EDO UNIVERSITY IYAMHO

Department of Biological Science

Plant Biology and Biotechnology Unit

PBB 213 – Bryology and Pteridology

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General overview of lecture: This course is intended to give the students a thorough knowledge of the lower plants, pteridophytes and bryophytes.

Prerequisites: Students should be familiar with the concepts plant biology with emphasis on classification and taxonomy.

Learning outcomes: At the completion of this course, students should be able to:

- Classify bryophytes taxonomically
- List the general characteristics of bryophytes
- Write notes on the life cycles of the liverworts, the hornworts and the mosses
- Outline the economic importance of bryophytes
- Classify pteridophytes taxonomically
- List the general characteristics of pteridophytes
- Write notes on the life cycles of the pteridophytes

Assignments: We expect to have 5 individual homework assignments throughout the course in addition to a Mid-Term Test and a Final Exam. Home works are due at the beginning of the class on the due date. Home works are organized and structured as preparation for the midterm and final exam, and are meant to be a studying material for both exams.

Grading: We will assign 10% of this class grade to homeworks, 10% for the programming projects, 10% for the mid-term test and 70% for the final exam. The Final exam is comprehensive.

Textbook: The recommended textbook for this class are as stated:
Title: *BOTANY*
Authors: A. C DUTTA

Main Lecture: Below is a description of the contents. We may change the order to accommodate the materials you need for the projects.

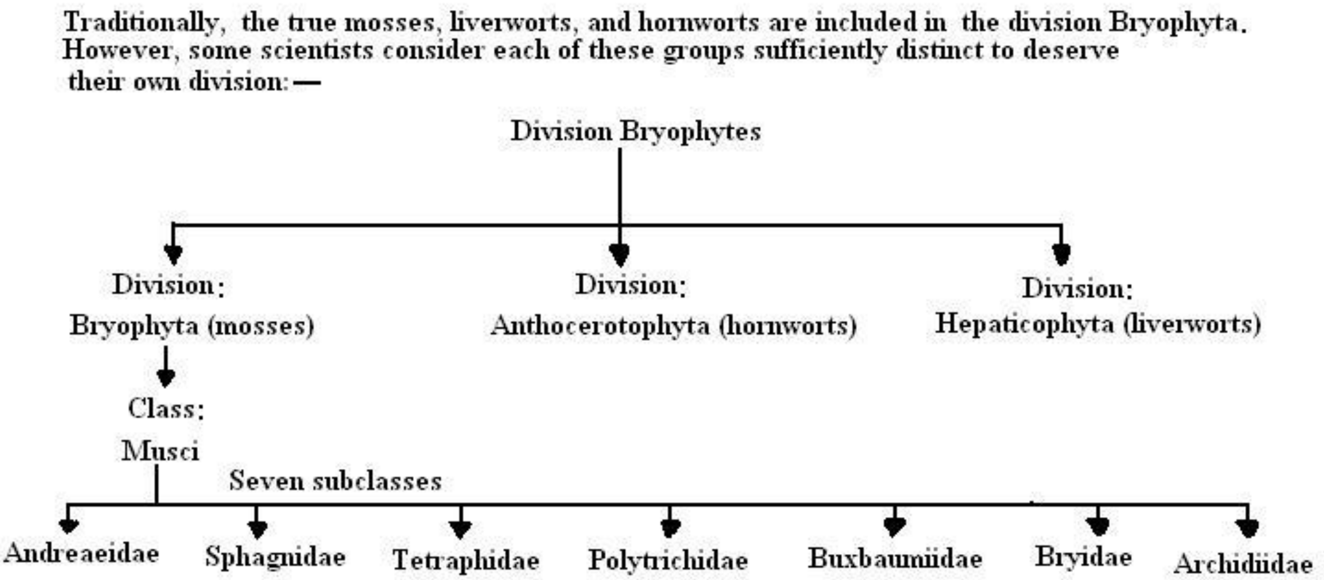
INTRODUCTION

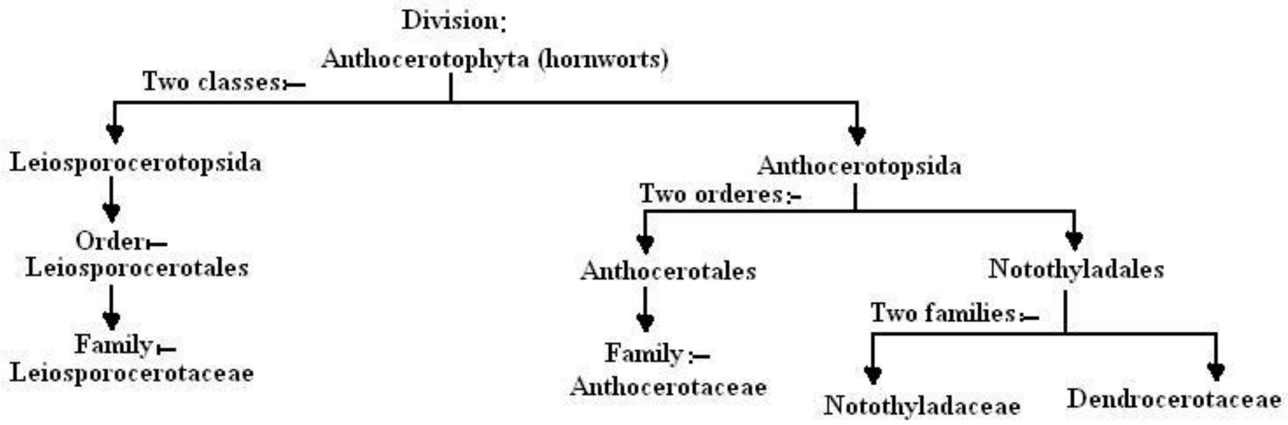
Bryophytes are non-vascular land Plants. They are an ancient and diverse group of non-vascular plants. They are not considered to have given rise to the vascular plants but they probably were the earliest land plants. Like the rest of the land plants, they evolved from green algal ancestors.

