SECOND PART: EMBRYOPHYTES

Embryophytes constitute a group of plants that includes all land plants, ranging from mosses to flowering plants (Angiosperms) and conifers. Formerly called cormophytes (comes from the Greek ***kormos*** (trunk, stem). Although the terms have sometimes been confused, embryophytes is a broader term than cormophytes. Cormophytes are a subgroup of Embryophytes that have a cormus-based organization (no longer a thallus) and vascular tissues**)**.

IV. Bryophytes (Mosses)

Belonging to the plant kingdom, bryophytes are the most primitive and simple group of cormophytes, as they lack vascular tissues and true roots. They form a division of small-sized plants, including mosses, liverworts, and hornworts. These plants are primarily terrestrial, usually growing in moist environments, such as soil, tree trunks, or rocks. The level of organization of bryophytes places them between green algae and the simplest vascular plants.

The term bryophyte refers to land plants that do not have a true vascular system. Today, bryophytes are small terrestrial plants, only a few centimeters long (the largest species do not exceed 1 meter). They contain chlorophyll and generally live in humid and shaded areas. Their life cycle is still strongly dependent on water, as male gametes must swim from the antheridium to the archegonium to fertilize the oosphere.

There are approximately 23,000 living species, classified into three main groups:

- 13500 species of mosses
- 9000 species of liverworts
- 350 species of hornworts

Figure : Bryophytes

1. Morphology

In general, the vegetative structure of bryophytes consists of a thallus-like body or rudimentary stem-like axes with poorly differentiated tissues. The epidermis often lacks stomata, and true vascular tissues are absent.

Unlike vascular plants, bryophytes do not have xylem or phloem (the tissues responsible for conducting water and nutrients). These vascular tissues evolved later in higher plants. However, some bryophytes possess specialized conducting cells, such as:

- Leptoids (conduct nutrients, similar to phloem).
- Hydroids (conduct water, similar to xylem but not lignified).

Bryophytes also lack true roots but have rhizoids (unicellular or multicellular structures) that help attach them to the substrate. However, rhizoids do not absorb water and nutrients from the soil. Instead, bryophytes absorb water through all parts of their body. Additionally, in extreme drought conditions, bryophytes can enter a dormant state (reviviscence), where they dehydrate and stop growing until favorable conditions return.

Like vascular plants, bryophytes can form symbiotic associations with fungi to enhance nutrient absorption.

2. Physiology

Due to their reviviscence ability, bryophytes can withstand prolonged dry periods by losing water and entering a dormant state. Once water becomes available, they quickly resume normal metabolic activities. This resilience allows bryophytes to be pioneer species, alongside lichens, in colonizing new environments. They can establish on bare rocks, walls, rooftops, and other mineral-rich surfaces, contributing to soil formation for other plants.

3. Habitat and Distribution

Bryophytes are highly ubiquitous, meaning they can thrive in a wide variety of environments. Like lichens, they can absorb nutrients from the air and atmospheric particles. They have colonized almost the entire planet, including subpolar regions. However, bryophytes are less tolerant of extreme environments than lichens. They are absent from marine habitats and struggle in extremely arid regions.

Thanks to their airborne spores, bryophytes are among the first species to colonize new ecosystems, such as:

- Volcanic islands
- Mining sites (terrils)
- Disturbed or exposed soils

Bryophytes are often found in natural reserves, old forests, and other undisturbed habitats where they contribute to ecosystem balance and biodiversity.

4- Classification

Bryophytes are classified into **03** main divisions:

- ***Bryophyta (Mosses)***
- ***Marchantiophyta (Liverworts)***
- ***Anthocerotophyta (Hornworts)***

4-1- ***Bryophyta (Mosses)*****:**

Mosses belong to a phylum of non-vascular land plants. They lack true roots and a lignified vascular system. Mosses are the most widespread and species-rich group of Bryophytes. They are found all over the world and generally grow to only a few centimeters in height.

a- Morphology:

Mosses have a leafy axis (cormus) bearing simple leaves arranged in a spiral pattern. These leaves do not have buds at their axils. The leafy axis has radial symmetry.

