Chapter 30: Plant Diversity II – The Evolution of Seed Plants

1. General Features of Seed-Bearing Plants

2. Survey of the Plant Kingdom II
   A. Gymnosperms
   B. Angiosperms
The 10 Phyla of Existing Plants

Chapter 29

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Number of Known Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liverworts</td>
<td>9,000</td>
</tr>
<tr>
<td>Mosses</td>
<td>15,000</td>
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<tr>
<td>Hornworts</td>
<td>100</td>
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Vascular Plants

Seedless Vascular Plants

<table>
<thead>
<tr>
<th>Common Name</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Lycophytes</td>
<td>1,200</td>
</tr>
<tr>
<td>Monilophytes</td>
<td>12,000</td>
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</table>

Seed Plants

Gymnosperms

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Number of Known Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginkgo</td>
<td>1</td>
</tr>
<tr>
<td>Cycads</td>
<td>130</td>
</tr>
<tr>
<td>Gnetophytes</td>
<td>75</td>
</tr>
<tr>
<td>Conifers</td>
<td>600</td>
</tr>
</tbody>
</table>

Angiosperms

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Number of Known Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowering plants</td>
<td>250,000</td>
</tr>
</tbody>
</table>
1. General Features of Seed-bearing Plants
Key Adaptations for Life on Land

Plant life on land is dominated by seed plants due to the following 5 derived characters:

1. SEEDS
2. REDUCED GAMETOPHYTES
3. HETEROSPORPHY
4. OVULES
5. POLLEN
Advantages of Seeds

A seed is a sporophyte embryo surrounded by nutrients packaged in a protective seed coat which provides the following advantages for the embryo:

• the fruit surrounding the seed can facilitate its dispersal over long distances

• the embryo can survive for years in a dormant state until conditions are favorable for germination

• nutrients to sustain the embryo during early growth
Advantages of Reduced Gametophytes

Seed plants have microscopic gametophytes that are fully contained within the sporangium of the sporophyte. This provides the following advantages:

- the reproductive tissues of the sporangium protect the gametophyte from environmental stresses (e.g., UV exposure, loss of moisture, extreme temperature)
- the sporophyte can provide nourishment to sustain the gametophyte
<table>
<thead>
<tr>
<th>PLANT GROUP</th>
<th>Mosses and other nonvascular plants</th>
<th>Ferns and other seedless vascular plants</th>
<th>Seed plants (gymnosperms and angiosperms)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gametophyte</strong></td>
<td>Dominant</td>
<td>Reduced, dependent</td>
<td>Reduced (usually microscopic), dependent on surrounding sporophyte tissue for nutrition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(usually microscopic and free-living)</td>
<td></td>
</tr>
<tr>
<td><strong>Sporophyte</strong></td>
<td>Reduced, dependent on gametophyte for nutrition</td>
<td>Dominant</td>
<td>Dominant</td>
</tr>
<tr>
<td><strong>Example</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Advantages of Heterospory

Most seedless plants are homosporous – produce one type of spore that develops into a bisexual gametophyte. Seed plants are heterosporous and produce 2 types of spores:

- **Megasporangium** on megasporophyll → **Megaspore** → **Female gametophyte** → Eggs
- **Microsporangium** on microsporophyll → **Microspore** → **Male gametophyte** → Sperm

This provides 2 key advantages:

1. male & female gametophytes can mature at different times avoiding self fertilization and increasing genetic diversity
2. a separate female gametophyte can better support a developing embryo
Egg Production in Ovules

Seed plants are unique in containing the **megasporangium** within the parent sporophyte surrounded by a protective **integument**.

The complete structure – **megaspore** within **megasporangium** within the **integument** – is called an **ovule**.
Pollen and Sperm Production

Microspores develop into multicellular pollen grains – a male gametophyte surrounded by a protective outer layer containing sporopollenin produced by the sporophyte.