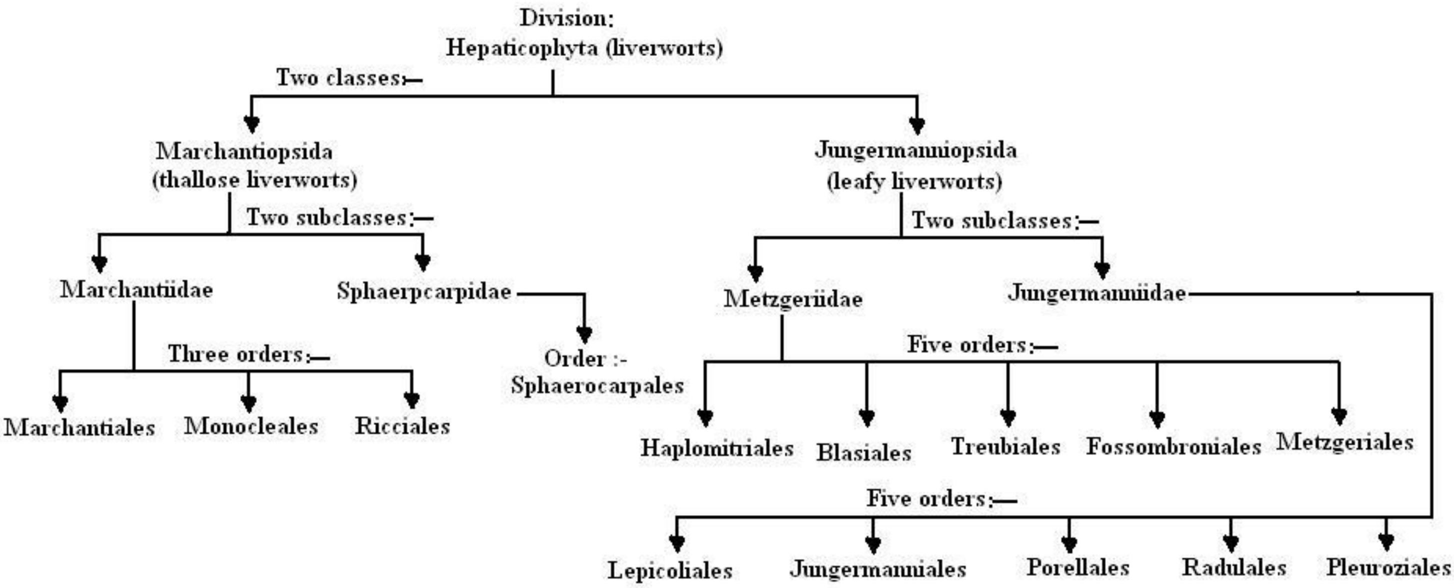
They are the only plants that produce an embryo (embryophytes), whose life history includes a dominant gametophyte (haploid) stage and dependent sporophyte (diploid) stage. They comprise three main taxonomic groups: mosses (Bryophyta), liverworts (Marchantiophyta or Hepatophyta) and hornworts (Anthocerotophyta), which have evolved quite separately. Most bryophytes have erect or creeping stems and tiny leaves, but hornworts and some liverworts have only a flat thallus and no leaves. Worldwide there are possibly 10,000 species of mosses, 7000 liverworts and 200 hornworts.

Small in size, but they can be very conspicuous growing as extensive mats in woodland, as cushions on walls, rocks and tree trunks, and as pioneer colonists of disturbed habitats.

CLASSIFICATION OF BRYOPHYTES:-







Although the bryophyte is used as a collective term for all of these – Bryophyta (mosses), Hepatophyta (liverworts), and Anthoceratophyta (hornworts).

