

Introduction to Botany

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Lectures 32–35

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Seed plants

- Diversity of seed plants
- “Higher” seed plants
- Conifers
- Gnetophytes
- Flowering plants
- Class Magnoliopsida, or Angiospermae
- Flower
- Flower development: ABC model
- Primitive flowers
- Four subclasses of angiosperms
- Pollination
- Inflorescences
- Seeds
- Fruits

Seed plants

Diversity of seed plants

Spermatophyta: seed plants

- ≈ 1000 species of non-angiosperms and $\approx 250,000$ species of angiosperms (99.6% of seed plants)
- Sporic life cycle with sporophyte predominance and **seed**
- Gametophyte is reduced to cells inside ovule or inside pollen grain. Minimum number of cells is 3 for male gametophyte (pollen grain) and 4 for female gametophyte (embryo sac of angiosperms). Antheridia are reduced. In angiosperms and Gnetales, archegonia are also reduced.
- Sporophyte always starts development from embryo located inside nutrition tissue, endosperm₁ (female gametophyte) or endosperm₂ (second embryo)
- Have axillary buds
- Homiohydric plants (same as ferns)
- Have secondary thickening

Spermatophyta classes

- **Ginkgoopsida**, ginkgo class
- **Cycadopsida**, cycads
- **Pinopsida**, conifers
- **Gnetopsida**, gnetophytes or chlamydosperms
- **Angiospermae**, or Magnoliopsida, flowering plants

Ginkgoopsida

- Smallest class, only one species (!), Chinese tree *Ginkgo biloba* which became extinct several thousand years ago but saved as a "church tree".
- Distinctive triangle-shaped leaves with dichotomous venation
- Ovules are solitary or paired; microsporangia are in catkin-like structures; has sexual chromosomes (!)
- Pollen grains produce two mutli-flagellate spermatozoa which swim to large oocyte
- Seeds are fruit-like (generally edible), become ripe laying on a ground for a long time
- Almost no phytophagous insects damage *Ginkgo* leaves; the fungal symbiont of *Ginkgo* also belongs to separate class inside basidiomycetes, Bartheletiomycetes.

Ginkgo biloba ovules



Ginkgo biloba male organs



Ginkgo biloba seeds



Cycadopsida

- Two families, dozen genera and ≈ 300 species distributed mostly in tropics
- Palm-like plants, with large (and usually very rigid) pinnate leaves
- Stem structure is not similar to conifers and *Ginkgo*; cycads have large pith and anomalous secondary thickening via multiple cambium rings
- Ovules are attached to modified leaves (sporophylls) and usually gathered in large upright cones; microsporangia are always in cones
- Also have multi-flagellate spermatozoa, archegonia and large oocyte
- Large seeds are animal-distributed; life cycle is extremely slow (several years from initiation of cone to germination of seed).

Cycadopsida families

- Two families, sometimes even placed in different orders:
 - Cycadaceae, with only genus *Cycas*. They do not have female cones, ovules are attached to leaves which are not radically modified. Leaves have fiddleheads (same in ferns!).
 - Zamiaceae, with all other genera (*Zamia integrifolia* is native to USA). Have female cones.

Cycas sp.: young leaflets form fiddleheads



Male *Cycas* sp. in dry season



Cycas sp. seeds



Encephalartos gratus (Zamiaceae)



Zamia integrifolia (Zamiaceae)



Seed plants

"Higher" seed plants

Spermatophyta classes

"Lower":

- **Ginkgoopsida**, ginkgo class
- **Cycadopsida**, cycads

"Higher":

- **Pinopsida**, conifers
- **Gnetopsida**, gnetophytes or chlamydosperms
- **Angiospermae**, or Magnoliopsida, flowering plants

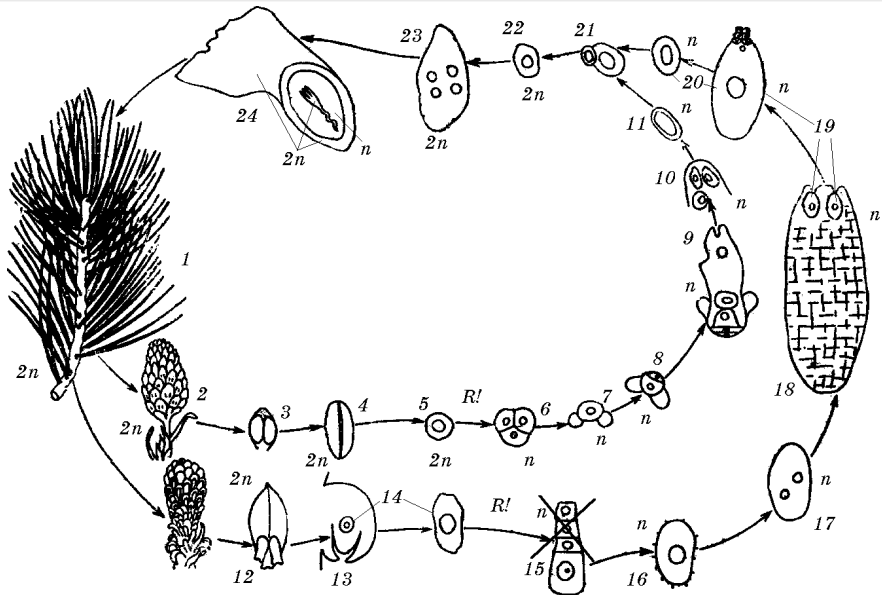
Seed plants

Conifers

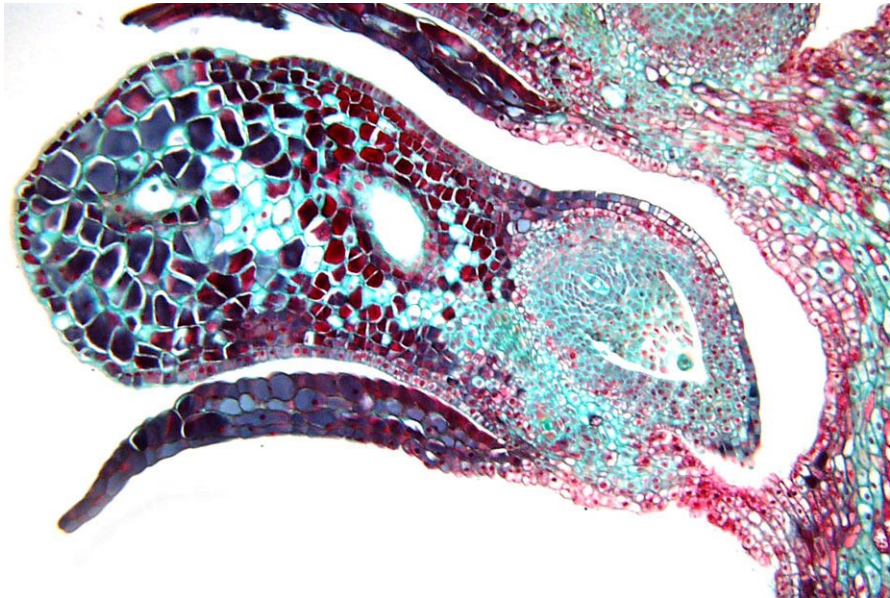
Pinopsida

- Three orders, several families and ≈ 600 species
- Mostly temperate evergreen trees, but some are deciduous (like *Larix*, *Pseudolarix*, and part of Cupressaceae)
- Stem with large amount of xylem, relatively small cork and minute pith
- Ovules are always attached to specialized leaves (seed scales) and together with bract scales they are compacted in cones; microsporangia are attached to microsporophylls and also occur in cones of simpler structure
- Male gametes without flagella (spermata), consequently, pollen grains grow into **pollen tubes**
- Female gametophyte is more reduced than in cycads and *Ginkgo*
- Seeds are wind- and animal-distributed, life cycle shorter but still up to two years