The sporophyte consists of:

- ✓ A foot, embedded in the gametophyte.
- ✓ A seta (stalk).
- ✓ A capsule with a columella, containing spores.

The "stem" is a simple strand covered with an epidermis that is weakly cutinized. In some tropical mosses and Sphagnum species, elongated cells called hydroids (specialized in water transport) and leptoids (responsible for transporting photosynthetic products) appear.

The "leaves" have pseudo-veins and are simple outgrowths of the stem. They consist of a single layer of chlorophyllous cells, except in the central region, where two or three layers of cells form a structure that mimics a vein. The stem is anchored to the ground by a tuft of rhizoids, which are multicellular filaments with oblique transverse walls.

b- Classification of Mosses:

The class of mosses consists of three orders, distinguished by morphological and anatomical characteristics:

- ❖ Bryales
- ❖ Sphagnales (Sphagnum mosses)
- ❖ Andreaeales (Andreaea mosses)

1. Bryales :

- The largest group of mosses, with over 15000 species.
- A Bryales plant consists of a vegetative gametophyte and a sporophyte, which produces spores.

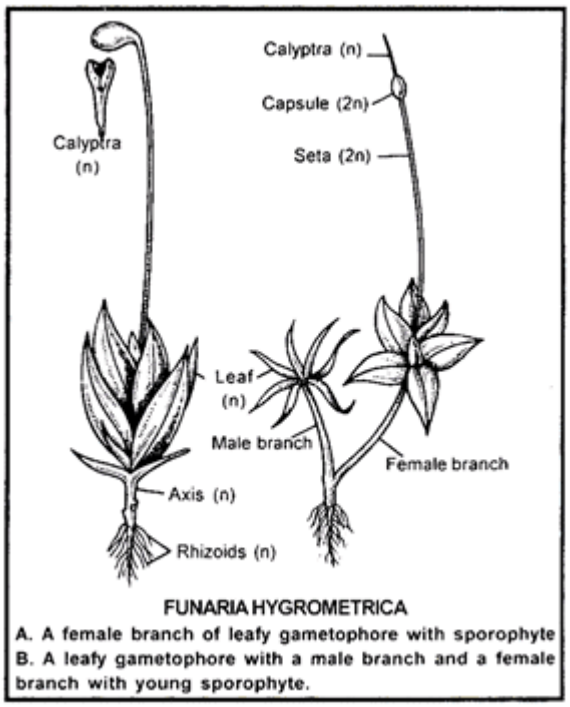

Figure : Bryale species

Gametophyte (Vegetative Stage): light green color, 2 to 3 cm high, formed of:

- **Rhizoids**: Hair-like filaments that anchor the moss to its substrate and absorb water and minerals.

- **Stem**: The main part of the moss, bearing spirally arranged leaves. It can be upright or prostrate.

- **Leaves**: Specialized for light capture, photosynthesis, and water absorption.

Sporophyte (Reproductive Stage):

- **Seta (stalk)**: A long, slender structure that supports the capsule and allows the transport of nutrients.
- **Capsule**: A hollow organ that produces spores for reproduction. It has a lid that opens when the spores are mature.

2. Sphagnales (Sphagnum Mosses)

- This order contains only one family (*Sphagnaceae*) and one genus (*Sphagnum*), with about 300 species.
- *Sphagnum* is widely used in the cosmetic industry.
- It is a medium to large plant (up to 20 cm long), growing in dense or loose tufts with highly variable colors (green, yellowish, brownish, or reddish).
- A typical bryophyte of very humid environments and acidic soils.

Morphological Features:

- The plant contains dead cells that retain water, making it highly water-retentive.
- Dioecious species: Separate male and female gametophytes.
- The gametophyte lacks rhizoids; water absorption occurs through the leaves and stem.
- Leaves are spirally arranged around the stem and branches (unlike liverworts, which have thalloid structures).
- The stem tip (capitulum) has numerous short branches, giving it a star-like appearance.
- The sporophyte consists of a hyaline pedicel (transparent stalk) and a brown capsule.
- Hanging branches (arched downwards).
- The lower part of the plant dies while the upper part continues to grow.