GENERAL CHARACTERISTICS OF BRYOPHYTES (LIVERWORTS, HORNWORTS AND MOSSES)

1. All of these are land plants (terrestrial) with some aquatic forms.
2. They are very small.
3. The sporophyte and gametophyte have very different morphologies (heteromorphic generations) and the sporophyte is usually partly dependent on the gametophyte.
4. Photosynthetic plants.
5. They are non-vascular plants.
6. Plant body is either :- **Thalloid** and attached to the substratum by hair-like structures called **rhizoids** (true roots are absent) or is differentiated into stem-like **(caulalia)** and leaf-like structures **(phyllids)**, true stems and leaves lacking.
7. Cuticle and stomata are absent.
8. The bryophytes show alternation of generations - the haploid gametophyte (producing gametes for sexual reproduction) alternates with diploid sporophyte (producing spores for asexual reproduction).
9. Gametophytes **homothallic or heterothallic**.
10. The gametophyte generation is dominant, conspicuous and independent.
11. The female sex organ is the **archegonium**. The male sex organs are **antheridia.**
12. The ovum remains in the archegonium and spermatozoids swim to it by chemotaxis.
13. Although bryophytes are land plants, they are still dependent upon water for fertilization, as the sperm swim in a water film.
14. The sporophyte is attached and dependent upon the gametophyte for nutrition i.e. is parasitic on the gametophyte.
15. The diploid sporophyte usually consists of a **basal foot**, an elevating **seta** and a terminal sporangium - the **capsule**.
16. Spores are produced as a direct result of meiosis.
17. Spores dispersed by a mechanism which ensures dispersal in dry weather only.
18. These plants (in either generation) lack specialized cells for the transport of materials (vascular tissue). Absence of vascular tissue limits bryophytes to moist habitats and small size.

GENERAL LIFE CYCLE

- **Archegonia** are stalked, multicellular, flask-shaped female sex organs.
- Archegonia are consisting of an elongated upper portion called **neck** and lower swollen portion **-venter**.
- The neck consists of an axial row of cells called **neck canal cells** surrounded by a **sterile jacket**. draw

- The venter also made up of a 1-2 layer-thick wall of sterile cells which encloses a larger egg cell or the ovum and the smaller ventral canal cell just above the egg.
- At maturity, the tip of the archegonium opens and the neck canal cells as well, as the ventral canal cells disintegrate, opening the neck for the entrance of the antherozoids.
- **Antheridia** consist of rounded structure consisting of a single layered jacket surrounding a central mass of cells - **androcytes**.
- Each changes into slender **biflagellated antherozoids**.
- The antherozoids are released when the **antheridium** ruptures, thus allowing them to swim freely in a water film.
- The antherozoids enter through the open necks and fuses with egg to form **diploid zygote**.
- After, divisions of zygote a **multicellular embryo** is formed, which is nourished by the gametophyte.
- The embryo grows and forms a **mature sporophyte,** within which sporogenous tissue will form **spore tetrads**, which in turn are released as the **spores**, forming either the gametophyte, or the protonema, which in turn forms the typical gametophyte.

Draw

DIVISION - BRYOPHYTA (MOSSES)

Characteristics of Mosses :-

i. Mosses are found in a range of habitats, mostly-terrestrial, although moist and shady habitats are more common.

ii. Mosses are often **epiphytes.**

iii. The **dominant phase** of the moss life cycle is the **gametophyte (haploid**).

iv. The plant is called a **thallus**, they may be erect or prostrate (axis along the ground).

v. Mosses have **radial symmetry**, in that a cut down the long axis of an individual gives two similar halves.

vi. The gametophyte has a stem like axis with spirally arranged leaves, which are known as **phyllids**.

vii. Mosses attach to their substrate with multicellular **rhizoids**.

viii. It lacks xylem and phloem. The plant body may have conducting tissue.

ix. The **xylem-like** water-and-mineral-conducting tissue is called **hydroid**. The **phloem-like** sugar-and-amino-acid-conducting tissue is called **leptoid**.

x. Moss leaves are variable in shape. Leaves usually consist of a single cell layer and are traversed by a midrib that is always more than one cell in thickness. The phyllids of mosses such as *Mnium* may be a single cell thick, but with a midrib with hydroids and leptoids.

xi. All mosses have a **sporic (diplohaplontic-diploid sporophyte and haploid**

gametophyte) life cycle that is **oogamous**.

Gametophyte Characters:-

Spore Germination and Protonemata :-

- Moss life cycle begins when haploid spores are released from a sporophyte capsule and begin to germinate.
- In the majority of mosses, germination is **exosporic**, i.e., the spore wall is ruptured by the expanding spore protoplast after its release from the capsule and prior to any cell division.
- However, in some mosses, e.g. *Andreaea, Drummondia*, and *Leucodon*, germination is precocious and **endosporic**, meaning that cell divisions occur prior to spore release and spore wall rupture, respectively.
- There are variations in patterns of germination of moss. In most mosses, a highly branched filamentous, uniseriate protonema are formed.
- Cell specialization occurs within the protonema as a result two types of filaments are formed:- a **horizontal system of reddish brown, anchoring filaments (rhizoids), called the caulonema** and **upright, green filaments, the chloronema.** Each protonema can spread over several centimeters, forming a fuzzy green film over its substrate.
- Formation of bud apical cells:- As the protonema grows, target cells usually on the caulonema generate bud initials that will ultimately divide by sequential oblique divisions to form bud apical cells. This initiates the growth of the leafy gametophore or shoot stage of the moss.

Sexual reproduction :-

For sexual reproduction, the moss gametophyte produces gametangia. The male and female gametangia may be on the same thallus (homothallic or monoecious) or on separate gametophytes (heterothallic or dioecious).

