Chapter 30

Plant Diversity II: The Evolution of Seed Plants

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

Neil Campbell and Jane Reece

Lectures by Chris Romero, updated by Erin Barley with contributions from Joan Sharp

Overview: Transforming the World

- Seeds changed the course of plant evolution, enabling their bearers to become the dominant producers in most terrestrial ecosystems
- A **seed** consists of an embryo and nutrients surrounded by a protective coat

Fig. 30-1

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

- In addition to seeds, the following are common to all seed plants
  - Reduced gametophytes
  - Heterospory
  - Ovules
  - Pollen

Advantages of Reduced Gametophytes

- The gametophytes of seed plants develop within the walls of spores that are retained within tissues of the parent sporophyte

Fig. 30-2

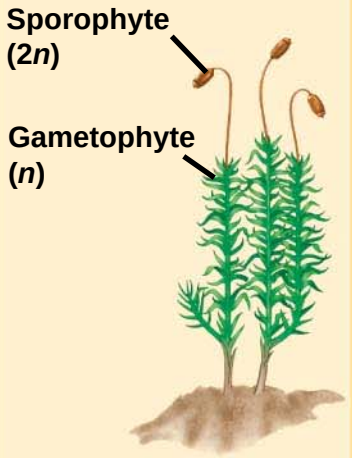
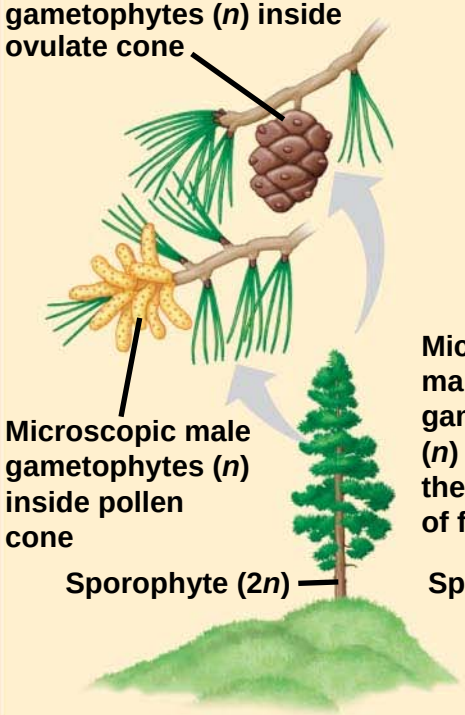
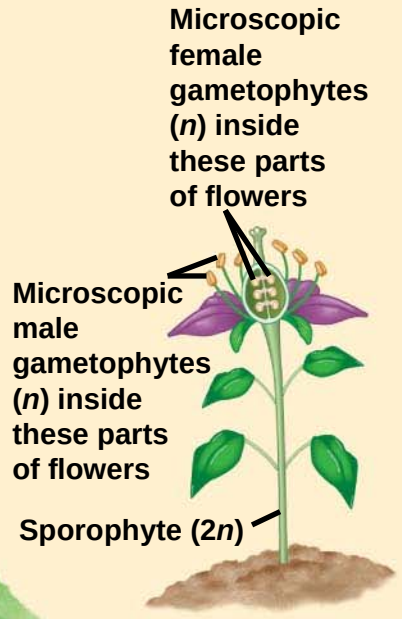
	PLANT GROUP		
	Mosses and other nonvascular plants	**Ferns and other seedless vascular plants**	**Seed plants (gymnosperms and angiosperms)**
Gametophyte	**Dominant**	**Reduced, independent (photosynthetic and free-living)**	**Reduced (usually microscopic), dependent on surrounding sporophyte tissue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

Fig. 30-2a

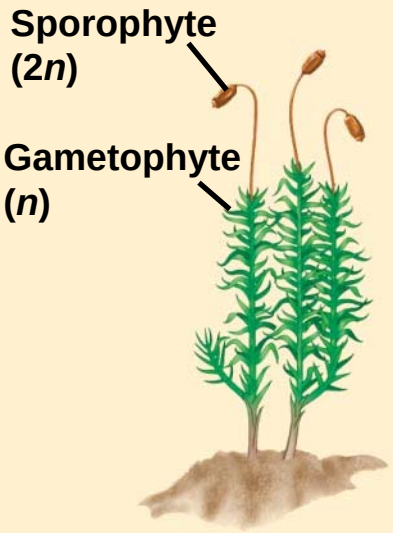
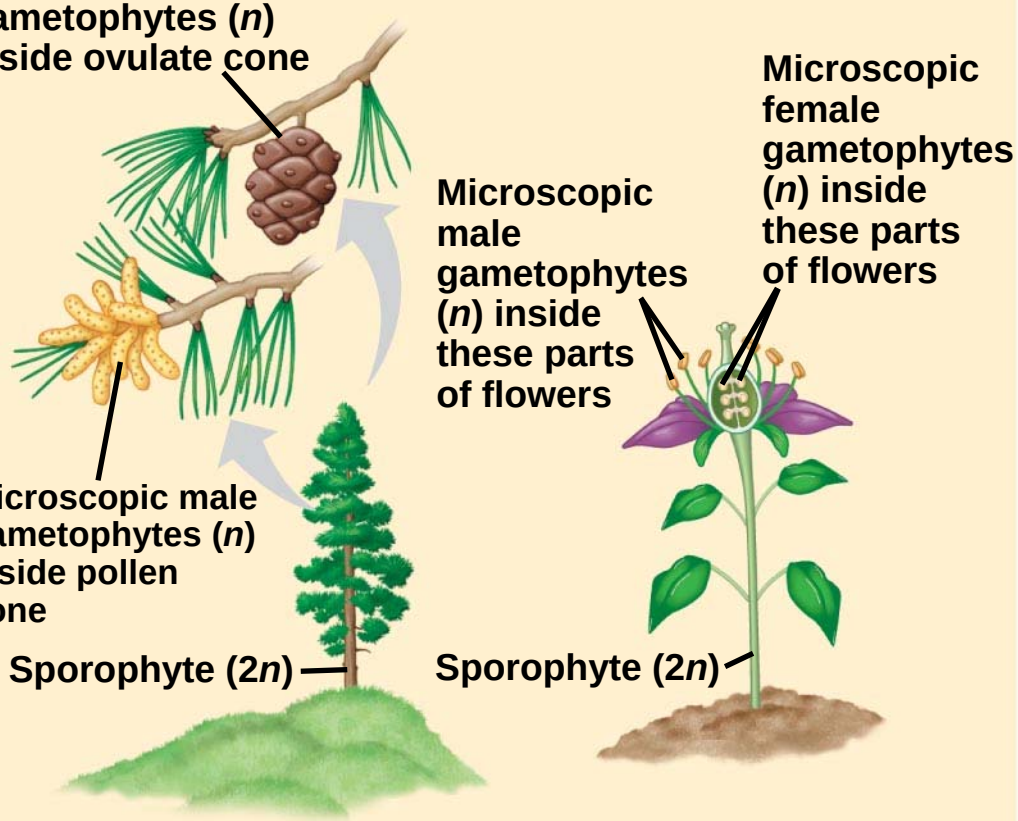
	Mosses and other nonvascular plants
Gametophyte	Dominant
Sporophyte	Reduced, dependent on gametophyte for nutrition
Example	

