Plant Diversity

• From Sea to Land
• Origins, Relationships, Diversity
• Shared Derived Traits (Synapomorphies)
• Nonvascular to Vascular Plants
• Seedless to Seeds

03 March 2009
ECOL 182R UofA
K. E. Bonine
The Evolution of Land Plants
(from the edge of the swamp...)

• chlorophylls $a$ and $b$

Green stuff
Land plants retain derived features they share with green algae (Charales): chlorophyll A and B, starch as a storage product, and cellulose in cell walls.
Land Plants are Monophyletic

Land plants are monophyletic, all descend from a single common ancestor.

One synapomorphy: development from an embryo protected by tissues of the parent plant. Therefore, also called embryophytes.

(*phyton* = plant)
Land Plants Comprise ~Ten Clades

**Nonvascular** (3 clades)
- paraphyletic group
- liverworts,
- hornworts
- mosses

**Vascular plants**, or *tracheophytes* (7 clades)—all have conducting cells called **-tracheids**.
- monophyletic group
Plants first appeared on land between 400–500 million years ago.

Environmental Challenges:

1. 
2. transport to all parts
3. (fight gravity)
4. disperse .

Some challenges met immediately, others took millions of years.
Plants first appeared on land between 400-500 million years ago.

Biological history

22.1 Earth’s Geological History (Part 2)

<table>
<thead>
<tr>
<th>ERA</th>
<th>PERIOD</th>
<th>ONSET</th>
<th>MAJOR EVENTS IN THE HISTORY OF LIFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cenozoic</td>
<td>Quaternary</td>
<td>1.8 mya</td>
<td>Humans evolve; many large mammals become extinct</td>
</tr>
<tr>
<td></td>
<td>Tertiary</td>
<td>65 mya</td>
<td>Diversification of birds, mammals, flowering plants, and insects</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>Cretaceous</td>
<td>144 mya</td>
<td>Dinosaurs continue to diversify; flowering plants and mammals diversify. Mass Extinction at end of period (=76% of species disappear)</td>
</tr>
<tr>
<td></td>
<td>Jurassic</td>
<td>206 mya</td>
<td>Diverse dinosaurs; radiation of ray-finned fishes</td>
</tr>
<tr>
<td></td>
<td>Triassic</td>
<td>248 mya</td>
<td>Early dinosaurs; first mammals; marine invertebrates diversify; first flowering plants; Mass Extinction at end of period (=65% of species disappear)</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>Permian</td>
<td>290 mya</td>
<td>Reptiles diversify; amphibians decline; Mass Extinction at end of period (=96% of species disappear)</td>
</tr>
<tr>
<td></td>
<td>Carboniferous</td>
<td>354 mya</td>
<td>Extensive “fern” forests; first reptiles; insects diversify</td>
</tr>
<tr>
<td></td>
<td>Devonian</td>
<td>417 mya</td>
<td>Fishes diversify; first insects and amphibians. Mass Extinction at end of period (=75% of species disappear)</td>
</tr>
<tr>
<td></td>
<td>Silurian</td>
<td>443 mya</td>
<td>Jawless fishes diversify; first ray-finned fishes; plants and animals colonize land</td>
</tr>
<tr>
<td></td>
<td>Ordovician</td>
<td>490 mya</td>
<td>Mass Extinction at end of period (=75% of species disappear)</td>
</tr>
<tr>
<td></td>
<td>Cambrian</td>
<td>543 mya</td>
<td>Most animal phyla present; diverse algae</td>
</tr>
<tr>
<td></td>
<td></td>
<td>600 mya</td>
<td>Ediacaran fauna</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5 bya</td>
<td>Eukaryotes evolve; several animal phyla appear</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.8 bya</td>
<td>Origin of life; prokaryotes flourish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.5 bya</td>
<td></td>
</tr>
</tbody>
</table>

