. Venter encloses the egg or oosphere.venter and neck are surrounded by a jacket of sterile cells

- Water necessary for fertilization. During fertilization many antherozooids may enter the neck, but only one fuses with the egg to form diploid zygote. Zygote represents the beginning of sporophytic generation
- Zygote undergo division without any resting period.
- The first division of the zygote is transverse and uppercell develops to an embryo within the venter of the archegonium.
- The sporophyte or sporogonium, developing from the embryo, is simple without rhizoids, stem or leaves.
- Sporophytes completely depending on gametophytes. In Riccia sporophyte represented by a capsule. In advanced forms like Bryum, Funaria it is projecting structure differentiated to foot, seta and capsule.
- Sporogenous cells of capsule form haplid spores after meiosis. All spores are similar in shape and size.
- Spores are non-motile and disseminated by wind.
- Under favourable condition each spore develops to young gametophyte (Riccia, Marchantia,) or forms a protonema (mosses) protonema has many buds develops to many gametophytes.

Alternation of generation

- Bryophytes are the non-vascular plants.
- In the life cycle, they are the only embryophytes (plants that produce an embryo) whose life history includes a dominant gametophyte (haploid) stage.
- Alternation of generations is a life-cycle involving two phases of life, which regularly alternate with each other.
- In Bryophytes, the first phase is the gametophytic phase, in which gametes are produced, that contain half the number of chromosomes. This is the dominant phase in the life of Bryophytes and reproduces sexually by egg and sperm.
- Once the egg and sperm fuse to produce a zygote, starts the second phase.
- The zygote germinates to produce the sporophyte, whose cells possess the complete number of chromosomes.
- This second phase, the sporophytic phase, is the spore producing phase. The sporophyte cannot exist independently. It is composed of a capsule, a stalk, and a foot that attaches the sporophyte body to the gametophyte.
- The sporophyte reproduces asexually by means of spores, which are produced by meiosis and are haploid.
- Each spore germinates to produce a gametophyte, which is the independent phase. This way, the life cycle is completed.

Apospory and Apogamy

- Bryophytes exhibit apospory and apogamy

- In apospory, the gametophyte develops from the vegetative cells of the sporophyte and not from the spore. Eg. *Anthoceros, Mosses*
- In appearance the aposporous gametophyte resembles the normal gametophyte , but possesses diploid number of chromosomes.
- In apogamy sporophyte develop from gametophyte , without gametic fusion. Eg. *Funaria hygrometrica, Physcomitrium coorgense*.

CLASSIFICATION

- Eichler(1813) grouped bryophytes to two claases
    1. Hepaticae(liverworts & hornworts)
    2. Musci(mosses)
- Engler (1892)

Division Bryophyta
- Class Hepaticae
    - Order Marchantiales
    - Order Jungermanniales
    - Order Antherocerotales
- Class Musci
    - Order Sphagnales
    - Order Andreales
    - Order Bryales

- Howe (1899) place amtherocerotales to class
  Three classes 1. Hepaticae
  2.Anthocerotae
  3. Musci
- Rothmaler (1951) changed it as Hepaticopsida, Anthocerotopsida, Musci.
- Prosakauer (1953),1957
  Class bryopsida divided into three subclasses
    1. Hepaticidae
    2. Anthocerotidae
    3. Bryidae

CUURENT CLASSIFICATION

DIVISION: BRYOPHYTA

- CLASS HEPATICOPSIDA
  - Order Sphaerocarpales
  - Marchantiales
  - Metzgeriales
  - Jungermanniales
  - Calobryales
  - Takakiales
- CLASS ANTHOCEROTOPSIDA
  - Anthocerotales
- CLASS BRYOPSIDA
  - Subclass Sphagnophyta
    - order Sphagnales
  - Andreabrya
    - Andreales
  - Eubrya
    - Funariales
    - Polytrichales

Class : Hepaticopsida

- Liverworts, 6 orders,9 families, 225 genera 8500 species
- Dorsiventrally flattened gametophyte which is either thalloid or foliose form , differentiated to axes and leaves
- In foliose form leaves devoid of midrib , arranged in two or three rows on the axis
- Sex organs develop from superficial cells. They are dorsal in most cases and terminal a few
- Sporophyte may be simple or differentiated either into capsule and foot or into capsule, foot and seta
- Sporophyte completely depends on the gametophyte for its nutritional requirements
- Archesporium or sporogenous tissue develops from the endothecium of sporogonium
- The wall of sporogonium is one to several –layered and is devoid of stomata
- Dehiscence of sporogonium is irregular

Class : Anthocerotopsida

- Hornworts, 1 order, 2 families, 6 genera, 300 species
- Gametophyte is dorsally flattened and thalloid, it remains attached to a substratum with a simple and smooth-walled, tuberculate rhizoids and ventral scales are absent
- Thallus is internally homogenous, thallus tissue is undifferentiated and each cell is uninucleate with a prominent chloroplast and a pyrenoid
- Sex organs remain embedded in the gametophytic tissue on the dorsal side of the thallus. Antheridia develop from hypodermal cells, and archegonia from superficial cells

- Sporogonium is elongated and cylindrical and its differentiated into foot, capsule and meristematu=ic region. Meristem is intercalary and it is active throughout the growing season
- The wall of the capsule is 4 or 6 cells thick and is provided with stomata
- The central sterile portion of sporogonium forms columella , which is surrounded by sporogenous tissue and spores
- The sporogenous mass develops from amphithecium and it arches over the columella

Class : Bryopsida

- Mosses, 28 families, 660genera, 15,500 species
- Gametophytic plant body is differentiated into axis or stem, leaves and rhizoids. Leaves are spirally arranged, and rhizoids are multicellular, branched and obliquely septate
- Leaves are arranged around the axis in 3 to 8 rows and have prominent midrib
- Sex organ are apical and they develop from the superficial cells of the gametophore
- Sporophyte is differentiated into foot, seta, capsule
- Capsular wall consists of several layers of chlorophyllous cells and is provided with stomata
- Sporogenous tissue (archesporium) and colummella develop from the outer layers of the endothecium

RICCIA

- 200 species, cosmopolitan distribution in the southern hemisphere
- Grows on damp soil, moist and shady rocks and other similar terrestrial habitat
- *R. fluitans* – free floating or submerged aquatic species
- *R. reticulata* – xerophytic
- 33 species- Indian, mainly on foot hills and plains
- *R. ciliata, R. robusta, R. gangetica, R. melanospora, R. discolor*
- *R. gangetica, R. pandei* – endemic to India.

External structure

- Gametophytic plant body. Fleshy, flat, prostrate, dorsiventral, dark-green and dichotomously branched.
- Rosette form, due to the presence of several dichotomies close to each other (ribbon like in R. fluitans)
- Branches of the thallus, called thallus lobes, may be linear or wedge –shaped. Each lobe is thicker in middle and gradually thin toward the margins
- Thick middle portion is midrib region.

- Midrib is marked by a shallow longitudinal groove, known as dorsal groove or furrow. It extends from the base to tip of thallus and terminates in an apical notch
- The growing point of the thallus is present the notch
- Ventral surface of the thallus bears rhizoids and scales.
- Rhizoids are unicellular, unbranched, elongated, tubular and hair like, simply outgrowth of lower epidermal cells.
- Rhizoids two types simple / smooth walled and tuberculate
- Simple rhizoids, outer and inner walls are stretched and smooth
- Tuberculate with innerwalls has a peglike or plate like ingrowth into the lumen, called tubercles
- Rhizoids for absorption and anchorage
- Scales multicellular, one cell thick and membraneous structures which afford protection to growing parts.
- Pink or violet coloured, due to presence of anthocyanin pigments.
- Arranged in a single transverse row along the margins of the thallus.
- Apocal region, scales overlap each other and project forward to protect the growing point.
- Terrestrial species have a small and ephemeral scales, those on dry species have large and persistent scales.

Internal structure

- Anatomically, thallus differentiated into dorsal assimilatory or photosynthetic region and ventral storage region.

a) Photosynthetic region
   - Consist of photosynthetic cells arranged in many vertical and unbranched rows or filaments.
   - All cells of these filaments, except the terminal one are similar with discoid chloroplasts.
   - Terminal cells large and colourless, one-cell thick, loose and discontinuous upper epidermis
   - Photosynthetic filament are separated from each other by narrow or wide air chambers or air canals.
   - Air chambers open to the exterior through simple air pores on the dorsal surface of the thallus.
   - This pores helps in gas exchange. Each pore surrounded by 4-8 epidermal cells

b) Storage region
   - Below to photosynthetic region on the ventral side
   - Made up with thin walled, colourless and compactly arranged parenchymatous cells without chloroplast and intercellular spaces or air chambers.
   - Cells contain starch as reserve food materials
   - Innermost layer of the region forms the lower epidermis

- Some lower epidermal cells gives off unicellular rhizoids and multicellular scales
- Rhizoids at mid ventral region and scales along the margins.

Growth of thallus or apical growth

- Growth of thallus takes place by the activity of one to several meristematic cells, that lie in the apical notch.
- This apical cells are triangular with three cutting faces.
- The cells, formed from the dorsal and ventral cutting faces constitute the major portion of the thallus.
- Each cell divides transversely into upper cell and lower cell.
- The upper cell, by repeated division gives rise to the assimilatory zone and sex organ
- The lower cell divides repeatedly and form the storage region.

REPRODUCTION

- Riccia reproduces by vegetative and sexual methods
- Sexual reproduction occurs usually after certain stages of maturity or rarely due to a sudden change in the environmental conditions.

VEGETATIVE REPRODUCTION

- Vegetative multiplication of the thallus takes place by athe following methods
  1. By progressive death and fragmentation of older parts
     - Commonest method of vegetative reproduction
     - Older parts of the dichotomously branched thallus gradually die off at old age. As the process of death approaches the point of dichotomy, the two branches of the thallus seperate and each grows into a new plant
  2. By adventitious branches
     - In *R. fluitans* adventitious branches develops on the ventral surface of the thallus.
     - These branch, when separated from the parent thallus grow to new plant.
  3. By the death of the thallus during drought
     - During continuous drought all parts of thallus , except apical part, dies
     - The apical parts grows deep in the soil and becomes thick. It becomes active and grows during the next season and develops to a new thallus
  4. By tubers
     - At the end of growing season, in certain species like *R. bulbifera, R. discolor* etc.
     - The apices of the thallus lobes form perenneting structures called tubers.
     - Tubers remain dormant during unfavourable period and grow to new thalli on the return of favourable conditions
  5. By rhizoids
     - The apices of rhizoids divided repeatedly and form a cellular mass.
     - These cells possess chloroplast and have the capability to grow to a new thalli.

SEXUAL REPRODUCTION

- With the help of male (antheridia) and female (archegonia) reproductive organs

- Most species are homothallic or monoecious –female and male sex organ on same thallus.
- In some species like R. discolor,R. frostii it is heterothallic or dioecious - female and male sex organ on different thallus
- Reproductive organs develop as the thallus matures. On dorsal surface in acropetal succession (from base to apex)
- Mature organs on base and younger towards apex
- In monoecious, several alternating groups of antheridia and archegonia occur along the midrib

ANTHERIDIUM

- Mature antheridium is globular or club shaped structure. It is attached to the botton of the antheridial chamber by a short multicellular stalk.
- The antheridial chamber opens on the dorsal surface of the thallus by a narrow pore called ostiole
- Body of antheridium consist of a solid central mass of fertile cubical cells called androcytes or androzoid mother cells. They are enclosed by a one cell thick sterile jacket layer.
- Each androcyte become an androzoid
- During favourable rainy season, the jacket layer imbibes water, gets disorganized and releases the androcytes. Rain drops help the androzoids to get in to the neck of archegonium.

ARCHEGONIUM

- Mature archegonium is a flask shaped structure, attached to the bottom of the archegonial chamber by a short multicellular stalk. It is differentiated into a basal swollen venter and upper elongated and narrow neck.
- Neck is composed of six vertical rows of cells and each row have six to nine cells
- Within the neck, lies a uniseriate ows of four to six neck canal cell
- Tip of neck covered by four relatively large cover cell.
- Venter is surrounded by a one cell thick jacket cells
- It encloses a large and naked egg or oosphere and a small venter canal cell
- Although the archegoinum is embedded in the archegonial chamber,the upper part of the neck always protrudes above the surface of the thallus

FERTILIZATION

- Takes place only the presence of water
- Water essential for liberation of antherozoids from the antheridium, for the swimming movements of antherozoids to the aechegonium, and also for the disintegration of neck canal cell.
- At maturity the neck canal cell and venter canal cell of archegonia disintegrate to form a mucilaginous mass.
- The mucilage imbibes water, swell and comes out by forcing upon the cover cells, forming narrow passage called the neck canal.
- In this condition fertilization takes place which requires the presence of water that act as the medium for swimming the antherozoids
- After rain or heavy dew, water is usually retained in the dorsal groove of the thallus in the form of thin film.

- The liberated spermatozoids swim in this water and they came near the archegonium due to chemotactic attraction induced by proteins and other chemicals coming out of follow archegonial neck
- A number of sperms pass into neck, reach the venter and ultimately one fertilizes the egg to form diploid zygote or oospore, thus the sporophytic generation begins

Sporophyte

- Zygote invest itself with a thin cellulose wall immediately after fertilization
- It increases greatly in size and almost completely fills up the venter of the archegonium
- Simultaneously, the walls of the venter divide periclinally and eventually form a two-layered calypra around the young sporophyte.

Development of the sporophyte

- First division of sporophyte is transverse
- Second division, at right angles to the first one, results in the formation of quqdrant stage of four cells
- Another division in a vertical plane at right angles to the former resulting in an octant stage of eight cells
- Subsequent divisions are in all directions giving rise to a spherical mass of 20 to 30 cells
- The superficial cells of this mass divides periclinally to form an outer amphithecium layer and inner mass endothecium
- The amphithecium forms the jacket of the sporophyte, while endothecium represent the archegonium
- The archesporial cells divide further to form two types of cell,
  a) Spore mother cell
  b) Sterile nurse cell with a watery vacuolated cytoplasm
- These nurse cells are probably the forerunners of elaters
- The spore mother cell or sporocyte are last cells of the sporophytic generation after which it begins to disintegrate
- Nurse cells and amphithecial jacket layer also disintegrate further followed by disintegration of the inner cell layer of the venter wall
- All the disintegrated products form a nutritive fluid within which the spore mother cells remain suspended

Sporogenesis

- Spore mother cell undergo meiosis form haploid spore tetrad
- Spore tetrad usually remain attached for a long time within a common spherical sheath
- Each haploid spore is uninucleate, pyramidal
- Mature spore show three layers
  Outermost-exposporium
  Middle –mesosporium
  Inner –endosporium

Structure of mature sporophyte

- It represented by only a single globular capsule which is found to be the simplest organization among the bryophyte

- Foot, seta completely absent
- Capsule lies embedded within the upper surface of the gametophytic thallus, where the spore mother cell are enveloped by a single layered jacket
- The capsule has 2 layered protective coverings called calyptra, is a part of the gametophyte
- The capsule wall degenerates before the formation of spore tetrads and then the inner layer of the calyptra degenerates
- The mature sporophyte doesnot contain a single diploid sporophyytic cell.
- Instead the structure contain some haploid spores surrounded by the outermost layer of the calyptra which is the gametophytic tissue, but of the previous generation
- Capsule is represented a sporophyte because it has been derived from a diploid cell(zygote).

Young gametophyte

- Spore is the first cell of gametophytic generation
- Spores are liberated only by the complete death and decay of the calyptra and the surrounding tissue of the gametophytic thallus
- The spores germinate in favourable environmental condition, when there is enough water in soil. The exosporium and mesosporium ruptures at the triradiate aperture and endosporium comes out as a tubular germ tube.
- Germ tube elongated to form club shaped structure
- Most of the protoplasm passes to the tip that is now cut off by a transverse wall to form a distal cell
- The distal cell undergo 2 vertical division at right angles to each other forming two tiers of four cell each
- One these four cell form an apical cell which divides to produce a new thallus.
- The first rhizoid develops from the base of the germ tube.

ANTHOCEROS

- Extensively distributed hornwort
- Common in the tropical and temperate regions of the world. The plant grows mostly shady places ,such as river banks ,forest tracts and rock cervices.
- Some species grow on decaying wood.
- The genus includes annuals (e.g.,*A.erectus, A.punctatus*) and perennials (e,g., *A.fusiformis,A.himalayennsis*).
- there are about 200 odd species of *Anthoceros* known to exist all the world over in India, there are about,mostly restricted to hilly regions.
- *A.himamlayaensis,A.erectus,A.chambensis,A.longii,A.erispulus,A.gollani,A.dixitti*,etc. are the commonest among them.

External features

- Gametophytic plant body is a dark-green, dorsiventral, prostrate and spongy thallus.
- Thallus is lobed and pinnately divided in *A.hallii* and deeply bilobed in *A.himalayensis*.
- In *A.erectus*, thallus is often raised on a thick which expands into a cup –like structure above.

- Thalllus thick in the middle and is without a well-defined midrib.
- Dorsal surface may be smooth (*A.laevis*),velvety (*A.crispulus*),or rough with spines and ridges(*A.fusiformis*). Ventral surface bears many unicellular and smooth-walled rhizoids along the median line. Tuberculate rhizoids,scales and mucilage hairs are absent.

Internal structure

- Internal structure of the thallus is very simple with appreciable cellular differentiation.
- All the cell the cell of the thallus are almost alike, even though the upper epidermal cell are realtively smaller.
- Thallus consists of distinct and continuous upper and lower epdermis,made up of comparatively small cells.
- the main bulk of the thallus is made up of thin-walled and isodiametic parenchymatous cells. Each cells has one or more discoid or oval chloroplasts which show lamellar structure,similar to that of higher plants.
- Chloroplasts possess pyrenoids,a characteristic feature,of anthocerotopsida.the thickness of the middle region of the thallus varies in different species (6 to 8 cells-thick in *A.laevis*.8-10 cells thick in *A.punctatus* and 30-40 cells thick in *A.crispulus*).
- There are no air pores and air chambers.
- Inter -cellular mucilage cavities are present, opening on the ventral surface through narrow stomata-like slits, called slime pores.
- These pores are formed by the partial separation of two adjacent cells of the epidermis.
- The mucilaginous cavities are often invaded by colonies of *Nostoc*, a blue-green alga. The filaments of this alga enter the thallus through the slime pores.
- The presence the *Nostoc* colonies in the thallus of *Anthoceros* is not considered as a symbiotic association because *Anthoceros* can grow normally even in sterilized soil, and also because mucilaginous cavities are absent in the thalli of some species. *Nostoc* lives in the thalli of *Anthoceros* probably as a space parasite.

Apical growth

- The thallus of *Anthoceros* grows by the activity of a single meristematic apical cell in some species (e.g., *A.fusiformis*), or by the activity of a group of marginal meristematic cells in other (*A. erectus, A. himalayaensis*).
- These meristematic cells are located in a shallow depression at the distal end of the thallus and are covered by a mucilaginous substance.
- Each cell has four cutting faces, one dorsal , one ventral, and the other lateral.
- The dorsal and ventral segment divide, forming outer and inner cells.
- The outer cells derived from the dorsal segment, form the upper epidermis and sex organs.
- In the same manner, the outer cells from the ventral segment from the lower epidermis and rhizoids. The inner cells from the dorsal and ventral segments from the middle part of the thallus.

Reproduction

1) Vegetative reproduction
   - By progressive death and decay and fragmentation

In this method, the thallus undergoes progressive death and decay up to dichotomy or branching point. As a result, the lobes gets separated and each lobe grow to a new thallus. This process is common.

- By tubers

  During unfavourable conditions of prolonged drought, tubers are formed in many species

  Tubers store food and also act as perennating organs. And formed behind the growing point or along the margins of thallus.

  Tubers have an outer protective corky layer and can resist extreme desiccation.

  They can penetrate even after the death of thallus. on return of favourable condition, they germinate and give rise to new plants.

- By gemmae

  Gemmae are the bear stalked structures on the dorsal surface of thallus.

  On separation from the parent thallus, gemmae give rise to new plants.

- By persistent growing apices

  The thallus are dry during summer season, apical part remain dormant during dry condition.

  On the return of favourable conditions, they become active and give rise to new plants.

- Aposopry

  Schwarzenbach and Lang (1927) reported apospory in *Anthoceros.*

  New thallus arises directly from the unspecialized vegetative cells of the different part of sporogonium, such as intercalary meristematic zone, sub-epidermal or sporogenous region of the capsule. Such thalli are diploid but normal in appearance.

Sexual reproduction

- It takes place with the help of antheridium and archegonium
- Species may be monoecious or homothallic and dioecious or heterothallic
- Monoecious are protrandrous (antheridia mature much before archegonium
- Mature antheridia is stalked and club-shaped or pouch like body, borne on a multicellular stout or slender stalk. It have outer sterile jacket cell and inner androcytes
- Endogenous development of antheridia
- Antheridium dehiscence and liberation of antherozoids thaken place through roof of antheridial chamber.
- Archegonium, female sex organ –flask shaped structure. Which is deeply embedded in the dorsal part of gametophytic thallus
- Archegonium have venter, neck canal cell and the innermost large egg cell.
- Archegonium embedded in the thallus tissue, neck canal cells are not clearly distinguishable from the cells of the thallus. These feature differs from some bryophytes and resembles some pteridophytes.
- Development of archegonium is a sequential process. From archegonial initial cell to the mature archegonium.
- Fertilization- Egg and antherozoids fuse to form diploid oospore.
- Mature diploid oospore is the mother cell of the sporophytic generation. It undergo post fertilization changes and develop a sporophyte, it involves cell division, cell differentiation and growth.

Sporophyte

- Mature sporophyte is thin, elongated structure, present on the dorsal surface of the thallus.
- Young sporophyte green color, but at maturity it turns to dark yellow or black from the apex to the base.
- Mature sporophyte has three distinct part like foot, capsule and meristematic zone.
- Foot-basal part, capsule –terminal part, meristematic zone is the middle part in between foot and capsule.
- Meristematic zone continuously adds new tissue to capsule from base to top in acropetal succession.
- Foot is basically for anchorage and absorption
- Capsule main part of sporophyte.
- Capsule is long, slender , cylindrical, upright and almost uniformly thick, with a slightly tapering tip. It project over the thallus as a bristle like or horn like process. So *Anthoceros* known to be horn worts.
- Internal structure of capsule is highly complex. It has three distinct parts like capsule wall or jacket layer, sporogenous tissue and columella.
- Capsule is the site of spore formation.
- Spores mature basipetally. At maturity, apex of capsule turns yellow, black or brown and loses water. This is followed by dehiscence of capsule.
- Spore liberated after some process. The spores are forcibly ejected out for some distance and are then dispersed far and wide by wind and air currents.
- Spores are nearly spherical, haploid and thick walled and they represent the mother cells of gametophytic generation.
- Spores germinate on a suitable substratum either immediately after liberation or after a period of rest.
- Exospore of spores ruptures and endospore comes out in the form of a long germ tube through a slit.
- The spore contents migrate to the germ tube.
- Through the successive division germ tube cell produces a structure like sporeling.
- Four distal cells of sporeling constitute an apical meristem whose activity results in the formation of new gametophyte. First rhizoids arises a little late as an outgrowth of any cell of the young thallus.