Fig. 30-2b

	Ferns and other seedless vascular plants
Gametophyte	Reduced, independent (photosynthetic and free-living)
Sporophyte	Dominant
Example	

Fig. 30-2c

	Seed plants (gymnosperms and angiosperms)
Gametophyte	Reduced (usually microscopic), dependent on surrounding sporophyte tissue for nutrition
Sporophyte	Dominant
Example	Gymnosperm / Angiosperm



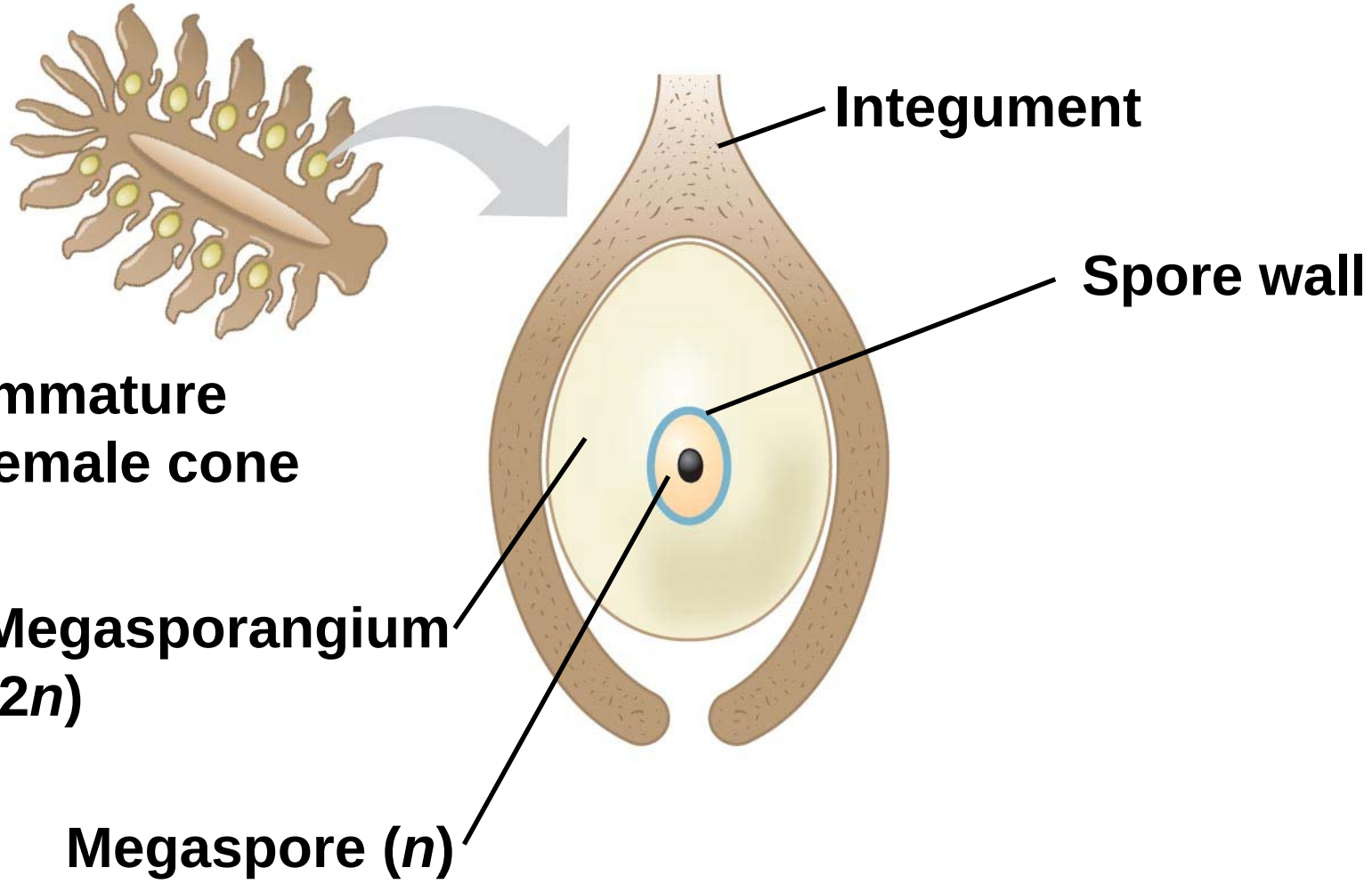
Heterospory: The Rule Among Seed Plants

- The ancestors of seed plants were likely homosporous, while seed plants are heterosporous
- Megasporangia produce megaspores that give rise to female gametophytes
- Microsporangia produce microspores that give rise to male gametophytes

Ovules and Production of Eggs

- An **ovule** consists of a megasporangium, megaspore, and one or more protective **integuments**
- Gymnosperm megaspores have one integument
- Angiosperm megaspores usually have two integuments

