A visit to the miniature forest

Insights into the biology and evolution of Bryophytes in Northeastern Connecticut

Jon Swanson, M.S.

Jessica M. Budke, Ph.D.

Bernard Goffinet, Ph.D.

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For information, please contact:

Jon Swanson
Edwin O. Smith High School
1235 Storrs Road
Storrs, CT 06268

Dr. Jessica M. Budke
Dr. Bernard Goffinet
Department of Ecology & Evolutionary Biology
University of Connecticut
75 N. Eagleville Road, Unit 3043

Biodiversity Beneath Your Feet

The naturalist walking through the forests and wetlands of Northeastern Connecticut searches for the hidden flowers and listens to the songs of the birds. The mosses and liverworts that cover the trail bank, color the tree trunks in shades of green and form soft cushions or carpets on the boulders, typically go unnoticed. Yet several hundred species of Bryophytes occur in our region, and provide important services to the ecosystem, including partially controlling water movement, decreasing erosion, and providing microhabitats for numerous invertebrates. They can even dominate the vegetation in an area or, as in rainforests, compose a majority of the biomass in a local area.

About this guide

Bryophytes are common, diverse and locally abundant. A closer look at their architecture, habitat, and life history provides insights into the ecological roles of bryophytes, the challenges encountered by plants on land and the solutions to some of these obstacles. This guide is not a field guide to the bryophytes of the forest. Accurate identification of bryophyte species often requires observation of microscopic characters. The guide aims to highlight some of the species common to the area, to raise awareness of bryophytes as a component of our forests, and present aspects of plant biology through the “eyes” of a bryophyte.

A useful tool

A hand lens, or loupe, is a useful tool to have when looking at tiny details used to distinguish the species of bryophytes highlighted in this guide. A 5 or 10 X magnification is sufficient to observe the diversity and the characteristics of bryophytes.

Happy hunting!

Bryophytes

Bryophyte is a term referring to mosses, liverworts, and hornworts. The evolutionary origin of these groups may date back some 600 million years, making them the oldest among today's plant lineages. In fact they mark one of the first successful conquests of land and the first plants to produce an embryo. Bryophytes also gave rise to the ancestors of vascular plants.

Bryophytes

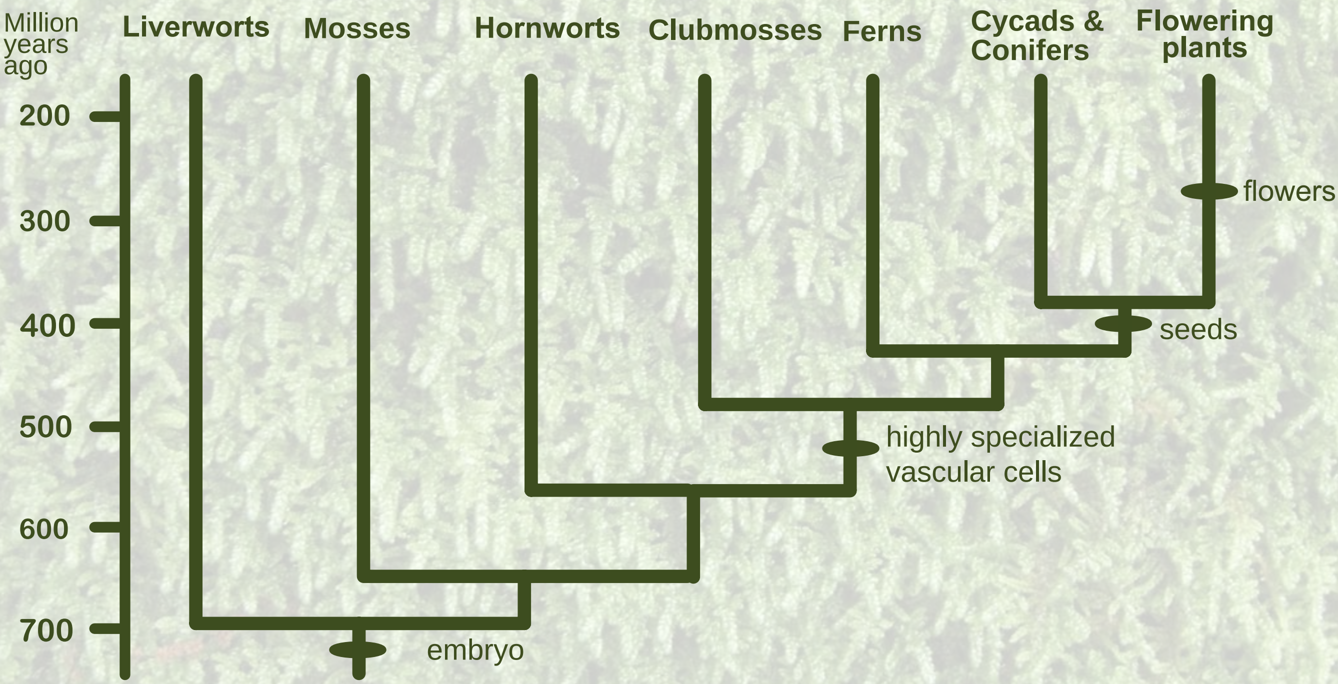
- include mosses, hornworts and liverworts (~20,000 species)
- develop their vegetative body from a spore and are thus haploid
- lack true water and nutrient conducting cells
- typically lack a thick cuticle and absorb water throughout their entire body surface
- may tolerate extensive periods of drought and recover from severe desiccation

