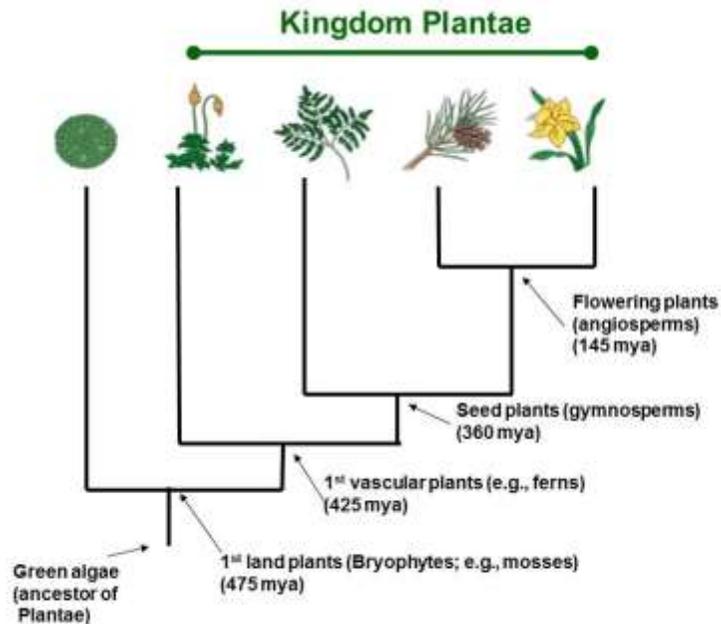


October 23 – Seedless plants

We began lecture with an overview of the evolutionary lineages within the Kingdom Plantae, and we drew the following phylogenetic tree:



Important vocabulary for phylogenetic trees:

Phylogenetic tree: A branching diagram showing the evolutionary relatedness among species (or groups of species).

Ancestor: The organism(s) from which later species (or groups of species) evolved

Common ancestor: an ancestor common to (i.e., shared) by two or more descendants.

Descendant(s): Organisms or species (or groups of species) descended from a specific ancestor. (ALWAYS context-specific; one never labels something as a descendant without naming the ancestor)

Lineage: group(s) of species related by descent from a common ancestor

If one traces the phylogenetic tree for Kingdom Plantae back far enough to its base, one learns that all plants are all descendants of aquatic green algae (green algae are the ancestors).

However, since the first plants (mosses and allies) evolved from algae, Kingdom Plantae has evolved further and now contains four different groups (or lineages!) of plants:

- (1) Mosses and allies (a.k.a. bryophytes) ~20,000 spp.
- (2) Ferns and allies ~12,000 spp.
- (3) Gymnosperms ~1000 spp.
- (4) Angiosperms (flowering plants) ~300,000 spp. (a common range suggested is 250,000-400,000)

Seedless plants are comprised of two groups:

- 1) **mosses and allies (aka, bryophytes)**
- 2) **ferns and allies** (here, the term “allies” implies closely-related evolutionary groups).

Mosses and allies (bryophytes)

Bryophytes were the first land plants to evolve from ancestral green algae. Imagine the evolutionary progression: As algae washed up on shorelines, they adapted to this new environment (and ultimately became bryophytes) with two especially three important adaptations:

- a) spores that are durable and resistant to desiccation (drying out). These spores are covered in **sporopollenin**, which contributes to their durability.
- b) primitive “roots” called **rhizoids** – these anchor mosses in place but do not absorb water as in vascular plants.
- c) Protective “chambers” for spores (sporangia), as well as sperm and eggs (antheridia and archegonia, respectively, which we will see and draw in lab. Egg and sperm are called gametes.

Sporopollenin: A chemically complex substance in the outer walls of spores and pollen grains. Very stable and durable, the variable and largely unknown composition includes fatty acids, phenolics, and carotenoids.

Rhizoids: Root-like structures that in mosses help anchor the plant and may absorb small amounts of water.