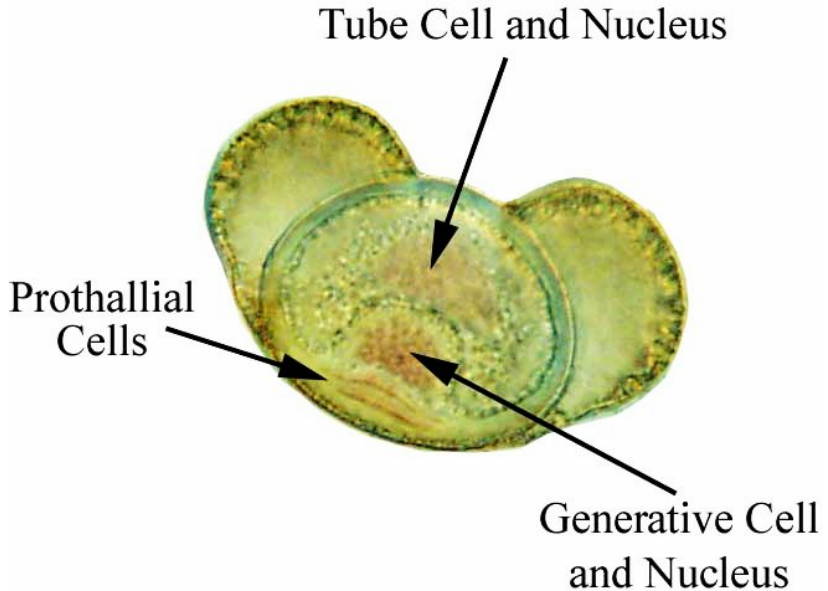
Life cycle of conifers: another view



Bract scale, seed scale and ovule



Pollen grain



Pinopsida orders and families

- Pinales
 - **Pinaceae.**
- Araucariales—grow mostly in tropics or in South Hemisphere.
 - Araucariaceae
 - Podocarpaceae
- Cupressales
 - Sciadopityaceae
 - Cupressaceae (incl. Taxodiaceae)
 - Cephalotaxaceae
 - Taxaceae

Pinaceae

- Have resin and needle-like leaves, often in shortened shoots, **brachyblasts**. Large cones with paired (seed and bract) scales.
- Biggest conifer family, include large genus *Pinus* (pine) and other genera like *Larix* (larch), *Cedrus* (cedar), *Picea* (spruce), *Abies* (fir) etc.

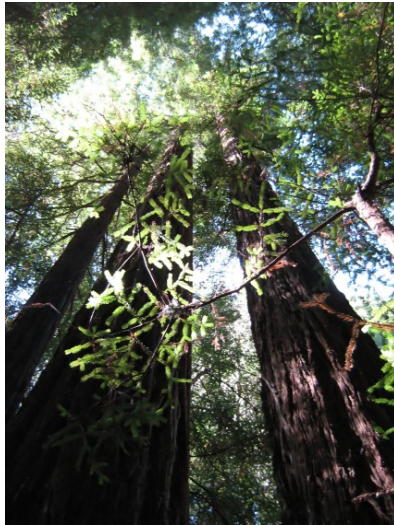
Cupressaceae and Taxaceae

- **Cupressaceae**—cypress family. No resin. Cones are small, with fused bract and seed scales. Leaves are dimorphic, needle-like and scale-like. Part of genera (formerly belong to Taxaceae family) are deciduous but with branches instead of leaves. Genera: *Cupressus* (cypress), *Juniperus* (juniper), *Taxodium* (bald cypress), *Sequoia* (coastal red cedar), *Sequoiadendron* (mountain red cedar), *Metasequoia* etc.
- **Taxaceae**—yew family. Female cones are modified in berry-like structures with one enlarged red scale. Leaves are needle-like. No resin. *Taxus* (yew) provides famous reddish-brown, springy wood.

Pseudolarix amabilis (Pinaceae), spring



Sequoia sempervirens (Cupressaceae)



Taxus baccata, Taxaceae



Seed plants

Gnetophytes

Gnetopsida

- Small class of only three genera (*Ephedra*, *Welwitschia*, *Gnetum*), which are so different that botanists place them in different orders (and sometimes even subclasses).
- Tropical trees (*Gnetum*) or desert shrubs (*Ephedra*) or nobody-knows-what (*Welwitschia*)
- Stem structure is similar to conifers but *Gnetum* and *Welwitschia* have vessels (like angiosperms)
- Ovules are solitary, **covered with additional outer integument** (however, **this is not a pistil** because micropyle come out of this cover)
- Male gametes are spermatia, have pollen tube and **no archegonia** in *Gnetum* and *Welwitschia* (like in angiosperms). Multiple fertilization and polyembryony is widespread, *Ephedra* and *Gnetum* even has a double fertilization (like angiosperms). Only one embryo survives, other are eaten (endosperm₂). Also have endosperm₁ (female gametophyte).
- *Welwitschia* is insect-pollinated, other are wind-pollinated like most non-angiosperms.
- Seeds are animal-dispersed (except *Welwitschia*).
- Amazingly, molecular data show relations with conifers, not with angiosperms!

Gnetum

- Tropical shrubs, vines or small trees (30–35 species) with opposite leaves with pterodromous venation (like angiosperms again!). However, investigation of leaf development showed that initially leaf had dichotomous venation (like *Ginkgo* and some conifers).
- Dioecious plants, male and female structures (fructifications) are catkin-like
- Seeds big, colored

Gnetum seeds



Gnetum female fructifications



Gnetum male fructifications



Welwitschia

- One species occurring in Namibian desert (South Africa)
- Life form is completely unusual, the best description is “overgrown seedling”: small trunk with only two (constantly growing on the basement and degrading on top) wide leaves with parallelodromous venation. Secondary thickening anomalous (like in cycads). Wood with vessels.
- Insect-pollinated (!) dioecious plants
- Fructifications are cone-like; male one is similar to flower and contain sterile ovule (!)
- Seeds are wind-dispersed

Welwitschia



Welwitschia



Welwitschia female cones



Welwitschia male cones



Welwitschia pollinators: *Odontopus sexpunctulatus* bug



Ephedra

- \approx 35 species growing in dry places across all North Hemisphere and also in South America
- Shrubs or small trees, leaves are usually reduced to scales, stems are articulate (like horsetails). Wood is similar to conifers.
- Plants are monoecious or dioecious, male and female (bisexual also occur) fructifications are short, covered with thick scales
- Wind-pollinated, animal dispersed
- *Ephedra sinensis* is a source of pharmaceutically important **ephedrine**
- In all, *Ephedra* is more primitive than two other genera of Gnetales: wood does not contain vessels, ovule has large archegonia

Ephedra



Ephedra nevadensis, female fructification



Ephedra nevadensis, male fructification



Ephedra seeds



Seed plants

Flowering plants

Flowering plants are “Spermatophyta 2.0”

- Reduction of gametophyte: 3-celled pollen and 7-celled embryo sac
- No archegonia and anteridia
- Spermatia, pollen tube
- Double fertilization
- New endosperm (second embryo)
- Cupule (pistil) and fruit
- In general, **angiosperms have accelerated life cycle** needed for fast-growing herbs

