Chapter 30

Plant Diversity II: The Evolution of Seed Plants

Overview: Transforming the World

- This chapter follows the emergence and diversification of seed plants, beginning ~360 mya

  - A seed consists of an embryo and its food supply surrounded by a protective coat
    - When mature, seeds are dispersed from their parent by wind or other means
      - A seed can therefore be compared to a detachable and mobile version of a pregnant woman's womb
    - This key adaptation allowed seed plants to become the dominant producers in most terrestrial ecosystems
  - Seed plants have had an enormous impact on human society
    - Beginning 13,000 years ago, humans began to cultivate wheat, figs, maize (corn), bananas, and other wild seed plant
      - This domestication of seed plants played a key role in transforming most human societies from wandering bands of hunter-gatherers to permanent settlements anchored by agriculture

Concept 30.1: Seeds and pollen grains are key adaptations for life on land

- We will first examine the general characteristics of seed plants
  - In addition to seeds, the following are common to all seed plants
    - Reduced gametophytes
    - Heterospory
    - Ovules
    - Pollen
  - These adaptations provided new ways for seed plants to cope with terrestrial conditions, like drought and UV radiation
    - They also freed seed plants from requiring water for fertilization, allowing reproduction to occur under a broader range of conditions than in seedless plants

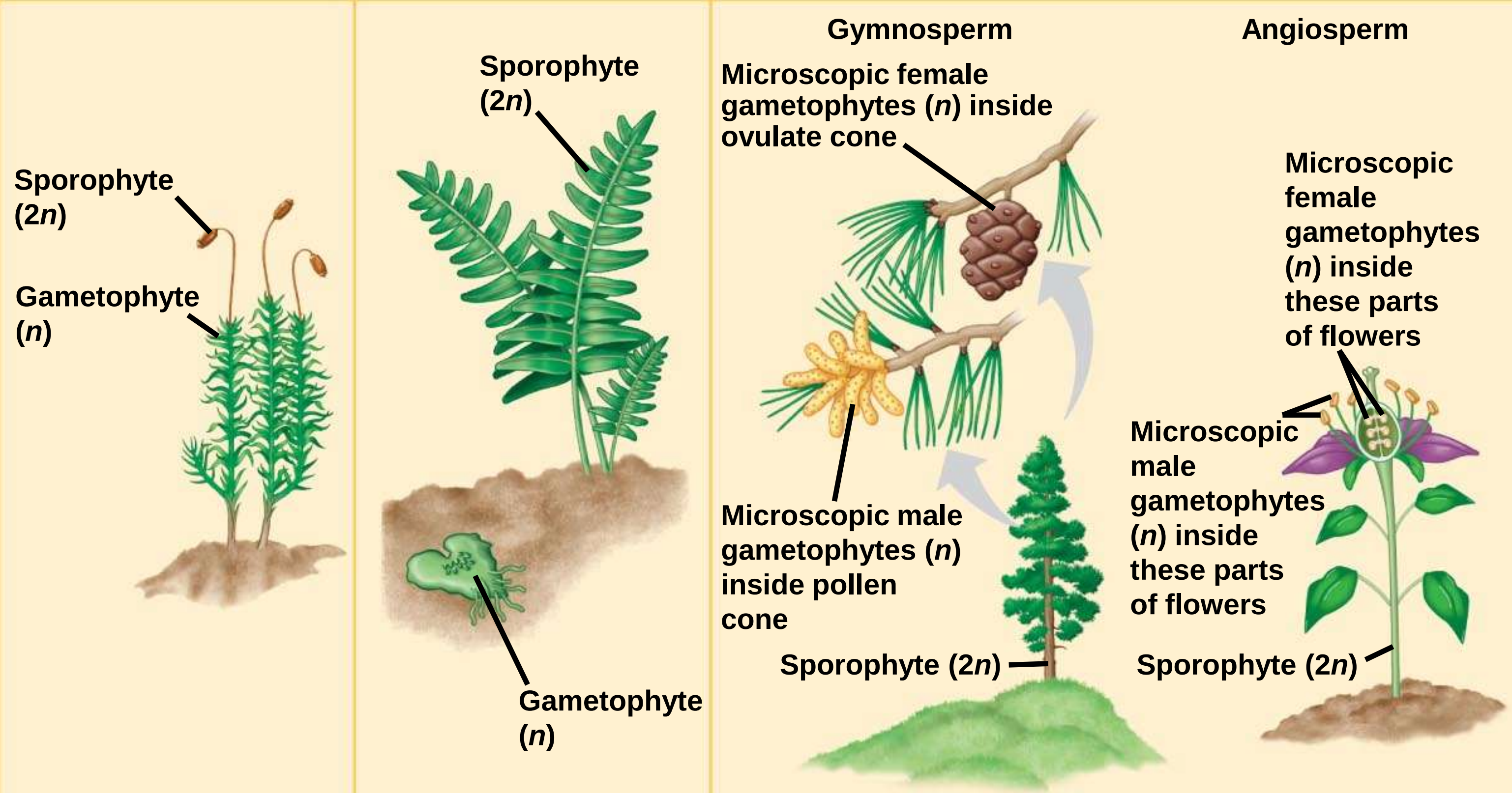
Advantages of Reduced Gametophytes

- Recall: mosses and bryophytes have life cycles dominated by gametophytes while that of seedless vascular plants is sporophyte-dominated
  - The evolutionary trend of gametophyte reduction continued further in the lineage of vascular plants that led to seed plants
    - While gametophytes of seedless vascular plants are visible to the naked eye, those of seed plants are mostly microscopic
  - This miniaturization allowed the important evolutionary innovation of allowing these tiny gametophytes to develop from spores retained within the sporangia of the parental sporophyte
    - This arrangement protects the delicate female (egg-bearing) gametophyte from environmental stresses, like drought and UV radiation
    - Its also enables these parent-dependent gametophytes to obtain nutrients from the sporophyte

Fig. 30-2

	PLANT GROUP		
	Mosses and other nonvascular plants	**Ferns and other seedless vascular plants**	**Seed plants (gymnosperms and angiosperms)**
Gametophyte	Dominant	Reduced, independent (photosynthetic and free-living)	Reduced (usually microscopic), dependent on surrounding sporophyte tissue for nutrition
Sporophyte	Reduced, dependent on gametophyte for nutrition	Dominant	Dominant

Example

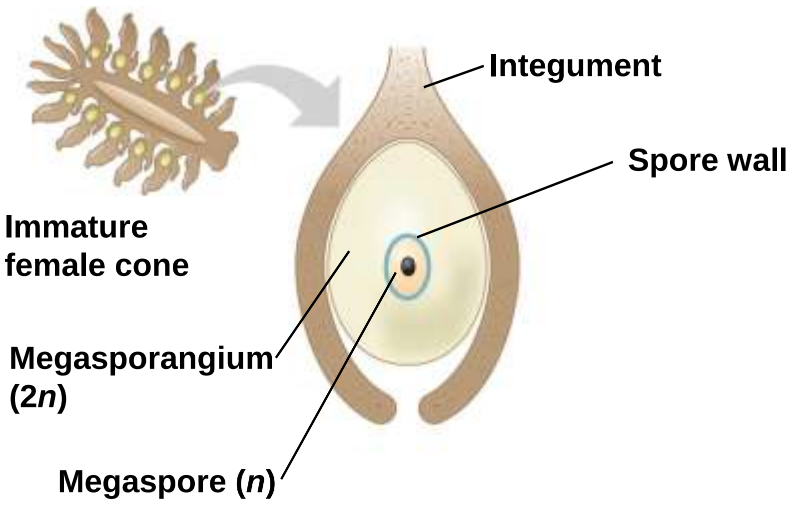


Heterospory: The Rule Among Seed Plants

- Nearly all seedless plants are homosporous, producing only one type of spore that usually gives rise to a bisexual gametophyte
  - The closes relatives of seed plants are also all homosporous, suggesting that the ancestors of seed plants were homosporous as well
    - At some point, however, seed plants or their ancestors became heterosporous (more than one type of spore):
      - Megasporangia each produce a single functional megaspore that give rise to the female gametophyte
      - Microsporangia produce many microspores that give rise to male gametophytes

Ovules and Production of Eggs

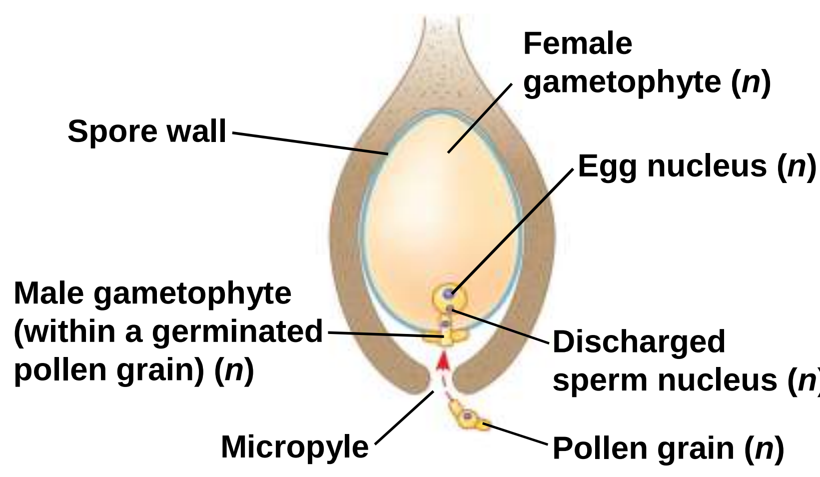
- Seed plants are unique in retaining the megasporangium and megaspore within the parental sporophyte
  - A layer of sporophyte tissue called **integument** envelops and protects the megasporangium
    - Gymnosperm megasporangiums are surrounded by one integument
    - Angiosperm megasporangiums usually have two integuments
  - Together, the megasporangium, megaspore, and their integument(s) form a structure called an **ovule**
    - Inside each ovule, a female gametophyte develops from a megaspore and produces one or more eggs