*a mya, million years ago; bya, billion years ago.
Biological history

8 Earth forms

Oldest fossils

Photo-synthesis evolves

Eukaryotic cells

Abundant life

Aquatic life

First land plants

First land animals

Forests Insects First mammals Dinosaurs dominant

Birds Flowering plants Rise of Mammals

First hominids Homo sapiens

Moss
Adaptations for Land

1. Cuticle
   - waxy covering that retards water_____ 

2. Gametangia enclosing gametes 

3. Embryos in a protective structure 

4. Pigments that protect against UV radiation 

5. Spore walls containing sporopollenin
   - resists desiccation and 

6. Mutualistic relationships with fungus 
   - to promote ________ from soil
Plants Help Create Soil

Ancient plants contributed to soil formation.

Acids secreted by plants help break down rock.

Organic material from dead plants contributes to soil structure.

Create habitat and pave way for succession of other species.
Nonvascular Plants Are Similar to Ancestral Land Plants

Today’s nonvascular plants are thought to be similar to the first land plants. They grow in moist environments in dense mats. They are small, there is no system to conduct water from soil to plant body parts.
Traits of Nonvascular Plants

Growth pattern of nonvascular plants allows water to move through mats by capillary action. Minerals can be distributed through the small plants by diffusion. Mutualistic relationship with fungi called glomeromycetes which promote absorption of water and minerals.
Extant Plants

Discuss ancestral first, then derived

Common ancestor of land plants
Protected embryos
Apical growth
Microphylls
Club mosses
Tracheids
Megaphylls
Seeds

Liverworts
Hornworts
Mosses
Whisk ferns
Most ferns
Gymnosperms
Flowers, carpels, triploid endosperm

Land plants

Vascular plants

Pteridophytes
Euphyllophytes
Seed plants

LIFE 8e, Figure 28.7
Three Nonvascular Clades (paraphyletic group)

- Liverworts
- Hornworts
- Mosses
Alternation of Generations

and

of gametophyte or sporophyte changes

All plants have alternation of generations (= multicellular haploid & multicellular diploid)
Moss Lifecycle
(Nonvascular Plant)

Sporophyte (2n) and attached to,

Water required for egg and sperm to meet

HAPLOID (n) Gametophyte generation

DIPLOID (2n) Sporophyte generation

Meiosis

Fertilization
Nonvascular: Gametophyte Dominates

In nonvascular plants:

gametophyte is larger, longer-lived, and more self-sufficient than the sporophyte.

gametophyte generation is photosynthetic.

sporophyte may or may not be photosynthetic, but is always nutritionally dependent on the gametophyte, and is permanently attached.

... of the... generation is a major theme in plant evolution.
Nonvascular Plant Reproduction

Male: antheridium

Female: archegonium

Antheridium (n)

Egg (n)

Archegonium (n)
Nonvascular Plant Reproduction

Base of archegonium grows to protect embryo during early development.

(land plants aka embryophytes)
Nonvascular Diversity

**Hornworts:** Anthocerophyta—100 species.

Gametophytes are flat plates of cells. Have **stomata**, which do not close. Hornwort cells have a **single, large chloroplast**.

The sporophyte has no stalk; but has a basal region capable of infinite cell division. Sporophytes can grow up to 20 cm.

Hornworts have internal cavities filled with **nitrogen-fixing cyanobacteria**.
Life cycle of a moss

Mosses are sister group to plants

Video 28-3
Moss...

*Sphagnum* grows in swampy places. The upper layers of moss compress lower layers that are beginning to decompose, forming *peat*. Long ago, continued compression led to the formation of ____.
Navajo Power Plant, Page, AZ
Paleozoic: Carboniferous

- Large glaciers and swamp forests of treeferns and horsetails.