FUNARIA

- Common terrestrial moss grows both in tropical and temperate regions of the world.
- Seen on moist shady places and grows in close tufts on damp alkaline soil, moist rocks, damp walls and rarely on tree trunks.
- Common Indian species- *Funaria hygrometrica*, *F.leptopoda*
- Number of species in India- 18 species
- **External features**
    - ✓ Erect gametophyte plant with erect leafy axis or stem attached to the substratum by rhizoids.
    - ✓ Axis is radial, often branched axillary or extra-axillary. Axis covered with spirally arranged leaves which are more crowded near the apex forming a rosette.

- ✓ Leaves are simple, sessile, and ovate (shape), with pointed apex, smoothed margin, attached to the stem by a broad base.
- ✓ Mature leaves with midrib, younger leaves devoid of midrib.
- ✓ Rhizoids are strong, much-branched, and multicellular.
- ✓ Rhizoids are characterized by the presence of oblique septa.
- ✓ Young rhizoids colorless but become brown or black when mature.
- ✓ Branches of rhizoids produce chloroplasts when exposed to sunlight.
- ✓ Rhizoids mainly for anchoring and absorbing nutrients.

- **Internal features**

1. Stem
   - ✓ Transverse section of the mature stem shows three distinct regions.
   - ✓ Outer epidermis, middle cortex and inner central strand.

   1. Epidermis

      -Outermost layer of the stem.
      -Epidermal cells contain chloroplasts and have no pores or stomata.
   2. Cortex
      - Multilayered zone between epidermis and central cylinder.
      - Consist of parenchymatous cells.
      - Cells contain chloroplast when young, but they are lost when the stem matures.
      - Cells of young stem are alike, but as the stem matures the outer cells of the cortex become thick walled and reddish brown.
      - Cortex also shows an isolated patches of small cells in the peripheral region, representing the leaf traces have blind ends and do not join the central cylinder.
   3. Central cylinder
      - Composed of long, narrow, thin walled colorless cells.
      - Cells devoid of protoplasm, helps in the conduction of water and solutes.

2. leaf
   - Transverse section of the leaf shows a well-defined central midrib and one cell thickend lamina.
   - Leaves are devoid of stomata and hairs.
   - Mibrib has a small strand of slightly thickened narrow cells, probably help in conduction.
   - Lamina cells are elongated, thin walled and rich in chloroplasts.

- Reproduction
  - ✓ *Funaria* reproduce both vegetatively and sexually.

1. Vegetative reproduction- through different methods.
   a. Fragmentation of primary protonema- the primary protonema developed through the germination of spores. Under certain circumstances, it breaks into several fragments. Each detached fragment bearing buds may grow into a new plant.

b. Secondary protonema- the protonema developing from any part of the plant other than spores called secondary protonema. Thus are produced from injured rhizoids, stem, leaves or reproductive structures. They bear buds that are capable of growing into a new plant.
c. Bulbils- multicellular, brown, bud-like structures that develop on the rhizoidal branches. The bulbils are useful for the propagation during unfavorable environmental conditions by detaching them from the parent plant
d. Gemmae- gemmae are multicellular green bodies formed from the terminal cells of the protonema. They remain dormant throughout the unfavourable condition. However, on return of favourable condition, a gemma detaches from the parent plant body and later germinates into a new plant.
e. Apospory- apospory is the condition in which the haploid (n)gametophyte is developed from the diploid (2n) sporophyte without the formation of spores.in this gametophytic protonema may develop from any unspecialized cells of the sporophyte. Later the protonema give rise to gametophyte plant body. Though aposporously develop, gametophyte are normal in appearance, but are diploid (2n). subsequently, the tetraplid sporophyte develops from the fusion of diploid gametes(2n) are sterile.

2. Sexual reproduction
   - ✓ It is autociously monoecious, become the male(antheridium) and female(archegonium) reproductive structures develop on separate shoots of the same plant.
   - ✓ Antheridia are borne on the main shoot of the plant. Female branch develops as side shoot, which grows more vigorously and become longer than the male branches.

ANTHERIDIUM

- ✓ Antheridia borne in clusters at the apex of the main axis.
- ✓ A number of long multicellular hairs, called paraphyses are intermingled with the antheridia.
- ✓ Both antheridia and paraphyses are surrounded by a number of bract-like leaves forming a reosette called the Perichaetium.
- ✓ Paraphyses have swollen tips(capitate) and contain chloroplasts.
- ✓ Besides their photosynthetic function, paraphyses protect the young antheridia agains dessication.
- ✓ Paraphyses assist the liberation of antherozoids.
- ✓ Antheridium develops from superficial antheridial initial located at the tip of the male branch.
- ✓ Mature antheridium has a multicellular long stalk and red or orange colored club shaped body.

- ✓ The apical cells of the jacket forms a thick walled, hyaline operculum or cap of the antheridium.
- ✓ The dehiscence of mature antheridium only takes place in presence of water.
- ✓ The opercular cells absorb dew or rain water and swells up.
- ✓ The pressure thus created ruptures the innerwall and eventually a pore is formed at the distal end of the antheridium. The androzoids spread out through the pore in the form of a viscous fluid due to the hygroscopic pressure developed within the antheridial cavity.

ARCHEGONIUM

- ✓ Archegonia are borne in clusters at the apex of the archegonial branch.
- ✓ A cell at the tip of the female shoot differentiated into the archegonial initial. Those archegonial initial will turns to mature archegonium through repeated division.
- ✓ Mature archegonium consist of a long stalk, a basal swollen venter and an elongated neck.
- ✓ The twisted and tubercular neck encloses 4 to 10 or more neck canal cells. The archegonial jacket is single layered thick in the neck region, but is double layered in the region of the venter. The venter contains a venter canal cell and an egg.

- ✓ During fertilization, venter canal cell and the neck canal cells of the archegonium disintegrate forming a mucilaginous substances. This mucilaginous substance absorb water accumulated as rain or dew water,then swells up and the resultant pressure breaks apart the terminal cover cell. Now the sugar containing mucilaginous substances ooze out through the opening of the srchegonial neck.

- ✓ The liberated antherozoids are now attracted chemaotactically towards the archegonia. A large number of antherozoids enter the neck, but only one of them fuses to form the diploid zygote.

- **SPOROPHYTE**
  - ✓ Fertilized egg or zygote is the first cell of sporophytic generation.
  - ✓ The zygote swell up, increases in size and forms a wall around it prior to further divisions.
  - ✓ The zygote divides transversely to form an upper epibasal cell and lower hypobasal cell.
  - ✓ Both epibasal and hypobasal cells divides repeatedly and form young embryo with with two growing points at the opposite ends, each representing an apical cell with two cutting faces.
  - ✓ The archegonial wall enlarges and forms calyptra which covers the capsule till maturity. A long slender sporophyte is then differentiated.

- ✓ The capsule differentiates at a large stage where the amphithecium sorrounds the endothecium.
- ✓ A multilayered jacket of the capsule is formed from the amphithecium, while the outer of endothecium forms the archesporium and axial layer produces the columella. The epibasal cell give rise to capsule and the upper part of the seta, while the hypobasal cell forms the lower part of the seta and the foot.
- ✓ A mature sporophyte differentiated into foot, seta and capsule.

1. Foot
    - It is poorly developed conical structure. Which is embedded in the apex of archegonial branch.
2. Seta
    - Long, green in colour when young, but become reddish brown at maturity.
    - T.S of seta shows outer single layered epidermis, a central conducting strand of thin walled cells surrounded by cortex made up of comparatively thick walled cells.
    - Seta helps in conduction of nutrients and water from gametophyte to capsule
3. Capsule
    - Mature capsule is pear shaped, asymmetrical.
    - Internally divided into three distinct parts

    a. Apophysis
    - Sterile basal region.
    - Lowermost part of capsule is the apophysis or the neck that connects it with the seta below.
    - Axis of apophysis shows in the lower part a central strand of thin-walled elongated cells connected with the similar tissue of the seta.
    - Here the chlorophyllous cells are bounded by a rather thick walled epidermis, interrupted by stomata.
    - The presence of chlorophyllous tissues in the apophysis makes the sporophyte carry out photosynthesis.
    - Therefore the sporophyte of funaria is not fully dependent on the gametophyte for nutrition.

    b. Theca or fertile zone
    - Central fertile zone of the capsule situated in between the apophysis and the operculum is called the theca.
    - It is a slight bent cylindrical structure, fertile in nature and has four distinct regions.
    - Capsule wall- Many layered, outer epidermis followed by 2-3 layered parenchymatous hypodermis. Inner 2-3 layered parenchymatous cells are chlorophyllous, which constitute the photosynthesis of the capsule.

- Spore sac- The central columella surrounded by two elongated spore-sac. Spore sac has innerwall of one layer of small cells and an outer wall of 3-4 layers of such cells. The spore sac are formed from the single layered archesporium. Archesporium initially develops 6-8 layers of sporogenous cells. The sporogenous layer become spore sac by the production of spores from spore mother cells through meiotic divisions.
- Air chamber- Outer wall of the spore sac is followed by a big cylindrical air chamber. It is traversed by a string of filaments of elongated green cells, known as trabeculae, which bridges air spaces between the outer wall of spore sac and the innermost layer of the capsule.
- Columella – Central, axial part of fertile zone, comprising of thin walled, colourless, compact, parenchymatous cells, constricted at the base just above the apophysis. Distal part of columella is cone shaped which projects into the concavity of operculum. The columella serves the purpose of conduction of water and nutrients to the growing sporophyte.

4. Apical region
    - It is a complicated structure.
    - This joins the capsule proper through a notch .
    - An annular rim or diaphragm of 2-3 layers of radially elongated small cells is present at the notch. The diaphragm demarcates the upper limit of the theca proper.
    - The operculum is an obliquely placed, dome-shaped lid that closes the mouth of the capsule. It is composed of 2-3 layers of thin walled parenchymatous cells.
    - The lower part of the operculum forms a ring of slightly large conspicuous cells, the annulus.
    - The operculum keeps the peristome teeth covered, while the annulus helps in the dehiscence of the capsule.
    - Peristome teeth lies just below the operculum and are attached beneath the edge of diaphragm. It consists of two rings of long triangular teeth, one within the other. The teeth are not cellular in nature and are made up of cuticle.

- **Dehiscence of the capsule and dispersal of the spores**
    - ✓ At maturity, the operculum begins to dry up due to the non- availability of water supply to the capsule. Consequently, the thin-walled cells of operculum, including the annulus which holds the operculum in place, shrink and shrivel.
    - ✓ The annulus breaks and loosened operculum is thrown away leaving the peristome teeth exposed.

- ✓ The peristome teeth are twisted spirally appearing like an iris diaphragm. The outer peristome teeth are hygroscopic which show inward and outward movements according to the presence or absence of moisture in the environment.
- ✓ During dry atmosphere, the outer peristome teeth bend outwards with jerky movements.
- ✓ The slits between the inner peristome teeth widens due to the outward movement of the outer peristome teeth, thus allowing the spores to escape through the slits.
- ✓ In high humidity, the hygroscopic teeth of the outer peristome absorb water and bend inwards and close the slits. This prevents the scopes in wet weather.
- ✓ Young sporophyte is covered by calyptra that develops from the old archegonial venter wall. It protects capsule from drying and sheds prior to its dehiscence.

- **New gametophyte**
  - ✓ Haploid spore is the first cell of gametophytic generation.
  - ✓ Spores are small, spherical, with outer thick brown coloured exine(exopsporium- outer wall) and inner thin, colourless intine (endosporium- innerwall).
  - ✓ Spores germinate under favourable condition.
  - ✓ The exine is ruptured and the intine protrudes out as germ tube. The germ tube elongates, becomes septate and produces a filamentous protonema.
  - ✓ The protonema branches freely and forms two types of branches freely and forms two types of branches viz., chloronemal branches and rhizoidal branches.
  - ✓ The chloronemal branches possess conspicuous chloroplast in their cells and become green in colour which are either erect or very close to the substratum that form the partition wall at right angles to the lateral walls.
  - ✓ The rhizoidal branches develop below the substratum, brown in colour and the partition walls are oblique to the lateral wall. The rhizoidal filaments are primarly for anchoring the protonema to substratum.
  - ✓ Later the chloronemal branches develop many buds and each bud grows into an erect leafy gametophore.
  - ✓ The gametophore becomes independent after the death of protonema. A young gametophore comprises of leafy stem, rhizoids and protonema.
  - ✓ It will become gametophyte.

<u>Pteridophytes- 3rd SEMESTER BOTANY</u>

Introduction

- *Pteridophytes* derived from Greek words, *pteron* “feather” + *phyton* “plants”.
- It includes to the most primitive seedless vascular plants that reproduce by means of spores.
- They are considered as the first true land plants that evolved after bryophytes.

- They are sometimes called **"Botanical Snakes"**, **"Snakes of plant kingdom"** or **"Amphibians of plant kingdom"** because they depend on an external source of water for fertilization.
- There are about 11,000 species of living Pteridophytes are known ranging from small aquatic plant to giant tree ferns of tropical forests.

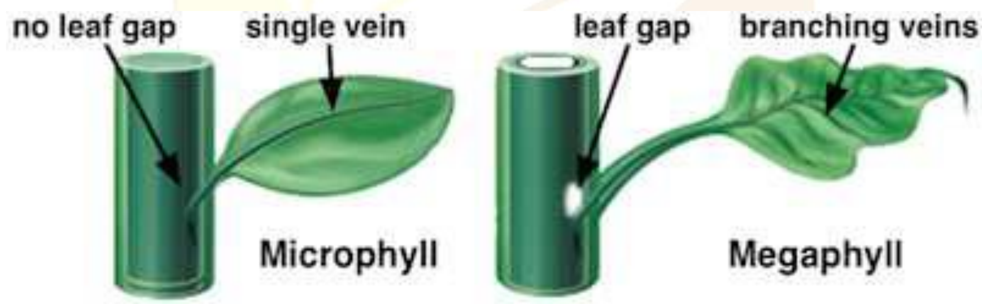
General Characters

- The Pteridophytes which include the ferns and a group of vascular plant of ancient or primitive land plant with worldwide distribution.
- They are found in all the continents except Antarctica and most islands, favoring moist temperate and tropical regions.
- Show much variation in form, size and habitat
- Vary in size from less than 1 cm in diameter to 25 meters tall.
- Small annuals (Azolla, salvinia) to large perennial tress (Angiopteris).
- Most of the living Pteridophytes are terrestrial.
- Some members are aquatic (Azolla, Marsilea, Isoetes, Salvinia)
- Few are xerophytes (*Selagineela rupestris*)
- Plant body is sporophytic, differentiated into root, stem and leaves.
- Mature sporophyte is nutritionally independent of gametophyte.
- Roots are simple, Ephemeral, uncomplicated and arise adventitiously along the rhizomes near the base of the fronds.
- Stems, for the most part, are **rhizomes that grow at, or** just under, the ground surface.
- Stem and root have permeanant growing apex.
- Stem usually branched
- Branching monopodial or dichotomous.
- Branches do not arises from the axils of leaves.
- Leaves and stem posses trichomes
- Most of them having herbaceous stem
- Fern leaves are *megaphylls that are commonly referred* to as **fronds**
- Early leaves are lopsided because they grow faster on their lower surface than their upper surface. This growth pattern, which is called ***circinate vernation, produces*** young leaves that are coiled into *"fiddle heads."*
- Leaves scaly in Equisetum, small ad sessile in Lycopodium and Selaginella and Large, petiolate in Pteris and Adiantum.
- Stomata are present on both surface of leaf

Circinate Vernation

Leaves in Pteridophytes

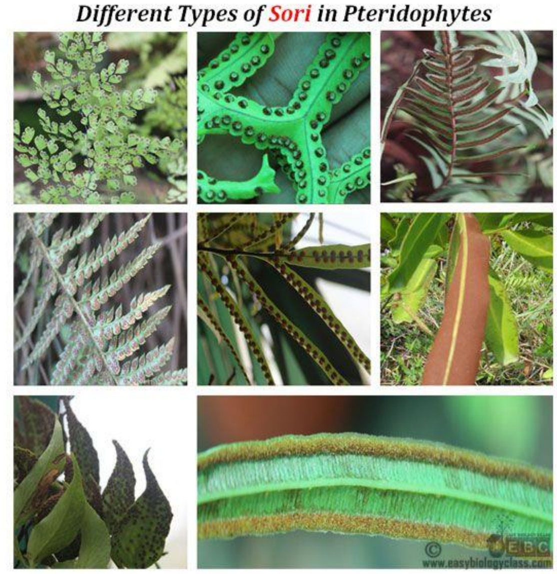
- Based on leaf structure petridophytes are classified into
  - Microphyllous:Simple leaves with single vein and no leaf gap formation (Lycopodium)
  - Macrophyllous: Large pinnatified, leaves having complex series of veins and they form prominent leaf gap in the stem stele (Pteris).
- Pteridophytes do not produce seeds but rather produces spores.
- Vascular tissues are present in all the vegetative parts of the plant body.
- Vascular structures are commonly called as stele.
- Vascular structure mainly composed of Xylem and Phloem
- Xylem made up of Trachieds; Xylem vessels absent.
- Xylem conduct water and minerals; Phloem conduct food materials.
- The sporophyte is the main plant body and it is mostly herbaceous.
- It is differentiated into roots, stem and leaves.
- The branching of the stem may be of monopodial or dichotomous type.
- The leaves may be smaller (**microphylls**) or larger (**megaphylls**).



- The plants may be **homosporous** - producing only one type of spore or **heterosporous** - producing two different types of spores; smaller **microspores** and larger **megaspores**.
- **Sorus- dark spots on the lower surface of fern leaves which is** actually a collection of sporangia
- These patches appear similar to fungal rusts
- Sori of some species are covered by an outgrowth from the leaf surface called **indisium**
- Ferns are divided into two groups based on the kind of sporangium they possess. The more primitive are the eusporangiate, and the more advanced the leptosporangiate.
- The more primitive species have a protostele, most have siphonosteles, and some have complex dictyosteles.
- **Eusporangia: These sporangia are thick-walled and open** by splitting transversely. They produce thousands of spores.
- **Leptosporangia: These thin-walled, delicate sporangia** are only one or a few layers thick. They have an area, the **annulus, where cell walls are thickened. When the**

annulus cells dry out at maturity, the sporangium splits and, like a catapult, throw out the spores.

- Cambium is absent; some Pteridophytes show secondary growth-Isoetes

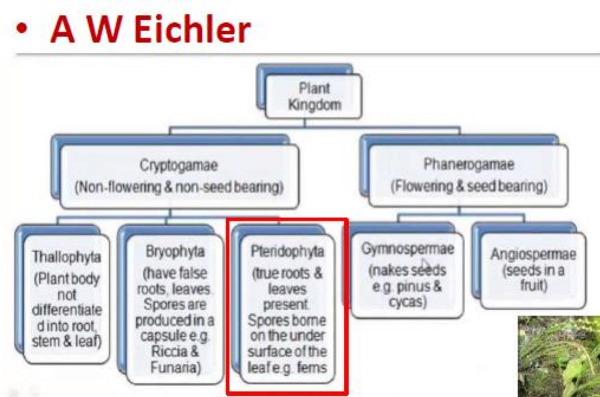


HABITAT

Some Pteridophyta are terrestrial and grow in moist and shady places while some are aquatic (hydrophyte) and sticking in other plant (epiphyte), or living in residue/waste of other plant (saprophyte).

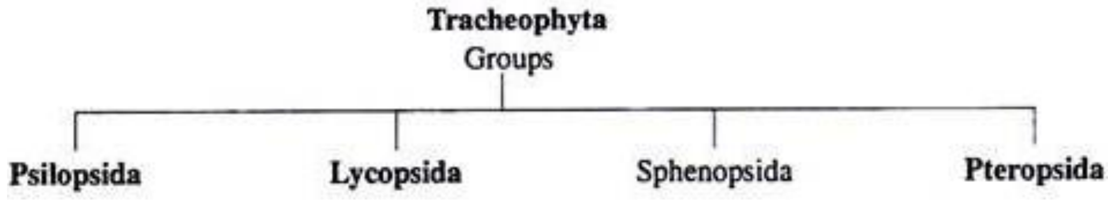
Classification of Pteridophytes

- The term Pteridophyta was first coined by Haeckel.
- Eichler (1883) divided the plant kingdom into Cryptogamia and Phanerogamia. The Cryptogamia was further divided into Thallophyta, Bryophyta and Pteridophyta.