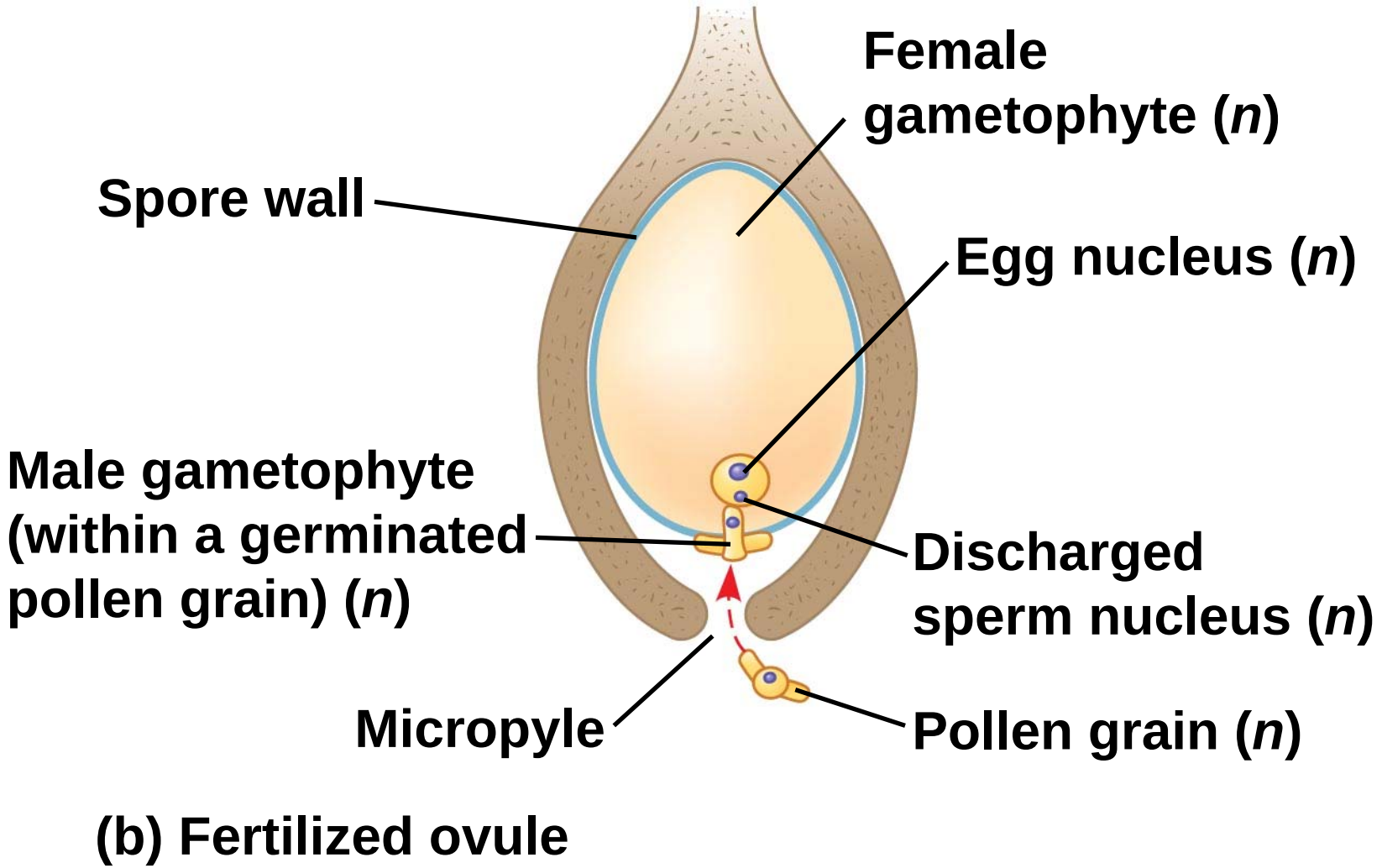
Fig. 30-3-1



Pollen and Production of Sperm

- Microspores develop into **pollen grains**, which contain the male gametophytes
- **Pollination** is the transfer of pollen to the part of a seed plant containing the ovules
- Pollen eliminates the need for a film of water and can be dispersed great distances by air or animals
- If a pollen grain germinates, it gives rise to a pollen tube that discharges two sperm into the female gametophyte within the ovule