(a) Unfertilized ovule

Pollen and Production of Sperm

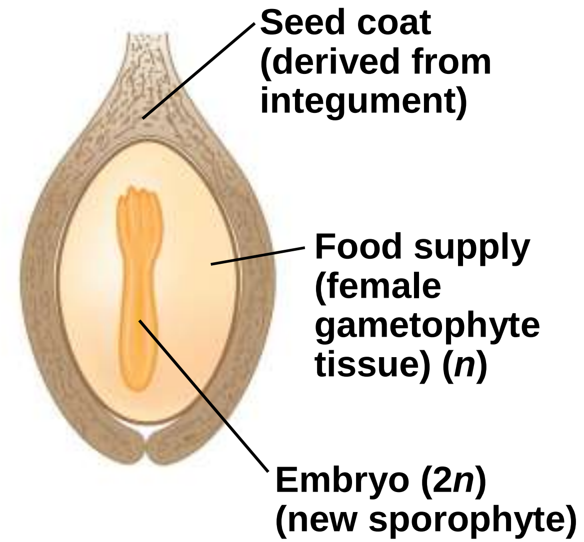
- Microspores develop into **pollen grains**, which contain the male gametophytes enclosed within the pollen wall
  - This pollen wall contains the polymer sporopollenin, which protects the pollen grain as it is transported from the parent plant by wind or other means
    - **Pollination** is the transfer of pollen to the part of a seed plant containing the ovules
  - If the pollen grain germinates (begins growing), it gives rise to a pollen tube that discharges sperm into the female gametophyte within the ovule
    - Pollen eliminates the need for a film of water and can be dispersed great distances by air or animals
    - It also eliminates the need for flagellated, motile sperm, since the sperm are carried directly to the eggs by pollen tubes



(b) Fertilized ovule

The Evolutionary Advantage of Seeds

- Once the sperm fertilizes the egg of a seed plant, the resulting zygote develops into a sporophyte embryo
  - The whole ovule develops into a seed that contains the sporophyte embryo and its food supply, packaged in a protective coat
- Seeds provide some evolutionary advantages over spores:
  - Unlike single-celled spores, the seed coat of seeds consists of a multicellular layer of tissue, which provides extra protection to the embryo
  - Also unlike spores, seeds have a supply of stored food, allowing the seeds to remain dormant for days to years, until conditions are favorable for germination
  - Because they do not require water films, they may also be transported long distances by wind or animals



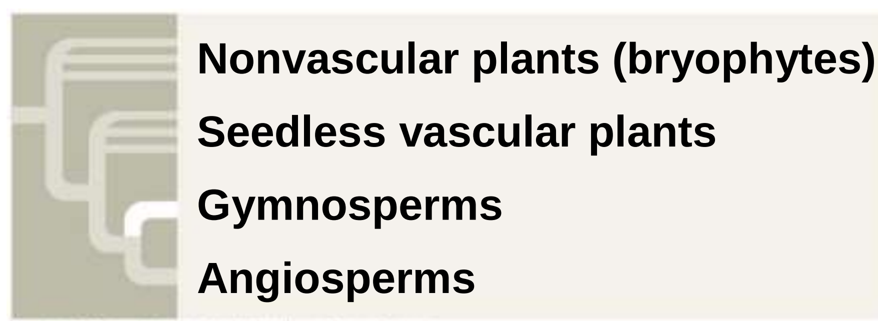
(c) Gymnosperm seed

Concept Check 30.1

- 1) Contrast sperm delivery in seedless vascular plants with sperm delivery in seed plants.
- 2) What additional features of seed plants, not present in seedless plants, have contributed to the enormous success of seed plants on land?
- 3) If seed plants were homosporous, what aspects of their reproduction would change? Explain.

Concept 30.2: Gymnosperms bear “naked” seeds, typically on cones

- The gymnosperms have “naked” seeds not enclosed by ovaries
  - These seeds are exposed on modified leaves (sporophylls) that usually form cones (strobili)
- The gymnosperms consist of four phyla:
  - Cycadophyta (cycads)
  - Gingkophyta (one living species: *Ginkgo biloba*)
  - Gnetophyta (three genera: *Gnetum, Ephedra, Welwitschia*)
  - Coniferophyta (conifers, such as pine, fir, and redwood)



Gymnosperm Evolution

- Fossil evidence reveals that by the late Devonian period some plants, called **progymnosperms**, had begun to acquire some adaptations that characterize seed plants
  - Ex) *Archaeopteris* was a seedless, though heterosporous, tree with a woody stem
- The first seed-bearing plants appeared in the fossil record ~360 mya, more than 200 my before the first angiosperm fossils
  - These early seed plants became extinct, along with several other later lineages
  - Morphological and molecular evidence place the surviving lineages of seed plants into two monophyletic sister clades:
    - Gymnosperms
    - Angiosperms

***Archaeopteris*, a progymnosperm**

- The earliest gymnosperm fossils are ~505 million years old
  - During this time, seedless vascular plants were still the dominant land plants
  - As the climate became drier, however, gymnosperms began to replace seedless vascular plants as the dominant flora
    - Gymnosperms were better suited than nonvascular plants to drier conditions:
      - Water-tight and protective seeds/pollen
      - Thick cuticles on the surfaces of stems and leaves preventing dessication
      - Smaller leaf surface area, decreasing rate of water loss
  - Although angiosperms now dominate most terrestrial ecosystems, many gymnosperms remain an important part of Earth’s flora
    - Today, cone-bearing gymnosperms called **conifers** dominate in the northern latitudes

- Of the 10 plant phyla, 4 are gymnosperms
  - **Phylum Cycadophyta** (cycads): individuals have large cones and palmlike leaves
    - These thrived during the Mesozoic, but relatively few species (~130) exist today
  - **Phylum Ginkgophyta**: consists of a single living species, *Ginkgo biloba* (maidenhair tree)
    - It has a high tolerance to air pollution and is a popular ornamental tree
    - It has deciduous fanlike leaves that turn gold in the fall

Cycas revoluta

Ginkgo biloba
pollen-producing tree

- Phylum Gnetophyta: consists of three genera
    - Genus *Gnetum:* includes ~35 species of tropical trees, shrubs, and vines that are native mainly to Africa and Asia
        - Their leaves look similar to those of flowering plants, and their seeds look somewhat like fruits
    - Genus *Ephedra:* includes ~40 species that inhabit arid regions worldwide
        - These desert shrubs produce the compound "ephedrine," used medicinally as a decongestant (and an appetite suppressant)
    - Genus *Welwitschia*: consists of a single species *W. mirabilis*, a plant that lives only in the deserts of southwestern Africa
        - It strap-like leaves are among the largest leaves known
- Species vary in appearance, and some are tropical whereas others live in deserts

Gnetum

Ephedra

Welwitschia

- **Phylum Coniferophyta**: by far the largest of the gymnosperm phyla, consisting of ~600 species
  - Most conifers are evergreens and can carry out photosynthesis year round
- *Douglas fir*: this evergreen tree provides more timber than any other North American tree species
  - Some uses include house framing, plywood, pulpwood for paper, railroad ties, boxes/crates
- *European larch*: the needle-like leaves of this deciduous conifer turn yellow before they are shed in the autumn
  - Native to the mountains of central Europe, this species is extremely cold-tolerant
- *Bristlecone pine*: found in the White Mountains of California, this species includes some of the oldest living organisms, reaching ages of more than 4600 years

Douglas fir

European larch

Bristlecone pine

- *Common juniper*: the “berries” of this tree are actually ovule-producing cones, consisting of fleshy sporophylls
- *Wollemi pine*: once thought to be extinct, living trees of this species were discovered in 1994 in a national park in Australia
    - Consists of just 40 known individuals in 2 small groves
- *Sequoia*: one of the largest living organisms (~2500 metric tons) and also among the most ancient (1800-2700 years old)

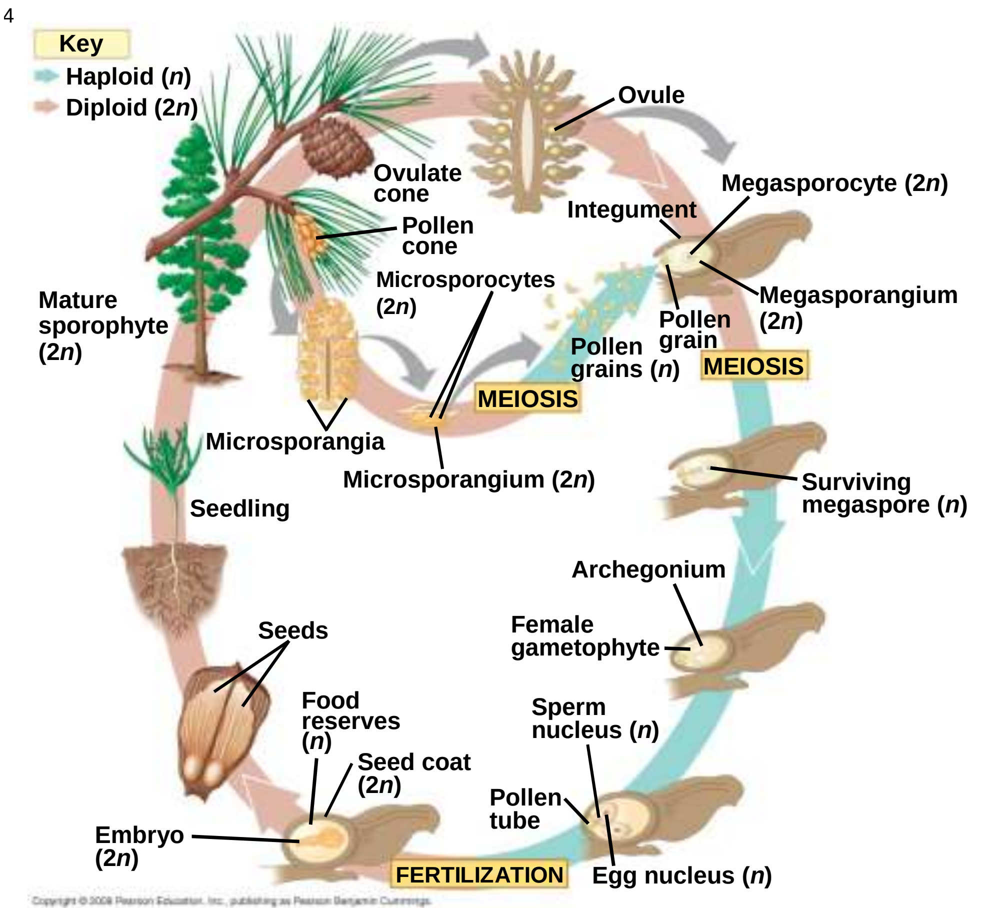
Common juniper

Wollemi pine

Sequoia

The Life Cycle of a Pine: *A Closer Look*

- Three key features of the gymnosperm life cycle are:
  - Dominance of the sporophyte generation
  - Development of resistant, dispersible seeds from fertilized ovules
  - The transfer of sperm to ovules by pollen
- The life cycle of a pine provides an example
  - The pine tree is the sporophyte
    - Its sporangia are located on scale-like structures packed densely in cones