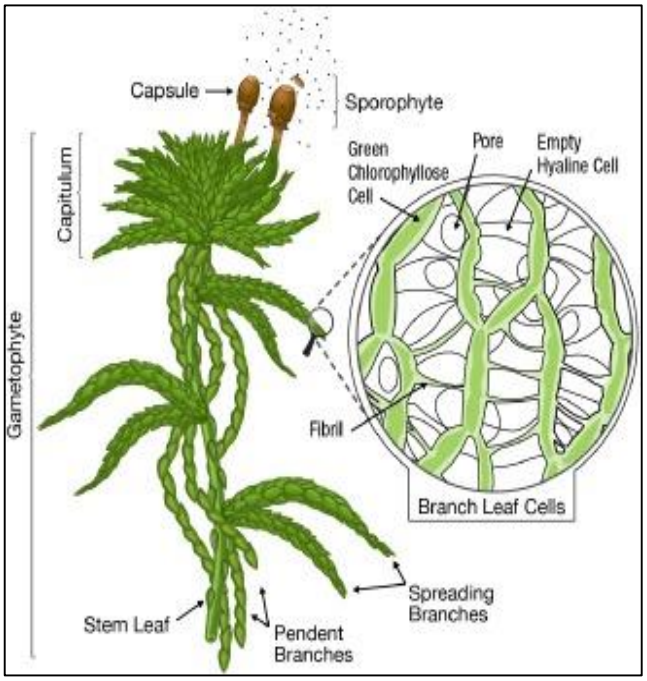

Figure : Sphagnum moss

3. Andreaeales (Andreaea Mosses)

- Mosses that grow on siliceous rocks in cold regions.
- The gametophyte structure is similar to that of Bryales.

Morphological Features:

- Has a stem with spirally arranged leaves.
- The pedicel is chlorophyllous (green, unlike in other mosses).
- The capsule is globular.
- *Unique feature*: The capsule opens into four segments, which is an exception among mosses.

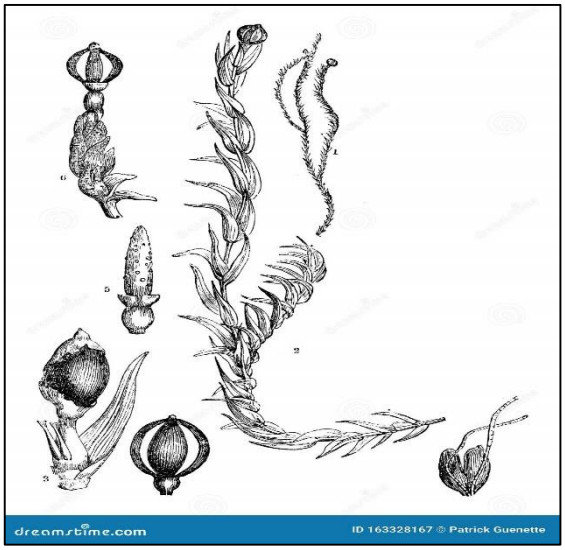

Figure : Andreaea moss

c- Reproduction of mosses

Mosses primarily reproduce sexually, but they can also reproduce asexually through **Fragmentation, gemmae** (small, specialized structures are produced and dispersed to form new moss plants) and **bud formation**.

Mosses reproduce sexually through oogamy, requiring water for fertilization. Their life cycle alternates between 02 stages:

1. **Gametophyte stage (Haploid, dominant)**
    - Male gametophytes produce **antheridia** (containing motile sperm).
    - Female gametophytes produce **archegonia** (containing the egg).
    - Fertilization occurs when sperm swim through water to reach the egg.
2. **Sporophyte stage (Diploid, dependent on gametophyte)**
    - The fertilized egg (zygote) develops into a sporophyte, consisting of a seta (stalk) and a sporangium (capsule).
    - Inside the capsule, haploid spores form through meiosis and are later released.
    - Spores grow into a protonema, which develops into a new gametophyte, continuing the cycle.

