ENTRI

MODULE 1

PTERIDOLOGY

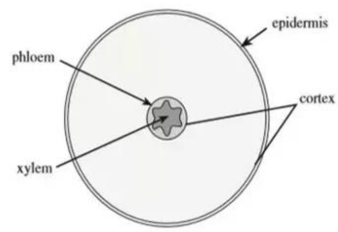
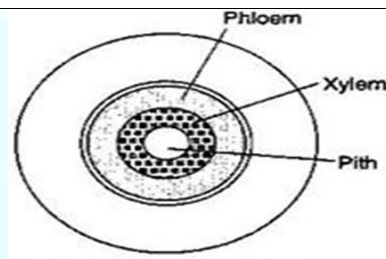
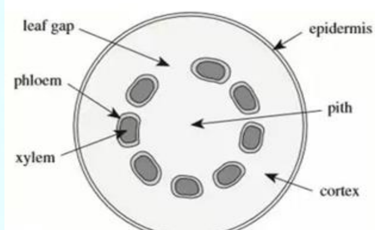
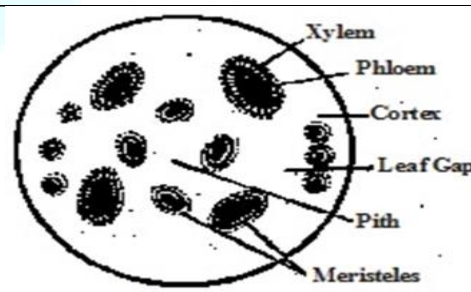
INTRODUCTION

- **Pteridophyta** – Haeckel (1866)
- **Pteron** - feather , Phyton - plant
- Vascular Cryptogams
- **Origin** – Silurian period of Paleozoic Era.
- Pteridology

SALIENT FEATURES OF PTERIDOPHYTES

- **Plant Body** – Sporophyte(2n)
- **Terrestrial**- cool, moist and shady places
  - **Aquatic** - *Azolla, Marsilea, Salvinia*
  - **Xerophytic** - *Selaginella lepidophylla, Equisetum arvense*
  - **Epiphytic** - *Lycopodium phlegmaria, Selaginella rupestris*
- Leaves are microphyllous or megaphyllous
  - Microphyllous – simple leaves with a single unbranched midvein.
  - Megaphyllous – large ,compound leaves with dissected vein.
- Root and stem possess well developed vascular system.Cambium is absent.
- Vascular tissue is usually arranged in various kinds of steles
  1. Protostele
  2. Siphonostele
  3. Dictyostele

4. Polycyclic stele

TYPES OF STELES	FEATURES	FIGURE
Protostele	A stele consisting of central core of xylem surrounded by phloem, without pith.	 Protostele
Siphonostele	A stele consisting of central core of pith, surrounded by concentric layers of xylem and phloem.	 Ectophloic Siphonostele
Dictyostele	A type of siphonostele with overlapping leaf gaps.	 Dictyostele
Polycyclic stele	Two or more concentric vascular bundles which are solenostelic in nature	 Fig. - Polycylic Stele

REPRODUCTION

- By means of spores produced in sporangia.
- Position of Sporangia – leaves, stems or on modified leaf like structures called sporophylls.
- **Psilotum** – Synangium

- **Equisetum, selaginella** – strobilus

- **Marsilea** – sporocarp

- **Ophioglossum –** spike

- **Pteris -** sorus

DEVELOPMENT OF SPORANGIUM

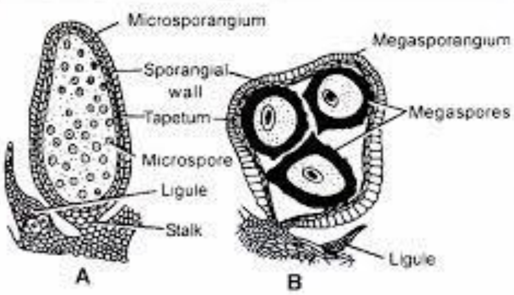
–By Eusporangiate and Leptosporangiate

- **Eusporangiate** – Group of superficial cells
- **Leptosporangiate** – From a single initial cell

- In order Filicales, sporangia are aggregated to form sorus.
- Sorus are of three types – Simple, Gradate, Mixed.

Spores

- Are of two types – Homosporous and Heterosporous
  - **Homosporous** – *lycopodium,pteris,equisetum*
  - **Heterosporou**s- *selaginella, marsilea,salvinia*



A. V.S. Microsporangium,
B. V.S Megasporangium

- Spores germinate to produce gametophyte(n).
- The gametophyte is a free living generation .It is highly reduced and is called a prothallus**.**

Sex Organs

– Antheridia and Archegonia

- The gametophyte bear antheridia and archegonia on same or different prothalli.
- Water is essential for fertilization.

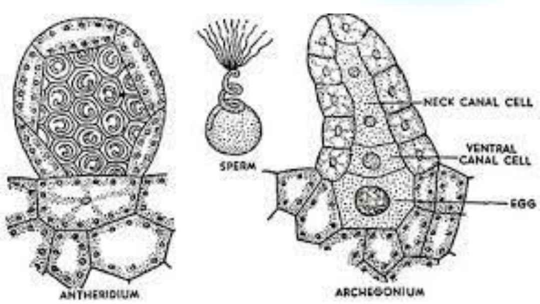
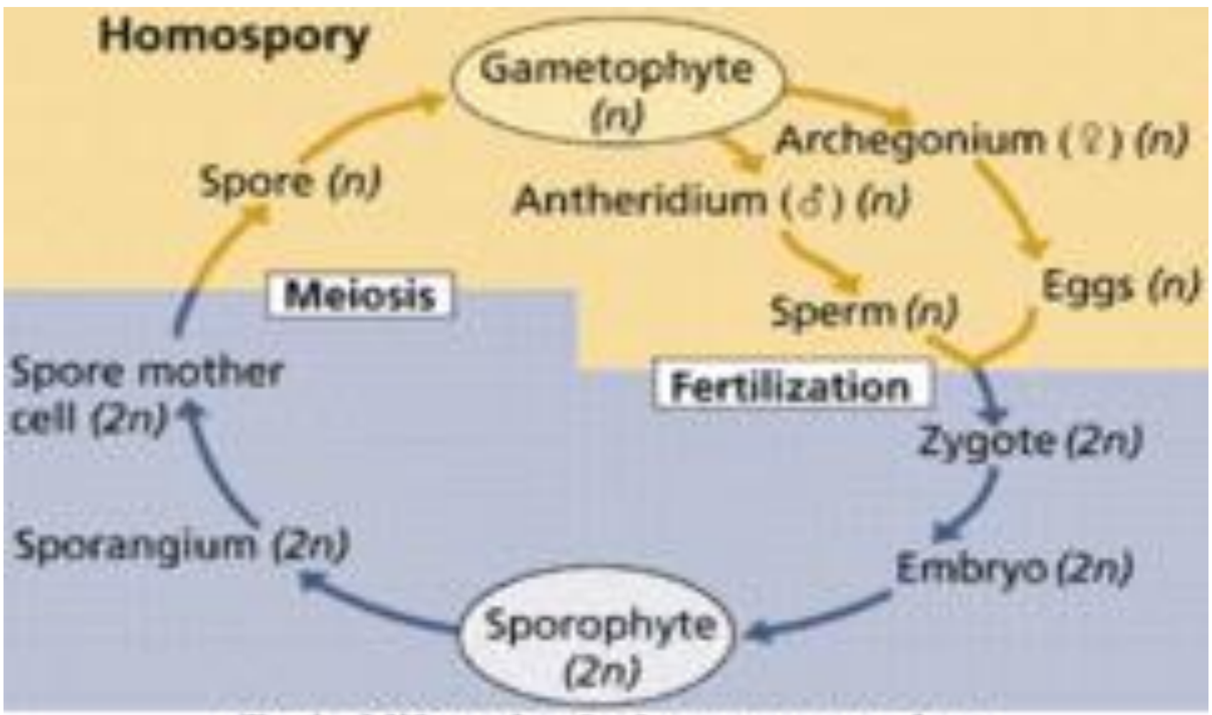


Fig. 213. Antheridium and archegonium of fern.

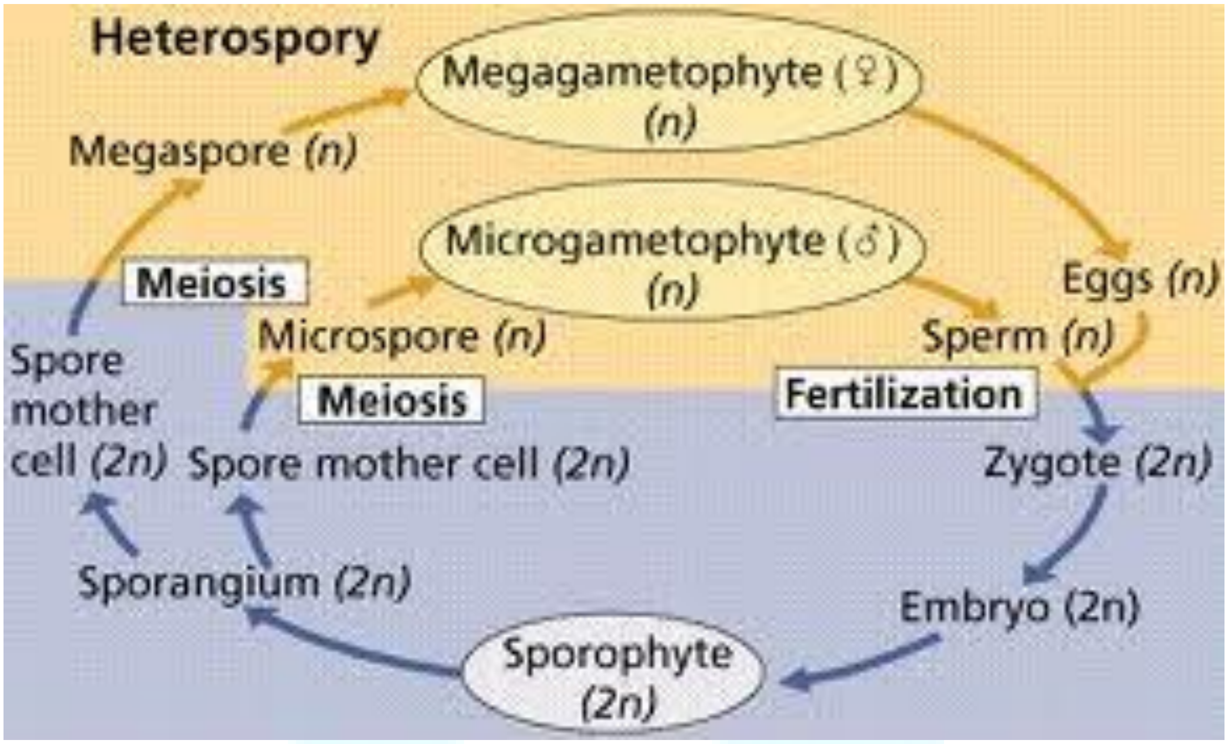
Zygote

- Male gamete (n) + egg(n) = zygote.
- **Zygote(2n)** – First cell of sporophytic generation.
- **Zygote** develops into a well developed sporophyte.
- The sporophytic generation is dominant and conspicuous, but dependent on gametophytic generation early in life.

PTERIDOPHYTES EXHIBITS ALTERNATION OF GENERATIONS



Typical life cycle of a homosporous plant.



Heterospory
Megagametophyte (♀)
(n)
Megaspore (n)
Microgametophyte (♂)
(n)
Meiosis
Eggs (n)
Microspore (n)
Sperm (n)
Spore
mother
cell (2n)
Meiosis
Fertilization
Spore mother cell (2n)
Zygote (2n)
Sporangium (2n)
Embryo (2n)
Sporophyte
(2n)

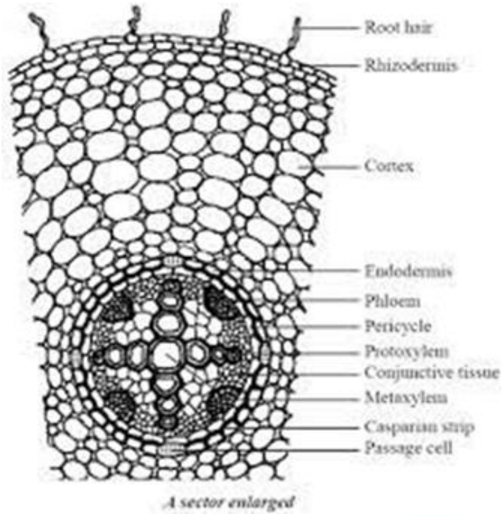
STELAR EVOLUTION

STELAR EVOLUTION IN PTERIDOPHYTES

- STELE – The central vascular cylinder in higher plants
- COMPONENTS OF STELE
  - Xylem
  - Phloem
  - Pericycle
  - Medullary Rays and Pith(if present)

STELLAR THEORY

- Proposed by *Van Tieghem* and *Douliot* (1886)
- **Highlights of stellar theory are** :
  - ✓ Stele is a real entity and present universally in all higher plants.
  - ✓ Cortex and stele are two fundamental parts of a shoot system.
  - ✓ Main components of stele are – Xylem and Phloem.
  - ✓ Pericycle, medullary rays and pith are also the components of stele.
  - ✓ Stele and cortex are separated by endodermis.



TYPES OF STELES IN PLANTS

1. **Protostele**
2. **Siphonostele**
3. **Solenostele**

1. PROTOSTELE

- A stele with a solid core of xylem at the centre surrounded by phloem, pericycle and endodermis.
- Pith is absent.
- Simplest and primitive type of stele.

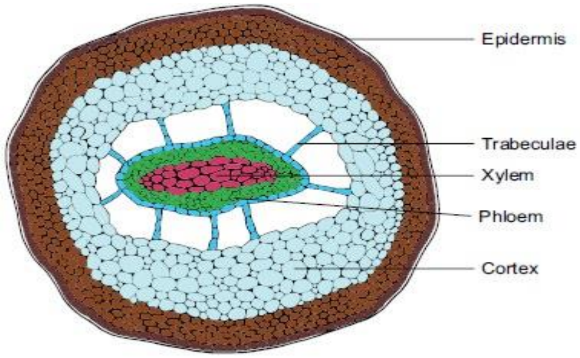


Figure 2.28: T.S. of Stem

Types of protostele in pteridophytes

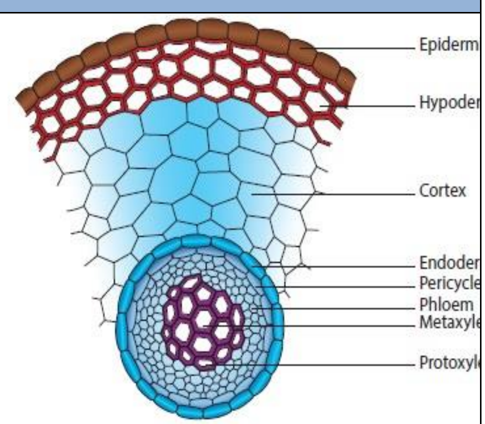
a. Haplostele

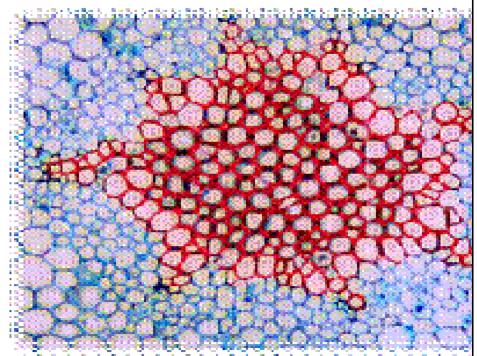
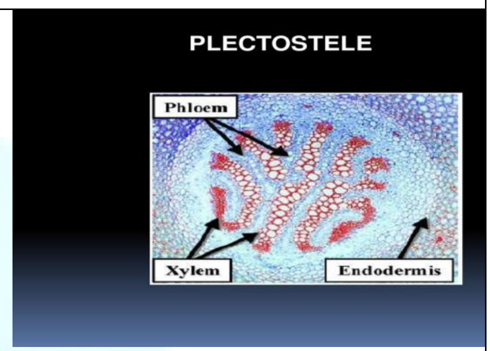
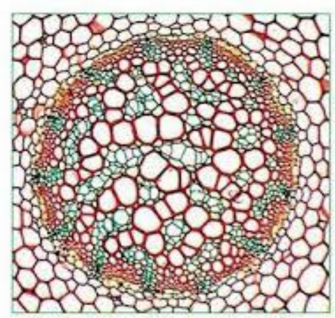
b. Actinostele

c. Plectostele

d. Mixed Protostele

e. Mixed Protostele With Pith

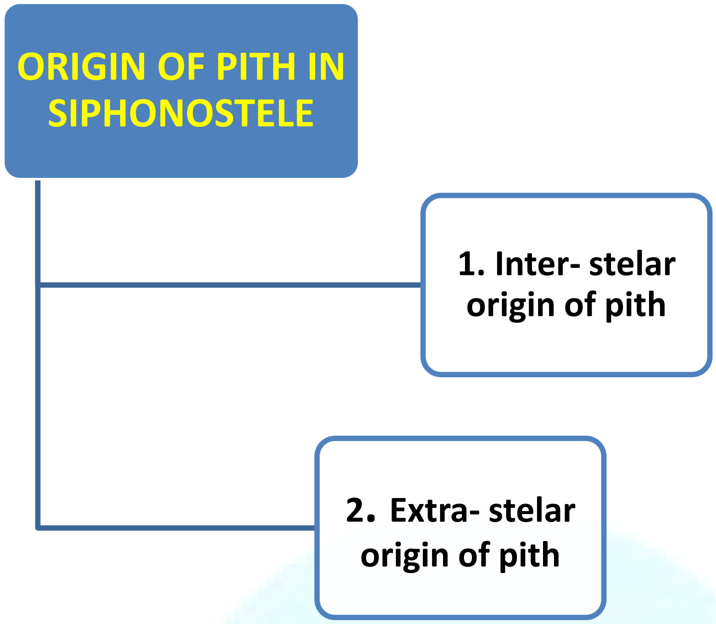
Types of protostele in pteridophytes	Features	Figure
Haplostele	• A protostele with a central core of xylem surrounded by uniform layers of phloem. • Named by Brebner in 1902 • Most primitive type of protostele. • Usually present in fossil genera – Rhynia . • Living genera – Selaginella, Lygodium	 **Figure 2.27:** T.S. of Rhizophore

Actinostele	• Protostele with xylem core having radial arms • Xylem is star shaped or stellate • Phloem is not continuous. • Named by Brebner in 1902. • Example – *Lycopodium serratum*. •	
Plectostele	• Xylem occurs as several plates which are more or less parallel to each other. • Xylem plates alternates with phloem patches. • Named by Zimmermann in 1930 • Example – *Lycopodium clavatum*	
Mixed Protostele	• Xylem is divided into several units or groups • Xylem groups are scattered in the ground mass of phloem • Example: *Lycopodium cernuum*	 Mixed Protostele (*Lycopodium cernuum*)

Mixed Protostele With Pith	• Formation of pith started for the first time in evolution. • Patches of parenchymatous region occur in association with xylem. • Most advanced among protostele • Considered as a connecting link between protostele and siphonostele • Example – *Lepidodendron selaginoides*	

2. SIPHONOSTELE

- Medullated protostele (central core of pith surrounded by xylem)
- Advanced type than protostele



1. **<u>Inter- stelar origin of pith</u>**

- Proposed by Bower in 1923 and supported by Fahn in 1960.
- Innermost vascular tissue in a protostele changes into parenchymatous cells.

2. **<u>Extra- stelar origin of pith</u>**

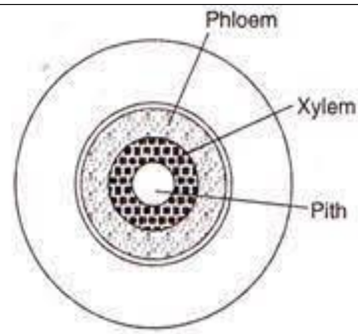
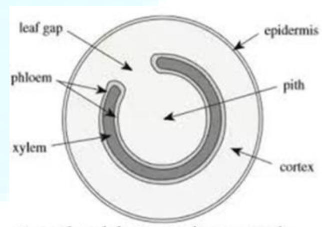
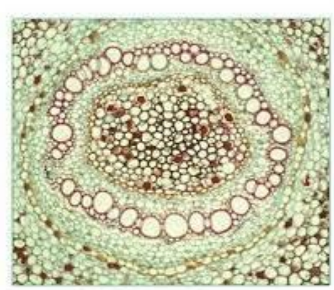
- Proposed by Jeffery.
- Pith is formed by the invasion of cortical parenchymatous cells into the stele

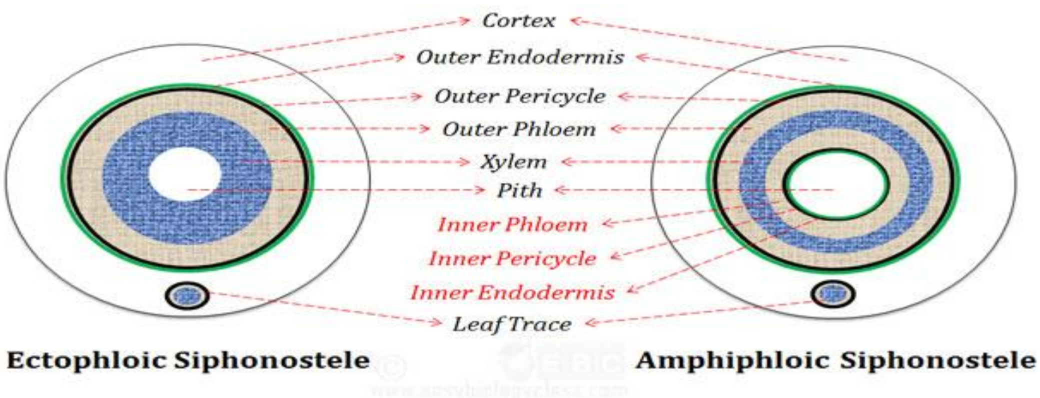
  Invasion of pith occurs through the leaf gap.

<u>Different types of siphonostele</u>

- Based on the position and distribution of phloem, siphonosteles are of two types. They are :

  1. **Ectophloic Siphonostele**
  2. **Amphiphloic Siphonostele**

TYPES OF SIPHONOSTELE	FEATURES	FIGURE
Ectophloic Siphonostele	• Phloem present only on the external side of the xylem. • Phloem is externally surrounded by pericycle and endodermis • Pith is located at the centre • Leaf traces present, but leaf gap absent • Example: Osmunda	 Ectophloic Siphonostele
Amphiphloic siphonostele	• Phloem is present on both sides of the xylem. • Pith is located at the centre • Xylem on inner side is surrounded by inner phloem,inner pericycle and inner endodermis • Xylem on outer side is surrounded by outer phloem, outer pericycle and outer endodermis • Example - Marsilea	 Amphiphloic siphonostele  **Amphiphloic Siphonostele** **(*Marsilea Rhizome*)**

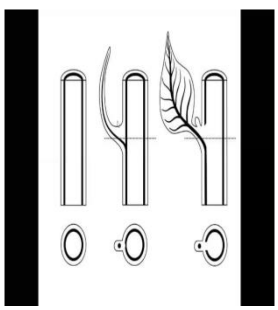


3. SOLENOSTELE

- Solenostele is a sub-category of siphonostele.
- A siphonostele with a leaf gap is called a solenostele.