Recall that mosses have a life cycle that includes a sporophyte and gametophyte. (We did NOT explore the following concepts: alternation of generations, meiosis, mitosis, haploid, diploid, 1n, and 2n: you will not be tested on these terms and concepts.) Know the following:

Gametophyte: The gamete-producing plant

Gamete: Haploid sex cell (e.g., egg, sperm)

Sporophyte: The Spore-producing plant

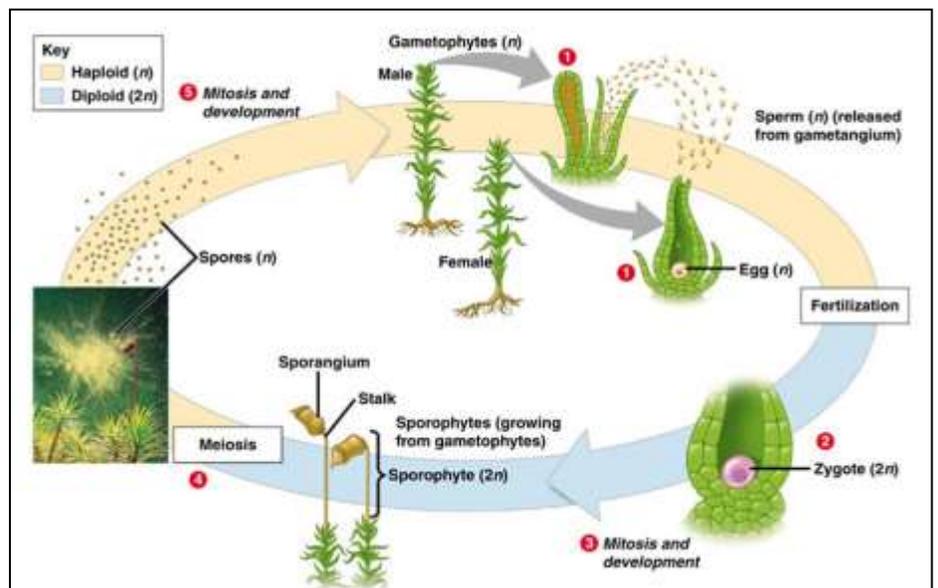
Spore: A durable haploid cell that can grow into an adult without fusing with another cell (fertilization).

Fertilization: the union of sperm and egg, producing a zygote (one 2n cell), which develops into an embryo.

Sporangium: protective chamber that houses spores.

WE DID NOT COVER THIS MATERIAL THIS SEMESTER, BUT I LEAVE IT HERE FOR YOUR REFERENCE

Moss life cycle (right) – as covered in lab. Not labeled here (but illustrated) are **antheridium** and **archegonium**. You need to know these!



In lab, we discussed three groups of bryophytes. There are ~20,000 species of bryophytes:

1) True mosses (Phylum Bryophyta)

2) Liverworts (Phylum Marchantiophyta)

3) Hornworts (Phylum Anthocerotophyta)

I will not ask you to distinguish among these three groups on exams. I am more interested in tracking the evolutionary position of bryophytes as intermediates between algae and seedless vascular plants (i.e., how are they different from algae, and how are they different from ferns and allies...?). To that end, consult the table below – there are many other differences that you can find in the text – but you are responsible for the information below.

NOTE – the yes/no categorizations are general trends – and there are exceptions to these (e.g., hornworts have stomata on their sporophytes...) do not get hung up on the exceptions – we are tracing the big picture here... We'll add more features later....

	bryophytes (mosses and allies)	Seedless vascular plants (Ferns etc)	gymnosperms	angiosperms
vascular system	no	yes	yes	yes
Cuticle	no	yes	yes	yes
Stomata	no	Yes	Yes	yes
Roots	No - rhizoids	Yes – adventitious off of rhizome	Yes	yes
Dispersal mode	spores (sporopollenin)	spores (sporopollenin)	Seed	Seed
(need moisture for fertilization?)	yes: flagellated sperm	yes: flagellated sperm	No*	No
Seed producing structure	No	No (but some with spore-bearing strobilus)	Cone (typically)	Flower (ovary) – ovary develops into a fruit

* a very few species (*Ginkgo* and cycads) have flagellated sperm—we'll get to this next week

Bryophytes: Because bryophytes lack vascular tissues (xylem and phloem), water must be obtained from the environment through absorption, and then be transported throughout the plant via diffusion/osmosis from cell to cell. Additionally, it is the thickening of xylem cells in vascular plants that gives them the structural support to grow vertically.