Mosses rely on water for reproduction and spore dispersal for survival and colonization. This cycle is digenetic haplodiplophasic.

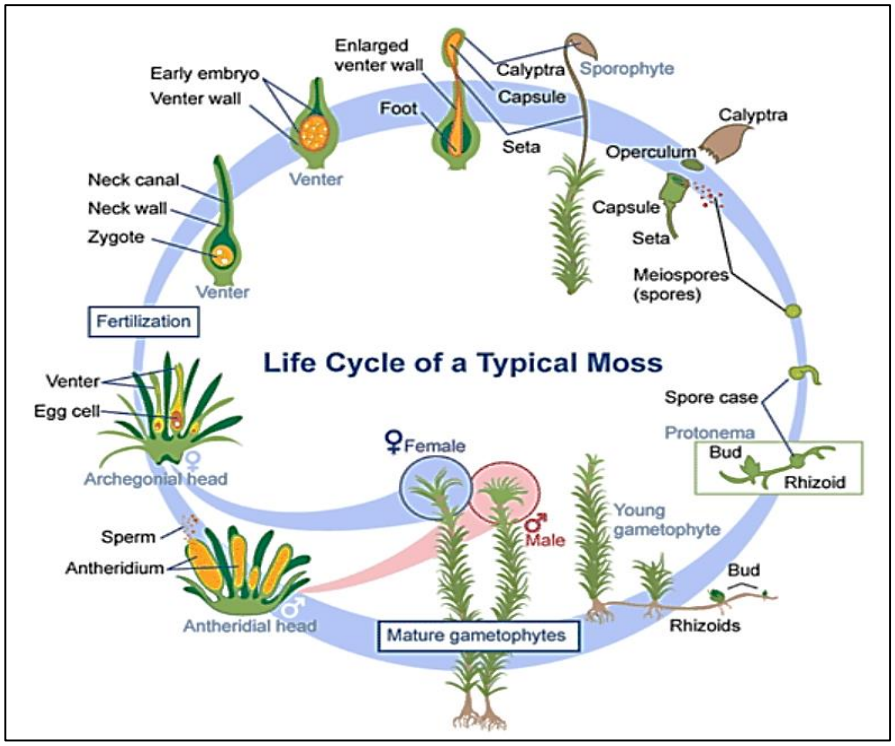

Figure : Life cycle of mosses

4- 2- *Liverworts*

Liverworts, also known as **Marchantiophytes**, are a class of non-vascular terrestrial plants and they are named after their resemblance to the lobes of an animal's liver.

a. Morphology

Liverworts are generally small and inconspicuous. They thrive in humid and shaded environments (streams, ponds, and springs).

Their vegetative body consists of a chlorophyllous**,** ribbon-like thallus that is dichotomously branched and closely adheres to the substrate. It has a dorsoventral symmetry and is composed of two differentiated tissue layers, visible in a cross-section.

Liverworts are generally more sensitive to drought than mosses. Their sporophyte is short-lived and bears a round capsule that opens through valves or splits into plates. Many species contain oil bodies (oleocorps) in their cells, making some of them highly aromatic. They grow on various substrates (decaying wood, soil, rocks).

Key characteristics of Liverworts:

- Presence of lipid inclusions called oil bodies (small droplets of oil).
- Ability to synthesize lunularic acid.
- Loss of stomata, replaced by air pores for gas exchange.

b. Ecology and habitat

Some liverworts are epiphytes, forming part of the epiphytic bryoflora on tree bark or even on leaves in humid tropical regions.

Some liverwort species are frequently found growing on tree bark (corticole species), including:

Frullania dilatata, ***Radula complanata***, ***Lejeunea cavifolia***

Additionally, many liverworts form symbiotic relationships with fungi, particularly Glomerales mycorrhizal fungi. This association likely helps some species survive in cold ecosystems, such as the tundra, taiga, and even parts of Antarctica.

c. Classification of Liverworts

The class **Marchantiophyta (liverworts)** is divided into three main orders:

- **Marchantiales** : 32 genera and 700 species
- **Jungermanniales** : 125 genera and 8000 species
- **Metzgeriales** : 17 genera and 550 species

1. Marchantiales (Thallose Liverworts)

These liverworts have a flat, green thallus measuring 4 to 8 mm wide and 2 to 3 cm long, which grows flat on the soil. They form layered mats on moist soil, rock surfaces, and stream banks.