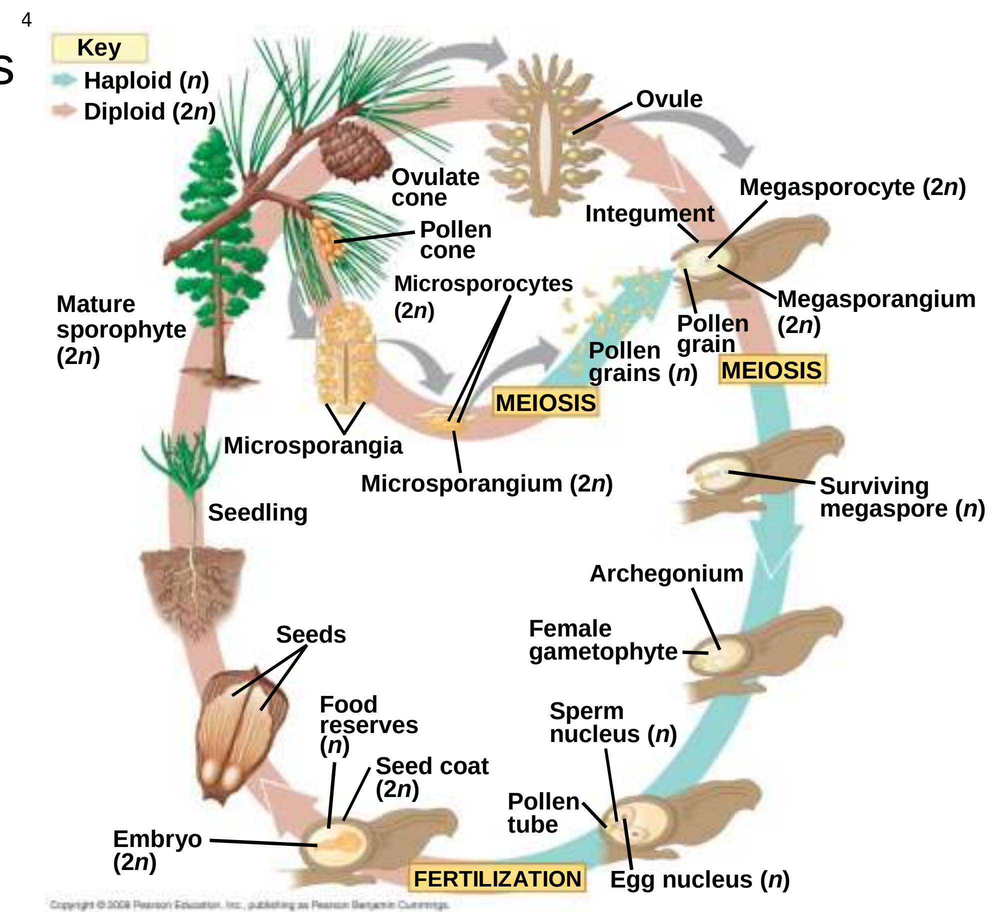


PLAY

Animation: Pine Life Cycle

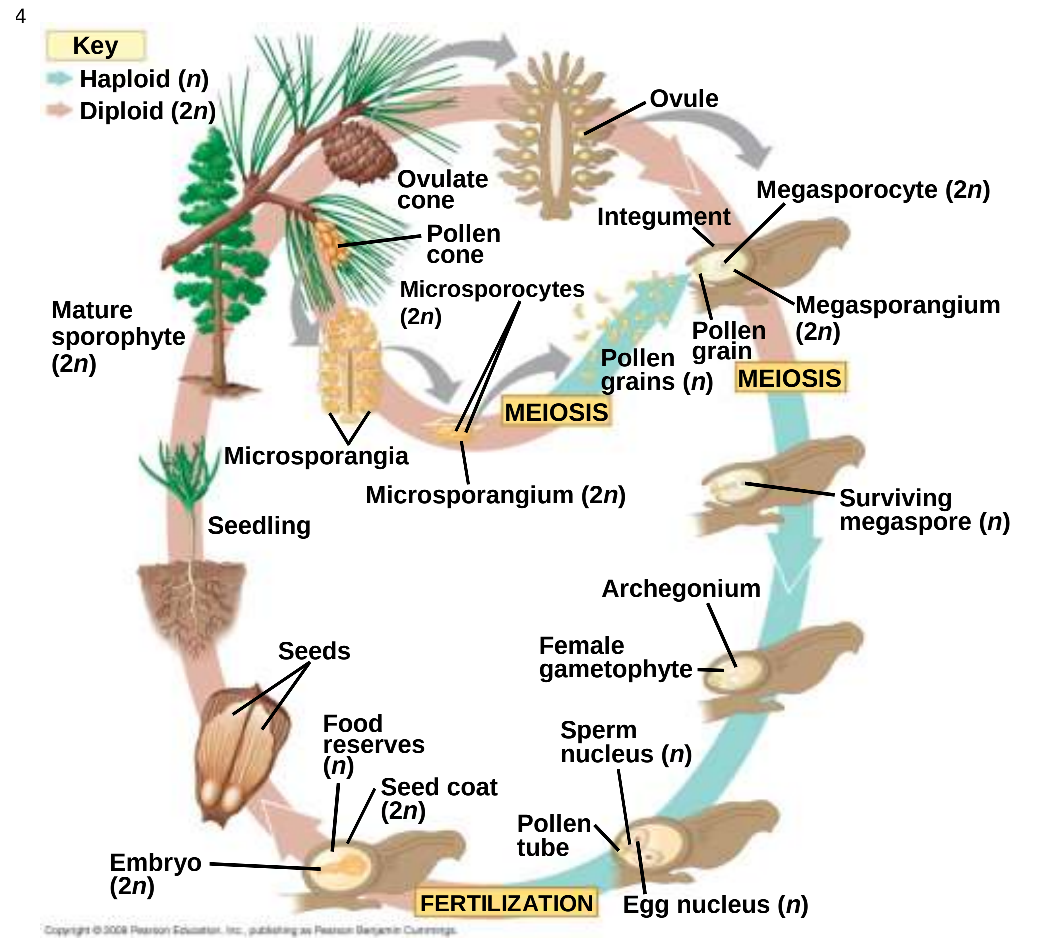
The Life Cycle of a Pine: *A Closer Look*

- Like all seed plants, conifers are heterosporous, with most pine species carrying both types of cones
  - A small pollen cone contains microsporocytes (microspore mother cells) that undergo meiosis to produce haploid microspores
    - Each microspore develops into a pollen grain containing a male gametophyte, which is released in large amounts and carried by the wind
  - Large ovulate cones contain megasporocytes (megaspore mother cells) that undergo meiosis to produce haploid megaspores inside the ovule
    - Surviving megaspores develop into female gametophytes that are retained within the sporangia



The Life Cycle of a Pine: *A Closer Look*

- It takes ~3 years for male and female gametophytes to be produced and brought together from the time cones appear on these trees
  - Once fertilized ovules are formed, the scales of the ovulate cone separate and seeds are dispersed by the wind
    - A seed that lands in a suitable environment then germinates, and its embryo emerges as a pine seedling



Concept Check 30.2

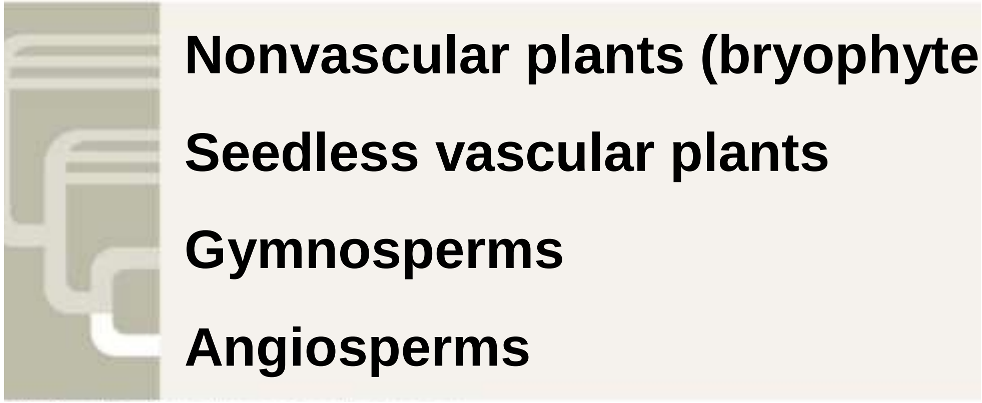
- 1) Use examples from Figure 30.5 (pp. 622-623) to describe how various gymnosperms are similar yet distinctive.

- 2) Explain how the pine life cycle (see Figure 30.6 pp. 624) reflects basic characteristics of seed plants.

- 3) Does the hypothesis that gymnosperms and angiosperms are sister clades imply that these 2 lineages originated at the same time? Explain.