- pollen grains protect the male gametes – sperm – and facilitate their dispersal without the requirement for water
- unlike seedless plants, the sperm contained in pollen grain are not flagellated and gain access to an egg at pollination through a pollen tube
### Five Derived Traits of Seed Plants

<table>
<thead>
<tr>
<th>Trait</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced gametophytes</td>
<td>Microscopic male and female gametophytes ( (n) ) are nourished and protected by the sporophyte ( (2n) )</td>
</tr>
<tr>
<td>Heterospory</td>
<td>Microspore (gives rise to a male gametophyte)</td>
</tr>
<tr>
<td></td>
<td>Megaspore (gives rise to a female gametophyte)</td>
</tr>
<tr>
<td>Ovules</td>
<td>Ovule (gymnosperm)</td>
</tr>
<tr>
<td></td>
<td>Integument ( (2n) )</td>
</tr>
<tr>
<td></td>
<td>Megaspore ( (n) )</td>
</tr>
<tr>
<td></td>
<td>Megasporangium ( (2n) )</td>
</tr>
<tr>
<td>Pollen</td>
<td>Pollen grains make water unnecessary for fertilization</td>
</tr>
<tr>
<td>Seeds</td>
<td>Seeds: survive better than unprotected spores, can be transported long distances</td>
</tr>
<tr>
<td></td>
<td>Seed coat</td>
</tr>
<tr>
<td></td>
<td>Food supply</td>
</tr>
<tr>
<td></td>
<td>Embryo</td>
</tr>
</tbody>
</table>

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**Summary of the Key Derived Traits of Seed Plants**
2A. Survey of the Plant Kingdom II

**Gymnosperms**

<table>
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<td><strong>Gymnosperms</strong></td>
</tr>
<tr>
<td>Angiosperms</td>
</tr>
</tbody>
</table>
Gymnosperm Characteristics

Gymnosperms are at least 300 million years old according to the fossil record and were the dominant group of land plants in the Mesozoic era, with many still existing today.

- gymnosperm means “naked seed” which refers to the exposed seeds produced on modified leaves (sporophylls) of cones
- cones are a type of strobilus, a collection of sporophylls

It takes approximately 3 years for an ovulate cone to produce mature seeds!
The Life Cycle of a Pine

- most conifers such as pines produce both ovulate (female) cones and pollen (male) cones
- conifer pollen grains have an aerodynamic morphology and reach megasporangia through the air
Gymnosperm Phyla

4 of the 10 plant phyla are gymnosperms:

• CYCADOPHYTA
• GINGKOPHYTA
• GNETOPHYTA
• CONIFEROPHYTA
Phylum Cycadophyta

Cycads have large cones and palm-like leaves.

- produce flagellated sperm unlike most seed plants
- widespread during the Mesozoic period, most modern species are endangered
Phylum Ginkgophyta

There is only one living species in this phylum: *Gingko biloba*

- produces flagellated sperm like the cycads
- a popular ornamental tree in southern California
Phylum Gnetophyta

This phylum contains only 3 genera: *Gnetum*, *Ephedra*, and *Welwitschia*

- some species are tropical and others thrive in deserts
Phylum Coniferophyta

- this is the largest gymnosperm phylum with ~600 known species
- most conifers are evergreens that carry out photosynthesis year round

Bristlecone pine  Common juniper  Sequoia  European larch
2B. Survey of the Plant Kingdom

**Angiosperms**

<table>
<thead>
<tr>
<th>Category</th>
</tr>
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<tbody>
<tr>
<td>Nonvascular plants (bryophytes)</td>
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</tbody>
</table>
Characteristics of Angiosperms

All angiosperms (literally “enclosed seeds”) or flowering plants belong to the phylum Anthophyta and have 2 key adaptations:

1. **Flowers** as sexual reproductive structures

2. Seeds enclosed in **fruits** which aid in seed dispersal
Flowers are modified shoots containing up to 4 types of modified leaves:

- **sepals** that enclose and protect the flower
- **petals** to attract pollinators
- **stamens** – the male reproductive organs
- **carpels** – the female reproductive organs
Variations in Flower Structure