Figure : Thallose Liverworts

Morphological features

- *Thalloid structure*: Their lower surface is in contact with the substrate and has unicellular rhizoids that help in attachment.
- *Dichotomous growth:* Their growth occurs due to apical cells, as they lack a meristem.
- *Lack of stomata*: Instead, they have permanently open air pores that lead to an air chamber, facilitating respiration and photosynthesis.
- *No true vascular tissue*: Water and nutrients move from cell to cell through diffusion.

2. Jungermanniales (Leafy Liverworts)

These liverworts have a stem-like structure (without specialized cells or channels) 2 to 4 cm long, with two rows of lateral leaves and sometimes a third row of smaller ventral leaves between the rhizoids.

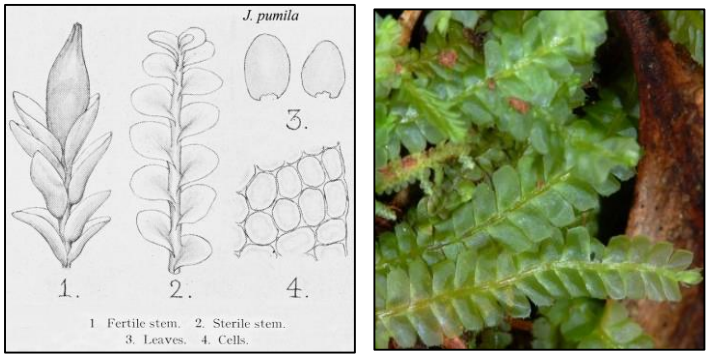

Figure : Leafy Liverworts

Morphological features

- The gametophyte has a creeping cylindrical axis with various lobes:

Dorsal lobes, lateral lobes, the largest ventral lobe, known as the amphigastrium

- The sporophyte is larger and consists of:
  - A suspensor (stalk or seta)
  - A terminal capsule that opens into 04 valves

3. Metzgeriales (Simple Thallose Liverworts)

Figure : Metzgeriales

These liverworts have a smooth thallus, a hyaline (translucent) stalk, and a round, brown capsule that splits into 04 valves upon maturity. Their sporange structure resembles that of leafy liverworts.

Morphological Features

- *Thin and delicate*: Most tissues consist of a single cell layer, making them translucent. Due to this simplistic structure, they are often referred to as "simple liverworts."
- *Unique reproductive structures*:

- In Jungermanniales, the archegonia (female reproductive organs) develop from the apical cell at the tip of a fertile branch.

- In Metzgeriales, the archegonia arise from a cell behind the apical cell, meaning the reproductive organs and sporophytes always develop on the dorsal surface of the plant.

Liverwort reproduction

- Asexual reproduction

Liverworts reproduce asexually through **gemma cups**, which contain specialized vegetative propagules. These structures develop on leaves, stems, or the thallus and disperse to form new plants.

- Sexual reproduction

- Male antherozoids develop in antheridial heads on male plants.
- Female archegonia form in archegonial heads on female plants.
- Fertilization occurs via a water film, leading to the formation of an embryo and then a sporophyte, which remains attached to the gametophyte.
- The sporophyte is reduced and produces a spore capsule, where meiosis occurs. The capsule opens, releasing haploid spores.

The dominant phase is haploid gametophytic (*n*), and the cycle is haplodiplophasic.