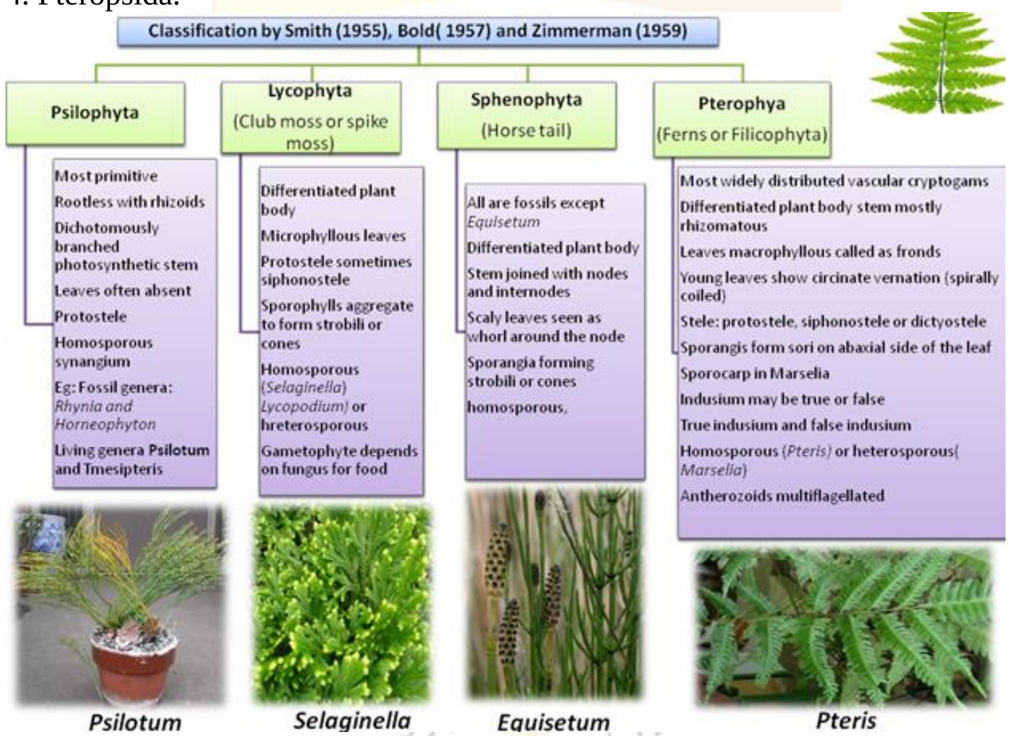


- Engler (1909) included the Bryophyta and Pteridophyta under Embryophyta.
- For a long time the division Pteridophyta included-the ferns, lycopods and horsetails. On the basis of their anatomy **Jeffrey in 1902** divided the vascular plants into two types or ‘stocks’. He included ferns, gymnosperms and angiosperms in a ‘stock’ known as **Pteropsida** lycopods and horsetails in another ‘stock’ known as **Lycopsida.**
- **Scott in 1923** ranked them as divisions. He segregated the horsetails as a separate division, **the Sphenopsida**.

- Arthur J. Eames (1936) classified Tracheophyta into following four groups on the basis of nature and relation of leaf and stem vascular anatomy and position of sporangia.



- According to **Eames (1936), Tippo (1942)** and others there is a single division, the Trachaeophyta consisting of four subdivisions.
  1. Psilopsida
  2. Lycopsida
  3. Sphenopsida
  4. Pteropsida.



- Classified into 4 divisions that have 40 families. They include about 10,000 living species (365 genera) distributed worldwide.

Psilophyta (Whisk ferns)

Two genera (Psilotum and Tmesipteris) and 4-8 species

- Sub-division Psilopsida (according to Wardlaw, 1955) or Division Psilophyta (according to Smith. 1955) includes living (Order Psilotales e.g., Psilotum), as well as fossil plants (Order Psilophytales e.g., Rhynia).
- The members are sporophytic.
- Roots are absent.
- The organization of the plant body of the members is very simple. It is differentiated into a subterranean (underground) rhizome and an erect aerial portion.
- Rhizome bears tufts of unicellular Rhizoids.
- Aerial portion is sparingly or profusely branched. The branching is usually of dichotomous type.

- Aerial axis may be leafless or sometimes may bear scaly appendages (e.g., Psilotum) or large foliage leaves (e.g., Tmesipteris)
- The vascular tissue is of primitive type i.e., simple, cylindrical protostele with annular or spiral racheids.
- The reproductive organs are in the form of sac like sporangia.
- Sporangia are borne at the apex of the aerial shoots. They are either solitary (e.g., Rhynia) or in groups and terminal in position. There was nothing like that of sporophyll.
- Sporangia always bearing the same type of spores i.e., they are homosporous.
- The gametophyte is known only in Psilotum and Tmesipteris (living genera) while unknown in Psilophytales.
- The gametophyte is cylindrical or branched, subterranean and colourless.
- Sex organs are partially embedded in the prothallus.
- Antherozoids are multiciliate in Psilotales.

Lycophyta (Club moss)

- It includes both fossil (e.g., Lepidodendron) and living Pteridophytes (five living genera e.g., lycopodium, Phylloglossum, Isoetes, Stylites and Selaginella).
- Its history indicates that these Pteridophytes developed during the Devonian period of the Palaeozoic era.
- The plant body is sporophytic and can be differentiated into root, stem and leaves.
- The leaves are small (microphyllous), simple with a single mid vein.
- They are usually spirally arranged, sometimes in opposite fashion and or even in whorls.
- In some cases the leaves are ligulate (e.g., Selaginella, Isoetes). The ligule is present at the base of each leaf.
- The vascular tissue may be either in the form of plectostele, siphonostele or sometimes even polystele.
- Leaf gaps are absent.
- Sporangia are quite large in size and develop on the adaxial surface of the leaves (sporophylls).
- Sporophylls are loosely arranged and form strobilus.
- Some members are homosporous (e.g., Lycopodium) while others are heterosporous (e.g., Selaginella).
- Antherozoids are biflagellate or multiflagellate.
- Gametophytes which are in the form of prothalli are formed by the germination of spores.
- Heterosporous forms have endoscopic gametophytes while in homosporous forms the gametophyte is exoscopic.

Sphenophyta (Horse tail)

- It includes both fossil plants (e.g., Calamophyton, Sphenophyllum) as well as living plants (e.g., Equisetum). It is represented by one living genus Equisetum and 18 fossil forms.
- These Pteridophytes evolved during the Carboniferous period of the Palaeozoic era.
- The plant body is sporophytic and can be differentiated into root, stem and leaves.
- The stem in majority of the forms is long, jointed or articulated and is ribbed i.e., having ridges and grooves.
- Stem is divisible into nodes and internodes and is developed as upright aerial branches from the underground creeping rhizome.
- Leaves are thin, small, scaly brown and are arranged in transverse whorls on the nodes of the aerial branches.
- Branches also develop in whorls from the axil of the scaly leaves.

- As the foliage leaves are reduced to scales, the process of photosynthesis is taken up by the stem and hence it becomes green.
- The stem has a solid protostele (e.g., Sphenophyllum) or medullated protostele (e.g., Equisetum).
- Secondary thickenings were observed in some extinct forms (e.g., Sphenophyllum).
- Sporangia are developed at the apex of the fertile branches in whorls forming compact cone.
- Living members are homosporous but some fossil forms are heterosporous (e.g., Catamites).
- Spores germinate to give rise to gametophytes (prothalli) which may be monoecious or dioecious.
- Antherozoids are large and multiflagellate.
- Embryo is without suspensor.

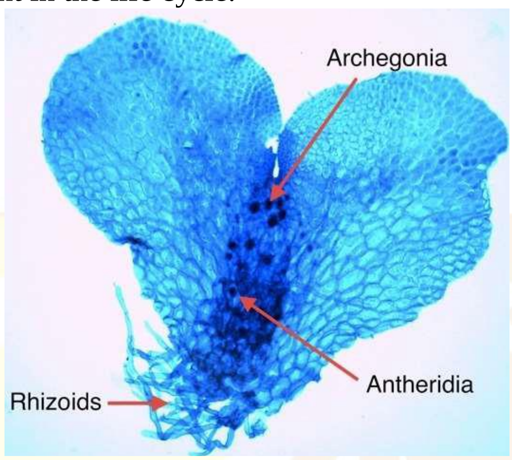
Pterophyta (Fern)

- This sub-division includes the plants which are commonly known as 'ferns'. It is represented by about 300 genera and more than 10000 species.
- These Pteridophytes were originated during the Devonian period.
- They occur in all types of habitats. Majority of the ferns are terrestrial and prefer to grow in moist and shady places. Some are aquatic (e.g., Azolla, Salvinia, Marsilea), xerophytic (e.g., Adiantum emarginatum), epiphytic (e.g., Asplenium nidus), halophytic (e.g., Acrostichum aureum) or climbing (e.g., Stenochlaena).
- Some members are very small while some members are tall tree like (e.g., Angiopteris).
- Majority of the members (except some tree ferns e.g., Angiopteris) have short and stout rhizome. The rhizome may be creeping, upright or growing above the soil.
- Leaves are large, may be simple (e.g., Ophioglossum) or compound (majority of the ferns for example, Pteridium, Marsilea, Adiantum etc.) and described as fronds.
- Young fronds are circinately coiled.
- Leaves are exstipulate (e.g., Filicales) while stipulate in some other groups.
- The vascular cylinder varies from a protosete to a complicated type of siphonostele.
- Vegetative reproduction takes place by fragmentation (e.g., Adiantum, Pteridium), stem tubers e.g., Marsilea), adventitious buds (e.g., Asplenium bulbiferum) or by apogamy (e.g., Marsilea).
- Sporangia arise from placenta (a swollen cushion of cells) in groups (sori).
- Sori develop on the margins or abaxial surface of the leaves (sporophylls) or leaflets.
- Sori are protected by true (e.g., Marsilea) or false indusia (e.g., Adiantum, Pteris).
- The sporangial development may be leptosporangiate (e.g., Osmunda) or eusporangiate type e.g., Ophioglossum).
- The sporangia in most cases have a distinct annulus and stomium.
- Members may be homosporous (e.g., Pteris, Adiantum etc.) or heterosporous (e.g., Marsilea, Regnellidium, Azolla, Salvinia etc.)
- Spores on germination form autotrophic prothalli (gametophyte).
- Antheridia and archegonia are partially or completely embedded in the gametophyte.
- Embryo may or may not have suspensor.

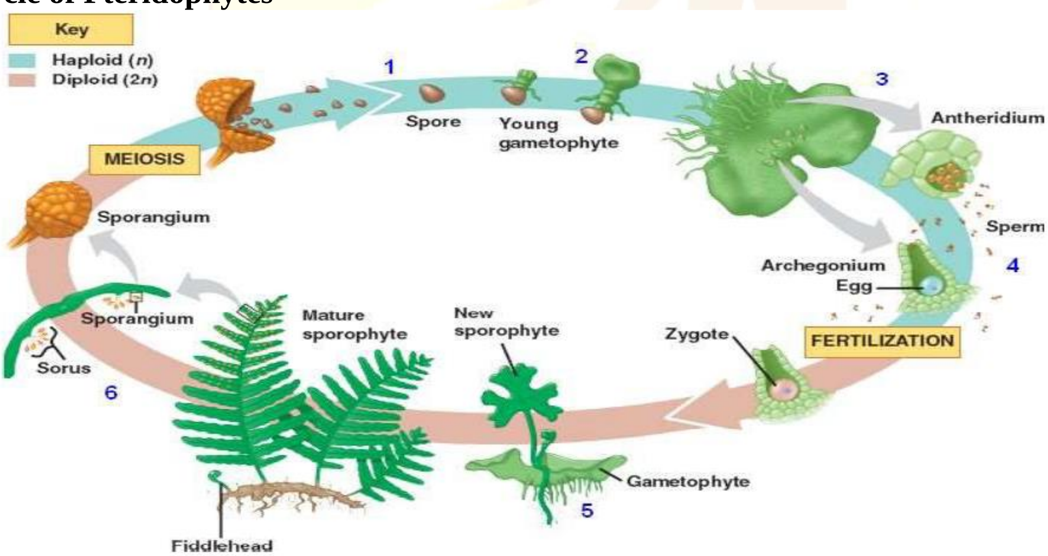
REPRODUCTION

- The spores germinate to produce a haploid gametophyte, called prothallus. The **homosporous pteridophytes** produce bisexual gametophytes while **heterosporous pteridophytes** produce unisexual gametophytes.

- In gametophytes, reproduction is of oogamous type. The male sex organs are called **antheridia** and female sex organs are called **archegonia**.
- Antheridia produce antherozoids and archegonia enclose the egg cell.
- Fertilization requires water. The diploid zygote is retained in the archegonial venter where it develops into an embryo. Subsequently it becomes a young sporophyte and grows into an independent adult plant. Thus the life cycle includes an alternation of diploid sporophytic generation with a haploid gametophytic generation. Sporophytic generation is dominant in the life cycle.



Life cycle of Pteridophytes



Stelar evolution in Pteridophytes

- According to the older botanists, the vascular bundle is the fundamental unit in the vascular system of pteridophytes and higher plants. Van Tieghem and Douliot (1886) interpreted the plant body of a vascular plant in the different way.
- The stelar theory was proposed by Van Tiegham and Douliot 1886 while earlear worker Thought that vascular bundel is the basic unit of vascular orgnization. But according to Van Tiegham and Douliot 1886 the stele is the basic unit structure. The fundamental part of the shoot is cortex and stele.
- Stele is comprise not only xyleme and phloem element but also pericycle and pith whatever is present .

- Jeffery 1898 viewed the stelar orgnization from the point of view of elolution.
- According to them the fundamental parts of a shoot are the cortex and a central cylinder is known as stele.
- The name stele has been derived from a Greek word meaning pillar. This way, the stele is defined as a central vascular cylinder, with or without pith and delimited the cortex by the endodermis.

• Van Tieghem and Douliot (1886) recognized only three types of steles. They also thought that the monostelic shoots were rare in comparison of polystelic shoots. It is an established fact that all shoots are monostelic and polystelic condition rarely occurs.

BASIC TYPES OF STELES

• **PROTOSTELE** – Central Xylem, surrounding Phloem. No Pith. Primitive.

Jeffrey (1898), for the first time pointed out the stelar theory from the point of view of the phylogeny. According to him the primitive type of stele is protostele. In protostele, the vascular tissue is a solid mass and the central core of the xylem is completely surrounded by a layer of phloem. This is the most primitive and simplest of steles.

There are several forms of the protostele which are as follows:

1. Haplostele:

• This is the most primitive type of protostele. Here the central solid smooth core of xylem is surrounded by a layer of phloem, e.g., *Salaginella sp.*

2. Actinostele:

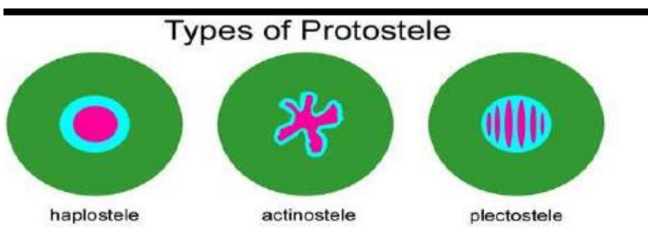
• This is the modification of the haplostele and somewhat more advanced in having the central xylem core with radiating ribs, e.g., *Psilotum sp.*

3. Plectostele:

• This is the most advanced type of protostele. Here the central core of xylem is divided into a number of separate plates arranged parallel to each other. The phloem alternates the xylem, e.g., *Lycopodium sp*.

4. Mixed-pith stele:

• Here the xylem elements (i.e., tracheids) are mixed with the parenchymatous cells of the pith. This type is found in primitive fossils and living ferns. They are treated to be the transitional types between true protosteles and siphonosteles, e.g., *Gleichenia sp.*, *Osmunda sp.*



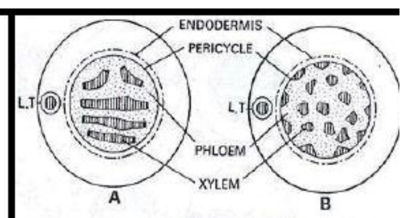


Fig. 32.3. Stelar system in ferns. A, plectostele; B, mixed

• SIPHONOSTELE – Protostele with Central Pith. Advanced

TYPES OF SIPHONOSTELES

• With the introduction of a central pith a protostele seems to have given rise to a siphonostele.

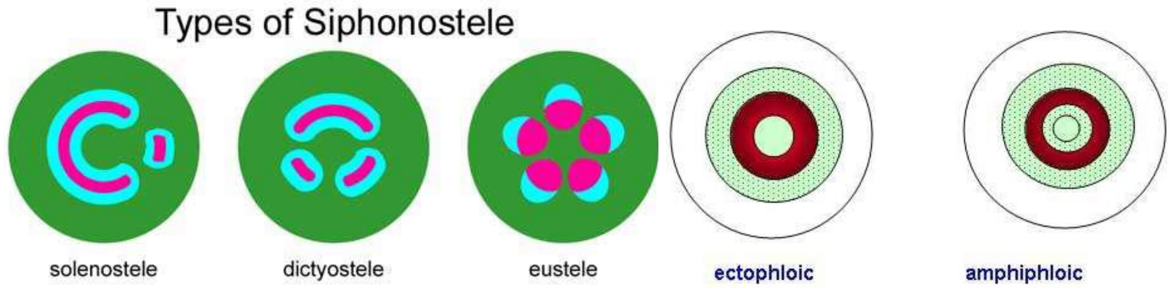
• The siphonostele are of two type

• Thus a stele with a central pith surrounded by vascular tissue is discribed as siphonostele (jeffery 1998)transition of protostele into a siphonosteleis seem in plant like Botrychium, Gleichenia, Osmunda, Schizaea etc.

• Cladosiphonic – No leaf traces

• Phyllosiphonic – with leaf traces

Ectophloic – Phloem outside xylem . Ex. Equisetum Amphiphloic – Outer and inner rings of Phloem, Xylem central. Ex. Marselia



Solenostele – Non-overlapping leaf traces. Ex. Adiantum

• The vascular plants have been divided into two groups on the basis of the presence or absence of the leaf gaps.

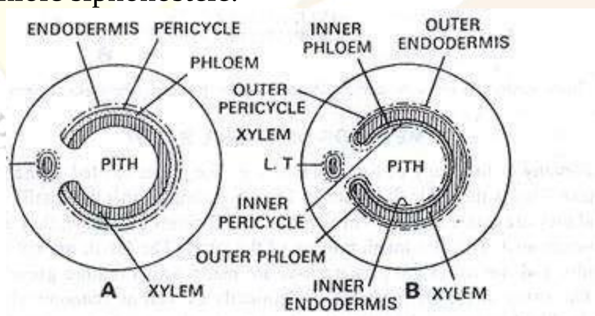
• These groups are

1. Pteropsida
2. Lycopsida.

• The ferns, gymnosperms and angiosperms are included in Pteropsida, whereas the lycopods, horse tails, etc., are included in Lycopsida.

• The simplest form of siphonostele has no leaf gaps, such as some species of Selaginella. However, among the simplest siphonostelic Pterospsida and siphonostelic Lycopsida, the successive leaf gaps in the stele do not overlap each other and are considerably apart from each other.

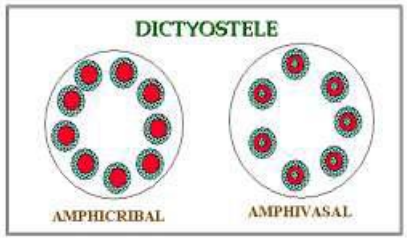
• According to Brebner (1902), Gwynne-Vaughan (1901) such siphnosteles which lack overlapping of gaps are known as solenosteies. They may be ectophloic or amphiphloic in nature. Some authors (Bower, 1947; Wardlaw, 1952; Esau, 1953), however, interpreted the solenostele as an amphiphloic siphonostele.



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

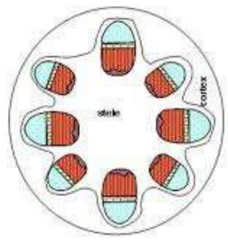
Dictyostele- Overlapping leaf traces Ex. OphioglossumIn the more advanced siphonosteles of Pteropsida, the successive gaps may overlap each other. Brebner (1902) called the siphonosteles with overlapping gaps as dictyosteles. In such cases the intervening portion of the vascular tissue meristele is of protostelic type. The dictyostele with many meristeles look like a cylindrical meshwork.

Polycyclic – Two or more concentric rings of vascular tissue. Complex type. Ex. Pteris This type of stelar organization is the most complex one amongst all pteridophytes. Such type of steles are siphonostelic in structure. Each such stele possesses an internal vascular system connected with an outer siphonostele. Such connections are always found at the node. A typical polycyclic stele possesses two or more concentric rings of vascular tissue. This may be a solenostele or a dictyostele. Two concentric rings of vascular tissue are found in Pteridium aquilinum and three in Matonia pectinata.

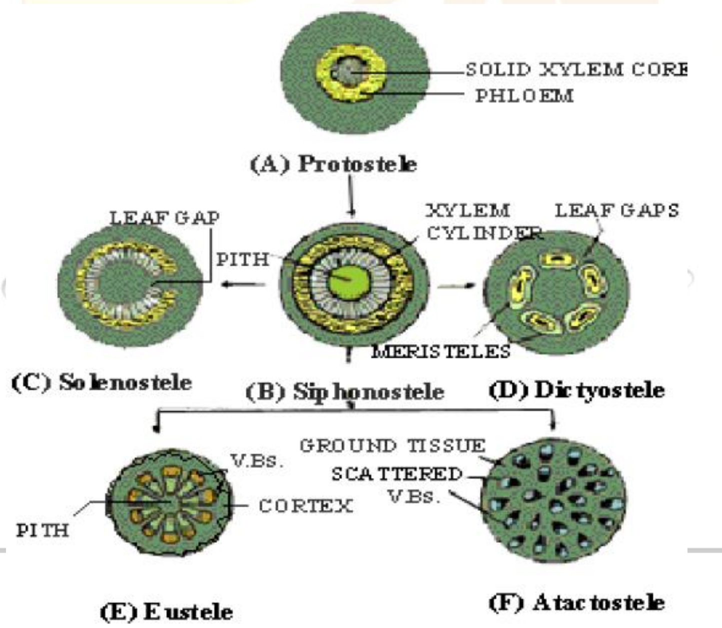


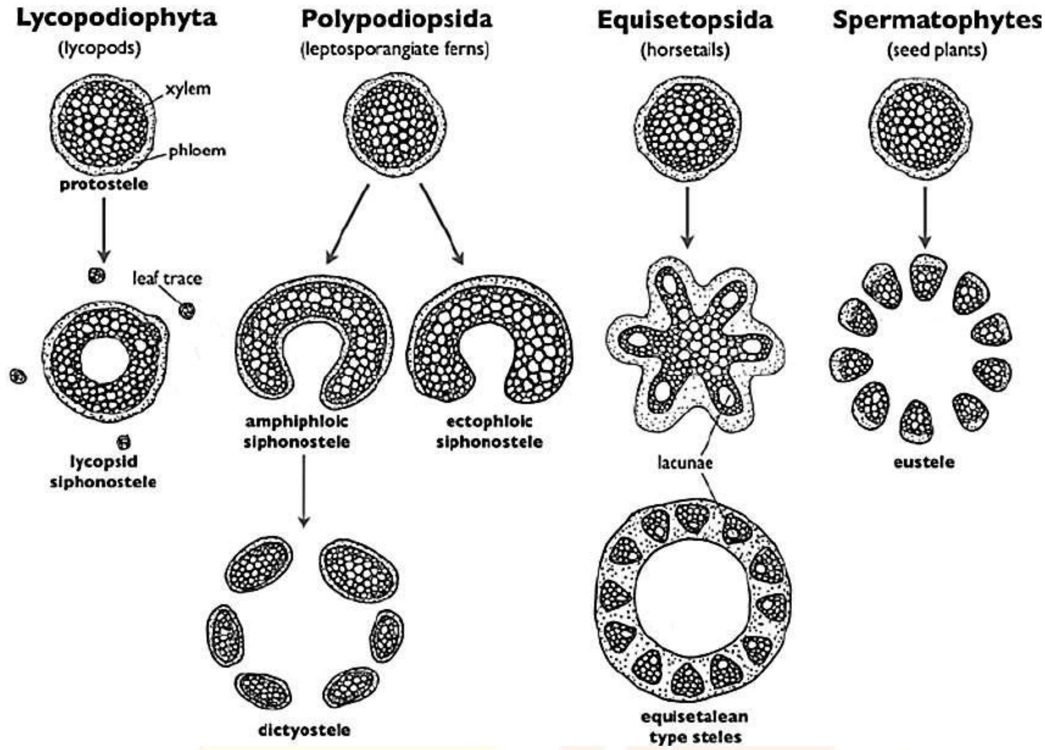
Eustele:

According to Brebner (1902) there is one more modification of the siphonostele, known as eustele. Here the vascular system consists of a ring of collateral or bicollateral vascular bundles situated on the priphery of the pith. In such steles the interfascicular areas and the leaf gaps are not distinguished from each other very clearly. The example of this type is Equisetum.