Fig. 30-3-2

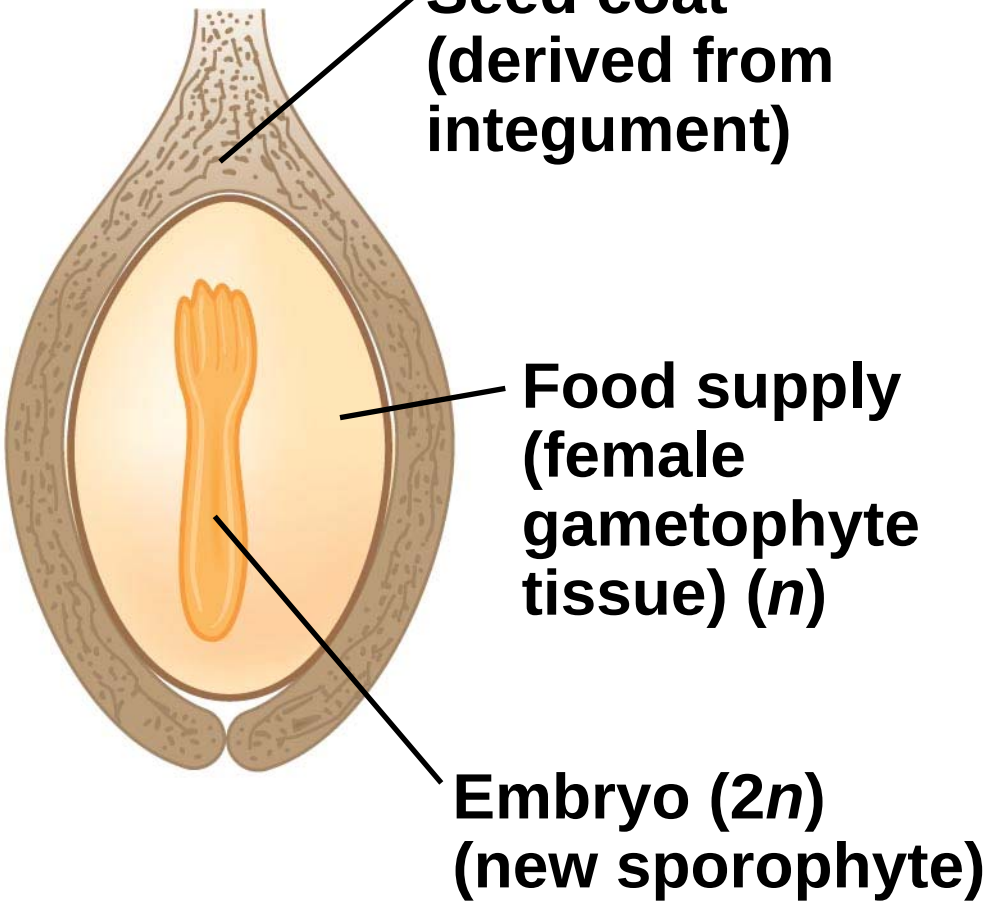


(b) Fertilized ovule

The Evolutionary Advantage of Seeds

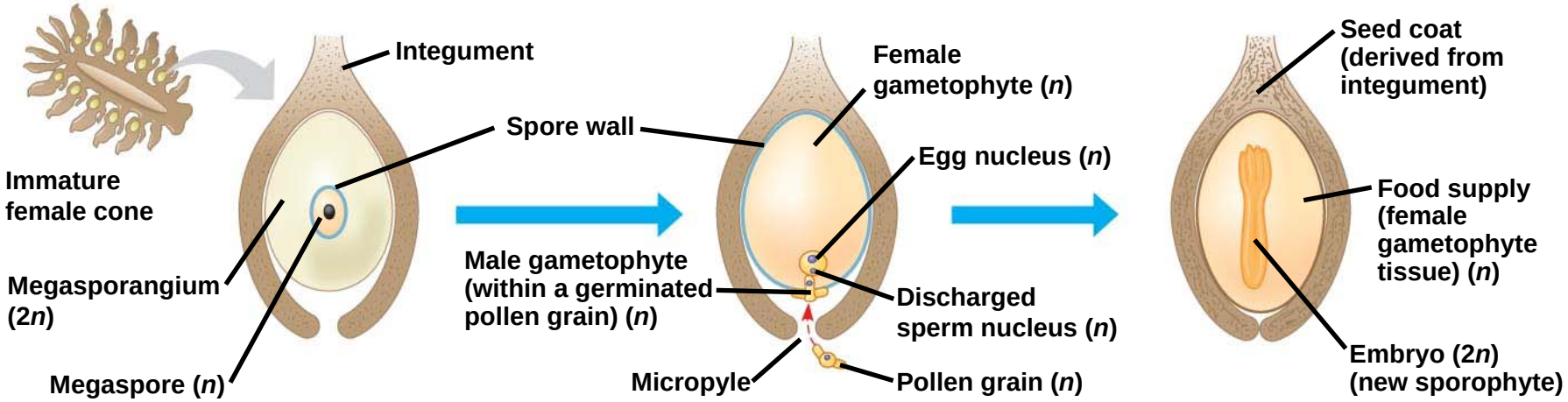
- A seed develops from the whole ovule
- A seed is a sporophyte embryo, along with its food supply, packaged in a protective coat
- Seeds provide some evolutionary advantages over spores:
  - They may remain dormant for days to years, until conditions are favorable for germination
  - They may be transported long distances by wind or animals

Fig. 30-3-3



(c) Gymnosperm seed

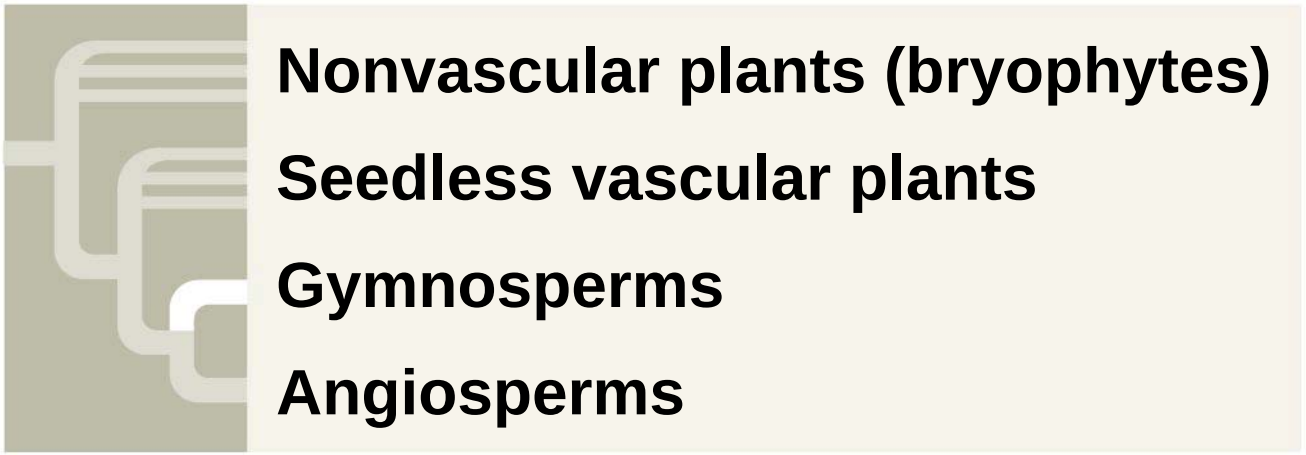
Fig. 30-3-4



Concept 30.2: Gymnosperms bear "naked" seeds, typically on cones

- The gymnosperms have "naked" seeds not enclosed by ovaries and 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)

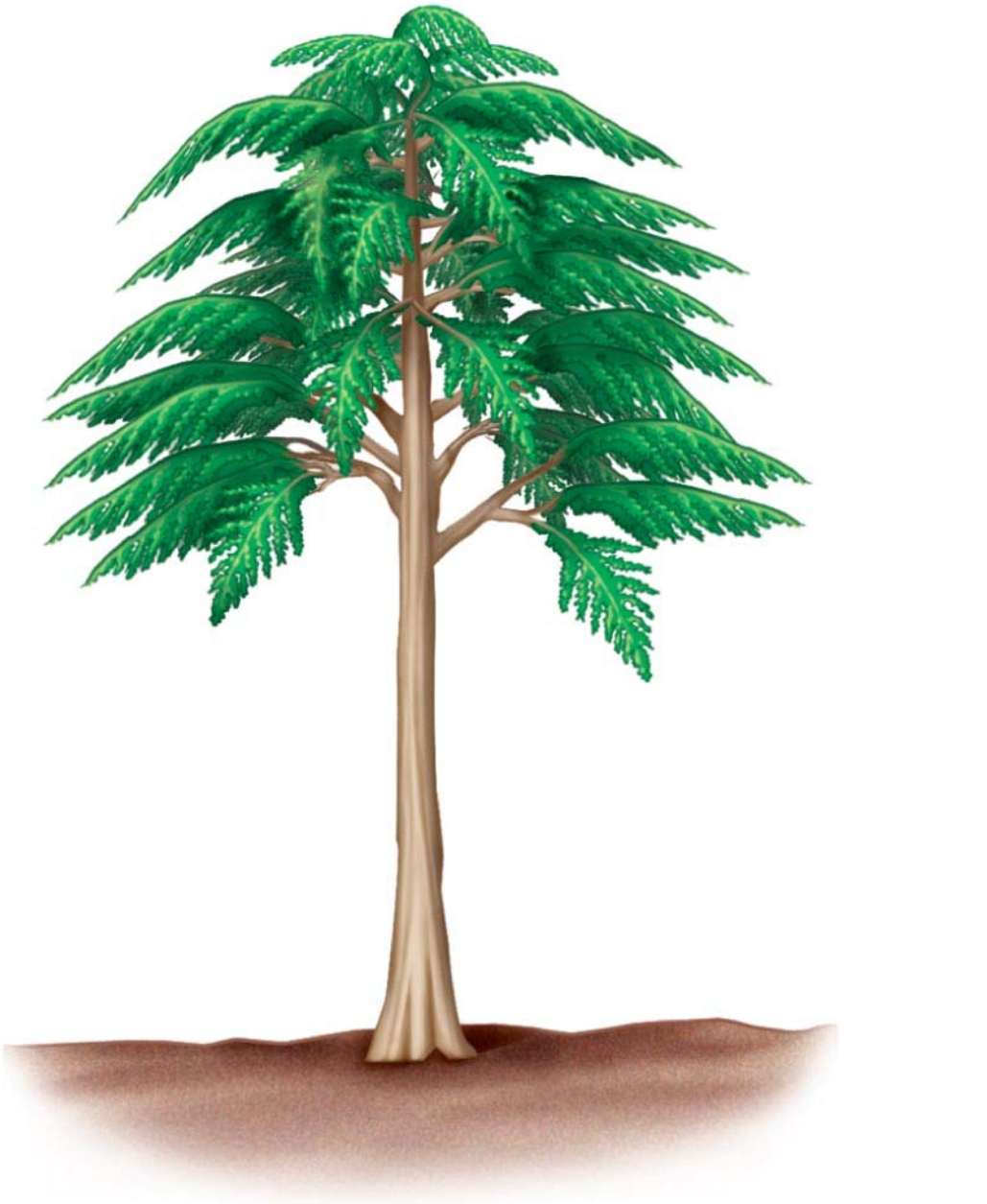
Fig. 30-UN1



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

Fig. 30-4



***Archaeopteris*, a progymnosperm**

- Living seed plants can be divided into two clades: gymnosperms and angiosperms
- Gymnosperms appear early in the fossil record and dominated the Mesozoic terrestrial ecosystems
- Gymnosperms were better suited than nonvascular plants to drier conditions
- Today, cone-bearing gymnosperms called **conifers** dominate in the northern latitudes

