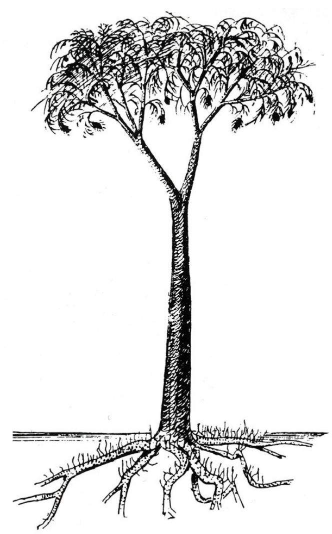
Diversity in the Plant Kingdom

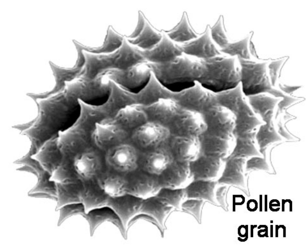
I. Introduction

All modern terrestrial plants are the descendants of algae that adapted to a terrestrial habitat roughly 500 million years ago. Compared to water, land is an erratic habitat where temperature and moisture availability may change abruptly and dramatically.



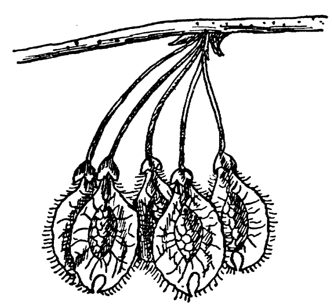
What were the adaptations that these primitive plants needed to survive on land?

- Surrounded by air, the land plant is in constant threat of desiccation and must have **waterproofing**, usually in the form of a waxy **cuticle** layer.
- While algae could obtain nutrients from the surrounding water, land plants needed to extract minerals (and now, even water!) from the soil; and **roots** adapted to take on this task.
- Evolution of rigid **structural support** allowed plants to grow to new heights, and better compete for sunlight.
- Yet, height must have coevolved with **vascular (transport) tissue**, the internal plumbing system needed to transport water and nutrients from the roots skyward.
- **Reproduction** now became problematic as well, as sperm could no longer swim through open water to meet with the egg. Thus evolved sperm cells protected within **pollen grains** that could instead use wind, and later, unwitting animals to be carried to the egg.



Pollen grain

- And what to do with the next generation? Conditions on land are much less predictable than in water, possibly unfavorably dry or hot after fertilization occurs. Packaging the immature (and dormant) plant in a **seed**, allowed it to survive until favorable growth conditions (or the correct season) arrived.



These were the traits that appeared during the evolution of plants, and they can be traced through a study of the different groups of plants that exist on earth today. Although you may be casually familiar with many of these plants, you may not appreciate their evolutionary significance or relationships.

The objectives of this lab exercise are that you understand the:

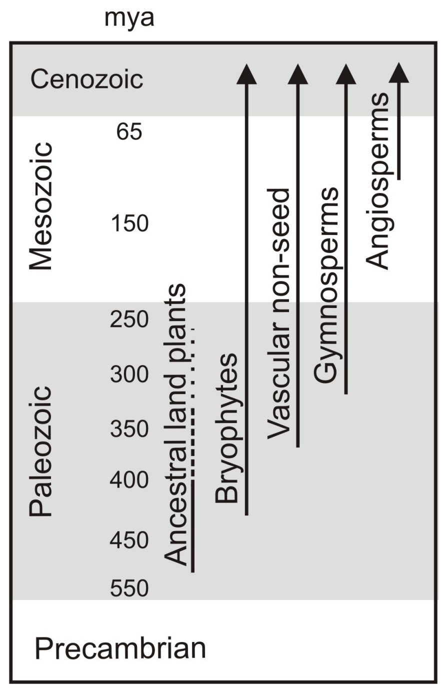
- Particular evolutionary innovations associated with the major groups of plants, and learn to identify these plants.
- Evolutionary relationships between these plant groups.
- The distinctive characteristics of plant reproduction.