Stele in Pteridophytes





Asexual reproduction is the form of reproduction that does not involve gametes. In this regard, apogamy and apospory refer to two asexual modes of reproduction in plants such as bryophytes/Pteridophytes

What is Apospory?

- Apospory refers to the development of gametophyte directly from the cell of sporophyte without spore formation or meiosis.
- The sporophyte is present in the vegetative cells of the plant. Therefore, when the gametophyte forms, the sporophytic generation marks its end. Moreover, this is important in the alternation of generations in plants.
- Since the cells of sporophyte are diploid, the developed gametophyte is also diploid in nature. Thus, the sporophyte and gametophyte share the same ploidy levels. However, this process does not involve the formation of gamete cells. So, it is asexual in nature.

What is Apogamy?

- Apogamy refers to an asexual reproduction process in plants where the embryo forms without undergoing fertilization. In such plants, sporophyte develops from the gametophyte without undergoing fertilization. Thus, the formed sporophyte will have the same ploidy level of the gametophyte.

What are the Similarities Between Apospory and Apogamy?

- Apospory and apogamy are asexual methods of reproduction.
- Both take place in plants.
- They participate in the alternation of generations in plants.
- In both phenomena, the gametophyte and the sporophyte share the same ploidy level.
- Moreover, there is no formation of gametes in both processes.

What is the Difference Between Apogamy and Apospory?

- Although both apogamy and apospory are asexual processes of reproduction in plants, they have differences in their development process. During apospory, the gametophyte develops from the sporophyte, while in apogamy, the embryo develops without fertilization. So, this is the key difference between apospory and apogamy.

- Moreover, another difference between apospory and apogamy is their ploidy levels. In apogamy, it forms a diploid gametophyte whereas, in apospory, it forms a haploid embryo.

Psilotopsida

- A division of vascular plants consisting of only two genera, *Psilotum and Tmesipteris, with very few species. These plants are characterized by the lack of* roots, and, in one species, leaves are lacking also.
- The green, photosynthetic stem is well-developed. The gametophyte plant, arising from germination of a spore, is small and colorless, and derives its nutrition through a specialized association with a fungus.
- Sexual structures on the gametophyte produce eggs and sperm. The motile sperm, with numerous flagella, are able to swim through a film of water to the egg. The fertilized egg, or zygote, first absorbs nourishment from the gametophyte, and later becomes photosynthetic and self-sustaining. The life cycle is very much like that of ferns.

Characteristics

- The Psilotophyta are small rootless plants that are epiphytic or grow on humus-rich soil and in rock crevices. The underground rhizomatous organs contain fungous hyphae (*endotrophic mycorrhiza). The stems are covered by an epidermis with stomata that are structurally similar* to the primitive stomata of fossil *Rhyniaceae.*
- There are two species of *Psilotum, each having small scale-like leaves and repeatedly* dichotomously branching stems that are 20–100 cm long. Both species are found in the tropics and subtropics of both hemispheres.
- The *synangia that form on the Psilotophyta are bilocular or trilocular. The spores, as they* sprout, give rise to underground gametophytes that lack chlorophyll and live *saprophytically* on fungi. The gametophytes do not differ from the young rhizomatous organs in size and form.

PSILOTUM (WHISK FERN)

- A genus of fern-like vascular plants, one of two genera in the family **Psilotaceae, orders Psilotales, and** class **Psilotopsida. The name of the genus is from** Greek *psilos = bare, referring to the lack of the usual* plant organs, such as leaves.

Kingdom: Plantae
Division: Pteridophyta
Class: Psilotopsida
Order: Psilotales
Family: Psilotaceae
Genus: Psilotum
Species: Psilotum nudum
Psilotum complanatum

Structure and form

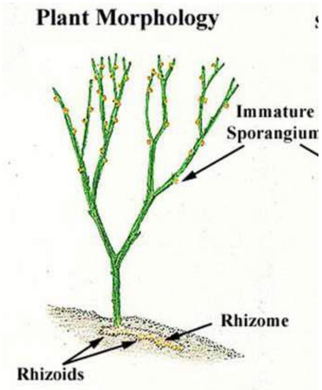
Sporophytes:

− Dichotomously forking stems
Above ground stems arise from rhizomes
− Lack leaves and roots
− Roots, aided by mycorrhizal fungi, scattered along rhizomes
− Has spore-producing called synangia.

Occurrence

- It is commonly called as whisk fern (because it is without fern and stem perform all function)
- Found in humus rich soil, in tropical and sub tropical regions.
- Some species grows as epiphytes (tree trunk)

Vegetative morphology



- Plant Body:
- It is sporophyte and contains following parts

Rhizome

The horizontal portion is rhizome

- Buried in soil or humus.
- Dichotomously branched
- 2 celled rhizoids are present near the apices of the younger branches
- These rhizoids absorb water and nutrients from soil for aerial branches

Aerial branch

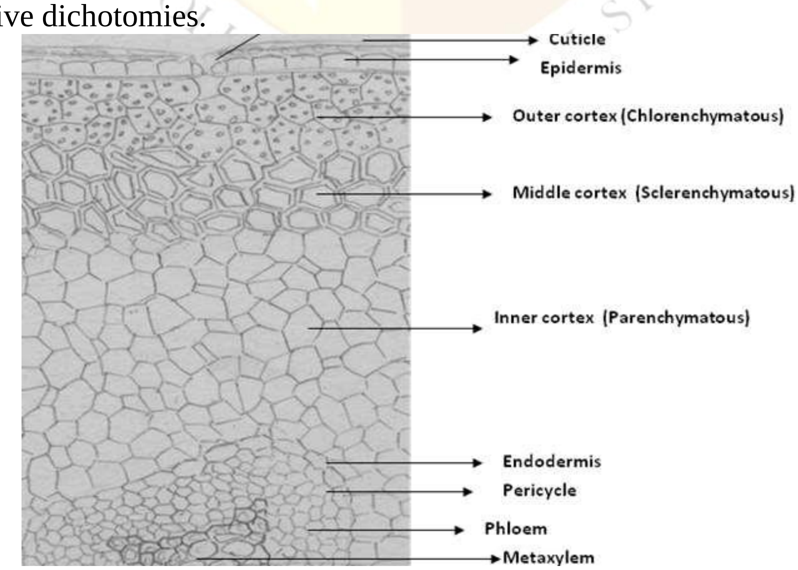
- Rhizome bears aerial branches
- The branches are green, cylindrical and dichotomously branched
- The leaves are small, scale like and are scattered over these branches.

Sporangia-The sporangia are borne in triads.

- They have very short stalks.
- They are borne in the axils of small bifid leaves on the aerial branches.
- This triad of sporangia is called a synangium.
- The two lobes of the leaf are closely united with the synangium.

Stem Anatomy

- It is circular in outline from base, pentagonal near the first dichotomy and triangular between successive dichotomies.



Epidermis

• There is a single layer of epidermis present outside
• It is heavily cutinized
• Stomata are also present on epidermis, situated at the grooves

Cortex

a) Chlorenchymatous cortex

• It is the outermost part of cortex and has 2 to 5 layers of cells.
• The cells are thin walled and are parenchymatous.
• They are photosynthetic as they contained chloroplast.

Scelerenchymatous cortex

• Below the parenchymatous cells there are 2- 4 layers of sclerenchymatous cells.
• The cells are thick walled and provide support

Parenchymatous

•They form the major portion of the stem.
•The cells are thin walled and no inter cellular spaces in them

Stelar system

1. Endodermis

There is well developed endodermis between the stele and the cortex. These cells has casparian bands on their radial walls

2. Xylem

The xylem is actinostelic and radial in outside in 6 rays, the protoxylem is located at the tip of the rays. In the center the metaxylem core is present. The cells of xylem are thick walled and their main function is transport of nutrients

3. Phloem

Between the endodermis and the xylem there is phloem. It is of thin walled cells. It consists of sieve cells and sieve areas in their oblique end walls. Nuclei disintegrate at maturity.

Anatomy of rhizome

•In rhizome the epidermis is inconspicuous and all the cells of outermost layer of cortex extend into rhizoids.
•The cortex is thin walled and cells contain fungus
•The endodermis is conspicuous
•The stele in rhizome is protostele (xylem is surrounded by phloem)
•The pith is absent
•Xylem occupies center of the axis and surrounded by the phloem

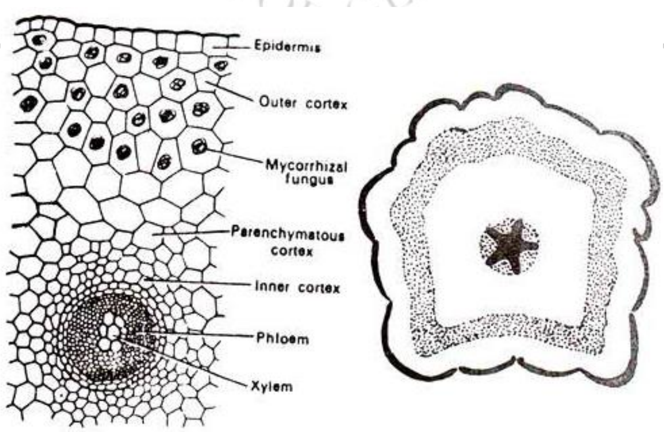


Fig. 20. *Psilotum* : T.S. of Rhizome.
A. Sector Enlarged, B. Ground Plan.

Reproduction
It is characterized by alternation of generation
•Both spore producing and gamete producing regeneration are independent
•Sporophyte reproduces by asexual reproduction
•Gametophyte reproduces by sexual reproduction
Asexual reproduction (Sporophyte)
Sporophytes reproduces by formation of asexual reproductive units Called as spores , produced in complex trilobed structure synangium.

Nature of synangium
1. The trilobed synangium is formed by fusion of two or more sporangia
2. One sporangium with 3 chambers (trilocular sporangium)
3. Synanium is cauline (developed at the apex of stem) in nature and it is actually modified trilocular sporangium present on lateral branches.
4. This concept was suggested by Bierhorst (1956) according to him each unit in synangium represents a condensed fertile axis. The synangium in Psilotum can be considered as homologus to fertile portion of (Rhynia) where one arm is fertile and other is sterile . The condensation of fertile arm is modified into synangium .the bract modified to surround the synangium.
Structure of synangium
•Each synangium is trilobed , stalked structure borne at the apex of short lateral branch .
•A bilobed appendage is present at the base of each synangium that curve and surround the stalk of synangium. It coinsist if three chambers or locules.
1. Wall of synangium is 3 – 4 layers
2. Thick outer wall forms the epidermis
3. Inner wall separates the three locules
4. Each locule is filled up with large number of spore. And these are homosporous in nature
5. Synangium splits up from 3 lines along the epidermis and dehiscence occurs.

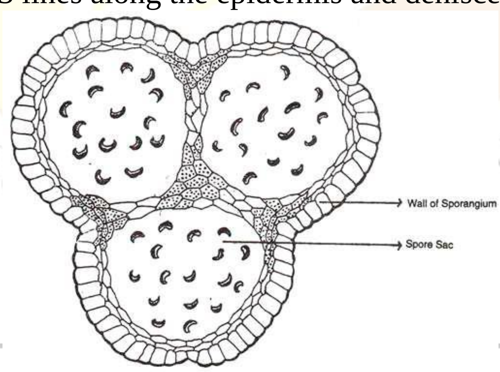
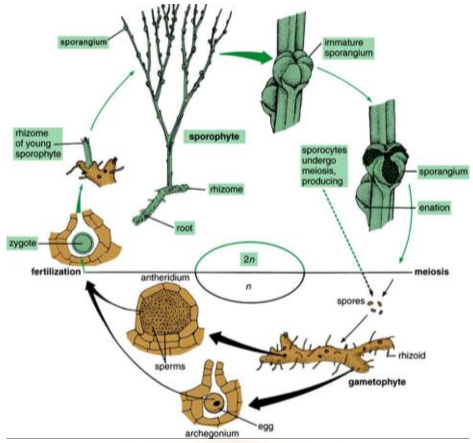


Fig. 24. *Psilotum*, T.S. of Mature Synangium with Spores

Sexual reproduction (gametophyte)
•The gametophyte lives underground as a saprophyte, sometimes in a mycorrhizal association. When the gametophyte is mature, it produces both egg and sperm cells.
•The gametophyte of Psilotum is unusual in that it branches dichotomously, lives underground and possesses vascular tissue.
•The gametophyte of Psilotum is called as Prothallus .
•It contains parenchyma cells and there is strand of tracheids extending back from the apex.

Life cycle



Selaginella
Taxonomic position
Division: Lycophyta
Class: ligulopsida
Order: Selaginellales
Family: Selaginellaceae
Genus: Selaginella

Habit and Habitat

- Selaginella is the only living genus of the order Selaginellales and is commonly known as 'spike mosses or 'small club mosses.
- It is a large genus comprising of about 700 species distributed all over the world.
- Abundantly it is found growing in tropical rain forests. Mostly the species prefer moist and shady places to grow but a 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.
- They curl and become ball like when dry and again become green and fresh when moisture is available.
- About 70 species have been reported from India.
- They are mainly found growing in eastern as well as Western Himalayas and the hills of South India.
- Some of the common Indian species are S. repanda, S. biformis, S. denticulata, S. monospora, S. semicordata, S. adunca etc. S. kraussiana is cultivated in green house.

Morphology

- The sporophyte is an evergreen, delicate herb.
- Its size varies greatly from species to species i.e., from a few cm. to 20 meters.
- Plants may be erect or prostrate depending upon the sub-genus.
- In the sub-genus homoeophyllum the plants are erect e.g., *S. rupestris*, *S. spinulosa* etc. and in the sub-genus heterophyllum the plants are prostrate e.g., *S. kraussiana*, *S. lepidophylla* etc.

The plant body is distinctly differentiated into following structures

(i) Stem.
(ii) Leaves.
(iii) Ligules.
(iv) Rhizophore.
(v) Roots.

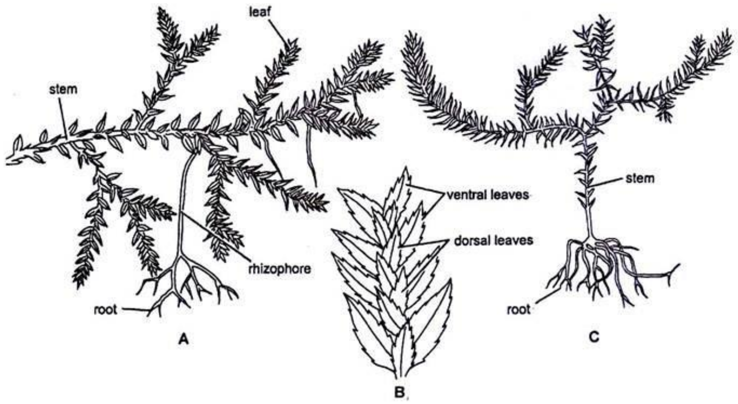


Fig. 1 (A–C). *Selaginella*. External features : A. *S. kraussiana*, B. Leaf arrangement in a branch of *S. kraussiana*, C. *S. spinulosa*

(i) 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.

(ii) 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 (Fig. 1 B).
- 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.

(iii) 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 (e.g., S. vogelii), fan shaped (e.g., S. martensii), fringed (e.g., S. cuspidata), or lobed (e.g., S. caulescens).
- 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 (Fig. 2 A, B).

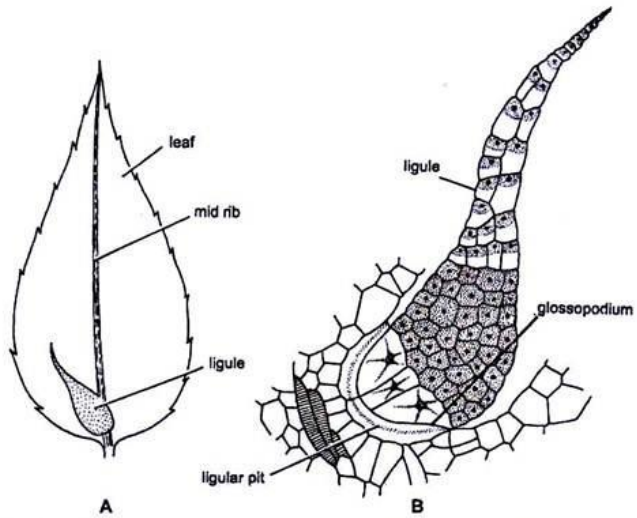


Fig. 2 (A, B). *Selaginella.* Structure ot ligule : A. Leaf with ligule, B. Longitudinal section of ligule

Glossopodium:

- It is the basal hemispherical part made up of large thin walled cells.
- It is surrounded by a glossopodial sheath.

Body of the ligule:

- Above the glossopodium is the body of ligule.
- It is made up of many large and small cells.
- The function of the ligule is not well known.
- It may be a water secreting or water absorbing or protective organ.
- According to Earner (1936) the ligule is perhaps a vestigial organ.

(iv) 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. krussiana* 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.

(v) Roots:

- They originate either from the tips of rhizophores or directly from the stem or from the swollen base of hypocotyl (Fig. 1 A, B).
- Their origin is endogenous.
- They are usually dichotomously branched structures.
- The roots are provided with root caps and root hairs.

Internal Structure of Selaginella:

1. Stem:

(i) Epidermis:

- It is the outer most covering layer comprising of a single cell in thickness.
- The cells of the epidermis are without hairs and stomata.
- The epidermis is surrounded on all sides by a thick coating of cuticle.

(ii) Cortex:

- Inner to the epidermis is present a well-defined zone of cortex.

- The cortex may or may not be differentiated into inner and outer cortex.
- In case of S. selaginoides, the whole of the cortex is made up of parenchymatous cells while in S. krussiana, it is differentiated into sclerenchymatous outer cortex and parenchymatous inner cortex.
- The parenchymatous cortex is usually made up of angular cells i.e., without intercellular spaces but in some cases the cells are rounded and provided with a few inter-cellular spaces.

(iii) Stele: Fig. 3 A, B

- 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.
- Phloem, in turn, is surrounded by a single layered pericycle.
- Pith is absent.
- 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 are present large spaces known as air spaces.
- The stele is surrounded by a single layered pericycle made of parenchymatous cells.
- The xylem is usually monarch (e.g., S. kraussiana), or diarch (e.g., S. oregana) or multiarch (e.g., S. spinulosa).
- It is usually exarch but sometimes it may be mesarch (e.g., S. selaginoides).
- Xylem is usually made of tracheids.
- Vessels are completely absent.
- Xylem is surrounded on all sides by phloem which consists of sieve cells and phloem parenchyma.
- Companion cells are absent in phloem.

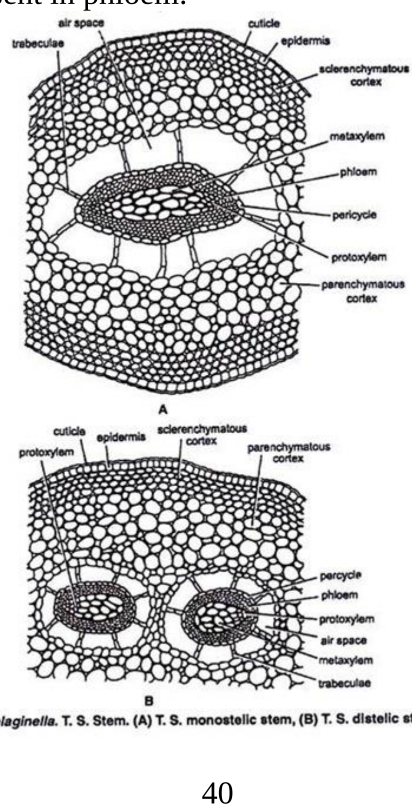


Fig. 3 (A–B). *Selaginella*. T. S. Stem. (A) T. S. monostelic stem, (B) T. S. distelic stem (a part cellular).

2. Root:

(i) Epidermis:

- It is the outermost covering layer and is only one cell in thickness.
- The cells are large and the unicellular root hairs arise from them.

(ii) Cortex:

- Just below the epidermis is present a wide zone of cortex.
- The cortex may be either wholly made up of thin walled parenchymatous cells or there may be sclerenchymatous outer cortex (hypodermis), 3 to 5 celled in thickness and parenchymatous inner cortex.
- In mature roots of S. densa the entire cortex may consist of thick walled sclerotic cells.
- Air spaces have also been reported in the inner cortex (e.g., S. willedenovii).
- It is traversed by trabeculae.

(iii) Endodermis:

- It is usually not well defined but in some species as for example, S. densa.
- It is a distinct structure and only one cell in thickness.

(iv) Pericycle:

- Endodermis is followed by one to three layered pricycle.
- It is made up of parenchymatous cells.

(v) Stele:

- It is a typical protostele.
- The xylem is exarch and monarch i.e., there is only one protoxylem group situated at the periphery.
- Xylem is surrounded by phloem on all sides.
- The structure of xylem and phloem elements is similar to that of stem.