Both the antheridium and archegonium have a sterile jacket of cells, which better protects the gametes against desiccation in the terrestrial environment.

Antheridium :- The antheridium consists of a stalk, a sterile jacket, and spermatogenic tissue. The antheridium sterile jacket has a cap cell which disintegrates when turgor pressure rises. By mitotic division of haploid spermatogenic tissue inside the sterile jacket haploid flagellated sperms are formed. Water is required for transfer of the motile sperm to egg. Most antheridia are in terminal disk-shaped clusters to facilitate water capture for sperm transfer. Sperms are chemotactic and swim through free-water up a concentration gradient of the chemotactic agent to find the open archegonium. The first drop of water landing in the cup causes the cap cell of the anteridium to burst providing an opening for sperm into the drop of water. Filaments of cells found between the antheridia, called paraphyses, swell up with water and squeeze the antheridia to help expel sperm into the water of the splash cup. The next raindrop to land in the splash-cup will splash out a solution containing sperm. These will swim through a film of rainwater to fuse with the egg.

Archegonium:-The archegonium consists of a stalk, a venter surround the egg, and a long neck. The neck is filled with canal cells. The sterile jacket has a cap cell which disintegrates when turgor pressure rises. All cells of the archegonium, including the egg cell, are produced by mitosis of haploid gametophyte cells. The disintegrating neck and ventral canal cells provide chemicals involved in sperm chemotaxis to fuse with the egg. After fusion of egg and sperm zygote is formed which diploid.

After fertilization, the sporophyte grows out of the archegonium, and nutrients for the developing sporophyte are provided by the gametophyte.

Meiosis in the capsule produces haploid spores. When spores are mature, the lid of the capsule, called the operculum, opens. Due to changes of humidity a row or rows of hygroscopic teeth, the operculum, open and release spores.

The gametophyte plant is produced by the germination of a haploid spore. As a spore germinates, it produces a branched filament of photosynthetic cells called a protonema. This branching filament is similar to a green alga. The protonema produces a caulonema filament which can produce either a leafy moss gametophyte or a hard, dry bulbil for asexual reproduction. The moss gametophyte produces male and female gametangia. The sperm and egg fuse in syngamy.

Sporophyte of Moss:- **Syngamy** of the egg and sperm produce a zygote within the archegonium. This zygote undergoes mitosis to produce an embryo, again retained within the archegonium. Finally, the embryo matures into a sporophyte. Diploid sporophyte is typically not photosynthetic and so is parasitic (dependent) on the gametophyte for its nutrition. The sporophyte consisting of :-

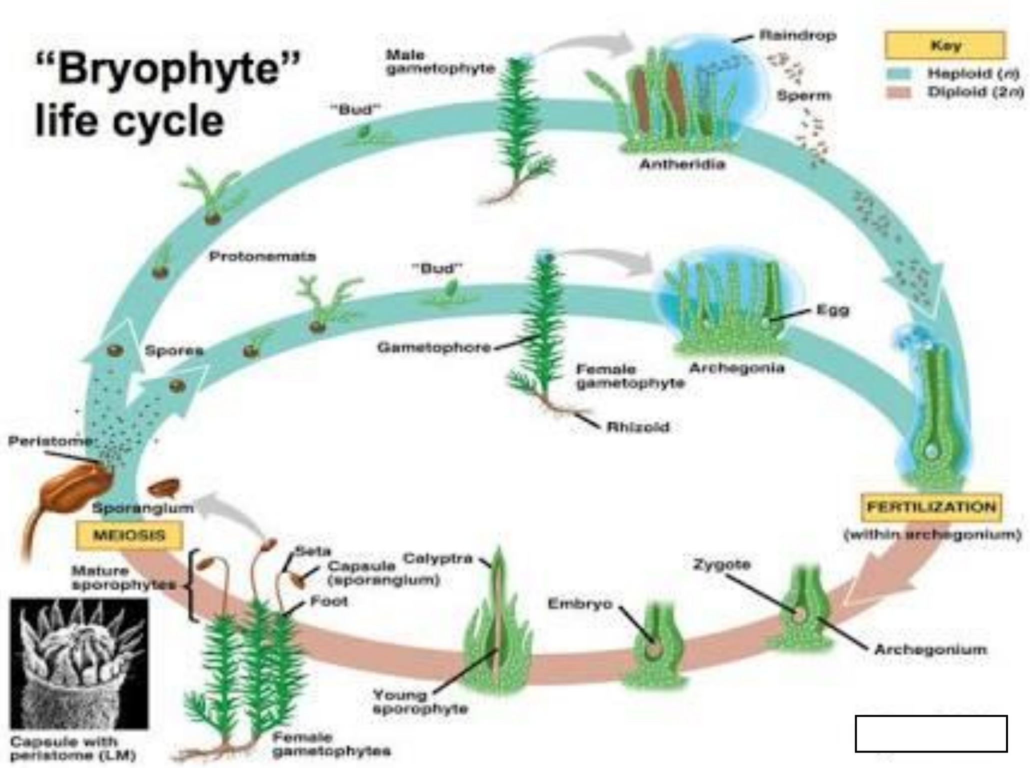
A sporangium (capsule):- Sporogenous tissue forms around the columella, and spore mother cells undergo meiosis to form tetrads of haploid spores. At the top of the capsule is the cap-like operculum beneath which is a double row of triangular peristome teeth. The teeth are attached to a thick-walled annulus around the upper end of the sporangium. When the sporangium is mature, the operculum breaks off, and the peristome is left holding the spores in place. The teeth are very sensitive to humidity (i.e. hygroscopic) and when wet or very humid weather occurs, they bend into the capsule, when dry, they straighten out and lift some spores out with them. The spores are then distributed by air currents, and later they germinate into protonemae.