What are the major groups of plants and when did they evolve?

There are four major groups that evolved in the following sequence:

1. **Bryophytes;** which include the mosses
2. **Seedless vascular plants;** which include the ferns
3. **Gymnosperms;** many of which are also called conifers
4. **Angiosperms;** the 'flowering' plants, which now predominate

The approximate ages during geologic time when these groups evolved are shown in the figure. Ancestral algae began to invade the land early in the Paleozoic, and plants that closely resemble modern bryophytes appeared shortly (say… 100 million years!) thereafter. Plants with advanced vascular systems appeared in the mid Paleozoic and quickly became the dominant plant form on earth. The gymnosperms reached predominance in the Mesozoic (triceratops was probably eating conifers) to be later replaced by the much more reproductively successful angiosperms.



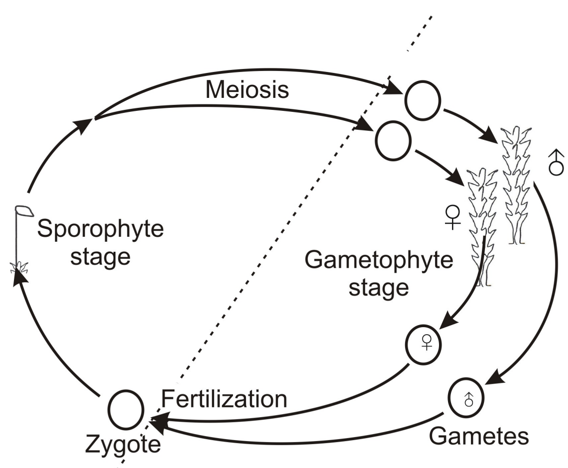
What are the sporophyte and gametophyte?

In **animals**, the adult (male or female) has specialized organs that produce reproductive cells called **gametes** (**sperm or egg cells**). Upon fertilization, the egg and the sperm combine to produce a zygote that can grow into another male or female adult.

Unlike animals, plants have two alternating life stages. The figure shows the '**alternation of generations'** as it occurs in a moss.

1. One stage – the **sporophyte** – produces spores;
2. the spores develop into a **gametophyte** stage plant, which may be male or female;
3. gametophytes produce either sperm or egg gametes;
4. egg and sperm cells unite and grow into another sporophyte.

Notice: spores develop into a whole plant; gametes must first unite then develop. **Animals do not produce spores.**



How did the life stages of plants change during evolution?

1. **Initially,** the gametophyte was the larger, more apparent stage; as in a moss.
2. **Later,** the sporophyte stage became more dominant and elaborate.
3. **Eventually,** the gametophyte stage became reduced to being only microscopic.

II. Characteristics of the major groups of plants

A. Bryophytes (nonvascular)

These are considered to be the most primitive of the plants. They are typically only found where water is readily available, and never grow more than a few inches tall for lack of a vascular system.

