Seed Plants

Angiosperms
- 250,000 species
- Flower power and diversification

Gymnosperms
- ~730 species
- Seed power

Cycads (oldest)
Conifers (largest)
Ginkgos
Gnetales (strangest?)

Gymnosperms and the Seed

1. Overview of evolutionary transition to seed plants
2. Adaptations of seed plants to land
3. Gymnosperms, one of the two clades of seed plants

Remember: most seedless vascular plants are homosporous, but some (e.g., the lycophyte Selaginella) are heterosporous.

Heterosporous life cycle was important in the evolution of the seed. In fact, all seed plants are heterosporous.
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The three most important new adaptations to land found in the seed plants are all shown in this diagram:
1. Very small gametophytes that are nourished by and protected inside the parental sporophyte
2. Pollen grains, which provide protection and dispersal for the male gametophyte
3. The seed, which protects and disperses the new sporophyte embryo

A seed represents 3 generations at once!

- Food Supply: Mother Gametophyte
- Seed Coat: Grand-Mother Sporophyte
- Embryo: Daughter Sporophyte

Figure 30.3 The development of a seed from an unfertilized ovule.

Figure 30.6x2 A grain of pine pollen. Microspores develop into pollen grains, which are coated with protective sporopollenin. They can be dispersed (after their release from the microsporangium) by wind or animals, and contain the male gametophyte.

Figure 38.6 If a pollen grain lands in the vicinity of an ovule, it will elongate a tube and release one or more sperm into the female gametophyte. This is called pollination. How is this mechanism of fertilization an advantage on land, compared to the method employed by seedless land plants?

Winged seed of a White Pine (Pinus strobus), a gymnosperm.
Advantages of the Seed

• Multicellular embryo gets a “head start” at the germination stage
• Stored food for embryo also allows a head start, and allows for extended dormancy
• Multicellular, larger and more complex than a spore = more resistant to harsh conditions, seed coat can govern dormancy
• Larger and more complex = increased capacity to develop dispersal adaptations

Advantages of Pollen

• Fertilization does not require water for sperm to swim through
• Pollen disperses well, allowing mating over long distances

Disadvantage of the Seed

• More energetically costly to produce
• To some extent, trade off quantity for quality

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Figure 30.5. Archaeopteris, a Progymnosperm

Progymnosperms first appeared in the Carboniferous (360 mya)

Figure 30.4. The only surviving species in Phylum Ginkgophyta: Ginkgo biloba. Ginkgo’s nice traits include that it is very tolerant of urban pollution, and turns a beautiful gold color in fall. A not-so-nice trait is that the seeds, when they decompose, smell like vomit, or worse. Ginkgos are also dioecious, so, if you want to play a bad horticultural joke on someone, plant a female Ginkgo in their yard.

Figure 30.4. Phylum Ginkgophyta: Ginkgo biloba

Ginkgos are dioecious
Figure 30.4x2  Ginkgo sperm is flagellated. Coniferophyta have non-flagellated sperm, as do all the flowering plants.

Key features of Ginkgophytes

- Exist today only as planted trees
- Dioecious (male and female gametophytes on separate plants)
  - (vs. monoecious)
- Flagellated sperm

Hypothetical phylogeny of the seed plants

Phylum Cycadophyta: cycads. These gymnosperms superficially resemble the palms, which are actually angiosperms. Only ~130 species today, the cycads thrived during the Mesozoic. Many cycads are insect-pollinated.

Gnetales: Division Gnetophyta

- A fuzzy window into seed plant evolution and phylogeny
- A rare glimpse into unique adaptations and extreme divergence
- A real puzzle
- What are the gnetales??
The gnetales

- Ephedra: ~45 species
  - Shrubs adapted to arid conditions
  - Photosynthetic stems
  - Reduced leaves
  - Source of ephedrin

- Gnetum: ~35 species
  - Moist tropics
  - Wide leaves
  - Vines, lianas
  - Unique female gametophyte development
  - Medicinal

- Welwitschia: one species
  - Dry - extreme xerophyte
  - Two leaves
  - Mostly below ground
  - Longer-lived
  - Extensive taproot

Gnetales-general characteristics

- Three genera: Ephedra, Gnetum, Welwitschia
- Ephedra and Welwitschia are adapted to dry climates, while Gnetum is moist tropical
- Largely disjunct distributions
- Mostly dioecious
- Vessels in xylem (??)
- Double fertilization (??)
- Evolutionarily derived traits
- Pollinated by wind and insects
- Important medicinals

Phylogeny of the Gnetales

- Cosmopolitan: arid regions of North America, Mexico, South America (Ecuador to Patagonia and lowland Argentina), Europe, Asia, and N Africa (including the Canary Islands)
- Photosynthetic stems
- Stems resemble equisetum (horsetails)
- Leaves opposite or whorled, scale-like
- Double fertilization
- Presence of vessels in the xylem (in addition to tracheids)

Genus Ephedra (mormon tea)

- ~ 45 species of shrubs
- Cosmopolitan: arid regions of North America, Mexico, South America (Ecuador to Patagonia and lowland Argentina), Europe, Asia, and N Africa (including the Canary Islands)
- Photosynthetic stems
- Stems resemble equisetum (horsetails)
- Leaves opposite or whorled, scale-like
- Double fertilization
- Presence of vessels in the xylem (in addition to tracheids)