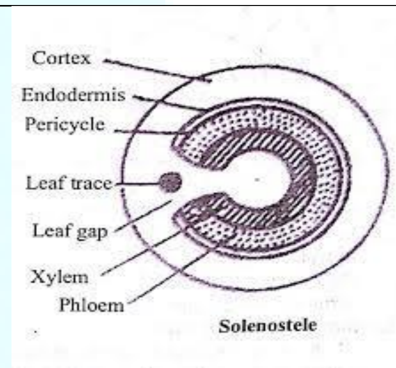
Leaf trace and leaf gap

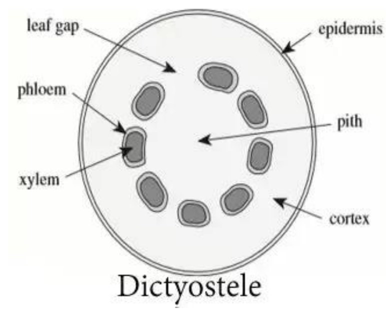
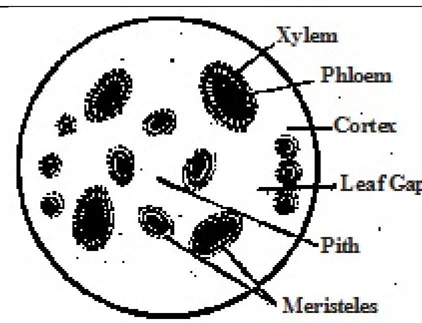
- Leaf Trace – is an extension of the vascular system of the stem with that of the leaf.
- Leaf Gap –is a break in the vascular tissue of a stem above the point of attachment of a leaf trace.

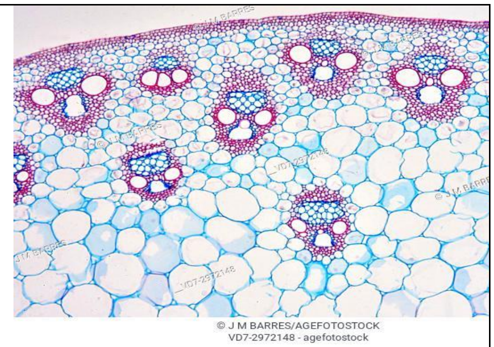


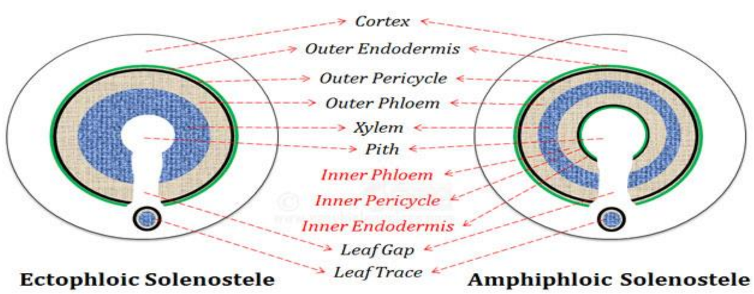
Different types of solenosteles

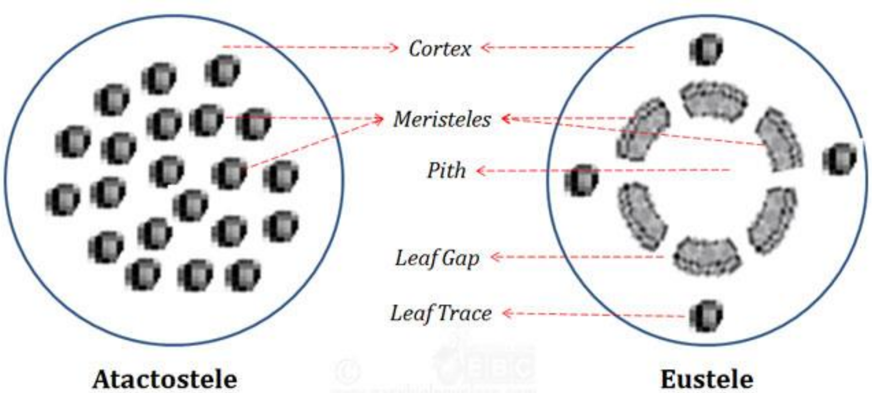
1. **Ectophloic solenostele**
2. **Amphiphloic solenostele**
3. **Dictyostele**
4. **Polycyclic stele**
5. **Eustele**
6. **Atactostele**

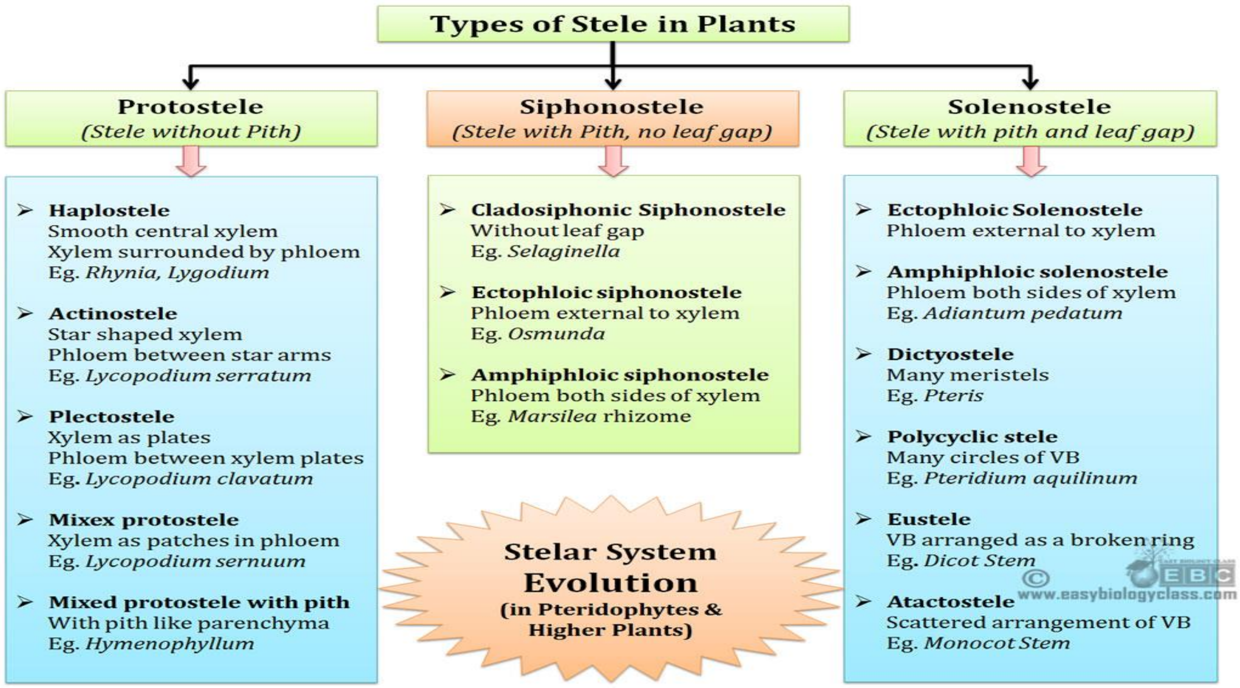
Different types of solenosteles	FEATURES	FIGURE
Ectophloic solenostele	• Derived from ectophloic siphonostele • Thus phloem is present only on the outer side of xylem. • Leaf trace and leaf gap is present	
Amphiphloic solenostele	• Derived from amphiphloic siphonostele • Phloem is present on both sides of the xylem. • Phloem in both sides is inturn surrounded by pericycle and endodermis • Leaf gap and leaf trace is present. • Example – *Adiantum pedatum*	

Dictyostele	• Solenostele(amphiphloic solenostele) is broken into many separate vascular strands • Each separate vascular strand – meristele • Large number of leaf gaps are present • Example - Pteris	
Eustele	• Type of ectophloic siphonostele with overlapping leaf gaps. • Stele is broken into distinct collateral vascularbundles then it is called eustele. • Individual vascular bundle in the eustele are arranged as broken ring in the ground tissue.	
Polycyclic stele	• Dictyostele arranged in two or more concentric rings • Always solenostelic in nature	 Fig. - Polycylic Stele

Atactostele	• Similar to eustele • But the individual vascular bundles are scattered in the ground tissue. • Named by Esau(1953) • Example –in monocots	






Types of Stele in Plants
Protostele
(Stele without Pith)
Siphonostele
(Stele with Pith, no leaf gap)
Solenostele
(Stele with pith and leaf gap)
Haplostele
Smooth central xylem
Xylem surrounded by phloem
Eg. Rhynia, Lygodium
Actinostele
Star shaped xylem
Phloem between star arms
Eg. Lycopodium serratum
Plectostele
Xylem as plates
Phloem between xylem plates
Eg. Lycopodium clavatum
Mixex protostele
Xylem as patches in phloem
Eg. Lycopodium sernuum
Mixed protostele with pith
With pith like parenchyma
Eg. Hymenophyllum
Cladosiphonic Siphonostele
Without leaf gap
Eg. Selaginella
Ectophloic siphonostele
Phloem external to xylem
Eg. Osmunda
Amphiphloic siphonostele
Phloem both sides of xylem
Eg. Marsilea rhizome
Stelar System
Evolution
(in Pteridophytes & Higher Plants)
Ectophloic Solenostele
Phloem external to xylem
Amphiphloic solenostele
Phloem both sides of xylem
Eg. Adiantum pedatum
Dictyostele
Many meristels
Eg. Pteris
Polycyclic stele
Many circles of VB
Eg. Pteridium aquilinum
Eustele
VB arranged as a broken ring
Eg. Dicot Stem
Atactostele
Scattered arrangement of VB
Eg. Monocot Stem
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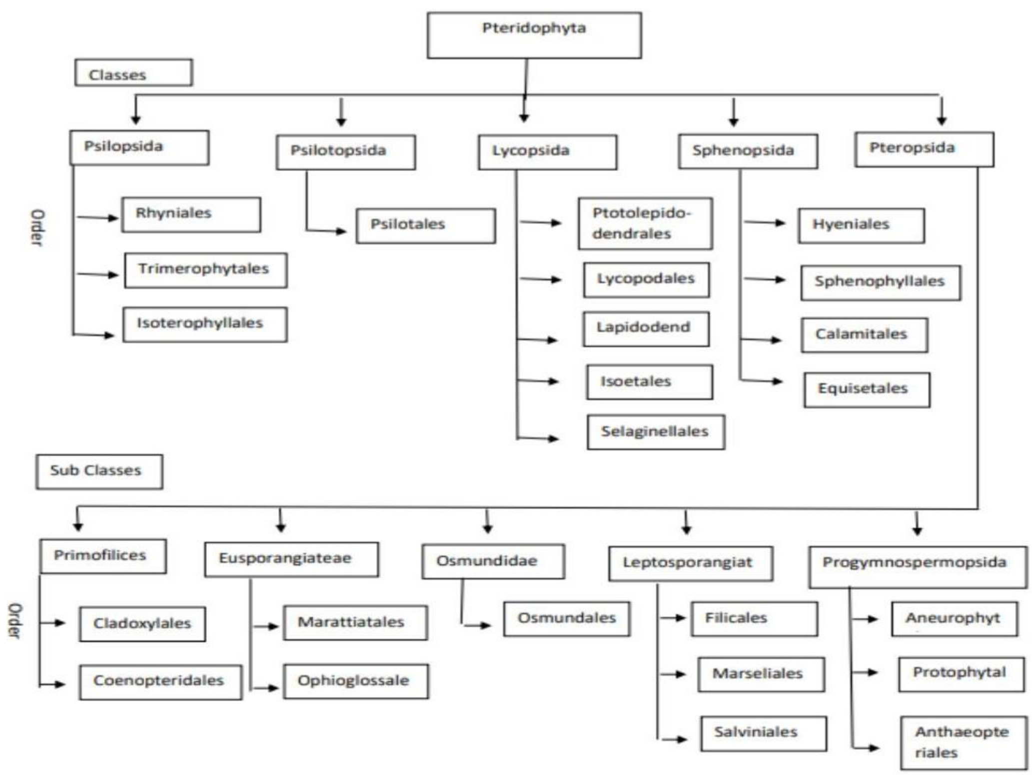
CLASSIFICATION OF PTERIDOPHYTES

- The term Pteridophyta was first coined by Haeckel(1866)
- 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.
- Sinnot (1935) introduced a new term Tracheophyta for a division which possess sporophyte with a well developed vascular tissue.
- 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.

1. **Psiloposida**
2. **Lycopsida**
3. **Sphenopsida**
4. **Pteropsida**

CLASSIFICATION OF PTERIDOPHYTES (Reimer(1954)& Sporne(1966))

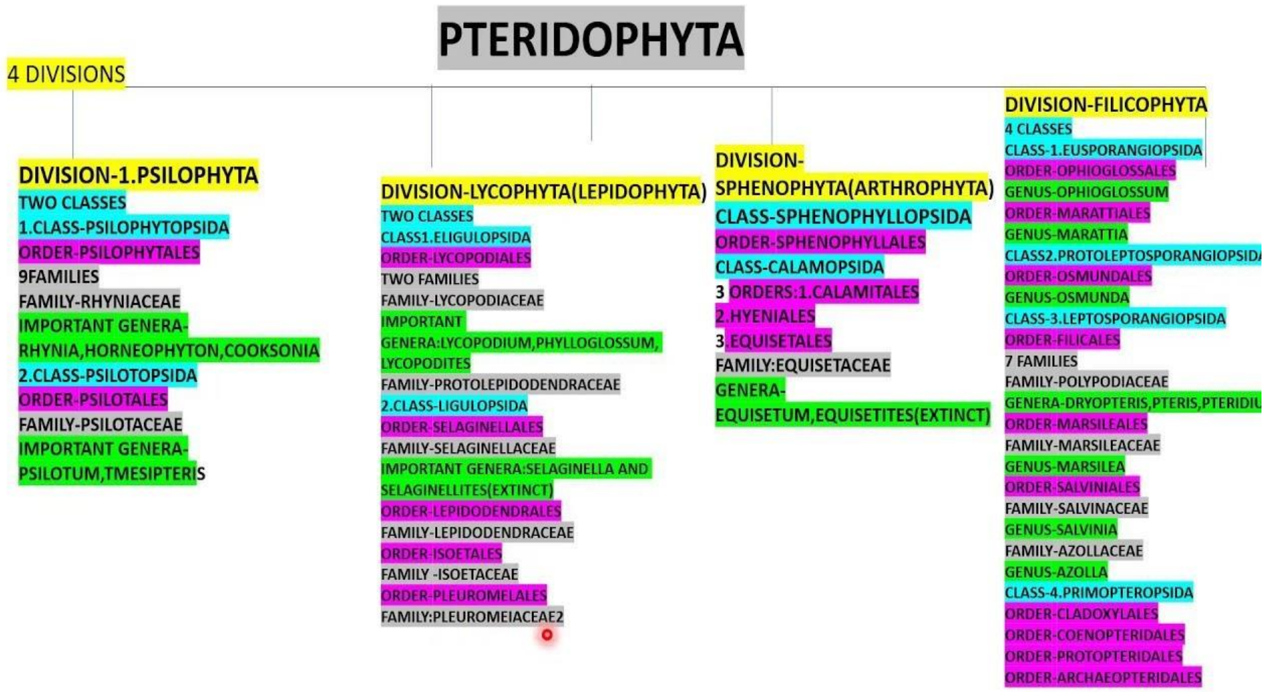


CLASSIFICATION OF PTERIDOPHYTES

- According to recommendation of I.C.B.N (1952) the name of the division should end in the suffix – phyta,of a sub-division in – phytina and a class in – opsida
- On the basis Smith (1955) divided the pteridophytes into

  four divisions

  1. Psilophyta
  2. Lycophyta
  3. Sphenophyta
  4. Pterophyta



RHYNIA

Division: Psilophyta

Class: Psilophytopsida

Order: Psilophytales

Family: Rhyniaceae

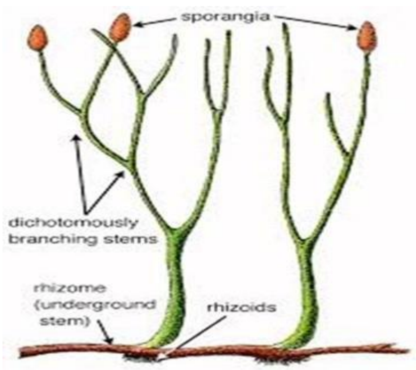
Genus: Rhynia

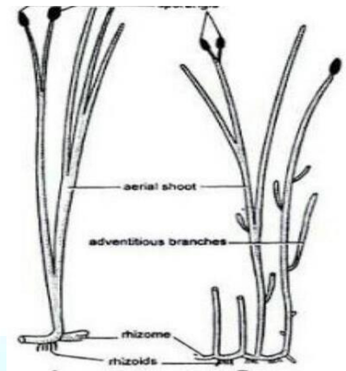
- Fossil plant
- *Rhynia major* and *Rhynia gwyne vaughani*
- Discovered by -Kidston and Lang (1971)
- Seen in Devonian period

Sporophyte:

- Plant Body – subterranean,creeping,cylindrical and dichotomously branched rhizome with dichotomously branched aerial leafless shoots.

- Root absent but tuft of rhizoids develop from rhizome.
- In *Rhynia gwyne vaughani* aerial shoots has many adventitious branches.
- Aerial branches ends in tapering vegetative apices or pear shaped sporangia.





ANATOMY OF RHYNIA STEM

- Epidermis – single layered,thick cuticle, stomata present
- Cortex – outer and inner
  - Outer–1-4 layered, compact polygonal parenchymatous cells.
  - Inner- spherical, parenchyma cells with intercellular spaces, the chief photosynthetic region.

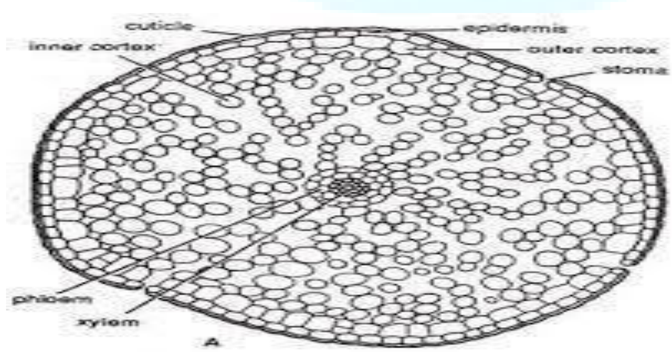


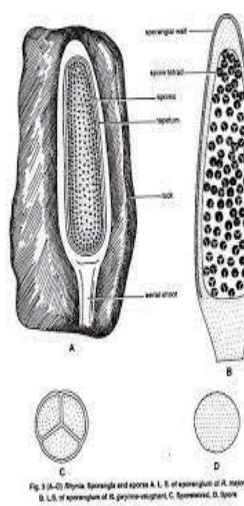
Fig. 207. Rhynia. A. T.S. rhizome; B.

- Central Cylinder
  - Protostele, primitive.
  - Xylem composed of tracheids with annular and spiral thickening.
  - No sieve plates in phloem.
  - Endodermis and pericycle absent.

REPRODUCTIVE STRUCTURES

- Sporangia were present singly at the tips of some aerial branches.
- Sporangia – oval to cylindrical, with distal pointed and broad basal end
- Sporangia of *Rhynia major* were larger than *Rhynia gwyne Vaughani.*

Structure of sporangium:



- Sporangium is surrounded by multilayered jacket.
- Each sporangium had a massive wall of 5 cells thick.
- Outer layer was a cuticularised epidermis.
- Middle layer – 2-3 layers of parenchyma cells.
- Innermost layer – tapetum.
- Large number of spore tetrad in sporangial cavity.
- Spores homosporous.
- No specialised mechanism for dehiscense.

ENTRI

GAMETOPHYTE

- Lyon (1957)-Some germinating spores which show multicellular structure developing at the end of germ tube was the indication of the presence of gametophyte in Rhynia.
- Merker(1959) is of the opinion that the underground creeping parts of Rhynia is the gametophyte but not the rhizome.
- Not much is known about gametophyte of Rhynia.

CHARACTERISTIC FEATURES OF PSILOPHYTOPSIDA

- Group of extinct plants.
- Plant body is a sporophyte.
- Possess dichotomously branched prostrate rhizome and dichotomously branched upright aerial branches.
- Tuft of rhizoids on the rhizome.
- Roots and leaves were absent.
- Stem is protostelic.
- Spores are homosporous.
- Spore tetrads were borne at the terminal sporangia.
- Example – *Rhynia, Horneophyton, Psilophyton, Asteroxylon.*

Division: Psilophyta

Class: Psilotopsida

Order: Psilotales

Family: Psilotaceae

Genus: Psilotum

- Two species –

  1. *Psilotum nudum*(25cm) – Whisk fern

  2. *Psilotum flaccidum* (90 cm pendulous epiphyte)

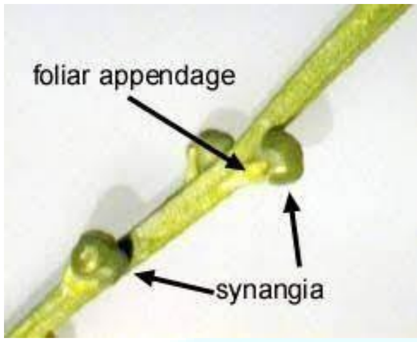
MORPHOLOGY

- The plant body is a sporophyte

1. Rhizome – branched, brown in colour ,lack roots, rhizoids are present
   -- is associated with mychorrhizal association
2. Aerial shoot – green, slender, cyindrical and dichotomously branched
3. Leaves- small scale like (sterile and fertile appendages)

Synangium

- Fertile appendages at the distal end of the aerial shoot bears in axils a trilobed structure



ANATOMY OF AERIAL SHOOT

1. **Epidermis** – single layered, thick cuticle, stomata
2. **Cortex** - outer – 2-5 layered chorenchymatous cells

   -middle – 4-5 layered sclerenchymatous cells

   -inner - many layered parenchymatous cells
3. **Endodermis** – well developed, casparian strip
4. **Stele** - Actinostele

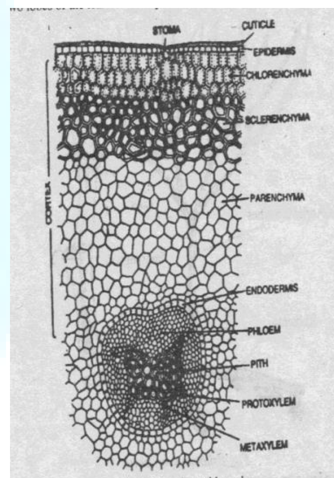


Fig: Section of aerial branches

ANATOMY OF RHIZOME

1. **Epidermis** – single layered,thick cuticle
2. **Cortex** - outer – endophytic mychorrhizal association

   - middle – prenchymatous cortex

   -inner –phlobaphene(brown)
3. **Endodermis** and **Pericycle** –single layered
4. **Stele** - protostele

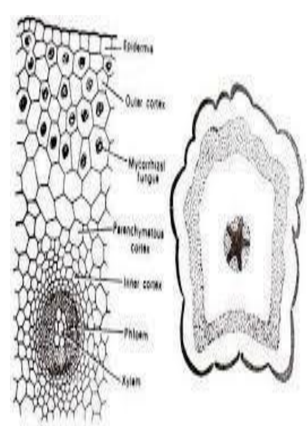


Fig. 20. Psilotum : T.S. of Rhizome.
A. Sector Enlarged, B. Ground Plan.

