The Evolution of Seed Plants

Late in the Devonian, some plants developed secondary growth: thickened woody stems of xylem.

First species with secondary growth were the progymnosperms: seedless vascular plants, now extinct.

Wood: proliferated xylem, gives support and allows plants to grow above their competitors for sunlight.
Seed Plants Took Over

Surviving seed plants fall into two groups: and cycads

: flowering plants
Evolution of Plants

Horsetails and ferns (Pteridophytes) replaced by

Living fossils: Gingko

Figure 2.6 Terrestrial plant species richness. Ferns, gymnosperms, and angiosperms have, in turn, dominated the world’s flora. (Modified from Signor 1990.)
Gymnosperms

Extant gymnosperms are probably a clade. Gymnosperm: “____________”—the ovules and seeds are not protected by ovary or fruit tissue.
Gymnosperms

Four major groups of living gymnosperms:

- **Cycads**: Cycadophyta—140 species
- **Ginkgos**: Ginkgophyta—**one living species**, *Ginkgo biloba*
- **Gnetophytes**: Gnetophyta—90 species in 3 genera
- **Conifers**: Coniferophyta—600 species, the cone bearers

- Cycads and Ginkgos still have
Gymnosperm Evolution

Most living gymnosperms have only tracheids for water conduction and support. Angiosperms have vessel elements and fibers alongside of tracheids.

Evolution of Seed Plants

*Gametophyte* generation is *reduced* even further than it is in ferns. Haploid *gametophyte* develops partly or entirely while *attached to the sporophyte*. 
Figure 29.3 The Relationship between Sporophyte and Gametophyte Has Evolved (Part 1)

Nonvascular

Sporophyte (2n)

Gametophyte (n)

Sporophyte (2n)

Gametophyte (n)

Seedless Vascular

Figure 29.3 The Relationship between Sporophyte and Gametophyte Has Evolved (Part 2)

Sporophyte (2n)

Female gametophyte (n)

Male gametophytes (n)

Anther

Ovary

Angiosperm
Evolution of Seed Plants

Seed plants are heterosporous: produce two types of spores.

Only one meiotic product survives and develops into the megagametophyte by mitotic divisions. Megagametophyte (haploid) produces an egg by mitosis.

Megagametophyte houses the next sporophyte generation when egg is fertilized.

Megasporangium is surrounded by integument made of sporophytic structures.

Megasporangium and the integument together form the (which develops into a).
Gymnosperm Example:

Megasporangium (cone)

Microsporangium (strobili)

Evolution of Seed Plants

In the microsporangium, microspores produce the male gametophyte, or pollen grain with sporopollenin in walls, the most resistant biological compound known.

Reproduction becomes independent of water in some Gymnosperms!

How do you think this affected the evolution and diversification of seed plants?
Conifers (Pine Cones...)

A cone is a modified stem, bearing a tight cluster of scales (reduced branches), specialized for reproduction. Megaspores are produced here.

**Strobilus**: cone-like structure; scales are modified leaves. Microspores are produced here.

Recall that evolution by natural selection typically involves modification of existing structures.

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Pine Life Cycle

- Wind carries pollen grains from strobilus to cone.
- Two sperm travel through pollen tube; one degenerates after fertilization.

Note that pollinization does NOT equal fertilization.
Evolution of Seed Plants

After fertilization, diploid zygote divides to produce an embryonic sporophyte.

Growth is then suspended, the embryo enters a dormant stage, with the end product being a multicellular seed.

How might suspension of growth be a fitness advantage?
Evolution of Seed Plants

Seeds have tissues from three generations:
1. *Seed coat* develops from the *sporophyte parent* (integument).

2. Female *gametophytic* tissue from the next generation contains a nutrient supply for developing embryo.

3. Embryo is the *new sporophyte* generation.

Seeds are well-protected resting stages. 
May remain *viable* for many years, 
*germinating* when conditions are favorable. 
*Seed coat* protects from drying out as well as predators. 
Many seeds have adaptations for *dispersal.*
Evolution of Seed Plants

Seeds and Secondary Growth are the main reasons for the success of seed plants—currently the dominant life forms in terrestrial environments.

Origin of Land Plants

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

Oldest angiosperm fossils are Cretaceous, 140 million years old.
Radiation was explosive; angiosperms became dominant in only 60 million years.
Over 250,000 species exist today.

Female gametophyte even more reduced—usually only seven cells.