Phylum Cycadophyta

- Individuals have large cones and palmlike leaves
- These thrived during the Mesozoic, but relatively few species exist today

Fig. 30-5a

Cycas revoluta

Phylum Ginkgophyta

- This phylum consists of a single living species, *Ginkgo biloba*
- It has a high tolerance to air pollution and is a popular ornamental tree

Fig. 30-5b

Ginkgo biloba
pollen-producing tree

Fig. 30-5c

Ginkgo biloba
leaves and fleshy seeds

Phylum Gnetophyta

- This phylum comprises three genera
- Species vary in appearance, and some are tropical whereas others live in deserts

Fig. 30-5d

Gnetum

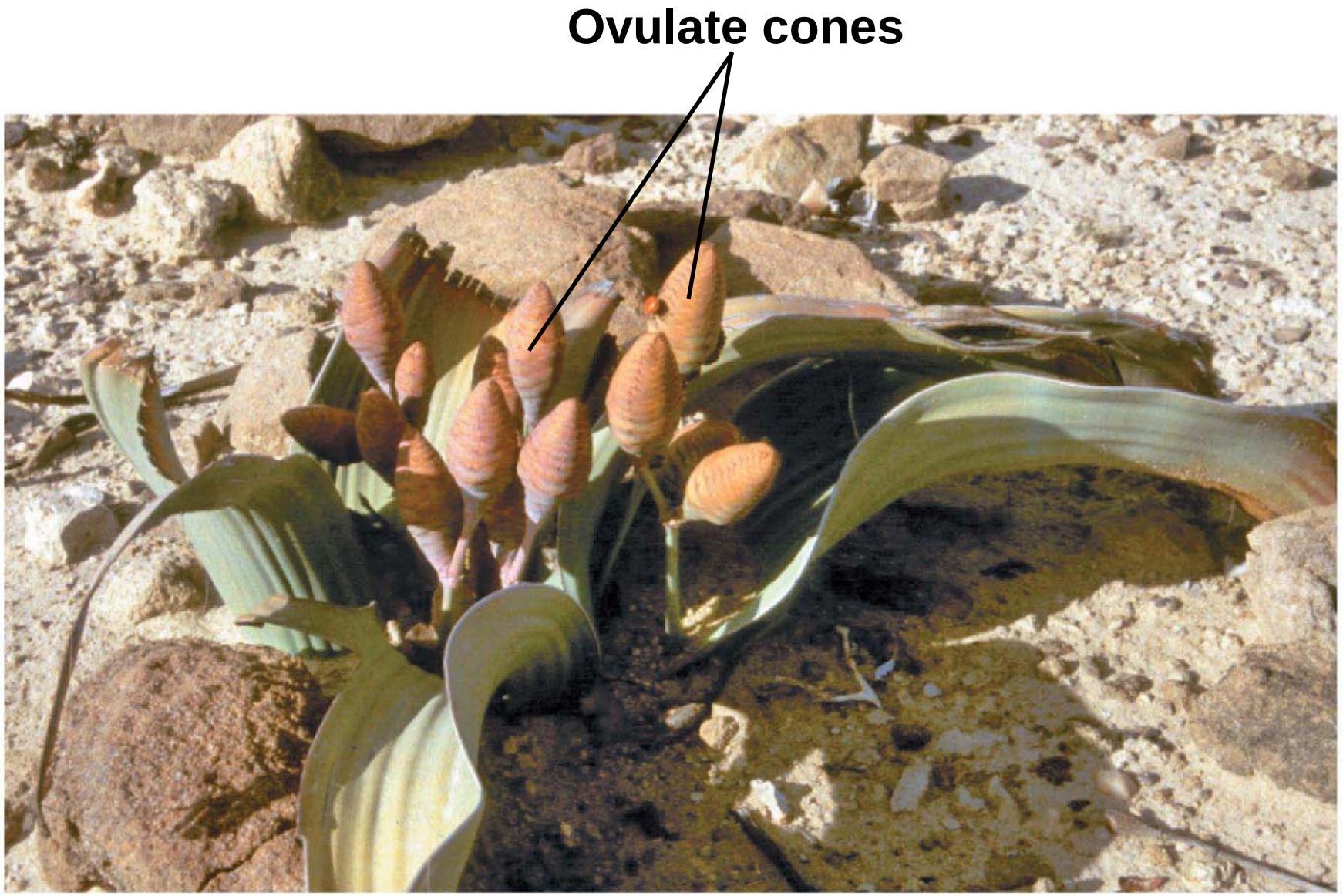
Fig. 30-5e

Ephedra

Fig. 30-5f

Welwitschia

Fig. 30-5g



Welwitschia

Phylum Coniferophyta

- This phylum is by far the largest of the gymnosperm phyla
- Most conifers are evergreens and can carry out photosynthesis year round

