Objectives

- Describe four shared characteristics and four distinct characteristics between charophytes and land plants
- Distinguish between the phylum Bryophyta and bryophytes
- Diagram and label the life cycle of a bryophyte
- Explain why most bryophytes grow close to the ground and are restricted to periodically moist environments
- Describe three traits that characterize modern vascular plants and explain how these traits have contributed to success on land
- Explain how vascular plants differ from bryophytes

- Distinguish between the following pairs of terms: microphyll and megaphyll; homosporous and heterosporous
- Diagram and label the life cycle of a seedless vascular plant
Overview of Plant Evolution

• Looking at a lush landscape it is difficult to imagine the land without any plants or other organisms
• For more than the first 3 billion years of Earth’s history the terrestrial surface was lifeless
• Since colonizing land plants have diversified into roughly 290,000 living species

Land Plants Evolved From Green Algae

• Researchers have identified green algae called charophyceans as the closest relatives of land plants
• Many characteristics of land plants also appear in a variety of algal clades
Morphological and Biochemical Evidence

• There are four key traits that land plants share only with charophyceans
  – Rose-shaped complexes for cellulose synthesis
  – Peroxisome enzymes
  – Structure of flagellated sperm
  – Formation of a phragmoplast
• Comparisons of both nuclear and chloroplast genes point to charophyceans as the closest living relatives of land plants

What is the Plant Kingdom?

• Systematists are currently debating the boundaries of the plant kingdom
• Some biologists think that the plant kingdom should be expanded to include some or all green algae
  – Until this debate is resolved most biologists use the embryophyte definition of kingdom Plantae
Adaptations Enabling the Move to Land

- In charophyceans a layer of a durable polymer called sporopollenin prevents exposed zygotes from drying out.
- The accumulation of traits that facilitated survival on land may have opened the way to its colonization by plants.

Derived Terrestrial Adaptations

- Many adaptations emerged after land plants diverged from their charophycean relatives.
- Five key traits appear in nearly all land plants but are absent in the charophyceans:
  - Alternation of generations
  - Multicellular dependent embryos
  - Walled spores produced in sporangia
  - Multicellular gametangia
  - Apical meristems
Alternation of Generations

- Plants alternate between two multicellular stages, a reproductive cycle called alternation of generations.
- The gametophyte is haploid and produces haploid gametes by mitosis.
- Fusion of the gametes gives rise to the diploid sporophyte, which produces haploid spores by meiosis.

Multicellular, Dependent Embryos

- The diploid embryo is retained within the tissue of the female gametophyte.
- Nutrients are transferred from parent to embryo through placental transfer cells.
- Land plants are called embryophytes because of the dependency of the embryo on the parent.
Walled Spores Produced in Sporangia

- The sporophyte produces spores in organs called sporangia
- Diploid cells called sporocytes undergo meiosis to generate haploid spores
- Spore walls contain sporopollenin, which makes them resistant to harsh environments
Multicellular Gametangia

- Gametes are produced within organs called gametangia
- Female gametangia, called archegonia, produce eggs and are the site of fertilization
- Male gametangia, called antheridia, are the site of sperm production and release

Apical Meristems

- Plants sustain continual growth in their apical meristems
- Cells from the apical meristems differentiate into various tissues
Additional derived units such as a cuticle and secondary compounds, evolved in many plant species.

Symbiotic associations between fungi and the first land plants may have helped plants without true roots to obtain nutrients.

The Origin and Diversification of Plants

- Fossil evidence indicates that plants were on land at least 450 million years ago.
  - Fossilized spores and tissues have been extracted from 450-million-year-old rocks.
  - Earliest evidence of plant spore fossils dates from 470 million years ago.
  - Large spore-bearing structures found in rocks dating from 425 million years ago.
• Whatever the age of the first land plants those ancestral species gave rise to a vast diversity of modern plants
• Land plants can be informally grouped based on the presence or absence of vascular tissue
  – Bryophytes (non-vascular plants)
    • Hepatophyta (also known as Marchantiophyta)
    • Anthocerophyta
    • Bryophyta
  – Seedless vascular plants
    • Lycophyta (also known as Lycopodiophyta)
    • Monilophyta

– Vascular plants
  • Gymnosperms
    – Ginkgophyta
    – Cycadophyta
    – Gnetophyta
    – Coniferophyta
  • Angiosperms
    – Anthophyta

