Lecture 7 Seedless non-vascular and vascular plants

<u>Key terms:</u>
Tracheids
Liverworts
Mosses
Vascular
Cuticle
Gametangia
Embryo
Sporopollenin
Matrotrophic
Antherium
Archegonium
Oogonium
Xylem
Pits
Pholem
Ferns
Sori
Strobili
Gymnosperms
Angiosperms
Lycophytes
Rhyniophytes
Overtopping growth
Dichotomous branching
Microphyll
Megaphyll
Heterospory
Homospory
Megasporangia
Microsporangia
Byrophytes
Apical meristems
Thallus
Stomata
Protonema
Buds
Apical cell division
Lignin
Rhizoids
Rhizomes

Early ancestors
The early ancestors of land plants are the green algae. The green algae have a number of key characteristics that the land plants have. They are

a) chlorophyll a, b
b) cellulose wall
c) haploid dominant life cycle
d) store excess carbohydrates as starch

These are the basic green algae. There are also advanced green algae that have the following characteristics:

a) possess unicellular sexual reproductive organs called **antheridium** and **oogonium** (these are what's called gametangia, "gamete cases")
b) Possess some primitive form of embryo by having something called **matrotrophic** feeding, which simply means taking nutrients from your parent.
c) These advanced green algae are haplonic, which means that they do not possess sporophytes. Therefore, they simply have a diploid zygote that undergoes meiosis to produce haploid spores. This is what the professor means by "reduced sporophytes".

It turns out that the advanced green algae, with all the characteristics listed above, is the ancestor of land plants.

Adaptations for living on land
There are also a number of differences between the land plants and their closest green algae relatives. Here are the key differences:

1) **Apical meristems**
   Plants needs water, light, minerals and carbon dioxide. They obtain light and carbon dioxide above ground, water and minerals underground. Therefore, it is advantageous to have your roots (stem underground) and shoots (stem aboveground) elongated and branched. This is where apical meristems comes in. They are localized regions of cell division at tips of shoots and roots that allow plants to grow longer and deeper.
2) **Embyro**
   This is perhaps the most crucial difference that separate the protists from the plants. Normally, in algae, the zygote is formed between the fusion of the sperm and egg. The zygote once formed, do not start developing until it is away from the parent. This all changes with plants. In plants, the zygote stays in the archegonium and develops into a young plant inside the archegonium through repeated mitosis. This young plant is called the embryo. This is the reason all land plants are known as **embyrophytes**.
3) Multicellular gametangia
   In the protist alga, all the gametangia are unicellular. With plants, you have multicellular gametangia. For example, in the archegonium, you now have a layer of cells called the sterile jacket that surrounds the sperm

making cells. This is something that is not present in oogonium, the unicellular version of the female gametangia.

4) Walled spores
   Well, now that are you on land, you need some tough spores to resist the environment. This is where **sporopollenin** comes in. It is the most durable organic material known and it protect the spores. In algae, you have zoospores (spores with flagella, not present in plants) and no such spore walls.
5) Alternation of generations.
   Alternation of generations is defined as having multicellular structures in both the diploid and haploid stage of the life cycle. In the protist algae, some have this alternation of generations while others have a diplonic or haplonic life cycles (no alternation of generations). In plants, all have alternation of generations. However, some plants have a more gametophyte dominant stage (non seed non vascular plants) while others have a more sporophyte dominant stage (all other plants). Also note that in some algae (like the sea lettuce) you have isomorphic. (Gametophyte and Sporophyte looks the same) This does not occur in plants. Yes, that's right. Isomorphism does not occur in plants.
6) **Cuticle**
   Cuticle is a waxy coating that helps plants to minimize water loss. This is not required in the aquatic environment that algae lives but it is very necessary in the terrestrial environment that land plants live. Along with cuticle comes **stomata.** Cuticle does not let in carbon dioxide in nor water out. Thus, you are going need pores that can open and close to let in carbon dioxide and let out water. This is essentially what stomata is: a pore that can open and close.

Land Invasion

This most likely happened when some freshwater algae living in ponds that dried out periodically evolved the ability to survive the dry seasons so as to take advantage of the photosynthesis and etc. Overtime, these algae were evolutionally advanced enough to survive on lands.