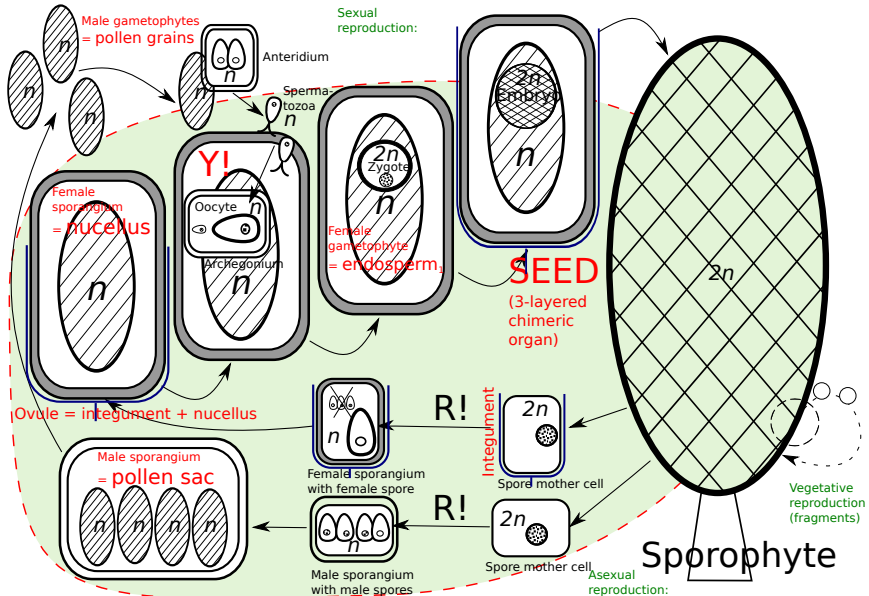
Note: angiosperms = flowering plants = class Magnoliopsida

Life cycle of angiosperms

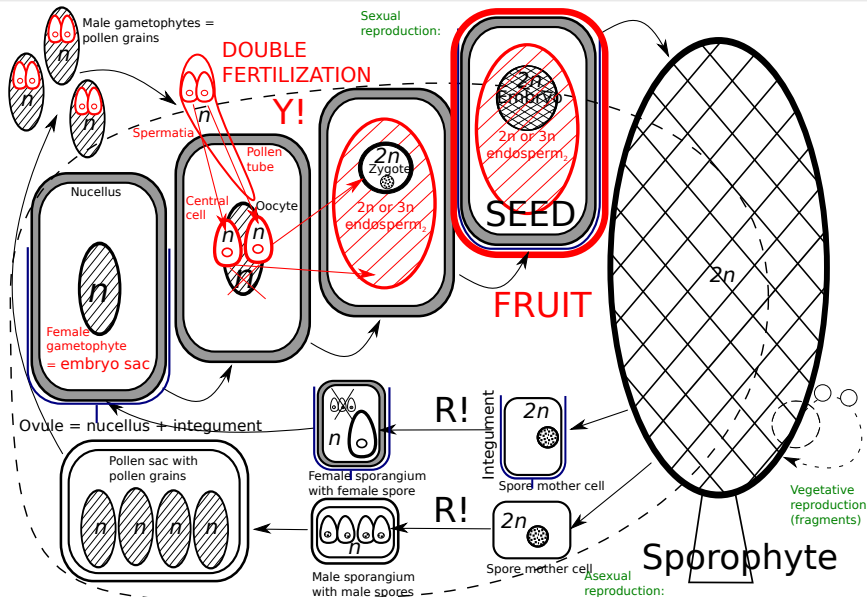
Terms covered:

- Embryo sac, central cell
- Spermatia (sperms without flagella), pollen tube
- Double fertilization
- Pistil and ovule → fruit and seed

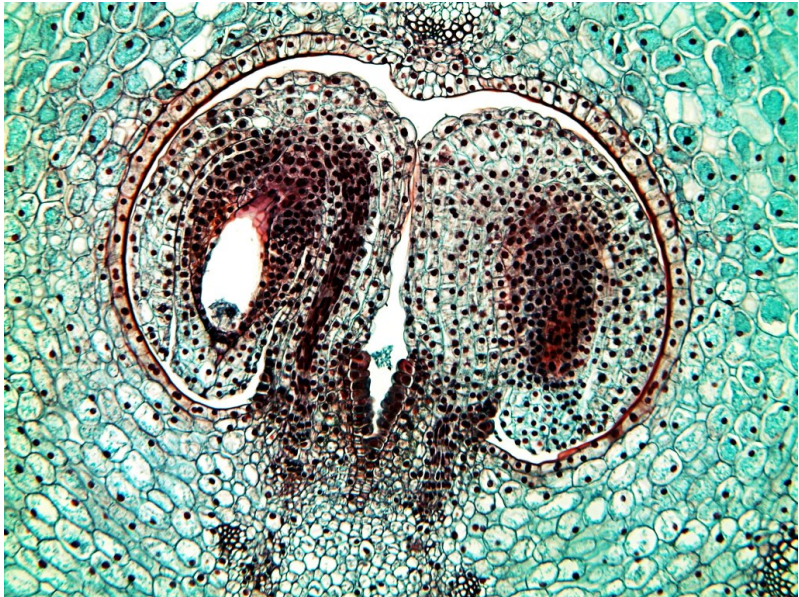
Life cycle of “gymnosperms”



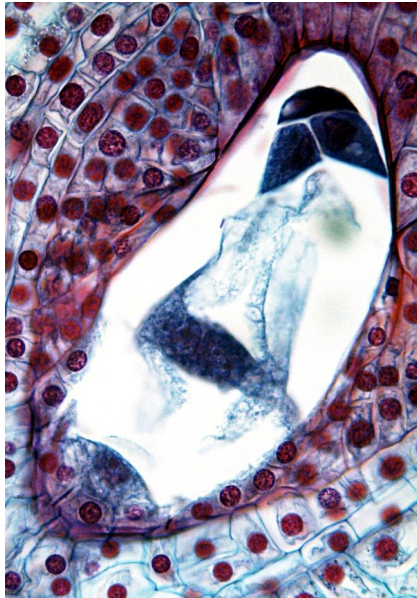
Life cycle of angiosperms: differences



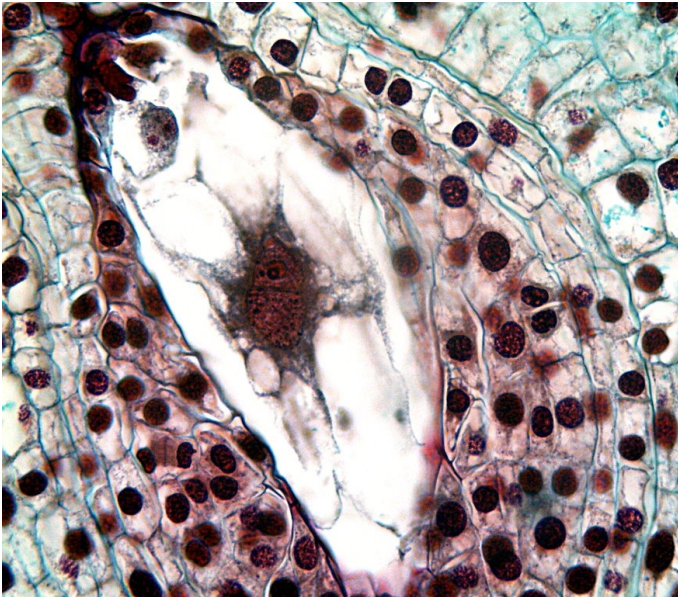
Ovules (*Lilium* sp., lily)



