Section A: An Overview of Land Plant Evolution

1. Evolutionary adaptations to terrestrial living characterize the four main groups of land plants
2. Charophyceans are the green algae most closely related to land plants
3. Several terrestrial adaptations distinguish land plants from charophycean algae
Introduction

• More than 280,000 species of plants inhabit Earth today.

• Most plants live in terrestrial environments, including deserts, grasslands, and forests.
  • Some species, such as sea grasses, have returned to aquatic habitats.

• Land plants (including the sea grasses) evolved from a certain green algae, called charophyceans.
1. Evolutionary adaptations to terrestrial living characterize the four main groups of land plants

- There are four main groups of land plants: bryophytes, pteridophytes, gymnosperms, and angiosperms.
- The most common bryophytes are mosses.
- The pteridophytes include ferns.
- The gymnosperms include pines and other conifers.
- The angiosperms are the flowering plants.
<table>
<thead>
<tr>
<th>Phylum / Common Name</th>
<th>Approximate Number of Extant Species</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bryophytes</strong></td>
<td></td>
</tr>
<tr>
<td>Phylum Hepatophyta</td>
<td>Liverworts 6,500</td>
</tr>
<tr>
<td>Phylum Anthocerophyta</td>
<td>Hornworts 100</td>
</tr>
<tr>
<td>Phylum Bryophyta</td>
<td>Mosses 12,000</td>
</tr>
<tr>
<td><strong>Vascular Plants</strong></td>
<td></td>
</tr>
<tr>
<td>Seedless Vascular Plants (Pteridophytes)</td>
<td></td>
</tr>
<tr>
<td>Phylum Lycophyta</td>
<td>Lycophytes 1,000</td>
</tr>
<tr>
<td>Phylum Pterophyta</td>
<td>Ferns, horsetails, and whisk ferns 12,000</td>
</tr>
<tr>
<td><strong>Seed Plants</strong></td>
<td></td>
</tr>
<tr>
<td>Gymnosperms</td>
<td></td>
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<tr>
<td>Phylum Ginkgophyta</td>
<td>Ginkgo 1</td>
</tr>
<tr>
<td>Phylum Cycadophyta</td>
<td>Cycads 100</td>
</tr>
<tr>
<td>Phylum Gnetophyta</td>
<td>Gnetae 70</td>
</tr>
<tr>
<td>Phylum Coniferophyta</td>
<td>Conifers 550</td>
</tr>
<tr>
<td>Angiosperms</td>
<td></td>
</tr>
<tr>
<td>Phylum Anthophyta</td>
<td>Flowering plants 250,000</td>
</tr>
</tbody>
</table>
• Mosses and other bryophytes have evolved several adaptations, especially reproductive adaptations, for life on land.
  • For example, the offspring develop from multicellular embryos that remain attached to the “mother” plant which protects and nourished the embryos.
• The other major groups of land plants evolved vascular tissue and are known as the vascular plants.
  • In vascular tissues, cells join into tubes that transport water and nutrients throughout the plant body.
  • Most bryophytes lack water-conducting tubes and are sometimes referred to as “nonvascular plants.”
• Ferns and other **pteridiophytes** are sometimes called *seedless plants* because there is no seed stage in their life cycles.

• The evolution of the seed in an ancestor common to gymnosperms and angiosperms facilitated reproduction on land.
  
  • A **seed** consists of a plant embryo packaged along with a food supply within a protective coat.
  
  • The first *seed plants* evolved about 360 million years ago, near the end of the Devonian.

• The early seed plants gave rise to the diversity of present-day **gymnosperms**, including conifers.
• The great majority of modern-day plant species are flowering plants, or angiosperms.

• Flowers evolved in the early Cretaceous period, about 130 million years ago.

• A flower is a complex reproductive structure that bears seeds within protective chambers called ovaries.
Bryophytes, pteridiophytes, gymnosperms, and angiosperms demonstrate four great episodes in the evolution of land plants:

- the origin of bryophytes from algal ancestors
- the origin and diversification of vascular plants
- the origin of seeds
- the evolution of flowers
Fig. 29.1

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2. Charophyceans are the green algae most closely related to land plants

- What features distinguish land plants from other organisms?

- Plants are multicellular, eukaryotic, photosynthetic autotrophs.
  - But red and brown seaweeds also fit this description.

- Land plants have cells walls made of cellulose and chlorophyll $a$ and $b$ in chloroplasts.
  - However, several algal groups have cellulose cell walls and others have both chlorophylls.

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• Land plants share two key ultrastructural features with their closet relatives, the algal group called charophyceans.
• The plasma membranes of land plants and charophyceans possess **rosette cellulose-synthesizing complexes** that synthesize the cellulose microfibrils of the cell wall.

• These complexes contrast with the linear arrays of cellulose-producing proteins in noncharophycean algae.
• A second ultrastructural feature that unites charophyceans and land plants is the presence of peroxisomes.
  • Peroxisomes are typically found in association with chloroplasts.
  • Enzymes in peroxisomes help minimize the loss of organic products due to photorespiration.
• In those land plants that have flagellated sperm cells, the structure of the sperm resembles the sperm of charophyceans.

• Finally, certain details of cell division are common only to land plants and the most complex charophycean algae

  • These include the formation of a phragmoplast, an alignment of cytoskeletal elements and Golgi-derived vesicles, during the synthesis of new cross-walls during cytokinesis.
3. Several terrestrial adaptations distinguish land plants from charophycean algae

- Several characteristics separate the four land plant groups from their closest algal relatives, including:
  - apical meristems
  - multicellular embryos dependent on the parent plant
  - alternation of generations
  - sporangia that produce walled spores
  - gametangia that produce gametes
In terrestrial habitats, the resources that a photosynthetic organism requires are found in two different places.

