Figure 29.1 Some highlights of plant evolution

Figure 29.2 Chara

Figure 29.3 Land plant trait #1: Apical meristems, which are localized regions of cell division at the tips of shoots (left) and roots (right)

Traits shared by charophyceans and land plants

• Very similar plastids (structurally similar, but especially similar chloroplast DNA)
• Very similar cellulose cell walls (cellulose is even produced by a similar rose-shaped structures)
• Anti-photorespiration enzymes packaged in peroxisomes
• Similar structure of flagellated sperm
• Similar structures during cell division (phragmoplasts)

The first land plants: bryophytes ("non-vascular" plants)

1. Traits shared by land plants, and lacking in the charophyceans
2. The earliest land plants: bryophytes (mosses, liverworts, hornworts)
Figure 29.4  Land plant trait #2: Multicellular, dependent embryos, which develop from zygotes contained within tissues of the female parent. Parental tissues provide nutrients for the embryo. Land plants are also known as the embryophytes.

Figure 29.6  Land plant trait #3: Alternation of generations life cycle, with two very different generations (one usually much larger & more prominent). Some algae also have alternation of generations, but not the charophyceans.

Figure 29.5  Sporangium of a moss (a bryophyte) sporophyte

Figure 29.6  Land plant trait #4: Walled spores produced by a multicellular sporangium. A polymer called sporopollenin, the most durable organic material known, makes up the walls.

Figure 29.9  Land plant trait #5: Gametangia, multicellular organs that produce gametes. Note: the most modern land plants, the flowering plants, do not have gametangia.

Archegonia and antheridia of Marchantia (a liverwort)
Land plant trait #6: Specialized epidermism for water conservation, including a cuticle and stomata. Cuticle of a stem from *Psilotum* (a pteridophyte) is shown below.

Figure 36.14 Guard Cells regulate water loss through opening and closing of stomata.

Land plant trait #7: Adaptations for water transport, especially vascular tissue. Found in all land plants except for most bryophytes. The stem of *Polypodium*, a fern (a pteridophyte), is shown below. Note: true leaves, stems, and roots are defined by the presence of vascular tissues.

Land plant trait #8: Secondary compounds: a diversity of chemicals with many functions related to living on land, including protection from UV radiation, signaling with symbiotic bacteria, deterring attack by pathogens or herbivores, and providing structural support. Quinine, a secondary compound produced by plants, is used by humans to help prevent malaria.

Derived traits of land plants

- Apical meristems
  - Plants “move” by growing

- Multicellular, dependent embryos
  - thus “Embryophytes”

- Alternation of generations
  - Heteromorphic
Derived traits of land plants

- Walled spores produced by multicellular sporangia
- Multicellular gametangia producing gametes
  - Except in flowering plants (still have gametes)
- Spore vs. Gamete
  - Spores grow directly into multicellular bodies
  - Gametes need to undergo fertilization first

Derived traits of land plants

- Epidermis for water conservation
  - Cuticle, stomata
- Vascular tissues (except bryophytes)
  - True vascular tissues have lignin
  - True roots, stems, and leaves have vascular tissue
- Secondary compounds
  - Protection, signaling, defense, support

The first land plants: bryophytes ("non-vascular" plants)

1. Traits shared by land plants, and lacking in the charophyceans
2. The earliest land plants: bryophytes (mosses, liverworts, hornworts)

Traits of bryophytes

- Most lack true vascular tissue, which places limits on their thickness and height.
- In their alternation of generations life cycle, the gametophyte is the larger, conspicuous stage. The sporophyte is smaller, and when it grows, it is dependent on the gametophyte for nutrients. Liverworts have especially small sporophytes.
- Many mosses can live in extremely dry or cold habitats, because they can almost completely dry out without dying.
Key features of bryophyte life cycle

- Gametophyte is dominant generation
- Sporophyte is smaller, dependent on gametophyte (but still multicellular)
- Fertilization is dependent on free water carrying sperm from antheridia to archegonia

Ecology of bryophytes

- All are photoautotrophs, primary producers
- Mostly live in moist habitats, although some mosses live in very cold and/or dry environments
- All need free water for fertilization, and this ultimately restricts their distribution
Figure 29.19. A peat moss bog in Norway. This landscape is probably similar to much of earth during the first 100 million years after land plants evolved: the only plants were short bryophytes. Why are bryophytes short?

Peat (Sphagnum) bogs...

- Cover nearly 1% of the Earth’s land surface
- Dead peat resists decomposition, thus peat bogs store tremendous amounts of carbon (400 billion tons worldwide)
- Structure of peat moss is highly absorbent, making it useful to people
  - Fuel
  - Soil Conditioner

Figure 29.18 Sphagnum, or peat moss: Harvesting for human use

Seedless Vascular Plants

1. Traits and adaptations of the first vascular plants: Pteridophytes
2. Two phyla of seedless vascular plants: Lycophyta (lycophytes) and Pterophyta (ferns & their relatives)
3. Overview of evolutionary transition to seed plants

Figure 29.7 Land plant evolution.

