MODULE-1

BRYOLOGY

GENERAL CHARACTERISTICS OF BRYOPHYTES

BRYOPHYTES

AN INTRODUCTION TO BRYOLOGY

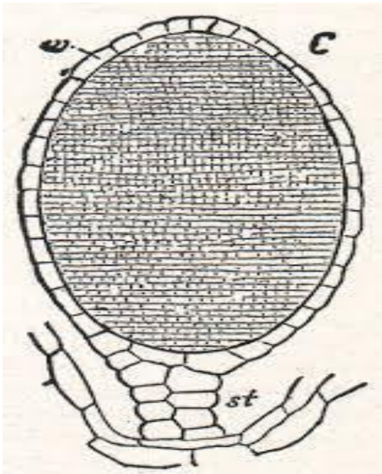
- The scientific study of bryophytes is known as Bryology.
- The term Bryophyta was given by R. Brown.
- The word Bryophyte is derived from two greek words.
  - **Bryon** = Moss, **Phyton** = Plant
- At present the phylum Bryophyta includes ~960 genera and ~24000 species.
- **Father of Bryology**- Hedwig.
- **Father of Indian Bryology**- S.R Kashyap.

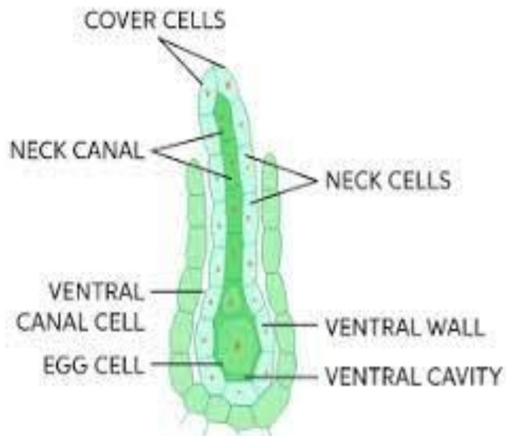
HABITAT OF BRYOPHYTES

- **Aquatic bryophyte-** *Riccia fluitans* (floating crystalwort)
- *Sphagnum* (Peat moss) is grown in bogs and marshy areas.
- *Porella* is an epiphytic form that grow on tree trunks.
- *Radula protensa* is an epiphyllous bryophyte.
- *Syntrichia caninervis* is an example for xerophytic bryophyte**.**

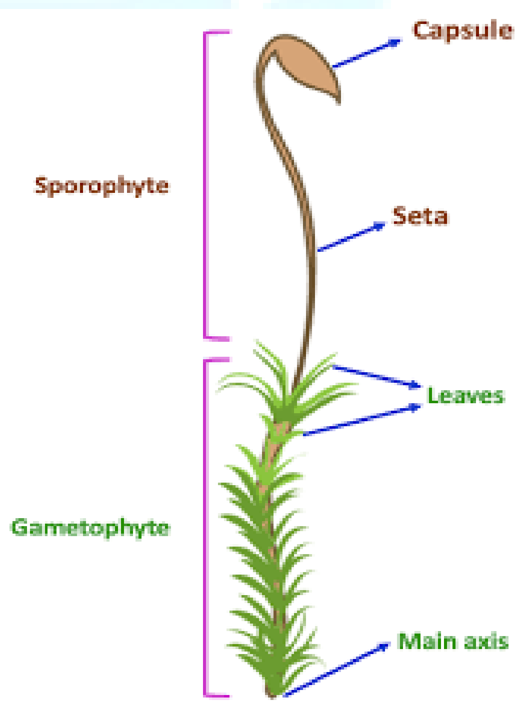
SALIENT FEATURES OF BRYOPHYTES

- Primitive and simplest plants of group Embryophyta.
- Bryophytes are nonvascular plants.
- They were evolved from green algae.
- They are present only in damp shady places and uncommon in marine environment.
- They are terrestrial plants but require water at every stages in their life cycle.
- The plant body is thallus like, i.e. prostate or erect.
- They do not have proper roots but have rhizoids.(unicellular/multicellular)
- Bryophytes are called **Amphibians of the plant kingdom**.
- In bryophytes gametophyte(n) is dominant and sporophyte(2n) is attached to it.
- **Vegetative reproduction** is quite common through fragmentation, tubers, gemmae, buds, adventitious branches, etc.
- Sex organs are multicellular and jacketed.
- **Sex organs in bryophytes** are Antheridia(male sex organ) and Archegonia(female sex organ).





- The antheridium produces antherozoids, which are biflagellated.
- The archegonium is flask shaped and produces an egg.
- The antherozoids fuse with egg to form a **zygote.**
- The zygote develops into a multicellular sporophyte.
- The sporophyte is semi-parasitic and dependent on the gametophyte for its nutrition.
- The sporophyte is differentiated into foot, seta and capsule.



AMPHIBIANS OF THE PLANT KINGDOM

- Bryophytes are dependent on water to complete their life cycle.
- Presence of water is required and essential for the;
  - Dehiscence of mature antheridia.
  - Liberation of antherozoids from antheridia.
  - Helps in transport of antherozoids.

Life Cycle of bryophytes will not complete in the absence of water, thus they are called as the **Amphibians of the plant kingdom**.

CLASSIFICATION OF BRYOPHYTES

1. Braun (1864) was the first person who introduce the term Bryophyta and called it acotyledonae. He included Algae, Fungi, Lichen and Mosses in it.
2. Schimper (1879) gave Bryophyta as the rank of a division.
3. Eichler (1883) divided Bryophyta into two groups Hepaticae and Musci.

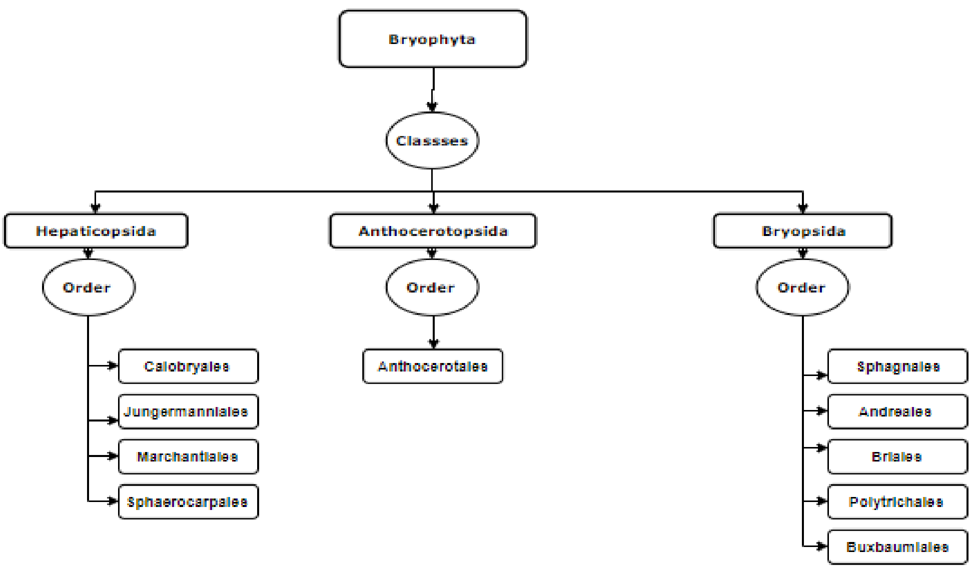
- Engler (1892) divided the division Bryophyta into two classes Hepaticae and Musci, and further divided each of the two classes into 3 orders.

Class HEPATICAE - 1. Marchantiales
2. Jungermanniales
3. Anthocerotales
} orders

Class MUSCI - 1. Sphagnales
2. Andreales
3. Bryales
} orders

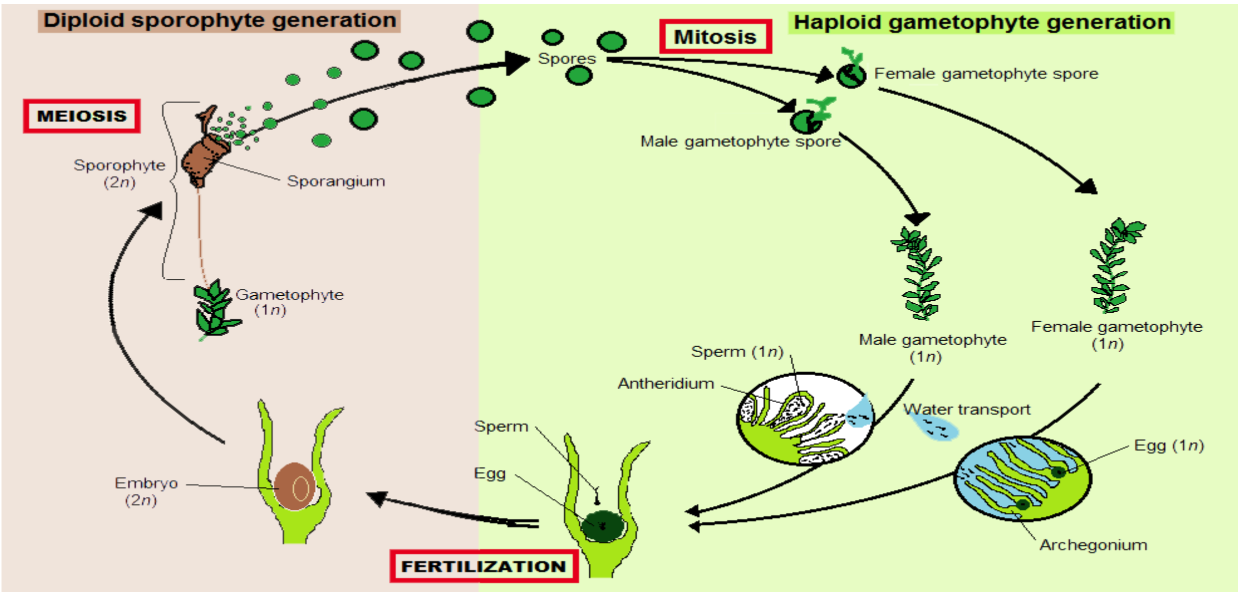
- Rothmaler (1951) changed the nomenclature of the three classes of Bryophyta to
  Hepaticopsida = Hepaticae,
  Anthoceropsida = Anthocerotae
  Bryopsida = Musci
  which are in accordance with the latest recommendations of the International Code of Botanical Nomenclature.
- Proskauer(1957) has changed the name Anthoceropsida to Anthocerotopsida.