Ephedra:
Source of the alkaloid ephedrin

- Used as a decongestant, a digestive aid, and when mixed with caffeine, is a powerful metabolic stimulator (used in weight control and muscle building)
- Controversial

Plant-derived chemical: ephedrine

- Ephedra plants contain ephedrine & related alkaloids
- Ma huang used in traditional Chinese medicine
- Mormon tea made use of ephedrine’s stimulant effect
- Modern dietary supplements for weight loss (now illegal)
- Asthma, cold medications
**Ephedra**

- Female (ovulate) cones
- Male (staminate) cones

**Genus Gnetum**

- 30-40 species
- Moist tropics - Pantropical (America, Asia, Africa)
- Wide leaves
- Netted venation in leaves
- Climbing vines, one tree, lianas
- Possible double fertilization
- Unique female gametophyte development: the embryo nourishing provision is a post-fertilization event

**Gnetum as a medicinal**

- Local name: Uña de gatto
- Harvested part: Bark
- Preparation: Soak in boiled water
- Medicinal application: arthritis, cancer, diabetes, aids
- Peru

**Ginkgo leaf:** parallel venation

**Gnetum leaf:** reticulate venation

**Gnetophytes are the only gymnosperms with vessel elements in their xylem**

**Flower-like reproductive structures (strobili)**
**Genus *Welwitschia***

- 1 species (*mirabilis*)
- Adapted to extremely dry conditions (extreme xerophyte)
- Extensive taproot
- Can live is over 1500 years!
- Most of the stem is underground
- One pair of leaves will last the entire life of the plant, but will split with exposure (continuous growth)
- Cone with female flowers is quite large
- Pollination likely by wind and by a beetle

**Distribution of *Welwitschia mirabilis***

Restricted to the skeleton coast region of the Namib Desert

**Desert Bushmen made maps to locate water and game. **Welwitschia** plants were used both as a source of water and on maps!**

**The controversy**

- The Gnetales (*Gnetum*, *Ephedra*, *Welwitschia*) have been assumed to be the closest living relatives to flowering plants.
- Evidence:
  - double fertilization
  - reduced female gametophyte
  - leaves with netted venation (*Gnetum*)
  - cones superficially resemble flowers
  - xylem with vessels
- However, recent molecular phylogenetic analyses place Gnetales with other conifers, leaving the closest relative of the flowering plants an extinct lineage of gymnosperms that we have yet to discover in the fossil record.

**Gnetales and other seed-plants - Morphological studies**

Anthophyte Hypothesis
(Crane, 1985; Crane et al., 1995)

Fits well with:
Double fertilization
(Friedman, 1990, 1994, 1996)
**Phylogeny**

1) Morphological studies placed gnetales sister to angiosperms
2) Molecular studies place gnetales sister to conifers

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**Peculiarities: xylem structure and reproduction**

Gnetales have vessels in the xylem in addition to tracheids - an angiosperm-like feature

Gnetales undergo a form of double fertilization, unique in non-flowering seed plants, and more like angiosperms

*These odd features (for a gymnosperm), have linked gnetales to angiosperms in some researchers’ eyes, and are simply evidence of derived traits in the eyes of others.*

**Comparison to angiosperms**

- Angiosperm double fertilization results in a 2N zygote and a 3N endosperm, in gnetales both are 2N
- In both it is a sister nucleus that is fertilized (ventral canal nucleus in is sister)
- Both sperm come from a single pollen tube
- In Gnetum, the embryo nourishing provision is a post-fertilization event (the only non-flowering seed plant)
- In gnetales, nourishment of the embryo depends on maternal reserves in the female gametophyte, as in other gymnosperms

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**So??**

- Is double fertilization homologous?
- Convergent evolution?
- Did it arise independently in gnetales and angiosperms?
- Useful result in angiosperms, but in gnetales?
- This needs further investigation!! A thorough study of basal angiosperm groups may provide insights…

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**Important features the gnetales share with angiosperms**

- Vessel elements in addition to tracheids in xylem
- Double fertilization in Ephedra and possibly gnetum
- Insect attractants

*None of the extant gnetophytes are relatives of angiosperms
These shared characteristics likely arose independently: convergent evolution rather than shared ancestry*
Key points

- Gnetales may provide clues to the origin of endosperm and a link to angiosperms
- They are likely more related to (sister to) the conifers than angiosperms
- Double fertilization and vessels in the xylem may have arisen more than once in plants (separately), and their presence does not automatically mean relatedness or ancestry
- Main characteristics:
  - Disjunct distributions
  - Dioecious
  - Evolutionarily derived traits
  - Pollinated by wind and insects
  - Important medicinals

Gnetales

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Flora

- **Monterey pine** (**Pinus radiata**) near Ano Nuevo, just north of Santa Cruz, CA. It is locally dominant in its small native range: 3 spots along the California coast, and two Mexican islands. It is also the most widely planted tree in the world for forestry, being the primary timber tree in New Zealand, Australia, Chile, Argentina, South Africa, and elsewhere. In some of those places, it has become a problematic invasive plant as well.

- **Figure 30.6** The life cycle of a pine (Layer 3)
A closer look at pine cones (*Pinus* sp.): male (microsporangiate) cones

Pollen is dispersed by wind.

**Conifer Ecology**

- Often locally dominant species
- Include some of the largest, oldest organisms on Earth
- Evergreens with needles - adapted to conserve water, deal with short growing season
- Wind-dispersed pollen
- Multi-year lifecycle