A seta (stalk):-

A foot:- Foot remains embedded in the gametophyte tissue. The continued attachment of the sporophyte to the gametophyte allows the sporophyte to absorb most of its needed nutrients from the gametophyte. A seta or stalk :- which elevates the sporangium, or capsule.

Typically, a portion of the gametophyte, called the calyptra, protects and covers the developing capsule.

The haploid hairy calyptra of *Polytrichum* is quite elaborate and a contrasting pink color covering the entire sporophyte capsule.



BRYOPSIDA (MUSCI)

Classification:

Division - Bryophyta

Class - Bryopsida

Order - Sphagnales

Family - Sphagnaceae

This is the largest class of bryophytes and includes about 600 genera and 14,500 species. Bryopsida is divided into seven subclasses but there are three major subclasses: Sphagnidae (peatmosses), Andreaeidae (rock mosses) and Bryidae (true mosses). Bryidae include about 14,000 species. You will study the genus *Funaria* as a representative of this order. Order Sphagnales is represented by a single genus *Sphagnum* which includes about 300 species.

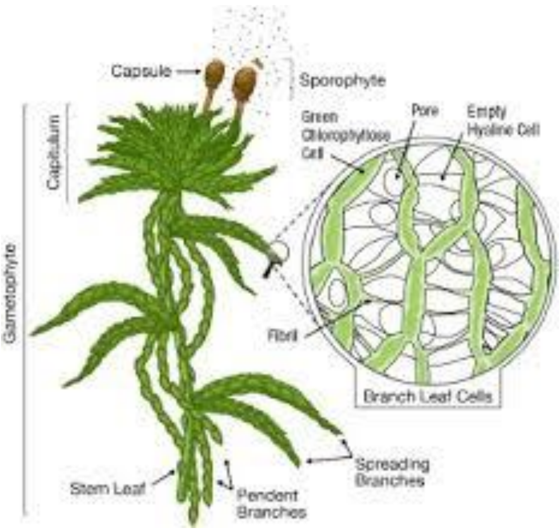
Sphagnum

Sphagnum forms peat bogs in northern parts of the world. In some countries peat is burnt as fuel. Sphagnum is also used in plant nurseries as packing material. Mats of this moss hold moisture and help the seeds of other plants to germinate and grow. Sphagnum is confined to acidic, water-logged habitat. It is the principal component of peat bogs where it forms a more or less continuous spongy layer. The adult gametophyte develops as an upright leafy-shoot, called gametophores from a simple thallose, one cell thick protonema. The gametophore is differentiated into stem and leaves. The terminal growth of the stem is due to an apical cell. The axis is attached to the soil by means of multicellular, branched rhizoids with oblique cross walls.

Rhizoids are present only in young gametophores and disappear when it matures. Afterwards, the gametophore absorbs water directly.

The mature gametophores consists of an upright stem bearing leaves. Every fourth leaf of the stem bears a group of three to eight lateral branches in its axis. These branches are of two types: (i) divergent and (ii) lying next to the stem. Sometimes, one of the branches in a tuft continues upward growth to the same height as the main axis and resembles it in structure. These strongly developed branches are called innovations and they ultimately get detached and become independent plants. The branches near the apex of a stem are short and densely crowded in a compact head called coma.

The leaves lack midrib. They are small and arranged in three vertical rows on the stem. In the surface view of a leaf one can observe two types of cells: (i) narrow, living, chlorophyll containing cells and (ii) large dead, empty, rhomboidal, hyaline (glass-like, transparent) cells with pores and spiral as well as annular wall thickenings. In transverse section, leaf shows beaded appearance, with large, dead hyaline cells regularly alternating with the small, green, chlorophyllous cells. The spiral thickenings provide mechanical support and keep the hyaline cells from collapsing when they are empty.