Vascular Plants

The group includes ferns, conifers, and flowering plants. They evolved from a bryophyte-like ancestor, and successively acquired highly specialized conducting cells, seeds, and ultimately flowers. Flowering plants thus combine all these traits, which may explain their success.

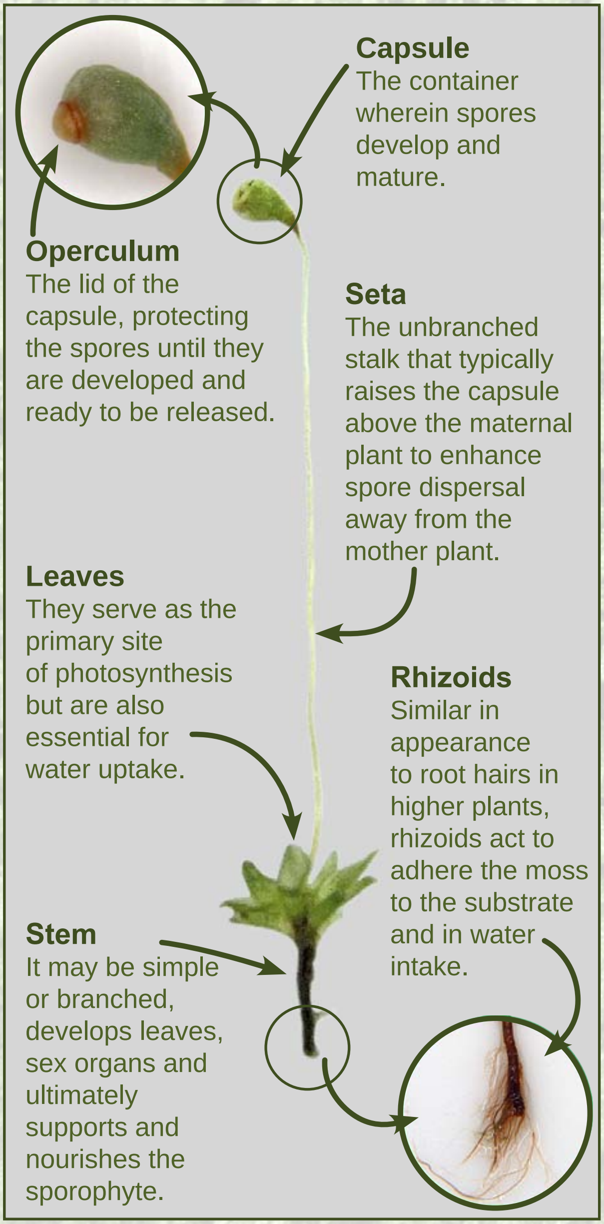
Vascular plants

- include nearly 300,000 species, the majority being flowering plants
- develop their vegetative body from an embryo and are thus diploid
- have highly specialized water and nutrient conducting tissues (xylem and phloem)
- typically seal their body with a thick cuticle and absorb water through their roots
- most avoid drought