- The modern bryologists, thus classify Bryophytes into the following three classes
  Class 1. Hepaticopsida (Hepaticae) - Liverworts
  Class 2. Anthocerotopsida (Anthocerotae) - Hornworts
  Class 3. Bryopsida (Musci) - Mosses



THE LIFE CYCLE OF BRYOPHYTES

- The bryophytes show an alternation of generations between the independent gametophyte generation, which produces the sex organs and sperm and eggs, and the dependent sporophyte generation, which produces the spores.



Diploid sporophyte generation
Mitosis
Haploid gametophyte generation
Spores
Female gametophyte spore
MEIOSIS
Male gametophyte spore
Sporophyte
(2n)
Sporangium
Gametophyte
(1n)
Male gametophyte
(1n)
Female gametophyte
(1n)
Sperm (1n)
Antheridium
Water transport
Sperm
Egg (1n)
Egg
Embryo
(2n)
Archegonium
FERTILIZATION

HEPATICOPSIDA

Hepaticopsida (Liverworts)

- The name *Hepaticopsida* comes from the latin word “hepatic” meaning liver.
- *Hepaticopsida* is further divided into 4 orders:
    1. ***Marchantiales*** (e.g. *Riccia*, *Marchantia*)
    2. ***Sphaerocarpales*** (e.g. *Sphaerocarpos*)
    3. ***Calobryales*** (e.g. *Calobryum*)
    4. ***Jungermanniales*** (e.g. *Pellia*)

CHARACTERISTIC FEATURES

GAMETOPHYTE

- Gametophyte plant is either thalloid or foliose.
- Thalloid forms are dorsiventral, lobed and dichotomously branched(*Riccia*, *Marchantia*).
- In foliose forms, leaves are without midrib and dorsiventral(*Porella*).
- Each cell of thallus contains many chloroplasts without pyrenoids.
- Rhizoids are unicellular, branched and aseptate.
- Multicellular scales are present.

SPOROPHYTE

- Sex organs are borne dorsally embedded in gametophytic tissues.
- The sporophyte is made up of only capsule (in *Riccia*) or foot, seta and capsule (in *Marchantia*).
- The columella is absent in the capsule.
- Sporogenous tissues develop from endothecium.
- Sporophyte is completely dependent upon the gametophyte for food and nutrition.
- Dehiscence of the capsule may be regular or irregular.

MARCHANTIA

Kingdom: Plantae
Division : Bryophyta
Class : Hepaticopsida
Order : Marchantiales
Family : Marchantiaceae
Genus : *Marchantia*

- Genus *Marchantia* has ~65 species.
- *Marchantia polymorpha* grows as a pioneer in the burnt forest soil after fire.
- 11 species in India, growing mainly in the Himalayas and the South-Indian hills.
- *Marchantia palmata* : eastern Himalayas.

MORPHOLOGY

- The vegetative plant represents the gametophytic plant body.
- Prostrate, dorsiventral and dichotomously branched thallus.
- **Dorsal**:
  - Distinct midrib.
  - marked on the dorsal surface by a shallow groove.
  - gemma cups and epidermal pores are present.
- **Gemma Cups:**
  - contain specialized.
  - Multicellular.
  - asexual reproductive bodies/granules called Gemma.
- **Ventral**:
  - Rhizoids and Scales.

- Rhizoids hyaline and unicellular.
- Scales are multicellular & violet in colour (anthocyanin pigments)

ANATOMY

❖ Photosynthetic region

- Contains numerous air pores analogous to the stomata in higher plants.
- Consist of air chambers separated with each other by Septa.
- Just beneath the upper epidermis, Simple or branched photosynthetic filaments are present and it is composed of Chlorophyll containing cells.

❖ Storage region

- Just below the photosynthetic region.
- Compact zone of several layers of polygonal parenchymatous cells.
- Achlorophyllous without intercellular spaces.
- Mostly contain starch or protein granules, mucilage and oil.
- Lower part of the storage region contains rhizoids and scales.
- Rhizoids are of two types smooth walled and tuberculate.
- Scales are also differentiated into two Ligulate and Appendiculate scale.

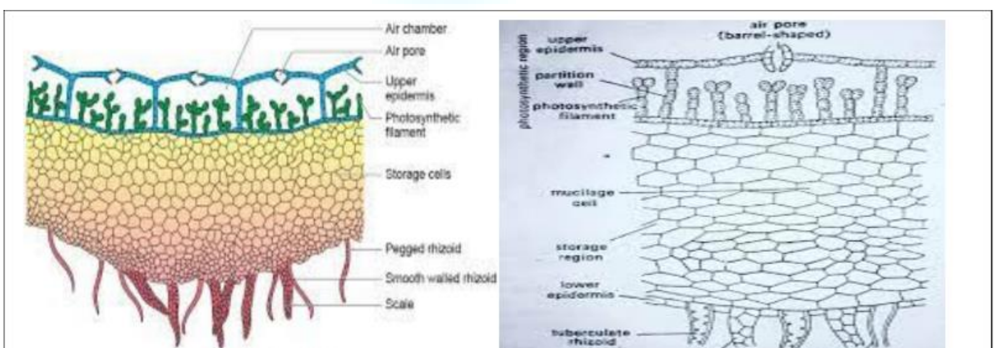
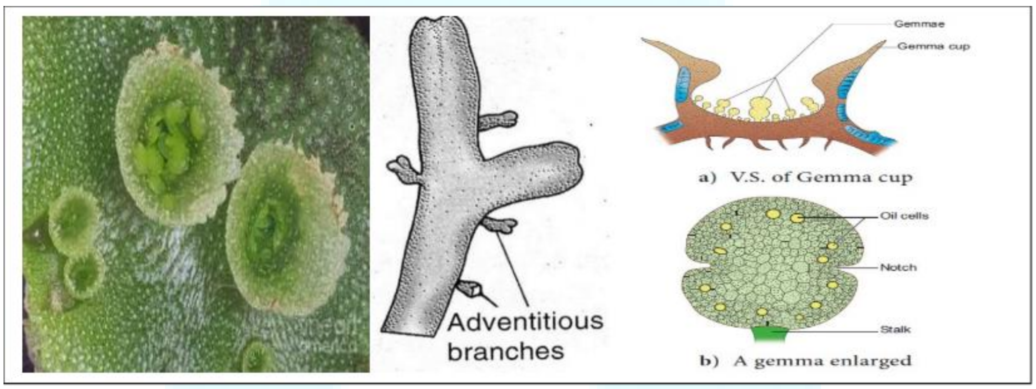


Figure 2.13: T.S. of Thallus

<u>REPRODUCTION</u>

1. <u>Vegetative reproduction by</u>

a) Progressive death and decay of the thallus.
b) Adventitious branches.
c) Gemmae.



2. <u>Sexual reproduction</u>

- *Marchantia* is dioecious or heterothallic that is male and female sex oragans on different thalli.
- There are exceptional cases and some are homothallic and it is known as Androgynophore.
- Eg; *M. palmatci*.
- Gametophores develop at the distal end of respective thallus (apical notch).
- **Antheridia**: on Antheridiophore.(male reproductive organ).
- **Archegonia**: on Archegoniophore.(female reproductive organ).
- They are terminal.

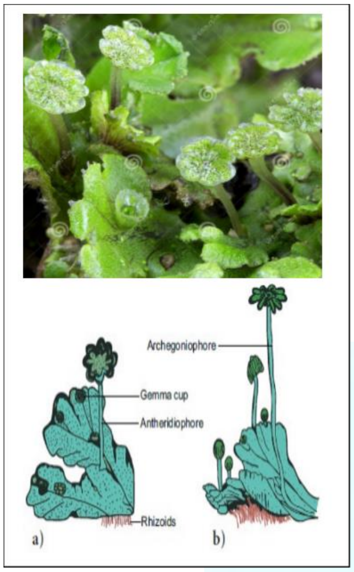
Antheridiophore

- Arises at the apical notch.
- Differentiated into a long stalk(1-3cm) and a terminal disc(8-lobed).
- But in *M. geminata* it is four lobed.
- Each lobe on the peltate disc have numerous minute cavities on the upper surface.
- Antheridial chambers embedded in the photosynthetic region.
- Each antheridial chamber contains a single antheridium.
- Each antheridia are borne in acropetal succession.

❖ **Development of Antheridium**

- The antheridial initial increases in size and divides by a transverse division to form an outer upper cell and a lower basal cell.
- Basal cell remains embedded in the tissue of the thallus, undergoes a little further development and forms the embedded portion Of the antheridial stalk.
- Outer cell divides to form a filament of four cells. Upper two cells of the four celled filament are known as primary antheridial cells and lower two cells are known as primary stalk cells.
- Primary antheridial cells divide by two successive vertical divisions at right angle to each other to form two tiers of four cells each.
- A periclinal division is laid down in both the tiers of four cells and there is formation of eight outer sterile jacket initials and eight inner primary androgonial cells.
- Jacket initials divide by several anticlinal divisions to form single layer of sterile antheridial jacket.
- Primary androgonial cells divide by several repeated transverse and vertical divisions resulting in the formation of large number of small androgonial cells.
- The last generation of the androgonial cells is known as androcyte mother cells.

➢ Each androcyte mother cells divides by a diagonal mitotic division to form two triangular cells called androcytes.
➢ Each androcyte cell metamorphosis into an antherozoid.