There are a number of environmental factors that these early ancestors had to take into account.

1) Drying out, perhaps the biggest threat. This is why cuticle are developed
2) Fertilization- evolutionally took the longest time to solve. It wasn't until the seed plants that water is finally not required for fertilization.
3) Gravity – water counter balanced some of the gravity's affect. Now, plants have to take care of gravity in order to grow tall. This is where lignin comes into play.
4) UV radiation-change of color of sunlight. Water absorbed some of wavelengths of light and provided some shielding affect. Now, plants take care of themselves by adapting specialized pigments.

Land plant division:
Land plants are divided into four groups:

1) **Bryophytes** (moss like plants, seedless, non vascular)
2) Pteridophytes (fern like plants, seedless, vascular)
3) Gymnosperms (conifers, seed, vascular)
4) Angiosperms (flowers, seed enclosed within fruit, vascular)

The emergence of these groups are marked by four important events in the evolution:

1) Origin of bryophytes from algal ancestors
2) Origin of vascular systems
3) Origin of seeds
4) Evolution of flowers

Byrophytes:
These seedless non vascular plants are short because they lack an efficient system of conducting water and mineral. Water goes through by capillary action and minerals are transported by diffusion. This is a very inefficient system but it worked for the bryophytes.

The key feature of bryophytes is the gametophyte generation dominant life cycle. The sporophytes of the bryophytes are dependent on the gametophyte for nutrients and cannot grow independently by themselves. The sporophyte is also much smaller and less noticeable. What we usually see as bryophytes really are the gametophyte structures.

The diploid zygote is formed when the flagellated sperms from the anteridium enters the archegonium with the aid of water and fuse with the egg. The zygote stays in the archegonium system and forms an embryo. The embryo matures and grow into a sporophyte that has its roots firmly attached to the gametophyte. Then the sporophyte develops sporoangium → meiosis → release spores. The sporophyte is attached to the gametophyte and absorb water and nutrients from it for its entire life duration. In this way, the sporophyte can be thought of as a parasite.

There are three groups within the bryophytes: liverworts, hornworts and mosses. We will only discuss the liverworts and the mosses here.

Liverworts
Liverworts commonly have a **thallus** structure. Thallus is a flattened, lobed structure not differentiated into leaves, stems and roots. It is really just a green photosynthetic plate. You have very short sporophytes at the top and **rhizoids** at the bottom that anchors the plant to the soil. Now, rhizoids are not the same as roots. Rhizoids are unicellular filaments that root non vascular plants to the ground. They do play a primary role in water and mineral absorption since they lack specialized conducting tissues.

Liverworts lack stomata that hornworts and mosses have. Of the features unique to land plants, liverworts have the cuticle, the multicellular reproductive organ, embryo, alternation of generations and walled spores.

Liverworts are able to reproduce asexually by forming tiny balls of tissues called gemma, that are borne on saucer shaped structures called gemma cups. When raindrops fall in or animals passes by, these gemma structures are transported and form into new liverworts.