Moss morphology

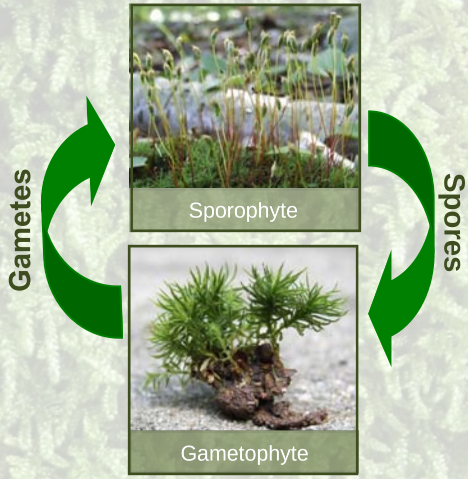
The architecture of a moss is simple: a leafy stem anchored to the substrate by hair-like fibers. They possess a stalk and capsule, but only after sexual reproduction.



One plant, two generations

The leafy green vegetative body of bryophytes represents only one half of the life cycle of the plant. Like all plants, bryophytes are defined by a life cycle composed of two alternating phases, the gametophyte and sporophyte.

Sporophyte is the plant that will produce and release the spores. It develops from the fertilized egg, and hence each of its cells is diploid, holding both maternal and paternal chromosomes. Spores are produced in **a capsule** elevated by a **seta**, through a reduction division called meiosis. They will be released to develop into new male and female gametophytes, continuing the life cycle.



Gametophyte is the haploid vegetative plant that is either ribbon shaped or composed of a **stem** with **leaves** and **rhizoids**. The term gametophyte refers to the fact that this stage produces the gametes, or sexual cells.

The female sex organ, the **archegonium,** holds a single egg; the male, or **antheridium,** releases thousands of swimming sperm cells.

Mosses vs. liverworts

Although sometimes difficult to distinguish, mosses and liverworts have characteristics that can be used to tell them apart.

Mosses

Vegetative body always a leafy stem

Leaves never lobed, but often with midrib

Capsule on top of a robust stalk

Liverworts

Vegetative body either a leafy stem or a ribbon

Leaves lobed or not, midrib absent

Capsule on top of a delicate stalk

Not a bryophyte

Some plants bear common names suggesting that they are mosses, but in fact they are not!

Club moss –
Similar to mosses, but these are actually more closely related to ferns. Typically taller and with yellowish cones terminating their stems.

Resurrection or spike moss –
Like club mosses these are cousins of ferns. The leaves are of two different sizes.

Spanish moss –
Does not occur in New England. This is in fact a flowering plant. Growing on rocks, live and dead wood, these lack the leafy stems of most mosses and liverworts.

Reindeer moss –
This is a lichen, a symbiotic association between a fungus and an alga. The thallus is densely branched, like a tiny shrub.

Iceland moss –
This is also a lichen. The body or thallus is composed of erect brown ribbons that are inrolled into a tube when dry.

Atrichum

Identification: Upright stems with a star-shaped arrangement of long leaves. Like in *Polytrichum*, the midrib is mounted by lamellae, or stacks of cells. *Atrichum* differs by its thinner leaves and a much narrower midrib.

Habitat: Found on soil in shaded to slightly open forests.

Not a vascular plant?

Mosses of the genus *Atrichum* are not considered to be vascular plants but do use conducting cells to transport water within their stems. The axis of the stem of *Atrichum* is made up of long dead cells that move of water through the plant, similar to the xylem of higher plants.

Shaking out the spores: To avoid releasing all spores at once, *Atrichum* uses a salt shaker system!

The teeth around the mouth of the capsule attach to a disc that covers the spores (Figure 1). When a breeze blows, or an animal brushes by, the spores sprinkle out of the spaces between the teeth. With hundreds of thousands of spores produced, *Atrichum* can release spores over several months.

Figure 1: Capsule and disc of *Atrichum*

Polytrichum

Identification: This is the most robust moss in the Northeast forest, commonly reaching 10 cm in height. The 1 cm long leaves are bluish green, revealing the presence of a cuticle. The seta of the plant is also long (> 5 cm) with an upward facing capsule.

Habitat: On soil along trails and forest edges.

Why mosses also repell water?