Figure 29.21 Lycophyte (club mosses)
Traits and adaptations of the first vascular plants

1. True lignified vascular tissue system (xylem and phloem), and thus true leaves, stems, and roots in most taxa
2. Dominant sporophyte generation that is branched and becomes independent of the parental gametophyte
3. No seeds
4. Traits 1 & 2 are shared by the other two groups of vascular plants: gymnosperms and angiosperms
5. Many adaptations to land inherited from bryophyte-like ancestor (meristems, embryos, alt. of gen. life cycle, walled resistant spores, gametangia, specialized epidermis, secondary compounds)—see previous lecture
Note: some plants are homosporous and some are heterosporous.

Homosporous

Sporophyte — Single type of spore

Bisexual gametophyte (with both kinds of gametangia)

Eggs & sperm

Heterosporous

Sporophyte

Microspore

Male gametophyte

Sperm

Megaspore

Female gametophyte

Eggs

The heterosporous life cycle was important in the evolution of the seed, which we’ll discuss next week.

Seedless Vascular Plants

1. Traits and adaptations of the first vascular plants: Pteridophytes

2. Two phyla of seedless vascular plants: Lycophyta (lycophytes) and Pterophyta (ferns & their relatives)

3. Overview of evolutionary transition to seed plants

Figure 29.7 Land plant evolution.

Figure 29.21 Pteridophytes (seedless vascular plants): Lycopodium (a club “moss”, top left), Psilotum (a whisk fern, top right), Equisetum (a horsetail, bottom left), fern (bottom right). The latter three represent phylum Pterophyta, and Lycopodium represents phylum Lycophyta. Another genus in Lycophyta, which we will see in lab, is Selaginella.

Figure 29.14 Lycopodium (a club “moss”) in the phylum Lycophyta.

Many grow on tropical trees as epiphytes

Others grow on temperate forest floors

Tiny gametophytes, sometimes underground

Upright stems with many small leaves (microphylls)
**Selaginella** (a spike “moss”) in the phylum Lycophyta.

Small, low to the ground
Grow horizontally

**Isoetes** (a quillwort) in the phylum Lycophyta.

Represented today by a single genus
Live in marshy areas

**Equisetum** (horsetail) in the phylum Pterophyta.

Often have separate vegetative and fertile stems
“Jointed plants” with rings of small leaves or branches at each joint
Bulk of photosynthesis in stem
Air canals carry oxygen to roots, which are often in waterlogged Soil
Homosporous

Modern *Equisetum* essentially identical to *Equisetites* from 300 mya.

*Equisetum* may be the oldest surviving genus of plants on Earth.
calamites were horsetails that grew into trees up to 18m tall and 45 cm thick during the Devonian (~300 mya)

**Psilotum** (whisk fern) in the phylum Pterophyta.

Dichtomously branching stems, no roots (like first vascular plants)
Stems have small scale-like outgrowths without vascular tissue - unclear if they predate leaves or are reduced leaves
Figure 29.14 Polypodium (a fern) in the phylum Pterophyta.

- Note megaphylls - fronds
- Most are homosporous
- Gametophytes shrivel and die
- Can produce LOTS of airborne spores

Figure 29.12 The life cycle of a fern: note the dominant diploid (sporophyte) generation, and the reduced gametophyte.
Among the seedless plants:

- Mostly homosporous
- Spike mosses and quillworts (both Lycophytes) are heterosporous
- But, heterospory appears to have evolved independently in first seed plants (i.e., analogous), since seed plants appear more related to Pterophytes than Lycophytes

Seedless Vascular Plants

1. Traits and adaptations of the first vascular plants: Pteridophytes
2. Two phyla of seedless vascular plants: Lycophyta (lycophytes) and Pterophyta (ferns & their relatives)
3. Overview of evolutionary transition to seed plants

Advantages of the Seed

- Multicellular embryo gets a “head start” at the germination stage
- Stored food for embryo also allows a head start, and allows for extended dormancy
- Multicellular, larger and more complex than a spore = more resistant to harsh conditions
- Larger and more complex = increased capacity to develop dispersal adaptations
Disadvantage of the Seed

- More energetically costly to produce
- To some extent, trade off quantity for quality

Remember: Alternation of generations is thought to have evolved via delayed meiosis. What might be the advantage of this more complex life cycle, for living on land?

Multicellular sporophyte = more than 4 spores produced by meiosis.

Charophycean body (n)
Zygote (2n) (retained by parent in primitive archegonium)
Meiosis delayed
Zygotic mitosis produces multicellular sporophyte
Sporophyte (2n)
Gametophyte (n)

Remember, algal sperm are flagellated, swim to eggs. This requires water. Harder to do on land.