- Fossilized forests formed the coal we now mine for energy.
Vascular Plants Arose from Nonvascular

Recently, fossilized fragments of ancient liverworts have been discovered.
Vascular Plants Comprise Seven Clades

10 clades of land plants:

Nonvascular (3 clades)
- liverworts, hornworts, and mosses
- paraphyletic group

Vascular plants, or tracheophytes (7 clades)
- conducting cells called tracheids.
- monophyletic group
# Seedless Vascular Plants

## Table 28.1

<table>
<thead>
<tr>
<th>GROUP</th>
<th>COMMON NAME</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NONVASCULAR PLANTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Hepatophyta</td>
<td>Liverworts</td>
<td>No filamentous stage; gametophyte flat</td>
</tr>
<tr>
<td>2 Anthocerophyta</td>
<td>Hornworts</td>
<td>Embedded archegonia; sporophyte grows basally (from the ground)</td>
</tr>
<tr>
<td>3 Bryophyta</td>
<td>Mosses</td>
<td>Filamentous stage; sporophyte grows apically (from the tip)</td>
</tr>
<tr>
<td><strong>VASCULAR PLANTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 Lycophyta</td>
<td>Club mosses and allies</td>
<td>Microphylls in spirals; sporangia in leaf axils</td>
</tr>
<tr>
<td>5 Pteridophyta</td>
<td>Horsetails, whisk ferns,</td>
<td>Differentiation between main stem and side branches (overtopping growth)</td>
</tr>
<tr>
<td></td>
<td>ferns</td>
<td></td>
</tr>
<tr>
<td><strong>SEED PLANTS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gymnosperms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Cycadophyta</td>
<td>Cycads</td>
<td>Compound leaves; swimming sperm; seeds on modified leaves</td>
</tr>
<tr>
<td>7 Ginkgophyta</td>
<td>Ginkgo</td>
<td>Deciduous; fan-shaped leaves; swimming sperm</td>
</tr>
<tr>
<td>8 Gnetophyta</td>
<td>Gnetophytes</td>
<td>Vessels in vascular tissue; opposite, simple leaves</td>
</tr>
<tr>
<td>9 Coniferophyta</td>
<td>Conifers</td>
<td>Seeds in cones; needle-like or scale-like leaves</td>
</tr>
<tr>
<td>10 Angiosperms</td>
<td>Flowering plants</td>
<td>Endosperm; carpels; gametophytes much reduced; seeds within fruit</td>
</tr>
</tbody>
</table>

*Note: No extinct groups are included in this classification.*
Traits of Vascular Plants

Thevascular systemconsists of tissue specialized for the transport of materials.

conducts water and minerals from soil up to aerial parts of plant. Some cells have
lignin—provides support.

Tracheids are the main water-conducting element in xylem. Angiosperms have tracheids plus a more efficient system of vessels and fibers.

conducts products of photosynthesis through plant.
Extant Plants

Common ancestor of land plants
Protected embryos

Vascular, but Seedless

Apical growth
Tracheids
Megaphylls
Microphylls

Liverworts
Hornworts
Mosses

Club mosses
Horsetails
Whisk ferns
Most ferns

Seeds
Gymnosperms
Flowers, carpels, triploid endosperm

Pteridophytes
Euphyllophytes
Seed plants

Seeds
Flowering plants

LIFE 8e, Figure 28.7
Evolution of Vascular Plants

Vascular plants have a branching, mature sporophyte is nutritionally independent from the gametophyte.

Still must have water for part of the life cycle—for the flagellated, swimming sperm.
Evolution of Vascular Plants

Earliest vascular plants (now extinct):

**Rhyniophytes** (Silurian) had dichotomous branching, but lacked leaves and roots. They were anchored by *rhizomes* (horizontal portions of stem) and *rhizoids* (water-absorbing filaments).

Earliest vascular plants
Evolution of Vascular Plants

Lycophytes appeared in the Silurian.

Pteridophytes appeared in the Devonian.

These groups had true roots and leaves, and two types of spores.