The raw materials needed for photosynthesis are carbon dioxide (CO_2), water and sunlight. CO_2 diffuses better in air than in water, and so when the plant absorbs water when it rains, it cannot acquire CO_2.The leaves of *Polytrichum* possess columns of cells mounted on the leaf, called **lamellae** (Figure 2). They are covered with wax, preventing the spaces between them from being filled with water. While the plant absorbs water from the soil by specialized conducting cells, CO_2 diffuses into the lamellae.

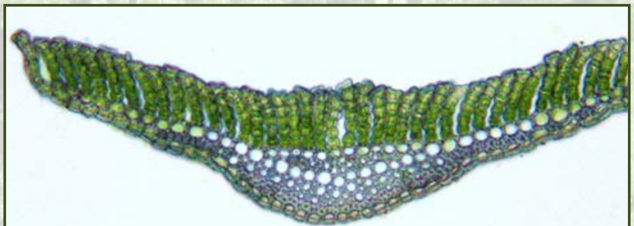


Figure 2: *Polytrichum* leaf cross section showing lamellae

Sphagnum

Identification: The branches occur in clusters along the stem and form a compact head at the tip. The leaves are pale green and always lack a midrib.

Habitat: In shaded stream or pond banks or in peatlands with a high water table.

Staying wet: Although their leaves are only one cell layer thick, *Sphagnum* species are able to hold a few hundred times their dry weight in water. This water holding capacity is possible due to the fact that every other cell in the leaf is empty, with large pores in their walls designed to let water fill them. The living cells are much narrower and sandwiched between dead cells (Figure 3), which act to prolong hydration and thereby prolonging photosynthetic activity.

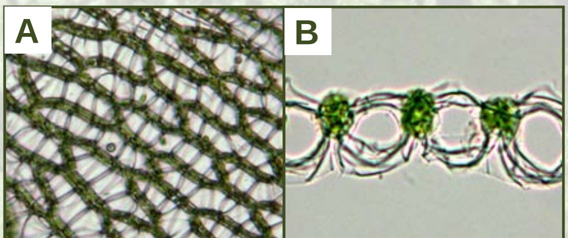


Figure 3: *Sphagnum* leaf surface (A) and cross section (B) showing empty and chlorophyll filled cells

A successful competitor: *Sphagnum* mosses are also known to decrease the pH of their environments by taking up salt ions and exchanging them for hydrogen ions. The release of protons lowers the pH of the water so much that most other plants, which cannot tolerate highly acidic soils, vanish from the habitat, leaving space for future generations of *Sphagnum*.

Leucobryum

Identification: The name refers to the distinctive pale color of the plants. *Leucobryum* forms tightly packed tufts with small but robust leaves. It is similar to *Dicranum*, but the leaves of *Leucobryum* are much thicker (multiple cell layers thick) and the color tends to be a paler green.

Habitat: Found on soil in shaded to slightly open forests.

The importance of dead cells: As in many mosses, dead cells play an important role in *Leucobryum*. The distinctive pale color of this genus is due to the fact that the leaves are actually composed of multiple layers of dead cells, called **hyaline cells**, layered above and below a single layer of living, photosynthetic cells, called **chlorophyllous cells** (Figure 4). These hyaline cells serve to hold water and/or air for the chlorophyllous cells to enable them to carry out photosynthesis.

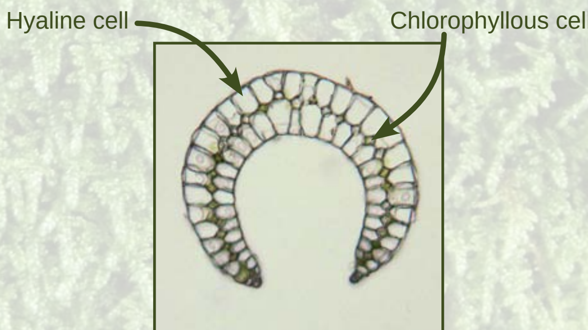


Figure 4: Cross section of *Leucobryum* leaf

Tetraphis

Identification: The small delicate plants bear spade-shaped leaves with a single midrib. The capsule long cylindrical, held upright at the top of the seta. Surrounding the mouth of the capsule are four long teeth which are visible with a loupe (Figure 5).