Concept 30.3: The reproductive adaptations of angiosperms include flowers and fruits

- Angiosperms are seed plants with reproductive structures called flowers and fruits
  - The name angiosperm (*angion* = container) refers to the seeds (mature ovaries) contained in fruits
- They are the most widespread and diverse of all plants
  - They include more than 250,000 species, making up ~90% of all plant species

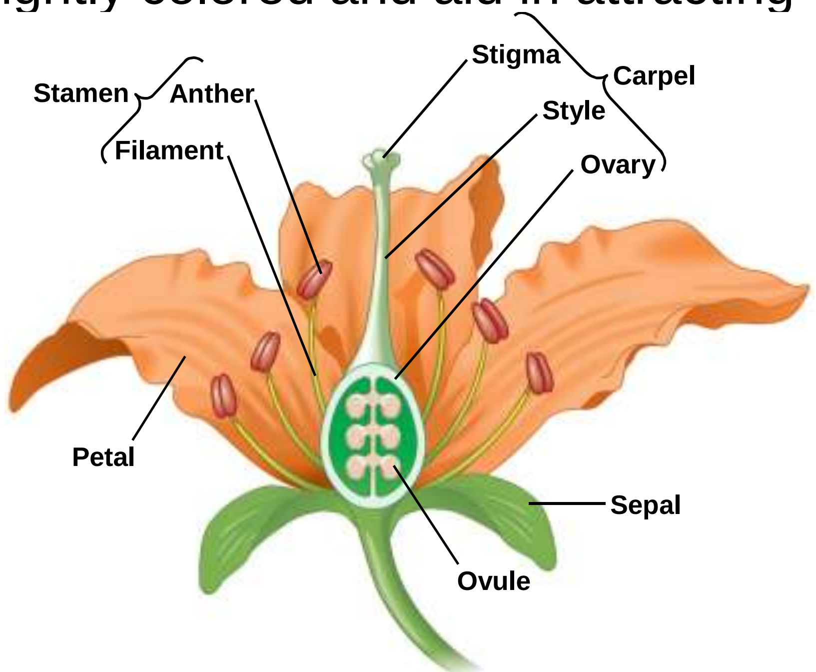


Characteristics of Angiosperms

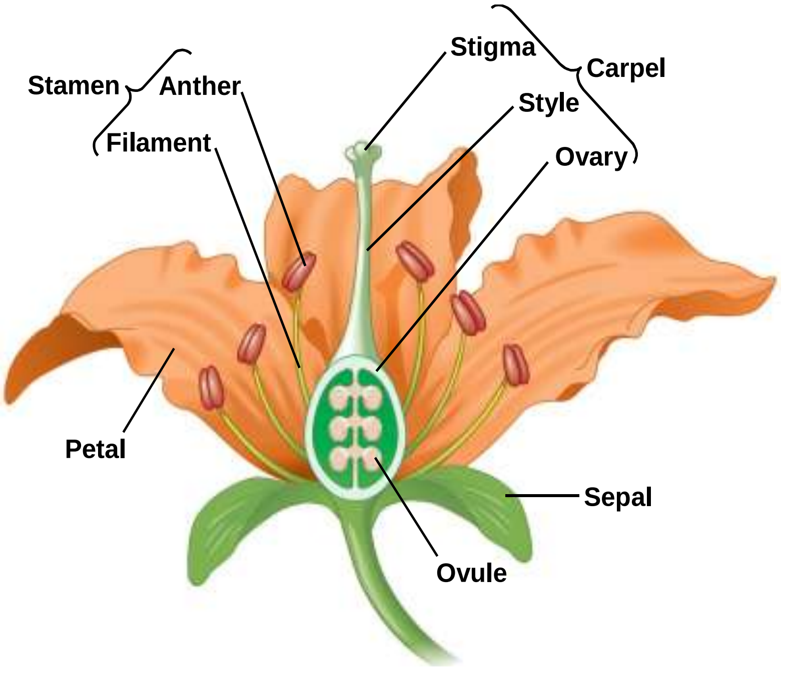
- All angiosperms are classified in a single phylum, Anthophyta
  - The name comes from the Greek *anthos,* flower
- Angiosperms have 2 key adaptations:
  - Flowers
  - Fruits

Flowers

- The **flower** is an angiosperm structure specialized for sexual reproduction
  - Many species are pollinated by insects or animals, while some species are wind-pollinated
- A flower is a specialized shoot with up to four types of modified leaves (sporophylls) called floral organs:
  - **Sepals**: found at the base of the flower, these structures are usually green and enclose the flower before it opens
  - **Petals**: structures that are usually brightly colored and aid in attracting pollinators
    - Flowers that are wind-pollinated generally lack brightly-colored parts
  - In all angiosperms, the sepals and petals are sterile floral organs not directly involved in reproduction



- **Stamens:** structures that produce pollen grains (developed from microspores) containing male gametophytes
  - Consists of:
    - A stalk called the **filament**
    - A terminal sac, called the **anther**, where pollen is produced



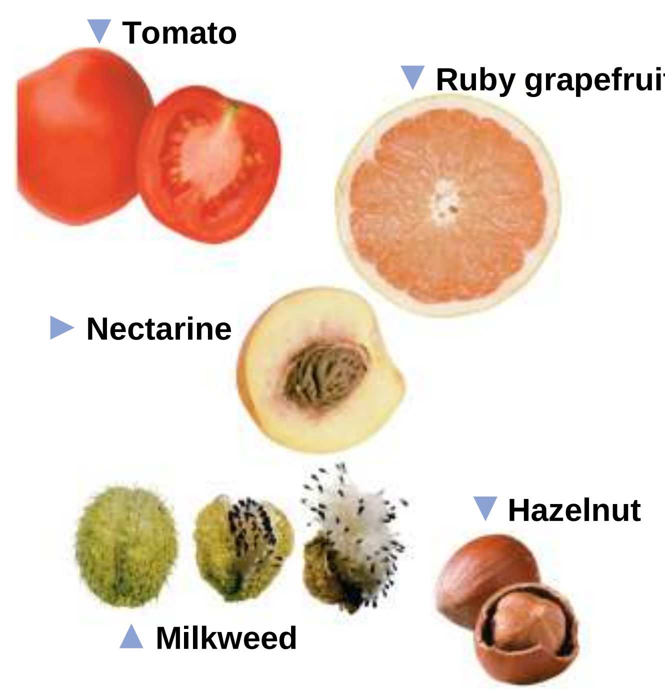
- **Carpels**: structures that produce megaspores and their products, female gametophytes
  - Consist of:
    - A sticky **stigma** that receives pollen found at the tip of the carpel
    - A **style** leading from the stigma to the ovary
    - An **ovary** at the base of the carpal, which contains one or more ovules
      - If fertilized, an ovule develops into a seed
  - Some flowers have a single carpal while others have several separate carpals

PLAY

Video: Flower Blooming (time lapse)

Fruits

- A **fruit** typically consists of a mature ovary but can also include other flower parts
  - The wall of the ovary thickens as seeds develop from ovules following fertilization
    - A peapod is an example of a fruit, with seeds (peas) encased in a ripened ovary (pod)
  - Fruits protect seeds and aid in their dispersal
  - Mature fruits can be either fleshy or dry
    - In fleshy fruits (oranges, tomatoes), the wall of the ovary becomes soft during ripening
    - Dry fruits include beans, nuts, and grains



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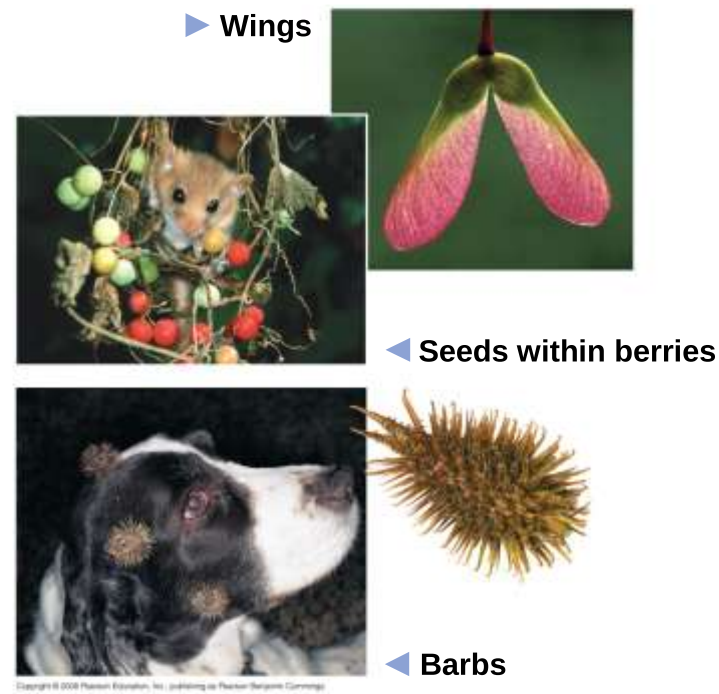
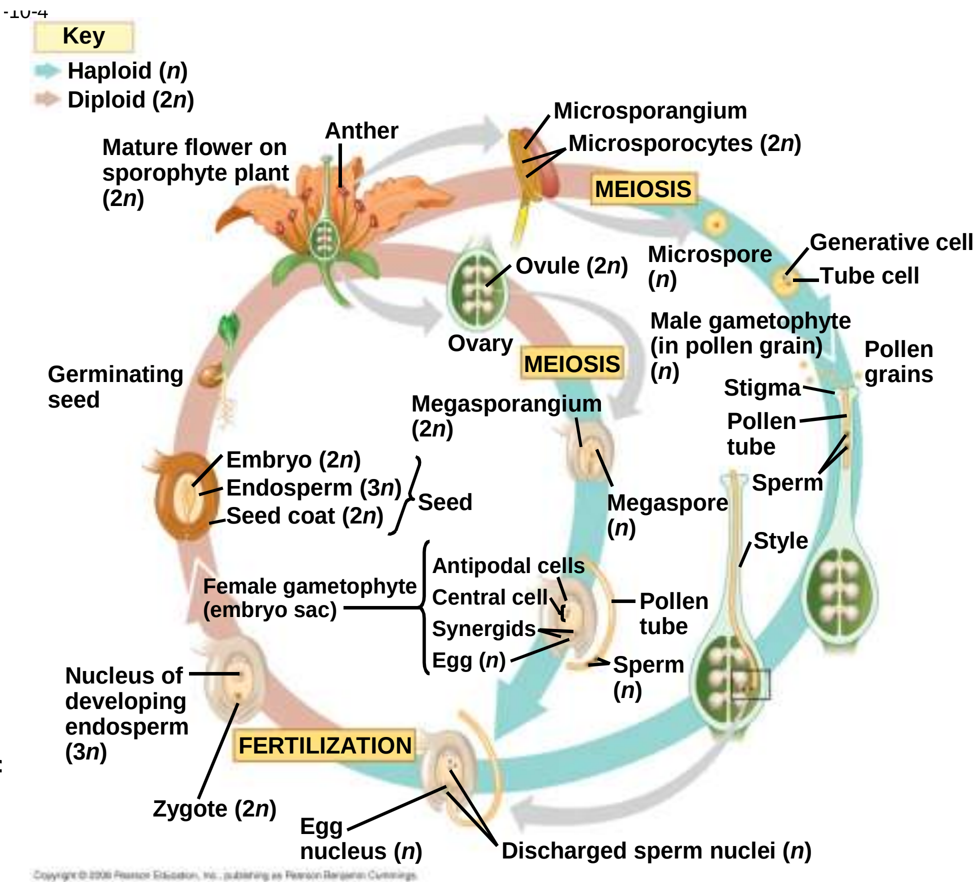
Animation: Fruit Development