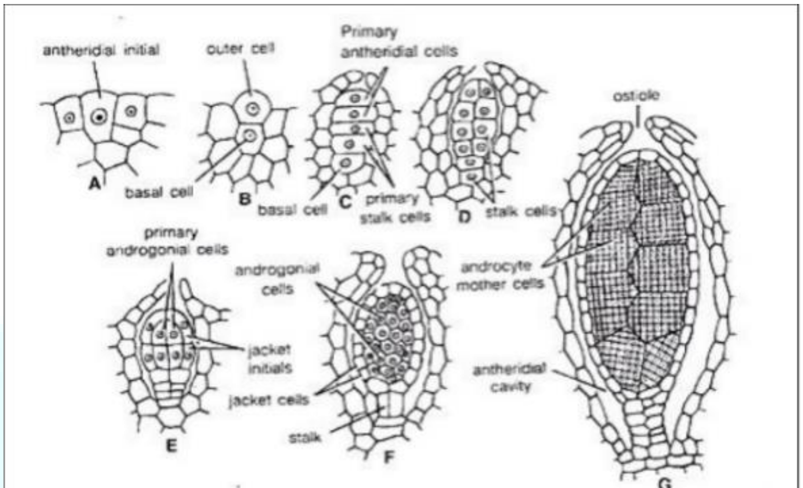


Fig. 7. (A-H). *Marchantia*. Development of antheridium (A-F). Successive stages in the development of antheridium, (G). A mature antheridium.

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✶ Anthredia

➢ The air chambers on the upper surface are alternated with numerous flask-shaped cavities,called the Antheridial Chambers.
➢ The antheridial chambers open externally by a pore, called Ostiole.
➢ Each antheridial chamber contains a single Antheridium.
➢ The mature antheridium is a globular structure, attached to the floor of the antheridial chamber by a multicellular stalk.
➢ The antheridium has a single layered sterile jacket, enclosing a mass of androcytes, which eventually metamorphose into antherozoids (minute, rod-like biflagellate male gametes).

❖ Dehiscence of Antheridia

➢ Dehiscence in presence of water.
➢ At maturity the pore of antheridial chamber becomes wide open through which water enters and fills the chamber.

- Sterile jacket cells imbibe water,become softened get disorganised.
- Antherozoids ooze out through the ostiole and they swim with the help of water.

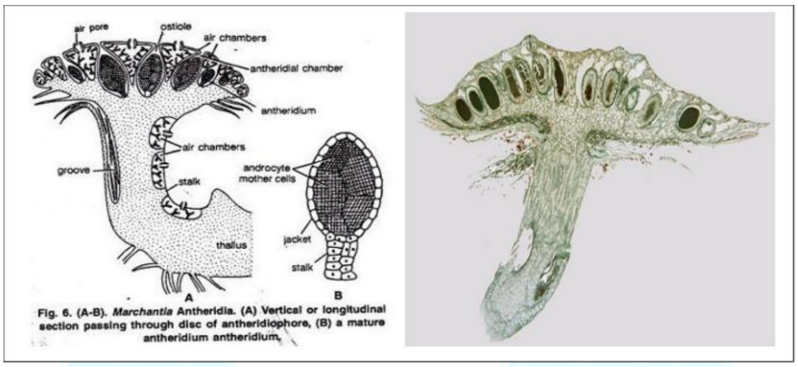


Fig. 6. (A-B). *Marchantia* Antheridia. (A) Vertical or longitudinal section passing through disc of antheridiophore, (B) a mature antheridium antheridium.

ARCHEGONIOPHORE

- It is the reproductive branch bearing archegonia.
- Arises at the apical notch.
- 3-5 cm stalk and a terminal disc.
- Disc is star shaped with 8-9 radiating arms or ‘Rays.
- Each ray contains a row of 12-14 archegonia embedded in a fertile pocket along the ventral ridge.

❖ Development of Archegonium

- The development of the archegonium starts on the dorsal surface of the young receptacle in acropetal succession.

- A single superficial cell which acts as archegonial initial enlarges and divides by transverse division to form a basal cell or primary stalk cell and an outer cell or primary archegonial cell.
- The primary stalk cell undergoes irregular divisions and forms the stalk of the archegonium.
- The primary archegonial cell divides by three successive intercalary walls or periclinal vertical walls resulting in the formation of three peripheral initials and a fourth median cells, the primary axial cell.
- Each of the three peripheral initials divide by an anticlinal vertical division forming two cells.
- In this way primary axial cell gets surrounded by six cells.These are called jacket initials.
- Six jacket initials divide transversely into upper neck initials and lower venter initials.
- Neck initial tier divides by repeated transverse divisions, to form a tube like neck.

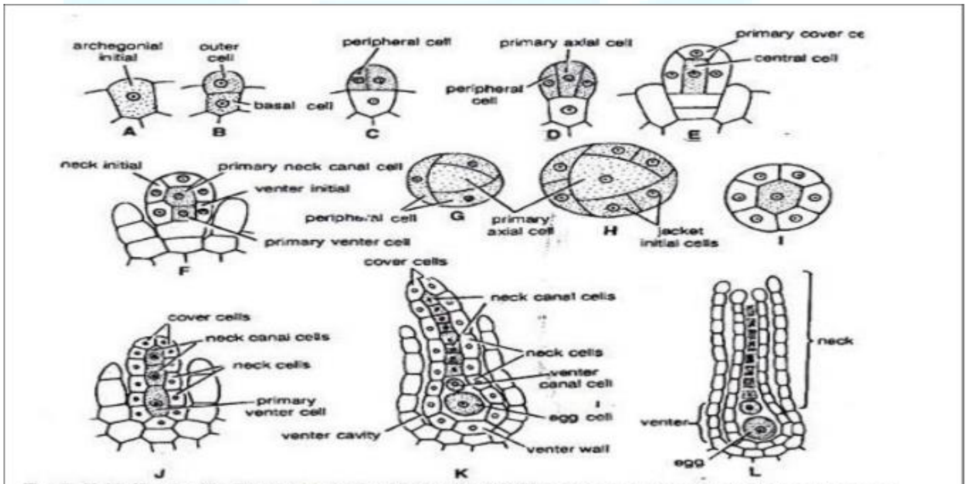
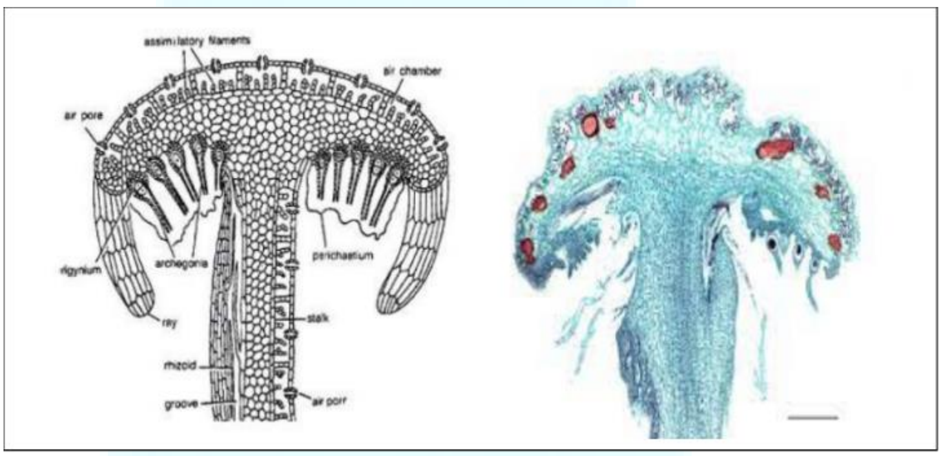


Fig. 9. (A-L) *Marchantia*. Development of archegonium. (A-K) successive stages in the development of archegonium. (L) A mature archegonium.

❖ Archegonium

- Archegonia are found in uniseriate fertile pockets along the ventral ridges of radiating discs, near the stalk.

- They are enclosed inside a mass of sterile tissue, called Perichaetium.
- The mature archegonium is pendant and attached to the ventral ridges of the radiating disc by a short stalk.
- It is an inverted flask-shaped structure, with a basal swollen Venter and an elongated Neck.
- The venter is surrounded by a single layered sterile Jacket and contains a large egg and a relatively smaller Venter Canal Cell.
- The neck consists of 6 vertical rows of cells, called the Neck Cells, which enclose a narrow canal with 4-8 Neck Canal Cells.
- The tip of the neck has a rosette of four Cover Cells.



FERTILIZATION

- The presence of water is necessary for fertilization.
- The transfer of antherozoids from the disc of antheridiophore to the convex disc of archegoniophore occurs by splashing of raindrops.
- The mucilaginous substance in the archegonial neck attract the antherozoids.
- Antherozoids swim down to the neck canal cells and one fuses with the egg.
- Zygote forms and the gametophytic phase of the lifecycle ends with this stage.

POST FERTILIZATION PROCESS

- Stalk of the archegoniophore elongates.

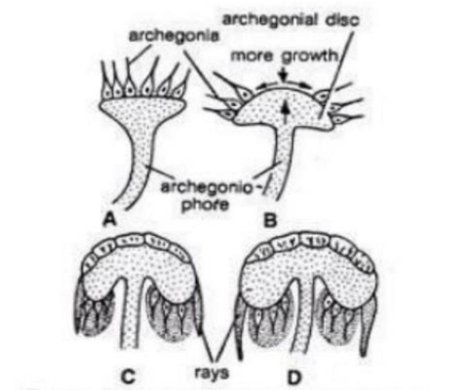


Fig. 10. (A-D). *Marchantia.* (A) Position of the archegonia before fertilization, (B-D). Inversion of the archegonia after fertilization.

- Remarkable over-growth takes place in the central part of the disc.
- Archegonia hangs towards the lower side with their neck pointing downwards.
- Wall of the venter divides to form two to three layered calyptra.
- A ring of cells at the base of venter divides and re-divides to form a one cell thick collar around archegonium called perigynium (Pseudo Perianth).
- A one celled thick, fringed sheath develops on both sides of the archegonial row.
- It is called perichaetium or involucre.
- The main function of these layers is to provide protection, against drought, to young sporophyte.
- Zygote develops into sporogonium.