Angiosperm Synapomorphies

• Xylem with vessel elements and fibers
• Phloem with companion cells
• Triploid endosperm
• Ovules and seeds
Double Fertilization & Endosperm

Microgametophyte has two male gametes. Nucleus of one combines with egg. The other nucleus combines with two haploid nuclei of female gametophyte to form a triploid nucleus—becomes the endosperm. Endosperm nourishes developing sporophyte.

Carpels

Angiosperm: “enclosed seed”—the ovules and seeds are enclosed in a modified leaf called a carpel. Carpels provide protection, and may interact with pollen to prevent self-pollination.
**Flowers**

**Stamens** bear microsporangia: consist of **filament** and **anther**.

**Carpels** bear megasporangia. One or more carpels form the **pistil**—**stigma**, **style**, and **ovary**.

**Flowers**

**Petals (corolla)** and **sepals (calyx)** are modified leaves. Often play a role in attracting pollinators.

The calyx often protects the flower bud before it opens.
Flowers

**Perfect** flowers: have *both* mega- and microsporangia.

**Imperfect** flowers: either mega or microsporangia.

**Monoecious**: “one-housed”; male and female flowers occur on the same plant.

**Dioecious**: “two-housed”; male and female flowers on different plants.

Inflorescence: grouping of flowers. Different families have characteristic types.
Flowers

Long styles in pistils and long filaments in stamens: length increases likelihood of pollination—either making them more accessible to insects, or to catch the wind.
Flowers

Most angiosperms are animal-pollinated—by insects, birds, and bats.
Many flowers entice pollinators with nectar and pollen.
Plants and their pollinators have coevolved; some relationships are very specific.
Angiosperm Lifecycle

Zygote develops into an embryo: consists of an embryonic axis (will become stem and root), and 1 or 2 cotyledons—seed leaves. Cotyledons absorb and digest the endosperm, some become photosynthetic.

Ovary and seeds develop into fruits. Fruit protects seed and aids in dispersal, (e.g., can become attached to or eaten by animals).
Fruits

*Simple* fruits develop from one carpel.

*Aggregate* fruits develop from several carpels.

*Multiple* fruits form from a cluster of flowers.

*Accessory* fruits develop from parts other than carpels.
Angiosperm Diversification

Most angiosperms are in two clades:

- **Monocots**: one cotyledon
- **Eudicots**: two cotyledons

Other clades include star anise and relatives, water lilies, and magnoliids.
Monocots

Palms
Lilies
Grasses

Eudicots

LIFE 8e, Figure 29.18
Plants Support Our World

Plants contribute to **ecosystem services**: processes by which the environment maintains resources that benefit humans.

Plants are **primary producers**: photosynthesis traps energy and carbon, making them available to consumers.

Plants Support Us

Seed plants are our primary **food** source.

Twelve are most important: rice, coconut, wheat, corn, potato, sweet potato, cassava, sugarcane, sugar beet, soybean, common bean, banana.

Half of the world’s population gets most of its food energy from rice.
Plants Support Us

Many medicines come from seed plants. Medicines are found by screening large numbers of plants, or screening large numbers of chemical compounds. Ethnobotanists also discover medicinal plants by studying people and their uses of plants all over the world.

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>PLANT SOURCE</th>
<th>MEDICAL APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atropine</td>
<td>Belladonna</td>
<td>Dilating pupils for eye examination</td>
</tr>
<tr>
<td>Bromelain</td>
<td>Pineapple stem</td>
<td>Controlling tissue inflammation</td>
</tr>
<tr>
<td>Digitalin</td>
<td>Foxglove</td>
<td>Strengthening heart muscle contraction</td>
</tr>
<tr>
<td>Ephedrine</td>
<td>Ephedra</td>
<td>Easing nasal congestion</td>
</tr>
<tr>
<td>Menthol</td>
<td>Japanese mint</td>
<td>Relief of coughing</td>
</tr>
<tr>
<td>Morphine</td>
<td>Opium poppy</td>
<td>Relief of pain</td>
</tr>
<tr>
<td>Quinine</td>
<td>Cinchona bark</td>
<td>Treatment of malaria</td>
</tr>
<tr>
<td>Taxol</td>
<td>Pacific yew</td>
<td>Treatment of ovarian and breast cancers</td>
</tr>
<tr>
<td>Tubocurarine</td>
<td>Curare plant</td>
<td>As muscle relaxant in surgery</td>
</tr>
<tr>
<td>Vincristine</td>
<td>Periwinkle</td>
<td>Treatment of leukemia and lymphoma</td>
</tr>
</tbody>
</table>