- Various fruit adaptations help disperse seeds
  - The seeds of some flowering plants (dandelions, maples) are contained within fruits that function like parachutes, enhancing wind-dispersal
  - Other fruits (coconuts) are adapted to dispersal by water
  - Many angiosperms rely on animals to carry seeds, some of which have fruits modified as burrs that cling to fur or clothing
  - Still other angiosperms produce edible, usually nutritious, sweet-tasting, and vividly-colored fruits
    - When animals eat the fruit, it digests the fruit's fleshy part, but the tough seeds usually pass unharmed through the digestive tract
    - Animals may deposit the seeds, along with a supply of natural fertilizer, many kilometers from where the fruit was eaten



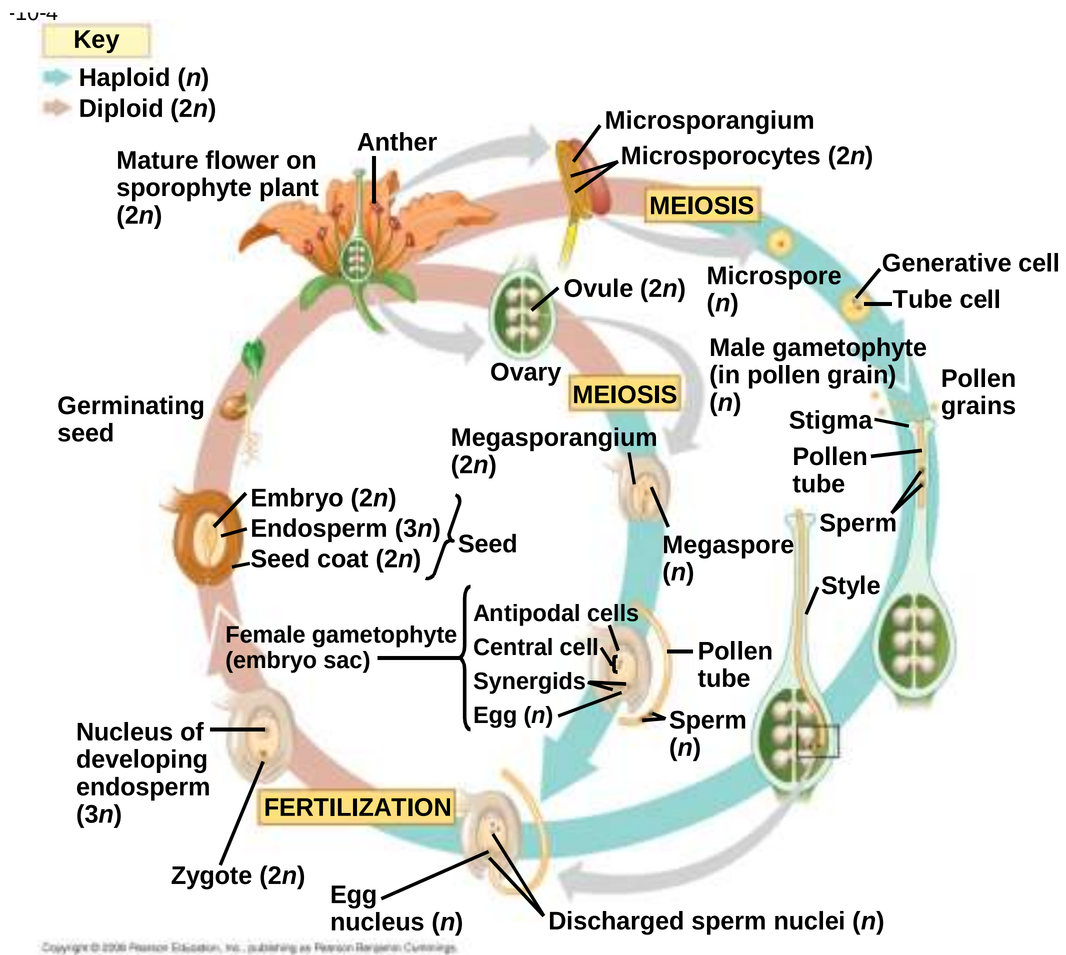
The Angiosperm Life Cycle

- The flower of the sporophyte is composed of both male and female structures:
  - Microspores produce male gametophytes
    - Male gametophytes are contained within pollen grains produced by the microsporangia of anthers
    - Each male gametophyte has 2 haploid cells:
      - One generative cell that divides to form 2 sperm
      - One tube cell that produces a pollen tube
  - Megaspores that form female gametophytes
    - The female gametophyte, or **embryo sac**, develops within an ovule contained within an ovary at the base of a stigma
      - The embryo sac consists of only a few cells, one of which is the egg