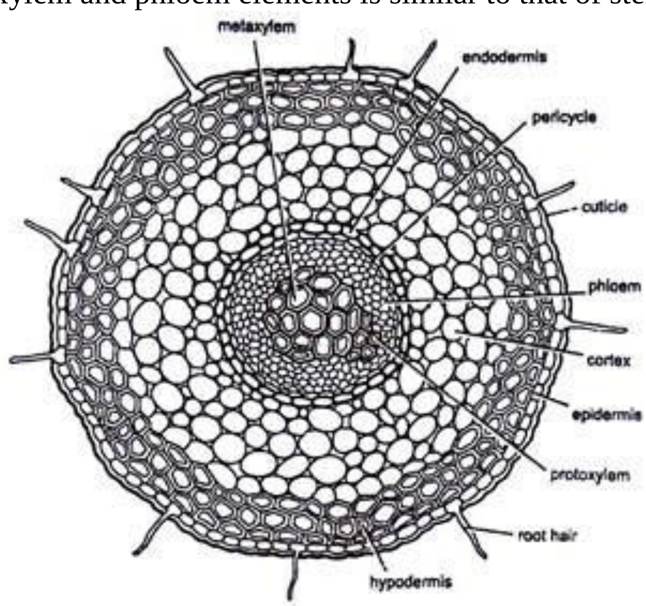


Fig. 4. *Selaginella*. T. S. of root

3. Rhizophore:

(i) Epidermis:

- It is single layered and the outer wall of epidermal cells is covered with a thick cuticle.
- Root hairs and stomata are absent.

(ii) Cortex:

- Inner to the epidermis is present a wide zone of cortex differentiated into outer sclerenchymatous and inner parenchymatous zones.

(iii) Endodermis:

- It is inner-most layer of the cortex. It is ill defined single layered structure.

(iv) Pericycle:

- Inside the endodermis is present a single layered parenchymatous pericycle.

(v) Stele:

- It is typically a protostele.
- The xylem is surrounded by phloem.
- Xylem shows distinct protoxylem and metaxylem elements.
- The position of protoxylem is different in different species.
- In S. martensii xylem is exarch and monarch. In S. atroviridis the metaxylem is crescentric with a number of protoxylem strands situated on the concave adaxial side.
- In *S. kraussiana*, *S. poulteri* etc. protoxylem is mesarch (centroxylic).

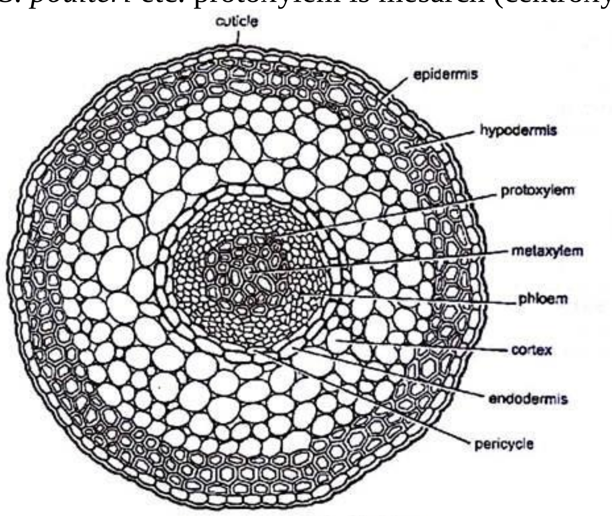


Fig. 5. *Selaginella* . T. S. rhizophore

4. Leaf:

(i) Epidermis:

- It is the outermost surrounding layer and is only one cell in thickness.
- In most of the species the stomata are present only on the lower epidermis near the midrib.
- The stomata may be present on both the outer and inner epidermis.
- The cells of the epidermis are provided with chloroplasts.

(ii) Mesophyll:

- It occupies a wide zone between upper and lower epidermis.
- The mesophyll is usually made up of parenchymatous cells which have conspicuous intercellular spaces.
- Each mesophyll cell has one (e.g., S. martensii), two (e.g., S. kraussiana), or eight (e.g., willedenovii) chloroplasts.
- Each chloroplast has several pyrenoid like bodies similar to order Anthocerotales (Bryophyta).
- In some species (e.g., S. concinna) the mesophyll is distinguished into upper palisade and lower spongy parenchyma.

(iii) Vascular bundle:

- Only one vascular bundle is present in the centre.
- It is concentric and amphicribal (ectophloic).
- It is made up of a few xylem tracheids (annular or spiral) surrounded by phloem elements (a few sieve elements).
- A single layered bundle sheath encircles the phloem on all sides.

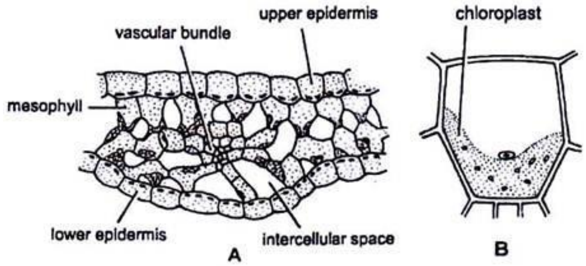


Fig. 6. (A–B). *Selaginella* : Internal Structure of leaf. A. T. S. of a part leaf of *S. kraussiana*, B. A mesophyll cell

Reproduction in Selaginella:

Selaginella reproduces by two methods: Vegetatively and by formation of spores.

1. Vegetative reproduction:

(i) Fragmentation:

- Under humid conditions in *S. rupestris*, trailing branches of the stem develop adventitious branches.
- These branches later disjoin from the parent plant and develop into separate individual plants.

(ii) Tubers:

- These appear towards the end of the growing season.
- The tubers may be aerial, developing at the apical end of aerial branches (e.g., *S. chrysocaulos*) or subterranean (e.g., *S. chrysorrhizos*).
- Under favourable conditions tubers germinate into a new plant (Fig. 7A).

(iii) Resting buds:

- These are the compact structures which develop at the apical end of some aerial branches.
- The leaves in this region are closely arranged and overlap the growing points.
- These resting buds are capable to pass on the unfavourable conditions.
- Under favourable conditions these buds give off rhizophore that bear roots at their tips (Fig. 7B).

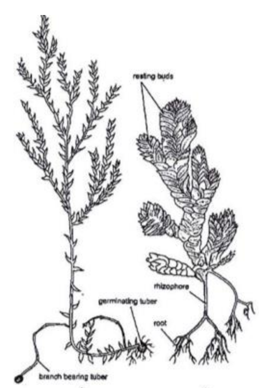


Fig. 7 (A–B). *Selaginella*. Vegetative reproduction, A. Tubers, B. Resting buds

2. Sexual Reproduction:

Spore producing organs:

- Selaginella is a sporophytic plant (2x) and reproduces sexually.
- The plants are heterosporous i.e., produce two different types of spores—megaspores and microspores.
- These spores are produced 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 which is usually a terminal structure (Fig. 8 A).

Strobilus:

- It is a reproductive structure formed by the aggregation of ligulate sporophylls at the apex of the branches of stem.
- The length of the strobilus varies from 1/4 inch to 2-3 inches in different species.
- In some species as for e.g., *S cuspidata*, S. patula etc. the growth of the stem continues beyond the strobilus and such condition is called selago condition (fertile part is alternated by vegetative parts, Fig. 8 B).
- The Longitudinal section (L.S.) of strobilus shows that it is a very simple structure.
- It consists of a central axis covered with spirally and densely arranged ligulate sporophylls.
- Each sporophyll adaxially bears a single stalked sporangium in its axis (Fig. 8C, D; 9A).
- The positions of the sporangia differ in different species.
- It may be in axil (axillary) or little upward on in position (cauline).
- Selaginella produces two types of spores—megaspores and microspores.
- The dimorphic condition of the spores is known as heterospory.
- In between the sporophyll and sporangium is present a small membranous structure known as ligule i.e., the sporophyll is similar to a vegetative leaf.
- The microsporangium produces large number of microspores whereas megasporangium produces usually 4 megaspores.
- Strobili are usually bisporangiate but the arrangement of microsporophylls and megasporophylls differ in different species.

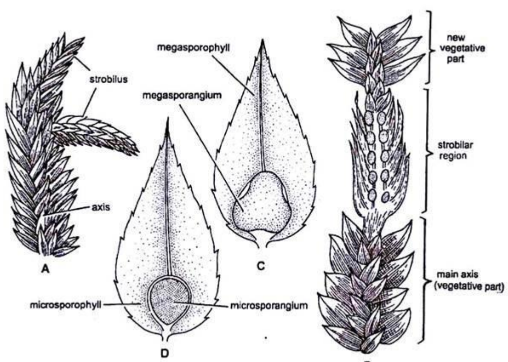


Fig. 8 (A–D). *Selaginella* : Structure of strobilus. A. A branch bearing strobilus, B. A branch after formation of strobilus region again changing into vegetative region, C. A megasporophyll, D. A microsporopyll

- In S. inaequalifolia (Fig. 9 A) the microsporophylls are present on one side and megasporophylls on the other side.
- In S. rupestris megasporophylls are present on the lower side and microsporophylls on the upper side of the strobilus (Fig 9 B).

- In case of S. martensii the microsporophylls are mixed irregularly with megasporophylls (Fig. 9 C).
- In S. kraussiana only one megasporophyll is present while all the rest are microsporophylls (Fig. 9 D). In case of S. gracilis the strobilus is unisporangiate i.e., either it bears microsporophylls or megasporophylls alone.

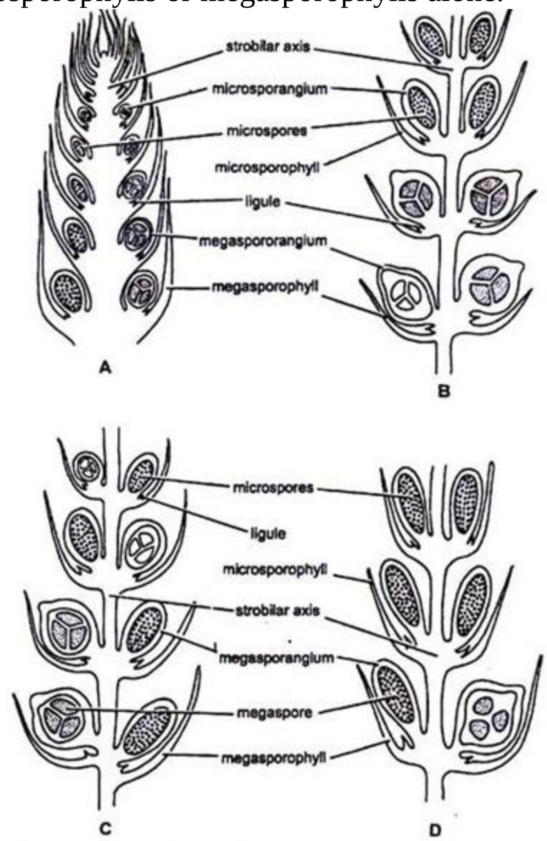


Fig. 9. (A–D). *Selaginella*. Longitudinal sections of strobili of different species showing position of microsporangia and megasporangia A. *S. inaequalifolia*, B. *S. rupestris*, C. *S. martensii*, D. *S. kraussiana*

Microsporangium:

- Each microsporangium is a stalked, globular or elongated structure (Fig. 8 D).
- Its colour varies from red, yellow to brown in different species.
- The wall is 2 layered thick which is followed by a conspicuous tapetum (Fig. 10 F).
- 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 (Fig. 10G).
- 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 (Fig. 10 G).

• The sporangia usually dehisce by a vertical slit formed in apical region of the sporangia and the spores are disseminated in the air.

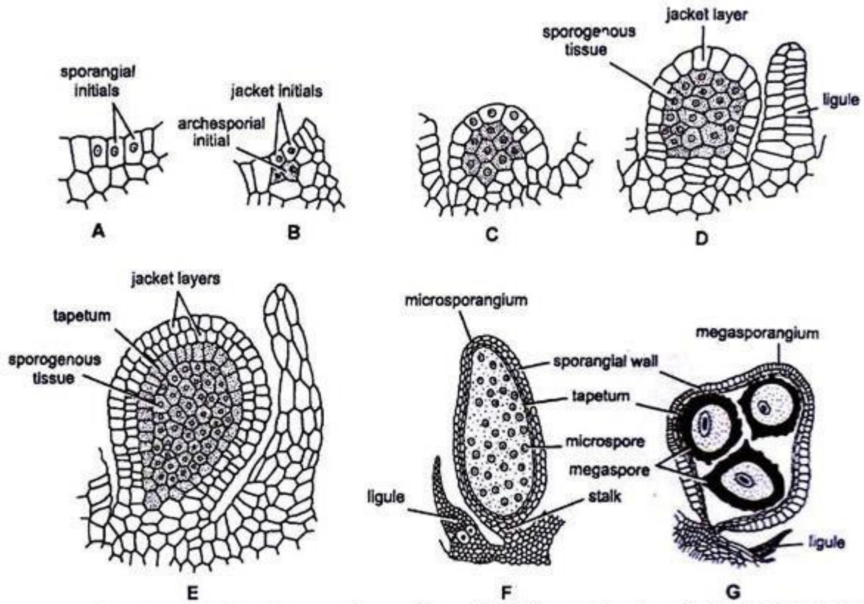


Fig. 10. (A–G). ***Selaginella*****. Development of sporanigum. (A–E). Successive stages in the development of microsporangium in *S. kraussiana*, F. Mature microsporangium, G. Mature megasporangium**

Development of sporangium and formation of spores:

• As the position of sporangium is either cauline or foliar, the initials are either situated on the axis or on the leaf respectively.

• The development of sporangium and formation of spores (micro-and mega) is similar upto the formation of spore mother cells.

• The development is of eusporangiate type i.e., it takes place with the help of a row of initials which are known as sporangial initials e.g., *Selaginella* kraussiana.

• These cells are superficial in position (Fig. 10 A).

• These cells divide periclinally forming outer jacket initials and inner archesporial initials (Fig. 10 B).

• The jacket initials by further periclinal and anticlinal divisions form the jacket which is 2 celled thick (Fig 10 E).

• The archesporial initials divide in all directions forming a group of cells known as sporogenous tissue.

• The cells of the outer most layer of sporogenous tissue divides periclinally forming a single layered tapetum just inner to wall of sporangium. It is a nourishing layer (Fig 10 C-E).

• Tissue at the base of sporangium divides to form the sporangial stalk. The cell of sporogenous tissue in case of microsporangium finally gives rise to microspore mother cells and in case of megasporangium gives rise to megaspore mother cells.

• In microsporangium all the microspore mother cells are functional and each one divides reductionally forming a tetrad of 4 haploid microspores, as a result of which a large number of tetrads of microspores are formed inside microsporangium. Later on these microspores separate from each other.

• The mature microsporangium dehisces by a vertical slit in the apical region. By the drying of unsplitted portion, the spores are forced out and then they are dispersed away by wind.

• In megasporangium all the megaspore mother cells degenerate except one which divides reductionally forming a tetrad (Fig. 11 D) of 4 haploid megaspores. The dehiscence of megasporangium is similar to that of microsporangium.

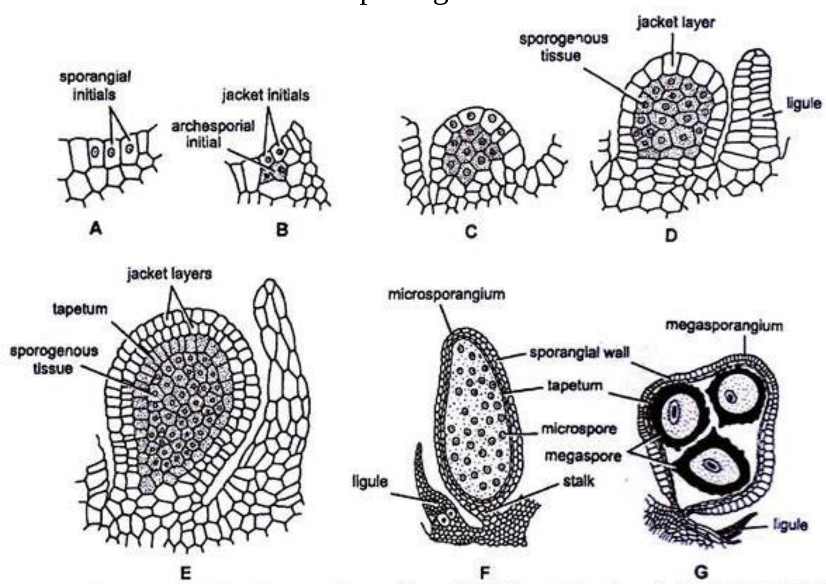


Fig. 10. (A–G). *Selaginella*. Development of sporanigum. (A–E). Successive stages in the development of microsporangium in *S. kraussiana*, F. Mature microsporangium, G. Mature megasporangium

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.

Spore:

• The microspores are small, 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, Fig 11 A-C).

• The megaspores are much larger than microspores, tetrahedral in shape and show triradiate ridge. The megaspore has three wall layers namely exospore, mesospore and endospore (Fig. 11 D, E). The microspores on germination give rise to male prothalli and megaspores to the female prothalli.

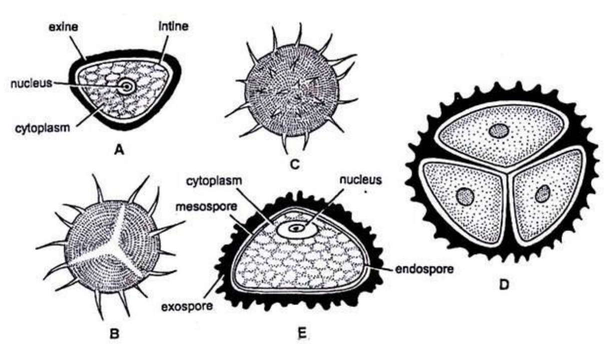


Fig. 11 (A–E). *Selaginella*. Structure of spores : A. A single microspore showing detailed structure, B. Apical view of spore, C. Basal view, D. Megaspore in tetraed, E. A single megaspore.

Development of male gametophyte:

• The microspore is the initial stage in the development of male gametophyte. The development of the microgametophyte is in situ or precocious i.e., it starts within the microsporangium. Generally a 13-celled microgametophyte is formed before the microsporangium dehisces.

• 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 (Fig. 13 A).

• The prothallial cell does not divide further and takes no part in further development of male gametophyte. The antheridial cell divides to form a group of 12 cells. The antheridial cell divides vertically (2-2) to the prothallial cell to form the two primary cells of the antheridium (Fig. 13B). At this stage the young gametophyte consists of 3 cells (2+1 cell, Figs. 12 A, B; 13 B).

• The wall which separates the two primary cells is called first primordial wall. Two primary cells thus formed divide transversely (3-3 Figs. 12 C). This division is at right angle to the first and can be seen only if we cut a vertical section of the spores. This stage of gametophyte consists 5 cells (2 + 2+1 cells).

• Out of these four cells formed by the division of primary cells, the basal cells divide no further and become the cells of the jacket layer of the antheridium. Upper two cells divide further by curving or arching wall (4-4, Fig. 12 D). In this way 6 cells are formed and microgametophyte has seven cells at this stage (4+ 2+1 cells).

• Out of the four cells formed by the last division, two bigger cells divide again by curved wall (5-5, Fig. 12 E) and thus a 9 celled microgametophyte is formed (6 + 2+1 cells, 8 antheridial cells and one prothallial cell). These antheridial cells are arranged in such a manner that four cells are present in the middle and two cells are present on either side i.e., above and below.

• The middle four cells divide by periclinal walls (6-6, Fig. 12 F; 13 D) to form 4 primary androgonial cells and 8 jacket cells. The gametophyte now consist 13 cells (1 prothallial cell + 4 androgonial cells + 8 jacket cells). In S. kraussiana the gametophyte is shed at this stage. Further development takes place after shedding.

• At this stage the spores are liberated and their exosporium ruptures. Primary androgonial cells divide and redivide to form 128 or 256 androcytes or antherozoid mother cells.

• Each antherozoid mother cell finally metamorphosis into a single antherozoid (Fig. 13 F, G) 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.

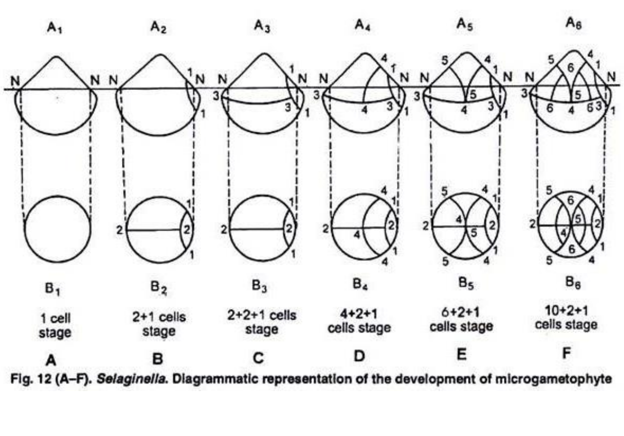


Fig. 12 (A–F). *Selaginella.* Diagrammatic representation of the development of microgametophyte

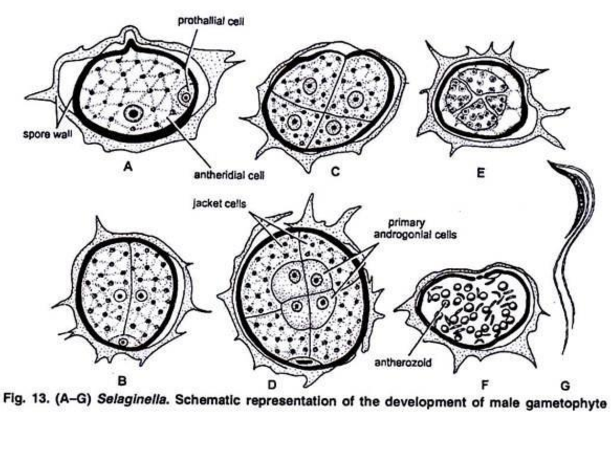


Fig. 13. (A–G) *Selaginella.* Schematic representation of the development of male gametophyte

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.
- First of all the exospore or outer wall grows faster than the mesospore which result in the formation of space between exospore and mesospore. The whole structure increases in size as a result of which a big central vacuole appears (Fig. 14 A).
- Now nucleus divides by free nuclear divisions, forming a large number of nuclei. First the nuclei are equally distributed in the cytoplasm but later on more nuclei collect in the apical region.
- At this stage wall formation starts from the apical region downwardly thus forming an upper cellular region known as female prothallus and a lower non-cellular region known as storage region. The wall of the lower cells becomes thick forming a diaphragm (Fig. 14 B-E). Later on the vacuole also disappears as the cytoplasm increases in amount.
- 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. 15).