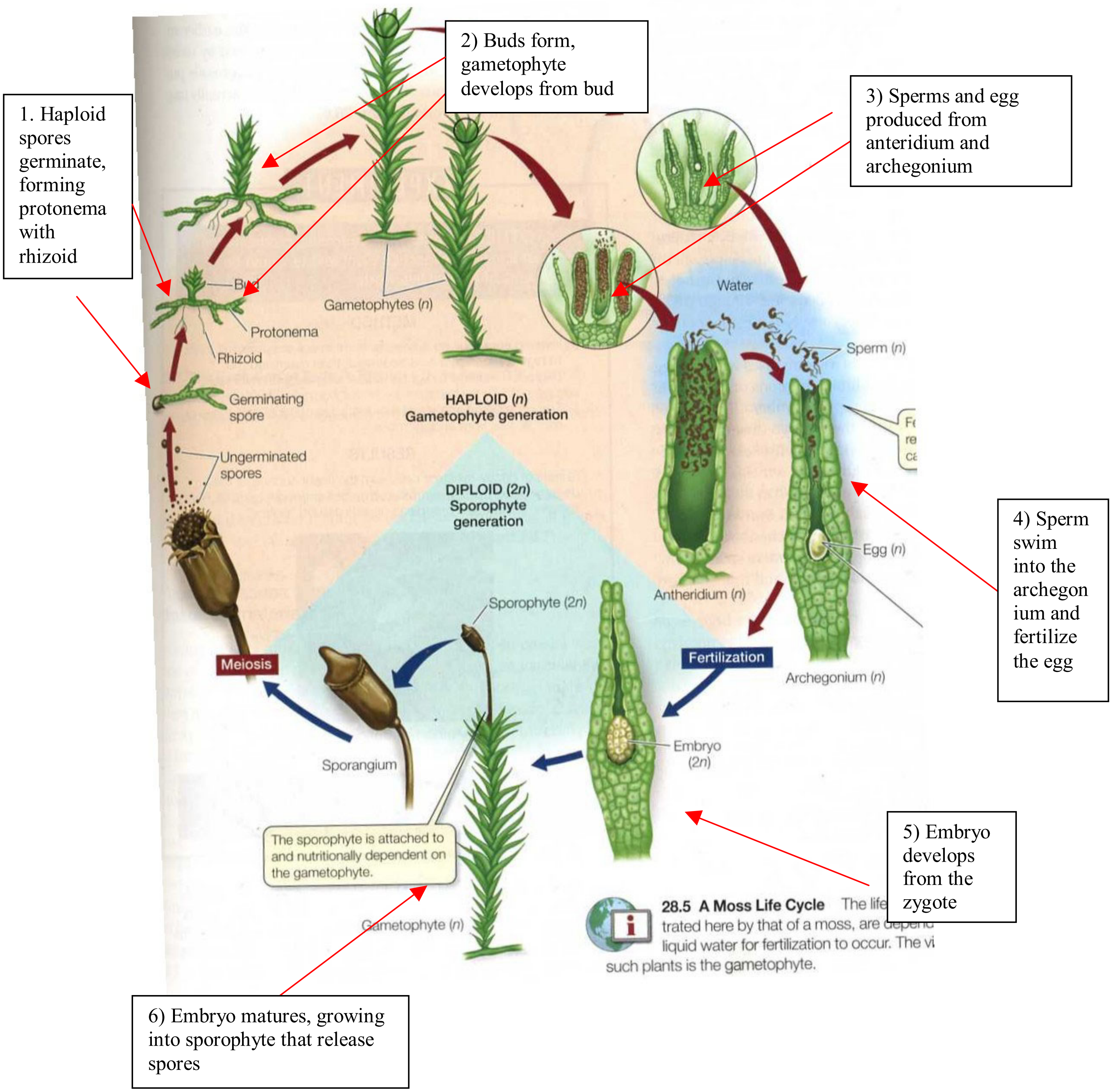
Mosses

There are a couple of key differences between liverworts and mosses. The first one is the presence of a complex sporophyte. Like the liverworts, the sporophytes of the mosses absorb nutrients from the gametophyte by using an absorptive foot anchored to the gametophyte. A stalk and a swollen sporangium forms the rest of the sporophyte. When the embryo matures, it breaks apart the tip of gametophyte and emerges. Now, this tip becomes the lid that covers the sporangium. Please note that this lid is not part of the sporophyte. It is part of the gametophyte. The lid is called the **operculum** and it “closes” the sporoangium until enough spores have been produced. Then the lid came off and spores are released. This is a far more complex spore dispersal method. The mosses can also control when the spores are released. This ensures that spores are only released when winds come so that the spores travel far away from the parent plant.

Mosses also have stomata. Some mosses have separate sexes in that there are gametophytes that only bear the anteridium and other ones that only bear the archegonium. However, this is not heterosporous (discussed later) since the all the spores came from a single sporoangium.

Mosses also share a derived trait with plants. They all grow by apical cell division. This allows a sturdy vertical growth that is only halted by the lack of lignin for structural support. Therefore, some mosses developed a better system of carrying water and minerals. There is a cell called hydrid that dies and becomes a channel for water to travel. However, this channel lacks the lignin and cell wall structure find in the tracheids and thus cannot be classified as a vascular system.

Lets study the life cycle of mosses.