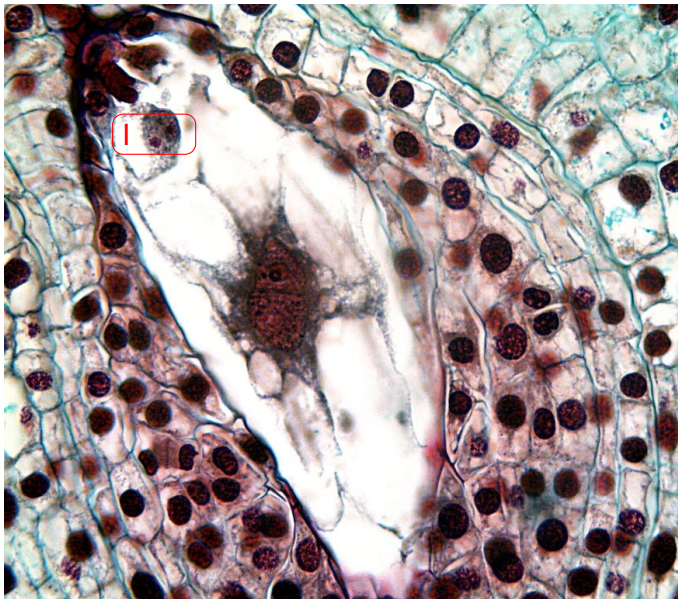
Embryo sac (*Lilium* sp., lily)



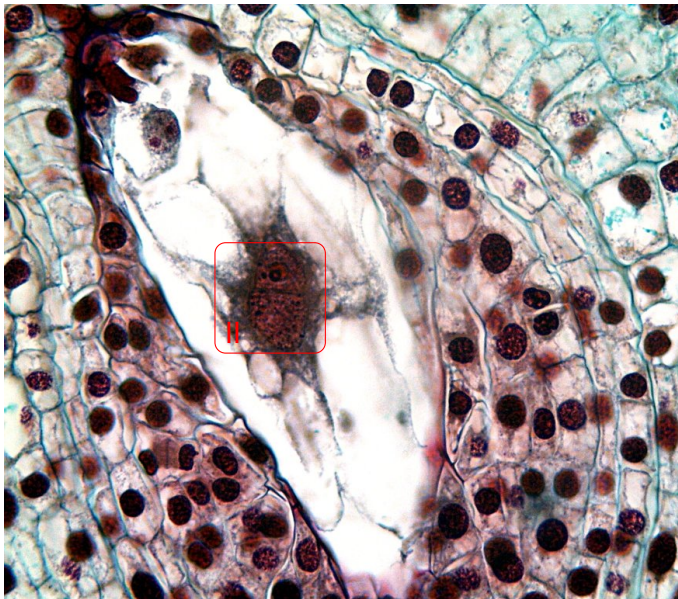
Double fertilization (*Lilium* sp., lily)



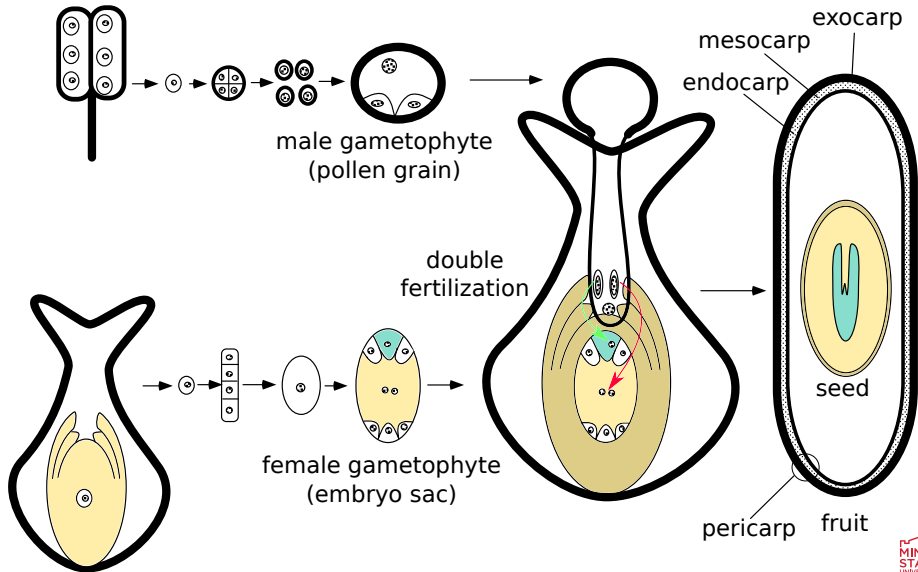
Double fertilization (*Lilium* sp., lily)



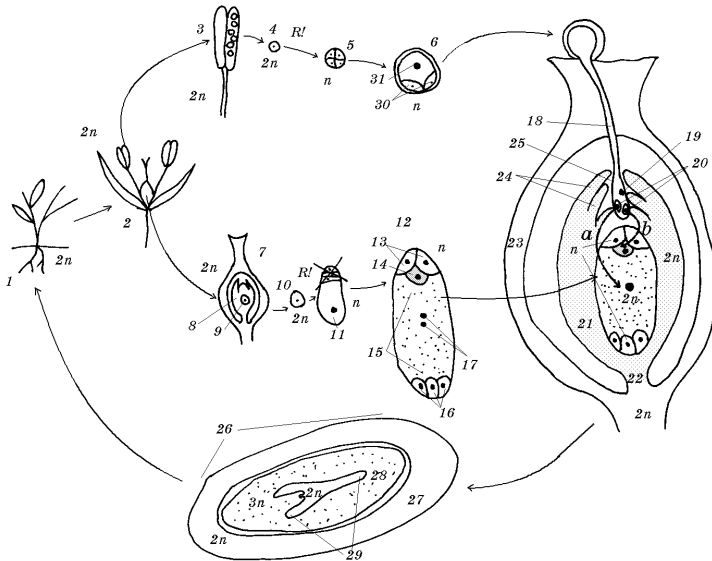
Double fertilization (*Lilium* sp., lily)



Angiosperms: relations between structures



Life cycle of angiosperms: another view



Seed plants

Class Magnoliopsida, or Angiospermae

Angiosperms in general

- Names: Magnoliopsida, Angiospermae (“angion” is a “bottle”), angiosperms, flowering plants
- 250,000 species, more than 90% of all plants diversity, the diversity is comparable with mollusks (200,000) and arthropods ($\approx 1,000,000$) and much more than fungi (75,000) and vertebrates (30,000)
- ≈ 300 families and ≈ 40 orders
- Grow everywhere except open ocean and central Antarctic

Diagnostic characters of angiosperms

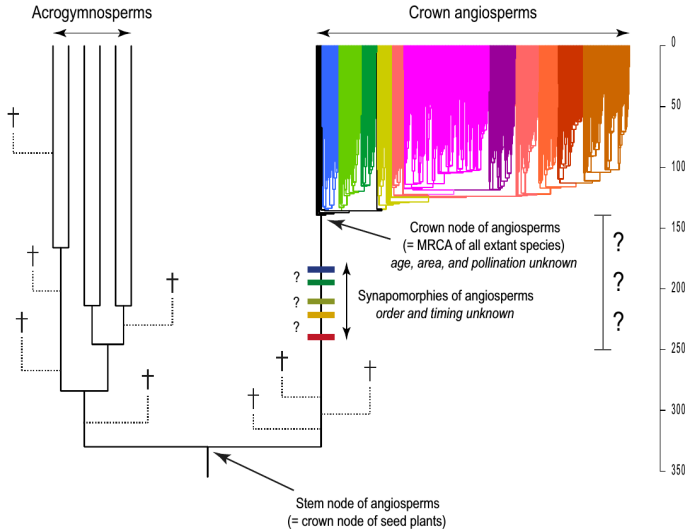
- Flower
- Angiospermy
- Stigma
- Double fertilization:
 - 1st sperm cell (1st spermatium, n) + egg cell (n) = zygote ($2n$)
 - 2nd sperm cell (2nd spermatium, n) + central cell ($2n$ or sometimes n) = mother cell of endosperm₂ ($3n$ or sometimes $2n$)

Second fertilization is a **signal** that first fertilization has been occurred. Endosperm₂ develops from the “signalized” female gametophyte.

