Angiosperms: Phylum Anthophyta, the flowering plants

1. Overview of seed plant evolution
2. Traits of flowering plants
   a) Flowers
   b) Monocots vrs. Dicots
3. Pollination
4. The angiosperm life cycle

Figure 29.7 Land plant evolution.

Three variations on gametophyte/sporophyte relationships.

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 (reduced even further in angiosperms)
2. Pollen grains, which provide protection and dispersal for the male gametophyte (often animal-dispersed in angiosperms)
3. The seed, which protects and disperses the new sporophyte embryo (angiosperms: develop in flowers, dispersed in fruits)
Flowering plants used to be divided into two groups: monocots and dicots.

We now know that there are a number of different lineages that have the dicot morphology. Dicots are not monophyletic.

Monocots are a monophyletic group.

Angiosperms:
- Are commonly known as flowering plants.
- Are seed plants that produce the reproductive structures called flowers and fruits.
- Are the most widespread and diverse of all plants.

Angiosperm evolution:
- First angiosperms appeared ~240 mya.
- By the end of the mesozoic (~65 mya), angiosperms dominated many landscapes.
- Coevolution between plants and animals very important:
  - Herbivores
  - Pollinators
  - Seed (often via fruit) dispersers
Amborella

- The most primitive angiosperm has moderate sized, perfect flowers,
- Parts are spirally arranged and have a moderate number of parts.
- Floral evolution moves towards unisexual flowers, larger AND smaller flower sizes, other perianth arrangements, and larger AND smaller numbers of flower parts.

Magnolias

- In one view, the most primitive angiosperm resembled a Magnolia
- had large, showy, unspecialized, spirally arranged flowers.
- No fusion of parts
- little differentiation of parts.

Hypothesis for the evolutionary origin of the carpel from a reproductive leaf (sporophyll)

- Angiosperms evolved from male gymnosperms
- Pollen and ovule producing structures combined into a single flower: mutation
- Mutation: ovules developed on some microsporophylls = carpels
- Evidence: Flower development genes are similar to pollen producing gymnosperm genes
- Position of ovules can be easily changed with mutations
Traits of angiosperms

• Vascular seed plants that produce flowers and fruits
• Extremely diverse: ~350,000 known species (compare to 720 gymnosperm spp.)
• Xylem tissue not only has tracheids, but also fibers and vessel elements (except Amborella)
• Life cycle includes “double fertilization”

Flowers

• A flower is a specialized shoot with modified leaves
  – Sepals, which enclose the flower
  – Petals, which are brightly colored and attract pollinators
  – Stamens, which produce pollen
  – Carpels, which produce ovules

Figure 30.7

Figure 30.7 The structure of a flower. Flower = modified reproductive shoot with 4 circles (“whorls”) of modified leaves

"Male" parts, produce microspores, which develop into pollen grains

"Female" parts, produce megaspores & thus female gametophytes, and ultimately ovules and seeds

How does this differ from the reproductive structures of the other seed plants, the gymnosperms?

More flower terminology

All stamens together = "androecium"

All petals together = "corolla"

All carpels together = "pistil" or "gynoecium"

Ovules found in cavity = "focula"
Flower terminology: symmetry

**Trillium:** a complete flower (has all 4 basic floral organs)

**Grass flower:** incomplete (lacks petals)

Note: most grasses wind-pollinated

Why might petals be unimportant for grasses?

**Bisexual (perfect) flowers have both stamens and carpels, like this Lily**
Begonia, a monoecious species with unisexual (imperfect) flowers. (staminate flowers (left), carpellate flowers (right).

In monoecious species, both sexes of flowers are found on a single plant. Why are the carpels and stamens similarly colored yellow?

Sagittaria: a dioecious species, with staminate flowers (left), and carpellate flowers (right) growing on separate plants.

Grape hyacinth has flowers clustered in inflorescences. A solitary flower grows on a stalk called a peduncle

Individual flowers in an inflorescence grow on pedicels

The whole inflorescence is attached to a peduncle
Pyrethrum, a composite flower (a special kind of inflorescence). Notice the two types of flowers, disc flowers (center) and ray flowers (at edge, each with a petal).