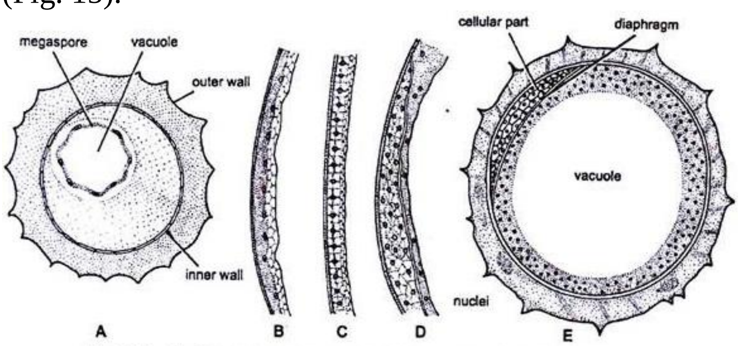


Fig. 14 (A–E). *Selaginella*. Stages in the development of female gametophyte

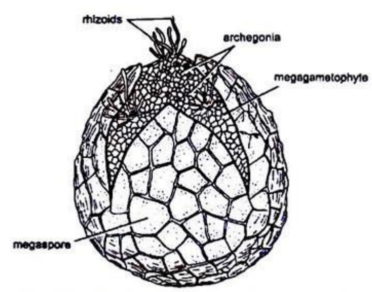


Fig. 15. *Selaginella*. Female gametophyte. A. Dehiscent megaspore and rhizoids in *S. kraussiana*

Development of archegonium:

- A few cells near the apex of female prothallus behave as archegonial initials which by further divisions; give rise to archegonia (Fig. 16H).
- Each archegonium develops from a single superficial cell of the female prothallus situated near the apical region and is termed as archegonial intitial (Fig. 16 A).
- It divides transversely forming an upper primary cover cell and a lower central cell (Fig. 16 B). The primary cover cell, by two vertical divisions at right angle to each other, forms 4 cells which by a transverse division forms a neck of 2 tiers of 4 cells each (Fig. 16 C, D).
- The central cell again divides to form an upper primary neck canal cell and a lower primary venter cell (Fig. 16 D). The former forms a single neck canal cell while the latter divides to form a ventral canal cell and egg (Fig. 16 E).

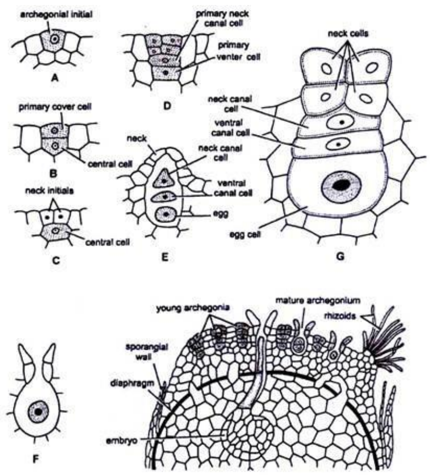


Fig. 16 (A–G). *Selaginella* : Development of archegonium. A–F. Various stages in the development, G. A mature archegonium before fertilization, H. A nearly median section of a mature prothallus showing various stages in the development of archegonium.

Structure of Mature Archegonium:

• The archegonium is a short flask shaped structure embedded in female gametophytic tissue (Fig. 16 H). 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 (Fig. 16 G). 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 (Fig. 16 F) 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.

• In some species e.g. S. intermedia the egg develops into embryo without fertilization. This phenomenon is known as parthenogenesis.

Embryo Development (Young Sporophyte):

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. 17 A, B).

• The suspensor initial further divides in all directions forming a multicellular suspensor which thrusts the developing embryo deep into the female gametophytic tissue to absorb food for further development of embryo. The embryo initial divides by 2 vertical divisions at right angle to each other thus forming 4 cells (quandrant. Fig. 17 C).

• One of these 4 cells divides by an oblique wall forming a shoot initial (Fig 17 D). Now the cells except the shoot initial divide sporophyte transversly forming 2 tiers of 4 cells each. Later on by further divisions it forms a multicellular structure which gets differentiated into foot, rhizophore, stem and cotyledons (Fig. 17 E-J).

• In some species of Selaginella (e.g., S. apus and S. rupestris the megagametophytes arenever shed from the megasporangium and remain on the strobilus. The oospore completes its development within the megasporangium and the young embryo grows into a seedling, develop primary root and then falls on the ground (Fig. 18).

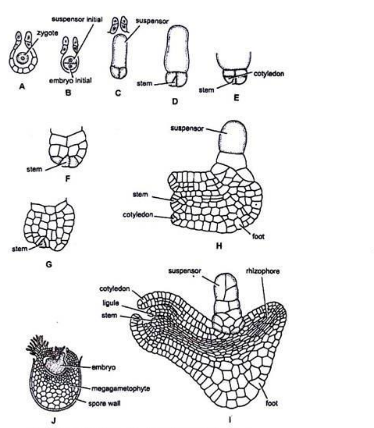


Fig 17 (A–J). *Selaginella* : Development of embryo.
A–I various stages in the development J. Longitudinal section of female gametophyte bearing embryo.

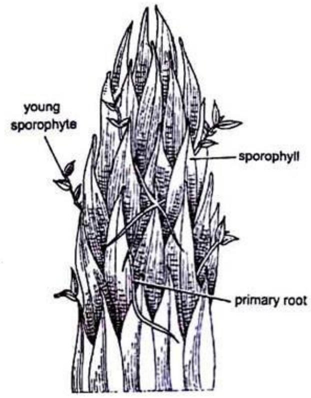


Fig. 18. ***Selaginella.*** **Young sporophytes developing upon the strobilus of parent plant in** ***Selaginella rupestris.***

Life Cycle Patterns of Selaginella:

- Selaginella is a sporophytic plant (2x) and produces two different types of spores i.e., microspores and megaspores. In other words we may call it as heterosporous plant. These spores on germination produce male and female gametophytes (x) respectively which in turn developing upon the strobilus of parent produce antherozoids and egg in antheridia and archegonia respectively.
- These reproductive structures after fertilization produce zygote (2x) which again on germination gives rise to a sporophytic plant (2x). In this way the sporophytic and gametophytic generations alternate with each other although the sporophytic phase is dominant over gametophytic phase (Figs. 19, 20).

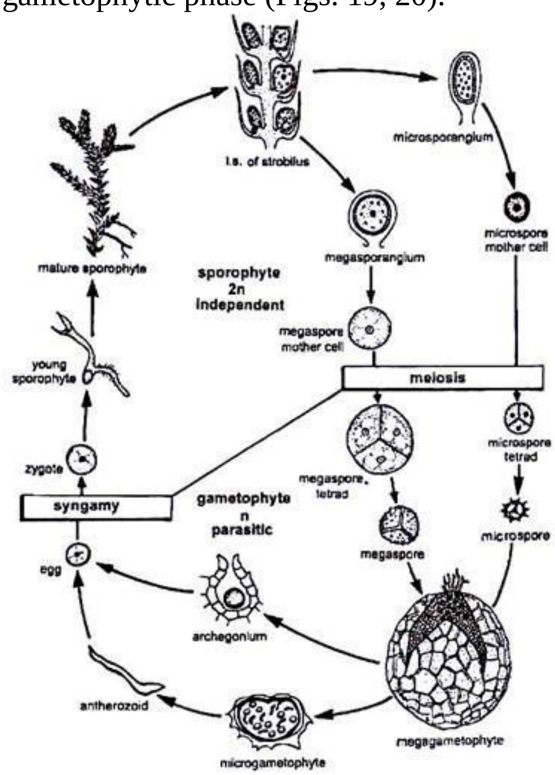


Fig. 19. Diagrammatic life cycle of *Selaginella*

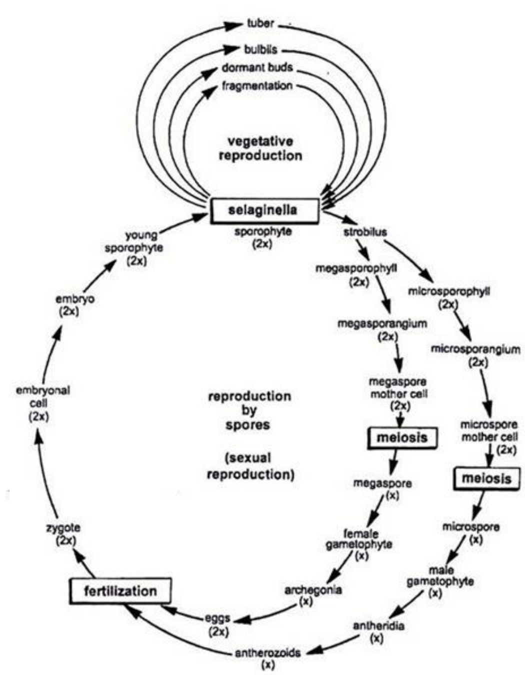


Fig. 20. *Selaginella* : schematic life cycle

Equisetum
Taxonomic position
Division:Sphenophyta
Class: Calamopsida
Order: Equisetales
Family: Equisetaceae
Genus: Equisetum

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.

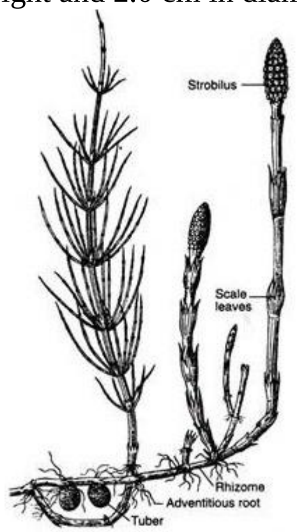


Fig. 7.83 : *Equisetum arvense* sporophyte

• 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, thus they are considered as 'gold indicator plants.

• 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.

• 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.

Internal Features of Stem:

• In T.S., the stem of Equisetum appears wavy in outline with ridges and furrows (Fig. 7.84). The epidermal cell walls are thick, cuticularised and have a deposition of siliceous material.

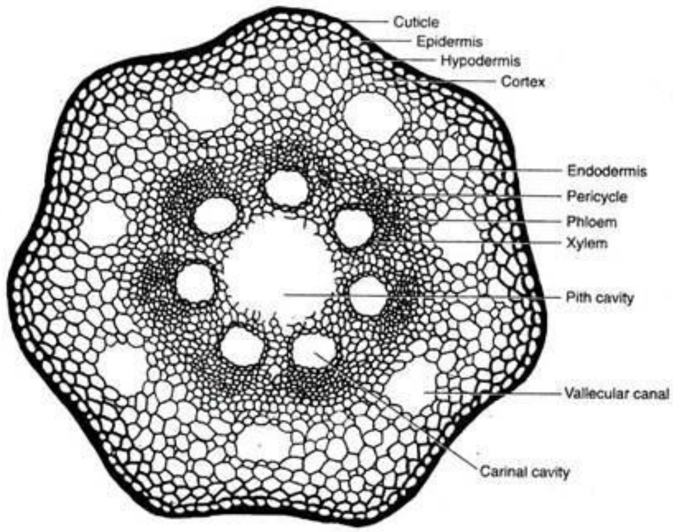


Fig. 7.84 : *Equisetum*: T.S. of stem (rhizome)

• Stomata are distributed only in the furrows between the ridges. A hypodermal sclerenchymatous zone is present below each ridge which may extend up to stele in E. giganteum. The cortex is differentiated into outer and inner regions.

• The outer cortex is chlorenchymatous, while the inner cortex is made up 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.

• New leaves and branches of Equisetum are produced by the apical meristem, however, most of the length of the stem are due to the activity of intercalary meristem located just above each node. The activity of intercalary meristem causes rapid elongation of the inter- nodal region.

• The stele is ectophloic siphonestele which is surrounded by an outer endodermal layer. An inner endodermis is also present in some species of Equisetum (e.g., E. sylvaticum). The endodermis is followed by a single-layered pericycle.

• The vascular bundles are arranged in a ring which lies opposite to the ridges in position and alternate with the vallecular canals of the cortex. Vascular bundles are conjoint, collateral and closed. In the mature vascular bundle, protoxylum is disorganised to form a carinal cavity which lies opposite to the ridges.

• The metaxylem tracheids (scalariform or reticulate) are present on both sides of the phloem. In some species vessels with reticulate perforations are reported. The central part of the internode of aerial shoot is occupied by a large pith cavity which is formed due to rapid elongation of the internodal region.

• The vascular bundles remain unbranched until they reach the level of node. At the nodal region, each vascular bundle trifurcates (divided into three parts).
• The middle branch of the trifurcation enters the leaf. Each lateral branch of the trifurcate bundle joins a lateral strand of an adjacent trifurcate bundle to form a vascuiar bundle of internode (Fig. 7.85). Thus the vascular bundles of internode alternate with those of internodes above and below.
• In the nodal region, the xylem is extensively developed as a conspicuous circular ring. There are no vallecular or carinal canals at this level. In addition, a plate of pith tissue occurs at the node which separates one internode from another.

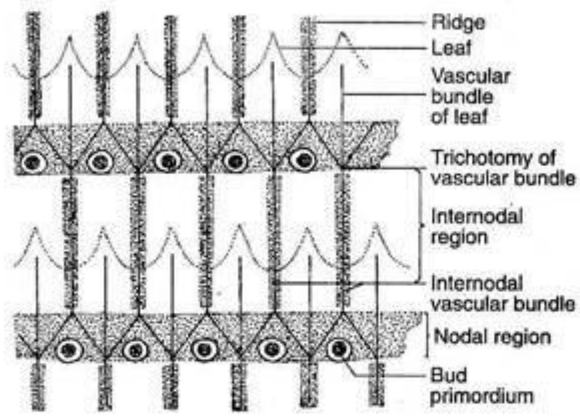


Fig. 7.85 : *Equisetum* : Schematic representation of a portion of vascular system in nodal and internodal regions

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

Xerophytic characteristics

(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.

Hydrophytic characteristics

(i) Developed aerating system like carinal canal,
(ii) Vallecular canal and central pith cavity
(iii)Reduced vascular elements.

Root:

• The primary root is ephemeral. The slender adventitious roots arise endogenously at the nodes of the stems. In T.S., the root shows epidermis, cortex and stele from periphery to the centre. The epidermis consists of elongated cells, with or without root hairs.
• The cortex is extensive; cells of the outer cortex often have thick walls (sclerenchymatous) and those of the inner cortex are thinner parenchymatous. The stele is protostelic where the xylem is triarch or tetrarch, or, in smaller roots, may be diarch.
• A large metaxylem element is present in the centre of the stele and the protoxylem strands lie around it. The space between the protoxylem groups is filled with phloem. There is no pith.

Leaves:

• The leaves of Equisetum are small, simple, scale-like and isophyllous; they are attached at each node, united at least for a part of the length and thus form a sheath around the stem. The sheath has free and pointed teeth-like tips.

• The number of leaves per node varies according to the species. The species with narrow stems have few leaves (e.g., 2-3 leaves in *E. scirpoides*) and those with thick stem have many leaves (e.g., up to 40 leaves in *E. schaffneri*).

• The number of leaves at a node corresponds to the number of ridges on the internode below. The leaves do not perform any photosynthetic function and their main function is to provide protection to young buds at the node.

Reproduction in Equisetum:

Equisetum reproduces vegetatively and by means of spores.

i. Vegetative Reproduction:

• The subterranean rhizomes of some species (e.g., E. telmateia, E. arvense) form tubers (Fig. 7.83) which, on separation from the parent plant, germinate to produce new sporophytic plants. The tubers develop due to irregular growth of some buds at the nodes of the rhizomes.

ii. Reproduction by Spores:

• Spores are produced within the sporangia. The sporangia are borne on the sporangiophores which are aggregated into a compact structure termed strobilus or cone or sporangiferous spike.

Strobilus:

• The strobilus is terminal in position and generally is borne terminally on the chlorophyllous vegetative shoot. However, they may be borne terminally on a strictly non- chlorophyllous axis (e.g., E. arvense).

• The strobilus is composed of an axis with whorls of sporangiophores. Each sporangiophore is a stalked structure bearing a hexagonal peltate disc at its distal end. On the under surface of the sporangiophore disc 5-10 elongate, cylindrical hanging sporangia are borne near the periphery in a ring.

• The flattened tips of the sporangiophores fit closely together which provide protection to the developing sporangia. The axis bears a ring-like outgrowth, the so-called annulus immediately below the whorls of sporangiophores which provide additional protection during early development.

• The annulus has been interpreted as a rudimentary leaf sheath by some botanists, whereas others consider it to be sporangiophoric in nature as occasionally it bears small sporangia.

Development of Sporangium:

• The mode of development of sporangium is eusporangiate, as it is not entirely formed from a single initial. Superficial cells adjacent to the original initial may also take part in the development of sporangium.

• Sporangia are initiated in single superficial cell around the rim of the young sporangiophore. The periclvnal division of the sporangium initial forms an inner and an outer cell. The inner cell, by further divisions in various planes, gives rise to sporogenous tissue.

• The outer cell, by periclinal and anticlinal divisions, gives rise to irregular tiers of cells, the inner tiers of which may transform into sporogenous tissue and the outer tiers become the future sporangial wall cells.

• The innermost layer of the sporangial wall differentiates as the tapetum. The sporogenous cells separate from each other, round off and eventually transform into spore mother cell. All but the two outermost wall layers disorganise to form periplasmodial fluid.

• However, not all of the sporogenous cells function as spore mother cells. Many of them degenerates to form a multinucleate nourishing substance for the spore mother cells. Each spore mother cell undergoes meiotic division (reductional division) and produces spore tetrad. All spores in a sporangium are of same size and shape i.e., homosporous.

Structure of Mature Sporangium:

- The mature sporangium is an elongated saclike structure, attached to the inner side of the peltate disc of the sporangiophore. It is surrounded by a jacket layer which is composed of two layers of cells. The inner layer is generally compressed and the cells of the outer layer have helical thickenings which are involved in sporangial dehiscence.

Dehiscence of Sporangium:

- At maturity, the strobilar axis elongates, as a result the sporangiophores become separated and exposed. Then the sporangium splits open by a longitudinal line due to the differential hygroscopic response of the wall cells.

Spores:

- The spores are spherical and filled with densely packed chloroplasts. The spore wall is laminated and shows four concentrate layers. The innermost is the delicate intine, followed by thick exine, the middle cuticular layer and the outermost epispore or perispore. The intine (endospore) and exine (exospore) are the true walls of the spore.
- The outer two layers i.e., cuticular layer and epispore are derived due to the disintegration of the nonfunctional spore mother cells and tapetal cells. At maturity, the epispore (the outermost layer) splits to produce four ribbon like bands or strips with flat spoon-like tips.
- These bands are free from the spore wall except for a common point of attachment and remain tightly coiled around the spore wall until the sporangium is fully matured. These are called elaters (Fig. 7.87A). The elaters are hygroscopic in nature. The spores remain moist at early stages of development, thus the elaters are spirally coiled round the spore.
- The spores dry out at maturity and consequently the elaters become uncoiled. These uncoiled elaters become entangled with the elaters of other spores. Through these actions the elaters help in the dehiscence process and also the dispersal of spores in large groups from the sporangium.

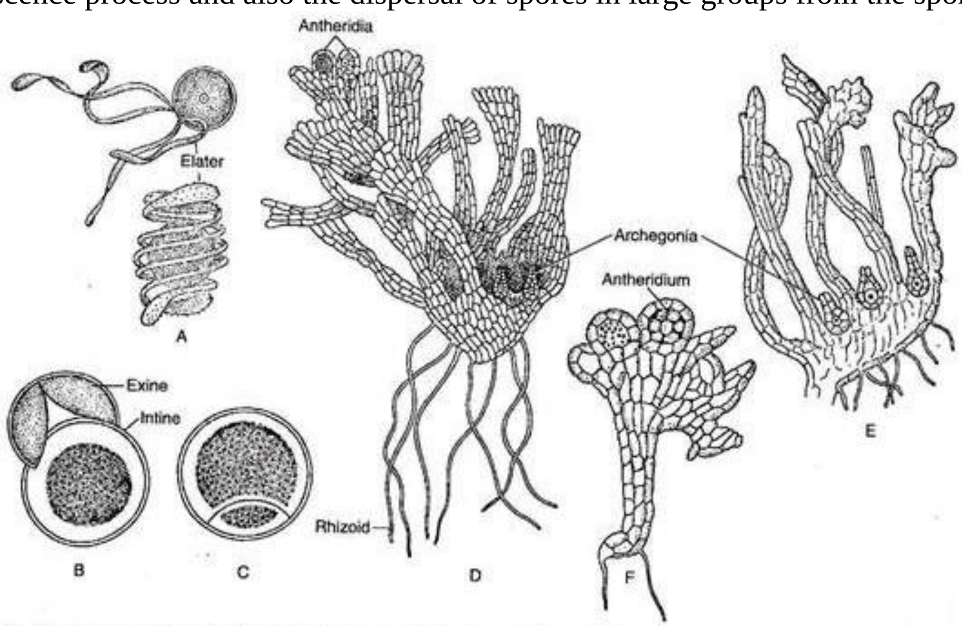


Fig. 7.87 : *Equisetum* : A. Spores with elaters, B–C. The stages of germination of spore, D. Monoecious gametophyte, E. Female gametophyte, F. Male gametophyte

The elaters of Equisetum are different from those of the bryophytes (Table 7.6).

Table 7.6 : Distinction between elaters of bryophytes and pteridophytes

Elaters of Bryophytes	Elaters of *Equisetum*
• They are differentiated from the complete cells.	• They are produced by splitting of the outer-most layer of the spore wall.
• They are diploid in nature, sterile, spindle-like and have spiral thickenings.	• They are haploid in nature, ribbon-like with spoon-like tips and without spiral thicke-ning.

Gametophyte Generation:

• Equisetum is a homosporous pteridophyte. The haploid spores germinate to form gametophyte. The germination takes place immediately if the spores land on a suitable substratum. If the spores do not germinate immediately, their viability decreases significantly.

• The spores swell up by absorbing water and shed their exine (Fig. 7.87B). The first division of the spore results in two unequal cells: a small and a large cell (Fig. 7.87C). The smaller cell elongates and forms the first rhizoid. The larger cell divides irregularly to produce the prothallus. The prevailing environmental conditions determine the size and shape of the prothallus.

• If a large number of spores are developed together within a limited space, then the prothalli formed are of thin filamentous type. But a relatively thick and cushion-shaped prothalli are formed from sparsely germinating spores. Mature gametophytic plants may range in size from a few millimeters up to 3 centimeters e.g., E. debile) in diameter.