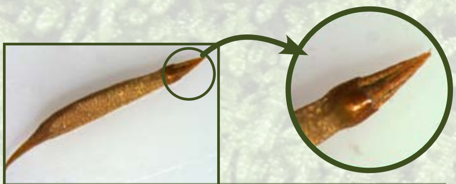


Figure 5: Capsule of *Tetraphis* showing teeth

Habitat: Found on decaying trunks and stumps in moist shaded forests.

Asexual reproduction: *Tetraphis*, like many mosses, has the ability to reproduce asexually. The upper leaves of the mosses' stems form a cup-shape (Figure 6A) where the plant develops **gemmae** (Figure 6B), small multicellular discs that are splashed out of the cup and grow into a new gametophyte plant. All the offspring are clones, but such reproduction is not dependent on fertilization and allows rapid spreading in the habitat.

Figure 6: Gemmae cups of *Tetraphis* (A) and gemmae (B)

Diphyscium

Identification: The stem of this species is short, with a few whorls of narrow, strap-shaped leaves. The sporophytes are much larger than the gametophyte. They consist of an "urn" shaped like an Indian oil-lamp, that sits close to the ground and is not elevated on a stalk.

Figure 7: *Diphyscium* mat in disturbed habitat supporting angiosperm seedlings and lichens

Habitat: Found in disturbed areas on the forest floor and on rock surfaces.

True pioneers: Some mosses are among the very first colonizers of open, bare substrates, such as mineral soil. Pioneers play important ecological roles: they contribute dead organic matter and initiate the development of enriched soil; they fix soil particules and thereby prevent erosion; they insulate the soil, and so reduce evaporation, and they provide food and shelter for microorganisms and invertebrates. All together these pioneers trigger the succession of plant communities and their associated fauna. It is not unusual to see a moss mat serving as a nursery for seedlings (Figure 7). Pioneer communities include mosses, lichens, algae, and cyanobacteria.

Dicranum

Identification: The moss forms tightly packed tufts to larger mats with thin, curved leaves. *Dicranum* is similar to *Leucobryum,* but has thinner, darker leaves that all tend to be curved in the same direction.

Habitat: Found on soil or rocks in shaded to slightly open forests.

Plant sexes: Unlike seed plants that disperse their sperm cells in pollen grains, bryophytes must release their sperm cells in water, for they must swim to reach the egg. In some species the distance between sex organs is short as they develop both on the same plant (**monoecy**), and sexual reproduction is common, but all offsprings are clones of their parents. In others the male and female sex organs occur on different plants (**dioecy**); sexual reproduction is less common, but offsprings are genetically diverse.

Figure 8: *Dicranum* showing tight arrangement of leaves

Tight tufts: The leaves and stems of *Dicranum* are packed into very tight tufts (Figure 8), reducing the overall surface exposed to the air, and thus decreasing water loss through evaporation. The leaves remain moist and photosynthetically active.

Mnium

Identification: *Mnium* (pronounced n-eye-um) has erect stems slightly over an inch tall. The leaves are slightly twisted when dry, but flat, erect and spreading when moist. The leaves bear a strong midrib, and a conspicuous border of long cells with teeth protruding in pairs at regular intervals (Figure 9).

Figure 9: *Mnium* leaf highlighting elongate cells and teeth on leaf margins

Habitat: Growing on moist soil, primarily along streams.

Dispersing gametes:

Mnium develops splash cups to disperse sperm cells. The leaves at the top of the stems form a tight rosette around the antheridia (Figure 10). Rain drops that land in the cups splash out, dispersing the sperm cells, which may have a greater chance reaching a female plant, and fertilizing an egg.

Figure 10: *Mnium* splash cup

Hypnum

Identification: Feathery stems with regular branching, and with leaves sickle-shaped, all pointing downward. The leaves lack a midrib, and all cells are elongate. The corners of the leaves appear bleached, as the cells there are devoid of chlorophyll and enlarged (Figure 11).

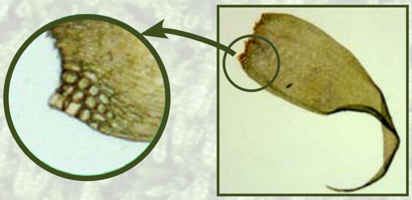


Figure 11: Leaf of *Hypnum* with clear cells in corners

Habitat: Decaying trunks and over rocks protruding from forest floor.