REPRODUCTION

1. **Vegetative Reproduction** – Gemmae
2. **Sporophyte reproduces** by asexual reproduction
3. **Gametophyte reproduces** by sexual reproduction

ASEXUAL REPRODUCTION

- Spores, produced in complex trilobed structure synangium.
- It is a 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.

Structure of synangium:

- Wall of synangium is 3-4 layered.
- Thick outer wall forms the epidermis.
- Inner wall separates the three locules.
- Each locule is filled up with large number of spores. Spores are homosporous.
- Mature spores are reniform.

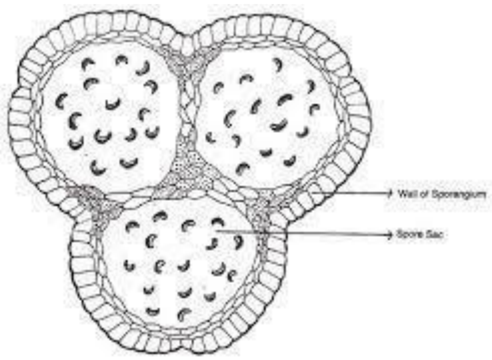


Fig. 24. *Psilotum*. T.S. of Mature Synangium with Spores

GAMETOPHYTE

- The prothalli are irregularly dichotomising, colourless and cylindrical structures covered with rhizoids.
- Endophytic mycorrhiza can be seen in the early stages of development.
- Prothallus is monoecious.

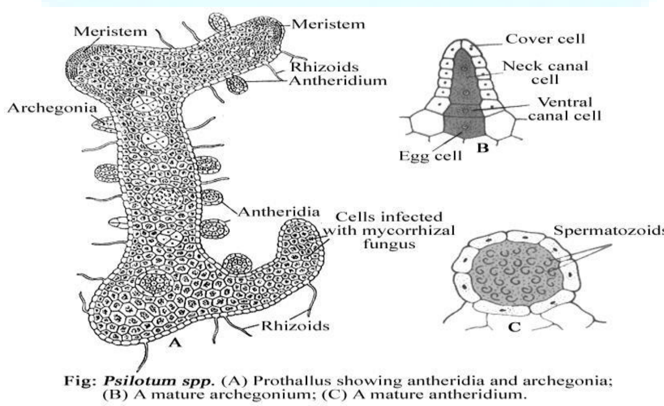
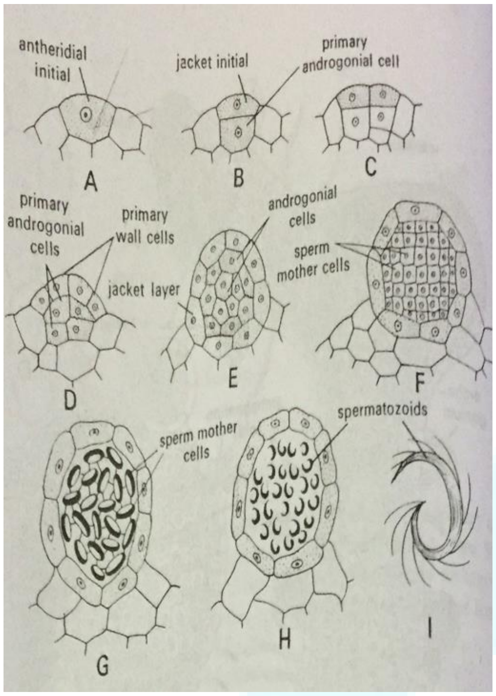
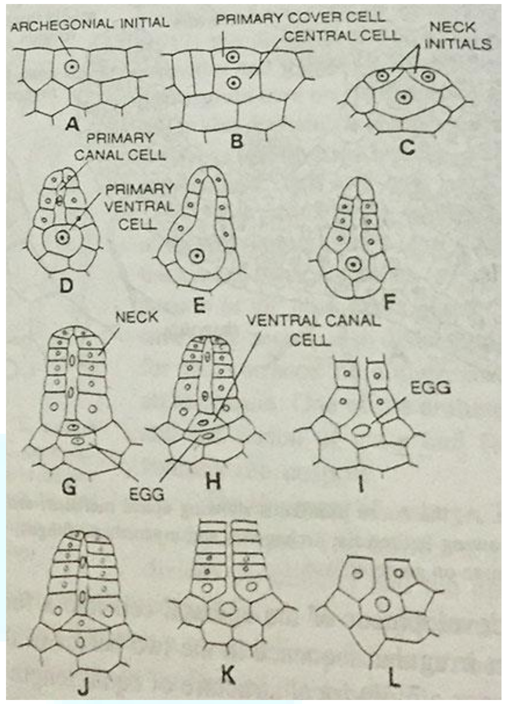


Fig: ***Psilotum spp.*** (A) Prothallus showing antheridia and archegonia; (B) A mature archegonium; (C) A mature antheridium.

● **Development of male sex organ and female sex organ**



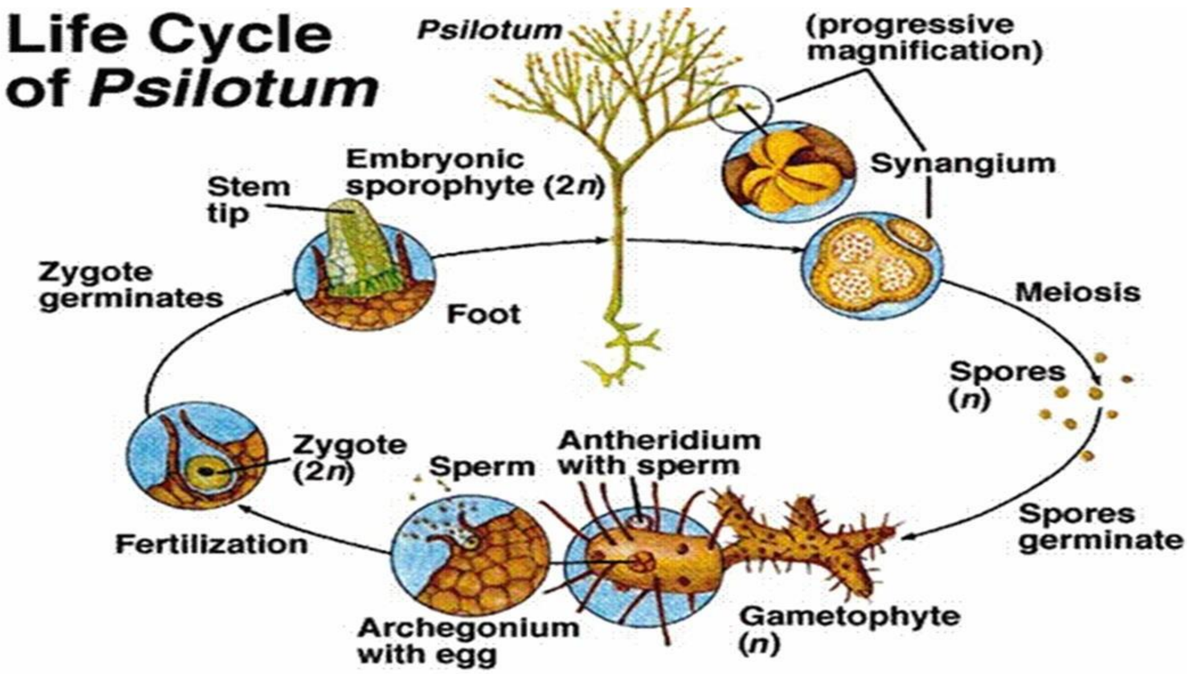


● Water is essential for fertilization

● Fusion of male gamete (n) and female gamete (n) occurs

● Zygote(2n) is formed after fertilization

● New sporophytic plant is formed



CHARACTERISTIC FEATURES OF PSILOTOPSIDA

- Includes two living genera – Psilotum and Tmesipteris.
- Plant body is a sporophyte and are rootless.
- Numerous rhizoidal hairs are present.
- Rhizome is subterranean and it has an aerial shoot.
- Aerial shoot possess many scaly or leaf like appendages.
- Spores are homosporous and are produced in sporangia or synangia.
- Gametophytes are colourless,branched,subterranean and are non photosynthetic. It grows as a saprophyte with fungus.
- Partially embedded antheridia are present on the gametophytes.
- Antherozoids are multiflagellate.

ENTRI

LYCOPHYTA

Division : Lycophyta
Class : Ligulopsida
Order : Lycopodiales
Family : Lycopodiaceae
Genus : Lycopodium

SALIENT FEATURES:

- Club moss, Ground pine, Trailing Evergreen.
- Cosmopolitan in distribution.
- Common Indian Species: *Lycopodium clavatum*, *L. cernuum, L. serratum*, *L. phlegmaria, L. volubile , L. selago* etc.
- Sporophytic plant body is well differentiated into roots, stems and leaves.
- Leaves are small and simple, with only a single unbranched vein or vascular bundle.
- Vascular cylinder is a Protostele in most cases, but is a siphonostele in a few extinct and some living forms.
- Leaf gaps are altogether absent
- Secondary growth is absent, except in *Isoetes.*
- Sporangia are located singly either at the tips of microphones or in their axils
- Sporophylls aggregate to form cones or strobili in most cases.
- Antherozoids are biflagellate or multiflagellate.

HABIT:

- Most species are herbaceous or shrubby sporophytes.
- **Epiphytic form** – *Lycopodium phlegmaria*
- **Erect and shrubby** – *Lycopodium reflexum*
- **Creeper** - *Lycopodium clavatum*
- **Climber** – *Lycopodium volubile*

EXTERNAL MORPHOLOGY:

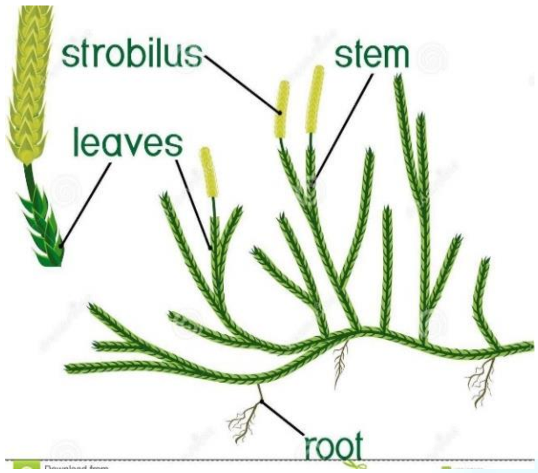
- Plant body is a sporophyte
- Differentiated into root, stem and leaves

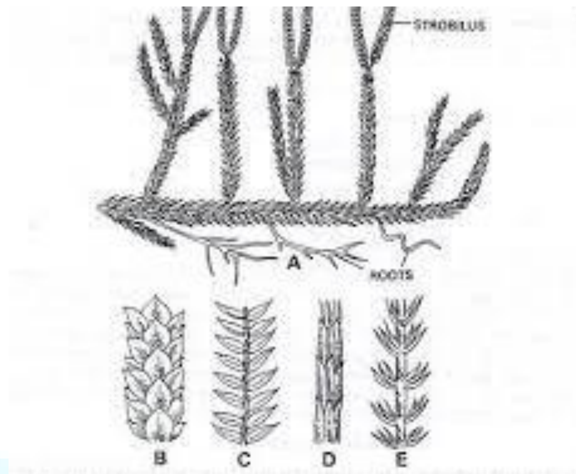
Stem:
- Weak, slender.
- Erect or pendant , creeping in others.
- Branches- basically dichotomous sometimes monopodial.
- Two branches of a forking may be equal or unequal.
- Stem and branches covered with leaves.

Root:
- Primary root is ephemeral.
- Older plants have adventitious roots; they arise from the pericycle or endodermis.

Leaf:

- Small, simple, sessile, eligulate.
- Single unbranched midvein.
- Leaf may be isophyllous or anisophyllous Eg. *Lycopodium volubile*.





Arrangement of Leaf :

- Spirally arranged on stem – eg : *Lycopodium clavatum*
- Whorled arrangement – eg : *Lycopodium cernuum*
- Opposite deccusate arrangement – eg : *Lycopodium complanatum*
- Considering the variation in habit of different species, Pritzel (1900) divide the genus *Lycopodium* into two sub genera:
    1. **Urostachya**
       Eg: *Lycopodium selago* and *L. Phlegmaria*
    2. **Rhopalostachya**
       Eg: *Lycopodium cernuum* and *L. Clavatum*

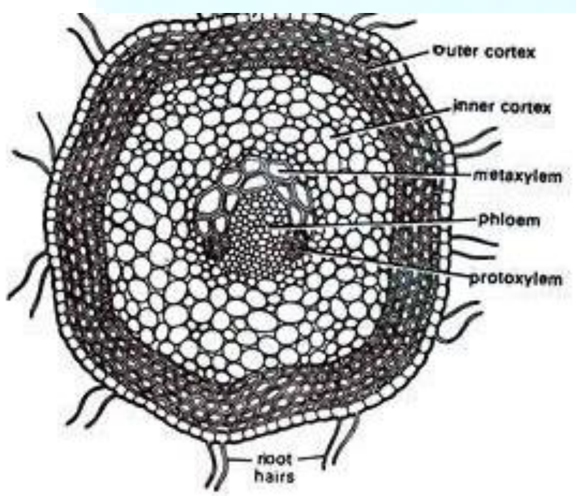
Urostachya	**Rhopalostachya**
● Erect or pendant stem	● prostrate stem with branches
● Stem –dichotomously branched	● first dichotomy later monopodial
● Root- from base of stem	● Adventitious roots along entire length of stem

• Leaves and sporophylls same size	• Sporophylls smaller than foliage leaves
• Vegetative reproduction by bulbils	• Sporophylls arranged to form cones or strobili
• Eg : *L. selago*, *L. phlegmaria*	• Eg : *L.cernuum*, *L.clavatum*

ANATOMY

ANATOMY OF ROOT:

- Epidermis - Single layered.
  - with thin walled cells .
  - sometimes possess unicellular root hairs.
- Cortex - composed of parenchymatous cells.
  - Older roots have thick walled sclerenchymatous cells for mechanical support.
- Stele- Protostele – monarch,diarch,triarch.
  - Xylem is curved (C or U).
  - Phloem lies in between the arms of xylem.

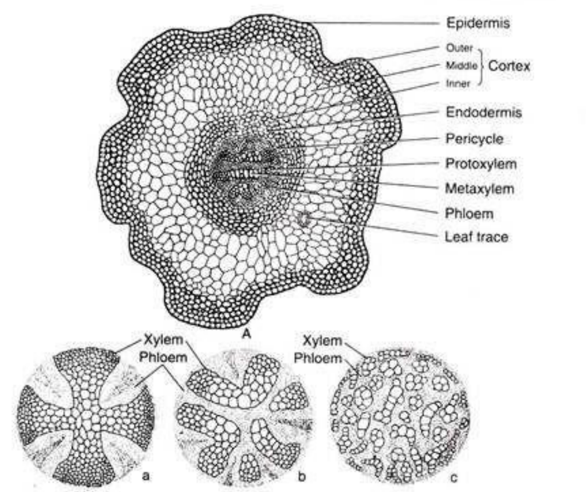


ANATOMY OF STEM:

- Epidermis - Single layered,thick cuticle.
- Cortex - Nature varies with species and stem diameter.
  - *Homogenous or heterogenous*.

  - ➢ Homogenous – either parenchymatous or sclerenchymatous
  - ➢ Heterogenous -

a) outer chlorenchymatous, middle parenchymatous and inner sclerenchymatous.
b) outer and inner elongated sclerenchymatous cells and middle thin walled parenchymatous cells.
c) Outer parenchymatous cortex and inner thickwalled sclerenchymatous region.



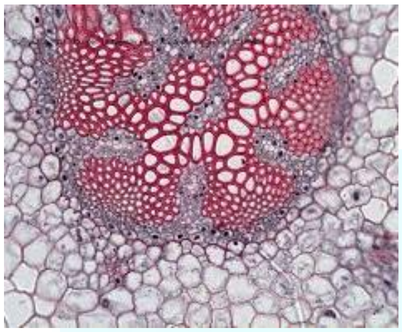
ɡ. 7.25 : A. T.S. of *Lycopodium clavatum* stem. B. T.S. of stelar regions of stems of (a) *L. serratum*, (b) *L. ann* and (c) *L. cernuum*

- Stele – Protostele
- Has only primary xylem and primary phloem
- Xylem – consists of protoxylem and metaxylem
- Phloem- sieve tubes,s ieve plates,phloem parenchyma. No companion cells
- Cambium absent
- Types of Protostele:
  1. Actinostele
  2. Plectostele

3. Mixed Protostele

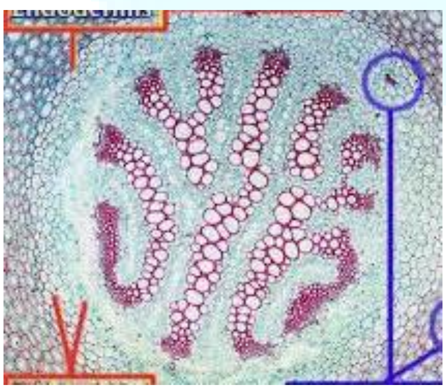
Actinostele

- Xylem star shaped.
- phloem between the arms of xylem.
- Eg – *Lycopodium serratum, L. selago*.



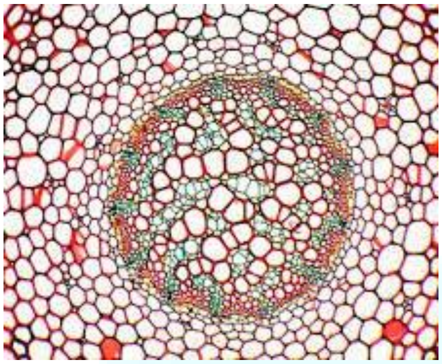
Plectostele

- Xylem in the form of plates.
- Xylem plates alternates with phloem patches.
- Eg – *Lycopodium clavatum, Lycopodium companulatum*.



Mixed protostele

- Xylem is divided into several units or groups.
- Xylem groups are scattered in the ground mass of phloem.
- Eg – *Lycopodium cernuum*



ANATOMY OF LEAF

- Leaf is triangular in outline.
- Outer epidermis is covered by cuticle.
- Amphistomatous
- In *L. companulatum* and *L. volubile* stomata are hypostomatous.
- Mesophyll is undifferentiated- made of chlorophyllous cells.
- A median concentric vascular bundle with xylem surrounded by phloem.

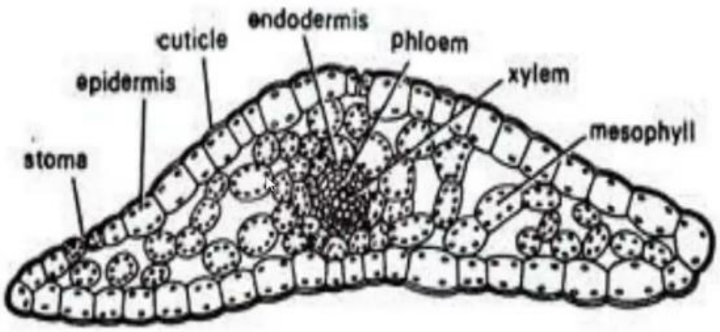


Fig. 229. Lycopodium. T.S. leaf.

REPRODUCTION

1. Vegetative Reproduction by
   - Gemmae
   - Fragmentation
   - Formation of bulbous buds
   - Formation of root tubercles
2. Asexual Reproduction by Spores – Homosporous condition
3. Sexual Reproduction by fusion of male and female gamete

Gemmae:

- Modified lateral branches that develop in the form of outgrowth near the stem apices.
- Consists of a short reduced axis surrounded by thick fleshy leaves with stored food material.
- Falls on the ground and grows into a new plant.
- Fragmentation - Death and decay of older parts of the stem leads to separation of younger branches which grow into new plants. Eg: *L. inundatum*
- Formation of bulbous buds - At the base of the stem arises large leafy buds, and on separating they develops into new plants. Eg : *L. phlegmaria*
- Formation of root tubercles - Swollen root tubercles are present in the adventitious roots of some species. Parenchymatous cells of the cortex of the root may give rise to such tubercles. Eg : *L. cernuum*

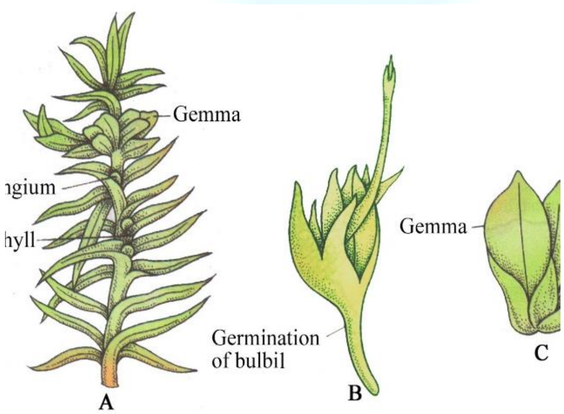


Fig: ***Lycopodium spp.*** (A) A portion of stem bearing gemma; (B) Germination of bulbil; (C) Germination of gemma.

Spore producing organ:

- Spores are present in sporangia.
- Sporangia bearing leaves are called sporophylls.
- Aggregation of sporophylls is called strobilus.
- A strobilus has a central axis on which spirally arranged sporophylls are present.
- Sporophyll and foliage leaves differ in different species.

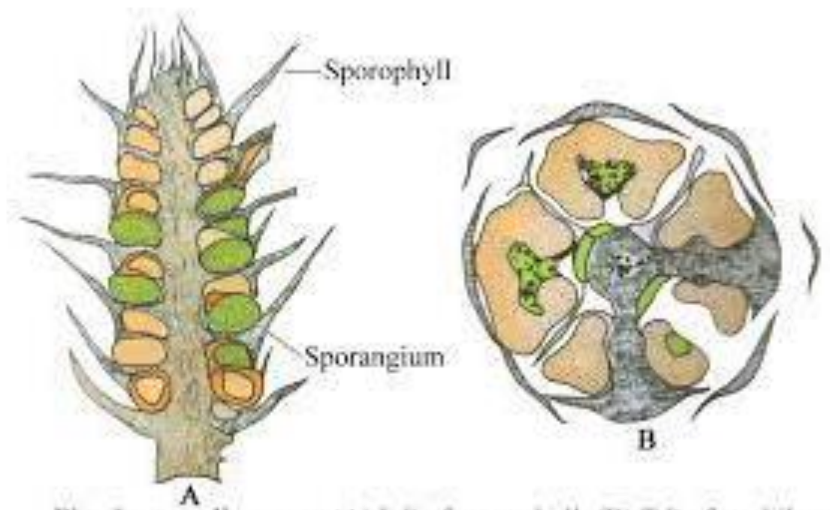


Fig: *Lycopodium spp.* (A) L.S of sporophyll; (B) T.S of strobilus.