- Fruit
- Parcellation

In all, any of these characters taken alone is not unique, but together they delimit the group

“Abominable mystery” (Ch. Darwin)



Whereas angiosperms are not unique, their origin is still obscure.

Seed plants

Flower

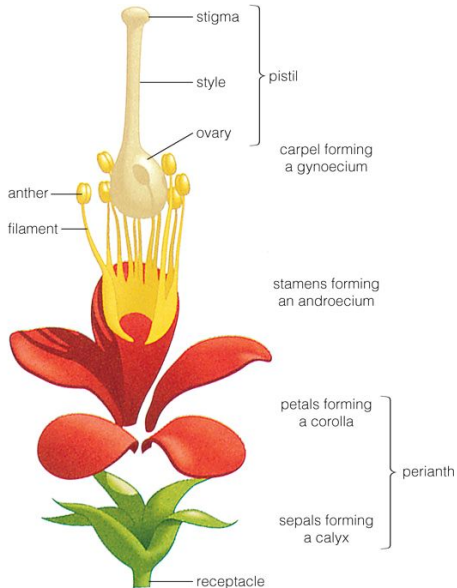
Definition of flower

- Compact generative shoot (= floral unit, FU) with three zones
- Three main zones: sterile (perianth), male (androecium) and female (gynoecium)
- General characters: sex, merosity, symmetry, position of gynoecium

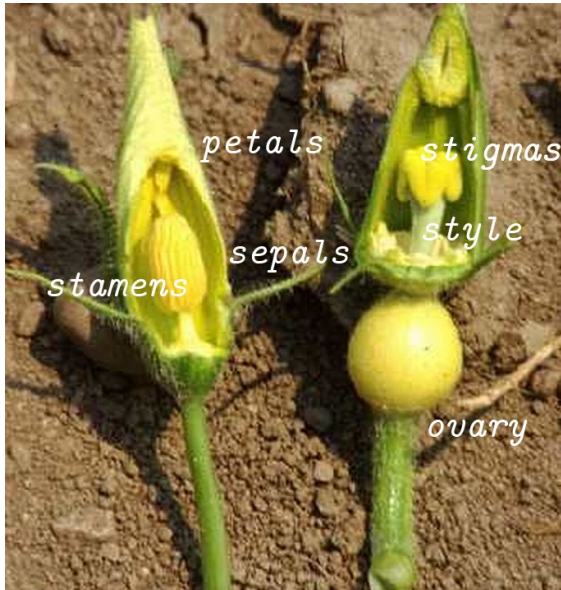
Structure of flower

- Perianth (consists of tepals)
 - Frequent case: double perianth
 - Calyx (consists of sepals)
 - Corolla (consists of petals)
- Androecium (consists of stamens)
 - Filament
 - Anther (consists of pollen sacs)
- Gynoecium (consists of pistils)
 - Ovary (consists of carpels)
 - Style
 - Stigma

Structure of flower



Pumpkin (*Cucurbita pepo*) flower



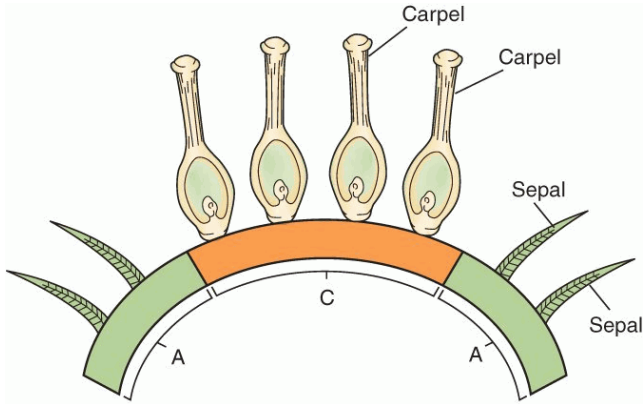
Seed plants

Flower development: ABC model

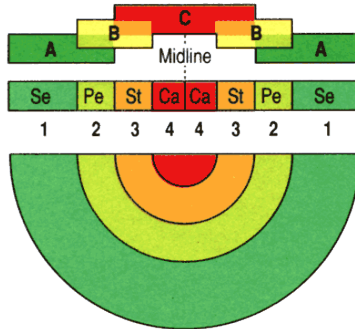
ABC-genes

- There are 3 classes of genes expressed in overlapping, concentric rings.
- The A class (like *apetala2* gene) is expressed in the outermost ring and C (like *agamous*) is expressed in the center; B (e.g., *apetala3*) is expressed at the boundary of A and C:
 - A alone → calyx
 - A + B → corolla
 - C + B → androecium
 - C alone → gynoecium

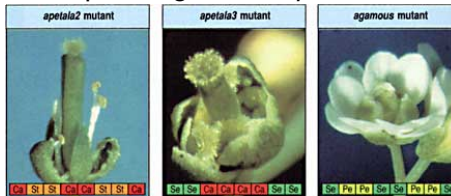
A and C genes “make” sepals and pistils



B genes “transform” them into petals and stamens



Corresponding *Arabidopsis* mutants:



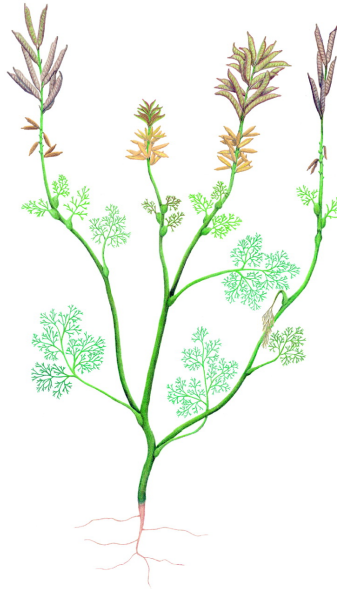
Seed plants

Primitive flowers

Archaeofructus

- Fossil water plant from lower Cretaceous of China
- Very primitive fructifications which are not yet compacted in flower
- Multiple free carpels, paired stamens

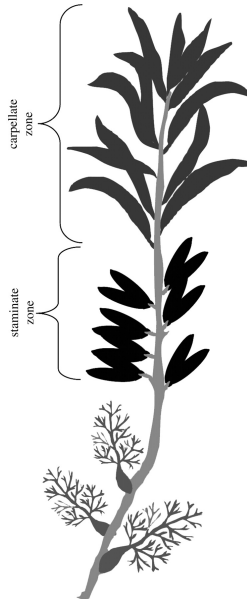
Archaeofructus reconstruction



Archaeofructus reconstruction, 3D



Archaeofructus, scheme of “flower”



Amborella

- Small forest shrub of New Caledonia (big island in Pacific ocean)
- Have irregular flowers, stilar canal, unusual embryo sac (5 cells)