Flower Symmetry

- Radial symmetry (daffodil)
  - Sepal
  - Fused petals

- Bilateral symmetry (orchid)

Location of Stamens and Carpels

- Common holly flowers with stamens
- Carpel
- Nonfunctional stamen
- Common holly flowers with carpels

- Stamens

• flowers of any given species of angiosperm may have radial or bilateral symmetry

• flowers of any given species may also be complete (have all 4 flower organs) or incomplete (lacking at least one flower organ)
Fruits develop from the ovary wall and aid in the dispersal of seeds by a variety of methods:

• animals disperse seeds in edible fruits
• wind disperses some seeds (e.g., dandelion)
• hitchhiker fruits act as barbs to stick to animals passersby
• some fruits burst open when dry to disperse seeds
  (e.g., peas)
Angiosperm Life Cycle

1. Mature flower on sporophyte plant (2n)
2. Germinating seed
3. MEIOSIS
   - Ovary
   - Ovule with megasporangium (2n)
   - Megasporangium (2n)
   - Integuments
   - Antipodal cells
   - Polar nuclei in central cell
   - Synergids
   - Egg (n)
   - Female gametophyte (embryo sac)
4. MEIOSIS
   - Microsporangium
   - Microsporocytes (2n)
   - Microspore (n)
   - Generative cell
   - Tubule cell
   - Tubule nucleus
   - Male gametophyte (in pollen grain) (n)
   - Pollen grains
5. FERTILIZATION
   - Zygote (2n)
   - Nucleus of developing endosperm (3n)
   - Egg nucleus (n)
   - Discharged sperm nuclei (n)
6. Endosperm (3n)
7. Seed coat (2n)
8. Seed

Key:
- Haploid (n)
- Diploid (2n)
**Angiosperm History**

- the oldest angiosperm fossil dates to ~140 million years ago
- angiosperms dominate the fossil record as of ~100 million years ago and still dominate the world today

(a) *Archaefructus sinensis*, a 125-million-year-old fossil

(b) Artist’s reconstruction of *Archaefructus sinensis*
Evolutionary Links with Animals

Many animals and angiosperms have coevolved due to close relationships that may be adversarial or mutually beneficial:

- angiosperms have evolved defenses in response to herbivores that would eat them
- angiosperms and their animal pollinators have evolved characters to reinforce their mutualistic symbioses
Angiosperm Phylogeny

Fossil and molecular evidence dictate the evolutionary history shown here.
Angiosperm Diversity

Angiosperms used to be divided into 2 groups – monocots & dicots – however now there are 6 distinct clades:

1. Amborella
2. Water Lilies
3. Star Anise & relatives
4. Magnoliids
5. Monocots
6. Eudicots
Water lilies, star anise and *Amborella* are minor angiosperm lineages that diverged from the rest of the angiosperms fairly early and collectively are referred to as basal angiosperms.
Magnoliids

Magnoliids are more closely related to the monocots & eudicots than the 3 basal angiosperms.

- includes magnolias, laurels & black pepper plants
Monocots vs Eudicots

**Embryos**
- Monocot Characteristics: One cotyledon
- Eudicot Characteristics: Two cotyledons

**Leaf venation**
- Monocot Characteristics: Veins usually parallel
- Eudicot Characteristics: Veins usually netlike

**Stems**
- Monocot Characteristics: Vascular tissue scattered
- Eudicot Characteristics: Vascular tissue usually arranged in ring
Monocots vs Eudicots (cont’d)

Monocot Characteristics
- Root system usually fibrous (no main root)
- Pollen grain with one opening
- Floral organs usually in multiples of three

Eudicot Characteristics
- Taproot (main root) usually present
- Pollen grain with three openings
- Floral organs usually in multiples of four or five
More than ¼ of angiosperm species are monocots, most of which are grasses, palms or orchids.

- much of the calories consumed by humans come from monocot grasses (e.g., corn, wheat & rice)
Eudicots

More than 2/3 of angiosperm species are eudicots of which there is great variety.

- the largest group is the legumes which includes peas & beans
- this also includes most fruit and non-conifer trees