Position of sporangium on sporophyll:

- Sporangia are present at the base of the sporophyll.
- Axillary in position.
- Directly on the stem in a position just above the sporophyll.

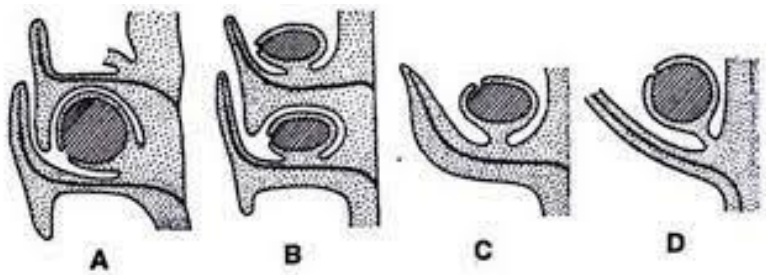
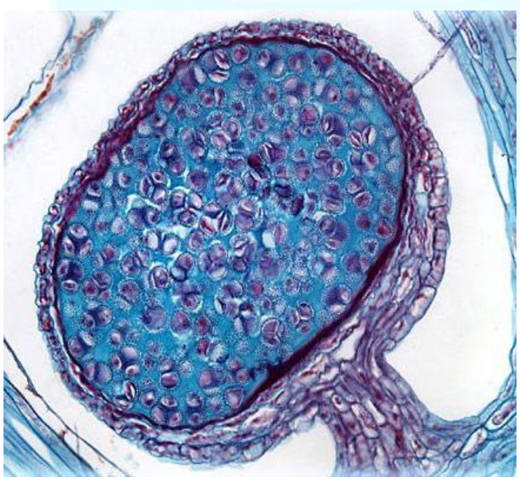


Fig. 7 (A–D) *Lycopodium* : A strobilus showing position of sporangia in various species; A. *L. inundatum*, B. *L. cernuum*, C. *L. squarrosum*, D. *L. lucidulum*

Structure of sporangium

- Sporangium is reniform.
- Size varies from 1.0-2.5mm in diameter.
- Has short and massive stalk.
- Sporangial wall is three layered.
- Innermost layer is the tapetum.
- Each sporangium is unilocular.
- Sporogenous mother cells undergoes meiosis and produce tetrads of spores
- Spores are homosporous.



Structure of spore:

- Homosporous
- Occur in tetrads
- Unicellular and range in size from 0.03-0.05mm in diameter.
- Three flat surfaces of the spores are separated with the help of weak triradiate ridges.
- Spore wall may be smooth or variously sculptured.
- Has a single haploid nucleus.
- Cytoplasm filled with reserve food material.

Dehiscence of sporangium:

- A line of cells are differentiated on the sporangial wall called stomium.
- Inner walls of cells of stomium are thick and lignified.
- Exposed sporangia lose water and dry.
- Split opens in the stomium and sporangia opens into two valves and spores are liberated.
- Air disseminates the spores.

Germination of the spore:

- Time taken for germination varies from few days to several years after their liberation from the sporangium.
- Germinating spores produce aerial, short lived and green prothalli.
- When spores take longer time to germinate, they get buried under the soil.
- And produce colourless subterranean prothalli that are large, tuberous and long lived .
- The spore germinate to produce the multicellular gametophyte.
- The gametophyte is called the prothallus.

- It is free living independent of the sporophyte.

Mature prothallus:

- Gametophyte are monoecious.
- It produces the antheridia and archegonia.
- It is free living independent of the sporophyte.

Gametophyte:

- Three types of prothalli are present in *Lycopodium*

1. Cernuum type
2. Clavatum type
3. Phlegmaria type

1. Cernuum type

- Independent prothallus- *Lycopodium cernuum, Lycopodium inundatum*
- Erect ,cylindrical body,2-3mm long
- Grows on the surface of the ground
- Colourless basal portion buried in the soil.
- Lobed generative zone –bearing sex organs at the base of the lobes
- Rhizoids restricted to lower buried portion.
- Endophytic fungus is present in the basal portion.

2. Clavatum type

- Reaches upto 1-2.5 cm in length or breadth and are disc or carrot shaped
- In the central region are present more or less elongated cells.
- Endophytic fungus is present in the cortical region
- The upper flattened surface bear the sex organs.
- Archegonia present on the margin and antheridia at the centre.

- Numerous rhizoids arise from the lower surface.

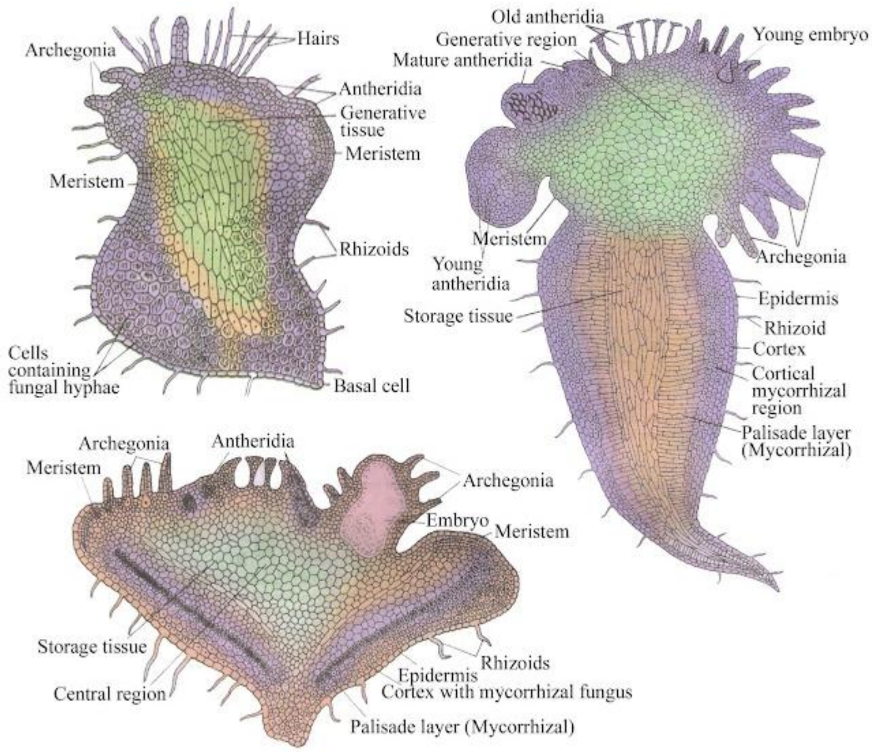
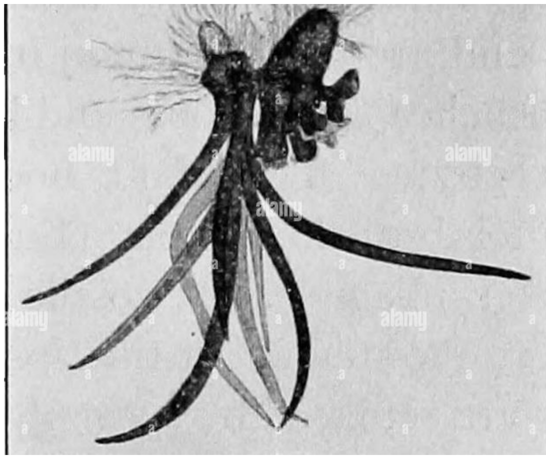


Fig: *Lycopodium.* Three different types of prothallus.

3. Phlegmaria type:

- The prothalli are aerial but saprophytic in nature, grow on tree trunks.
- The prothallus consists of a short, tuberous central part from which a number of colourless, slender and cylindrical branches develop in an irregular fashion.
- Branches bears sex organs and are surrounded by glandular hairs paraphysis.



VEGETATIVE REPRODUCTION IN GAMETOPHYTE

1. By bulbils
2. By fragmentation
3. By budding

Sex organs in gametophyte

1. **Prothalli** are monoecious
2. Male sex organ –Antheridia
3. Femlae sex organ – Archegonia

Development of antheridium:

- An epidermal cell of the gametophyte behave as an antheridial initial.
- Antheridial initial undergoes periclinal division to form outer jacket cell and inner primary androgonial cell.
- Outer jacket initial divides and redivides to form a jacket layer.
- Inner primary androgonial cell also divides and redivides to form a mass of many androgonial cells.
- The androgonial cells transform into androcytes.
- The androcytes metamorphosis into antherozoids.

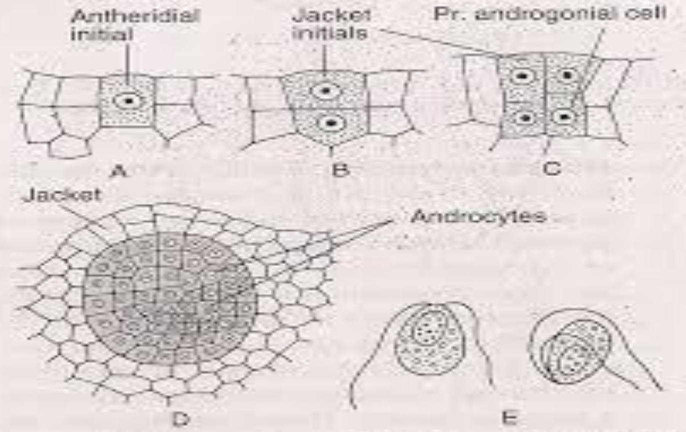


Fig. 7.31 : Lycopodium : A–D. Stages in the development of antheridium, E. Antherozoids

Structure of antheridium:

- Antherozoids are uninucleate and biflagellate structures having pointed anterior end and broad posterior end.
- Mature antheridia are completely or partially sunken in the gametophytic tissue.

Development of archegonium:

- An epidermal cell of the gametophyte behave as an archegonial initial.
- Archegonial initial undergoes periclinal division to form upper primary cover cell and lower central cell.
- Mature archegonium consists of a short neck composed of four vertical rows of neck cells , formed from primary cover cells through repeated divisions.
- Lower central cell undergoes periclinal division to form an upper primary canal cell and lower primary venter cell.

Structure of archegonium:

- Neck encloses 4-8 neck canal cells(formed from primary canal cell through transverse divisions)
- Venter consist of venter canal cell and egg cell (formed from primary venter cell)
- Venter is embedded in the gametophytic tissue.

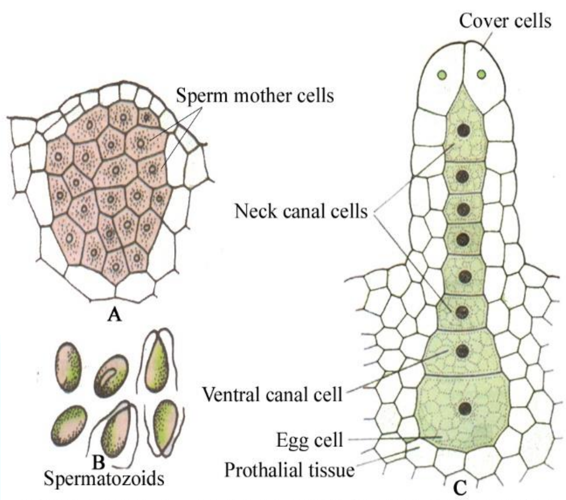
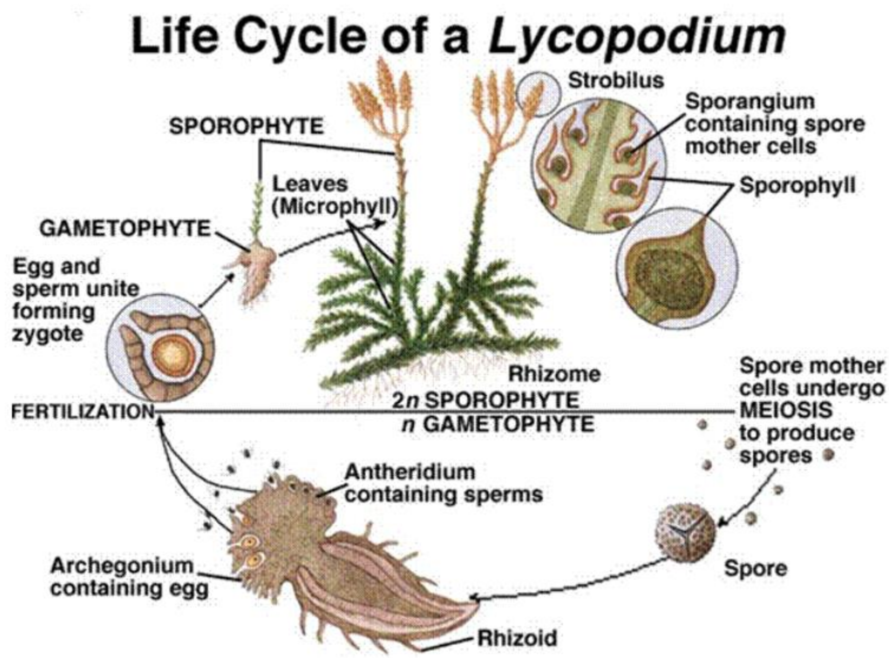


Fig: *Lycopodium spp.* (A) An antherisium; (B) Spermatozoids; (C) Archegonium

FERTILISATION

- When archegonium matures, tip of neck cells split, neck canal cells and venter canal cell disintegrate and form a mucilaginous substance.
- Antherozoids enter the archegonium and one fuses with the egg to form the zygote.
- The diploid zygote germinates and produces the sporophytic generation.



CHARACTERISTIC FEATURES OF LYCOPSIDA

- Includes fossils (eg. *Lepidodendron*) and living genera (eg. *Lycopodium, Selaginella, Isoetes, Stylites, Phylloglossum*)
- Sporophytic plant body is differentiated into root,stem and leaves.
- Leaves are small, unveined, spirally arranged and eligulate (*Lyopodium*)
- Both sporangia and sporophylls are arranged in the form of strobilus.
- Spores may be homosporous(*Lycopodium*) or hetrosporous(*Selaginella*)
- The gametophyte develops independently.
- Antherozoids are biflagellate or multiflagellate.

LYCOPHYTA

Division : Lycophyta
Class : Ligulopsida
Order : Selaginellales
Family : Selaginellaceae
Genus : Selaginella

SALIENT FEATURES

- Small Club Moss, Spike Moss.
- Cosmopolitan in distribution.
- Mostly found in tropical regions
- **Common Indian species** – *Selaginella kraussiana,Selaginella monospora,Selaginella rupestris,Selaginella megaphylla* etc
- **Xerophytes** – *Selaginella rupestris,Selaginella lepidophylla* Resurrection Plants
- **Epiphyte** – *Selaginella oregana*
- **Creeper** –*Selaginella kraussiana*
- **Climber** - *Selaginella alligans*

EXTERNAL MORPHOLOGY

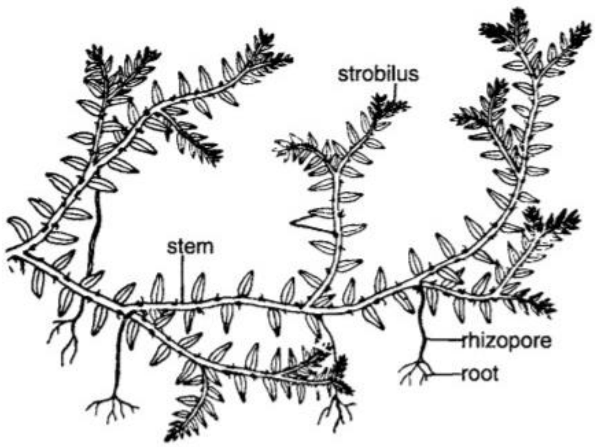
- Plant body is the sporophyte
- Differentiated into root, stem ,leaves, ligules and rhizophore

Root

- The root of young sporophyte is of primary root while others are adventitious.
- The adventitious roots arises from the apices of rhizophores.

Stem

- It is green, dorsiventral and prostrate with short erect branches
- The branching is always dichotomous
- Reproductive structures called strobili develop at the apices of these branches
- Apical growth of stem takes place by the activity of a single apical cell or group of apical initials.



Selaginella. External features.

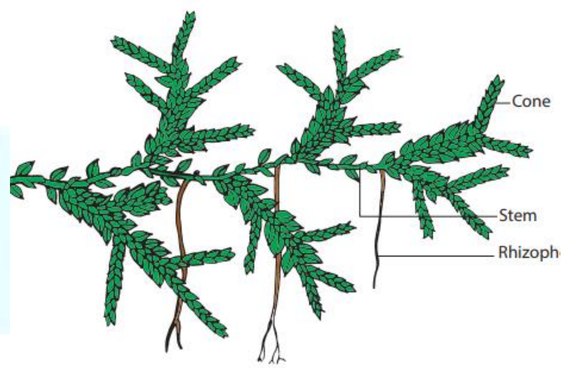


Figure 2.25: *Selaginella* Habit

Rhizophore

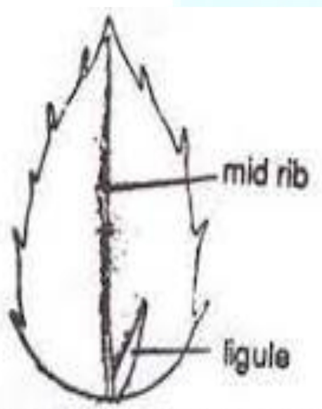
- In rhizophore some species, long, cylindrical, leafless and colourless branches arise from the prostrate stem near the point of dichotomy.
- These grow vertically downwards and have group of adventitious roots at its distal end.
- They are called as rhizophores.

Leaves

- Leaves – small ,simple,sessile(microphylls)
- Each leaf has an unbranched mid-vein
- Vegetative leaves and sporophylls are ligulate
- They are of two types – Isophyllous and Anisophyllous
- The anisophyllous leaves are in pairs. They may be
- Small –inserted on the dorsal side of stem
- Large – inserted on the ventral side of stem

Ligule

- Small tongue like outgrowth on adaxial side(upper side) of the leaf near the base is called ligule.
- Exact function is not known.
- Ligules are considered to be associated with water absorption and water secretion.
- Thus they prevent the dessication of the shoot.
- Concerned with upward movement of inorganic solutes.
- Pointed outgrowth seen at the base of the leaf.
- Has three portions – glossopodium, body and terminal lamella.
- Glossopodium - large, thin-walled and polygonal cells ,rich in granular cytoplasm..
- It is covered by glossopodial sheath. The sheath cells have casparian strips.
- Body and lamella are formed of isodiametric cells, densely packed with protoplasm.



Selaginella. Adaxial surface of a leaf showing ligule.

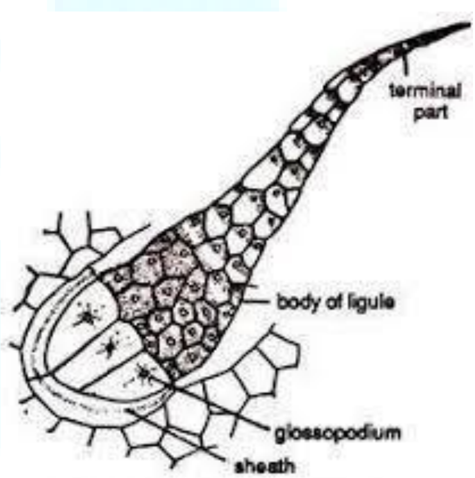


Fig. 212. Selaginella. A single ligule.

ANATOMY OF STEM

- Epidermis – uniseriate epidermis,thin walled rectangular cells(prosenchymatous),covered with cuticle, devoid of stomata.
- Cortex - Outer and inner cortex
  - Outer – thick walled sclerenchyma cells and it forms the hypodermis.
  - Inner - Below the hypodermis is thin walled chlorenchymatous cells.

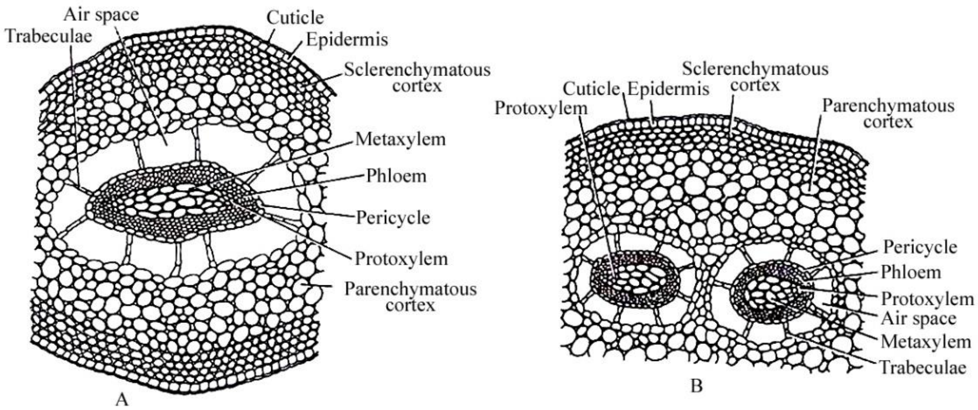


Fig: *Selaginella spp.* T.S of Stem. (A) T.S of monostelic stem; (B) T.S of distelic stem.

- **Endodermis**
  - The cortex and central tissue is connected by radially elongated cells called trabeculae
  - they contain casparian strips
  - trabeculae are modified endodermal cells
  - Central stele is separated from cortex by large air spaces
- **Pericycle**- single layered,thin walled ,enclosing vascular tissues
- **Stele** - protostele
- Xylem present in the center. It consists of protoxylem and metaxylem
  - Protoxylem – occupies two ends of metaxylem
  - Metaxylem – occupies the major portion of stele
- Xylem is composed of tracheids and parenchyma cells. Fibers are absent

- Phloem is composed of sieve cells and phloem parenchyma.
- Companion cells are absent.
- Phloem surrounds the xylem completely

ANATOMY OF RHIZOPHORE

- **Epidermis** – single layered and cutinized
- **Cortex** - outer and inner cortex
  - outer many layered, sclerenchymatous hypodermis

- Below the hypodermis is thin walled parenchymatous region

- **Endodermis** is single layered
- Thin walled **pericycle** is present around the vascular tissue
- **Stele** - protostele-monarch and exarch

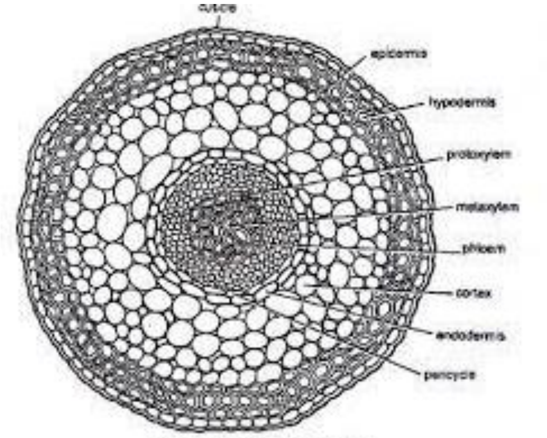


Fig. 5. *Selaginella* . T. S. rhizophore

ANATOMY OF LEAF

- Epidermis –both upper and lower epidermis. Are uniseriate and have chloroplasts
- Amphistomatous (stomata present on upper and lower epidermis) or hypostomatous.
- Below the epidermis there is mesophyll tissue having thin walled parenchyma cells.
- These cells contain chloroplasts and have air spaces.
- Central VB is surrounded by bundle sheath.
- Xylem at the centre is surrounded by phloem.