<table>
<thead>
<tr>
<th>Table 29.1 Ten Phyla of Extant Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common Name</td>
</tr>
<tr>
<td>Nongenital Plants (Bryophytes)</td>
</tr>
<tr>
<td>Phylum Hepatophyta</td>
</tr>
<tr>
<td>Phylum Bryophyta</td>
</tr>
<tr>
<td>Phylum Anthocerophyta</td>
</tr>
<tr>
<td>Vascular Plants</td>
</tr>
<tr>
<td>Seedless Vascular Plants</td>
</tr>
<tr>
<td>Phylum Lycophyta</td>
</tr>
<tr>
<td>Phylum Monilophyta</td>
</tr>
<tr>
<td>Seed Plants</td>
</tr>
<tr>
<td>Gymnosperms</td>
</tr>
<tr>
<td>Phylum Ginkgophyta</td>
</tr>
<tr>
<td>Phylum Cycadophyta</td>
</tr>
<tr>
<td>Phylum Gnetophyta</td>
</tr>
<tr>
<td>Phylum Coniferophyta</td>
</tr>
<tr>
<td>Angiosperms</td>
</tr>
<tr>
<td>Phylum Anthophyta</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Bryophytes

• Bryophytes are represented today by three phyla of small herbaceous (nonwoody) plants
  – Liverworts, phylum Hepatophyta
  – Hornworts, phylum Anthocerophyta
  – Mosses, phylum Bryophyta
• Debate continues over the sequence of bryophyte evolution
  – Earliest fossil spores have features only found in living liverworts
  – Hornworts are most closely related to vascular plants

Bryophyte Gametophytes

• In all three bryophyte phyla gametophytes are larger and longer-living than sporophytes
  – A spore germinates into a gametophyte composed of a protonema and gamete-producing gametophore
  – Bryophyte gametophytes
    • Produce flagellated sperm in antheridia and produce an egg in each archegonium
    – Sperm swim through a film of water to reach and fertilize the egg
    • Generally form ground-hugging carpets and are at most only a few cells thick
  • Rhizoids anchor gametophytes to substrate
  • The height of gametophytes is constrained by lack of vascular tissues
    – Some mosses have conducting tissues in the center of their “stems” and may grow vertically
Bryophyte Sporophytes

- Bryophyte sporophytes
  - Grow out of archegonia
  - Are the smallest and simplest of all extant plant groups
  - Consist of a foot, a seta, and a sporangium
  - Hornwort and moss sporophytes have stomata for gas exchange

Liverworts (Hepatophyta)

- Less conspicuous than mosses
- Plant body sometimes divided into lobes
- Life cycle similar to mosses
  - Sporangia have coil-shaped cells (elaters) that spring out of capsule and disperse spores
- Can reproduce asexually from gemmae (plantlets)
  - Released from cups on surface of gametophyte when hit by rainwater
- Greatest diversity in tropical forests
Hornworts (Phylum Anthocerophyta)
- resemble liverworts
  - sporophytes are horn-shaped and grow from mat-like gametophyte
- photosynthetic cells have one large chloroplast
– Mosses (Bryophyta)
  • tight pack of many mosses forms spongy layer that can absorb and retain water
  • grips substratum with rhizoids
    – elongated cells or cellular filaments
  • photosynthesis occurs mostly in stems and leaf-like structures in upper parts of plant
    – not homologous with similar structures in vascular plants
  • cover about 3% of land surface
    – contain large amounts of organic carbon

**Ecological and Economic Importance of Mosses**

• Mosses are capable of inhabiting diverse and sometimes extreme environments, but are especially common in moist forests and wetlands
  – Some mosses might help retain nitrogen in the soil
Sphagnum, or “peat moss” forms extensive deposits of partially decayed organic material known as peat.

- Plays an important role in the Earth’s carbon cycle.
Seedless Vascular Plants

- Bryophytes and bryophyte-like plants were the prevalent vegetation during the first 100 million years of plant evolution.
- Vascular plants began to evolve during the Devonian and Carboniferous periods.
  - Vascular tissue allowed these plants to grow tall.
  - Seedless vascular plants have flagellated sperm and are usually restricted to moist environments.