Hypogynous

Superior ovary

Perigynous

Semi-inferior ovary

Epigynous

Inferior ovary

Figure 30.12 Representatives of major angiosperm clades

- Flowering plants used to be divided into two groups: monocots and dicots
- We now know that there are a number of different lineages that have the dicot morphology
- Monocots are a monophyletic group

Figure 30.12 Monocots vs. Dicots
Monocots vs. non-monocots
("dicots" = eudicots and other lineages)

- Monocots (incl. lilies, orchids, yuccas, palms, grasses) usually have parallel veins in leaves, a single cotyledon, fibrous root systems, floral parts in multiples of three, and complexity arranged vascular bundles in stem

- Dicots usually have net-like venation, two cotyledons, a taproot system, floral parts in multiples of four or five, and vascular bundles arranged in a ring in stem

Review of flower terminology

- 4 floral organs: sepal, petal, stamen, carpel
- radial vs. bilateral symmetry
- complete vs. incomplete flowers
- bisexual (perfect) vs. unisexual (imperfect) flowers
- monoecious vs. dioecious plants
- inflorescences and composite flowers
- ovary position

Pollination

- Avoiding self pollination
- Mechanisms of pollination: abiotic and biotic
- Pollination syndromes
Pollination: getting pollen to the stigma

• Required for sexual reproduction in plants: pollination allows fertilization to take place. What are the potential advantages and disadvantages of sexual reproduction?

• A huge variety of adaptations have evolved in plants to ensure successful pollination, including biotic (via animals) and abiotic (via wind or water) mechanisms.

Sexual vs. asexual reproduction

• Key potential advantage of sex: genetic variation in the offspring, which could allow some to survive when faced with a rapidly changing environment (such as rapidly evolving diseases or a changing climate).

• Potential disadvantages of sex:
  - Only half of the population (females) can produce offspring. In an asexual species, all individuals can reproduce, by cloning themselves.
  - Sexual structures (e.g. flowers) are often costly.
  - Pollination can sometimes be difficult, if animal pollinators or wind are not available, or if other members of the species are sparse.
  - Sex can break up successful genotypes: offspring may be less-suited for the current environment than are the parents.

Ways to reproduce and avoid the disadvantages of sexual reproduction

1. Self-pollination or “selfing.” This is sexual reproduction (i.e. it involves meiosis and fertilization), but offspring from selfing are genetically very similar to the parent.

2. Asexual reproduction, or cloning. Only mitosis is involved, and offspring are genetically identical to the parent (unless mutations occur during DNA replication).

Many plant species reproduce only by self-pollination, and many also have the ability to reproduce asexually. In what environments or situations would you expect these strategies to evolve?

Mechanisms for avoiding self-pollination in sexual reproduction

1. Being dioecious: male and female parts on separate plants.

2. In monoecious plants, with separate male and female flowers on the same plant, these flowers mature at different times or are physically separated.

3. Dichogamy: stamens and carpels mature at different times on the same (perfect) flower.

4. Stamens and carpels are physically separated in the same flower.
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4. Stamens and carpels are physically separated in the same flower.
5. Genetic self-incompatibility: pollen will not successfully fertilize if its self-sterility genes match those of the recipient plant.

Pollination ecology

- 2 main modes of dispersal for pollen: abiotic (mostly wind but also water) and biotic (usually animals such as insects, birds, and bats).
- These 2 strategies are thought to have different advantages in different environments.
**Wind pollination**

- May be advantageous in habitats that lack reliable animal pollinators, such as a newly-colonized habitat
- More common in open habitats and at higher latitudes and elevations, with low humidity and rainfall
- Feathery stigmas and long stamens
- Pollen grains abundant, small, and smooth
- Flowers usually lack nectar, fragrance, and petals, and are unisexual
- Most grasses, and many trees (such as birches, and most gymnosperms)

**Biotic (animal) pollination**

- Only advantageous in habitats that have reliable animal pollinators, such as bees
- Common in a wide variety of habitats, from dry to moist, tropical to temperate
- Simple stigmas and variable stamens
- Pollen grains less abundant, variable in size, and often with elaborate ornamentation
- Flowers usually have nectar, fragrance, and a showy perianth (petals and/or sepals), and are usually bisexual

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**Pollination “syndromes” in flowers**

- Some flowering plant species have evolved specific morphologies that attract certain kinds of animal pollinators

- However, remember that many important pollinators (such as honey bees) are *generalists*, i.e. they associate with many different kinds of plant species, and many plant species attract a *variety* of pollinators
### Examples of pollinator-specific flower morphologies
- Hummingbird-pollinated: red, odorless, with long corolla tube and copious nectar
- Moth or bat-pollinated: white, with strong sweet odor emitted only at night
- Bee-pollinated: brightly-colored yellow or blue petals with distinct markings, and a landing platform
- Fly-pollinated: dark red-brown color with foul odor (like rotting flesh)