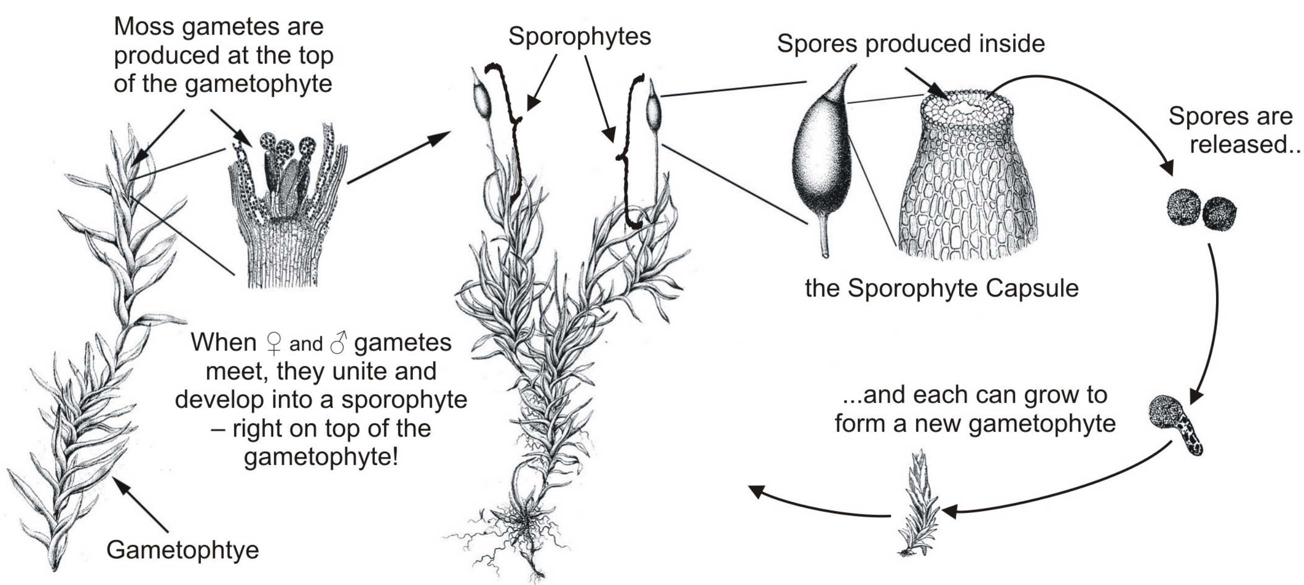
What are the distinguishing characteristics of the Bryophytes?

- **Bryophytes disperse through spores, not seeds.**
- **Bryophytes lack a vascular system.** There are no tree-size bryophytes because water could never travel adequately from the rootlets to the very top.
- **The gametophyte stage is dominant.** Bryophytes are the only group of plants where the gametophyte stage is larger than the sporophyte stage**.**

There are three divisions of bryophytes, two of which are on display.

1. Mosses

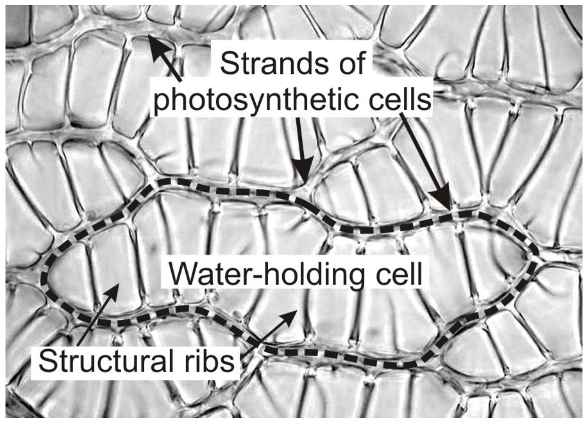
Note: Not everything called a "moss" is a bryophyte; Spanish moss is a flowering plant, Irish moss is a marine Red Alga, Reindeer moss is a lichen, and Club mosses are a primitive vascular plant called a Lycopod.

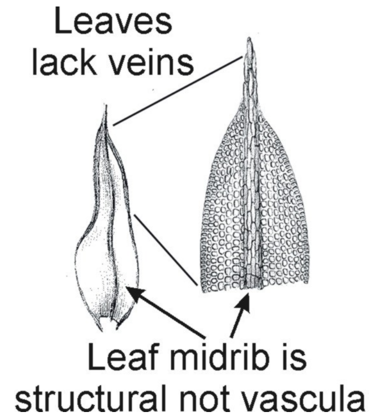


The alternation between the gametophyte stage and the sporophyte stage is shown above.

Mosses lack a vascular system. The leaves contain many photosynthetic cells and a structural midrib. Stems can conduct water only short distances.

Sphagnum moss has small scale-like leaves that are adapted for water retention. Under the microscope one can see large (dead) water holding cells reinforced by ribs. The photosynthetic cells occur in strands extending around these huge cells.