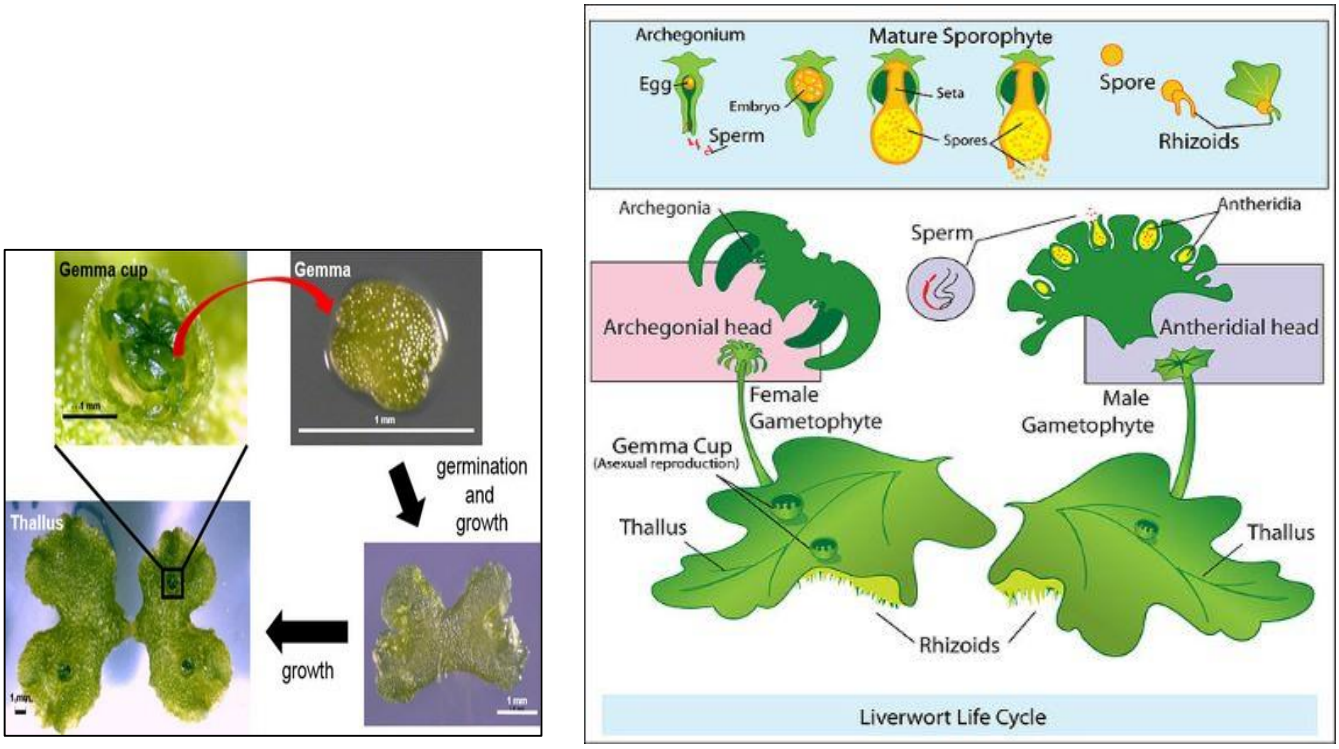

Figure : Liverworts life cycle

4-3- The Anthocerotophyta (Hornworts)

Hornworts are a small group of plants, with approximately 150 species worldwide, classified into four to six genera. They are a class of non-vascular terrestrial plants. Although they resemble liverworts, they differ in their sporophytes, whose capsules elongate into a horn-like structure. This class includes only the order Anthocerales. Some tropical species are epiphytes, growing on leaves, branches, or tree trunks.