Sporophytic generation

- Each sporogonium is differentiated into foot,seta and capsule.
- It is enclosed within a protective covering called Calyptra.
- The other protective coverings are perigynium which encloses single sporogonium and perichaetium which covers the group of sporangia.
- From the sporogonium spores forms and by this stage the sporophytic generation of life cycle ends.

❖ Development of Sporogonium

- ➢ After fertilization the diploid zygote or oospore divides by transverse division (at right angle to the archegonium axis) to form an outer epibasal cell and inner hypo basal cell.
- ➢ The second division is at right angle to the first and results in the formation of four cells called quadrant stage.
- ➢ The epibasal cell forms the capsule and hypo basal cells form the foot and seta.
- ➢ Since the capsule is developed from the epibasal cell and forms the apex of the sporogonium, the type of embryogeny is known as exoscopic.

- The next division is also vertical and it results in formation of eight celled stage or octant stage.
- Irregular divisions takes place and globular embryo forms.
- The lower cells divide to form a massive and bulbous foot.
- The cells of the seta divide in one plane to form vertical rows of cells.
- In upper region of capsule periclinal division occurs and it differentiates it into outer single layered amphithecium and multilayered endothecium.
- The cells of the endothecium divide only by anticlinal divisions to form a single layered sterile jacket or capsule wall.
- The endothecium forms the archesporium.
- Its cells divide and re-divide to form a mass of sporogenous cells (sporocytes).
- Half of the sporogenous cells become narrow and elongate to form the elater mother cells.
- The elater mother cells elongate considerably to form long, slender diploid cells called elaters.
- Elaters are pointed at both the ends and have two spiral bands or thickenings on the surface of the wall.

❖ **Development of gametophyte**

- Spore is the first cell of gametophytic generation.
- Spore has thick wall differentiated into outer exine and inner intine.
- Each spore mother cells produces 4 spores out of which 2 develop into male and 2 develop into female thalli.
- Thus it shows physiological heterospory.
- Since the plant bodies of two generations are morphologically dissimilar it is called heterologous type of alternation of generations and the lifecycle is diplohaplontic.

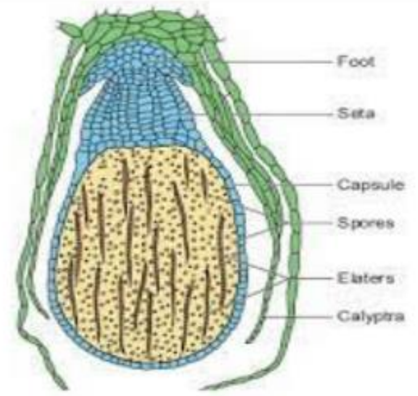
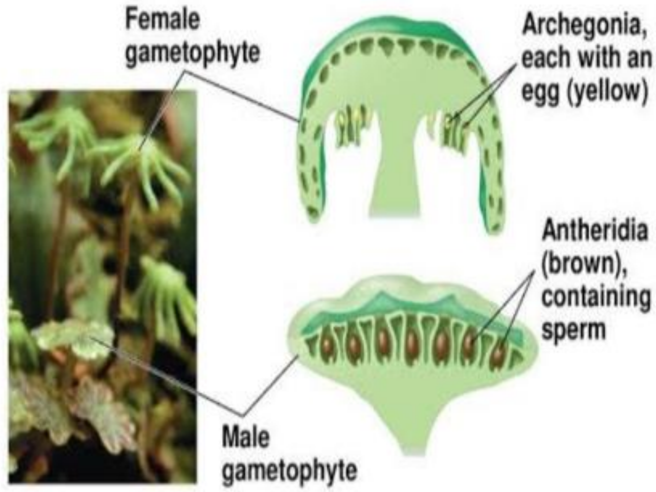


Figure 2.16: *Marchantia* - V.S. of Sporophyte



LIFE CYCL OF MARCHANTIA

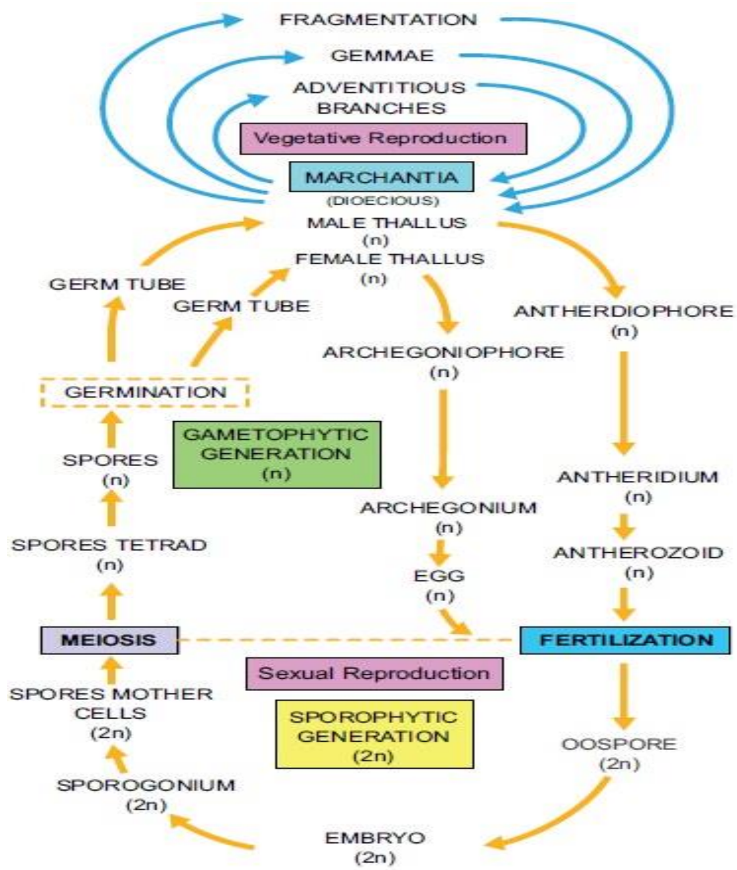


Figure 2.17: Life cycle of *Marchantia*

ANTHOCEROTOPSIDA

GENERAL FEATURES

- Commonly known as Hornworts.
- Hornworts found in places that are damp or humid.
- *Dendroceros* - found on bark of trees.
- The plant body of a hornwort is a haploid gametophyte and this stage usually grows as a thin rosette or ribbon-like thallus between 1-5 centimeters in diameter.

- The gametophytic plant body is thalloid and dorsiventral.
- The tissues of the thallus are not differentiated.
- Air chambers and air-pores are absent.
- Each cell of the thallus usually contains just one chloroplast and a large pyrenoid that enables more efficient photosynthesis and stores food.
- The rhizoids are simple and smooth walled.
- Tuberculate rhizoids and ventral scales are altogether absent.
- Hornworts develop internal mucilage-filled cavities or canals.
- This will secrete hormogonium-inducing factors (HIF) that stimulate nearby, free-living photosynthetic cyanobacteria, especially species of *Nostoc*, to invade and colonize these cavities.
- Colonies of bacteria growing inside the thallus give the hornwort a distinctive blue-green color.
- Small slime pores are present on the ventral surface and these pores superficially resemble the stomata of other plants.
- The **horn-shaped sporophyte** grows from an archegonium embedded in the gametophyte.

- Hornworts have true stomata on their sporophyte.(The exceptions are the genera *Notothylas* and *Megaceros*.)
- The sporophyte of most hornworts are also photosynthetic.
- In a mature sporophyte a central rod-like columella running up the center is present, and a layer of tissue in between that produces spores and pseudo-elaters.
- The pseudo-elaters are multicellular, unlike the elaters of liverworts.
- The antheridia are endogenous.
- The antheridia are developed within the antheridial chambers, singly or in groups on the dorsal side of the thallus.
- The archegonia are found in sunken condition on the dorsal side of the thallus.
- The spores are polar, usually with a distinctive Y-shaped tri-radiate ridge on the proximal surface, and with a distal surface ornamented with bumps or spines.

ANTHOCEROS

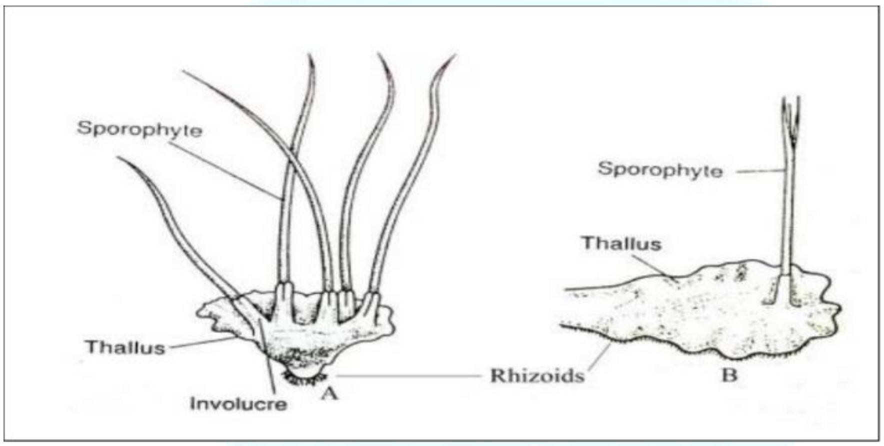
Division-Bryophyta
Class- Anthocerotopsida
Order-Anthocerotales
Family-Anthocerotaceae
Genus- *Anthoceros*

- Anthoceros is represented by about 200 species.
- All species are terrestrial and cosmopolitan in distribution.
- In India Anthoceros is represented by about 25 species.
- *A. himalayensis, A. erectus* and *A. chambensis* are commonly found growing in the Western Himalayan regions.

MORPHOLOGY

- The gametophytic plant body is thalloid, dorsiventral, prostrate, dark green in colour and shows dichotomous branching.

