The life cycle of plants alternates between sporophyte and gametophyte generations.
Floral Organs: Structure and Function
• Flowers develop from compressed shoots, from four whorls of modified leaves
• Flowers consist of four organs,
  • Non-reproductive floral organs
    • Sepals
    • Petals
  • Reproductive floral organs
    • Stamens
    • Carpels
• Reproductive organs contain sporangia – chambers in which gametophytes develop:
  • male gametophyte: pollen grain
  • female gametophyte: embryo sac

Lily

Details of the female reproductive organ
Pistil is a female reproductive structure containing one or more carpels; many flowers have two or more fused carpels, which may be referred to as fused pistils
The base of a pistil is an ovary
The ovary contains one or more ovules, each of which contains a megasporangium

The ovary develops into a fruit adapted for seed dispersal

Relationship between a pea flower and a fruit
Idealized Flower

Overview of angiosperm life cycle

- **Pollen grain** develops in chambers within the anther
- **Embryo sac** develops inside ovule which in turn is enclosed in ovary

• Sperm-bearing pollen is the male gametophyte
• Egg of an ovule is fertilized in the ovary, by a sperm cell released from a pollen tube
• Egg is part of the embryo sac; the female gametophyte
Overview of angiosperm life cycle

Pollination, Growth of Pollen Tube, and Double Fertilization

- **Pollination**: pollen lands on stigma
- **wind pollination**: many grasses, trees…
- **animal-mediated pollination**: many angiosperms
- **self-pollination**: evolution of mechanisms preventing this in many angiosperms

- **Pollen grain** produces tube that grows between cells of style, toward the ovary
- **Tube discharges two sperm into embryo sac**
  - One fertilizes egg, forming zygote
  - One combines with the two polar nuclei of the embryo sac’s large central cell, forming triploid cell; develops into 3n nutritive tissue, the endosperm

- **Double fertilization**: conserves resources – nutrients only develop in ovules with fertile egg
- **Ovule** develops into seed
- **Ovary** develops into fruit enclosing the seed
Details of Angiosperm Double Fertilization

1. Initially the pollen tube contains two haploid cells, the generative cell (sperm) and the tube cell.

2. The generative cell divides, producing two haploid sperm cells.

3. The sperm cells enter the cytoplasm of a synergid.

4. The synergid breaks down; one sperm nucleus fertilizes the egg, forming the zygote, the first cell of the 2n sporophyte generation.

5. The other unites with the two polar nuclei, forming the first cell of the 3n endosperm.

Development of ovule into seed with developing embryo and nutrient supply

Endosperm development

- Triploid nucleus divides, forming multinucleate "supercell"; the endosperm, which becomes multicellular as cell membranes & walls are laid down
- Nutrient-rich endosperm provides nourishment for developing embryo

Embryo development

- Transverse mitotic division produces terminal cell & basal cell
- Terminal cell divides, gives rise to proembryo
- Cotyledons form as bumps on proembryo, grow to envelope the embryo
- Embryo elongates: embryonic apical root and shoot meristems differentiate (root meristem develops partly from basal cell in some species); embryonic primary meristems differentiate
- Transverse divisions of basal cell gives rise to suspensor that will anchor embryo to ovule integuments, transfer nutrients from parent plant and, in some plants, from endosperm

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Self Incompatibility

Genetic variation among offspring regarded as adaptive, and is a leading hypothesis for evolution, maintenance of sexual reproduction.

Inbreeding, ie reproduction with close relatives, is selected against.

Many plants reject pollen from their own flowers, ie, are self-incompatible.

Self-incompatibility promotes genetic variation.

Self-incompatibility promotes outbreeding in the sense that selfing is a form of breeding with a close relative.
As they mature, seeds dehydrate and become dormant (low metabolism, no growth & development). Germination is the resumption of growth, development and metabolic rate, is triggered by the environmental conditions.

**Example in Barley Seed** Imbibition of water induces embryo to release gibberellins, a hormone, which induces aleurone (outer layer of endosperm) to secrete digestive enzymes (e.g., alpha-amylase) that hydrolyze starch. Sugars and other nutrients are absorbed by cotyledon (scutellum) from endosperm and are consumed during growth of embryo into seedling (after Campbell 2002).
Transition to Flowering State

Apical meristems in vegetative state are called vegetative apical meristems; give rise to leaves lateral buds, internodes

Through a cascade of gene expression, vegetative apical meristems differentiate into reproductive meristems, either inflorescence or floral meristems

Inflorescence meristems typically then generate bracts and floral meristems

Floral meristems produce four whorls of floral organs; sepals, petals, stamens, carpels, with highly reduced internodes

Apical meristems and some inflorescence meristems generate indeterminate growth; floral meristems generate determinate (restricted) growth

Overview of regulatory gene control, an example Homeotic genes (produce transcription factors) play an important role

Through expression of floral meristem identity genes, inflorescence meristem gives rise to floral meristem

Expression of as-yet unidentified regulatory genes participates in pattern formation; organization of whorled floral organs

Expression of organ identity genes participate in specifying the successive whorls

Inflorescence in queen anne’s lace is an umbel; each umbel bears flowers on stalks that arise from a common center
Maryland Mammoth tobacco flowers only when days are shorter than 14 hours; that is, its critical day length is 14 hours.

Henbane flowers only when days are longer than 14 hours, its critical day length.

Maryland Mammoth tobacco (short-day plant)

Henbane, Hyoscyamus niger (long-day plant)

Long days: plant remains vegetative  Short days: plant flowers  Long days: plant flowers  Short days: plant remains vegetative
**Evolutionary perspective Angiosperm reproductive biology**

Decline of some woody plants; rise of herbaceous plants

Extinction of some plant species

Expansion of extensive grasslands and deserts; decline of forests

Flowering plants continue to diversify

Spread of forests; flowering plant communities expand

Flowering plants dominant

Semi-tropical vegetation – flowering plants and conifers widespread

Rise of flowering plants
The pollen grain is the male gametophyte.
The zygote (from 3 nuclei) forms the embryo and female gametophyte.
The pollen tube grows toward the female gametophyte.

Flowers in a primitive lineage -- Magnolias

Trends in Floral Symmetry

In most members of the Sunflower family, the flowers are clustered in a radially symmetrical head. Part of the corolla of each ray flower is enlarged and extends out into a petal-like ray.

Flowers are bilaterally symmetrical in species in the Orchid family.
Number of petals is reduced to five in wild geranium.

In the hanging flowers of Baobob, the stamens are united into a tube around the style.