Structure and morphology of *Sphagnum*: A) a mature gametophyte with attached sporophyte at the apex

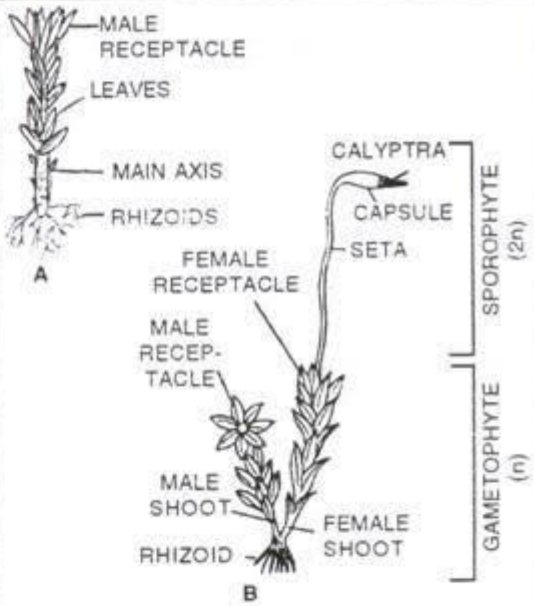
The pores help in rapid intake of water and also in exchange of cations for H^+ions which are the metabolic products of Sphagnum. Hence, they create acidic environment in their immediate surroundings. The hyaline cells take up and hold large quantities of water, sometimes as much as twenty times the weight of the plant. The narrow chloroplast containing cells carry on photosynthesis. In a mature leaf these two types of cells are arranged in a reticulate manner. This peculiar leaf structure accounts for the ability of the *Sphagnum* plant to absorb and retain large quantities of water and consequently for its outstanding bog-building properties. Because of their water absorbing quality they are used in gardening.

Funaria

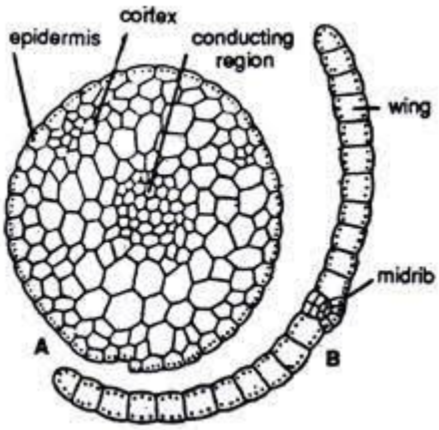
Classification:
Division - Bryophyta
Class - Bryopsida
Sub-class - Bryidae
Order - Funariales
Family - Funariacea

Funaria is a very common moss. It is very widely distributed throughout the world. One species, *Funaria hygrometrica* is cosmopolitan and it the best known of all the mosses. Like other bryophytes that you have studied, the most conspicuous form of the moss plant is the adult gametophyte. This consists of a main erect axis bearing leaves which are arranged spirally. This adult gametophyte is called gametophores. It is small, about 1-3 cm high. The leaves do not have a stalk but show a distinct midrib. The gametophore is attached to the substratum by means of rhizoids which are multicellular, branched and have oblique septae. The gametophyte bears sporophyte which has foot, seta and capsule. The gametophores develops from a filamentous, green short-lived protonema.

The protonema produces buds at certain stage of development, which initiate the development of upright leafy green axis the gametophore.



Funaria sp. A. Unbranched Gametophyte B. Branched Gametophyte



Funaria. A, T.S. axis; B, V.S. 'leaf'.

HEPATICOPSIDA – THE LIVERWORTS

Liverworts have one of two body plans: a thallus or a leafy structure. Thallus-type liverworts have a dichotomously branched and dorso-ventrally flattened body that spreads out along moist riverbanks, on the surface of marshes, or on rotting forest logs. *Marchantia polymorpha* is most commonly used in introductory biology courses because of the unique shape of its antheridiophores and archegoniophores. The most-studied thallus liverwort is Marchantia. Its ribbon-like, dichotomously-branched gametophyte germinates from haploid spores. When male gametophytes mature, they produce small, umbrella-like structures called antheridiophores (means 'antheridia-bearing'), which have numerous antheridia embedded along their dorsal surface. Female gametophytes produce archegoniophores (means 'archegonia-bearing') that resemble miniature palm trees. Archegonia are formed on the ventral surface of the archegoniphore head (where the coconuts would be). Rain stimulates the antheridia to release sperm that make their way to a female gametophyte, up the archegoniophore stalk, and to the egg contained within the archegonium, where fertilization takes place and the zygote formed. Diploid sporophytes develop within swollen archegonia and sporangia are formed. Mature sporangia contain both spores (via meiosis) and elaters. As the elaters dry, they twist and disperse spores. *Marchantia* can also form new gametophytes asexually by means of gemmae, small multicellular bodies produced within gemma cups. Leafy liverworts do not look anything like the thallus types; instead, they resemble diminutive mosses. However, they differ from mosses in several important ways, liverworts: 1) lack a protonema, 2) have single-celled rhizoids, and 3) have a 2-ranked leaf arrangement. In mosses, spores germinate to form protonema, they have multiple-celled rhizoids, and their leaves are usually 3- or 5-ranked.

Classification:

Division – Hepaticophyta

Class - Hepaticopsida

Order -

Family – *Ricciaceae*

Riccia

Riccia is a thalloid liverwort showing distinct dichotomous branching having the form of a rosette. The upper (dorsal) surface of the thallus has a longitudinal groove along the whole length of the mid-rib. The lower (ventral) surface has a row of scales at the apex and a number of unicellular rhizoids. The rhizoids are of two types, the smooth and tuberculate rhizoids. The thallus is thicker in the middle and thinner at the two margins. The growth of the thallus takes place through a single wedge-shaped, apical cell situated in the apical notch. The segments of the thallus are obcordate or linear, their margin sometimes ciliated. Species of *Riccia* are terrestrial and grow as a green carpet on wet ground, old damp walls, old tree trunks and moist rocks. The only aquatic species is *Riccia fluitans*.