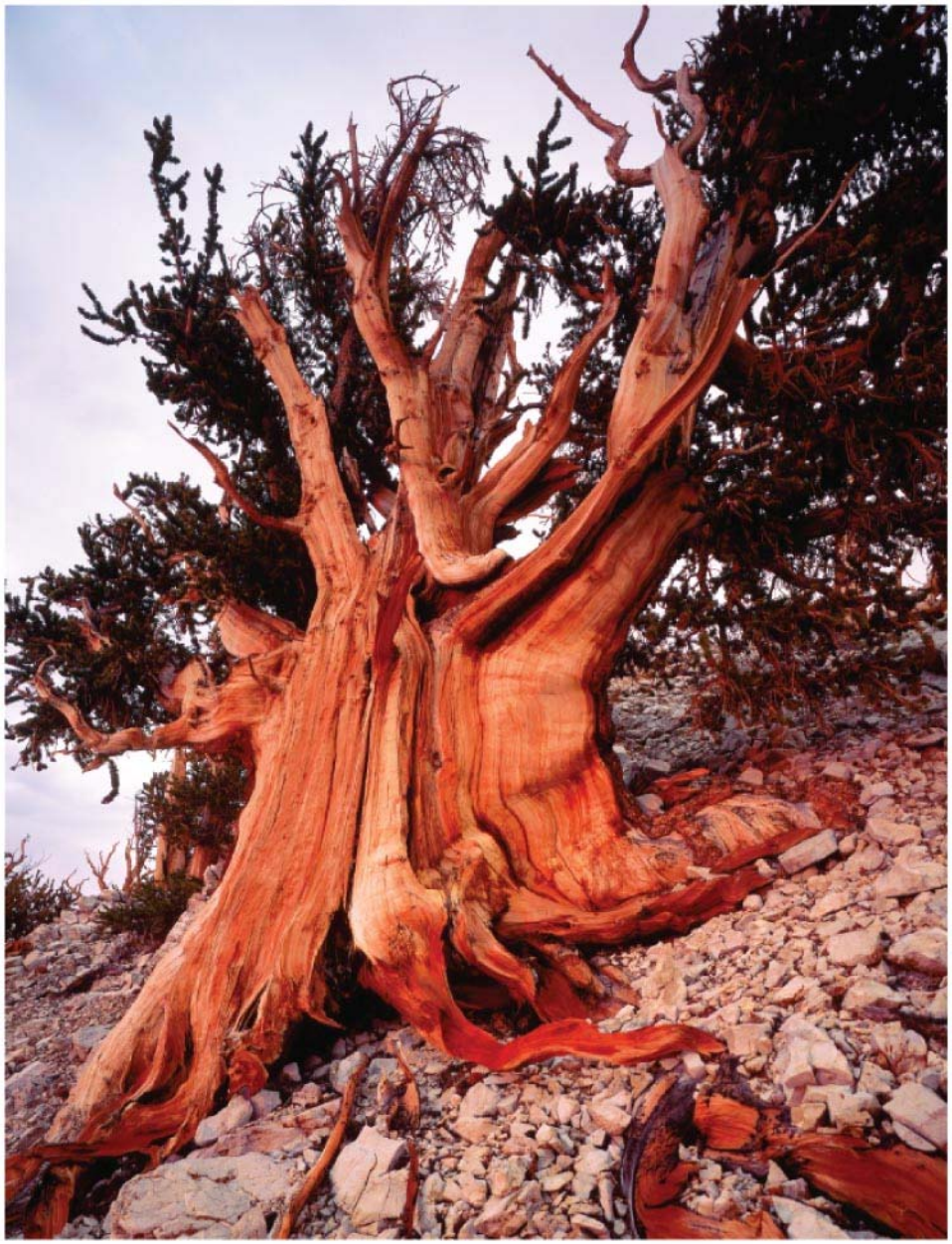
Fig. 30-5h

Douglas fir

Fig. 30-5i

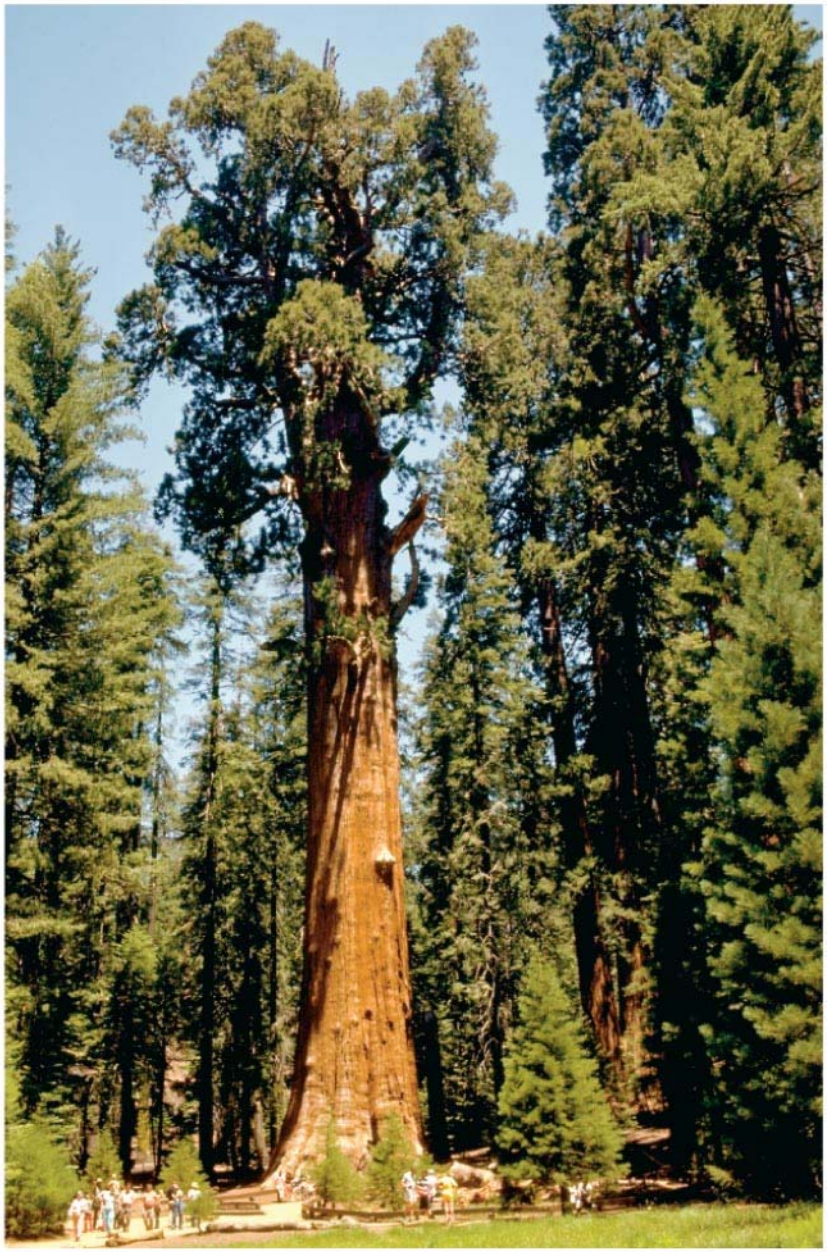
European larch

Fig. 30-5j



Bristlecone pine

Fig. 30-5k



Sequoia

Fig. 30-5l

Wollemi pine

Fig. 30-5m

Common juniper

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 seeds from fertilized ovules
  - The transfer of sperm to ovules by pollen
- The life cycle of a pine provides an example

PLAY Animation: Pine Life Cycle

- The pine tree is the sporophyte and produces sporangia in male and female cones
- Small cones produce microspores called pollen grains, each of which contains a male gametophyte
- The familiar larger cones contain ovules, which produce megaspores that develop into female gametophytes
- It takes nearly three years from cone production to mature seed