Thus, bryophytes are:

- Small in size (because water must be absorbed and diffuse throughout plant)
- Short (because they lack structural support)
- Lack a thick outer covering (“cuticle”) on the above-ground tissues (remember thy must absorb their water), and thus they are “soft” to the touch – that’s why a ‘bed of bryophytes’ is unbeatable when sleeping in the woods!!
- Constrained (*mostly*) to wet habitats (again, no cuticle to slow evaporative water loss, and no vascularized roots and stems to move high volumes of water, – they do have small root-like structures (called **rhizoids**, whose primary function is attachment), but rhizoids do not absorb and transport water like vascular plants)

The constraint to wet habitats is reinforced by the fact that bryophytes have flagellated sperm (sperm with flagella) that require a wet environment in which to swim and fertilize. (Note: Some mosses survive and thrive in dry environments – but they are exceptional).

Sphagnum and peat bogs:

We discussed *Sphagnum* moss in lecture. *Sphagnum* is a genus of moss that can hold large volumes of water in its tissues. As it grows in large flat areas prone to flooding, it can form dense accumulations called peat, and the location is known as a peat bog.

Peat: an accumulation of partially decayed vegetation (often mosses).

Peat bog (aka bog): a location where peat is accumulated.

Peat constructed from *Sphagnum* spp. is call ***Sphagnum* moss or *Sphagnum* peat.**

Because *Sphagnum* is predisposed to forming peat, it is often referred to as “**peat moss**”.

Sphagnum resists decomposition, and thus forms peat, for three reasons:

- 1) **Phenolic** compounds (remember these secondary metabolites?!!) in cells of *Sphagnum* spp.
- 2) Water in peat bogs is often **anoxic** (remember – water holds, by volume, ~ 1/70th the number of oxygen molecules found in air). This means that bacteria and fungi cannot conduct cellular respiration and cannot decompose the peat.
- 3) *Sphagnum* is highly **acidic** (due in large part to the phenolic compound sphagnum acid) and bogs are highly acidic – and the acidity slows or eliminates decomposing organisms.

The extent to which peat resists decomposition is evidenced by archaeology:

- 1) Human remains have been found

Example: Tollund Man – discovered in 1950 by Danish farmers who were cutting peat (more below). The farmers initially thought they had discovered a recent murder victim – the man is so well preserved that stubble is visible on his face. Later archaeological work dates Tollund Man at ~300 BC

- 2) Humans once stored food in bogs, - “bog butter”

Peat in bogs can be many meters thick. The mosses probably only grow 1-few mm per year, so a bog that is 3000 mm (3 meters, or ~ 10ft) is at least 3,000 years old. Humans dig peat and have found many uses for it over the centuries, and millennia:

- 1) Burned as a heating fuel, and more rarely to fire power plants (remember, peat formation is an initial step in the formation of coal!!).
- 2) Used to flavor scotch whisky
- 3) Used as insulation in homes
- 4) used as a “gauze” or bandage to dress wounds – it is absorbent and the low pH (acidity) kills some bacteria.
- 5) Soil conditioner to increase water holding capacity, also makes soil lighter, thus improving root penetration and diffusion of O₂ to the roots.
- 6) Soil amendment for acid-loving plants (e.g., blueberries).

Ferns: Ferns and allies overcame many of the habitat and structural limitations of bryophytes with a few important adaptations: (There are ~12,000 species of ferns and allies)

- 1) Ferns have vascular tissues, and acquire/transport water via transpiration as described in previous lectures.
- 2) They have a cuticle and stomata.
- 3) Ferns have true leaves, stems, and roots (roots grow from a rhizome).