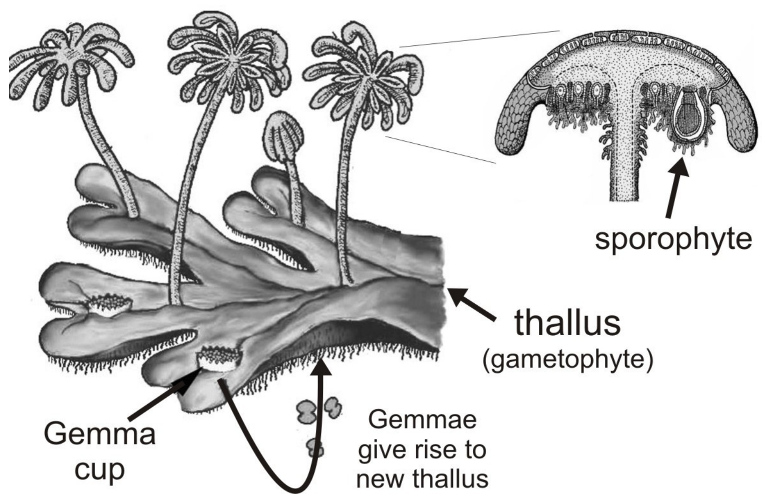




2. Liverworts

There are several groups of liverworts. For one group, the **thallus**-forming liverworts, the gametophyte looks like a flat, branching green ribbon. Gametes are produced beneath the umbrella-shaped structures and the fertilized eggs develop into the sporophytes. The **sporophyte generation** is small and not easily visible -- it occurs only as tiny bag-like structures underneath the little umbrella-shaped structures growing out of the thallus.

"G**emma cups"** produce small clusters of cells called '**gemmae**' capable of asexual reproduction. After being splashed out of their 'cups', the gemmae can develop into another thallus.



B. The seedless vascular plants

The **vascular plants** are believed to have evolved from moss-like plants 300-400 million years ago. They were the first plants to grow to large size and away from open water. These capabilities were made possible by the **presence of a vascular system** which allowed these plants to form the first forests on earth. The vascular system extends from the roots, through the stem and branches, and into the leaves, allowing efficient transport of water and nutrients throughout the plant. While the bryophyte's life cycle has the gametophyte as the dominant stage, **all vascular plants** have the **sporophyte generation** as the **dominant stage.**

This group of plants is distinguished by:

- the presence of a vascular system
- a dominant sporophyte stage
- dispersal through spores

On display are representatives of three Divisions of seedless vascular plants:

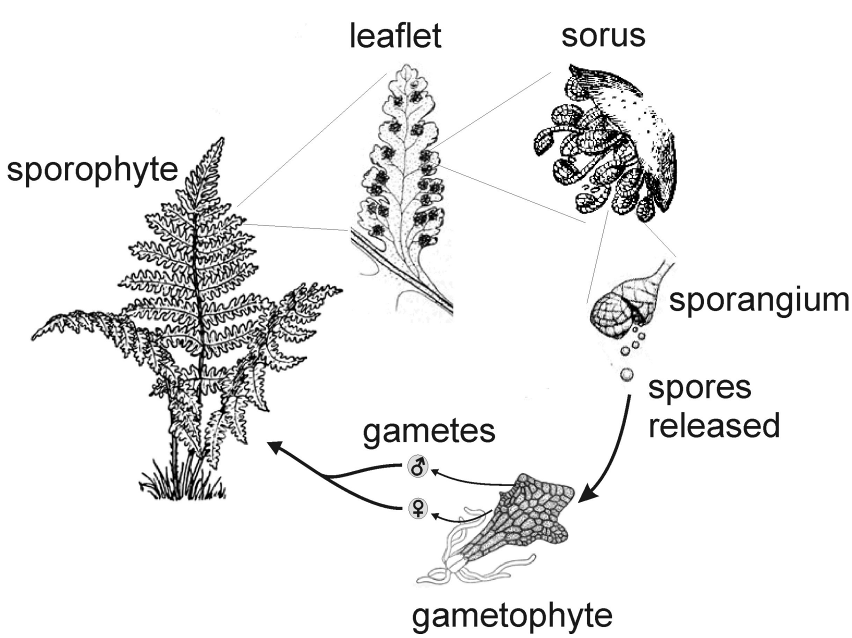
1. Ferns (Division Pterophyta)

Ferns produce leaf-like fronds and spore-producing structures called sori on the bottom side of fronds.