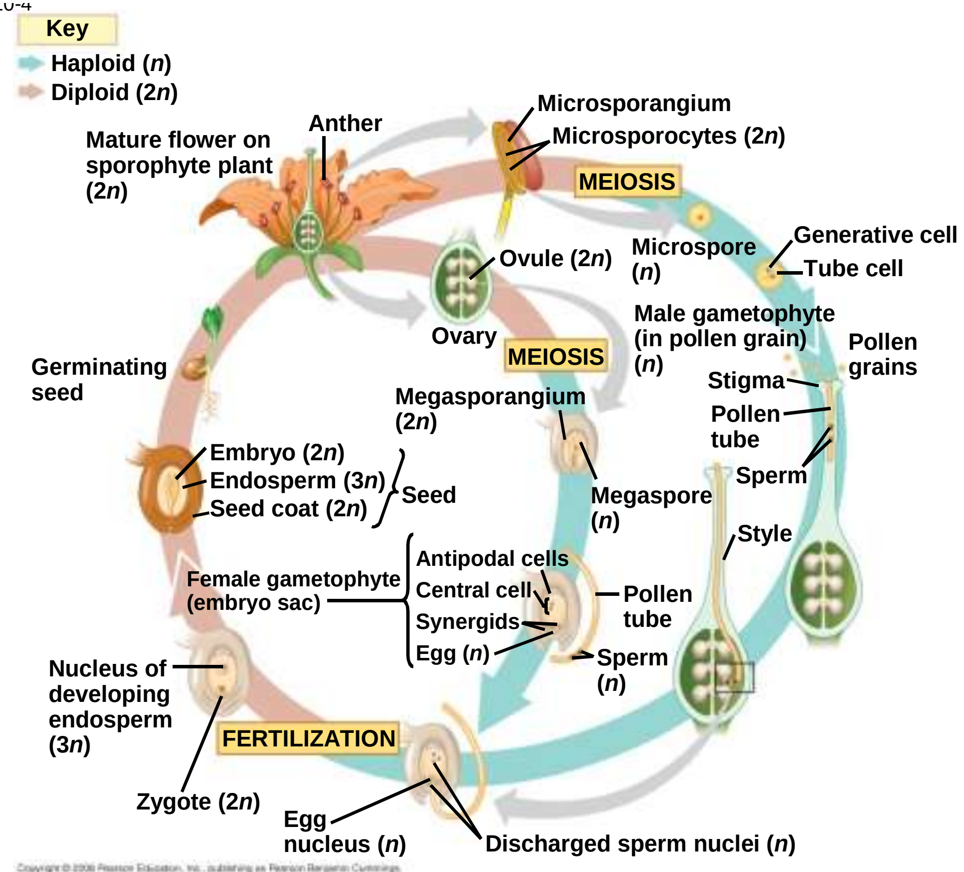


The Angiosperm Life Cycle

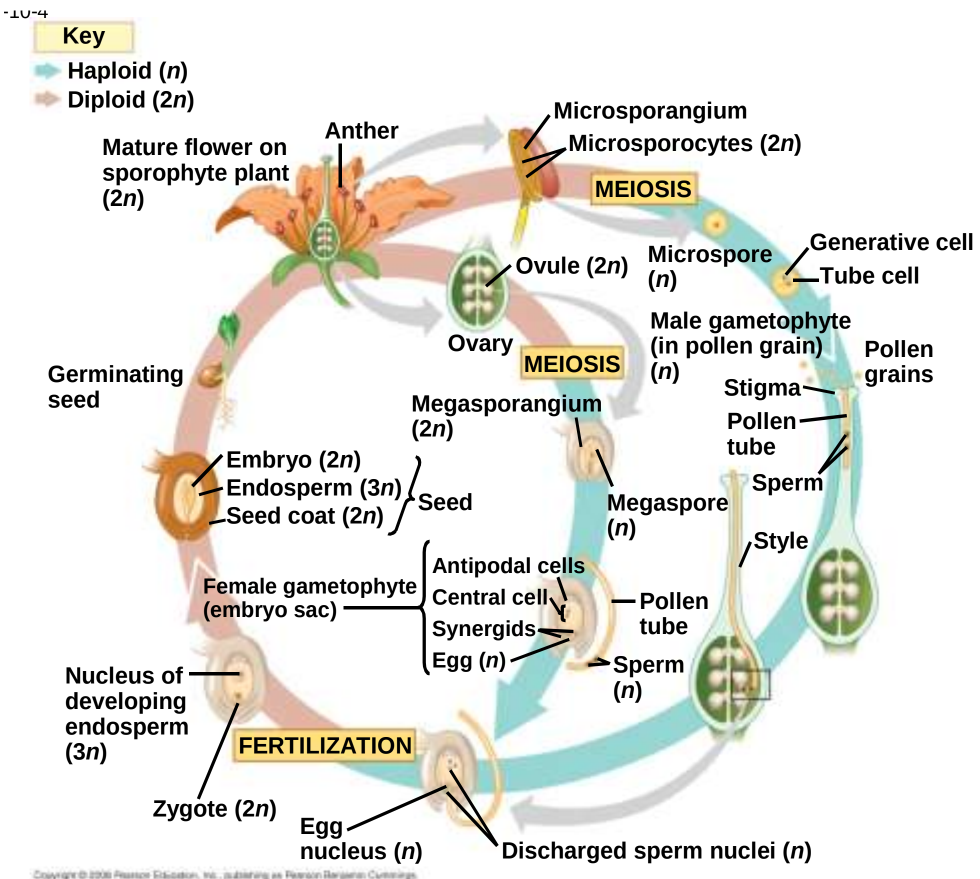
- After being released from the anther, pollen is carried to the sticky stigma at the tip of the carpal
  - Although some flowers self-pollinate, most flowers have mechanisms to ensure **cross-pollination** between flowers from different plants of the same species
    - Stamens and carpals of a single flower may mature at different times, or they may be arranged so that self-pollination is unlikely
      - Cross-pollination enhances genetic variation



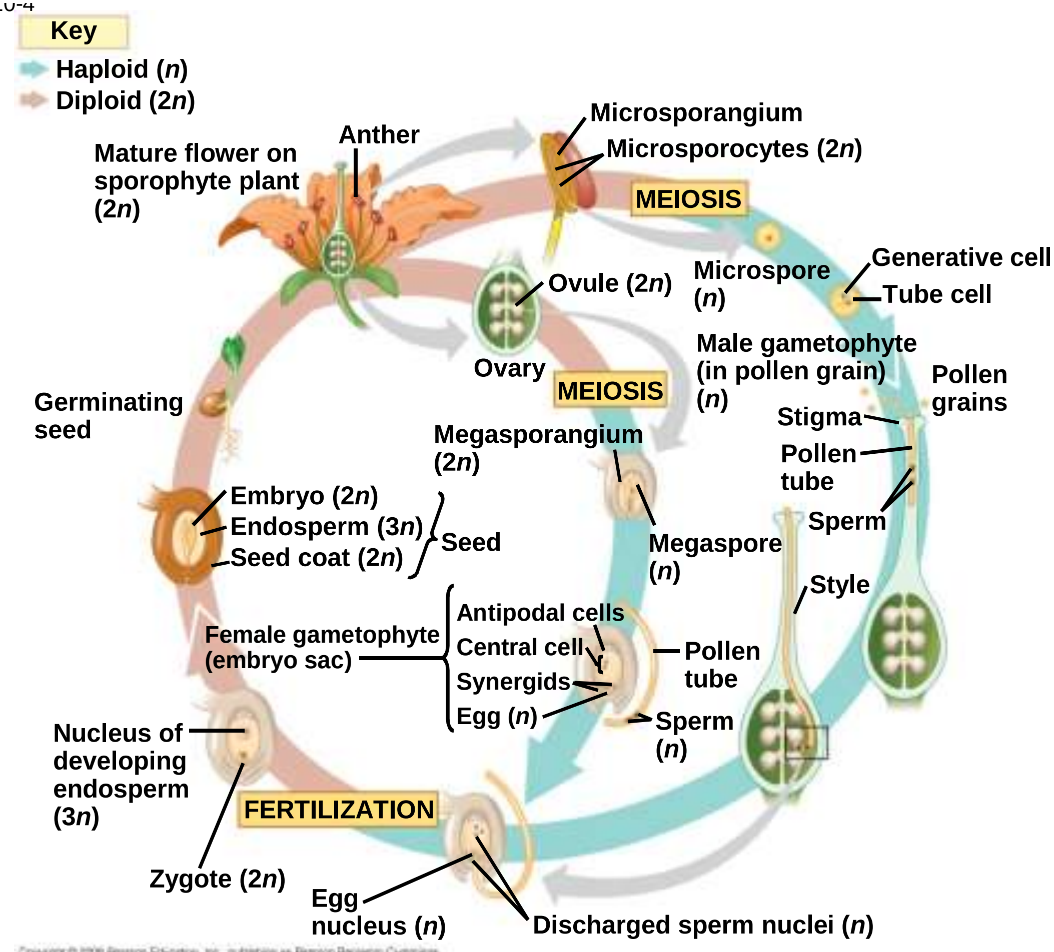
- A pollen grain germinates after it adheres to the stigma of a carpel
  - The pollen's male gametophyte extends a pollen tube that grows down within the style of the carpel
    - After reaching the ovary, this tube penetrates through a pore in the integuments of the ovule called the micropyle
    - Here, 2 sperm cells (**double fertilization**) are discharged into the female gametophyte (embryo sac) within an ovule
      - One sperm fertilizes the egg, forming a diploid zygote
      - The other sperm fuses with the two nuclei in the large central cell of the female gametophyte, producing a triploid cell



- After double fertilization, the ovule matures into a seed
  - The zygote develops into a sporophyte embryo with a rudimentary root and one or two seed leaves called **cotyledons**
  - The fertilized nucleus of the central cell of the female gametophyte divides repeatedly and develops into a tissue called **endosperm**
    - This tissue is rich in starch and other food reserves that nourish the developing embryo
- Double fertilization synchronizes the development of food storage in the seed with the development of the embryo
  - This prevents flowering plants from wasting nutrients on infertile ovules



- The seed consists of the embryo, endosperm, and a seed coat derived from the integuments
  - The ovary develops into a fruit as the ovules become seeds
  - After being dispersed, a seed may germinate if environmental conditions are favorable
    - The coat ruptures and the embryo emerges as a seedling, using food stored in the endosperm and cotyledons



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Animation: Plant Fertilization

PLAY

Animation: Seed Development

PLAY

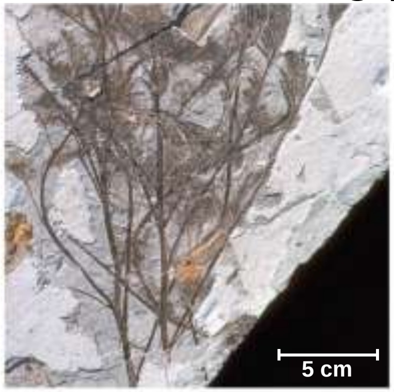
Video: Flowering Plant Life Cycle (time lapse)

Angiosperm Evolution

- Angiosperms originated at least 140 mya
  - During the late Mesozoic, the major branches of the clade diverged from their common ancestor
  - By the mid-Cretaceous (100 mya), angiosperms began to dominate many terrestrial ecosystems
- To understand how the angiosperm body plan emerged, scientists are studying fossils

Fossil Angiosperms

- Primitive fossils of 125-million-year-old angiosperms display derived and primitive traits
  - *Archaefructus sinensis,* for example, has anthers and seeds inside closed carpels but lacks petals and sepals
    - After completing a phylogenetic comparison of A. sinensis with 173 living plants, researchers concluded that this fossil species may belong to the earliest-diverging group of angiosperms known
      - This suggests that the ancestors of flowering plants were herbaceous rather than woody
      - The discovery of this fossilized plant alongside fish fossils also implies that angiosperms may have originated as aquatic plants

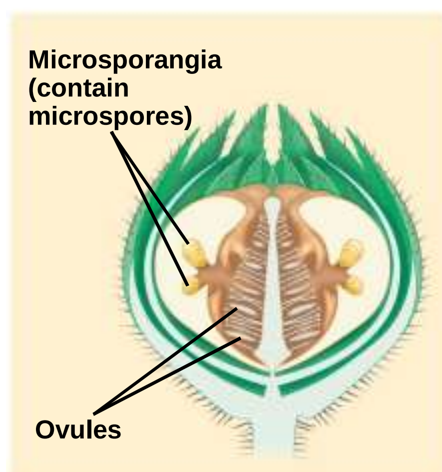


(a) ***Archaefructus sinensis*, a 125-million-year-old fossil**

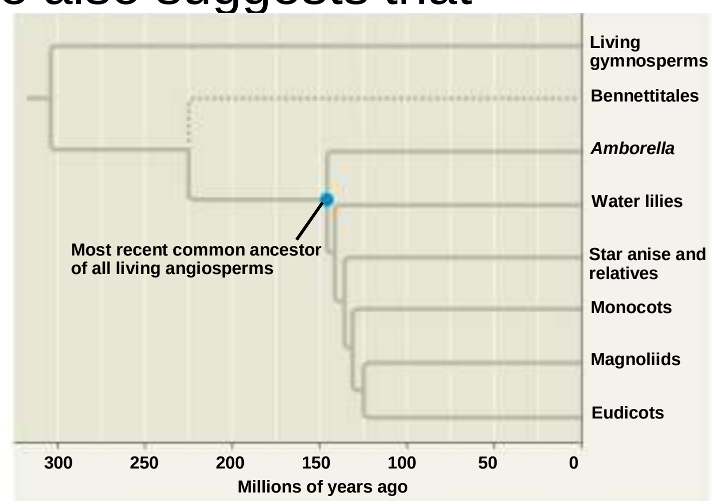
(b) Artist's reconstruction of *Archaefructus sinensis*