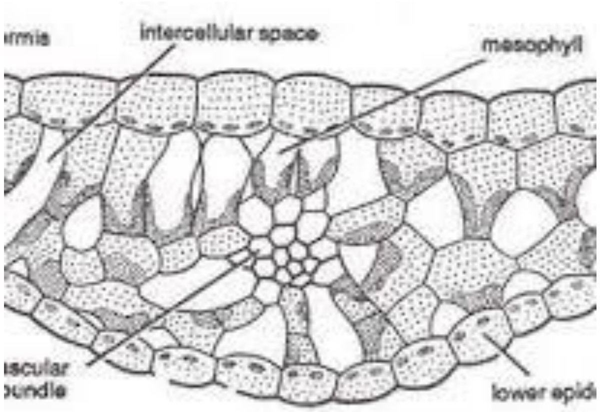


Fig. 216. *Selaginella. T. S. leaf.*

ANATOMY OF ROOT

- **Epidermis** – single layered epidermis ,covered by thick cuticle
- **Root hairs** arise from epidermis
- **Cortex**
  - outer sclerenchymatous hypodermis
  - inner parenchymatous cortex
- Single layered **endodermis** and pericycle
- **Stele** is protostele
- Root xylem is monarch to tetrach and exarch
- Phloem is in the form of ring around the xylem

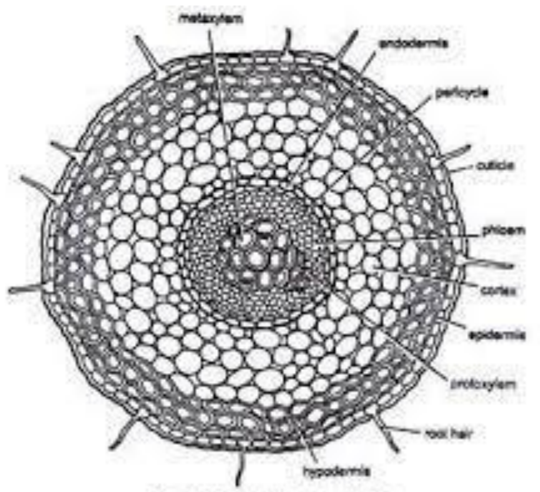


Fig. 4. Selaginella T. S. of root

REPRODUCTION

- Life cycle exhibits alternation of generations
- Both spore producing and gamete producing generations are independent
- Some species reproduces vegetatively.

VEGETATIVE REPRODUCTION

- By **fragmentation**
  - During favourable conditions prostrate branches produce roots.
  - These branches break away from the parent plant and grow to new plants
- By **stem-tubers**
  - The tubers produced by certain species may be aerial, developing at the apices of aerial branches or sub-terranean.
  - During favourable conditions tubers grow to new sporophytes
- By production of **resting buds**
  - At the ends of aerial branches bear resting buds which germinate to new plants during favourable conditions

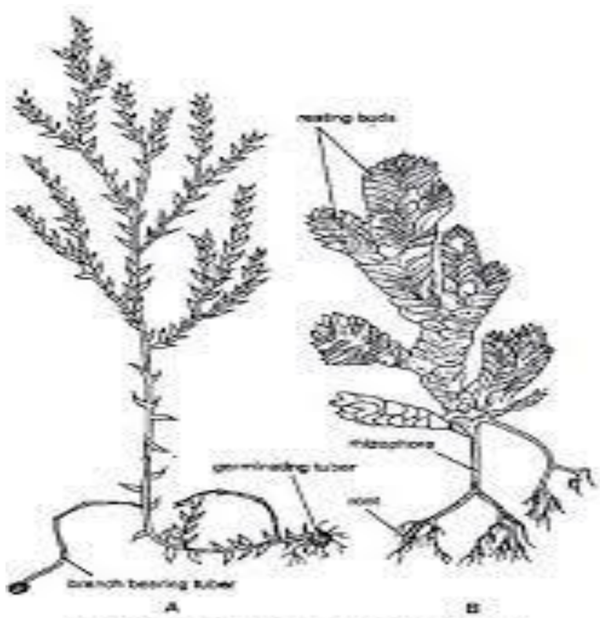
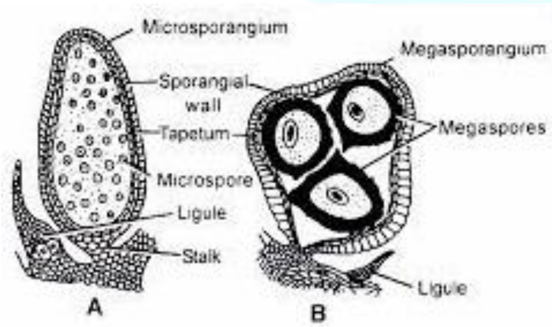


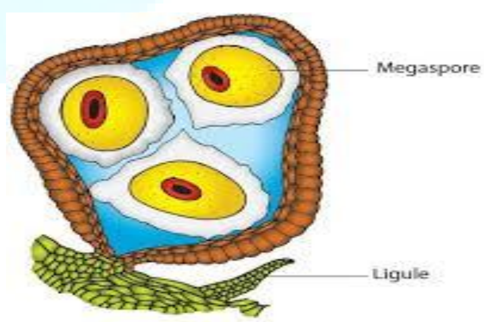
Fig. 7 (A–B). Selaginella. Vegetative reproduction. A. Tubers, B. Resting buds

REPRODUCTION BY SPORES

- Spores are **heterosporous** – microspores and megaspores.
- Small size microspores are produced in microsporangia.
- Large size megaspores are produced in megasporangia.
- Sporangia are dimorphic.



A. V.S. Microsporangium,
B. V.S Megasporangium



c) A megasporangium enlarged

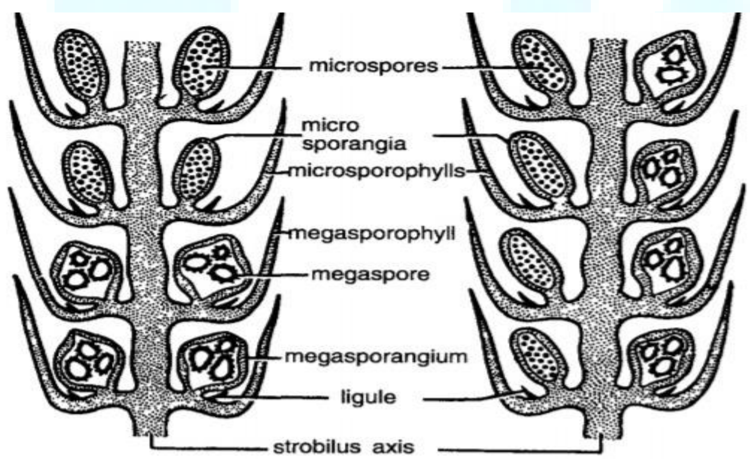
Figure 2.29: Reproduction in *Selaginella*

Strobilus

- Sporangia are produced on the axils of ligulated leaves called sporophylls.
- Microsporophylls and megasporophylls.
- These sporophylls are organised to form fertile region called strobilus or cones at the end of shoots.

L.s. of cone

- Each cone has a sporophyll bearing axis.
- In most species, both micro and megasporangia are found within the same strobilus.
- In most species, megasporangia are present in the basal part and microsporangia in the upper part of strobilus.
- In *Selaginella inaeqalifolia*, one side of the strobilus bears only megasporangia and the other side bears microsporangia
- In *Selaginella kraussiana* ,there is only one megasporangium at the base of the cone and all others are microsporangia



Selaginella. L.s. strobilus showing different positions

Structure of sporangium

- Microsporangia – they are small, stalked, oval and varying in shapes.
- Megasporangia – they are stalked and lobed, larger in size and present at the base of strobilus, spores are of larger size.

- Both consists of 2 layered sporangial wall surrounding the tapetum and sporogenous tissue.
- Tapetum is developed from innermost layer of sporangial wall.
- The spores are formed by the meiotic division of spore mother cells.
- In microsporangia, all spore mother cells undergo meiosis and form microspores.
- But in megasporangia ,only one of them forms the functional spore mother cell and the others degenerate.
- It undergoes meiosis to form four haploid megaspores.
- Number of functional megaspores in a megasporangium ranges from 1-4.
- Both differ in their size, location and number of spores.
- To release spores, both sporangia form vertical cleft in wall.

Gametophyte

- Spores form the first cell of gametophytic generation.
- Two types of spores are produced in Selaginella(heterosporous)
- Microspore develop into the male gametophyte.
- Megaspore develop into the female gametophyte.

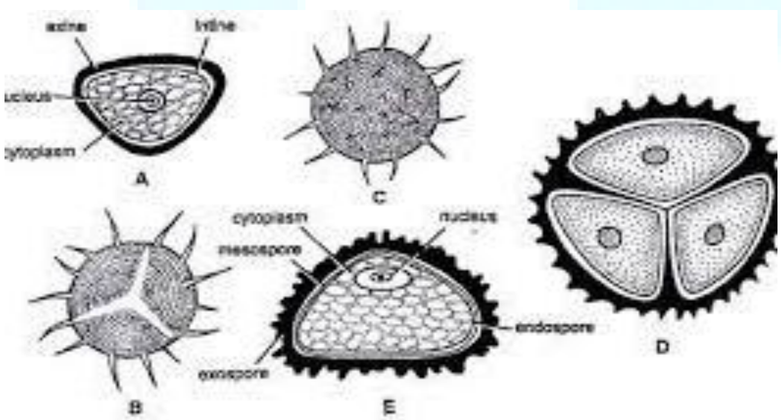


Fig. 11 (A–E). *Selaginella*. Structure of spores : A. A single microspore showing detailed structure, B. Apical view of spore, C. Basal view, D. Megaspore in tetrad, E. A single megaspore.

Male gametophyte

- Microspore has 2 layers and single nucleus surrounded by cytoplasm.
- Outer thick exine and inner thin intine.

- Start germination in microsporangia itself (insitu),upto 13-celled stage
    - 1 – prothallial cell
    - 8- jacket cells
    - 4- primary androgonial cells
- Further development takes place after the liberation from microsporangia.
- Primary androgonial cells divides to form numerous antherozoid mother cells or androcytes.
- Jacket cells disintegrate ,so that androcytes can free float in the fluid.
- Finally each androcyte metamorphosis into spirally coiled biflagellated antherozoids/ spermatozoids.
- They liberate by breaking the wall of jacket.
- They can swim freely and reaches into female gametophyte.

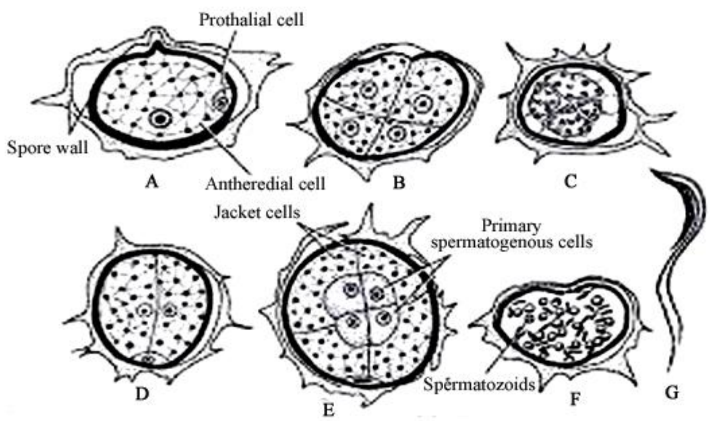
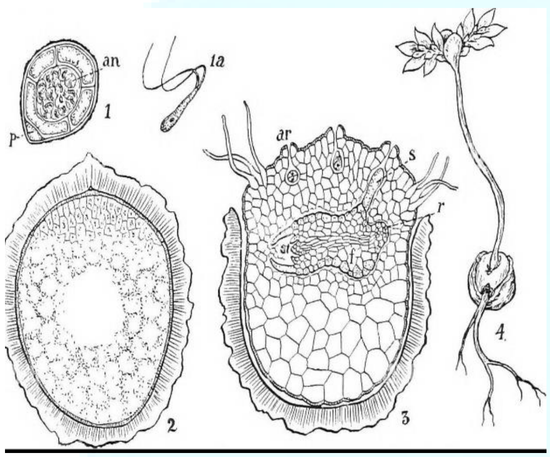


Fig: *Selaginella*. (A-G) Stages in the development of male gametophyte.

Female gametophyte

- Megaspores –larger,1.5-5mm in diameter
- It has 3 wall layers and single haploid nucleus ,surrounded by cytoplasm
    - outer thick exospore
    - middle mesospore
    - inner endospore
- Megaspore germination and development of megagametophyte takes place within megasporangium
- During germination ,megaspore nucleus divides continuously resulting in the formation of large number of free nuclei

- They remain distributed in peripheral cytoplasm, centre is occupied with large vacuole
- Cell wall formation begins from periphery to centre ,in the apical region of spore
- Continuous cell formation at the apex results in the formation of cellular cushion
- It is differentiated from rest of the megaspore by a diaphragm
- Below this tissue, gametophyte is still in free nuclear stage
- Diaphragm separates 2 clear cut zones
    - Apical cellular cushion/generative region
    - lower nutritive region
- Few archegonial initials develop at the apical region



<u>Development of archegonia</u>

- Archegonia are produced in large numbers and occupies at the central position of apical cushion.
- Are produced from archegonial initial.
- Archegonial initial undergoes periclinal division to form upper primary cover cell and lower central cell.

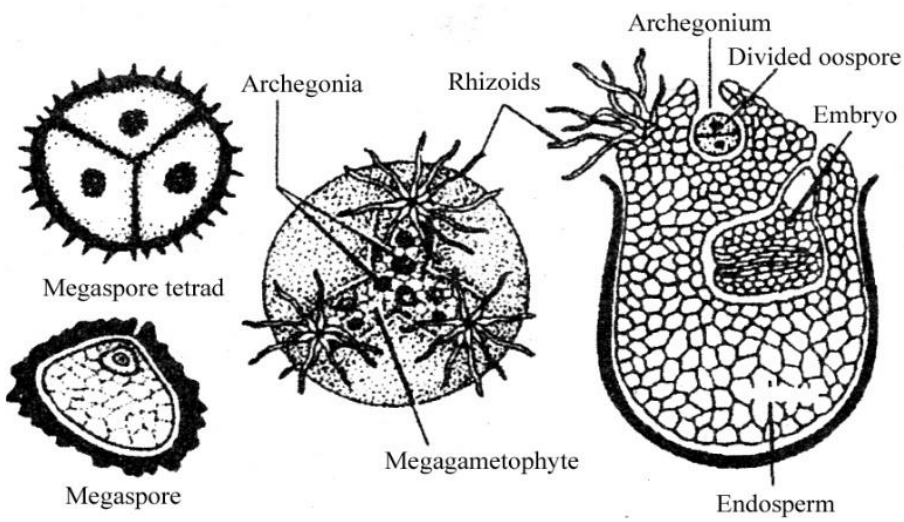


Fig: *Selaginella spp.* Development of female gametophyte.

- Lower central cell undergoes periclinal division to form an upper primary neck cell and lower primary venter cell.
- The primary venter cell divides and form an egg and a venter canal cell.
- In the mean time the primary cover cell undergoes two divisions and forms four neck initials which later on form a short neck.
- The primary neck cell does not undergo any further division ,but it directly functions as the single neck canal cell.
- Mature archegonium consists of a distinct neck and a venter.
- The neck is composed of two tiers of four cells each.
- The upper tier functions as cover cells.
- Neck encloses a single neck canal cell.
- The venter consists of a single venter canal cell and an egg
- Venter is embedded in the gametophytic tissue.

FERTILIZATION

- Fertilization takes place even when the female gametophyte is within megasporangium.
- Before fertilisation NCC and VCC disorganise and form free passage for the entry of antherozoids.

- Bi- flagellated antherozoids swim in water, attracted towards chemical substance secreted by archegonial neck, fuses with the egg forming diploid zygote.

EMBRYO DEVELOPMENT

- Zygote divides transversely and form
- upper epibasal (suspensor) cell and
- lower hypobasal (embryonic) cell.
- Suspensor cell divides to form suspensor which pushes developing embryo deep into the female gametophyte.
- Rest of embryo develop from embryonic cell.
- The cells nearer to suspensor divide and form the foot.
- At first the foot act as a haustorial organ.
- At this stage, 2 cotyledons get differentiated at the apical region. In the axil of each cotyledon a ligule develops.
- The part of the embryo posterior to cotyledons develops to the hypocotyledonary part of the stem.
- The stem grows with the help of the apical cell of the embryo.

- After the formation of cotyledons and stem, the apical cell of the root differentiates on the lateral surface of the foot

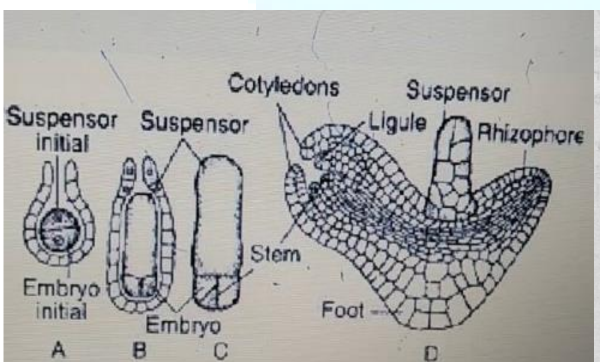
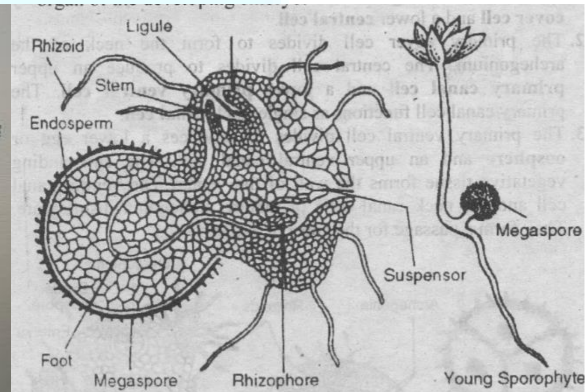


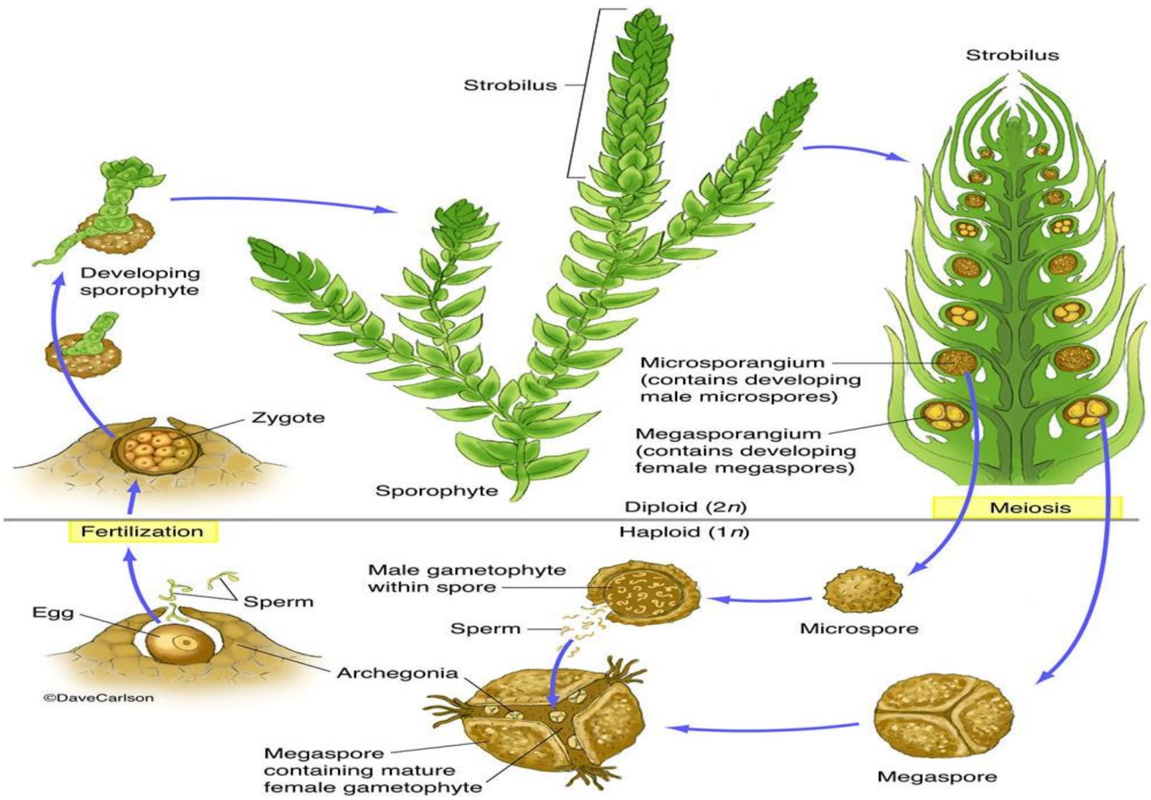
Fig. 7.57 : *Selaginella* A–D. The stages in the development of embryo.



Germination of megaspore within female gametophyte and young sporophyte

- The derivative of this cell develop to the rhizophore.
- Root develops at the apex of the rhizophore.
- After the establishment of root and stem, the sporophyte becomes independent.

ALTERNATION OF GENERATION



CHARACTERISTIC FEATURES OF LYCOPHYTA

- Includes fossils (eg. *Lepidodendron*) and living genera(eg. *Lycopodium, Selaginella, Isoetes, Stylites, Phylloglossum*)
- Sporophytic plant body is differentiated into root, stem and leaves
- Leaves are small, unveined, spirally arranged and ligulate (*Selaginella*)
- Both sporangia and sporophylls are arranged in the form of strobilus
- Spores may be homosporous(*Lycopodium*) or hetrosporous(*Selaginella*)
- The gametophyte develops independently
- Antherozoids are biflagellate or multiflagellate

SPHENOPHYTA

Division : Sphenophyta

Class : Calamopsida

Order : Equisetales

Family : Equisetaceae

Genus : Equisetum

- Latin. Equus = horse and seta = bristle
- Horse tail, Scouring rush
- Cosmopolitan in distribution
- Most species occur in Northern Hemisphere
- Common Indian species – *Equisetum arvense, Equisetum debile, Equisetum diffusum, Equisetum ramosissimum* etc

HABITAT

- Ponds or on banks of streams– *Equisetum palustre*
- Damp and shady places – *Equisetum pratense*
- Xerophytic habitat (in open grass lands, road side)- *Equisetum arvense*
- Field horse tail - *Equisetum arvense*
- Grow in hydrophytic and xerophytic conditions – *Equisetum debile*
- Ecological indicators – to indicate mineral content of the soil in which they grow.