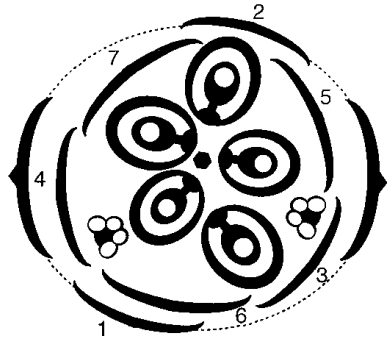
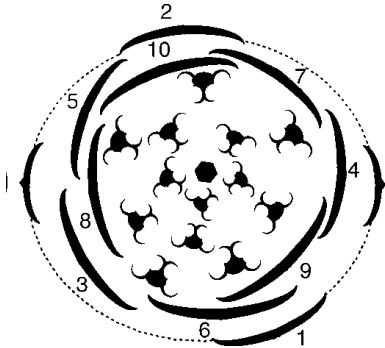
Amborella, branch with male flowers



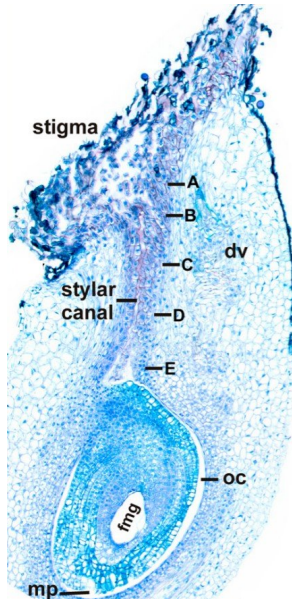
Amborella, male and female flowers



Amborella, diagrams of male and female flowers



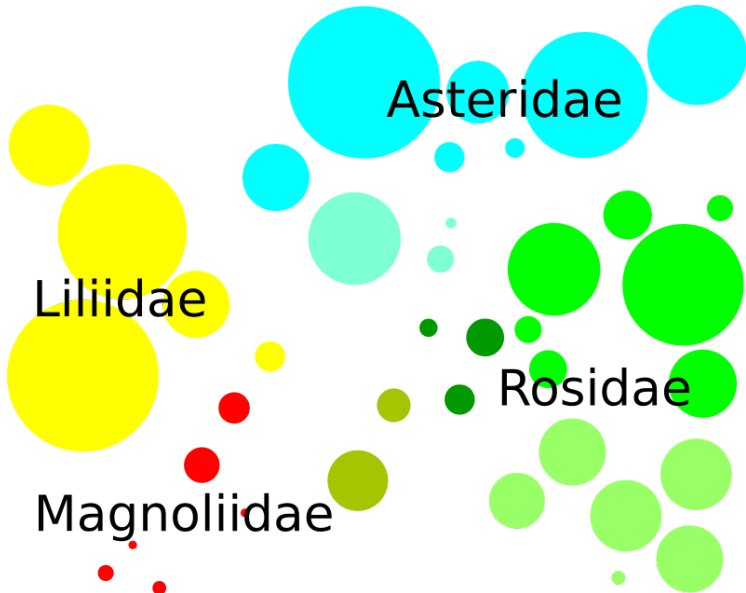
Amborella stilar canal



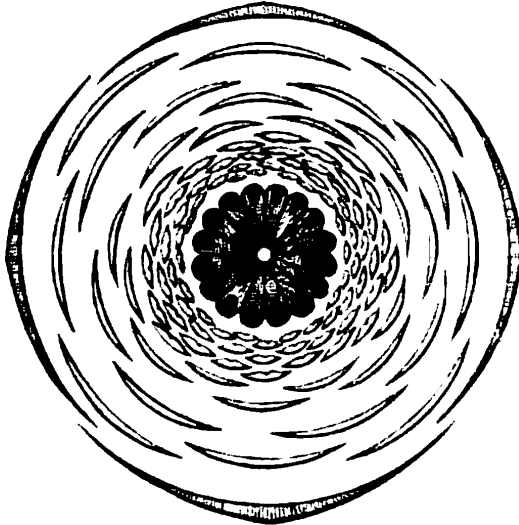
Seed plants

Four subclasses of angiosperms

Angiosperms: subclasses and orders

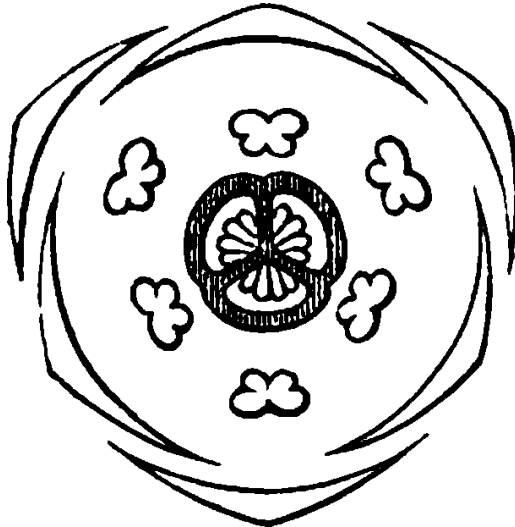


Magnoliidae portrait



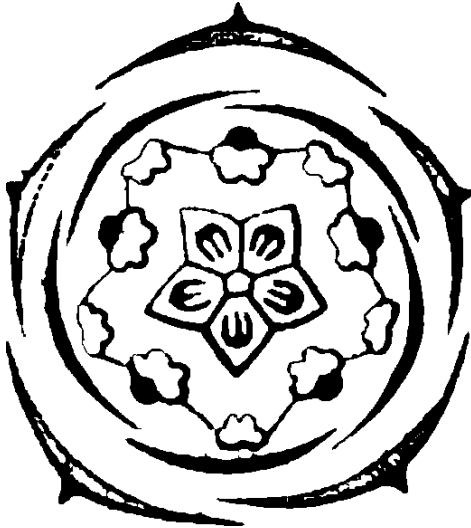
Nymphaea sp. (water-lily): multiple, disorganised

Liliidae portrait



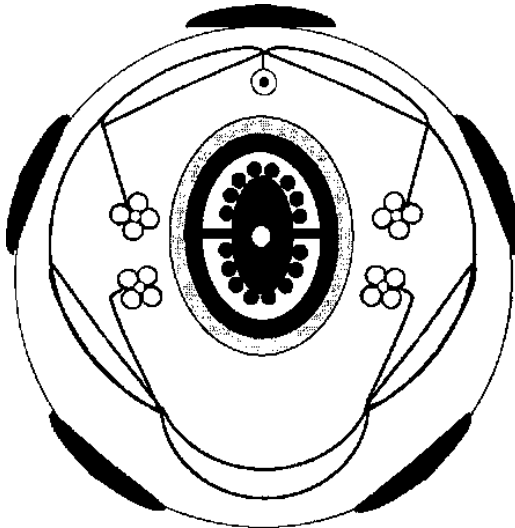
Acorus calamus (calamus, or sweet flag): trimerous

Rosidae portrait



Geranium sp.: pentamerous or tetramerous, petals free

Asteridae portrait



Penstemon sp. (beard-tongue): petals fused, more petals than carpels

Seed plants

Pollination

How to avoid pollination: apomixis

- Apomixis is a reproduction with reproductive organs but without fertilization
- **Apospory**: embryo develops from maternal diploid tissue, without meiosis; here asexual reproduction becomes vegetative
- **Apogamy** (i.e., parthenogenesis): embryo develops from unfertilized gamete after diploidization; sexual reproduction becomes vegetative