Asexual reproduction

Riccia produces vegetatively by the progressive decay of older portions of the thallus, at the base, and its separation into branches that grow into new thalli.

Sexual reproduction

It produces sexually through gametes borne in the antheridia (male gamete) and archegonia (female gamete)

Distinguishing Characters of Division - Bryophyta (Mosses), Division-Marchantiophyta or Hepaticophyta (Liverworts) and Division – Anthocerotophyta (Hornworts)

Character	Bryophyta	Marchantiophyta	Anthocerotophyta
Protonema	Filamentous, forming many buds	Globose, forming one bud	Globose, forming one bud
Gametophyte form	Leafy shoot	Leafy shoot or thallus; thallus simple or with air chambers	Simple thallus
Leaf arrangement	Leaves in spirals	Leaves in three rows	Not Applicable
Leaf form	Leaves undivided, midvein present.	Leaves divided into 2+ lobes, no midvein	Not Applicable.
Special organelles	None	Oil bodies	Single plastids with pyrenoids.
Water conducting cells	Present in both gametophytes and sporophytes	Present only in a few simple thalloid forms	Absent.
Rhizoids	Brown, multicellular	Hyaline, one-celled	Hyaline, one-celled
Gametangial position	Apical clusters	Apical clusters (leafy forms) or on upper surface of thallus	Sunken in thallus, scattered
Stomates	Present on sporophyte capsule.	Absent in both generations	Present in both sporophyte and gametophyte.
Seta	Photosynthetic, emergent from gametophyte early in development	Hyaline, elongating just prior to spore release	Absent.
Capsule	Complex with operculum, theca and neck; of fixed size	Undifferentiated, spherical or elongate; of fixed size	Undifferentiated, horn-shaped; growing continuously from

			a basal meristem.
Sterile cells in capsule	Columella.	Spirally thickened elaters	Columella and pseudoelaters.
Capsule dehiscence	At operculum and peristome teeth	Into 4 valves	Into 2 valves.

1. Ecological Importance:

Bryophytes are of great ecological importance due to following reasons:

(a) Pioneer of the land plants. Bryophytes are pioneer of the land plants because they are the first plants to grow and colonize the barren rocks and lands.

(b) Soil erosion. Bryophytes prevent soil erosion. They usually grow densely and hence act as soil binders. Mosses grow in dense strands forming mat or carpet like structure.
They prevent soil erosion by:

(i) Bearing the impact of falling rain drops

(ii) Holding much of the falling water and reducing the amount of run-off water.

(c) Formation of soil. Mosses are slow but efficient soil formers. The progressive death and decay of mosses help in the formation of soil.

(d) Bog succession. Peat mosses change the banks of lakes or shallow bodies of water into solid soil which supports vegetation e.g., Sphagnum.

(e) Rock builders. Some mosses in association with some green algae (e.g., Chara) grow in water of streams and lakes which contain large amount of calcium bicarbonate. These mosses bring about decomposition of bi-carbonic ions by abstracting free carbon dioxide. The insoluble calcium carbonate precipitates and on exposure hardens, forming calcareous (lime) rock like deposits.

2. Formation of Peat:

Peat is a brown or dark colour substance formed by the gradual compression and carbonization of the partially decomposed pieces of dead vegetative matter in the bogs. Sphagnum is an aquatic moss. While growing in water it secretes certain acids in the water body.

This acid makes conditions unfavorable for the growth of decomposing organisms like bacteria and fungi. Absence of oxygen and decomposing microorganisms slows down the decaying process of dead material and a large amount of dead material is added year by year. It is called peat (that is why Sphagnum is called peat moss).

Various Uses of Peat are:
(a) Used as fuel in Ireland, Scotland and Northern Europe.
(b) In production of various products like ethyl alcohol, ammonium sulphate, peat, tar, ammonia, paraffin, dye, tannin materials etc.
(c) In horticulture to improve the soil texture.
(d) In surgical dressings.

3. As Packing Material:

Dried mosses and Bryophytes have great ability to hold water. Due to this ability the Bryophytes are used as packing material for shipment of cut flowers, vegetables, perishable fruits, bulbs, tubers etc.

4. As Bedding Stock:

Because of great ability of holding and absorbing water, in nurseries beds are covered with thalli of Bryophytes.

5. In Medicines:

Some Bryophytes are used medicinally in various diseases for e.g.,

(a) Pulmonary tuberculosis and affliction of liver—*Marchantia spp*.

(c) Acute hemorrhage and diseases of eye—Decoction of *Sphagnum*.

(d) Stone of kidney and gall bladder—*Polytrichum commune.*

(e) Antiseptic properties and healing of wounds—Sphagnum leaves and extracts of some Bryophytes for e.g., *Conocephalum conicum, Dumortiera, Sphagnum protoricense, S. strictum* show antiseptic properties.

6. In Experimental Botany:

The liverworts and mosses play an important role as research tools in various fields of Botany such as genetics. For the first time in a liverwort, Sphaerocarpos, the mechanism of sex determination in plants was discovered.