SIZE

- The height of the plant varies from 15 cm (*Equisetum scirpoides*) to 10 m (*Equisetum giganteum*)
- Most species range in between 15-60 cm in height
- Indian species - *Equisetum ramosissimum* attain a height of 4 m

EXTERNAL MORPHOLOGY

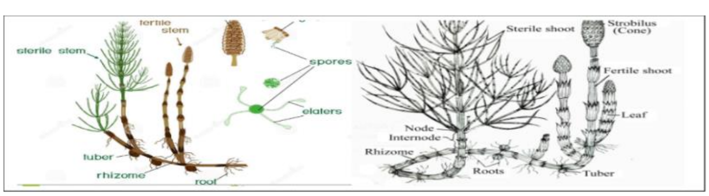
- Plant body is the sporophyte
- Differentiated into rhizome, aerial shoot, root and leaves.

Rhizome

- Long, creeping ,underground and branched rhizome.
- It is divided into nodes and internodes.
- Roots arise from the node of rhizome.
- Rhizome possess round bodies called tubers - *Equisetum arvense*.

Aerial shoot

- From the rhizome ,the aerial shoots arise towards the upper side.
- Aerial shoots may be branched or unbranched.
- Branched aerial shoots – *Equisetum arvense, Equisetum limosum, Equisetum palustre.*
- Unbranched aerial shoots– *Equisetum hyemale.*
- In most species, shoots are chlorophyllous and some of them bear strobili at their apices – eg –*Equisetum debile. E. Ramosissimum*
- The aerial shoots exhibits dimorphism – eg- *E.arvense*
- Vegetative/Sterile shoots – are well branched, green and photosynthetic in function
- Fertile shoots – unbranched, brownish in colour(achlorophyllous),bears cones at their apices and are reproductive in function.
- The rhizome as well as sterile and fertile shoots are articulated.
- Both sterile and fertile shoots are divided into nodes and internodes.
- Both rhizome as well as aerial shoots posses scaly leaves at its nodes.
- Externally the internodes have ridges and furrows and internally hollow tube like structures.



Leaves

- Leaves – are small, scaly and microphyllous.
- Leaves are present in the form of a whorl over the node of rhizome as well as aerial shoot.
- The number of leaves per node varies in different species (2-40).
- The distal end of scaly leaves are free.
- The lower ends of each leaf unite to form a sheathing leaf base.
- The number of leaves at a node corresponds to the number of ridges on the internode.

Roots

- Develop from the node of rhizome
- Long , slender, well branched and adventitious

Functions of different parts

- **Roots-** Absorption of water and fixation of plant in the soil
- **Rhizome** – Storage of food
- **Sterile aerial shoot -** Photosynthesis
- **Fertile aerial shoot -** Reproduction

ANATOMY OF INTERNODE OF AERIAL STERILE SHOOT

- Epidermis, cortex, central stele and large central pith cavity.
- Entire structure appears wavy due to the presence of ridges and grooves.

Epidermis

- uniseriate ,thick cuticle.
- stem appears hard and rough due to silica deposition.
- possess sunken stomata.

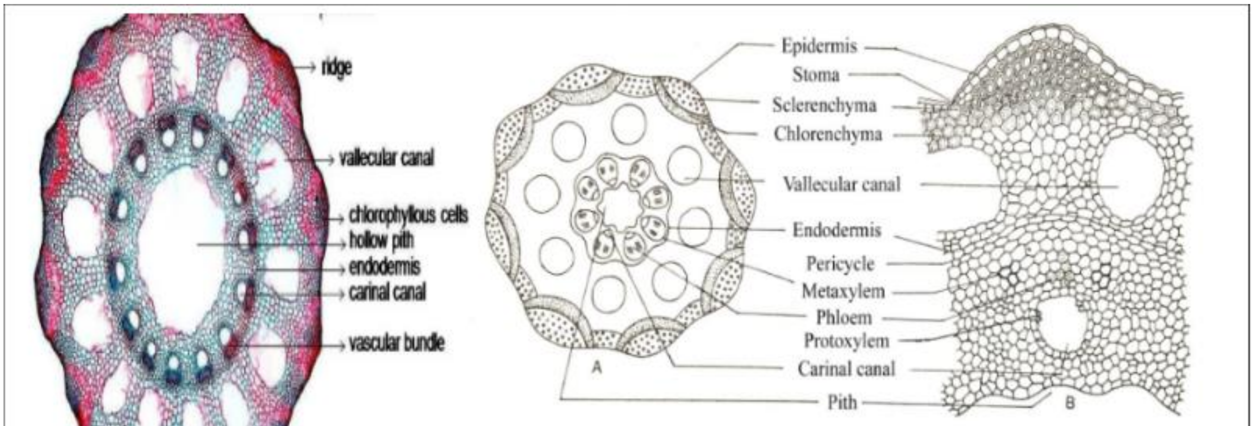


Fig: *Equisetum spp*. TS of aerial branch through an internode, (A) Duagramatic; (B) Cellular.

Cortex

- Inside each ridge is present a large patch of sclerenchyma, followed by chlorenchymatous tissue.
- Chlorenchyma extends upto the epidermis in each furrow, in which lie the stomata.
- Chlorenchymatous cells are elongated palisade like.
- The sclerenchyma is mechanical in function, while chlorenchyma is photosynthetic in function.
- Rest of the multilayered cortex is parenchymatous.
- Just inside each groove is present a large air canal in the parenchymatous cortex. This is called Vallecular canal.
- Vallecular canals are present inside the grooves.

Endodermis

- form a general sheath around the central stele
- Cells have casparian bands on radial walls

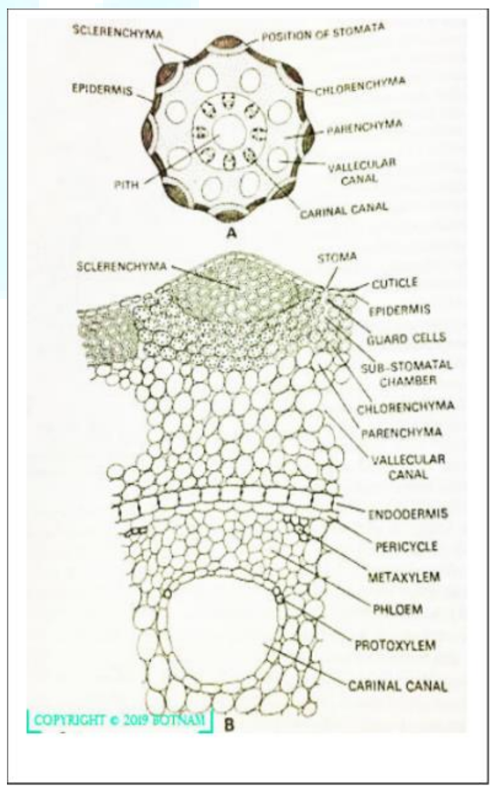
- All VB have common endodermis – *E. arvense, E.palustre*
- Each VB has its own endodermis *– E. Giganteum*
- VB is covered by two layers of endodermis – *E. hyemale and E. Sylvaticum*

Pericycle

- Uniseriate
- below the endodermis

Vascular Cylinder:

- Siphonostele
- The vascular bundles are arranged in a ring and present below the ridges and alternate with the vallecular canals of the cortex
- The number of VB and vallecular canals is equal to the number of ridges and grooves respectively
- Each VB is conjoint, collateral, closed and consists of xylem, phloem and some parenchyma
- In each VB water containing cavity called carinal canal is present.



Stele

- The xylem is V shaped, poorly developed.
- endarch and consists of protoxylem and metaxylem.
- In each VB the phloem is present in between two strands of metaxylem.
- It consists of sieve tubes and phloem parenchyma.

Pith

- it is in the form of cavity

Xerophytic characters of aerial shoot

- Presence of ridges and grooves.
- Thick walled cuticle.
- Presence of sunken stomata.
- Presence of silica in the epidermal walls.
- Reduced and scaly leaves.
- Well developed sclerenchyma.
- Presence of chlorenchymatous cortex which indicates the photosynthetic nature of stem.
- Presence of well developed vascular cylinder.

Hydrophytic characters of aerial shoot

- Presence of vallecular canals.
- Presence of carinal canals.
- Presence of well developed pith cavity.

ANATOMY OF INTERNODE OF RHIZOME

- Ridges and grooves are not so prominent as in aerial shoot.
- Absence of sunken stomata.
- Poorly developed sclerenchyma.
- Absence of chlorenchymatous cortex .
- It will developed pith cavity

ANATOMY OF INTERNODE OF AERIAL FERTILE SHOOT

- Absence of stomata.

- Poorly developed sclerenchymatous region.
- It will developed chlorenchymatous cortex.

ANATOMY OF ROOT

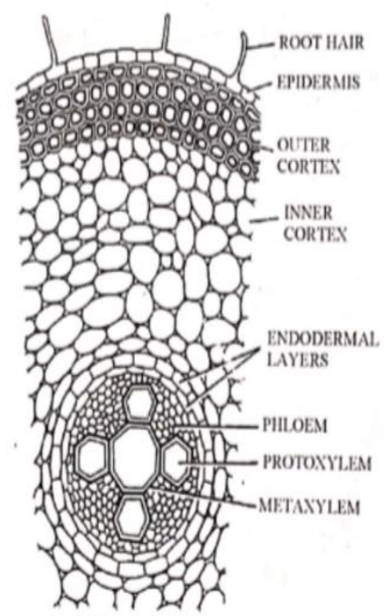


Fig. 7 : T.S. of root

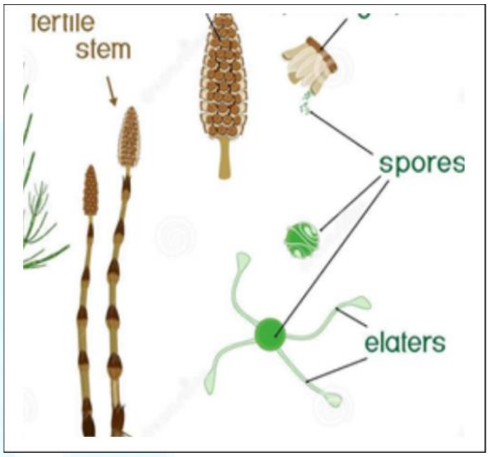
- **Epidermis**
  - single layered
  - with root hairs
- **Cortex**
  - outer and inner cortex
  - outer few layered, thick walled exodermis
  - Inner 3-4 or more layers of thin walled parenchymatous cortex
- **Endodermis** :
  - Two layered
  - Outer endodermal layer with casparian strips
  - Lateral roots originates from inner endodermal layer
  - Lacks Pericycle
- **Stele** : Protostele
  - Triarch to hexarch
  - Having 3-6 protoxylem groups surrounding a single metaxylem element in the centre
  - The space between the protoxylem groups remain filled with phloem
  - The xylem consists of many spiral tracheids while the phloem is made up of phloem parenchyma and sieve tubes

REPRODUCTION

Vegetative reproduction - By tubers

- The subterranean rhizome of some species (Equisetum arvense) forms tubers
- Which separation from the parent plant
- Germinate to produce new sporophytic plants

By spores



- Spores are present in sporangia.
- Sporangia are borne in cones.
- The cones are compact structures present terminally on the main axis.
- Typically the vegetative shoots may bear cones in most of the species.
- In some species two different types of branches are formed having different functions.
- i.e. some are sterile and green while others are fertile and non-green.
- The fertile branches in such species are short lived and wither soon after spore dispersal.

Structure of cone

- Each cone has a thick central axis called cone axis.
- On the cone axis are attached many umbrella shaped sporangiophore.
- Each sporangiophore is a stalked and sporangia bearing organ, the free end of which become flattened to form a peltate disc.

- The flattened tip of the peltate disc provides protective covering for the sporangia.

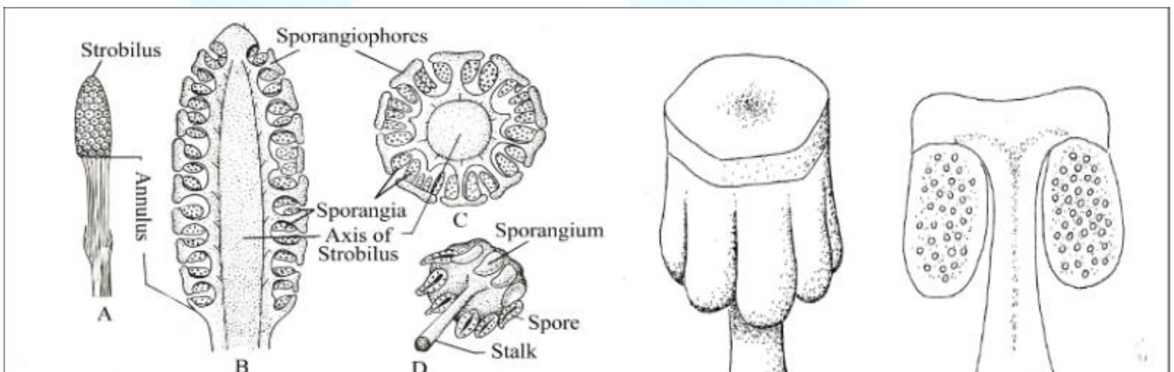
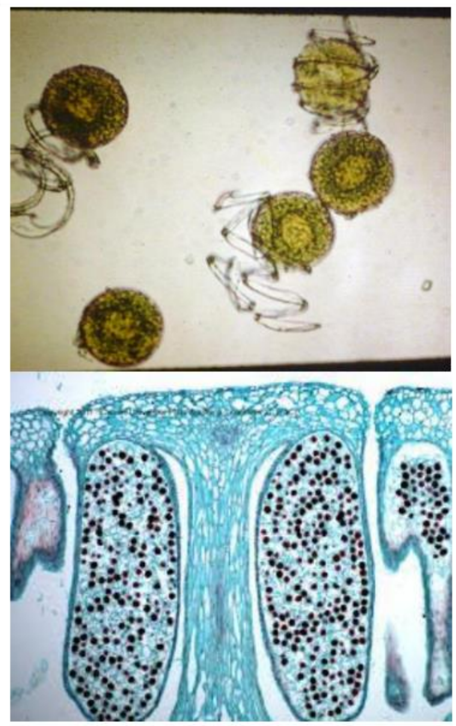


Fig: ***Equisetum spp.*** (A) A part of fertile shoot bearing strobilus; (B) LS of strobilus; (C) TS of strobilus; (D) Single sporangiophore.

- Each sporangium is an elongated ,pendant and sac like structure having a round apex.
- The sporangia vary in size ,and their number varies from 5-10 in each sporangiophore.
- Below each strobilus is present a calyx like whorl in some species . It is called Annulus.
- It is protective in function.

Mature sporangium



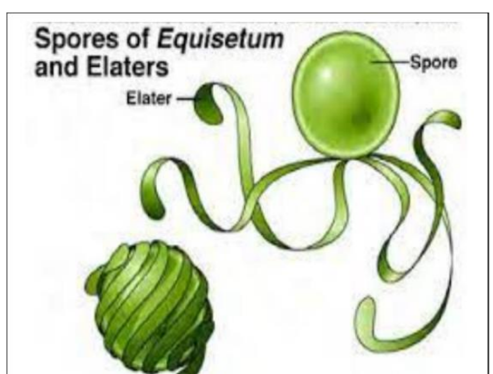
- It is an elongated sac like structure surrounded by jacket layer, generally consisting of 2 layers.
- Inside the jacket are enclosed many spores.
- Spores are homosporous.

Spore

- The spores are spherical or globular in shape.
- Each spore contain a central nucleus and filled with densely packed chloroplasts.
- The spore wall shows four concentric layers.
- Innermost is the delicate intine/ endospore, followed by thick exine/ exospore, the middle cuticular layer and the outermost epispore or perispore.
- The intine and exine are the true walls of the spore.

Elaters

- At maturity , the outermost layer – epispore splits to produce four ribbon like bands or strips with flat spoon like tips. They are called elaters.



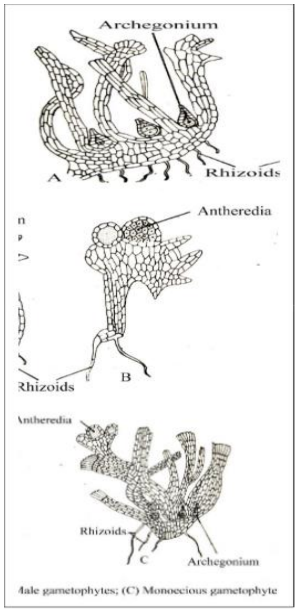
- Four such bands are attached to common point on the spore.
- The elaters are hygroscopic in nature and quickly respond to environmental changes.
- In moist conditions –elaters remain coiled round the spore but in dry conditions they become uncoiled and free.

Function of elaters

- The function of elaters is not known
    - The expansion of elaters may help in the dehiscence of sporangium
    - Help in the dispersal of spores

GAMETOPHYTE

- Equisetum is homosporous.
- The haploid spores germinate to form gametophyte.
- The germination takes place immediately if the spores land on a suitable substratum.
- The spores are very delicate and after shedding they remain viable only for a few days.
- The spore swell up by absorbing water and shed their exine.
- The first division of the spore results in two unequal cells – a small and a large cell.
- 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.
- Prothalli are of two types:
    1. **Filamentous type**
    2. **Cushion type**
- If a large number of spores are developed together within a limited space ,then thin filamentous type prothalli are formed.
- Thick and cushion type prothalli are developed from sparsely germinating spores.



Mature gametophyte

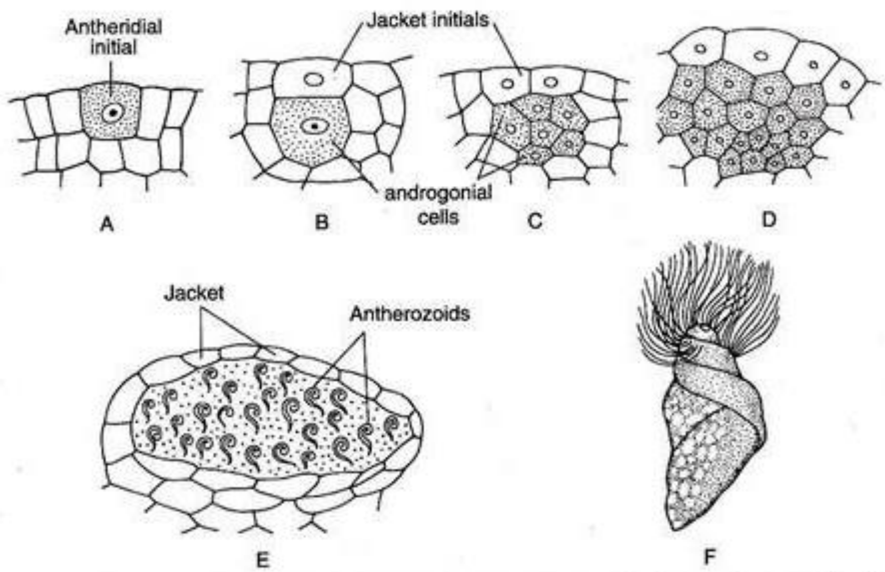
- Mature gametophytic plants may range in size from a few millimeters upto 3 cm (*Equisetum debile*) in diameter
- The mature prothalli are green ,thalloid and branched structures, each divisible into a compact cushion like basal portion and many erect ,green photosyntheic lobes.
- The prothallus may be monoecious or dioecious.
- *Equisetum arvense* is a monoecious species.
- *Equisetum debile* is a dioecious species.

SEX ORGANS

Antheridium

- Male sex organ
- 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 gametophyte.
- The periclinal division of the superficial antheridial initial give rise to jacket initial and an androgonial cell.
- The jacket initial divides anticlinally to form a single –layered jacket.
- The repeated divisions of androgonial cells form numerous cells which on metamorphosis, produce multiflagellated ,spirally coiled antherozoids or spermatozoids.
- The lower part of antherozoid is expanded whereas the apical portion is spirally coiled.

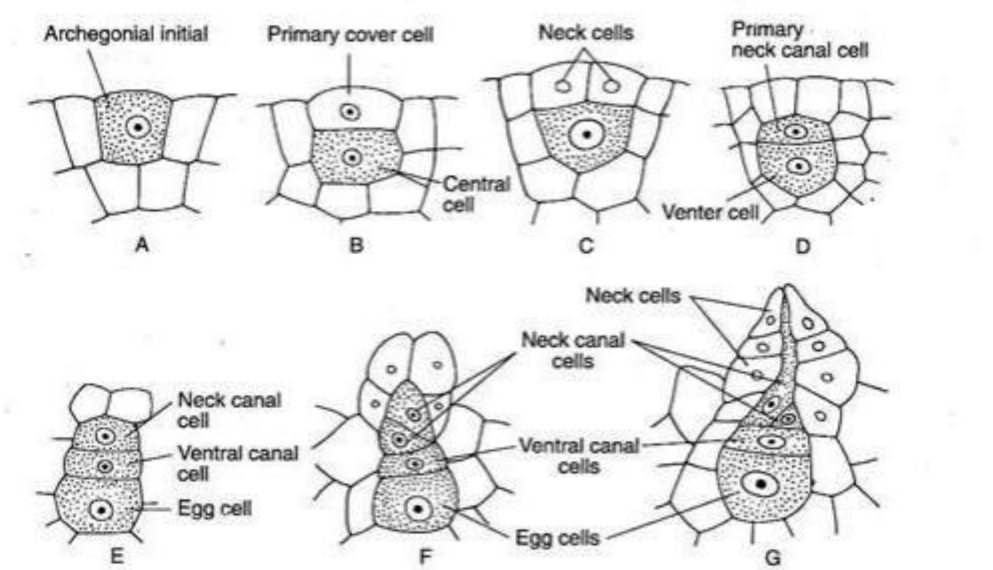
* The antherozoid escape through a pore created by the separation of the apical jacket.



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

Archegonium

* Female sex organ.
* Any superficial cell in the marginal meristem act as an archegonial initial.
* Archegonial initial undergoes periclinal division to form upper primary cover cell and lower central cell.
* The upper primary cover cell , by two vertical divisions at right angle to each other forms a neck.



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

Development of archegonia

- Lower central cell undergoes periclinal division to form an upper primary two neck canal cells and lower primary venter cell.
- The primary venter cell divides and form an egg and a venter canal cell.
- The primary neck cell does not undergo any further division ,but it directly functions as the single neck canal cell.