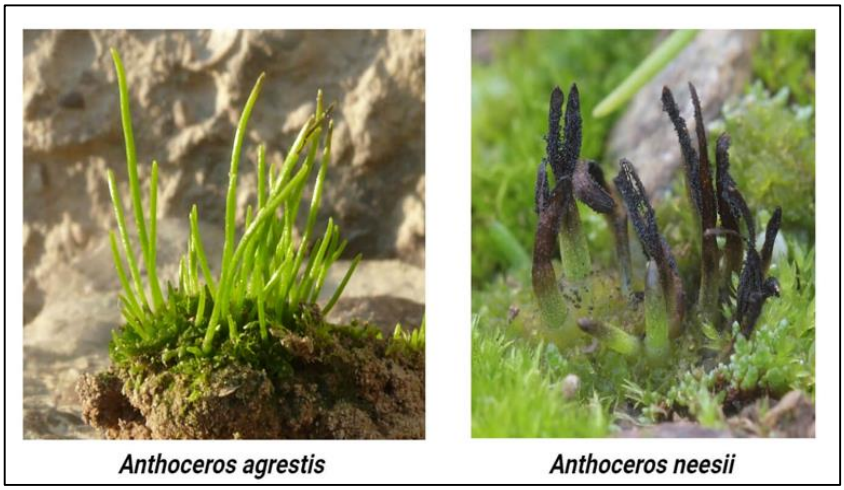

Figure : Hornworts

Morphology

The gametophyte is a flattened, green, leaf-like thallus attached to the substrate (usually soil) by rhizoids, which serve for anchorage and theoretically for absorption. This thallus has internal cavities connected to the exterior through pseudo-stomata located on its lower and sometimes upper surface.

A single chloroplast per cell contains a pyrenoid, a feature distinguishing hornworts from other bryophytes. Symbiotic algae colonize the thallus cavities, and the pseudo-stomata facilitate their entry.

The sporophytes are almost always present. They consist of a haustorial foot and a cylindrical**,** photosynthetic capsule, which grows from a basal meristematic zone. Unlike mosses and liverworts, hornwort sporophytes lack a seta (stalk) and exhibit indeterminate growth. The meristematic zone is protected by an involucre formed by gametophyte tissues.

The sporangium (capsule) splits open from the top into two valves to release spores along with elaters—sterile, unicellular structures aiding in spore dispersal. These elaters, are also found in liverworts.

Hornworts are recognizable by their single plastid with pyrenoids. The gametophytes develop in internal crypts within the plant. After fertilization, the sporophyte emerges as a tube, and dehiscence occurs through a longitudinal slit. A columella is present at the center of the capsule.

Reproduction

- Asexual reproduction

Hornworts reproduce asexually through propagules, similar to liverworts.

- Sexual reproduction

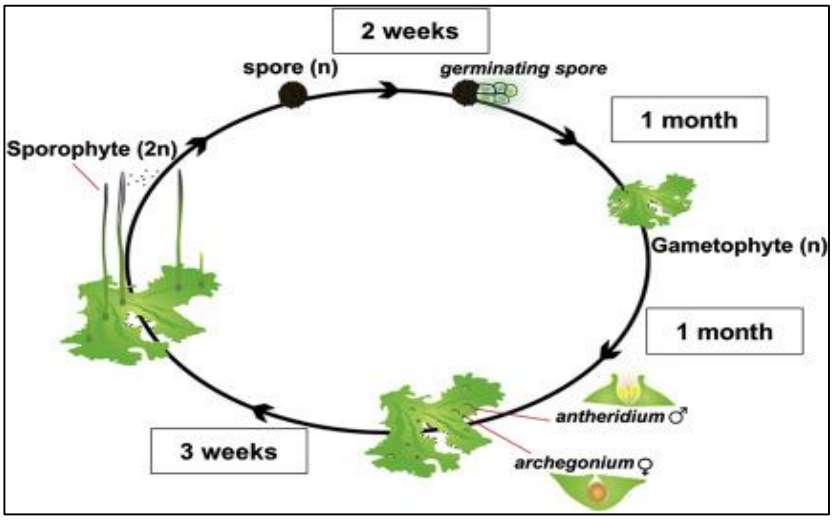

Figure : Hornworts life cycle

- Monoicous thallus with embedded gametangia (antheridia and archegonia).
- Sperm cells travel via water droplets to fertilize the egg in the archegonium.
- The diploid zygote undergoes mitosis, forming a sporophyte (2n).
- The sporophyte contains sporangia, where meiosis produces haploid spores.
- The sporophyte splits open longitudinally to release spores.
- Under favorable conditions, spores germinate into a protonema, which develops into a haploid gametophyte.
- The life cycle is haplodiplophasic with alternating gametophyte and sporophyte generations.