Angiosperm Phylogeny

- The ancestors of angiosperms and gymnosperms diverged about 305 million years ago
  - This does not necessarily imply that angiosperms originated 305 mya, but that the most recent common ancestor of these groups lived at that time
    - Angiosperms may be closely related to Bennettitales, extinct seed plants with flowerlike structures that may have been pollinated by insects
    - Molecular and morphological evidence also suggests that *Amborella* and water lilies are living representatives of 2 of the most ancient angiosperm lineages



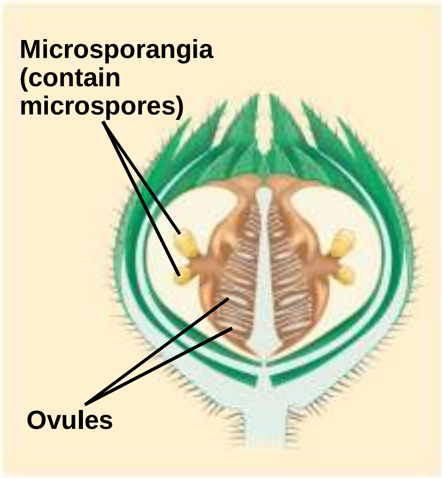
(a) A possible ancestor of the angiosperms?



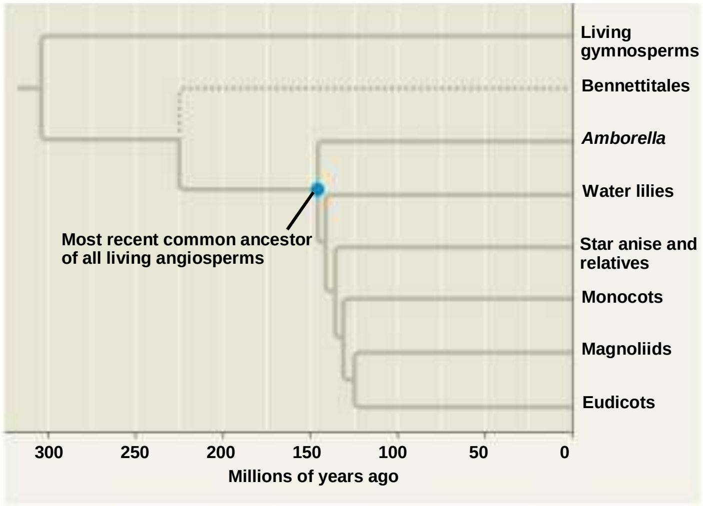
(b) Angiosperm phylogeny

Developmental Patterns in Angiosperms

- Additional clues about the origin of flowering plants are emerging from studies of plant development
  - Egg formation in the angiosperm *Amborella* resembles that of the gymnosperms
  - Researchers are also currently studying expression of flower development genes in gymnosperm and angiosperm species



(a) A possible ancestor of the angiosperms?



(b) Angiosperm phylogeny

Angiosperm Diversity

- Until the late 1990s, most systematics divided flowering plants into 2 groups based partly on the number of cotyledons (seed leaves) in the embryo
  - Species with one cotyledon were called **monocots**
    - Ex) Orchids, palms, and grain crops (maize, wheat, rice)
  - Species with two cotyledons were called **dicots**
    - Ex) Roses, peas, sunflowers, and maples
- Other features (flower/leaf structure) were also used to define the 2 groups
  - Monocots typically have parallel leaf veins (grass blades)
  - Most dicots have veins with a net-like pattern (oak leaf)

Angiosperm Diversity

- Recent DNA studies, however, indicate that the monocot-dicot distinction does not completely reflect evolutionary relationships
  - Current research supports the hypothesis that monocots form a clade but reveals that dicots are actually polyphyletic
  - The vast majority of species once categorized as dicots form a large clade now known as **eudicots** (“true” dicots)
    - The rest of the former dicots are now grouped into several small lineages
      - Three of these lineages are informally called **basal angiosperms**
        - Basal angiosperms are less derived and include the flowering plants belonging to the oldest lineages
      - A fourth lineage known as the **magnoliid**s evolved later
        - Magnoliids share some traits with basal angiosperms but are more closely related to monocots and eudicots

- Basal angiosperms:
  - Three small lineages constitute the basal angiosperms, totaling ~100 species, including:
    - *Amborella trichopoda:* the sole survivor of the oldest angiosperm lineage, found only on the South Pacific island of New Caledonia
    - A clade including the water lilies
    - Another clade consisting of the star anise and its relatives

Amborella trichopoda

Water lily

Star anise

- Magnoliids consist of ~8,000 species, including magnolias, laurels, and black pepper plants
  - They include both woody and herbaceous species
  - Although they share some traits with basal angiosperms, magnoliids are more closely related to monocots and eudicots
    - Ex) Southern magnolia: a woody magnoliid
      - The variety shown is called “Goliath,” named for flowers that measure up to a foot across

Southern magnolia

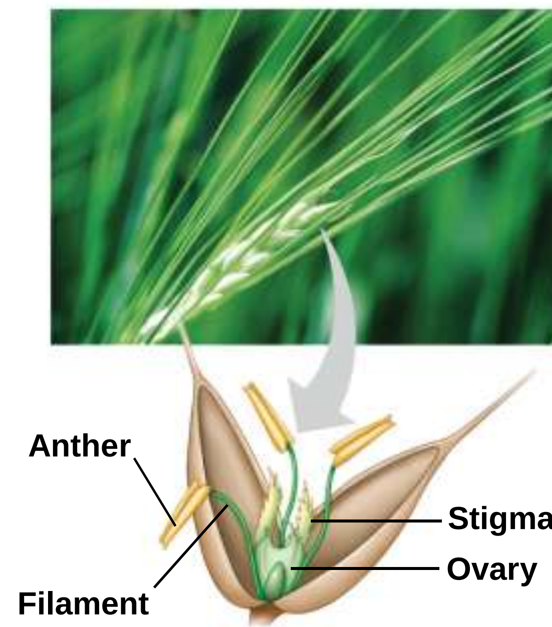
- More than one-quarter of angiosperm species are monocots, including ~ 70,000 species

Orchid

Lily

Pygmy date palm (*Phoenix roebelenii*)

Barley



- More than two-thirds of angiosperm species are eudicots, roughly 170,000 species