Origins and Traits of Vascular Plants

- Fossils of the forerunners of vascular plants date back about 420 million years.
- These early tiny plants had independent, branching sporophytes.
  - Lacked other derived traits of vascular plants.
- Living vascular plants are characterized by:
  - Life cycles with dominant sporophytes.
  - Vascular tissues called xylem and phloem.
  - Well-developed roots and leaves.
Life Cycles with Dominant Sporophytes

- In contrast with bryophytes sporophytes of seedless vascular plants are the larger generation, as in the familiar leafy fern
  - The gametophytes are tiny plants that grow on or below the soil surface

Transport in Xylem and Phloem

- Vascular plants have two types of vascular tissue
  - Xylem
    - Conducts most of the water and minerals
    - Includes dead cells called tracheids
  - Phloem
    - Distributes sugars, amino acids, and other organic products
    - Consists of living cells
Evolution of Roots

- Roots are organs that anchor vascular plants
  - Enable vascular plants to absorb water and nutrients from the soil
  - May have evolved from subterranean stems

Evolution of Leaves

- Leaves are organs that increase the surface area of vascular plants, thereby capturing more solar energy for photosynthesis
- Leaves are categorized by two types
  - Microphylls, leaves with a single vein
  - Megaphylls, leaves with a highly branched vascular system
- According to one model of evolution, microphylls evolved first, as outgrowths of stems
Sporophylls and Spore Variations

- Sporophylls are modified leaves with sporangia
  - Sori are clusters of sporangia on the undersides of sporophylls
  - Strobili are cone-like structures formed from groups of sporophylls

- Most seedless vascular plants are homosporous, producing one type of spore that develops into a bisexual gametophyte
- All seed plants and some seedless vascular plants are heterosporous
  - Megaspores give rise to female gametophytes and microspores give rise to male gametophytes

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
Classification of Seedless Vascular Plants

- Seedless vascular plants form two phyla
  - Lycophyta, including club mosses, spike mosses, and quillworts
  - Pterophyta, including ferns, horsetails, and whisk ferns and their relatives

Phylum Lycophyta: Club Mosses, Spike Mosses, and Quillworts

- Modern species of lycophytes are relics from a far more eminent past
  - Survived through Devonian and dominated land during Carboniferous
  - Some temperate, low-growing plants with rhizomes and true leaves
  - Modern lycophytes are small herbaceous plants
    - some species of lycophytes are epiphytes
  - Club mosses and spike mosses have vascular tissues and are not true mosses
Phylum Monilophyta: Ferns and Their Relatives

- Ferns are the most diverse seedless vascular plants
  - Psilophytes, the whisk ferns, used to be considered a "living fossil"
    - dichotomous branching and lack of true leaves and roots seemed similar to early vascular plants
    - comparisons of DNA sequences and ultrastructural details, indicate that the lack of true roots and leaves evolved secondarily
  - Sphenophytes
    - commonly called horsetails because of their often brushy appearance

- During the Carboniferous, sphenophytes grew to 15m
  - survive as about 15 species in a single widespread genus, Equisetum
  - often found in marshy habitats and along streams and sandy roadways
  - Roots develop from horizontal rhizomes that extend along the ground
  - Upright green stems, the major site of photosynthesis, also produce tiny leaves or branches at joints
Horsetail stems have a large air canal to allow movement of oxygen into the rhizomes and roots, which are often in low-oxygen soils.

Reproductive stems produce cones at their tips:
- these cones consist of clusters of sporophylls
- sporophylls produce sporangia with haploid spores

Ferns:
- First appeared in Devonian
- coexisted with tree lycopods and horsetails in Carboniferous forests
- Most represented of modern seedless plants
- more than 12,000 existing species; most diverse in tropics
- Generally larger than lycopods and have a different evolutionary origin
  - lycopods have microphylls, small leaves, evolved from stem emergences, with single vascular strand
  - ferns have megaphylls, leaves with branched vein system

Have compound leaves:
- coiled frond unfurls as it grows
- leaves may sprout directly from stem

The leafy fern is homosporous sporophyte:
- specialized sporophylls have sporangia on undersides
  - can be arranged in clusters called sori
  - equipped with spring-like devices to catapult spores into the air; increases spore dispersal

The free-living gametophyte requires moist environment:
- water is necessary for fertilization
• flagellated sperm cells must swim from antheridium to archegonium
• sporophyte embryo develops in archegonium

The Significance of Seedless Vascular Plants

• The ancestors of modern lycophytes, horsetails, and ferns grew to great heights during the Carboniferous, forming the first forests
• The growth of these early forests may have helped produce the major global cooling that characterized the end of the Carboniferous period
  – This material decayed and eventually became coal