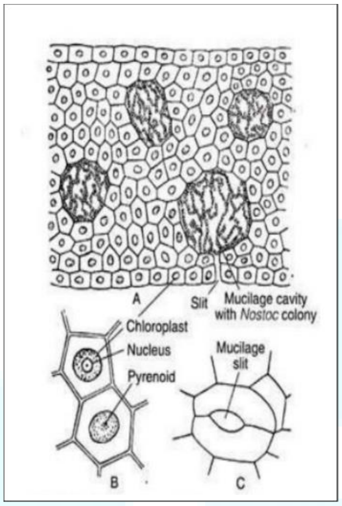
- The dorsal surface of the thallus may be smooth (*A. laevis*) or velvety because of the presence of several lobed lamellae (A. *crispulus*) or rough with spines and ridges (*A. fusiformis*).
- It is shining, thick in the middle and without a distinct mid rib.
- The ventral surface bears many unicellular, smooth-walled rhizoids.
- Tuberculated rhizoids, scales or mucilaginous hairs are absent.
- Many small, opaque, rounded, thickened dark bluish green spots can be seen on the ventral surface, These are the mucilage cavities filled with Nostoc colonies.
- Sporangia are horn like and arise in clusters.
- Each sporogonium is surrounded by a sheath like structure on its base- involucre.



ANATOMY

- The transverse section of the thallus shows a very simple structure.
- There are no distinct zones like *Marchantia*.
- It is uniformly composed of thin walled parenchymatous cells. The outermost layer is upper epidermis.
- Each cell of the thallus contains a single large discoid or oval shaped chloroplast with a pyrenoid.
- The air chambers and air pores are absent in Anthoceros.
- The cavities are seen in the thallus with mucilage and are called mucilage cavities.

- These cavities open on the ventral surface through stoma like slits or pores called slime pores.
- With the maturity of the thallus the mucilage in the cavities dries out and forms air filled cavities.
- The blue green algae *Nostoc* invades these air cavities through slime pores and form a colony in these cavities.



REPRODUCTION IN ANTHOCEROS

- Anthoceros reproduces by vegetative and sexual methods.

VEGETATIVE REPRODUCTION BY

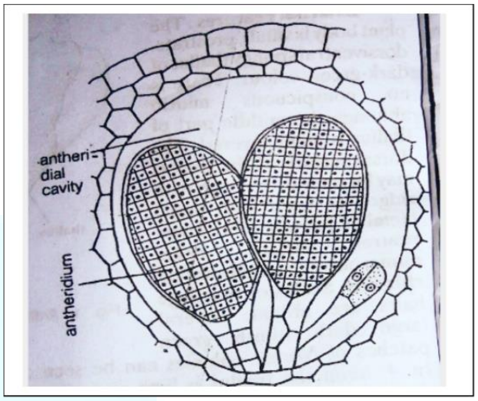
1. Death and decay of the older portion of the thallus or fragmentation.
2. Tubers.
3. Gemmae.
4. Persistent growing apices.
5. Apospory.

SEXUAL REPRODUCTION

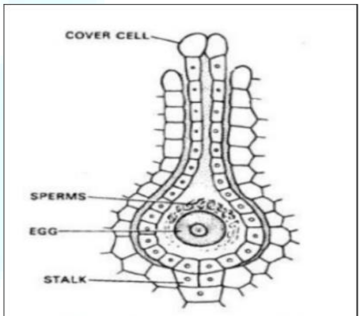
- Sexual reproduction is oogamous.
- Male reproductive bodies are known as antheridia and female as archegonia.

- Some species of Anthoceros are monoecious (*A. crispulus* and *A. himalayensis*), while some species are dioecious like (*A. erectus* and *A. laevis*).
- The monoecious species are protandrous i.e., antheridia mature before archegonia.

Antheridium



- A mature antheridium has a stalk & pouch like body.
- A single or a group of two to four or more antheridia are present in the same antheridial chamber.
- A single layered sterile jacket encloses the mass of androcytes which develop into antherozoids.
- A mature antherozoid is unicellular, uninucleate, biflagellated and has a linear body.
- Sometimes just near the attaching point of the flagella to the body the Blepharoplasty(flagellated cell or basal body) is visible.



A mature archegonium

Archegonium

- A mature archegonium consists of two to four cover cells, an axial row of four to six neck canal cells, a venter canal cell and an egg.
- The jacket layer is not distinct from the other vegetative cells like other Bryophytes.

FERTILIZATION

- On absorbing water, the mature archegonium, the venter canal cell along with neck canal cells disintegrate and form a mucilaginous mass.
- This mucilaginous mass becomes continuous with the mucilage mound and make an open passage down to egg is formed.

- The mucilaginous mass consists of chemical substances. Many antherozoids get attracted towards these chemicals and reach up to the egg, and fertilization takes place.
- Fertilization lead to the formation of diploid zygote or oospore.

SPOROPHYTIC PHASE

- After fertilization the diploid zygote or oospore still enlarges in size and fills the cavity of the venter of the archegonium.
- It secretes an outer cellulose wall.
- The mature sporophyte consist a bulbous foot and a smooth, slender, erect, cylindrical, structure called capsule.
- The sporogonium appears like a ‘bristle’ or ‘horn’.(hornworts)

ANATOMY OF THE SPOROGONIUM

- A mature sporogonium is consists of **three parts** the foot, seta and the capsule.

Foot:

- It is bulbous, multicellular and made up of a mass of parenchymatous cells.
- It acts as ac haustorium and absorbs food and water from the adjoining gametophytic cells for the developing sporophyte.

Meristematic zone / intermediate zone / intercalary zone:

- Seta is represented by meristematic zone.
- This is present at the base of the capsule and consists meristematic cells.
- These cells constantly add new cells to the capsule at its base.

Capsule:

- It consists of Columella, Archesporium, Capsule wall.
- Columella: It is central sterile region.
- It provides mechanical support, functions as water conducting tissue and also helps in dispersal of spores.
- Archesporium: Present between the capsule wall and the columella.

- It extends from base to the top of the capsule.
- In upper part of the capsule it gets differentiated into sporogenous tissue which produces spores and pseudo elaters.
- Pseudo elaters may be unicellular or multicellular, branched or unbranched.
- Capsule wall: It consists of four to six layers of cells, of which the outermost layer is epidermis with stomata.
- The cells of the inner layers have intercellular spaces and contain chloroplast.
- Thus, the sporogonium is partially self-sufficient to synthesize its own organic food but partially it depends on the gametophyte for the supply of water and mineral nutrients.

Dehiscence of the capsule

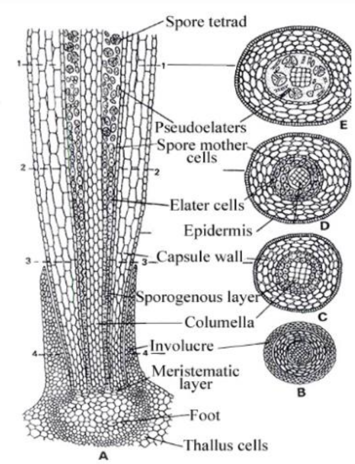
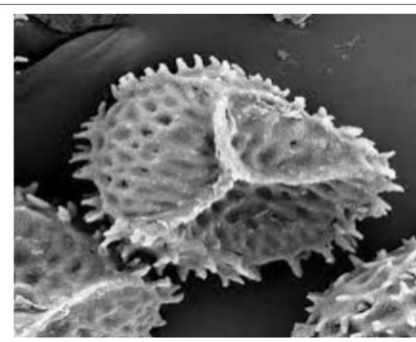


Fig: *Anthoceros.* (A) LS of sporangium; (B-E) Cross section of sporophyte

- As the capsule matures, its tip becomes brownish or black.
- Narrow slits appear in the capsule wall all along the shallow grooves (line of dehiscence), which gradually widen and extend, towards the base.
- The pseudo elaters also dry out, twist and help to loosen the spores.
- Thus, the twisting of the valves and the movement of the pseudo elaters in the exposed spore mass helps in the shedding of the spores.
- Air currents also help in the dispersal of spores.

Structure of spore



- The spores are haploid, uninucleate.
- Each spore remains surrounded by two wall layers.
- The outermost layer is thick ornamented and is known as exospore.
- The inner layer is thin and is known as endospore.

- Wall layers enclose colourless plastids, oil globules and food material.

Germination of spore

- Under favourable conditions the spores germinates.
- At the time of germination spore absorbs water and swells up.
- Exospore ruptures and endospore comes out in the form of germ tube.
- And after many division give rise to new gametophyte.
- First rhizoid develops as an elongation of any cell of the young thallus.
- As the growth proceeds, the mucilage slits appear on the lower surface and these slits are infected by *Nostoc.*

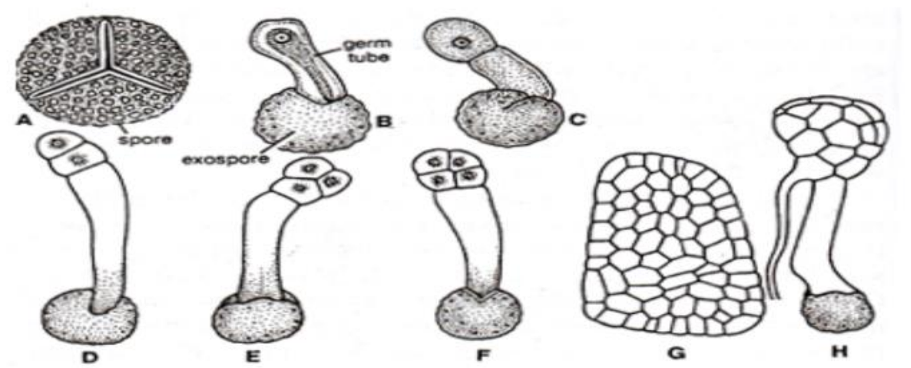


Fig. (A–H). *Anthoceros*. Successive stages in the germination of spore and formation of gametophyte.

LIFE CYCLE

- In Anthoceros, two morphologically distinct phases (haplophase and diplophase)constitute the life cycle.
- The life cycle of this type which is characterised by alternation of generation is known as heteromorphic &diplohaplontic.