Fern Life Cycle

The fern "**plants**" with which you are familiar are the dominant **sporophyte** stage which, like the small sporophyte of moss, produces <u>spores.</u> Ferns also have a **gametophyte** stage which develops from the germinating spores, but the fern gametophyte is very small, about the size of a child's fingernail.

The fern frond (leaf) may have on its underside some small <u>brownish spots</u> called **sori** (singular: sorus), which consist of clusters of lollipop-shaped **sporangia** that produce **spores**. Each sporangium has thick-walled cells on one side of the sporangium; upon drying, these thick-walled cells contract, causing the sporangium to tear open and then violently fling the spores away from the plant, catapult-style.



2. Lycopods (Division Lycophyta)

-- produce small leaves around the stem

3. Horsetails (Division Sphenophyta) ⟶

-- appear almost like 'naked' stems, with occasional whorls of scale-like leaves.

For both, the spores are typically produced in small cone-like structures at the shoot tips.

The fossil record indicates that these plants were dominant during the Carboniferous period (300 mya) and grew to the size of trees. The partially decomposed bodies of these plants along with tree ferns eventually created the coal deposits that we now use as an energy source. Because of their long evolutionary lineage, the lycopods and horsetails are often called "living fossils."

III. The seed-producing plants: Gymnosperms and Angiosperms

Why have seed-producing plants been so successful?

1) The plant can remain dormant as a seed until conditions favorable to growth occur; this may be the following spring, or for some desert plants, years later.
2) Seed plants also **broke the dependence on external water in reproduction**; the sperm do not swim through external water but rather are within the **pollen grains** that travel through the air.
3) Both pollen and seeds can be dispersed more efficiently than spores, and can withstand harsher conditions. The seed is a rugged package for dispersal; within the tough seed coat is a dormant plant embryo as well as stored food for the embryo to use in resuming growth and getting established.

The gametophyte is reduced to two microscopic structures:

- **a pollen grain** – a tiny male gametophyte containing sperm.
- **a small portion inside an ovule** – a tiny female gametophyte containing an egg cell. After pollination, an ovule develops into a seed.

Gymnosperms (the naked-seed plants): Conifers, Cycads, Ginkgo

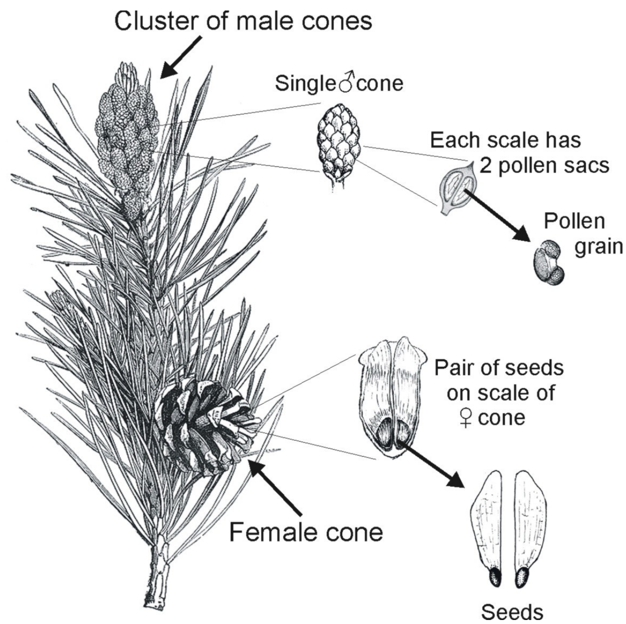
What are the distinguishing characteristics of gymnosperms?