### Many orchids (plant family Orchidaceae) have evolved very specific pollination relationships with bees. For example, some mimic the body and pheromones of female bees, to attract the males as pollinators

### Traits of angiosperms
- Vascular seed plants that produce flowers and fruits
- Extremely diverse: ~350,000 known species (compare to 720 gymnosperm spp.)
- Xylem tissue not only has tracheids, but also fibers and vessel elements (except Amborella)
- Life cycle includes “double fertilization”
Angiosperm seeds consist of diploid and triploid tissues

Figure 38.6 Growth of the pollen tube and double fertilization

1. If a pollen grain germinates, a pollen tube grows down the style toward the ovary.

2. The pollen tube discharges two sperm into the female gametophyte (embryo sac) within an ovule.

3. One sperm fertilizes the egg, forming the zygote. The other sperm combines with the two polar nuclei of the embryo sac’s large central cell, forming a triploid cell that develops into the nutritive tissue called endosperm.

Embryo:
- Diploid (from fertilized egg)
- Triploid (from polar nuclei and second sperm)

Food Supply:
- Endosperm (from polar nuclei)

Seed Coat:
- Diploid (from ovule wall)

Embryo:
- Diploid (from fertilized egg)
- Triploid (from polar nuclei and second sperm)

Ovule
- Polar nuclei
- Egg
- Two sperm about to be discharged

Endosperm nucleus (3n)
- (2 polar nuclei plus sperm)

Zygote (2n)
- (egg plus sperm)
Angiosperm seeds consist of diploid and triploid tissues

Why double fertilization?

- According to one hypothesis, double fertilization synchronizes development of food supply (endosperm) with development of the embryo: if no fertilization of the egg occurs, no resources are wasted on building the food supply.
Endosperm-derived foods

Figure 38.7 The development of a dicot plant embryo

Figure 30.10 Detailed life cycle of an angiosperm

Land Plant Lifecycles: all have...

- Alternation of gametophyte (n) and sporophyte (2n) generations
- Sporophyte (2n) produces spores (n) through meiosis
- Spores (n) grow into gametophyte (n)
- Gametophyte (n) makes gametes (eggs or sperm, both n) through mitosis
- Gametes (n) fuse to form zygote (2n) though fertilization; zygote (2n) grows into sporophyte (2n)
Land Plant Lifecycles: differences...

- Which generation (sporophyte/gametophyte) is dominant: larger, longer lived?
- Is the other generation dependent or independent?
- Homosporous or heterosporous?
- Is free water required for fertilization?
- Is the embryo (young sporophyte) enclosed in a seed?
- Is the seed produced by a flower? Enclosed in a fruit? Is there double fertilization?

Gymnosperm vs. Angiosperm

- **Seeds**
  - Food Supply: Triplet
  - Female Gametophyte
  - Embryo: Diploid
  - Seed Coat: Diploid

Angiosperms

- Angiosperm life cycle, double fertilization
  - Be careful about megaspore mother cell vs. megaspore
  - Recognize stages as coming before/after meiosis, fertilization
- Advantages and disadvantages of sexual vs. asexual reproduction, environments favoring each
- Advantages and disadvantages of selfing, mechanisms to avoid selfing
- Biotic vs. abiotic pollen dispersal, advantages of each; pollination syndromes

Angiosperms

- Fruits vs. seeds (ovaries vs. ovules)
- Fruit types
- Ecology of fruit dispersal
- Advantages of seed dormancy, cues and mechanisms for breaking dormancy
- Germination process, roles of the radicle and hypocotyl/cotyledon
Seed adaptations for survival and germination

- Many seeds exhibit dormancy, a temporary condition of low metabolism and no growth or development. Some seeds can survive like this for decades or more. What are the potential benefits of dormancy?
- Dormancy in some seeds is simply broken by favorable environmental conditions, but others only germinate after specific cues.
- What would you expect the cues to be for seeds living in deserts, fire-prone habitats (such as California chaparral), or at high latitudes? How about for seeds borne in berries eaten by mammals?

The four steps of seed germination: 1. imbibition of water, 2. enzyme digestion of stored food, 3. embryo begins growth and radicle is pushed through the seed coat, and 4. shoot tip grows toward soil surface.

Germination of a barley seed is shown below.

Figure 38.8 Review: Three types of seed structure

Figure 38.10 Two ways that young shoots break through the soil surface.