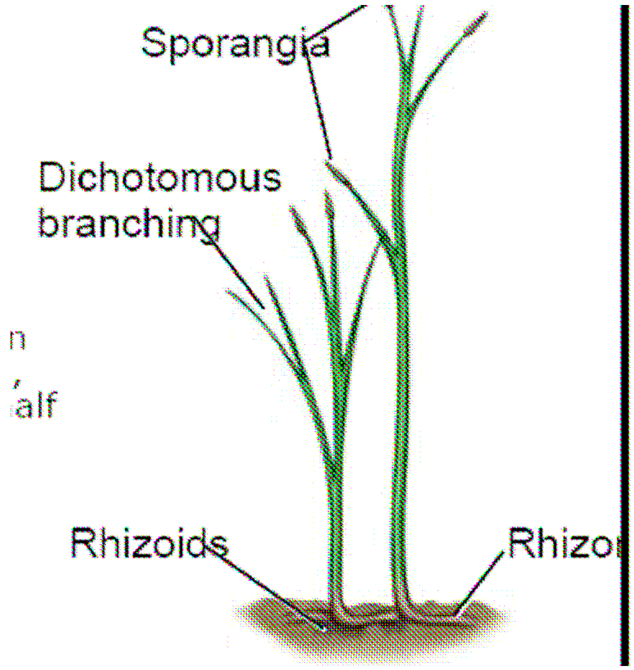
As you can see, the life cycle is fairly straightforward once you understand how non vascular land plants commonly reproduce.

Development towards vascular plants
What we talked above are non vascular plants, not lets take a look at the vascular plants. First though, how did plants evolve from non vascular to vascular?

The earliest vascular plant lacked leaves or roots. It was called **rhyniophytes** and was made up of mostly true stems. The stem was true in the sense that it had **xylem** and **phloem** but it did not have true tracheids.

The xylem is a channel for the transportation of water and minerals in the plant. It is made up of **tracheids,** a specialized kind of cell that elongates and then died. Once it died, the cytoplasm and nucleus disintegrated and you have a cell with en empty middle, like a tube. There are pits on the surface of the tracheids that allows water and minerals to be transported across the thacheids. Later on, lignin was added to the tracheids for structural support.

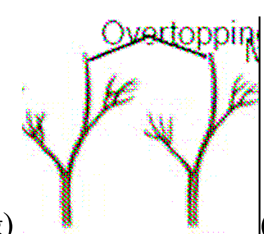
Horizontal portions of the stem, called **rhizomes**, anchored this plant to the soil. Unicellular filaments called **rhizoids** extended from the rhizomes. They can be think of as “root hairs”. These rhizoids are not the same as the ones in the non vascular plants. The stem had the top also branched in a **dichotomous** pattern. This means that the tip divided to produce two equivalent new branches, each diverge at the same angle from the original stem. Some of the aerial stems ended with a sporgania at the top.



Then the lycophytes or club mosses came along. These plants have what's called true roots and true leaves. (True because these are developed on plants with xylem and phloem) The true roots are developed from stems like the rhizomes that remained underground. Overtime, they were subjected to different selection pressures and developed into the multicellular structure that we recognize.