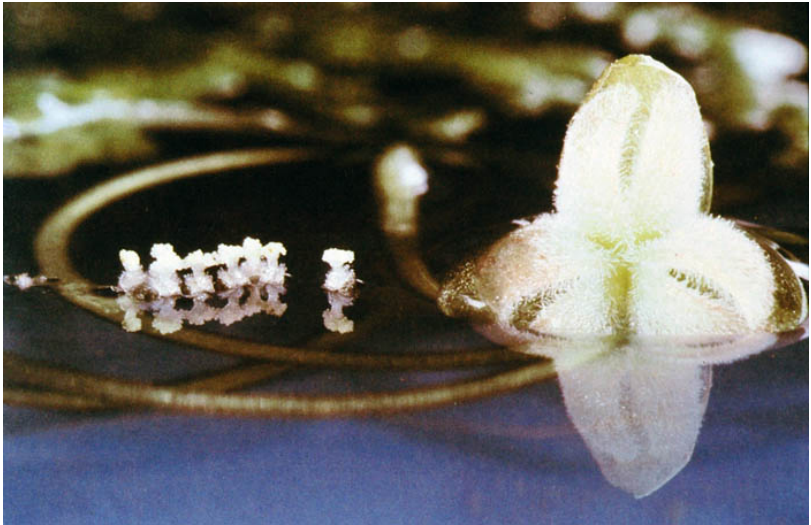
Pollination

- Self-pollination (only slightly better than apogamy)
- Cross-pollination: abiotic (gravity, wind, water) and biotic (insects, birds, bats, sometimes even possums)
- Every pollination type has associated **pollination syndrome**

Wind pollination: hazelnut



Water pollination: vallisneria



Bat pollination: cacti



Possum pollinator: Australian Myrtaceae



Seed plants

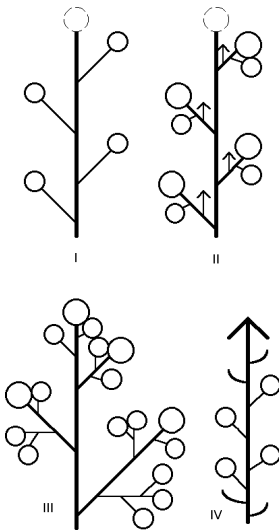
Inflorescences

Types of inflorescences

Inflorescence is an isolated generative shoot bearing flowers

- Model I. Raceme and its derivatives
 - Simple: raceme (developed main axis, developed lateral axes: 11), spike/catkin (developed main axes, reduced lateral axes: 10), umbel (01), head (00)
 - Compound: compound raceme (11/11), compound umbel (01/01) etc.
- Model II. Thyrsus and its derivatives
 - Reduced (cymes): dichasium, cincinnus (scorpioid inflorescence) etc.
 - Thyrses in a strict sense
- Model III. Closed panicle (also umbel-like panicles)
- Model IV. Intercalary inflorescences

Models of inflorescences



Seed plants

Seeds

Definition

- “Mature ovule”
- Chimeric organ consists of seed coat, endosperm and embryo

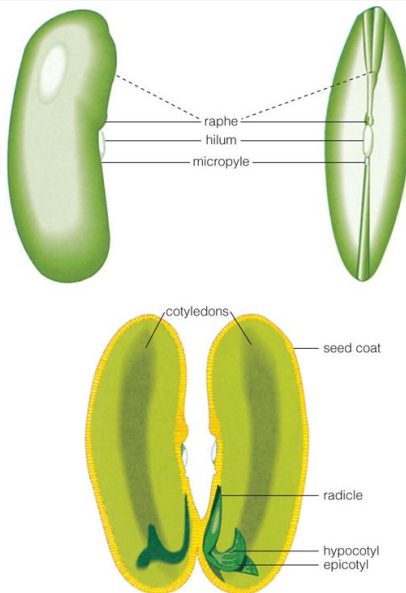
Origin of seed layers

Layer	Ploidy	Origin
Seed coat	$2n$	Integument of ovule
Endosperm ₂	$3n$, sometimes $2n$	Fertilized central cell of embryo sac
Embryo	$2n$	Fertilized egg
Endosperm ₁	n	Female gametophyte (gymnosperms!)
Perisperm	$2n$	Nucellus of ovule

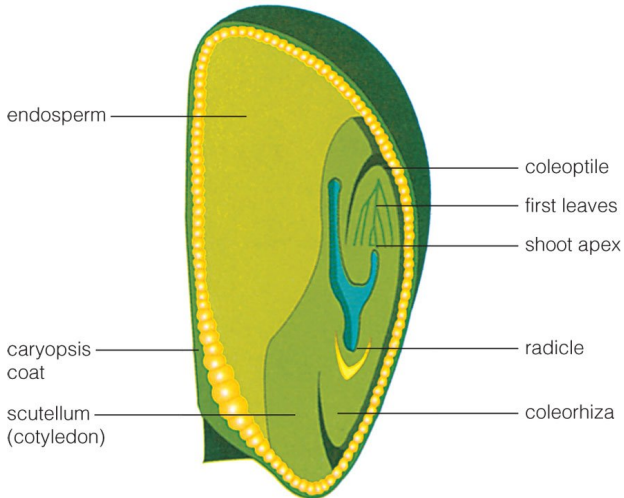
Seed structure variations

- Seed with endosperm (onion): cotyledon(s): embryonic leaves, radicle: embryonic root, apex: embryonic bud
- Seed without endosperm (beans and other Leguminosae): cotyledons, radicle, hilum, raphe
- Grass (Gramineae) seeds: coleoptile, coleorhiza, scutellum

Bean seed



Grass seeds



© 2006 Brooks/Cole - Thomson

Cotyledons

- Monocots have lateral bud and terminal primary leaf (cotyledon)
- Other seed plants have terminal bud and multiple (2 to many) primary leaves (cotyledons)

Pinus sp.: multiple cotyledons

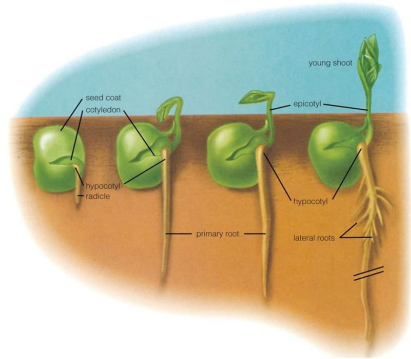
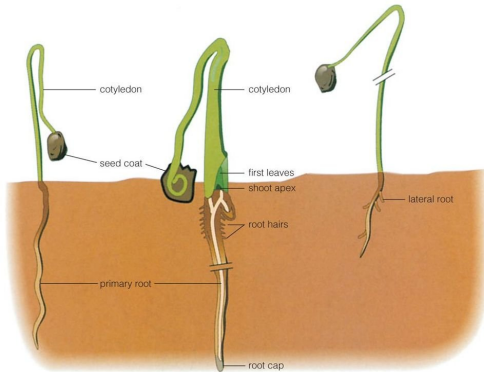


Germination

- Epigeal (e.g., onion, pea). They expose cotyledons and both hypo- and epicotyl.
- Hypogeal (e.g., bean, grasses, palms). They expose only epicotyl (first internode), cotyledons and hypocotyl (root/stem transition) is underground.

Both variants have advantages and disadvantages.