Pyrenean oak

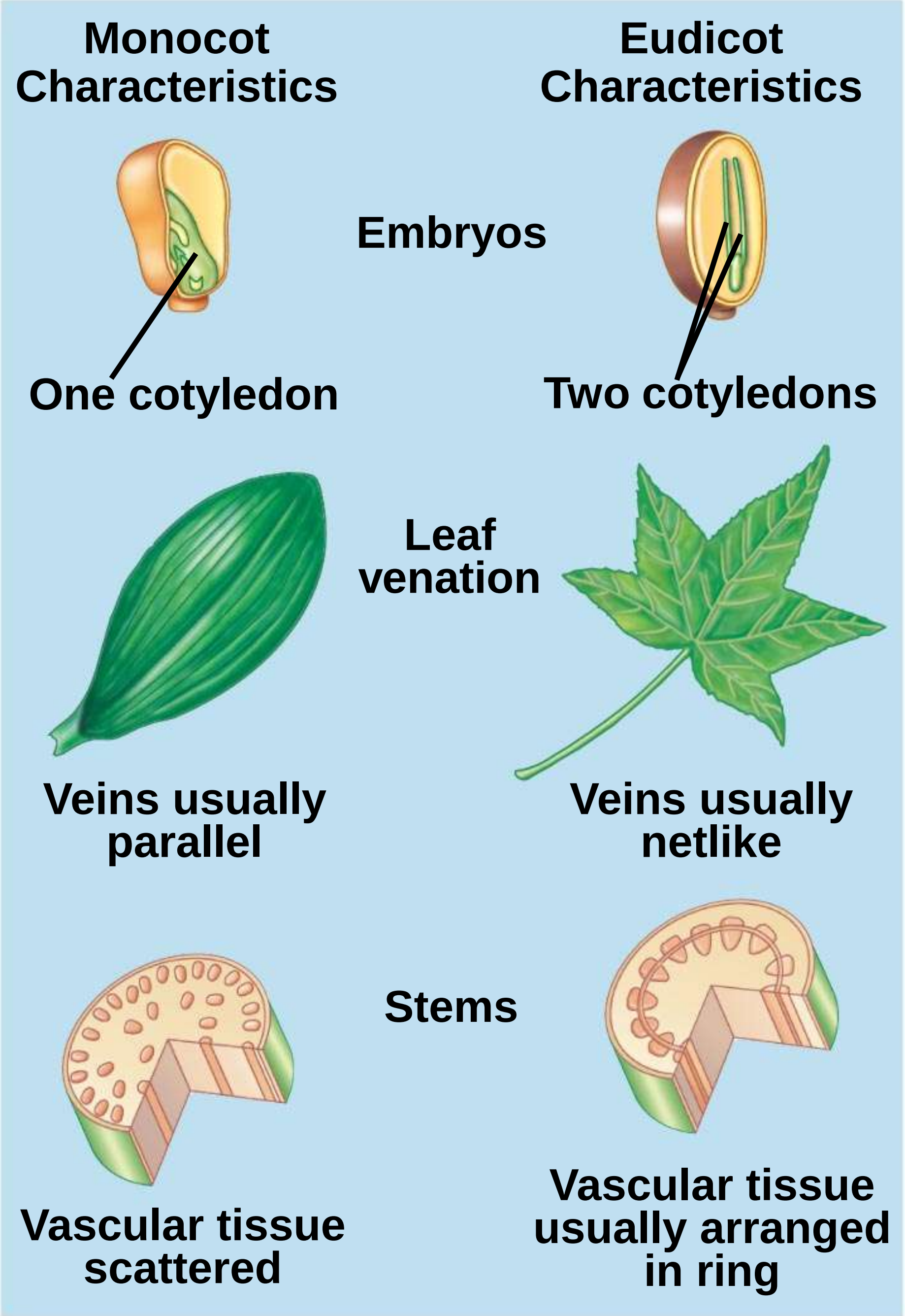
Snow pea

Zucchini flowers

California poppy

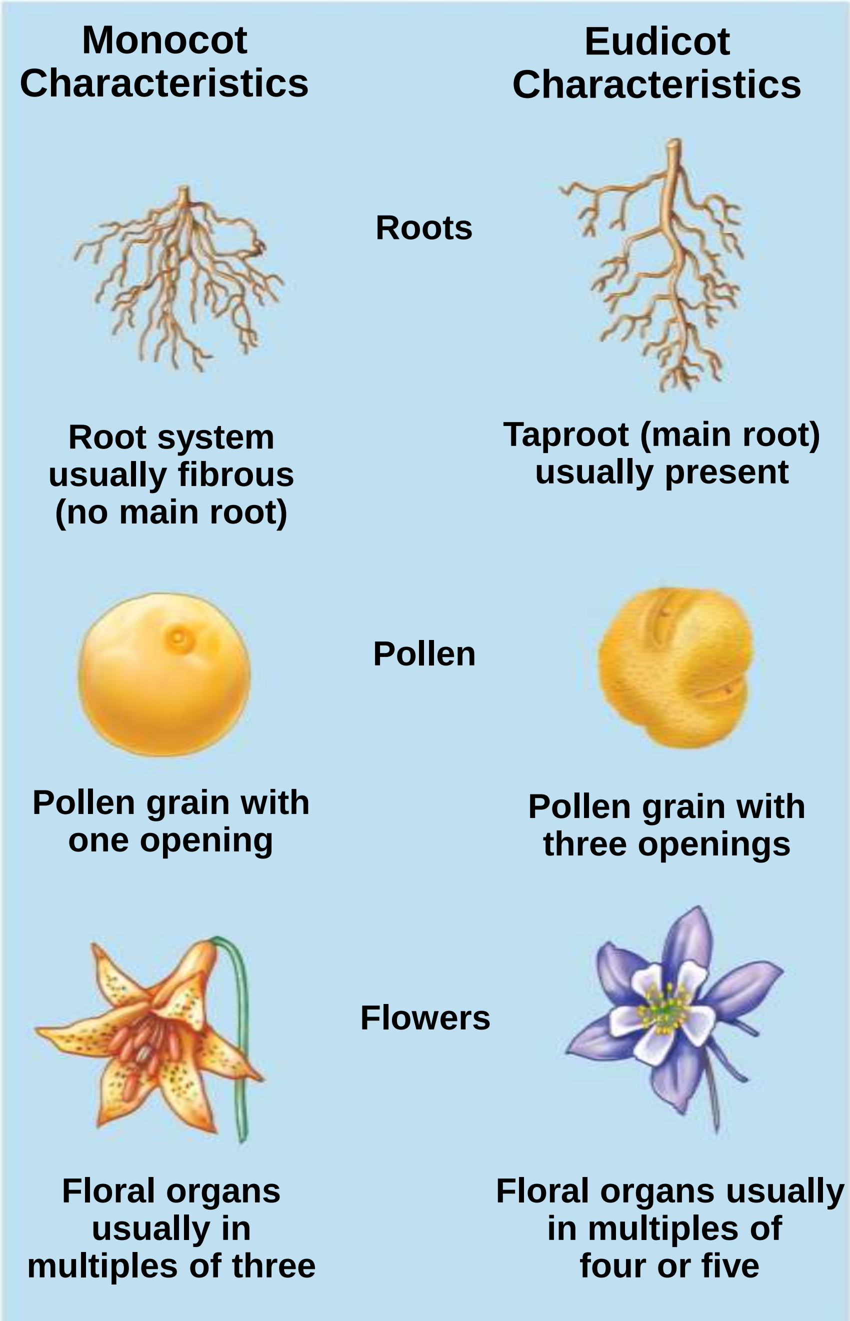
Dog rose

Fig. 30-13n



Monocot Characteristics
Eudicot Characteristics
Embryos
One cotyledon
Two cotyledons
Leaf venation
Veins usually parallel
Veins usually netlike
Stems
Vascular tissue scattered
Vascular tissue usually arranged in ring

Fig. 30-13o


Monocot Characteristics
Eudicot Characteristics
Roots
Root system usually fibrous (no main root)
Taproot (main root) usually present
Pollen
Pollen grain with one opening
Pollen grain with three openings
Flowers
Floral organs usually in multiples of three
Floral organs usually in multiples of four or five

Evolutionary Links Between Angiosperms and Animals

- Pollination of flowers and transport of seeds by animals are two important relationships in terrestrial ecosystems
  - Flowers can be arranged symmetrically in one direction only (bilateral symmetry) or symmetrically in all directions (radial symmetry)
    - On a flower with bilateral symmetry, an insect pollinator may only be able to obtain nectar when it approaches the flower from a certain direction
      - This makes it more likely that, as an insect moves from flower to flower, pollen is placed on a part of the insect's body that will come into contact with the stigma of a flower of the same species
    - As a result of this specificity of pollen transfer, gene flow may be reduced more easily in diverging populations with bilateral symmetry
      - Research has shown that clades with bilaterally symmetrical flowers do indeed have more species than those with radially symmetrical flowers

PLAY Video: Bee Pollinating

PLAY Video: Bat Pollinating Agave Plant

Concept Check 30.3

- 1) It has been said that an oak is an acorn's way of making more acorns. Write an explanation that includes these terms: sporophyte, gametophyte, ovule, seed, ovary, and fruit.
- 2) Compare and contrast a pine cone and a flower in terms of structure and function.
- 3) If researchers discovered a 135-million-year-old fossil angiosperm that had woody tissues as well as sepals and petals, how would their findings affect current interpretations of *Archaefructus sinensis* fossils?

Concept 30.4: Human welfare depends greatly on seed plants

- No group of plants is more important to human survival than seed plants
  - Plants are key sources of food, fuel, wood products, and medicine
    - Our reliance on seed plants makes preservation of plant diversity critical
  - Most of our food comes from angiosperms
    - Six crops (wheat, rice, maize, potatoes, cassava, and sweet potatoes) yield 80% of the calories consumed by humans
      - Modern crops are products of relatively recent genetic change resulting from artificial selection
        - The number and size of seeds in domestic plants is greater than those of their wild relatives
    - In addition to staple crops, flowering plants provide other edible products
      - These include tea leaves, coffee beans, cocoa, chocolate, and spices

- Many seed plants provide wood, which is absent in all living seedless plants
  - Wood is the primary source of fuel for much of the world
  - Wood pulp, mainly derived from conifers like fir and pine, is used to make paper
  - Wood is also the most widely used construction material
- Secondary compounds of seed plants are also used in medicines
  - Willow leaves and bark have been used since ancient times in pain-relieving remedies
    - Their medicinal properties have been traced to the chemical salicin, from which a derivative called acetylsalicylic acid (aspirin) was made
  - In the US, ~25% of prescription drugs contain one or more active ingredients extracted or derived from plants, typically seed plants

Table 30.1 A Sampling of Medicines Derived from Seed Plants

Compound	Source	Example of Use
Atropine	Belladonna plant	Pupil dilator in eye exams
Digitalin	Foxglove	Heart medication
Menthol	Eucalyptus tree	Ingredient in cough medicines
Morphine	Opium poppy	Pain reliever
Quinine	Cinchona tree (see below)	Malaria preventive
Taxol	Pacific yew	Ovarian cancer drug
Tubocurarine	Curare tree	Muscle relaxant during surgery
Vinblastine	Periwinkle	Leukemia drug

Cinchona bark, source of quinine

Threats to Plant Diversity

- Destruction of habitat is causing extinction of many plant species
  - This problem is especially severe in the tropics, where ~35 million acres (roughly the size of Iowa) are cleared each year
    - This rate will completely eliminate Earth's tropical rain forests within 100-150 years
  - Loss of plant habitat is often accompanied by loss of the animal species that plants support
    - At the current rate of habitat loss, 50% of Earth's species will become extinct within the next 100–200 years
      - Such losses constitute a global mass extinction rivaling those of the Permian and Cretaceous mass extinctions

- Though many people have ethical concerns about contributing to the extinction of living organisms, there are many practical reasons to be concerned about the loss of plant diversity
  - So far, we have only explored the potential uses of a tiny fraction of more than 290,000 known plant species
    - Almost all our food is based on the cultivation of only about two dozen species of seed plants
    - Fewer than 5,000 plant species have been studied as potential sources of medicine
      - The tropical rain forest may be a “medicine chest” of healing plants that could go extinct before we even learn of their existence

Concept Check 30.4

- 1) Explain why plant diversity may be considered a non-renewable resource.
- 2) How could phylogenies be used to improve the efficiency with which researchers search for novel medicines derived from seed plants?

You should now be able to:

1. Explain why pollen grains were an important adaptation for successful reproduction on land
2. List and distinguish among the four phyla of gymnosperms
3. Describe the life history of a pine; indicate which structures are part of the gametophyte generation and which are part of the sporophyte generation

You should now be able to:

4. Identify and describe the function of the following floral structures: sepals, petals, stamens, carpels, filament, anther, stigma, style, ovary, and ovule
5. Explain how fruits may be adapted to disperse seeds
6. Diagram the generalized life cycle of an angiosperm; indicate which structures are part of the gametophyte generation and which are part of the sporophyte generation

7. Explain the significance of *Archaefructus* and *Amborella*

8. Describe the current threat to plant diversity caused by human population growth