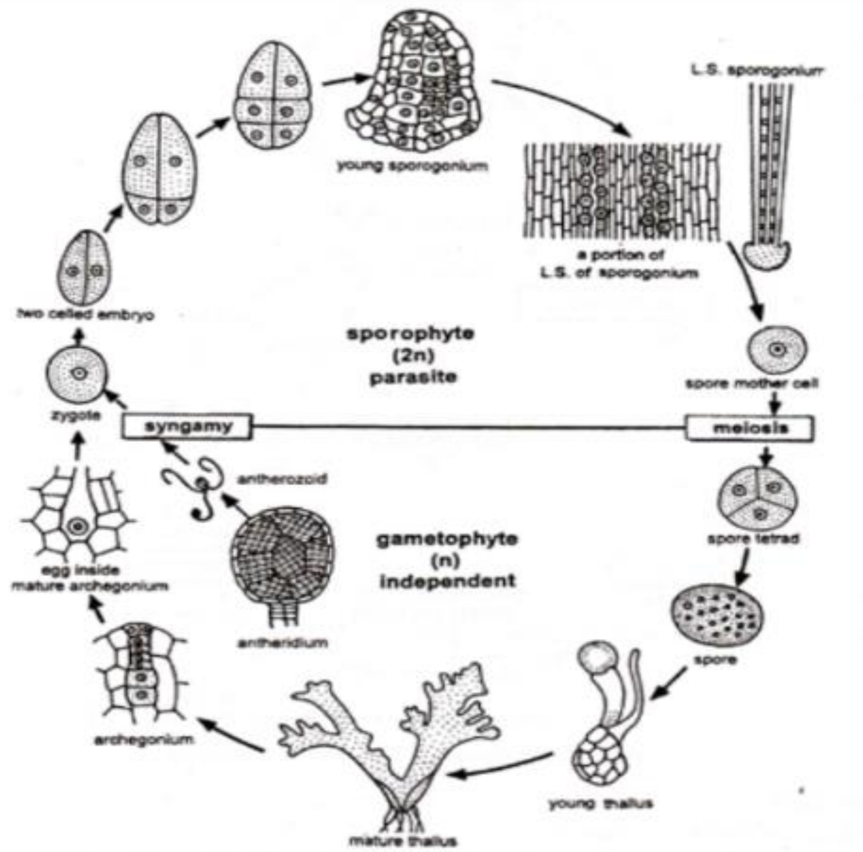


Fig. 11. *Anthoceros*. Diagrammatic life cycle.

BRYOPSIDA

GENERAL CHARACTERISTICS

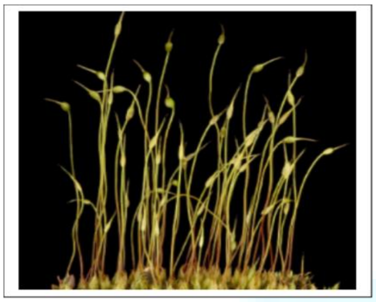
- The Bryopsida is the largest class of bryophytes.
- It consists of ~ 11,500 species.
- Mosses slow down erosion, store moisture and soil nutrients.
- Mosses have green, flat structures that resemble true leaves, which absorb water and nutrients.
- Mosses shows adaptations to dry land, such as stomata present on the stems of the sporophyte.
- Mosses are bryophytes that live in many environments and are characterized by their short flat leaves, root-like rhizoids, and peristomes.
- Rhizoids helps in anchorage and are multicellular with oblique septa.
- Elaters are absent.
- The sporophyte is differentiated into foot, seta and capsule.
- Columella is present.
- Dehiscence of the capsule takes place by separation of the lid.
- The group is distinguished by having spore capsules with teeth that are arthrodontous.

- These teeth are exposed when the covering operculum falls off.
- The moss life cycle follows the pattern of alternation of generations.

FUNARIA

Division: Bryophyta
Class : Bryopsida
Order: Funariales
Family: Funariaceae
genus : *Funaria*

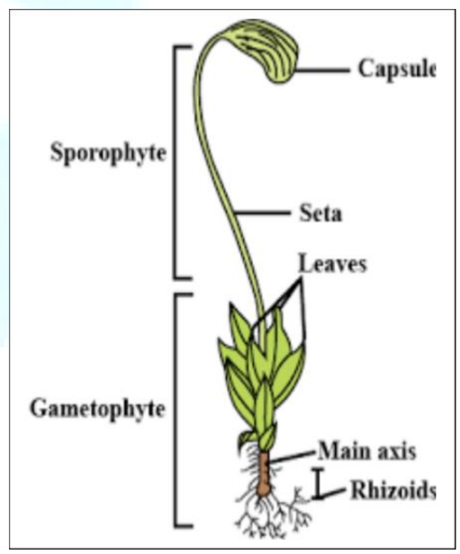
- It have dark green,velvety patches and grows in moist shady places.
- They are the common moss, also known as cord moss or green moss.
- *Funaria hygrometrica* is the most common species.
- Calcium ,Potassium,Nitrogen,and Phosphorus helps in colonization.



MORPHOLOGY

It is a long 1-3 cm in height and differentiated into rhizoids, axis (stem) and leaves.

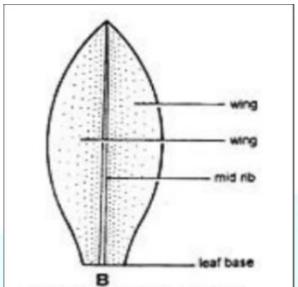
- **RHIZOIDS:**
  - Multicellular.
  - Colourless.
  - root-like structures.
  - with oblique septa.
  - help in anchorage.
  - and absorption.



- **AXIS:**
  - It is 1-3 cm in height.
  - Branched.
  - The axis and its branches covered with spirally arranged leaves.

- **LEAVES:**
  - Leaves are small-Ovate, sessile and green.
  - Each leaf has a mid rib.

- on both side of which single layered wing present.
- These are called foliage leaves.
- they are spirally arranged.
- Leaves also surrounds sex organs and these leaves are larger in size.



t, (B) Outline sketch of a leaf.

ANATOMY

- **Axis or stem anatomy:**
  - The transverse section (T. S.) of axis can be differentiated into three distinct regions:

    1. **Epidermis**:
       - Outer layer.
       - Cuticle and stomata are absent.
    2. **Cortex**:
       - It is present between the epidermis and conducting tissue.
       - It is made up of parenchymatous cells.
    3. **Central conducting strand or central cylinder**:
       - It is made up of long, narrow thin walled dead cells.
       - which lack protoplasm,(Hydroids).
       - Helps in conduction.

- **Leaf anatomy**
  - Internal structure of leaf shows a well-defined midrib with two lateral wings.

- Except the midrib region, the leaf is composed of single layer of parenchymatous polygonal cells.
- The cells contains chloroplasts.
- The central part of the mid rib has narrow conducting strand of thick walled cells which help in conduction.

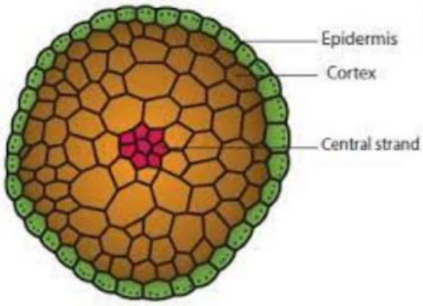


Figure 2.19: T.S. of axis

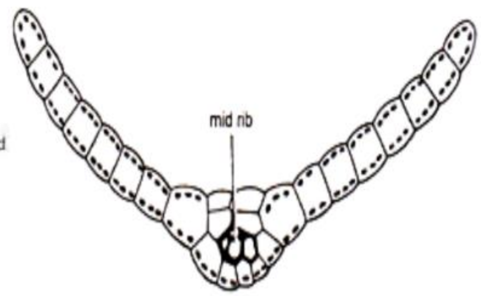


Fig. 3. *Funaria*. Transverse section (T.S.) of 'leaf'

REPRODUCTION IN FUNARIA

1. VEGETATIVE REPRODUCTION

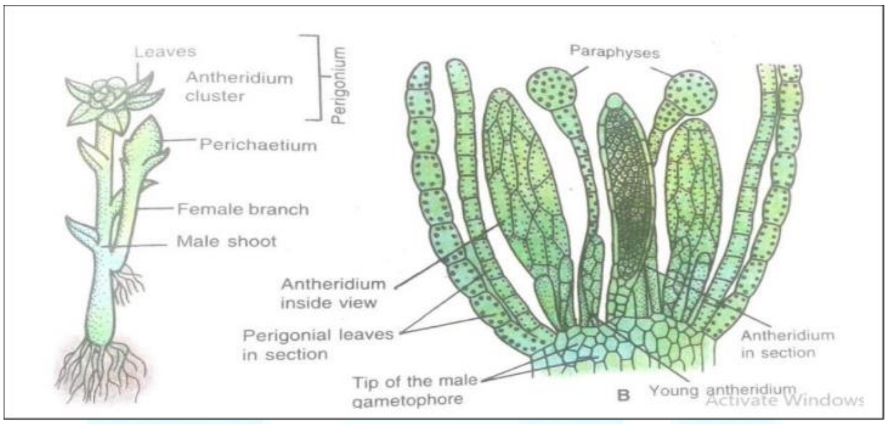
- Fragmentation
- Protonema
- Bulbils
- Gemmae
- Apospory

2. SEXUAL REPRODUCTION

- Sexual reproduction is oogamous.
- Male reproductive structure is known as antheridium and female as archegonium.
- Funaria is monoecious (having male and female sex organs on the same thallus) and autoicous (antheridia and archegonia develop on separate branches of the same thallus).
- Sex organs are borne on leafy gametophores in terminal clusters.
- Funaria is protandrous (antheridia mature before the archegonia)

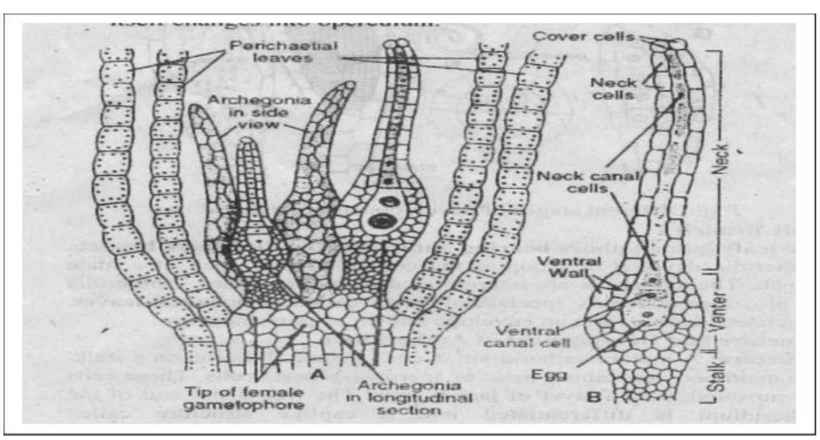
- **Antheridial branch & antheridium:**
    - The main axis is called male shoot or antheridiophore.