Epigeal *versus* hypogeal germination



Seed plants

Fruits

Definition and origin

- **Fruit** is a ripened ovary, flower or inflorescence
- Fruit coat and pericarp (exocarp + mesocarp + endocarp) origin mostly from pistil wall

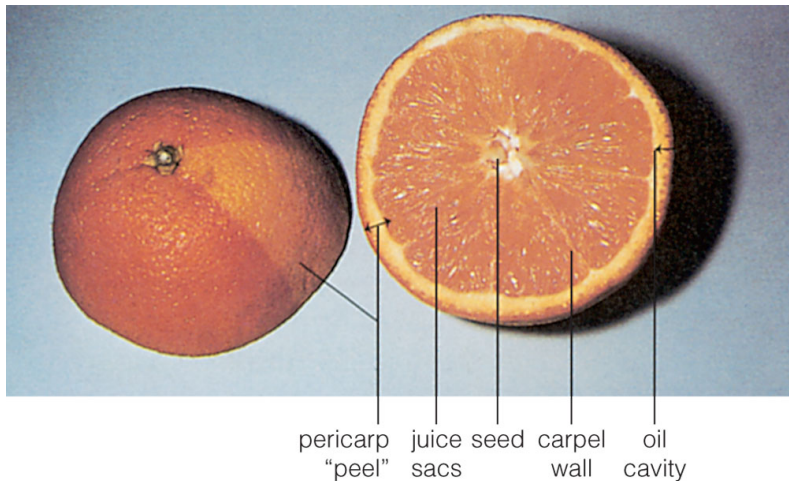
Trivial classification: criteria

- **Simple, multiple** (aggregate) or **compound**. Simple fruits are from one pistil (cherry), multiple from many pistils of one flower (raspberry), compound—from multiple flowers (pineapple).
- **Dry** or **fleshy**. Fleshy fruits are adapted to animal dispersion through their digestive tract.
- **Dehiscent, indehiscent** or **schizocarpic**. Dehiscent (opening) fruit will delegate dispersal function to individual seeds; indehiscent (closed) fruit will take these functions but will require less seeds per fruit to avoid competition between seedlings. Schizocarp has multiple seeds but will be fragmented to many one-seeded parts.

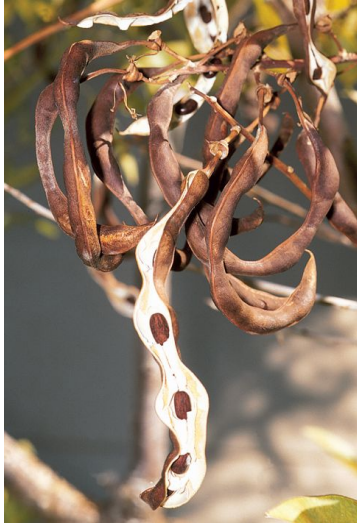
Trivial classification: examples

Type	Consistency	Opening	Example
Simple	Fleshy	Indehiscent	Drupe (one seed), Berry (multiple seeds), Hesperidium (citruses), Pome (apple, pear: from inferior ovary)
Simple	Dry	Dehiscent	Legume (pod), Capsule, Silique (fruit of cabbage family)
Simple	Dry	Schizocarpic	Regma (spurge), Samara (maple), Shizocarp (umbel family)
Simple	Dry	Indehiscent	Caryopsis (grain, fruit of grasses), Nut (incl. acorn), Achene (fruit of aster family)
Multiple	Fleshy	Indehiscent	Multiple drupe (raspberry)
Multiple	Dry	Dehiscent	Follicle (many pods together)
Multiple	[Dry]	Indehiscent	Multiple nut (strawberry)
Compound	Fleshy	Indehiscent	Compound berry (pineapple)
Compound	[Dry]	Indehiscent	Compound nut (fig)

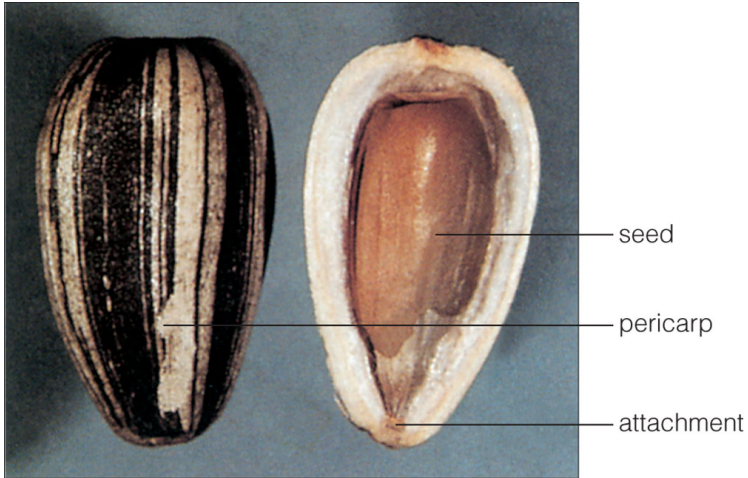
Simple, fleshy, indehiscent: **hesperidium** (or berry if you like it simpler) of *Citrus*



Simple, dry, dehiscent: **pod** of *Erythrina* legume

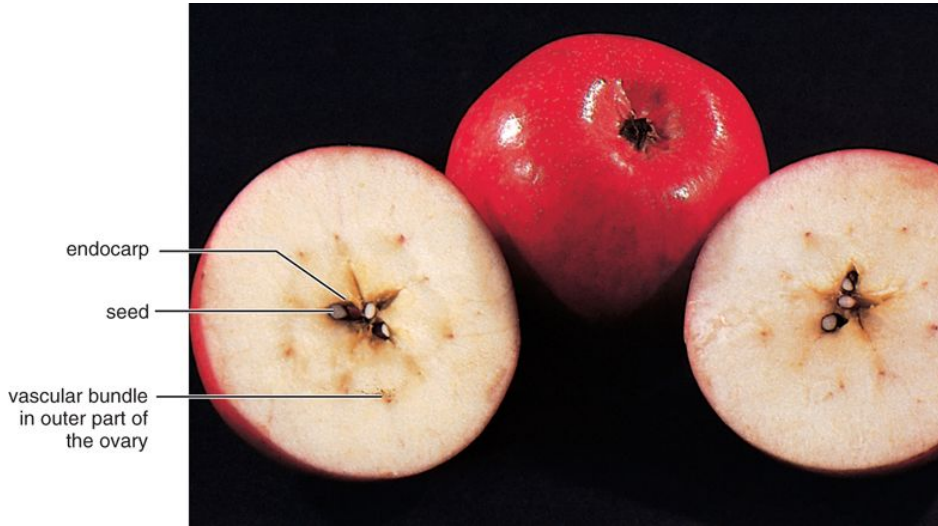


Simple, dry, indehiscent: **achene** (not “seed”!!!) of *Helianthus*



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Simple, fleshy, indehiscent: **pome** of *Pyrus*



Samara of *Acer*



Schizocarp of *Zizia*



Multiple nut of *Fragaria* sp. (strawberry)



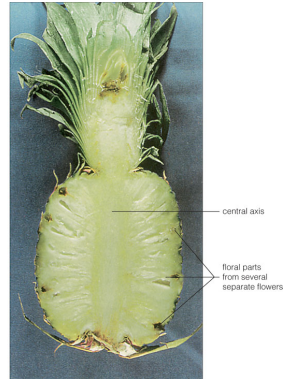
Multiple drupe of *Rubus* sp. (raspberry)



Compound berry of *Ananas comosus* (pineapple)



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Compound fruit of *Ficus carica* (fig tree)



Short anonymous absolutely voluntary survey

- A What do you **like** most in Biology 154?
- B What do you **dislike** most in Biology 154?
- C **Which lab** do you remember most of all?
- D Please grade (1—bad, 5—excellent):
 - A. Lectures
 - B. Labs
 - C. Final questions
 - D. Exams
- E How to improve the textbook?

Summary

- **Flower** is a compact three-zoned generative shoot
- Three main zones of flower: sterile (**perianth**), male (**androecium**) and female (**gynoecium**)
- **ABC-genes** determine the fate of cells which are forming flower
- **Inflorescence** is an isolated generative shoot bearing flowers
- **Seed** is a chimeric organ consists of seed coat, endosperm and embryo
- **Fruit** is a ripened ovary, flower or inflorescence
- **BOTANY IS COOL!**

For Further Reading



A. Shipunov.

Introduction to Botany [Electronic resource].

Mode of access:

http://ashipunov.info/shipunov/school/biol_154