Chapter 29: Plant Diversity I – How Plants Colonized Land

1. Evolutionary History of Plants
2. General Features of Plants
3. Survey of the Plant Kingdom
   A. Nonvascular Plants
   B. Seedless Vascular Plants
1. Evolutionary History of Plants
The “Greening” of Earth

The fossil record indicates that photosynthetic organisms similar to cyanobacteria were present over 3 billion years ago.

Based on geologic evidence, $O_2$ accumulation in the atmosphere due to oxygenic photosynthesis began at least 2.4 billion years ago.

Evidence for the first photosynthetic bacteria and protists on land dates to ~1.2 billion years ago.

The first evidence of land plants dates to ~470 million years ago.
The First Land Plants

Based on the fossil record and molecular data, land plants are thought to have evolved from green algae.

- the closest living relatives of land plants are the charophytes which share the following characteristics with plants:
  
  1. Rings of cellulose-synthesizing proteins
  2. Similar structures in flagellated sperm
  3. **Sporopollenin** to protect from drying out
  4. Formation of a **phragmoplast** during cytokinesis
The earliest fossils of vascular plants date to ~425 million years ago.

- these first vascular plants had independent branching sporophytes
- the vascular tissue provided these plants additional support and allowed the distribution of nutrients throughout the plant
Evolutionary History of Plants

Land plants are a subgroup within the supergroup Archaeplastida that are also referred to as embryophytes – plants with embryos.
Land plants include a variety of phyla with nonvascular plants giving rise to seedless vascular plants and ultimately the seed plants:
2. General Characteristics of Plants
Five key traits appear in nearly all land plants that are not seen in the charophytes:

1. “Alternation of Generations” life cycle
2. Multicellular, dependent embryos
3. Walled spores produced in sporangia
4. Multicellular gametangia
5. Apical meristems
Haploid spores divide by mitosis to produce a multicellular haploid gametophyte from which some cells differentiate into haploid gametes.

Fertilization produces a diploid zygote that develops into a multicellular diploid sporophyte which produces haploid spores by meiosis.
Multicellular, Dependent Embryos

Zygotes develop into multicellular diploid embryos located within and dependent upon the gametophyte.
Sporophytes contain organs called *sporangia* within which diploid *sporocytes* undergo meiosis to produce haploid spores.

The haploid spore walls contain *sporopollenin* to protect the spores from harsh, dry environments.
Multicellular Gametangia

Gametes differentiate within multicellular gametangia within the gametophyte.

- Female gametangia are called archegonia and produce eggs.
- Male gametangia are called antheridia and produce sperm.
Apical meristems are tissues at the tips of roots and shoots that contain **undifferentiated** stem cells. Stem cells divide by mitosis to give rise to new more differentiated cells as part of the growth process.
Additional Derived Characteristics of Plants

In addition to the key five key characteristics of land plants, many plants also have:

- a waxy cuticle covering their epidermal tissues
- microscopic openings called stomata on their leaves
- mycorrhizae, a mutualistic symbiosis between beneficial fungi and the roots of the plant
2A. Survey of the Plant Kingdom: Nonvascular Plants

- Nonvascular plants (bryophytes)
- Seedless vascular plants
- Gymnosperms
- Angiosperms
Features of Nonvascular Plants

Nonvascular plants, commonly called “bryophytes”, lack a vascular system to transport material and provide structural support throughout the plant and thus have the following features:

- relatively small and thin so that no cells are far from the plant surface where water and nutrients are obtained
- require moisture to avoid drying out and to allow flagellated sperm to reach an egg
- gametophyte is much more prominent than the sporophyte

The 3 phyla of vascular plants are the:

BRYOPHYTA  HEPATOPHYTA  ANTHOCEROPHYTA
Phylum Bryophyta – “Mosses”

- the gametophyte comprises the majority of a moss

- the sporophyte is not always visible and is much smaller

- rhizoids anchor the gametophyte to its substrate

*Polytrichum commune*, hairy-cap moss
Life Cycle of a Moss

Key
- Haploid (n)
- Diploid (2n)

Protonemata (n)

“Bud”

Male gametophyte (n)

Antheridia

Sperm

Female gametophyte (n)

“Bud”

Egg

Archeronia

Sperangium

Spore dispersal

Gametophore

Peristome

Spores

Sporangium

Seta

Capsule (sporangium)