- Light and carbon dioxide are mainly aboveground.
- Water and mineral resources are found mainly in the soil.

Therefore, plants show varying degrees of structural specialization for subterranean and aerial organs - roots and shoots in most plants.
• The elongation and branching of the shoots and roots maximize their exposure to environmental resources.

• This growth is sustained by apical meristems, localized regions of cell division at the tips of shoots and roots.

• Cells produced by meristems differentiate into various tissues, including surface epidermis and internal tissues.
• Multicellular plant embryos develop from zygotes that are retained within tissues of the female parent.

• This distinction is the basis for a term for all land plants, *embryophytes*.
• The parent provides nutrients, such as sugars and amino acids, to the embryo.
  
• The embryo has specialized **placental transfer cells** that enhance the transfer of nutrients from parent to embryo.
  
• These are sometimes present in the adjacent maternal tissues as well.
• All land plants show **alternation of generations** in which two multicellular body forms alternate.
  
• This life cycle also occurs in various algae.
  
• However, alternation of generation does not occur in the charophyceans, the algae most closely related to land plants.
• One of the multicellular bodies is called the **gametophyte** with haploid cells.

• Gametophytes produce gametes, egg and sperm.

• Fusion of egg and sperm during fertilization form a diploid zygote.

Fig. 29.6
• Mitotic division of the diploid zygote produces the other multicellular body, the sporophyte.
  • Meiosis in a mature sporophyte produces haploid reproductive cells called spores.
  • A spore is a reproductive cell that can develop into a new organism without fusing with another cell.
• Mitotic division of a plant spore produces a new multicellular gametophyte.
Unlike the life cycles of other sexually producing organisms, alternation of generations in land plants (and some algae) results in both haploid and diploid stages that exist as multicellular bodies.

- For example, humans do not have alternation of generations because the only haploid stage in the life cycle is the gamete, which is single-celled.

- While the gametophyte and sporophyte stages of some algae appear identical macroscopically in some algae, these two stages are very different in their morphology in other algal groups and all land plants.
The relative size and complexity of the sporophyte and gametophyte depend on the plant group.

- In bryophytes, the gametophyte is the “dominant” generation, larger and more conspicuous than the sporophyte.

- In pteridophytes, gymnosperms, and angiosperms, the sporophyte is the dominant generation.
  
  - For example, the fern plant that we typically see is the diploid sporophyte, while the gametophyte is a tiny plant on the forest floor.
• Plant spores are haploid reproductive cells that grow into a gametophyte by mitosis.
  • Spores are covered by a polymer called sporopollenin, the most durable organic material known.
  • This makes the walls of spores very tough and resistant to harsh environments.

Fig. 29.7
• Multicellular organs, called **sporangia**, are found on the sporophyte and produce these spores.

• Within a sporangia, diploid **spore mother cells** undergo meiosis and generate haploid spores.

• The outer tissues of the sporangium protect the developing spores until they are ready to be released into the air.

Fig. 29.8

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• The gametophytes of bryophytes, pteridophytes, and gymnosperms produce their gametes within multicellular organs, called **gametangia**.

• A female gametangium, called an **archegonium**, produces a single egg cell in a vase-shaped organ.
  
  • The egg is retained within the base.
• Most land plants have additional terrestrial adaptations including:
  • adaptations for acquiring, transporting, and conserving water,
  • adaptations for reducing the harmful effect of UV radiation,
  • adaptations for repelling terrestrial herbivores and resisting pathogens.
• Male gametangia, called **antheridia**, produce many sperm cells that are released to the environment.

• The sperm cells of bryophytes, pteridiophytes, and some gymnosperms have flagella and swim to eggs.

• A sperm fuses with an egg within an archegonium and the zygote then begins development into an embryo.

Fig. 29.9b
• In most land plants, the epidermis of leaves and other aerial parts is coated with a cuticle of polyesters and waxes.
  
  • The cuticle protects the plant from microbial attack.
  
  • The wax acts as waterproofing to prevent excessive water loss.

Fig. 29.10
• Pores, called **stomata**, in the epidermis of leaves and other photosynthetic organs allow the exchange of carbon dioxide and oxygen between the outside air and the leaf interior.

• Stomata are also the major sites for water to exit from leaves via evaporation.

• Changes in the shape of the cells bordering the stomata can close the pores to minimize water loss in hot, dry conditions.
• Except for bryophytes, land plants have true roots, stems, and leaves, which are defined by the presence of vascular tissues.
  • Vascular tissue transports materials among these organs.

• Tube-shaped cells, called **xylem**, carry water and minerals up from roots.
  • When functioning, these cells are dead, with only their walls providing a system of microscopic water pipes.

• **Phloem** is a living tissue in which nutrient-conducting cells arranged into tubes distribute sugars, amino acids, and other organic products.
- Land plants produce many unique molecules called secondary compounds.
  - These molecules are products of “secondary” metabolic pathways.
  - These pathways are side branches off the primary pathways that produce lipids, carbohydrates, and other compounds common to all organisms.
• Examples of secondary compounds in plants include alkaloids, terpenes, tannins, and phenolics such as Flavonoids.

• Various secondary compounds have bitter tastes, strong odors, or toxic effects that help defend land plants against herbivorous animals or microbial attack.

• Flavonoids absorb harmful UV radiation.

• Other flavonoids are signals for symbiotic relationships with beneficial soil microbes.

• Lignin, a phenolic polymer, hardens the cell walls of “woody” tissues in vascular plants, providing support for even the tallest of trees.
• Humans have found many applications, including medicinal applications, for secondary compounds extracted from plants.

• For example, the alkaloid quinidine helps prevent malaria.