• They are dorsiventral and consist of a basal non-chlorophyllous cushion-like portion from which a number of erect chlorophyllous muticellular lobes develop upwards. Unicellular rhizoids are formed from the basal cells of cushion (Fig. 7.87D). The prothallus bears sex organs and reproduces by means of sexual method.

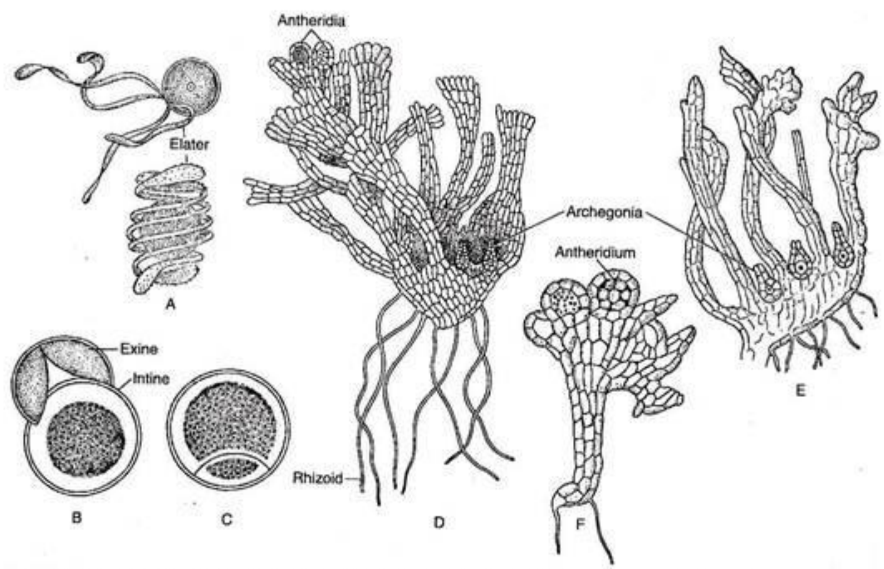


Fig. 7.87 : *Equisetum* : A. Spores with elaters, B–C. The stages of germination of spore, D. Monoecious gametophyte, E. Female gametophyte, F. Male gametophyte

Sexuality in Equisetum:

• The gametophytic plant body bears sex organs i.e., antheridium (male) and archegonium (female). The gametophyte are basically bisexual (homothallic) i.e., they bear both male and female sex organs (Fig. 7.87D). Although, some unisexual (dioecious) members are also reported (Fig. 7.87E, F). Some are initially unisexual and then become bisexual.

• Some other fragments produced archegonia, which subsequently bore antheridia in increasing numbers. This phenomenon supports the contention that Equisetum gametophytes are potentially bisexual.

• Equisetum is homosporous and, therefore, definite sex-determining mechanism is absent. But, the sexuality demonstrated by some of the members appears to be related to environmental factors. Therefore, it is termed as environmental sex determination.

Sex Organs of Equisetum:

i. Antheridium:

• In monoecious species, antheridia develop later than archegonia. They are of two types — projecting type and embedded type. Antheridia first appear on the lobes of the gametophyte (Fig. 7.87D). The periclinal division of the superficial antheridial initial gives rise to jacket initial and an androgonial cell (Fig. 7.88A, B).

• The jacket initial divides anticlinally to form a single-layered jacket. The repeated divisions of androgonial cells form numerous cells which, on metamorphosis, produce spermatids/antherozoids (Fig. 7.88C-E). The antherozoids escape through a pore created by the separation of the apical jacket cell.

• The apical part of the antherozoid is spirally coiled, whereas the lower part is, to some extent, expanded (Fig. 7.88F). Each antherozoid has about 120 flagella attached to the anterior end.

ii. Archegonium:

• Any superficial cell in the marginal meristem acts as an archegonial initial which undergoes periclinal division to form a primary cover cell and an inner central cell (Fig. 7.89A, B). The cover cell, by two vertical divisions at right angle to each other, forms a neck (Fig. 7.89C). The central cell divides transversely to form a primary neck canal cell and a venter cell (Fig. 7.89D).

• Two neck canal cells are produced from the primary neck canal cell. While, the venter cell, by a transverse division, forms the ventral canal cell and an egg (Fig. 7.89E).

• At maturity, an archegonium has a projecting neck comprising of three to four tiers of neck cells arranged in four rows, two neck canal cells of unequal size, a ventral canal cell, and an egg at the base of the embedded venter (Fig. 7.89F-G). The archegonia are confined to cushion region in- between the aerial lobes (Fig. 7.87D).

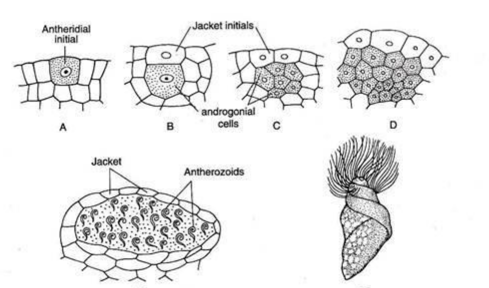


Fig. 7.88 : *Equisetum* : Development of antheridium. A–D. Successive stages in the development of antheridium, E. A mature antheridium, F. An antherozoid

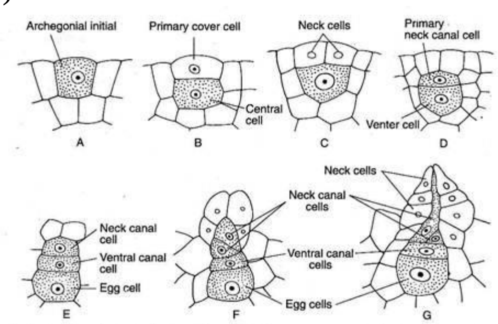


Fig. 7.89 : *Equisetum*. Development of archegonium : A–E. Successive stages in the development of archegonium, G. A mature archegonium

Fertilization:

• Water is essential for fertilisation. The gametophyte must be covered with a thin layer of water in which the motile antherozoides swim to the archegonia. The neck canal cells and ventral canal cell of the archegonia disintegrate to form a passage for the entry of antherozoids.

• Many antherozoids pass through the canal of the archegonium but only one of them fuses with the egg. Thus diploid zygote is formed. Generally more than one archegonia are fertilised in a prothallus.

Embryo (The New Sporophyte):

• The embryo is the mother cell of the next sporophytic generation. Unlike most pteridophytes, several sporophytes develop on the same prothallus. The first division of the zygote is transverse. This results in an upper epibasal cell and lower hypobasal cell. The embryo is therefore exoscopic (where the apical cell is duacted outward i.e., towards the neck of the archegonium) in polarity.

• No suspensor is formed in Equisetum. The epibasal and hypobasal cells then divide at right angles to the oogonial wall, and as a result a tour-celled quadrant stage is established (Fig. 7.90A). All the four cells of the quadrant are of different size and shape.

• The four-celled embryo undergoes subsequent divisions and the future shoot apex originate from the largest cell and leaf initials from the remaining cells of one quadrant of the epibasal hemisphere.

• One cell of the epibasal quadrant and a portion of the adjacent quadrant of the hypobasal region contribute to the development of root. The first root develops from one of the epibasal quadrants and a portion of the adjacent hypobasal quadrant. The shoot grows rapidly.

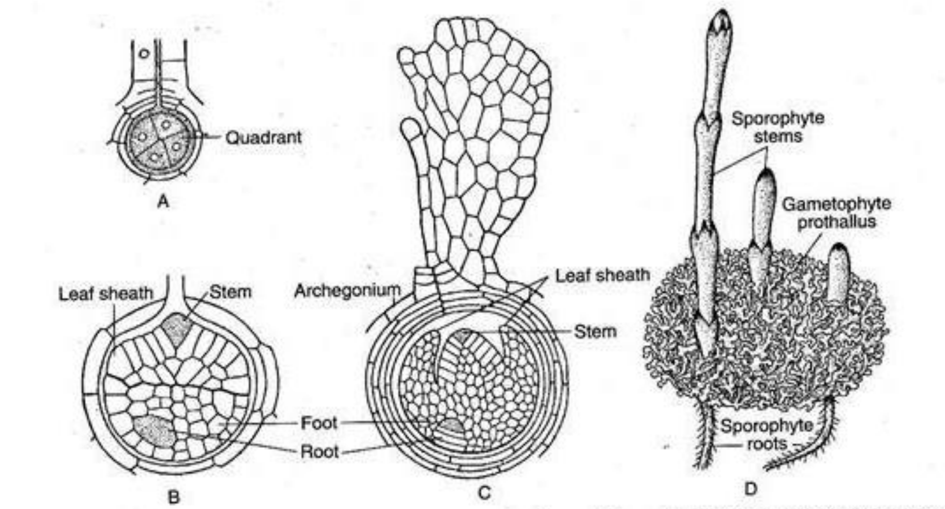


Fig. 7.90 : *Equisetum* : A–C. The stages in the development of embryo within venter, D. Young sporophytes developing from a gametophyte

• Later the root grows directly downward and penetrates the gametophytic tissue to reach the soil or substratum (Fig. 7.90B, C). A number of such sporophytes may develop from a large mature gametophyte if more than one egg is fertilised (Fig. 7.90D).

Life Cycle of Equisetum:

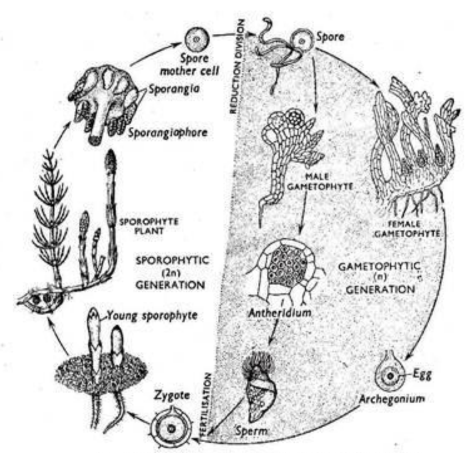


Fig. 7.91 : Life cycle of *Equisetum arvense* (dioecious)

Pteris:
Taxonomic position
Division:Filicophyta
Class: Leptosporangiopsida
Order: Filicales
Family: Polypodiaceae
Sub-family:Pteridiaceae
Genus: Equisetum

Sporophyte:

The main sporophytic plant body is differentiated into root, rhizomatous stem and leaves (Fig. 7.102A).

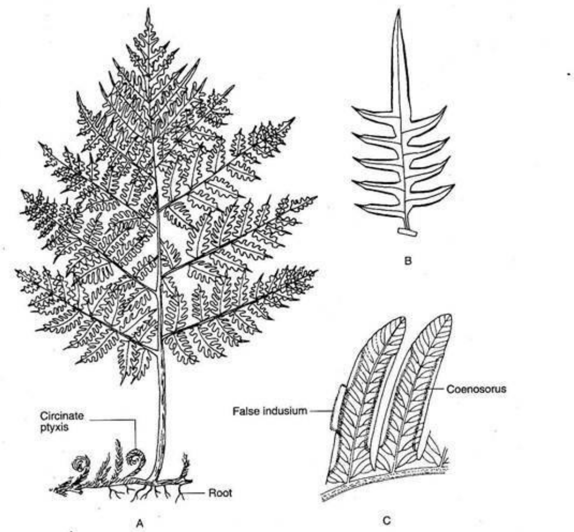


Fig. 7.102 : *Pteris* : A. A sporophyte showing habit, B. A lateral pinna, C. Abaxial surface of a portion of the lateral pinna showing two pinnules

1. Root:

- The primary root is ephemeral, and is replaced by a large number of adventitious roots developed all over the surface of the rhizome. The roots are small and branched (Fig. 7.102A).
- The T.S. of root shows an outer piliferous layer, a cortex and a central stele. The cortex is differentiated into a parenchymatous outer cortex and a sclerenchymatous inner cortex. The stele is protostelic with diarch and exarch xylem.

2. Rhizome:

- The rhizome or stem may be creeping (P. grandiflora) or erect (P. cretica, P. vittata) which may or may not show branching. The rhizome is differentiated into nodes and internodes and its entire surface is covered with scales. The growing point of rhizome is covered with ramenta.
- Anatomically, the rhizome shows an outer single-layered epidermis, a few-layered thick sclerenchymatous hypodermis and a broad parenchymatous cortex with a diversified stelar organisation (Fig. 7.103). It may be solenostelic (P. grandiflora, P. vittata) or dictyostelic.
- Even the diversity is noted in different regions of the rhizome in the same species. For example, in *P. biaurita*, the lower part of the rhizome shows mixed protostele which becomes siphonostelic a little up and exhibits polycyclic dictyostele near the apex.
- In general, the stele is made up of a number of meristeles forming two rings (Fig. 7.103). The inner ring consists of 2 to 3 large meristeles and the outer ring comprises of a number of small meristeles. Each meristele has a band or platelike mesarch xylem surrounded by phloem. Each stele is bounded by its own endodermis.

3. Leaf:

• The leaves are borne on the upper surface of the rhizome. When young the leaves are spirally coiled and show circinate vernation that is typical of true ferns (Fig. 7.102A).

• The leaves are unipinnately or multipinnately compound or decompound with a long rachis (Fig. 7-.102B).

• The pinnae are small near the base as well as towards the apex, while they are large towards the middle. The pinnae are very often coriaceous. All leaves are fertile, bearing sori along the ventral margin of pinnae, except the apices of the segments.

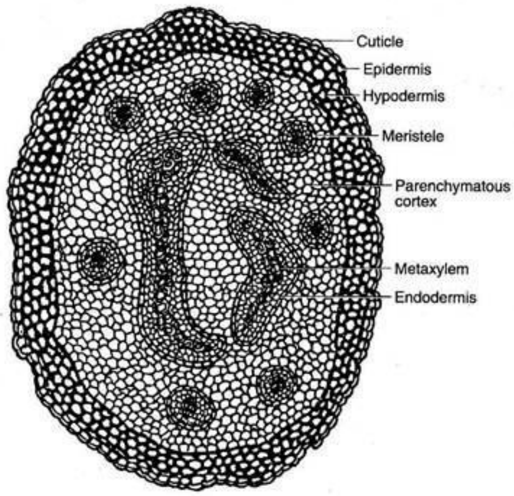


Fig. 7.103 : *Pteris.* T.S. of rhizome

• The rachis is traversed by a single C/U/ V-shaped leaf trace. The lamina is bifacial, hypostomatic. Mesophyll cells may or may not be differentiated. A concentric vascular bundle with distinct bundle sheath is present in the midrib.

Reproduction in Pteris**:**

Pteris reproduces by means of spores.

Spore-Producing Organ:

• Pteris is a homosporous fern. The sorus of Pteris is called coenosorus (Fig. 102C). Coenosori are marginal, borne continuously on a vascular commissure connected with vein ends.

• Thus the sporangia of Pteris form a continuous linear sorus along the margin, hence the individuality of sori is lost.

• The coenosori are protected by the reflexed margin (false indusium) of the pinnae. Sori are of mixed type intermingled with many sterile hairs in between the sporangia (Fig. 7.104).

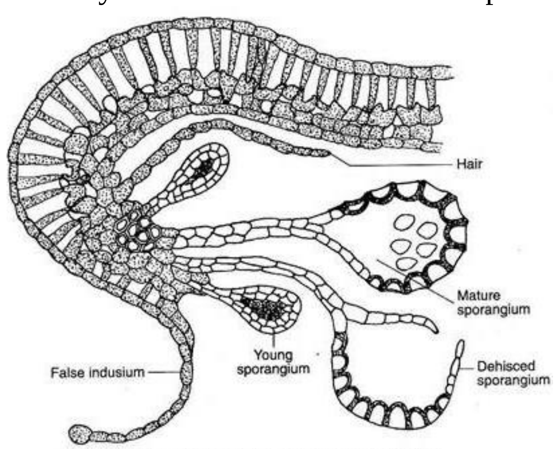


Fig. 7.104 : *Pteris :* T.S. of pinnule showing sorus (a portion)

Development of Sporangium:

• The development of sporangium in Pteris is of leptosporangiate type (Fig. 7.105A-G). A single superficial cell of the receptacle functions as the sporangial initial which divides transversely to produce an upper cell and a lower cell.

• The lower cell does not take part in sporangium development, while the upper cell, by intersecting oblique walls, gets differentiated into an apical cell with three cutting faces. The apical cell cuts off two segments along each of its three cutting faces.

• The apical cell divides periclinally to form an outer jacket initial and an inner tetrahedral archesporial cell. The jacket initial divides, anticlinally to form a single-layered jacket of the sporangium. The archesporial cell further divides periclinally to form an outer tapetal initial and an inner primary sporogenous cell.

• The tapetal initial by one periclinal and several anticlinal divisions forms two-layered tapetum. The primary sporogenous cell divides to form 12 spore mother cells. The spore mother cells divide meiotically to produce haploid spores, while the tapetal cells disorganise and provide nutrition to the spores.

Structure of a Mature Sporangium:

A mature sporangium has a long stalk that terminates in a capsule (Fig. 7.106).

The jacket of the capsule is single-layered, but with three different types of cells:

(1) A thick walled vertical annulus incompletely overarches the sporangium,

(2) A thin-walled radially arranged stomium, and

(3) Large parenchymatous cells with undulated walls.

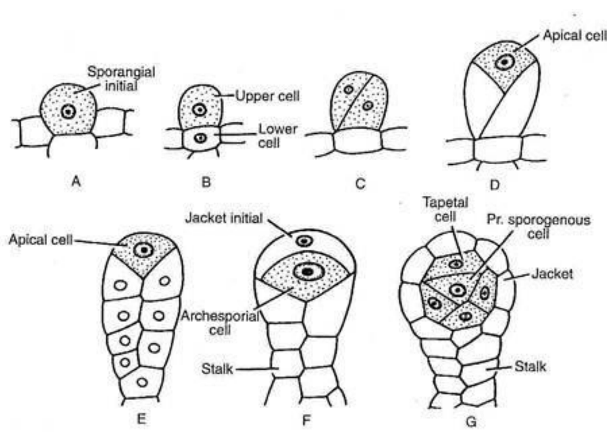


Fig. 7.105 : *Pteris* : A–G. The successive stages in the development of sporangium

• The capsule contains many spores. All spores are structurally and functionally alike; hence Pteris is a homosporous pteridophyte. Spores are triangular in shape with trilete aperture, bounded by two walls. The outer wall, exine, is variously ornamented.

• The sporangium dehisces transversely along the stomium due to the shrinkage of annular cells (Fig. 7.104). The spores are dispersed through air to a moderate distance.

Gametophyte:

• The spores germinate after falling on a suitable substratum. Initially the spore wall (exine) ruptures and the inner content come out in the form of a germ tube and subsequently by a transverse division in the germ tube forms the first rhizoid and the first prothallial cell. The prothallial cell divides to form a small filament having an apical terminal cell with two cutting faces.

• The apical cell further divides and a spathulate prothallus is formed first. Finally a mature prothallus is formed which becomes cordate, dorsiventrally flattened, aerial and photosynthetic (Fig. 7.107).

• The prothallus is made up of parenchymatous cells which are single-celled thick towards the margin and many-celled thick towards the centre. The growing points are located in the apical notch. Rhizoids are formed over the ventral surface. The prothallus is monoecious, protandrous. Antheridia appear first and are confined to the basal central or lateral regions among the rhizoids. Archegonia develop near the apical notch.

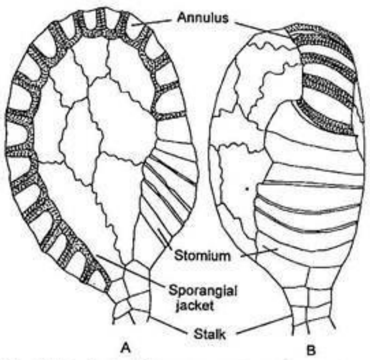


Fig. 7.106 : *Pteris* : Mature sporangium. A. Front view, B. Side view

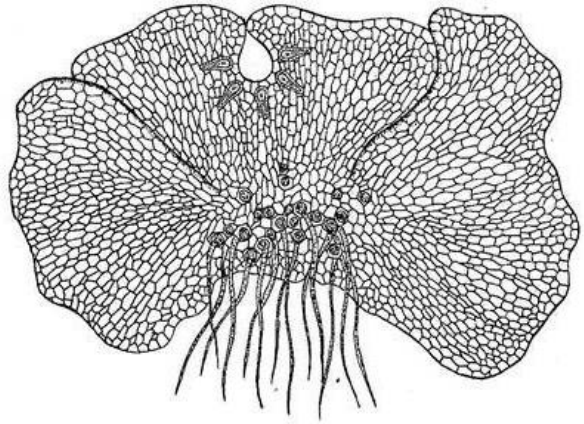


Fig. 7.107 : *Pteris* : Gametophyte

Antheridium:

• A superficial cell on the ventral surface of the prothallus functions as an antheridial initial (Fig. 7.108A-I).

• This divides transversely to form an outer upper cell and an inner lower cell (first ring cell). Due to the higher turgor pressure in the upper cell, the cross-wall between these two cells bulges down and as a result the upper cell becomes dome-shaped.

• Then the upper cell divides by an arched periclinal wall to form a dome cell and the primary androgonial cell. The dome cell further divides transversely forming a cover cell and a second ring cell.

• Then the cover cell and two ring cells by anticlinal divisions form a single-layered jacket of the antheridium. The primary androgonial cell divides repeatedly to form 20-25 androcytes and eventually each androcyte metamorphoses to form a multiflagellated coiled antherozoid.

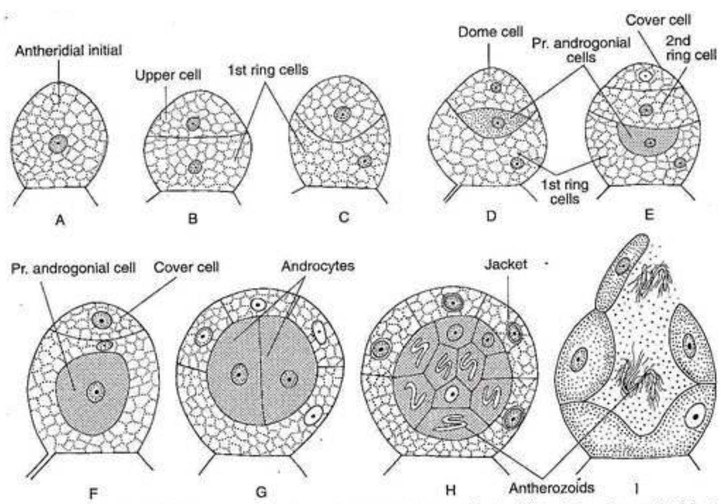


Fig. 7.108 : *Pteris* : A–H. The successive stages in the development of antheridium, I. A mature antheridium

Archegonium:
A mature archegonium of Pteris consists of a 5-6 celled projecting curved neck, a neck canal cell, a ventral canal cell and an egg (Fig. 7.110).