Foot

Mature sporophytes

Capsule with peristome (LM)

MEIOSIS

2 mm

FERTILIZATION (within archegonium)

Young sporophyte (2n)

Zygote (2n)

Embryo

Archeronium

Foot

Capsule with peristome (LM)
The Ecological Importance of Mosses

Results

- mosses help retain nitrogen compounds in soil
- mosses follow lichens in the process of ecological succession
Phylum Hepatophyta – “Liverworts”

Marchantia polymorpha, a “thalloid” liverwort

Marchantia sporophyte (LM)

Thallus

Gametophore of female gametophyte

Sporophyte

Foot

Seta

Capsule (sporangium)

Plagiochila deltoidea, a “leafy” liverwort

Marchantia sporophyte (LM)
Phylum Anthocerophyta – “Hornworts”

An *Anthoceros* hornwort species
2B. Survey of the Plant Kingdom: Seedless Vascular Plants

Nonvascular plants (bryophytes)
Seedless vascular plants
Gymnosperms
Angiosperms
Features of Vascular Plants

The vascular system of vascular plants consists of:

**XYLEM** – transports water and minerals from root system

**PHLOEM** – transports photosynthetic products (sugars) from leaves and stems

In addition to providing the means to transport materials internally, a vascular system also provides structural support. For both these reasons, vascular plants can be much larger than nonvascular plants.

The sporophyte is much more prominent than the gametophyte.
The Evolution of Leaves & Roots

Leaves are organs in vascular plants that increase the surface area for photosynthesis.

- the simplest, most primitive leaves a single vein and are called **microphylls**
- leaves with branched vascular tissue are called **megaphylls**
Sporophylls & Spore Generation

Sporophylls are modified leaves with sporangia:

- **sori** are clusters of sporangia on the underside of sporophylls
- **strobili** are cone-like structures formed from clusters of sporophylls
Variation in Spore Generation

**Homosporous spore production**

Sporangium on sporophyll → Single type of spore → Typically a bisexual gametophyte

- **Eggs**
- **Sperm**

**Heterosporous spore production**

- **Megasporangium** on megasporophyll → **Megaspore** → Female gametophyte → **Eggs**

- **Microsporangium** on microsporophyll → **Microspore** → Male gametophyte → **Sperm**
2 Phyla of Seedless Vascular Plants

**LYCOPHYTA**

- spike mosses, club mosses and quillworts
- all of these are vascular and thus are not true mosses or other bryophytes

**MONILOPHYTA**

- ferns and horsetails
Phylum Lycophyta – “Spike Mosses, Club Mosses & Quillworts”

*Selaginella moellendorffii*, a spike moss

*Isoetes gunnii*, a quillwort

*Strobili* (clusters of sporophylls)

*Diphasiastrum tristachyum*, a club moss
Phylum Monilophyta – “Ferns & Horsetails”

Athyrium filix-femina, lady fern

Equisetum telmateia, giant horsetail

Psilotum nudum, a whisk fern
The Life Cycle of a Fern

**Key**
- Haploid (n)
- Diploid (2n)

**MEIOSIS**

1. **Sporangium**
2. **Sporangium**
3. **Sorus**
4. **Sporangium**
5. **Mature sporophyte (2n)**
6. **New sporophyte**
7. **Zygote (2n)**
8. **Fiddlehead (young leaf)**

**FERTILIZATION**

- **Antheridium**
- **Sperm**
- **Archeogonium**
- **Egg**

**Spore dispersal**
- **Spore (n)**
- **Young gametophyte**
- **Rhizoid**
- **Underside of mature gametophyte (n)**
- **Archegonium**
- **Egg**

**Gametophyte**
- **New sporophyte**
- **Zygote (2n)**
- **Gametophyte**

**Mature sporophyte (2n)**

- **Rhizoid**
- **Underside of mature gametophyte (n)**
- **Archegonium**
- **Egg**

**Spores**

- **Young gametophyte**
- **Rhizoid**
- **Underside of mature gametophyte (n)**
- **Archegonium**
- **Egg**

**FERTILIZATION**

- **Sporangium**
- **Sporangium**
- **Sorus**
- **Sporangium**
- **Mature sporophyte (2n)**
- **New sporophyte**
- **Zygote (2n)**
- **Fiddlehead (young leaf)**