Dehydration? No problem!

Most bryophytes lack a thick waxy cuticle covering their leaves. This allows them to absorb water through the leaf surface. Of course, if water can move in, it can move out. Bryophytes are unable to maintain a high internal water balance, and their water content reflects the atmospheric moisture. When the air dries out, so do the bryophytes. Many bryophytes can lose substantial amounts of their water, and enter a dormant state.When it rains, they become rehydrated, and resume photosynthesis within minutes or hours. While most vascular plants avoid dryng out by developing a cuticle, bryophytes tolerate dehydration and even severe desiccation.

Thuidium

Identification: The stems, and branches are regularly and repeatedly branched, giving the plant a soft feathery appearance. The leaves are short, triangular, and bear a single midrib. The stem is coated by a fuzzy layer of green hair-like filaments. The stems and leaves form a mat of feathery "fronds." Similar to *Hypnum,* but *Thuidium* leaves do not curl under at the tips and the branches of *Thuidium* tend to have multiple levels of branching.

Figure 12: *Thuidium* stem highlighting papillae on leaves

Habitat: Forms a thick layer on rocks, and decaying trunks in moist, shaded locations.

Water transport: Most mosses lack highly specialized water conducting cells. Some move water externally along their body, through tiny capillary spaces between the leaves and stem, or short filaments coating the stems and branches. Small warts or **papillae** (Figure 12) on the leaf surface increase the surface area to absorb water and create capillary spaces to retain water. Such external capillary water is critical for the plant. When the air dries out, this pool of water will evaporate first, delaying the dehydration of the cells and thus allow the plant to photosynthesize longer.

Nowellia

Identification: This tiny liverwort produces deeply lobed leaves, with the lobes narrowing to fine points. The base of the leaf is bent over forming an inconspicuous water pouch (Figure 13). The plants are green in summer, turning to a deep red as the canopy opens in the fall.

Figure 13: Folds of *Nowellia* leaf

Habitat: Grows exclusively on moist wood of decaying trunks (not bark).

Color changes in leaves: Similar to the leaves of the deciduous trees of the area, the leaves of *Nowellia* change to a deep red in fall. Unlike their angiosperm cousins, they do not do this in preparation for dropping their leaves but rather they may change their leaf color to the darker hue to absorb more of the sun's radiation, keeping the plant warmer in the winter months. This increased leaf temperature results in an increase in rates of photosynthesis despite the colder temperatures of the winter months.

Frullania

Identification: Easily overlooked because of its small size and dark color, *Frullania* is, however, a spectacular liverwort. The smaller ventral lobe of the divided leaf is highly modified into a stalked helmet-shaped water-sac (Figure 14).

Figure 14: Leaf lobes of *Frullania*

Habitat: Grows on bark of hardwood trees, forming thin circular mats.

Microhabitats: As do many of the bryophytes, *Frullania* provides habitat for many invertebrates and their larvae. The mats of many bryophytes provide cover and protection for ants, tartigrades, and nematodes among many others. The shape of the bilobed leaves of *Frullania* form a small cup at the base of the leaf, providing a small pool where invertebrates can live. Up to 70% of *Frullania* plants harbor rotifers. This creation of habitat for the tiny inhabitants of the forest makes this liverwort an important part of forest food webs without being a significant food source itself.

Pallavicinia

Identification: *Pallavicinia* does not possess true stems or leaves but rather is composed of clumps of a ribbon-like **thallus**, with a distinct midrib (Figure 15).

Figure 15: Thallus of *Pallavicinia* showing midrib.

Habitat: Grows on soil and among other bryophytes in rather shaded mesic habitats.

An untapped source for medicines:
Recently, species from the genus *Pallavicinia* have been investigated for their anti-microbial properties. Certain chemical compounds produced by the liverwort have been shown to inhibit the growth of both bacteria and fungi, two groups that can cause human ailments. In the wild, the liverwort may be producing these chemicals to protect itself from bacteria and fungi. Although the chemical(s) responsible for this activity have not been identified, when isolated, they may provide a new group of medicines against problems caused by these microbes.

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