Structure of archegonia

- Mature archegonium consists of a short neck ,and a sunken base
- Neck encloses two neck canal cells.
- The venter consists of a single venter canal cell and an egg.
- Venter is embedded in the gametophytic tissue.

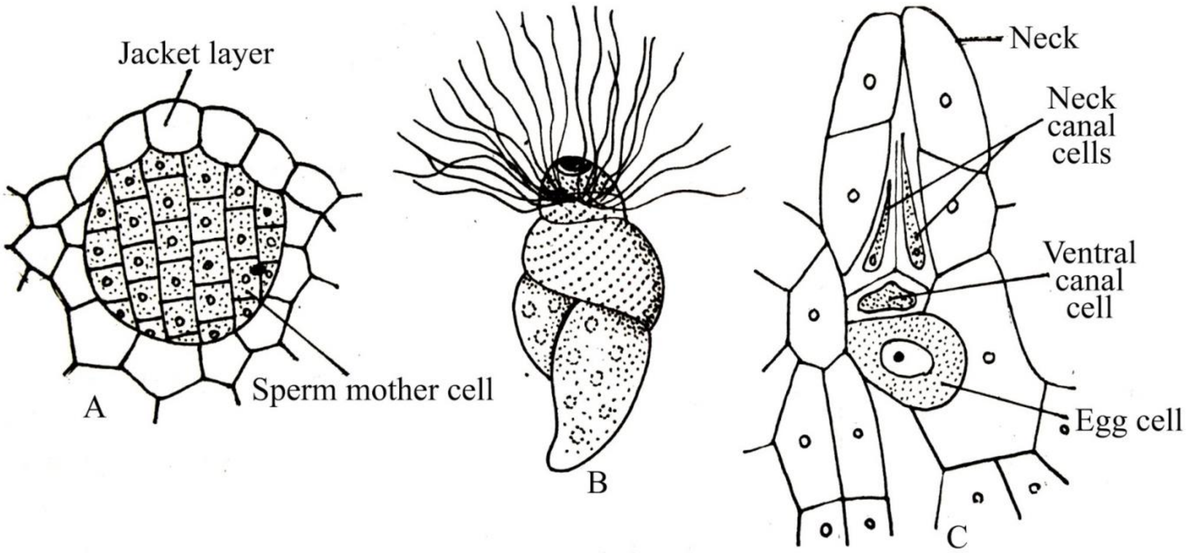


Fig: ***Equisetum spp.*** (A) Single antheridium (immature); (B) Single spermatozoid; (C) An archegonium (mature).

FERTILIZATION

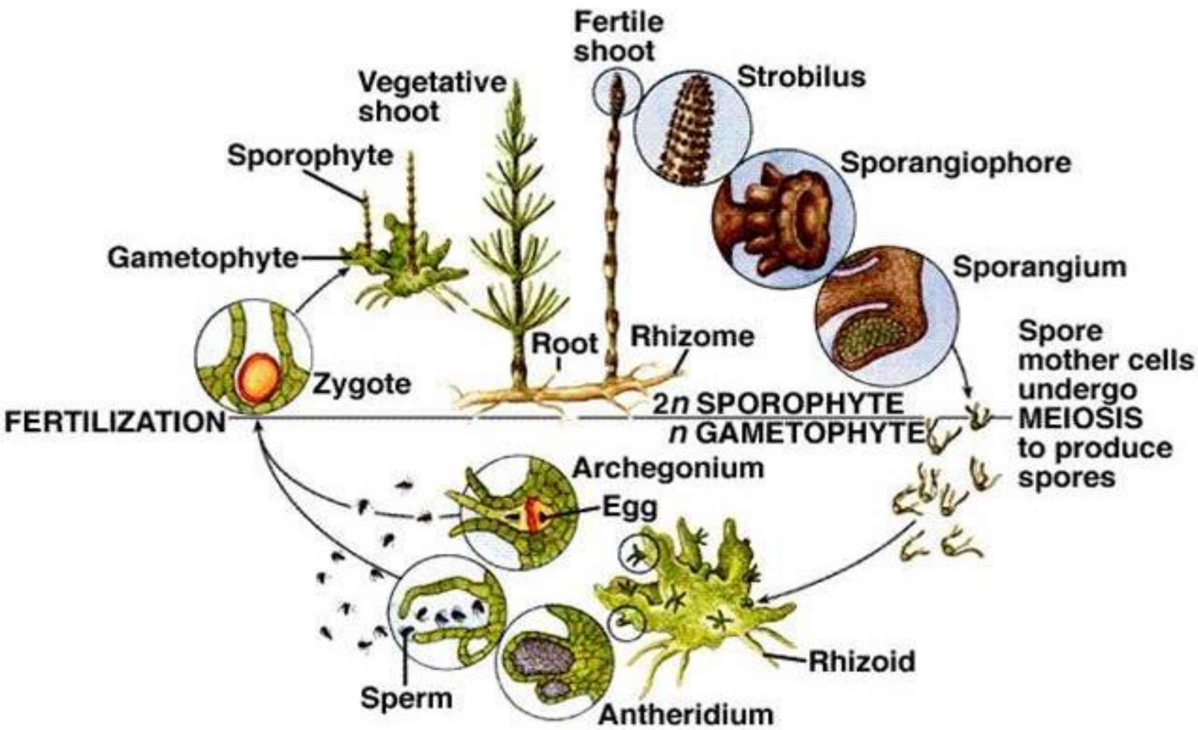
- Water is essential for fertilization.
- Before fertilisation 2 –Neck Canal Cells and 1-Venter Canal Cell disorganise and form free passage for the entry of antherozoids.
- Many multi- flagellated, spirally coiled antherozoids swim in water, attracted towards chemical substance secreted by archegonial neck canal cells and venter canal cell.
- Finally one of the antherozoid fuses with the egg forming diploid zygote.

EMBRYO DEVELOPMENT

- Zygote divides transversely and form
  - upper epibasal cell
  - lower hypobasal cell
- In *Equisetum arvense*
  - Entire shoot develops from epibasal region.
  - foot and root differentiate from hypobasal region.
- In *Equisetum debile*
  - Stem, root and other parts develops from epibasal region.

➢ foot from hypobasal region.

ALTERNATION OF GENERATIONS LIFE CYCLE OF EQUISETUM



CHARACTERISTIC FEATURES OF SPHENOPHYTA

- Only one living genus – *Equisetum.*
- Sporophyte is differentiated into root, stem and leaves.
- Stem contains nodes and internodes.
- Leaves are small, scaly and arranged on the nodes in the form of a whorl.
- Sporangia are formed in special appendages called sporangiophore.
- Peltate disc of sporangiophores possess compact strobilus.
- Equisetum is homosporous.
- The gametophyte is photosynthetic.
- Possess spirally coiled, multiflagellate antherozoids.

FILICOPHYTA

Division : FILICOPHYTA

Class : LEPTOSPORANGIOPSIDA

Order : FILICALES

Family : POLYPODIACEAE

Genus : PTERIS

- *Pteris vittata*, *Pteris cretica*, *Pteris stenophylla*, *Pteris quadriaurita* tropical and sub-tropical regions of the world.

EXTERNAL MORPHOLOGY

- Plant body is the sporophyte.
- Differentiated into rhizomatous stem that produces root and leaves.

RHIZOME

- Creeping and branched in – *Pteris vittata,Pteris grandiflora,Pteris biaurita*
- Rhizome is stumpy, semi-erect and branched in *Pteris erectica*
- Rhizome is covered with scales - Ramenta

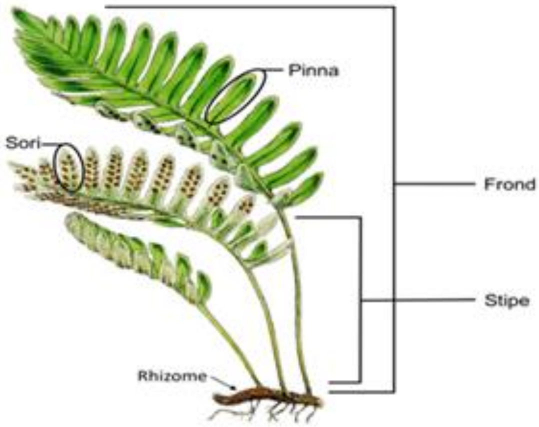
ROOTS

- Primary roots are ephemeral.
- Usually adventitious roots develop from the lower surface of the rhizome.
- But in some species ,they arise from all over the rhizome surface.

eg: *Pteris biaurita*

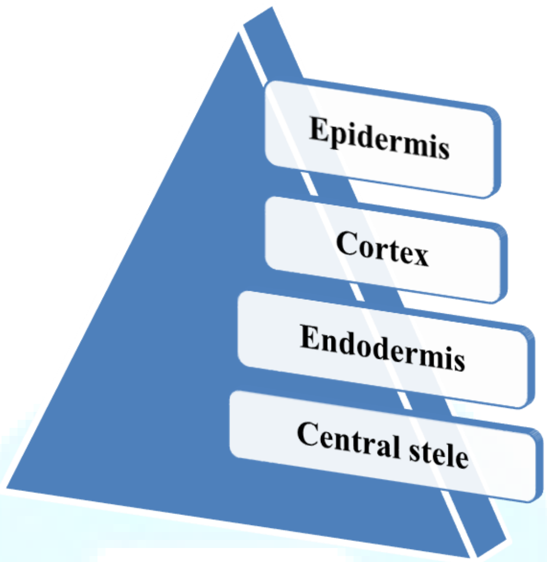
LEAVES

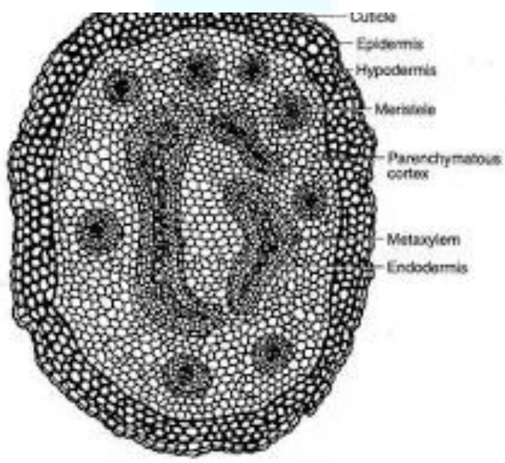
- Leaves arise from upper surface of rhizome.
- Leaves are unipinnately or multipinnately compound,with a long rachis.
- The pinnae are sessile and rough.
- Pinnae are small near the base, large towards the middle,and small towards the apex-spindle like appearance.
- The leaf apex is occupied by an odd leaflet or pinna.
- Petiole is covered with scales.



- Vienation is open and furcate (forked).
- Each pinna is traversed by a central midrib which gives off lateral veins that bifurcate near the tip.
- Leaves bear reproductive structure called sori, along the ventral margin of the pinnae.
- Leaves shows circinate vernation- typical feature of ferns.

ANATOMY OF RHIZOME





a. EPIDERMIS

- uniseriate with thick walled cuticle
- Young parts of the rhizome is covered by ramentum

b. CORTEX

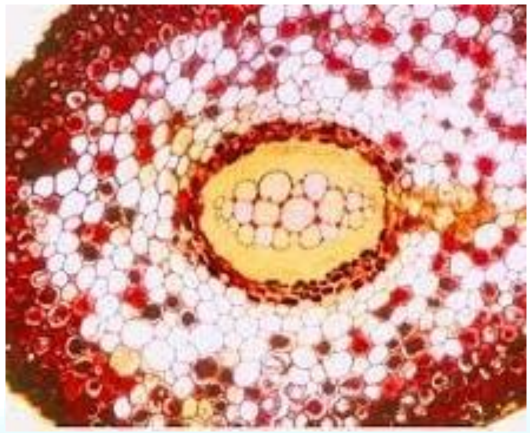
- Differentiated into outer and inner cortex.
- Outer cortex is sclerenchymatous and it forms the hypodermis.
- Inner cortex is parenchymatous.
- Endodermis – uniseriate,form a general sheath around the central stele
- Pericycle – stelar region is externally delimited by pericycle

c. STELE

- Stelar organisation of the rhizome varies with species.
- May be solenostelic, dictyostelic, mixed protostele.
- Solenostelic in – *Pteris vittata* and *Pteris grandiflora*
- Dictyostelic – *Pteris eretica*
- Mixed protostele - *Pteris biaurita*
- **Meristele**
  - The vascular strands are broken due to the presence of leaf gaps.
  - Each broken strand is called a meristele.
  - The stele consists of a number of meristeles, usually arranged in two rings ,inner and outer.
  - The inner ring consists of 2 or 3 large meristeles while the outer ring consists of a number of meristeles.
  - Each meristele has a plate like xylem mass.
  - One or two protoxylem groups remain embedded in the meristele – Mesarch.
  - Surrounding the xylem is the phloem.
  - Each meristele possess its own endodermis.

ENTRI

ANATOMY OF ROOT



- **Epidermis** – single layered, with thick walled cuticle and root hairs.
- **Cortex** – outer and inner cortex
- outer thick walled sclerenchymatous region, forms the hypodermis
- Inner thin walled parenchymatous cortex.
- **Stele:**
  - Protostele : has Exarch or diarch Xylem.

ANATOMY OF LEAF

Has three main parts – Epidermis, mesophyll and stele.

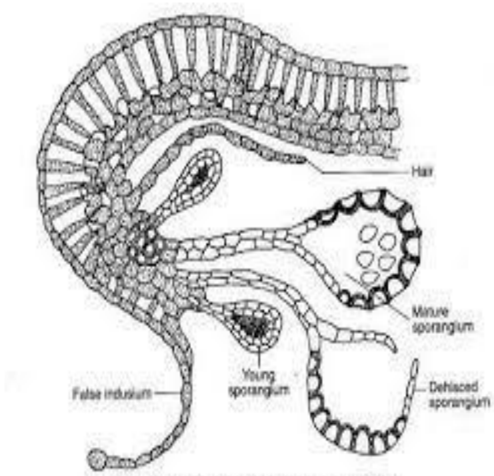


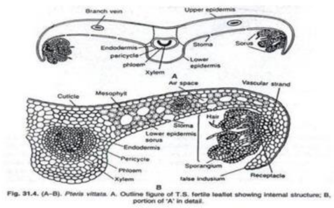
Fig. 7.104 : Pteris : T.S. of pinnule showing sorus (a portion)

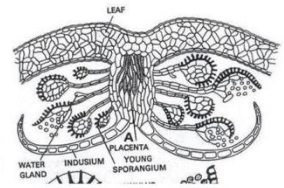
a. Epidermis

- possess upper and lower epidermis.
- The cells of upper epidermis are large with thick outer walls.
- The cells of the lower epidermis are small and thin-walled.
- Stomata are restricted to the lower epidermis.

b. Mesophyll

- Mesophyll may or not be differentiated into palaside and spongy parenchyma.
- Palaside and spongy tissue is absent around the mid –rib.
- Possess distinct endodermis and pericycle.
- Vascular strand
    - Mid-rib region has a single concentric type of vascular strand.
    - Bundle sheath extensions is prominent.



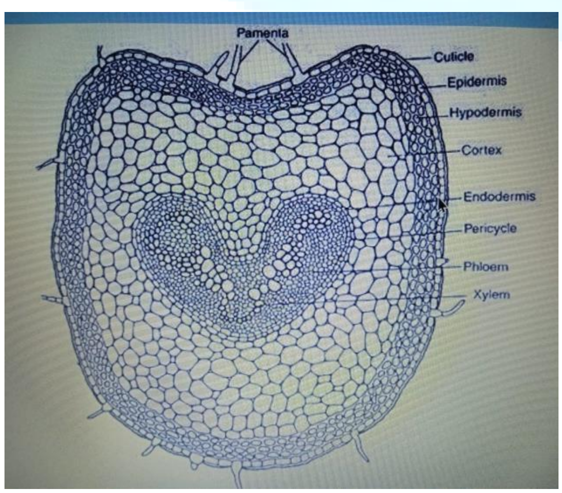


•It is protected by the upper indusial flap that is formed by the curving of margins of the pinnae (false indusium)

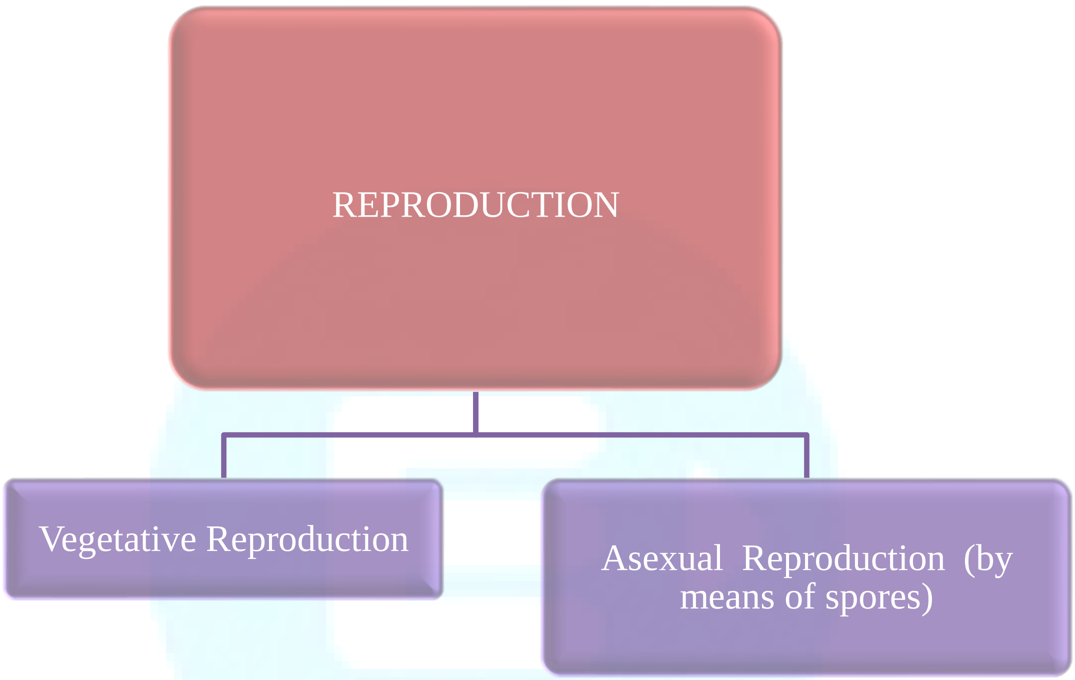
•A delicate membranous structure, known as indusium also arises from the lower side placenta and covers the sorus of sporangia

ANATOMY OF PETIOLE

- **Epidermis**
  - it is single layered and covered by thick cuticle.
  - Ramenta arise from some of the epidermal cells.
- **Cortex**
  - Differentiated into outer and inner cortex.
  - outer thick walled sclerenchymatous region, forms the hypodermis.
  - Inner thin walled parenchymatous cortex.



REPRODUCTION



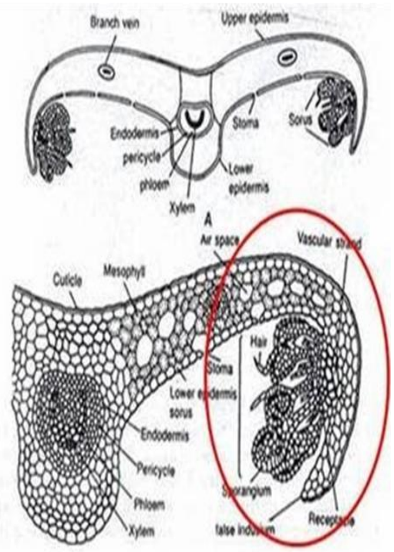
1. VEGETATIVE REPRODUCTION

- By the death and decay of older portion of rhizome.
- When the decay reaches the branching regions,the two branches separate and grow as individual plants.

2. BY SPORES

- In order Filicales , sporangia are aggregated to form sorus.
- Sori are usually borne on the margins of leaves called sporophylls.

- All spores are of same type – homosporous
- Sori are of the continuous type – coenosorus
- They are borne on marginal connecting veins and are protected by false indussium,formed by the reflexed margin of the pinnae.



REPRODUCTION BY SPORES

- Sorus are of three types – Simple, Gradate, Mixed.
- In Pteris, sori are of mixed type.
- Sterile hairs are preset in between the sporangia.

ENTRI

DEVELOPMENT OF SPORANGIUM

- The development of sporangium is leptosporangiate type.
- A single superficial cell of the receptacle functions as the sporangial initial which divides transversely to produce an upper cell and a lower cell.

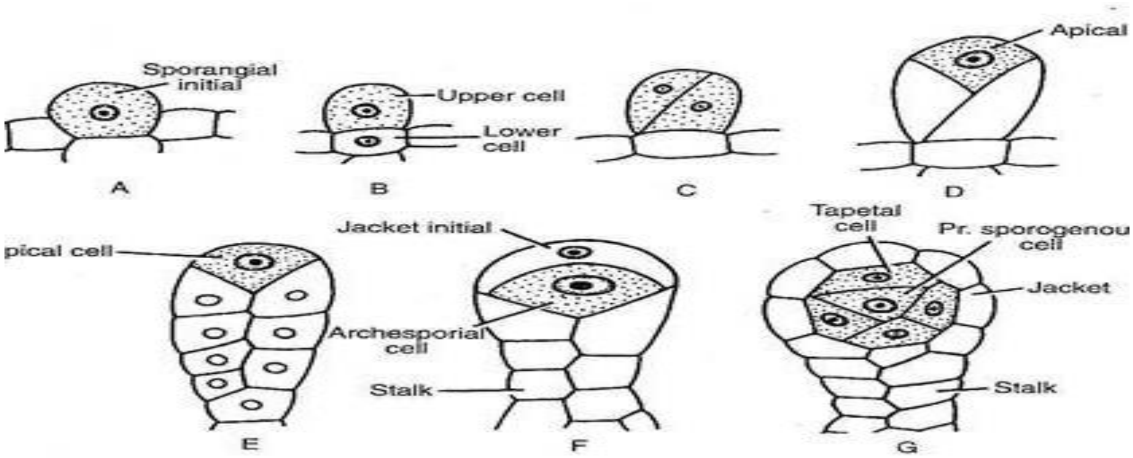


Fig. 7.105 : *Pteris* : A–G. The successive stages in the development of sporangium

- 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.

STRUCTURE OF SPORANGIUM

A mature sporangium has a stalk which terminates in a capsule.

The wall of the capsule has the following three parts:

1. An obliquely vertical annulus which completely overarches the sporangium.
2. A thin walled and radially arranged stomium.
3. Large parenchyma cells with undulated walls.

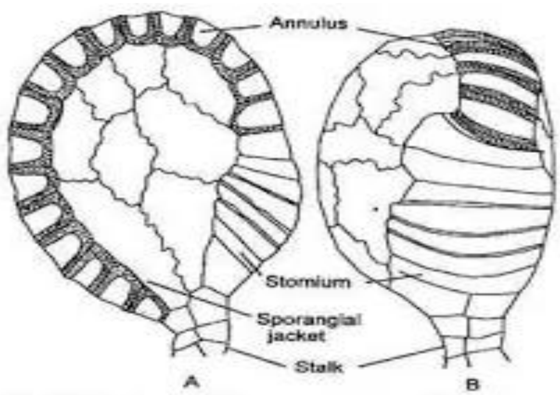


Fig. 7.106 : *Pteris* : Mature sporangium. A. Front view, B. Side view

SPORE

- The spores are triangular in shape.
- Each spore contain a central nucleus and filled with densely packed chloroplasts.
- The spore wall is thick and has an outer exine and inner intine.
- Exine is variously sculptured.