7. As Food:

Some Bryophytes e.g., mosses are used as food by chicks, birds and Alaskan reindeer etc.

PTERIDOPHYTES
GENERAL CHARACTERISTICS

1. The sporophyte of pteridophyte is dorminant over the smaller and nutritionally independent gametophyte.
2. The sporophytes are photosynthetic, long-lived and highly branched.
3. The gametophytes are either photosynthetic or obtain their nutrition from decaying organic matter.
4. The cells of these plants have chlorophylls a and b, and also carotenoids.
5. The cell wall is principally cellulose and the storage carbohydrate is starch.
6. The secondary cell walls of fern plants have cellulose and lignin that enable them grow tall.
7. Stomata are present and function efficiently to prevent water loss.
8. The sporophytes of seedless plants undergo meiosis to produce haploid spores. Each of the spores germinates and grows into a haploid gametophyte that produces gametes. The gametes fuse, become the diploid zygote and develops into the sporophyte.

DIVISION PSILOPHYTA – THE WHISK FERNS

Only two genera of whisk ferns are living today: Psilotum and Tmesipteris. Psilotum is a tropical and subtropical plants that occurs in the extreme southern parts of the United States, whereas Tmesipteris is found in many South Pacific islands.

Psilotum has no leaves or roots (but rhizoids are present), just dichotomously divided branches and with sporangia produced at the ends of short, lateral branches.

Psilophytes are homosporous and have a nutritionally independent, gametophyte prothallus that produces antheridia and archegonia. Sperm from the antheridia are released in wet habitats and make their way to the eggs, which are inside the archegonia. The diploid zygote develops into the sporophyte.

DIVISION LYCOPODA – THE CLUB MOSSES AND QUILLWORTS

There are only five genera of Lycopods, three of which are common in Michigan: Lycopodium and Selaginella (both are club mosses), and Isoetes (a quillwort). Club mosses resemble over-sized mosses with an elongated cone at its apex. Lycopodium is homosporous and has a bisexual, prothallic gametophyte. Selaginella is heterosporous in which the haploid microspores have male gametophytes developing inside them, and the haploid megaspores contain the female gametophyte. Isoetes is a small aquatic plant whose leaves resemble porcupine quills and is commonly found on lake bottoms.

DIVISION SPHENOPHYTA – THE HORSETAILS AND SCOURING RUSHES

The sphenophytes reached their maximum abundance approximately 300 million years ago, but today are all extinct except for the single genus, Equisetum. Some of the fossil forms were tree-like, reaching heights of nearly 15 meters.

Equisetum has two sporophyte types: both fertile and sterile shoots. Each shoot is comprised of sections joined at nodes.

Sterile shoots have whorls of long, narrow leaves at each node, whereas fertile shoots lack leaves and chlorophyll. However, fertile shoots terminate with a sporangia-containing structure called a strobilus. Equisetum shoots have silica deposits in their outer tissue for strength. Early American pioneers often used Equisetum to their clean pots and pans, thereby earning the common name, scouring rush.

Equisetum is homosporous and produces independent, prothallic gametophytes (either male or bisexual), about the size of a pinhead, on recently flooded soils. Bisexual gametophytes produce eggs and multiflagellated sperm from their respective archegonia and antheridia. Equisetum also reproduces asexually as shoots along an underground rhizome.

DIVISION PTEROPHYTA – THE FERNS

Ferns are the largest group of seedless plants living today. Again, the sporophyte is the most conspicuous portion of the plant. Most of the fern stem is an underground rhizome that has aerial, pinnately compound leaves. The typical fern leaf has sporangia-containing sori along its underside, but some species have separate fertile and sterile leaves.

Most ferns are homosporous and germinate heart-shaped, bisexual gametophytes, called prothalli. Many ferns have prothalli that are photosynthetic. Archegonia appear as small, raised bumps on the underside of the prothallus’s notched end;

a single egg is produced with each archegonium. Antheridia are also found on the underside of the prothallus, but they are scattered among the many hair-like rhizoids towards the gametophyte’s apex end. Antheridia are distinguished by the cluster of sperm nuclei they contain. Sperm swim through moist soils to the archegonia, and upon fertilization, a new sporophyte develops.

The aquatic fern, Marsilea, is heterosporous. Its sporophyte leaves have a long petiole attached to four floating leaflets, suggesting a floating four-leaf clover. Sporangia are enclosed within a modified leaf structure called a sporocarp. Sporocarps are filled with a thick gelatinous material and a mass of microspores and megaspores. As the sporocarp decays, it breaks open from pressure produced by the expanding gelatin. Marsilea is excellent for observing a fern life cycle, because the male and female gametophytes have rapid development. While still in the gelatinous mass, microspores break open, the male gametophyte germinates and matures, and within 24 h, sperm are released. Marsilea sperm are cork-screwshaped with multiple flagellae. Megaspores contain the female gametophyte, which is composed of a single, large cell and a small, multicellular archegonium. The female gametophyte matures within 14 h, produces a chemical attractant for the perm, and fertilization normally occurs within 24 h. The embryonic sporophyte is also fast developing and can usually be seen in approximately 2–3 d.