Significance of these adaptations:

- In a nutshell, the presence of a cuticle and vascular tissues allowed ferns to be taller, more durable, and spread into habitats that were too dry or too hot for bryophytes:
- The presence of vascular tissues means that ferns do not need to acquire water via absorption across the above-ground tissues. This has left their leaves “free” to evolve functions that don’t interfere with absorption – one of these is a thickened **cuticle**. The value of a cuticle is that it slows water loss and protects leaves from other physical damage (freezing, tearing, etc...) and biological damage (e.g. grazing by insects or other animals).
- The ability to move water via vascular tissue also allowed ferns to evolve larger body sizes.
- The xylem they contain provides the physical support and allows ferns to grow taller than bryophytes. (FYI: there is not true secondary growth in ferns and allies. That is to say, xylem in ferns is primary but none arises from the activity of lateral meristems as in gymnosperms and angiosperms.

Like bryophytes, ferns have flagellated sperm (sperm with flagella) that require a wet environment (at some point during the life cycle...) in which to swim to the egg and achieve fertilization, form a zygote and develop as a young embryo.

Easily identifiable macroscopic features of most ferns include “*fiddle head*” pattern of growth at the apical meristem, and wing-like shapes of the leaves (hence the name Pteridophyta, from the greek “*pteron*” or “*wing*”, + “*phyte*” or “*plant*”). It is in some ferns and allies that the **strobilus** first appears:

Strobilus: Reproductive structure in which modified leaves/scales that bear spores or seeds are arranged around the tip of a stem. (‘Cone’ is often used as a synonym, but many botanists reserve the term ‘cone’ to refer to woody cones as in conifers such as pines etc..).

Unique ferns mentioned in class and lecture slides: horsetail ferns (*Equisetum*), tree ferns, maidenhair ferns, and desert ferns

Ferns and closely related species of seedless vascular plants formed vast forests between 360-300 mya. Due to the large biomass (comprised mostly of carbon atoms!!) stored in these plants, this period of Earth’s history is known as the **Carboniferous Period**. (Carboniferous literally translates as Carbon “coal” + iferous “bearing”). The biomass that accumulated and died during the Carboniferous formed large deposits that eventually became coal deposits (hence this period is known as the Carboniferous, or “coal-bearing” period). We burn these deposits in coal-fired power plants. Coal is one type of ‘fossil fuel’.

Fossil fuels: hydrocarbons, primarily coal, fuel oil or natural gas, formed from the remains of dead plants and animals.

Many of the interesting looking seedless vascular plants that existed during the carboniferous are now extinct. Those that are not extinct are referred to as **fossil species**:

Fossil species (aka living fossil): A currently living species that is represented in the fossil record from long ago, and which has not changed significantly through evolutionary time. A classic example in the fern lineage is *Equisetum* spp. (horsetail ferns), in the fossil record >300mya.

Two of my favorite extinct genera, which we examined in lecture were: *Lepidodendron* spp. and *Sigillaria* spp. These two genera have fossilized beautifully! You do not need to know these for exams, but they'd be wonderful extra credit material...(note: the following descriptions pasted from Wikipedia):

Lepidodendron spp

A now extinct genus of primitive, vascular, arborescent (tree-like) plant. They were part of the coal forest flora. They sometimes reached heights of over 30 metres (100 ft), and the trunks were often over 1 m (3.3 ft) in diameter, and thrived during the Carboniferous Period (about 359.2 ± 2.5 Mya (million years ago) to about 299.0 ± 0.8 Mya).

Sigillaria spp.

A genus of extinct, spore-bearing, arborescent (tree-like) plants which flourished in the Late Carboniferous period. *Sigillaria* was a tree-like plant, with a tall, occasionally forked trunk that lacked wood. Support came from a layer of closely packed leaf bases just below the surface of the trunk, while the center was filled with pith. The old leaf bases expanded as the trunk grew in width, and left a diamond-shaped pattern, which is evident in fossils.