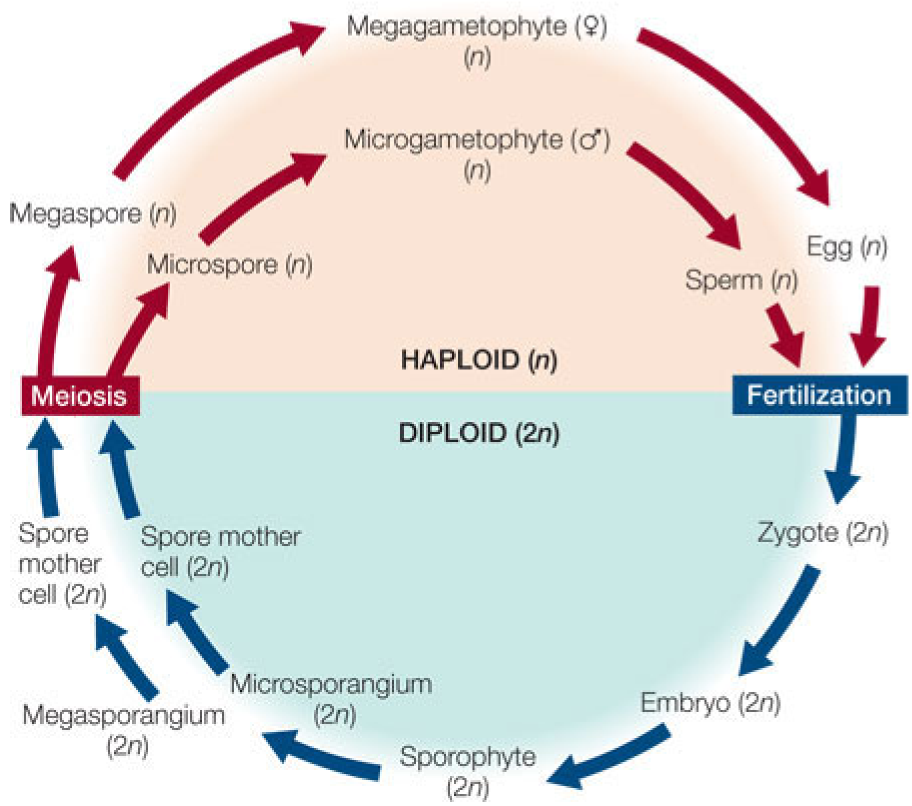
The lycophytes, however, still divided in a dichotomous manner. The first true leave could have come from sterile sporangia on the ancestors of lycophytes. This would form what's called the **microphyll** leaves. This kind of leaf is unique in that it came from a single, unbranched vascular strand. The vascular strand departed from the vascular system in such a way that the vascular system is not disturbed.

It takes the arrival of ferns and allies and the overtopping growth they had to develop another kind of leaves, the **megaphylls. Overtopping growth** is a kind of branching where one branch branches off and grow beyond the others. This is more advantageous than the dichotomous branching because it allowed the branches to better compete for light.


(Dichotomous branching)

(overtopping growth)

This overtopping growth lead to the flattening of some of the dichotomous branches. Flat photosynthetic plates developed between the branches and this formed the **megaphyll** leaves. The megaphylls are typically larger than the microphyll leaves due to the branched vascular system it contains. Megaphylls usually have better photosynthetic productivity than microphylls due to the extensive amount sugar it can produce thanks to the large photosynthetic area and the extensive branched vascular that can carry water/minerals in and sugar out.

The other key innovation that some vascular plants have is heterospory. Early vascular plants and plants before them has **homospory**, where the sporophyte produced one kind of spores that geminate into one kind of gametophyte that carried both the anteridium and the archegonium. With **heterospory,** the sporophyte produced two kinds of sporangia. The microsporangia and the megasporangia. Each of them produce a type of spores. One kind of spore, the **megaspore** (from the megasporangia), developed into female gametophytes that carry only the archegonium. The other kind of spore, the **microspore**, developed into male gametophytes that carry only the anteridium. Only some of the advanced non seed vascular plants have heterospory. Most non seed vascular plants only have homospory. All seed vascular plants are heterospory and this is one of the defining characteristics that distinguish them from the non seed vascular plants.



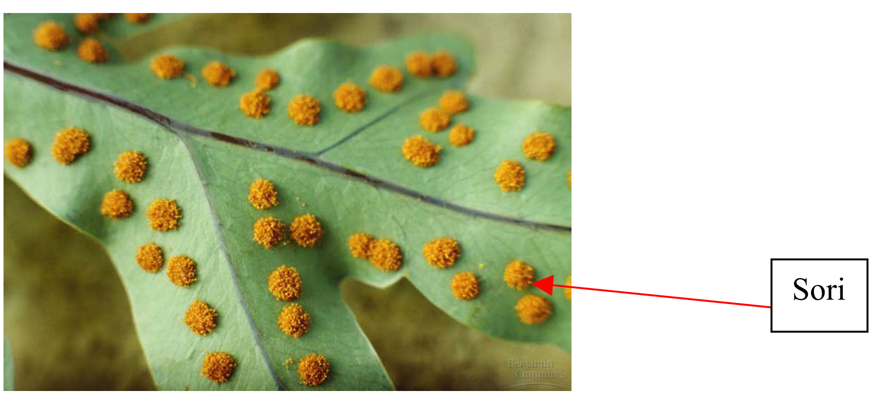
In terms of the life cycle, the vascular plants are very different. Non vascular plants are gametophyte dominant. Sporophyte depends entirely on the the gametophyte for surivial. In vascular plants, the sporophyte is more dominant and is independent of the gametophyte. Embryo still forms in the gametophyte by mitosis of the zygote but becomes separate from the gametophyte soon after. The gametophyte is short lived and very short in length.