Overtopping evolved --new branches grow beyond the others—an advantage in the competition for light
Evolution of Vascular Plants

Leaf: a flattened photosynthetic structure arising from a stem or branch; has true vascular tissue.

Two types: microphylls and megaphylls.
Evolution of Leaves

Small megaphylls first appeared in the Devonian. Large megaphylls did not appear until the Carboniferous.

One theory: high CO$_2$ concentrations in the Devonian prevented development of stomata.

Stomata allow heat to be lost by the evaporation of water. Large leaves with no stomata would have resulted in ______________.
Evolution of Vascular Plants

**Horsetails**: Fifteen species in one genus—*Equisetum.* Silica in cell walls—“scouring rushes.” Have **true roots**
Figure 28.17 Horsetails

(A) Sporangium  Fertile shoot

Equisetum arvense

(B) Leaves

Equisetum palustre
Evolution of Vascular Plants

**Ferns:** 12,000 species. About 97 percent are in a clade—leptosporangiate ferns—sporangia walls only one cell thick, borne on a stalk.

Sporophytes have **true roots, stems, and leaves.**
Figure 28.19 Fern Leaves Take Many Forms

(A) Adiantum pedatum

LIFE 8e, Figure 28.19 (Part 1)
Ferns...

Most ferns are in shaded, moist environments.

Tree ferns can reach heights of 20 m.

Sporangia occur on undersides of leaves in clusters called sori.

Some genera have a tuberous gametophyte that depends on a mutualistic fungus for nutrition.
Life cycle of a fern

Vascular but Seedless

Adiantum pedatum

LIFE 8e, Figure 28.19 (Part 1)
The Life Cycle of a Homosporous Fern

Sporophyte and Gametophyte are each

**Mature gametophyte** (about 0.5 cm wide)

- Archegonium
- Egg

**Spermatophyte**

- Antheridium
- Sperm

**Fertilization**

**HAPLOID** ($n$)

- Meiosis
- Germinating spore
- Sporangium

**DIPLOID** ($2n$)

**Mature sporophyte** (typically 0.3–1 m tall)

- Sori (clusters of sporangia)
- Sporophyte
- Gametophyte
- Embryo
- Roots
- Sporangium

**Microsorum sp.**

*LIFE 8e, Figure 28.20*
Ferns...

DNA research suggests that diversification of modern ferns is fairly recent.

Ferns may have taken advantage of shady environments created by angiosperm trees.
Early Vascular Plants

During the Permian, the continents came together to form Pangaea. Extensive glaciation occurred late in the Permian.

Lycophyte-fern forests were replaced by *gymnosperms*. 
Bristlecone Pine

If you could imagine a living tree as old as the pyramids of Egypt, what do you think it would look like? It would look like a bristlecone pine, *Pinus longaeva*, the oldest known tree species in the world.

The bristlecone pine only lives in scattered, arid mountain regions of six western states of America, but the oldest are found in the Ancient Bristlecone Pine Forest in the White Mountains of California. There the pines exist in an exposed, windswept, harsh environment, free of competition from other plants and the ravages of insects and disease. The oldest bristlecones usually grow at elevations of 10,000 to 11,000 feet.
The oldest known tree is "Methuselah", which is 4,789 years old. To keep Methuselah from harm, this tree isn't labeled, as the other trees are. An older tree called Prometheus was killed shortly after it was discovered in 1964. This happened when a geologist searching for evidence of Ice Age glaciers was taking some core samples from several bristlecones. Just as he realized he had found a tree over 4,000 years old, his coring tool broke. Amazingly the U.S. Forest Service gave him permission to cut down the tree. Prometheus turned out to be 4,950 years old. It was a 300 year old tree when the pyramids were being built in Egypt.

http://www.ltrr.arizona.edu/

Bristlecone Pine
Which of the following are vascular plants?

a. Juniper
b. Sunflower
c. Fern
d. Moss
e. Horsetail
f. Liverwort
g. Lily