- ➢ The tip of male shoot has a convex disc or receptacle on which a cluster of club-shaped antheridia intermingled with capitates like paraphysis arises.
- ➢ The receptacle is surrounded by rosette of perigonial leaves.
- ➢ Each mature antheridium has a short stalk and a club-shaped jacketed body.
- ➢ Inside the jacket, a mass of androcyte mother cells present, each of which diagonally divides into two androcytes.
- ➢ Each androcyte develops into a biflagellate antherozoid.



● Archegonial branch & archegonium

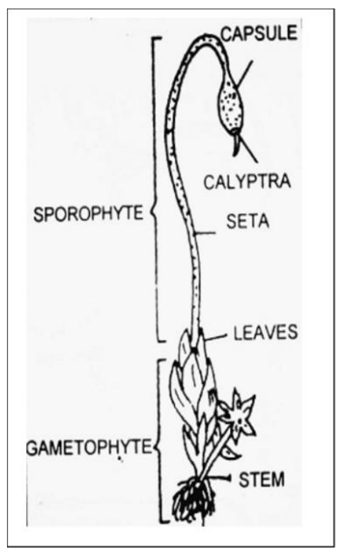
- ➢ The female shoot arises on archegonial branch or archegoniophore.
- ➢ The apex of female shoot is called female receptacle from which cluster of archegonia arise intermixed with non- capitate paraphysis.
- ➢ The female receptacle is surrounded by perichaetial leaves.
- ➢ Each archegonium has a stalk, flask-shaped venter and a neck.
- ➢ Venter encloses a basal egg cell (oosphere) and upper smaller venter canal cell.
- ➢ Neck consists of 6 or more neck canal cells.



- **Dehiscence of sex organs**
  - With the presence of water the mature antheridia burst releasing the male gametes (antherozoids).
  - The male gametes swim towards archegonia.
  - In each mature archegonium, neck canal cell and venter canal cells degenerate to form mucilage.
  - The mucilage swells up and opens the tip to create a passage up to egg.
  - The mucilage contains sucrose which attracts the male gametes (chemotactic).

- **Fertilization**
  - Water is essential for fertilization.
  - During heavy rains, the antherozoids reach the archegonial neck and swim down to venter.
  - One antherozoid fuses with egg to form zygote (2n).
  - Soon, the zygote secretes a cell wall and becomes the oospore.
  - The oospore divides and re-divides to form embryo.
  - Later the embryo grows into a sporophyte or sporogonium.
  - Zygote or oospore is the first cell of sporophyte generation.

- **STRUCTURE OF SPOROPHYTE**
  - Diploid zygote divides to produce sporophyte of *Funaria.*
  - The sporogonium of *Funaria* is photosynthetic, hence semi-parasitic on gametophore.
  - It differentiates into foot, seta and capsule.
  - The foot embedded in the female receptacle and absorbs inorganic nutrients.
  - Seta is a thick and thread like structure, It is hygroscopic in nature it conducts water and nutrients also helps in dispersal of spores.
  - Capsule has 3 parts-basal apophysis, central theca and terminal operculum.



➢ As the sporogonium grows, the venter grows along with it in the form of a protective covering called calyptra.
➢ Later the calyptra ruptures and remains like a cap on the capsule.
➢ Calyptra is haploid because it develop from venter wall.

- **Operpercular region:**

➢ The opercular region comprises operculum which covers peristome.
➢ The peristomial teeth are present in peristome.
➢ They are arranged in two whorls-outer and inner whorls.
➢ Total 32 peristomial teeth are present.
➢ These teeth are help in dispersal of spores.
➢ Opercular region is separated by theca region, by two rings.

1. Rim or Diaphragm (lower)
2. Annulus (upper)

- **Theca region:**

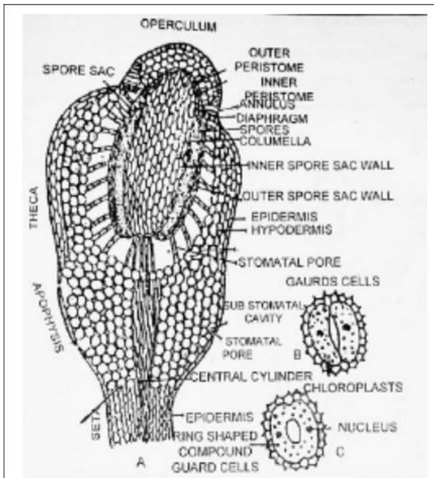
➢ The middle theca region is distinguishable into epidermis, hypodermis, chlorenchymatous region (2-3 layered), filamentous trabeculae with large air spaces, two layered spore sacs and central sterile region is columella.

➢ Elaters are absent in spore sac.

➢ Function of columella : It provides water and food to developing spores in spore sac.

➢ Function of trabeculae : It connects the innermost layer of capsule wall to outermost layer of outer wall of spore sac.

- **Apophyseal region:**

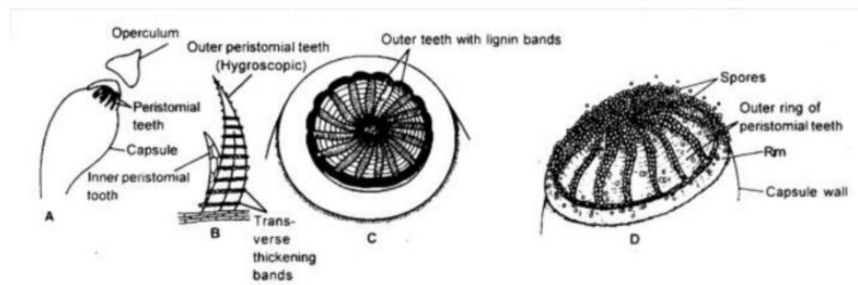


Funaria (A) L.S. capsule (B) a young stoma (C) a stoma with compound guard cell

- The apophyseal region is the lowermost part of the capsule which has conducting strand and attached with seta.
- This is surrounded by chlorenchymatous cells with prominent intercellular spaces.
- The epidermis has stomatal aperture which is guarded by two guard cells.
- In mature stomata stomatal aperture is guarded by single ring like guard cell.

Dehiscence of capsule and dispersal of spores

- Funaria is a stegocarpous moss.
- Stegocarpous means the dehiscence of capsule always along a predetermined line.
- As the capsule matures, the thin walled cells including columella dries up.
- The thin walled cells of annulus break away and thus operculum separated along the annulus and exposing the peristome.
- The hygroscopic nature of outer peristomial teeth helps in dispersal of spores.
- The inner peristomial teeth check sudden dispersal of spores.
- They reach at far places through the medium of air.
- In moss capsule, spore dispersal takes place by censor mechanism.



(A) CAPSULE WITH PERISTOMIAL TEETH, (B) OUTER & INNER PERISTOMIAL TOOTH,
(C) THE STRUCTURE OF CAPSULE AFTER THE SEPERATION OF OPERCULUM
(D) DISPERSAL OF SPORES

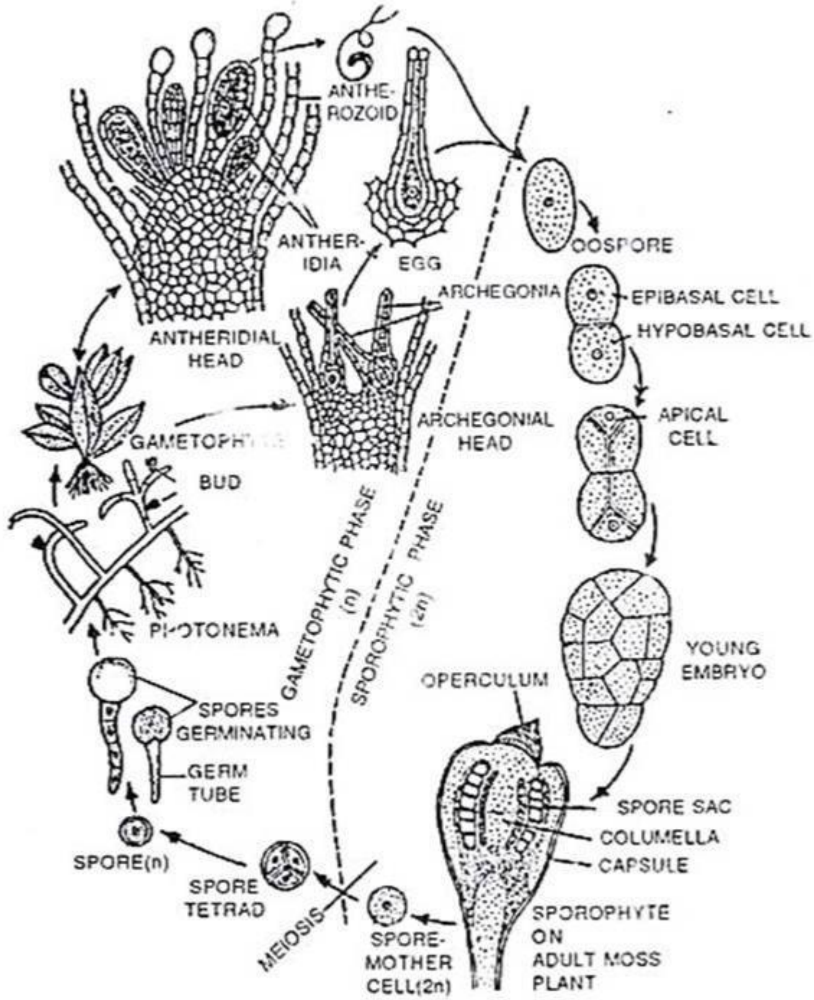
Structure of spores and germination of spores

- Spore is the first cell of gametophytic generation.
- Spores are spherical in shape and double layered.