Fig. 30-6-1

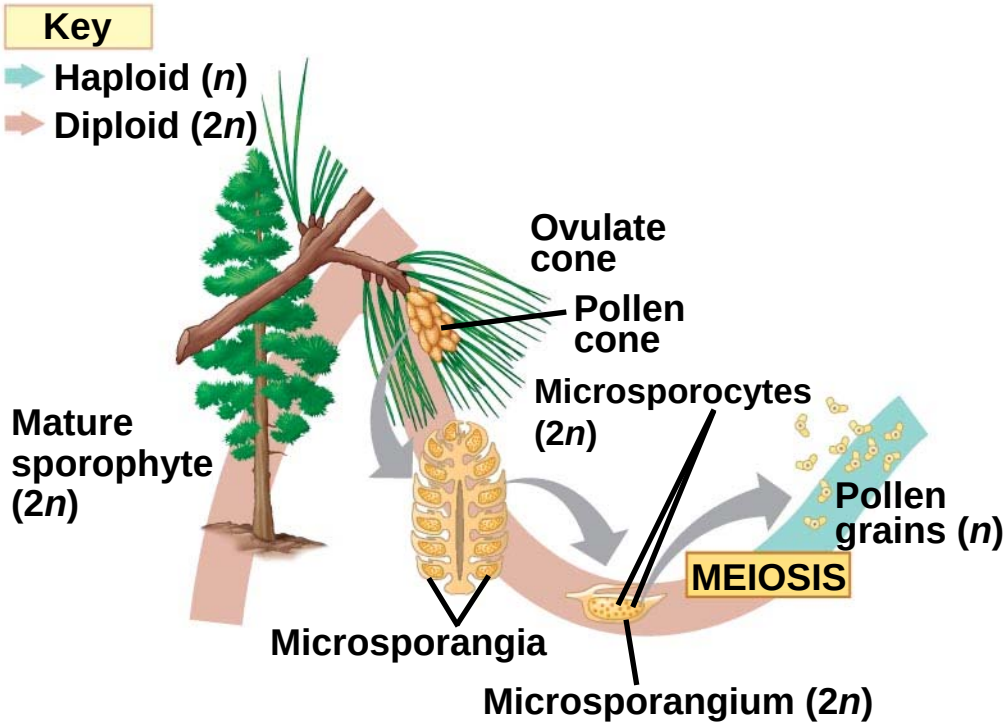


Fig. 30-6-2

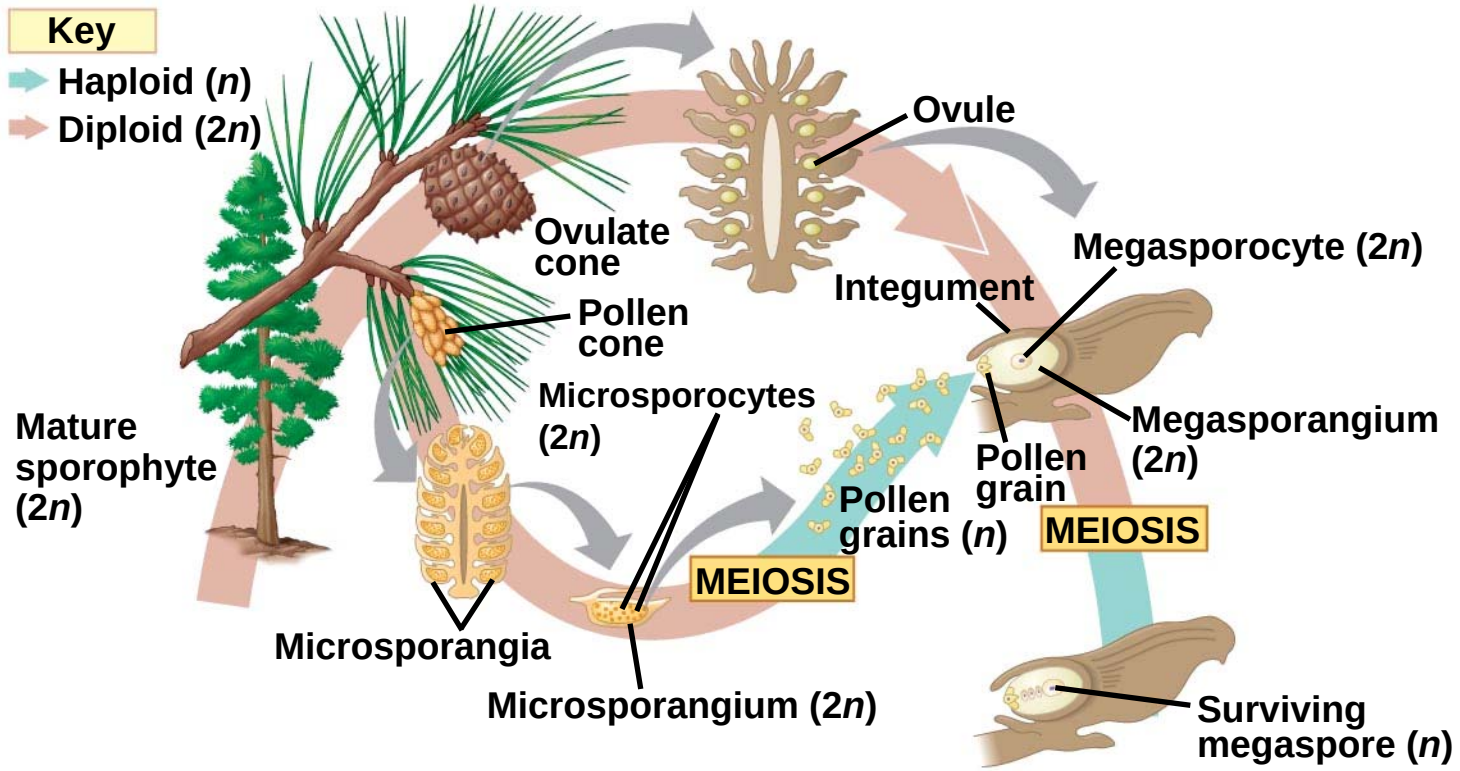