GAMETOPHYTE

- Pteris is homosporous.
- The germination takes place immediately if the spores land on a suitable substratum.

- The haploid spores germinate to form gametophyte, called prothallus.

PROTHALLUS

- Prothallus is small, green, flat and somewhat heart shape in outline.
- Numerous delicate, brown hair like, thin walled unicellular rhizoids arise from its lower end.
- Prothallus is monoecious, with antheridia and archegonia.
- Antheridia are found among the rhizoids and archegonia towards the apical notch.

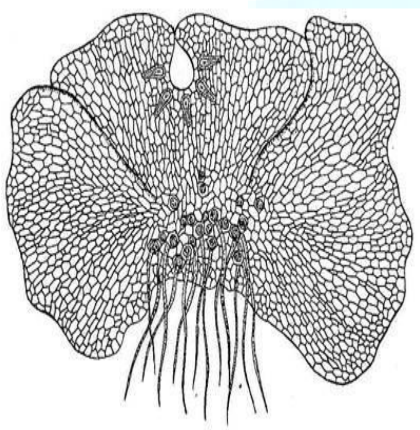


Fig. 7.107 : *Pteris* : Gametophyte

DEVELOPMENT OF ANTHERIDIUM

- A superficial cell on the ventral surface of the prothallus, functions as an antheridial initial.
- This divides transversely to form an outer upper cell and an inner 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.

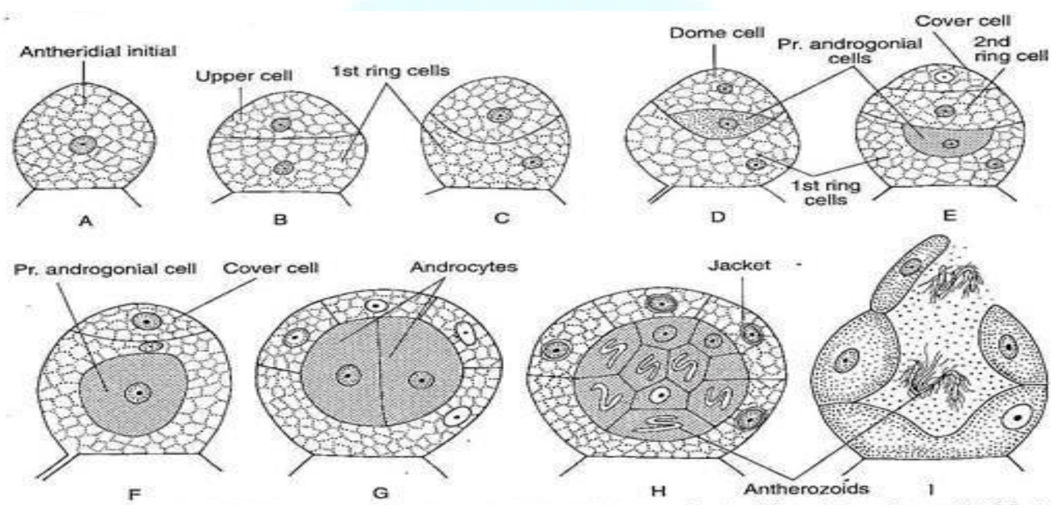


Fig. 7.108 : *Pteris* : A–H. The successive stages in the development of antheridium, I. A mature antheridium

MATURE ANTHERIDIUM

- The mature antheridium is a projected structure.
- It remains surrounded by a jacket consisting of two ring cells and a cover cell
- Inside the jacket are present 20-50 uninucleate, coiled and multiflagellate antherozoids.
- At maturity ,the antheridium absorbs water and swells.
- Its cover cells open out, releasing antherozoids.

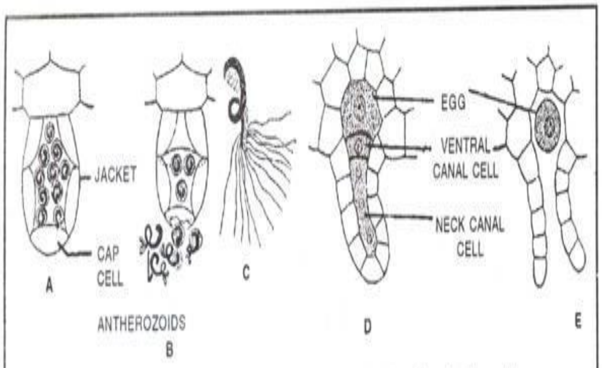


Figure 8.5 Sex organs of fern. A. Mature antheridium, B. Liberation of antherozoids, C. An antherozoid. D. Young archegonium, E. Mature archegenium.

DEVELOPMENT OF ARCHEGONIUM

- Archegonial initial undergoes periclinal division to form upper primary cover cell and lower central cell.
- The upper primary cover cell divides vertically and thus four neck initials are formed.
- Each of these neck initials divides transversely to give rise to a neck of 5-7 cells in height.

Structure of archegonium

- Mature archegonium consists of a swollen base, or the venter, and a projecting, short and slender neck.
- Neck encloses a small neck canal with a single long neck canal cell.
- Venter is embedded in the gametophytic tissue
- Venter has no venter wall,but contains the naked egg and a venter canal cell.

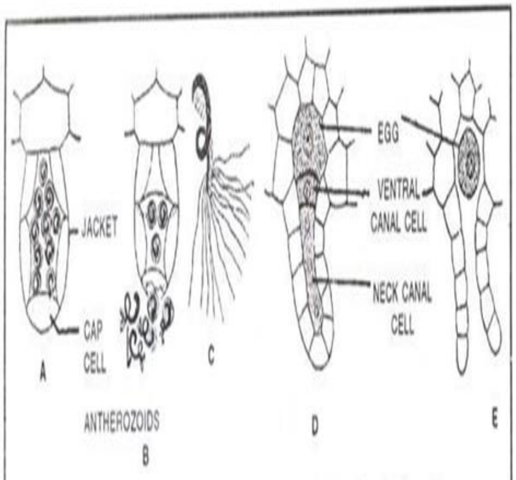


Figure 8.5 Sex organs of fern. A. Mature antheridium, B. Liberation of antherozoids, C. An antherozoid. D. Young archegonium, E. Mature archegonium.

FERTILIZATION

- Fertilization takes place in water.
- Before fertilisation NCC(Neck Canal Cells) and VCC(Ventral Canal Cells) disorganise and form free passage for the entry of antherozoids.
- Many multi- flagellated ,coiled antherozoids swim in water, attracted to the egg by the fluid formed by the disintegration of NCC and VCC.
- Though many antherozoids enter the neck ,only one of them fuses with the egg to form a diploid zygote.

EMBRYO DEVELOPMENT

- The *zygote*, undergoes two initial divisions and forms a quadrant.
- The first division of the zygote is vertical and the second one transverse.
- Further division result in the formation of a 32-celled embryo.
- Embryonic development is endoscopic and there is no formation of suspensor.

ENTRI

- Hypobasal cells of the embryo form stem apex and foot and epibasal cells form cotyledons and root.
- Root develops earlier and it pierces the prothallus and reaches the soil.

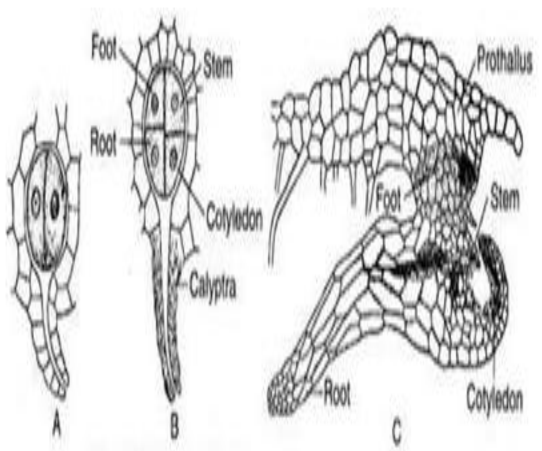
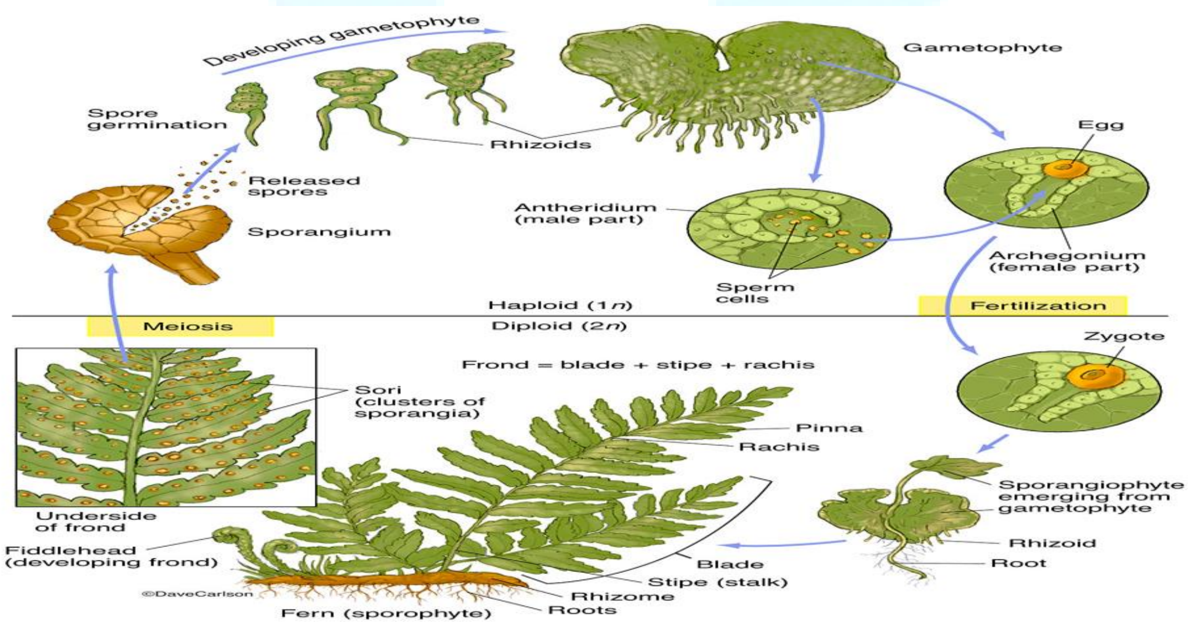


Fig. 7.109 : Pteris : A-C. Stages in the development of embryo

ALTERNATION OF GENERATIONS



CHARACTERISTIC FEATURES OF FILICOPHYTA

- Pinnately compound leaves are called fronds.
- Sporangia occur in groups called sori.
- Sori occur on the margin or abaxial surface of leaves.
- Spores may be homosporous or heterosporous.
- Spores germinate and develop into prothalli and bear sex organs.

HETEROSPORY,SEED HABIT AND ECONOMIC IMPORTANCE OF PTERIDOPHYTES

TYPES OF SPORES IN PTERIDOPHYTES

A) **Homospores**

B) **Heterospores**

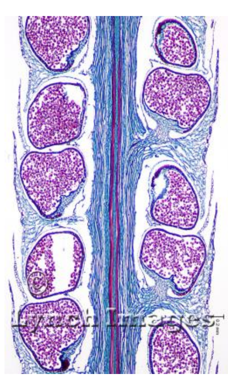
Homospores

- The Pteridophytes that produces one kind of similar spore.
- Such Peridophytes are known as homosporous and this phenomenon is known as homospory.
- Eg. Psilotum, Lycopodium etc

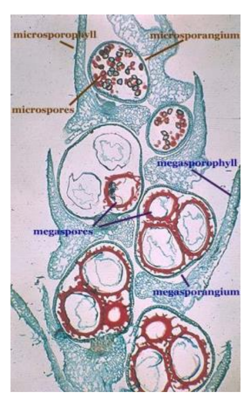
Heterospores

- Pteridophytes that produces two different types of spores.
- Spores - differ in size, structure and function.
- Eg : Selaginella, Marsilea etc

Homospores



Heterospores



HETEROSPORES CONDITION

- The two types of spores are microspores and megaspores.
- Microspores are smaller in size and develop into the male gametophyte.
- Megaspores are larger in size and develop into the 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

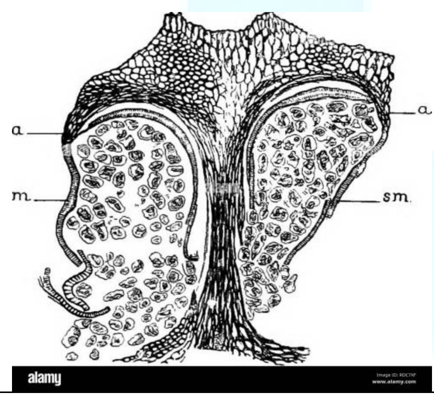
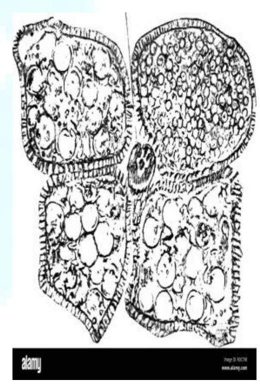
The origin of heterospory can be better discussed on the basis of

1. **Paleobotanical evidences**
2. **Developmental studies**
3. **Experimental studies**

1. Palaeobotanical evidences:

- It has been suggested that heterospory arose due to **degeneration of spores within 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 were all homosporous and the **heterosporous condition appeared in the lowermost upper Devonian period.**
- A number of heterosporous genera belonging to the *Lycopsida*, *Sphenopsida* and *Pteropsida* were known in in the late Devonian and early Carboniferous periods.

- Some fossil plants of late devonian and carboniferous period were heterosporous:
    - *Lepidocarpon, Lepidostrobus, Mazocarpon, Pleuromeia, Sigillariostrobus* - **members of Lycopsida**
    - *Calamocarpon, Calamostachys, Palaeostachys*- **members of Sphenopsida.**
- According to Williamson and Scot (1894) an indication of heterospory can be seen in two species of Calamostachys
- These species were *Calamostachys binneyana* and *Calamostachys casheana*

Calamostachys binneyana	***Calamostachys casheana***
• Most of the sporangia possess small. • Some sporangia have larger spores. 	• Microspores and megaspores present in different sporangia. • Some megaspores are abortive. 

- A similar abortion of species was also observed in certain species of *Lepidocarpon, Calamocarpon and Stauropteris*.
- Lepidocarpon and Calamocarpon possess only a functional megaspore ,as other spores are aborted during development.
- In *Stauropteris*, the megasporangium had two functional megaspores and two aborted spores.
- So the paleobotanical evidences suggest that heterospory evolved in fossil plants and it happens due to disintegration of some spores in sporangium.

2. Evidences from Developmental Studies:

- Developmental studies of a spore, particularly meiosis, maturation of spores and formation of sporocytes help to understand the heterospory
- In Selaginella :
  - In the microsporangium, all the sporocytes undergo meiosis and form a large number of microspores.
  - However, in megasporangium, all the sporocytes except one disintegrate and the surviving sporocyte undergoes meiosis to form 4 large functional megaspore.
- Variations in spore size of some species of *Selaginella*
- In *Selaginella stenophylla*
  - out of 4 megaspores in a tetrad, two are larger and two are smaller.
- In *Selaginella molliceps*
  - out of 4 megaspores in a tetrad, one megaspore is larger and the remaining three are smaller in size.
- In Selaginella erythropus
  - single large megaspore.

- In *Isoetes* there are 1,50,000-1,000,000 microspores in microsporangium and 50-300 megaspores in megasporangium
- 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 megasporangium 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 produces 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.

IMPORTANCE OF HETEROSPORY

- Heterospory expresses sex determining capability of the plant.
- There is biological significance of species showing heterospory- the growth of gametophyte occurs inside the spore only that is endosporic. So the nutrition for the developing gametophyte is derived from the sporophytes hence the gametophyte development is not affected by ecological factors as in case of independently growing gametophytes in homosporous species
- Fertilisation and early embryo development also takes place in sporophyte ensures that nutrition available for developing embryo.

SEED HABIT

- The seed habit is the characteristic features of higher organisms like gymnosperms and angiosperms.
- The spermatophytes always give rise to two types of spores- microspores (pollengrains) and megaspores.
- Angiosperms have only one functional megaspore which remain attached with megasporangium (ovule) after fertilisation and during development of seed.
- The male and female gamete fuse to form zygote and embryo development takes place inside the ovule.
- For the development of seed, the embryo and the gametophytic tissue (integuments and ovary wall) are involved to form the seed.
- After getting separated from the mother plant, seed germinates and forms a new plant.

SEED HABIT IN PTERIDOPHYTES

- Similar characteristics of seed occur in some vascular cryptogams but they do not develop seeds but following features in Pteridophytes support that seed habit has evolved in vascular cryptogams.

i. Formation of two types of spores (heterospory).
ii. Development of functional megaspore by reduction of other megaspores which reduces their number to one in per megasporangium.
iii. Retention of megaspore in the megasporangium after fertilization till embryo development.
iv. The megasporangium is modified at the apical part to receive microspores or pollen grains.
v. Sufficient nutrition availability for the development of embryo.

- **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.

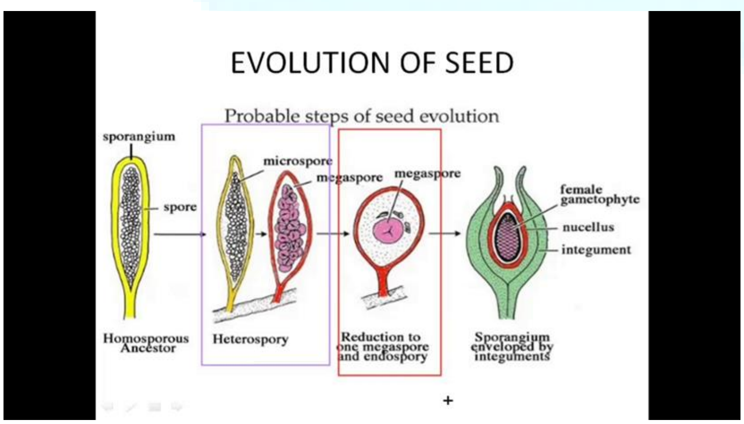
4. Development of only one megaspore per megasporangium for example, in Selaginella monospora, S. rupestris, S. erythropus etc.

- **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.



ECONOMIC IMPORTANCE OF PTERIDOPHYTES

1. Pteridophytes Used as Biofertiliser:

- *Azolla* is a free-floating water fern which can multiply very quickly through vegetative propagation
- Azolla species contains endophytic cyanobacterium (*Anabaena azollae*) in its leaf cavity.
- The relationship between the alga and Azolla is symbiotic, where the algae provides nitrogen to the plant. Thus, Azolla in full bloom in the waterlogged rice fields may serve as a green manure.

  These plants are used as biofertiliser in rice fields

Pteridophytes Used as Indicator Plants:

- Like angiosperms, pteridophytes are being used as indicator plants. *Equisetum* accumulates minerals, especially gold, in their stem. *Equisetum* may be referred to as gold indicator plants which help in searching a region for gold ore deposits.
- *Asplenium adulterinum* is an indicator of nickel.
- *Actinopteris australis* is a cobalt indicator plant.
- *Pteris vittata* is an indicator of arsenic.
- Thus, these plants are found to be valuable in prospecting for new ore deposits.

2. Pteridophytes Used as Horticultural Plants:

- Many variants and cultivars of *Psilotum* have been brought in cultivation in nurseries and greenhouses in the nickname 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.
- *Nephrolepis* and *Pityrogramma calomelanos* are planted in gardens.
- The tree fern species like *Cyathea contaminans*, *C. felina* and *C. magna* are grown in gardens.
- *Adiantum (*Maiden hair fern) species are planted in the garden beautification
- Several species of *Selaginella* are used as a ground cover in an undisturbed area because of their decent foliage and colour.
- *Selaginella 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.

3. **Pteridophytes Used as Medicine:**

- The Dryopteris flix-mas fern has been used for the treatment of tapeworm.
- The *Lycopodium clavatum* and *Lycopodium longifolium* are used for curing stomach ache and diarrhea.
- The *Pteridium aquilinum* is used to cure tooth ache and mouth infection.
- The leaves of *Cyclosorus* species is used for treatment of nasal infection.
- *Selaginella flabellata* is used to control fever, headaches and menstruation.
- The leaves of *Pteris ensiformis*, *Aspidium latifolium* and *Dryopteris milnean* roots are being applied to ulcers, boils and wounds
- The root decoction of *Osmunda regalis* is used for treatment of jaundice.
- *Adiantum caudatum* is used to cure skin diseases.

- The rhizome decoction of *Ophioglossum reticulatum* is used as antidote to snake bite.
- *Marsilea quadrifolia* whole plant extract is used as aphrodisiac.
- *Lygodium japonicum* is used for the expulsion of intestinal worms.
- *Pteridium revolutum* is used to treat gastric problems.

4. Pteridophytes Used as Food:

- The young leaf tips of *Diplazium esculentum* , the *circinate ptyxis* or the chroziers are used as vegetable.
- The young fronds of *Ampelopteris prolifera* are used as food
- 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.
- Sporocarps of *Marsilea*, a water fern, yield starch that is cooked and eaten by certain tribal.
- 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.

5. Pteridophytes Used as Weed:

- Aquatic fern *Salvinia* – block water flow.
- Terrestrial ferns like *Nephrolepis* species, *Christella* species and *Spharostephanous* species and *Pteridium* species grow very fast and known as troublesome weeds.

6. 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**.**

7. Dye yielding pteridophytes:

PLANTS	OBTAINED DYE
Asplenium ensiformis	Red dye
Equisetum arvense	Red dye
Pteridium aquilinum	Yellow dye

8. Source of certain chemicals:

As CHEMICALS

Plants	Yields chemical
Pteris vittata	Phenols
Psilotum nudum	Psilotic acid, Gibberellin
Pteridium aquilinum	Protein, sugar, starch, H.C.N,beta-carotene
Azolla pinnata	Protein, carotinoids
Diplazinum esculentum	Iron ,calcium
Equisetum arvense	Oxalic acids, malic acid, vinilic acid

Table 2.4: Economic importance of Pteridophyte	
Pteridophyte	**Uses**
Rumohra adiantiformis (leather leaf fern)	Cut flower arrangements.
Marsilea	Food
Azolla	Biofertilizer.
Dryopteris filix–mas	Treatment for tapeworm.
Pteris vittata	Removal of heavy metals from soils - Bioremediation
Pteridium sp.	Leaves yield green dye.
Equisetum sp.	Stems for scouring.
Psilotum, Lycopodium, Selaginella, Angiopteris, Marattia	Ornamental plants