Fertilisation:
- The antheridium at maturity absorbs water and swells. Due to the increase in pressure within the antheridium the cover cells split apart releasing the antherozoids in a thin film of water present on the surface of the prothallus.
- At the same time the ventral canal cell, the neck canal cell and the neck cells at the top disintegrate forming an open passage for the antherozoids to come towards the egg and, eventually, one of the antherozoids fuses with the egg to form the zygote.

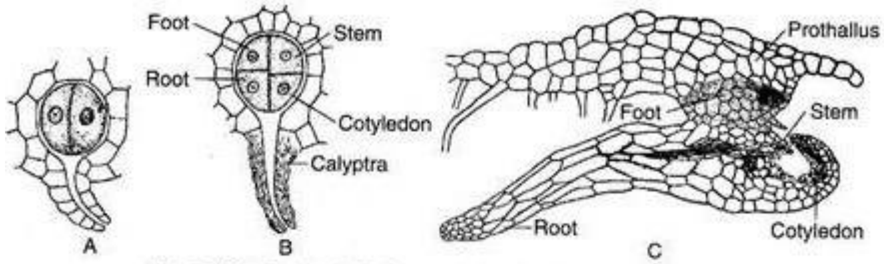


Fig. 7.109 : *Pteris* : A–C. Stages in the development of embryo

New Sporophyte (Embryo):
- In Pteris the first division of the zygote is vertical (Fig. 7.109A) followed by a second transverse division resulting in the formation of a quadrant (Fig. 7.109B). Further a 32-celled embryo is formed due to further divisions of the quadrant.
- The differentiation of embryo begins at this 32-celled stage. No suspensor is formed; the hypobasal cells form stem apex and foot, while epibasal cells form cotyledon and root (Fig. 7.109C). With the development of embryo, the venter of the archegonium forms a protective layer, called catyptra, around the embryo. In the young embryo the root and cotyledon grow more rapidly than the shoot. The root pierces the prothallus and establishes the sporeling in the soil. Later, the first leaf develops.

Life cycle of Pteris

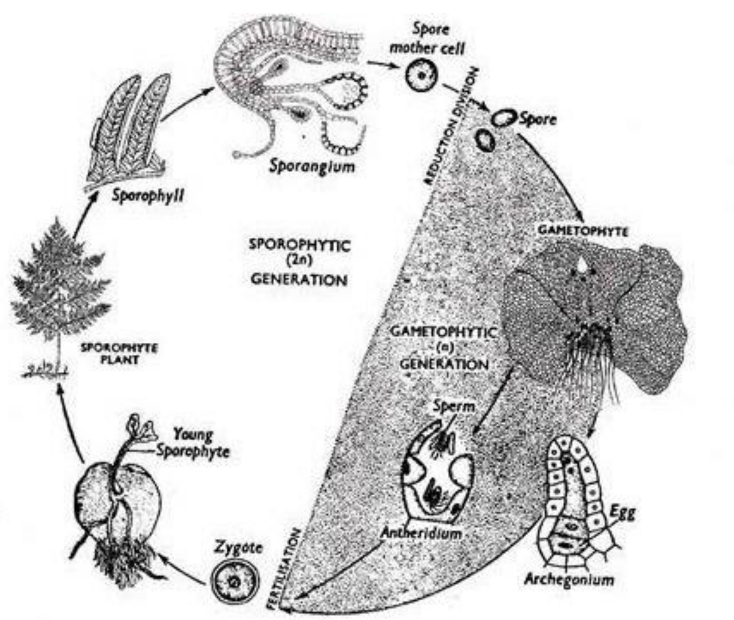


Fig. 7.110 : Life cycle of *Pteris*

Apogamy and Apospory

Apospory and apogamy are two types of asexual reproduction processes taking place in plants. Therefore, in both processes, the formation of gametes and syngamy do not take place. However, these two processes could lead to the alteration of sexual reproduction in plants.

What is Apospory?

Apospory refers to the development of gametophyte directly from the cell of sporophyte without spore formation or meiosis. The sporophyte is present in the vegetative cells of the plant. Therefore, when the gametophyte forms, the sporophytic generation marks its end. Moreover, this is important in the alternation of generations in plants.

Since the cells of sporophyte are diploid, the developed gametophyte is also diploid in nature. Thus, the sporophyte and gametophyte share the same ploidy levels. However, this process does not involve the formation of gamete cells. So, it is asexual in nature. Apospory is an asexual reproduction method commonly seen in bryophytes.

What is Apogamy?

Apogamy refers to an asexual reproduction process in plants where the embryo forms without undergoing fertilization. In such plants, sporophyte develops from the gametophyte without undergoing fertilization. Thus, the formed sporophyte will have the same ploidy level of the gametophyte.

What are the Similarities Between Apospory and Apogamy?

• Apospory and apogamy are asexual methods of reproduction.
• Both take place in plants.
• They participate in the alternation of generations in plants.
• In both phenomena, the gametophyte and the sporophyte share the same ploidy level.
• Moreover, there is no formation of gametes in both processes.
• Both these processes mainly take place in bryophytes.

What is the Difference Between Apogamy and Apospory?

Although both apogamy and apospory are asexual processes of reproduction in plants, they have differences in their development process. During apospory, the gametophyte develops from the sporophyte, while in apogamy, the embryo develops without fertilization. So, this is the key difference between apospory and apogamy.

Moreover, another difference between apospory and apogamy is their ploidy levels. In apogamy, it forms a diploid gametophyte whereas, in apospory, it forms a haploid embryo.

Heterospory in Pteridophytes:

Most of the Pteridophytes produce one kind of similar spore. Such Peridophytes are known as homosporous and this phenomenon is known as homospory. However, there are some Pteridophytes which produce two different types of spores (differing in size, structure and function). Such Pteridophytes are known as heterosporous and the phenomenon is known as heterospory. The two types of spores are microspores and megaspores. Microspores are smaller in size and develop into the male gametophyte while the megaspores are large and develop into female gametophyte.

According to Rashid (1976) only 9 genera of Pteridophytes are heterosporous. These are Selaginella, Isoetes, Stylites, Marsilea, Pilularia, Regnellidium, Salvinia, Azolla and Platyzoma.

Origin of Heterospory:

1. Palaeobotanical evidences:

It has been suggested that heterospory arose due to degeneration of some spores in a few sporangia. As more nutrition becomes available to less number of spores, the surviving spore grow better, hence increase in their size. Palaeobotanical evidences show that the earlier vascular plants wert all homosporous and the heterosporous condition appeared subsequently in the lowermost upper Devonian. Anumber of heterosporous genera belonging to the Lycopsida, Sphenopsida and Pteropsia were known in the late Devonian and early Carboniferous periods.

During this period important heterosporous genera were Lepidocarpon, Lepidostrobus, Mazocarpon, Plaeuromeia, Sigillariostrobiis (members of Lycopsid) Calamocarpon, Calamostachys, Palaeostachys (members of Sphenosida). Some of these forms even arrived at the seed stage.

According to Williamson and Scot (1894) two species of Calamostachys form the initial stage that might lead to the heterospory. These species were C. binneyana and C. casheana. In C. binneyana most of the sporangia were with large number of small spores in tetrads but in some sporangia spores were large. However, in C. casheana two different types of spores-microspores and megaspores were present in different sporangia. Similar type of abortion of spores was also observed in Stauropteris (Chaloner, 1958Lepidocarpon and Calamocarpon).

2. Evidences from Developmental Studies:

In heterosporous Pteridophytes the development of micro and megasporangia follow the same pattern. They have identical organization but for their size. While in megasporangia most of the spore mother cells degenerate but in microsporangia only a few mother cells are disorganize.

The phenomenon of heterospory becomes distinct either before or after meiosis. In Selaginella Isoetes it is distinct before meiosis. In the microsporangium all the sporocytes undergo meiosis and form a large number of microspores. However, in megasporangium, a part of the sporogenous tissue degenerates they provide nutrition to growing sporocytes (megaspores). In Isoetes there are only 50-300 megaspores in megasporangium. In Selaginella erythropus megasporangium contains only one megaspore which is functional.

In Marsilea, Salvinia and Azolla the phenomenon of heterospory becomes distinct after meiosis. In Marsilea 64 microspores and 64 megaspores are formed after meiosis in microsporangium and megasporangium respectively. In microsporangium all the microspores are functional while in magasporangium one megaspore is functional and rest degenerate.

3. Evidences from Experimental Studies:

Experimental studies on Selaginella (Goebel, 1905) and Marsilea (Shattuck, 1910) suggest that nutritional factors mainly govern the heterospory. Under conditions of low light intensity, the photosynthetic activity of Selaginella was retarted and it produced microsporangia. By sudden lowering of the temperature, the size of the microspores in the sporocarp of Marsilea increases by six times.

Biological Significance of Heterospory:

The phenomenon of heterospory is of great biological significance on account of the following facts:

(i) The development of the female gametophyte starts while the megaspore is still inside the megasporangium.

(ii) Same is true of microspores i.e., they also start germinating into male gametophytes while they are still inside microsporangium.

(iii) The female gametophyte derives its nourishment from the sporophyte i.e., female gametophyte is dependent on sporophyte for its nourishment.

(iv) The dependence of female gametophyte on sporophyte for its nourishment provides better starting point for the development of new embryo than an independent green prothallus which has to manufacture its own food.

Seed Habit in Pteridophytes:

The adoption of heterospory and the retention and germination of a single megaspore within megasporangium to form a female gametophyte, led to the phenomenon of “seed habit”, a characteristic feature of the spermatophytes. A seed is that ovule which contains an embryo developed as a result of fertilization.

The origin of seed habit is associated with the following:

(i) Production of two types of spores (heterospory).

(ii) Reduction in the number of megaspores finally to one per megasporangium.

(iii) Retention and germination of the megaspores and fertilization of the egg.

(iv) Continued development of the fertilized egg into the embryo while still in situ.

From the above observations it is concluded that the life history of Selaginella approaches towards seed habit because of the following features:

1. The occurrence of the phenomenon of heterospory.
2. Germination of megaspore inside megasporangium.
3. Retention of megaspore inside megasporangium either till the formation of female gametophyte or even after fertilization.
4. Development of only one megaspore per megasporangium for example, in Selaginella monospora, S. rupestris, S. erythropus etc.

Even then the seeds are not formed in Selaginella because:

1. Megasporangium is not surrounded by integument.
2. The retention of megaspore permanently inside the megasporangium has not been well established.
3. The embryo immediately gives rise to the sporophyte without undergoing a resting period.

Contributions of Indian Pteridologists

The major contributions on South Indian Pteridology starts with R. H. Beddome, followed by V. S. Manickam and V. Irudayaraj who published "Pteridophyte Flora of the Western Ghats, South India" on 1992 after a lapse of 128 years from the publication of " Ferns of Southern India" by R. H. Beddome (1864). South Indian pteridophytes are also well studied cytologically by various workers like Abraham, Ninan, Matthew, Kuriachan, Bhavanandan, Sankariammal, Manickam, Irudayaraj and Dominic Rajkumar from Kerala and Tamilnadu. Unfortunately, without vouchers, much of cytological studies by workers from Kerala University is of no value. Cytology of ferns of the Western Ghats, South India by Manickam and Irudayaraj (1988) is with vouchers. Father V. S. manickam contributed a lot on South Indian ferns along with his team members. He has done systematically from Taxonomy, Ecology, Cytology, Phytochemistry and Conservation of South Indian Pteridophytes by establishing the internationally recognised herbarium, XCH (St. Xavier's College Herbarium), Centre for Biodiversity and Biotechnology and Kodaikanal Botanic Garden. He has published half a dozen books and hundreds of papers on South Indian Pteridophytes.

In Kerala, Dr. B. K. Nayara, Prof. P. V. Madhusoodanan and his students are eminent pteridologists who have contributed a lot to Ferns of the Western Ghats with the discovery of many new species. Pullaih, T and Rajagopal have also contributed knowledge on Pteridophytes of Andhrapradesh and Karnataka. Today numerous young researchers mainly involved in investigating the medicinal uses of South Indian Pteridophytes. But, now a days, the interest on the field oriented research - Taxonomy is declined among the youngsters. Not only pteridophytes are endangered, but also pteridologists are endangered. We can not conserve the rare and endangered pteridophytes without having eminent Taxonomists-Pteridologists. The Indian Fern

Society founded by late Prof. S. S. Bir encourages all the pteridologists by giving various Fellowship, certificates and medals.

Economic Importance of Pteridophytes:

The economic importance of pteridophytes is not well-documented, because due attention has not been given towards their use in human welfare. However, there are many reports on their uses, specially as food plants, medicinal plants and horticultural plants.

Some of the aspects of economic importance of pteridophytes are given:

i. Pteridophytes Used as Food:

The young leaf tips of ferns, the circinate ptyxis or the chroziers are used as vegetable. The young fronds of Ampelopteris prolifera are sold in the market as ‘dheki shaak’ in India and Bangladesh. The croziers of Matteuccia struthiopters as canned or frozen are served as spring vegetable in USA and Canada. Leaves of Marsilea, commonly called ‘shushni’, are used as vegetable. The rhizome of many ferns such as Pteris, rich in starch, is used as food. The corm (modified stem) of Isoetes is used as food by pigs, ducks and other animals.

ii. Pteridophytes Used as Fodder:

Dry fronds of many ferns form the livestock for catties. The quadrifid lamina of Marsilea resembles a clover (Trifolium) has been used as fodder for animals as a substitute for clover.

iii. Pteridophytes Used as Medicine:

The spores of Lycopodium have been widely used in pharmacy as protective dusting powder for tender skin and also as water-repellants. The foliages of Lycopodium are used as tincture, powder, ointment and cream as a stomachic and diuretic. The foliage decoction is used in home-opathy to treat diarrhoea, bladder irritability, eczema, rheumatism, constipation and inflammation of liver. Equisetum is rich in silicic acid and silicates. Potassium, aluminium and manganese, along with fifteen types of flavonoid compounds, have been reported from Equisetum. The flavonoids and saponins are assumed to cause the diuretic effect. The silicon is believed to exert connective tissue-strengthening and anti-arthritic action.

Several ferns have been used as herbal medicine. An oil (5% Filmaron and 5-8% Filicic acid) extracted from the rhizome of Aspidium is used as a vermifuge, especially against tapeworm. The decoction of Asplenium is used for cough and a good hair wash. The expectorant of Polypodium is used as a mild laxative, while the tonic is used for dyspepsia, loss of appetite and hepatic problem. The root decoction of Osmunda regalis is used for treatment of jaundice. The ointment made from its root is used for application to wound. The extraction of Osmanda vulgaris, commonly known as ‘Green oil charity’, is used as remedy for wounds. The chemically active principal ‘Marsiline’ isolated from Marsilea is found to be very effective against sedative and anti-convulsant principal. The rhizome and frond bases of Dryopteris have been used to determine the origin and pathways of dispersed pathogenic insects like corn ear- worm. The preparation of Ophioglossum vulgatum as ‘Green oil charity’ is also used as remedy for wounds.

iv. Pteridophytes Used as Horticultural Plants:

Many species of pteridophytes are cultivated for their aesthetic value. Many variants and cultivars of Psilotum have been brought in cultivation in nurseries and greenhouses in the nick-name of ‘whisk fern’. Some epiphytic species of Lycopodium (e.g., L. phlegmaria, L. lucidulum) are aesthetically more valued and can be grown on hanging baskets. Several species of Selaginella are used as a ground cover in an undisturbed area because of their decent foliage and colour. Salaginella willdenovii, S. uncinata, etc., are grown in gardens for their decent blue colour. S. lepidophylla, S. bryopteris, etc., are sold as dried under the name ‘resurrection plants’ which rejuvenate on contact with water.

Several ferns such as Angiopteris, Asplenium, Marattia, Microsorium, Nephrolepis, Phymatodes, etc., have aesthetic values for their beautiful habit, graceful shape of the leaves, and beautiful soral arrangement. Thus, these characteristics make them horticulturally important plants.

v. Pteridophytes Used as Biofertiliser:

Azolla is a free-floating water fern which can multiply very quickly through vegetative propagation. There are hundreds of moss-like leaves harbouring live colonies of dinitrogen fixer Cyanobacterium — Anabaena azollae. The relationship between the alga and Azolla is symbiotic where the alga provides nitrogen to the plant. Thus, Azolla in full bloom in the waterlogged rice fields may serve as a green manure. Rice farmers of our country are using Azolla as biofertiliser for the better production of their crops.

vi. Pteridophytes Used as Indicator Plants:

Like angiosperms, pteridophytes are being used as indicator plants.

Equisetum accumulates minerals, especially gold, in their stem. The rate of accumulation even reaches up to 4.5 ounce per ton. Equisetum may be referred to as gold indicator plants which help in searching a region for gold ore deposits. Similarly, Asplenium adulterinum is an indicator of nickel and Actinopteris australis is a cobalt indicator plant. Thus, these plants are found to be valuable in prospecting for new ore deposits.

vii. Pteridophytes Used for Various Purposes:

The stem of Equisetum was used for polishing wood in ancient times and to clean utensils. The roots and stems of Osmunda are used to make beds for growing orchids. Water boiled with Lycopodium clavatum is used for dyeing the woollen clothes which becomes blue when dipped in a bath of Brazil wood.

The powder of Lycopodium is highly inflammable and is used in pyrotechny and for artificial lighting. Thus, Lycopodium powder finds its wide use in demonstration of artificial lighting on the stage, because it disperses easily in the air and only a small quantity is needed to produce an explosion. Some of the pteridophyte members are considered to be the obnoxious weeds. Pteridium aquilinum is a carcinogenic plant which can rapidly invade the open forest lands, thus eliminating the other plants of the forest floor. The free-floating water fern, Salvinia, quickly propagates vegetatively, and thus occupy the entire water surface of lakes, ponds and irrigation reservoirs preventing free flow of water.

Affinities of Pteridophytes with Bryophytes

Resemblances of Bryophytes with Pteridophytes

- Both have the heteromorphic alternation of generations.
- Multicellular sporangia.
- The presence of cuticle.
- Terrestrial habitat.
- Sexual reproduction – Oogamous.
- Flagellated male gametes while female non-motile.
- No siphanogamy, so fertilization is internal with the requirement.
- No separate asexual reproduction by spores as seen in algae and fungi.

Differences of Bryophytes with Pteridophytes

1. The body structure of bryophytes has leafy or thalloid plant body, while in pteridophytes plant body in differentiated into roots, stems, and leaves.
2. No vasculature system in bryophytes which means xylem and phloem tissues absent, whereas in pteridophytes proper vasculature is present which means xylem and phloem tissues is present.
3. No roots are present in bryophytes instead rhizoids are present; In pteridophytes roots are present.

4. Cell are haploid type in bryophyte, and diploid cells are present in pteridophytes
5. No true stems or leaves are present in bryophytes, whereas pteridophytes have true stems and leaves.
6. Archegonium and its formation are properly exposed and neck is formed of six rows of cell in bryophytes; Partially embedded archegonium and its neck have only four rows of cells in pteridophytes.
7. Antheridium is stalked kind of bryophytes; In pteridophytes sessile kind of antheridium.
8. Bryophytes are homosporous, whereas pteridophytes can be homosporous or heterosporous.
9. In bryophytes, the gametophyte is dominating whereas saprophytes are dominating in pteridophytes.
10. Examples include mosses, liverworts, hornworts of bryophytes while spikemosses, clubmosses, ferns, quillworts are examples of pteridophytes.
11. Gametophytes of bryophytes are always autotrophic and macroscopic; while in pteridophytes, gametophytes are saprophytic or extremely reduced microscopic structures.

BASIS	BRYOPHYTES	PTERIDOPHYTES
Body definition	Bryophytes has leafy or thalloid plant body.	In pteridophytes plant body in differentiated into roots, stems, and leaves.
Vasculature system	No vasculature system, which means xylem and phloem absent.	Proper vasculature is present which means xylem and phloem is present.
Vascular tissue	Absent	Present
Presence of roots	No roots, instead rhizoids are present helps in anchoring	Roots are present.
Presence of stems or leaves	No true stems or leaves are present.	True stem and leaves are present.
Archegonium and it's formation	Common exposure of archegonium, whose neck is formed of six rows of cells.	Partially embedded archegoninum and it's neck has only four rows of cells.
Antheridium	Stalked.	Sessile.
Dominating part	Gametophyte is dominating.	Sporophyte is dominating.
Cell type	It has haploid cells.	It has diploid cells.
Sporophytic phase	Depends completely on gametophytic.	Saprophytic phase is an independent autotrophic.
Examples	Mosses, liverworts, hornworts.	Spikemosses, clubmosses, quillworts

Affinities of Pteridophytes with Gymnosperms

Resemblances of Gymnosperms with Pteridophytes

1. Plant body is sporophytic, and the sporophyte is differentiated into roots, stem and leaves in both gymnosperms and pteridophytes.
2. Members of both the groups show a regular alternation of sporophytic and gametophytic generations.
3. Cercinate vernation of the young leaves is seen in both the groups.
4. Xylem consists of tracheids and xylem parenchyma. Vessels are absent in pteridophytes as well as gymnosperms (except Gnetales).
5. Phloem lacks companion cells in both the groups.
6. Heterospory is common in both gymnosperms and pteridophytes.
7. Gametophytic generation is dependent upon sporophytic generation.
8. Cycads resemble pteridophytes in possessing ciliated sperms.
9. Permanent retention of megaspores within the mega-sporangium is observed in both the groups.
10. **"Ferns with seeds"** (Pieridosperms) was the common name given to the primitive gymnosperms like Cycadofilicales due to their resemblances with the ferns.

Differences of Gymnosperms with Pteridophytes

Gymnosperms	Pteridophytes
Mostly trees	Mostly herbs or shrubs
Grow in xerophytic conditions	Grow in mesophytic condition
Tap root system	Adventitious root system
Secondary growth present	Secondary growth usually absent
Ovules and seeds present	Ovules and seeds absent
Gametophyte is fully dependent on sporophyte	Gametophyte and sporophyte are two separate plants
Pollen tube is formed	No pollen tube formation
Neck canals cells are absent	Neck canal cells present