Non seed vascular plant groups
There are a number of non seed vascular plant groups. We will take a look at the lycophytes, ferns and horsetails.

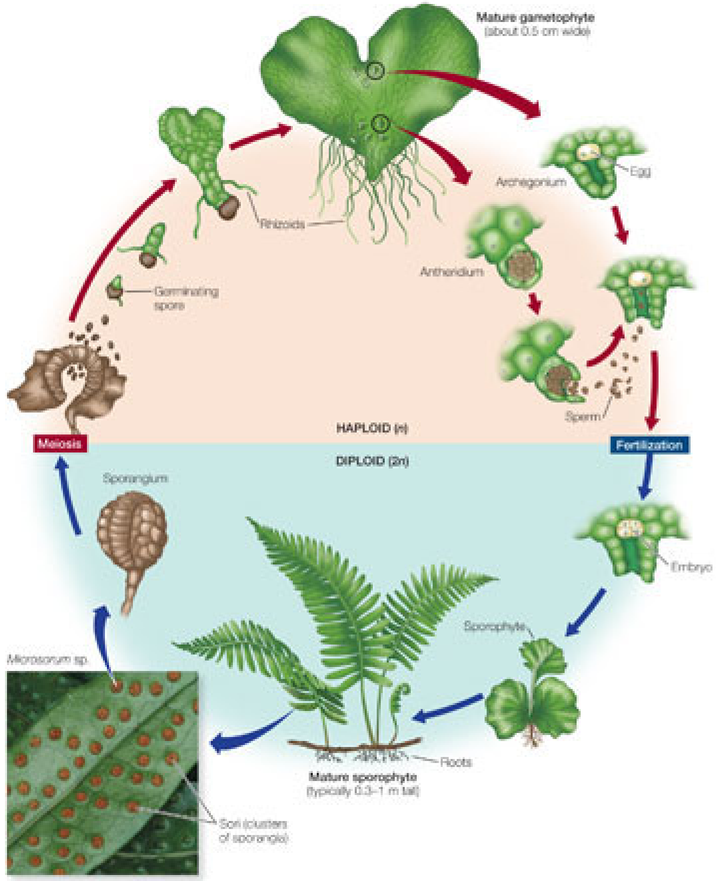
Lycophytes or club mosses, as we mentioned above, have microphyll leaves. They also have branches that branched dichotomously. The reproduction of lycophytes is rather unique. There are special leaves called the sporophylls that bear sporangia. These leaves aggregate together to form a club like cone shape structure called **strobili.**

Some advanced species of lycophytes are heterosporous.

Ferns have large megaphylls with branching vascular strands. Sometimes the leaf can be compound –divided into many leaflets. The reproductive structure of ferns is the **sori.** The sori is a cluster of sporangia that can be find on the underside of leaves. This cluster is covered by what’s called an **indusium**, an umbrella shaped protective cover. Some groups of ferns also have developed heterospory.



Here is the fern life cycle, where is also very straightforward if we keep in mind that the sporophyte no longer grows in the gametophyte.



Horsetails are basically ferns with reduced megaphylls that form circles around the stem at each node. It features a segmented stem growth with the "base" of each segment as the disc of dividing cells just above each whorl of leaves. It also have the sporoangia enclosed in cones, which is different from the ferns. Horsetails also feature silicon in their cell walls, which make them rough and good for cleaning pots.

(segemented stem) (cone like strobilis)

The lycophytes, ferns, and horsetails were once very tall tree structures and formed the majority of the coal forest. These forests no longer exists today.

All of them also require water to reproduce since the sperms need water to enter the archegonium.