- The **pollen grains and ovules** are produced in cones.
- They produce **seeds**, although the seeds are **not** encased by an outer layer (which is called a fruit in angiosperms). The name gymnosperm means '**naked seed**'.

Some examples of Gymnosperms include:

Conifers (Division Coniferophyta)
Cycads (Division Cycadophyta)
Ginkgoes (Division Ginkgophyta)

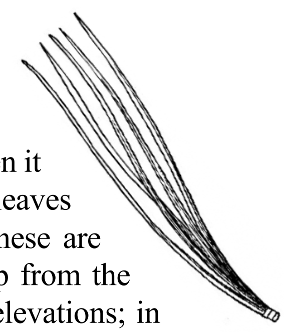
A. Conifers



Conifers produce cones in the spring—male cones and female cones. The small non-woody **male cones** produce **pollen grains**. A pollen grain is a microscopic male gametophyte that contains only 3 cells, one of which is a **sperm**.

The larger **female cones** produce **ovules, each** containing a microscopic female gametophyte containing an **egg;** the ovule will develop into a **seed** after pollination. Maturation of the female cones for some species, such as pines, may require two years.

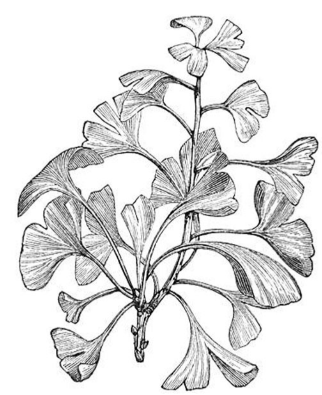
Conifers rely upon wind to disperse the pollen grains and bring them to the female cones, and to carry away the seeds. Conifer seeds are usually **winged** -- having a papery extension of the seed coat to aid in wind dispersal.



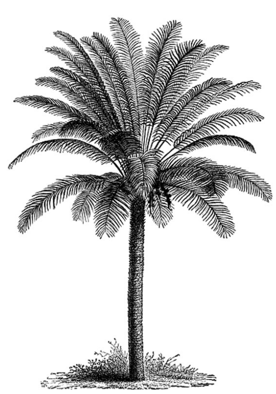
Conifer leaves (needles)

Most conifers are "evergreen" and do not drop their leaves in the winter when it is cold and a lot of the water is tied up in snow and ice. The surface area of conifer leaves is much smaller than that of broadleaf trees and has a thick waxy covering. These are adaptations to surviving cold winters when very little water can be transported up from the ground. They are well adapted to colder northern latitudes and higher mountain elevations; in these habitats, retaining their leaves also helps conifers get a "quick start" and make the most of the short growing season.

B. Ginkgo and Cycad



The **GINKGO** tree is the sole surviving member of an evolutionary line that extends back to the Paleozoic; it also was a dominant tree during the Carboniferous period. Known from fossils, it was thought extinct until western explorers discovered it in the 1800s growing in temple gardens in the mountains of China. The shape of the leaf and the branching pattern of the veins are considered to be primitive traits.



The **CYCADS** are non-flowering seed plants that look like very short-stemmed palms. Some cycads have the common name of "Sago Palm" which is a misnomer; it's not a palm; palms are flowering seed plants; these plants produce 'naked' seeds on a large central cone, a more primitive trait.

Angiosperms (the flowering plants)

What are the distinguishing characteristics of angiosperms?

- The **pollen grains and ovules** are produced in **flowers**.
- They produce **seeds** that are encased by an outer layer called a **fruit**.

Through their color, smell and edible nectar, flowers attract insects and animals that unwittingly carry pollen between flowers to achieve pollination; this is much more efficient than merely releasing pollen into the wind. Likewise, fruits may also help recruit animals, this time to help disperse the seeds.

Reproduction in flowering plants will be examined in more detail in a separate lab exercise.