- The outer wall-exosporium(thick) and inner wall endosporium (thin).
- Spores have oil droplets and chloroplast.
- The spore germinates to form the primary protonema.

LIFE CYCLE OF FUNARIA

- The life cycle of *Funaria* is haplo-diplontic type.
- In the life cycle free living haploid gametophyte alternates with a semi-parasitic diploid sporogonium (Sporophyte).
- In this type alternation of generations is called as heteromorphic or heterologous.



ECONOMIC IMPORTANCE OF BRYOPHYTES

- Bryophytes are important compound of the flora of the earth.
- Lilliputians amongst land plants.
- Shows their economic and ecological importance since stone age when prehistoric man had uses of Feather moss (*Neckera crispa*).

ECONOMICALLY IMPORTANT BY VIRTUE OF THEIR MULTIPLE USE IN

1. **In industry**
2. **As medicine**
3. **As antibiotic**
4. **In horticulture**
5. **As a source of food**
6. **In experimental botany**
7. **As packing material**
8. **As absorbent bandages**
9. **As fuel**

1. Industrial uses of bryophytes

- Preparation of ethyl alcohol from peat.
- Obtain ammonium sulphate as by-product in the production of gas from peat.
- Nitrates, brown dye and tanning materials from peat.

- Peat also produces peat tar, ammonia and paraffin.
- Peat has been manufactured into paper, woven fabrics and artificial wood.
- Peat employed as a mattress filler and bedding material for domesticated animals.
- Sphagnum peat has been developed as new construction material through the use of binders for solidification and strengthening , resulting in new products like peatcrete**.**

2. **Medicinal uses of bryophytes**

- Watt (1891) reported medicinal use of *Marchantia polymorpha*, *Stella conica* and few species of Jungermannia, *Anthoceros* and *Riccia.*
- Roig Y Mesa(1945) mentioned liverwort *Marchantia polymorpha* used to cure pulmonary tuberculosis.
- Hartwell(1971) reported that extracts of *M.polymorpha*, *M.stellata* and *Polytrichum commune* possess anti-tumorous properties.
- Acute haemorrhage and diseases of the eye is cured by using *Sphagnum* decoction.
- In the ancient times, various mosses (e.g. *Bryum, Mnium, Philonotis*) were crushed into a paste and applied as a poultice.
- Burned ash of mosses, mixed with honey and fat, is used as an ointment for cuts and wounds.

- *Marchantia polymorpha* and *M. palmata* are used as medicines for boils.
- A paste made from various species of *Riccia* is applied externally to cure ringworm.
- Tea made of *Polytrichum commune* helps to dissolve stones of kidney and gallbladder.
- Alaskan Indians prepared a healing ointment by mixing *sphagnum* leaves with grease or tallow. It was used in the treatment of wounds and cuts .
- Peat tar is antiseptic and is used as a preservative**.**
- A distillate of peat tar **Sphagnol** has been effective against skin diseases.

3. Antibiotical activities of bryophytes

- Scanty information about the occurrence.
- In recent years antimicrobial activities of bryophytes drawn attention of several workers.
- Hayer(1947)reported that aqueous extract of *Conocephalum conicum* is antibiotically active.
- Two species of *Sphagnum* inhibited the growth of *Staphylococcus aureus* and *Pseudomonas aeruginosa*.

4. Uses of Bryophytes in Horticulture

- Dried Sphagnum as garden mulch to retain high soil acidity.
- Substratum for seed germination.
- Packing material for grafting scions to protect them against drying influence of the surrounding air.

5. Bryophytes as a source of food

- Not directly used as human food.
- Landley(1856) made mention of *Sphagnum* as a wretched food in Barbarous countries.
- Read(1946) listed peat moss as a famine food in China.
- Hains (1877) recorded Laplanders having made use of *Sphagnum* as an ingredient in the preparation of bread.
- Moss capsules of *Bryum* and *Polytrichum* is the chief diet of the Norwegian grouse chicks.
- Alaskan reindeer grazes upon Polytrichum sp and grasses in summer.

6. In experimental studies

- Liverworts and mosses as research tools in various phases of botany such as genetics, experimental morphology and physiology.
- The mechanism of sex determination in plants was discovered for the first time in a liverwort *Sphaerocarpos*.
- Studies on the genetics of bryophytes, heteroploid bryophytes and experimental studies on polyploidy liverworts.
- Growth forms in mosses, desiccation and regeneration of bryophytes have been studied.

7. Bryophytes as packing material

- Ability to hold tenaciously Dried *Sphagnum* and Moss peat are used as packing material. For shipment of live plants, cut flowers, vegetables, perishable fruits, bulbs and tubers.
- Retaining moisture content for long time may protect against heat and cold.
- Thus Peat is as well used as a packing material for fruits, fish, eggs and meat for cold storage

.

8. Uses as absorbent bandages

- Peat moss as suitable material for use in surgical dressings due to its antiseptic properties and its great absorbing power.
- *Sphagnum* used for making absorbent bandages in the treatment of boils and wounds.
- Porter (1917) observed that the *sphagnum* dressings are cooler, softer and less irritating than those made with cotton.

9. As fuel

- The thick deposits of peat are cut into blocks and dried.
- Being rich in carbon the dried blocks are used as a fuel.
- Peat fuel is used on a commercial scale in some developing countries.
- Also peat is used to generate power and making illuminating gas.

ECOLOGICALLY IMPORTANT BY VIRTUE OF THEIR ROLE

1. **Community succession**
2. **Soil formation**
3. **Soil conservation**
4. **Monitoring and control of environmental pollution**
5. **Bio-indicators of water and air pollution**
6. **Rock builders**

1. Community succession

- Weaver and Clements (1938) remarked that mosses play an important role in bog succession from **open water to climax forest**.

- The mosses especially **peat mosses** established on the banks of lakes and other shallow water bodies forms a thick mats over the surface of water with their intertwined stems, It gives the appearance of solid soil to the water bodies.

- Such areas are called **Quaking bogs**.
- Mosses can change the landscape from open soil to climax forest.
- The thick mat formed of mosses forms suitable substratum for germination of hydrophilic seeds due to the presence of water and humus.
- In the course of time, the dead and decayed mosses and hydrophilic plants form a solid soil for mesophytic development.

2.Formation of soil & development of vegetation cover

- The lichens and mosses play an important role in soil formation.
- Both are slow but efficient soil formers.
- Lichens however are the pioneers to colonise barren, bare rocky surfaces where no other plants can grow.
- The acid secreted by lichens, death and decay of mosses helps in soil formation.

3. As aids in soil conservation

- The mosses prevent sheet erosion of soil.
- They grow in dense stands forming a mat or carpet- like structure.
- The intertwined moss stems and the underground rhizoids bind the soil particles to a considerable depth so firmly.
- Thus there is no erosion even on a steepy hillside, Even the moss protonema mat checks soil erosion.

4. Monitoring and control of pollution

- It was Gordon and Gorham who first made an attempt to study the effect of certain pollutants upon some plants and mosses.
- They first studied the effect of SO_2 on the growth of such plants
- Found that mosses are very sensitive to pollutants of the air.
- Thus certain bryophytes taken as bio-indicators of air pollution.
- The rate of pollution is measured by comparison of changes of bryophytes from polluted and unpolluted areas.

5. Bio-indicators of water pollution

- *Amblystegium riparium* is the indicates the presence many nutrients.
- *Fontinalis antipyretica* is used to monitor the presence of heavy metals and pollutants of water.
- *Scapania undulata* is a liverwort used to study the presence of heavy metals like Cadmium, Zinc, Lead etc.
- It is also widely used to monitor mining of metals because of its high tolerance ability to metals.
- Thus the purification of water from heavy metals can also be absorbed by bryophytes.
- Peat moss absorbs metals, oils, detergents, dyes etc.
- Hence this moss is used as a filtering and absorbing agent for the treatment of wastewater and effluents of factories.

6. Bio-indicators of air pollution

- The bryophytes are very sensitive to air pollution.

- Some of them are **tolerant** and **some are sensitive**.
- **Moss protonema** is more sensitive to air pollution.
- Sensitivity of bryophytes towards air pollution increases from terricolous to saxicolous and corticolous species.
- Air pollutant affect habitat and growth form
- Some sensitive species are *Ulota crispa, Paraleucobryum longifolium, Lophocolea minor*, etc.
- Some tolerant species includes *Tortula princeps, Bryum rubrum, Pohlia cruda* and *Ceratodon purpureus*.
- Thus bryophytes in general can provide an integrated information of environmental pollution.

7. Role as rock builders

- Certain mosses growing in association with aquatic plants play a remarkable role as rock builders.
- These plants grow in shallow waters of lakes, streams and springs.
- Which contain a large amount of **calcium bicarbonate**.
- The plants bring about decomposition of bicarbonate ions by abstracting free carbon dioxide.
- The insoluble calcium carbonate precipitates.
- This insoluble mineral, on exposure, hardens forming calcareous(lime) rock-like deposits around these plants.
- These travertine deposits continue to grow by the aid of mosses and algae in the water extending over areas of several hundreds square feet.
- The travertine rock deposits are extensively used as a building stone.