Fig. 30-6-3

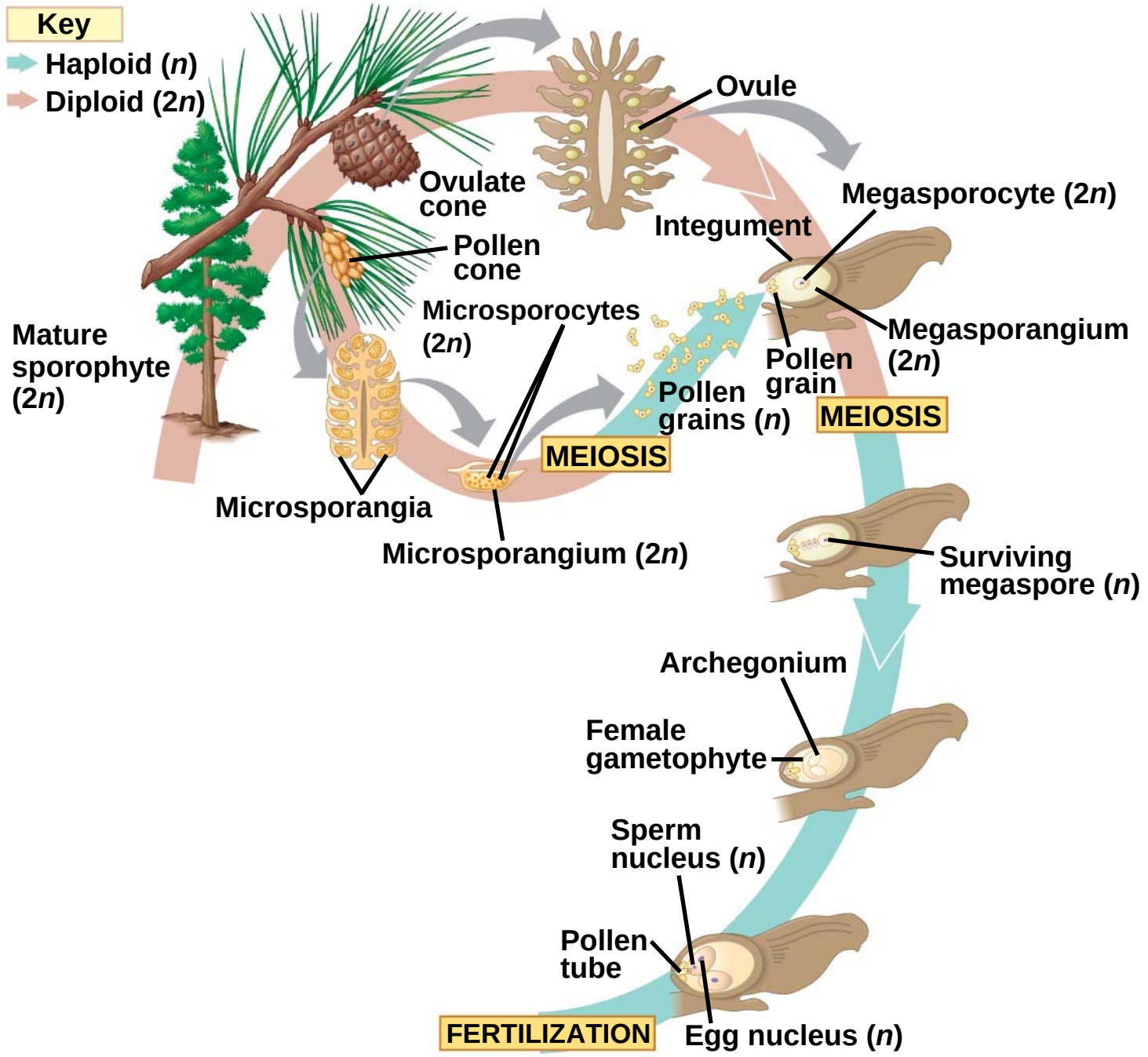
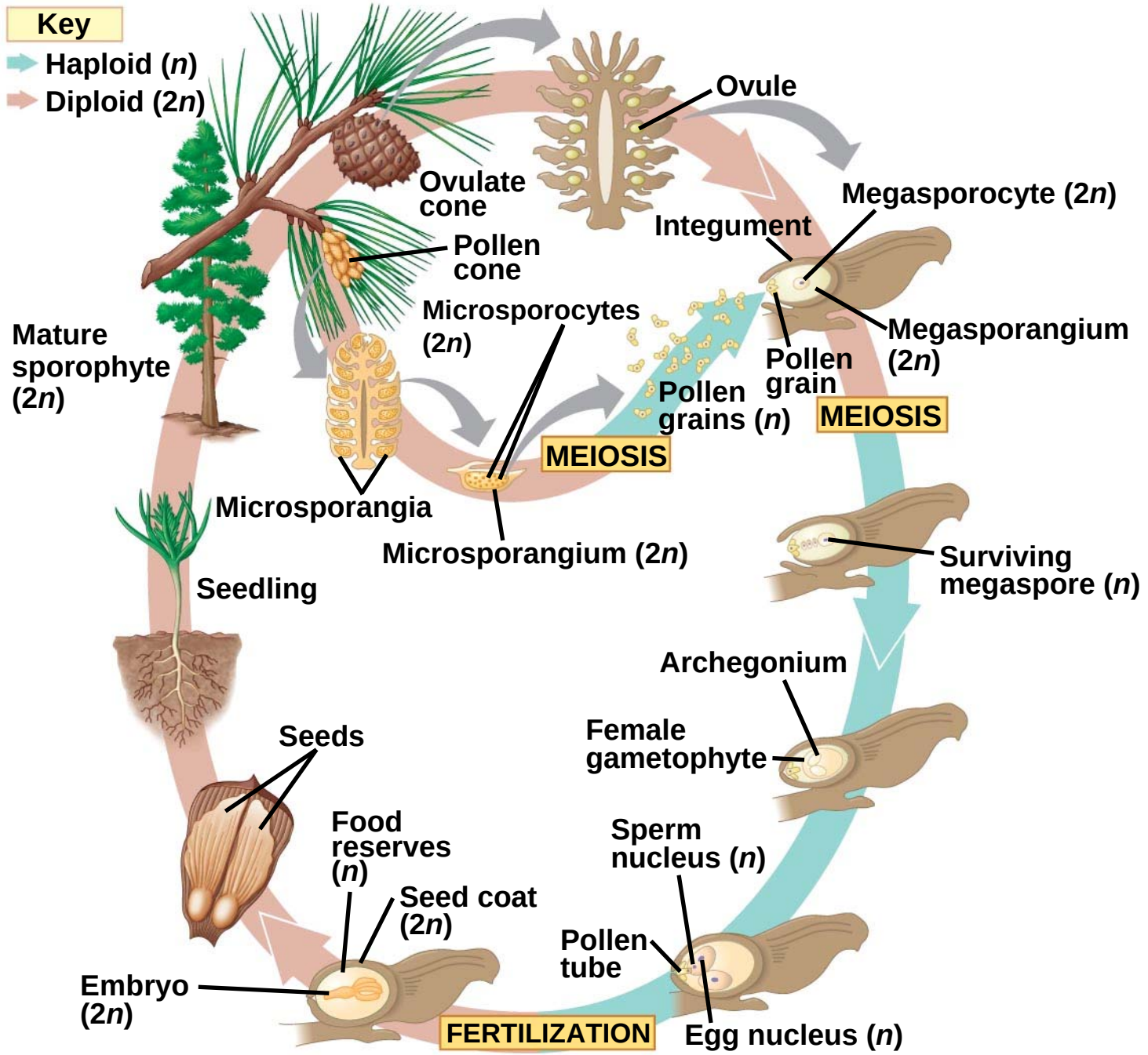


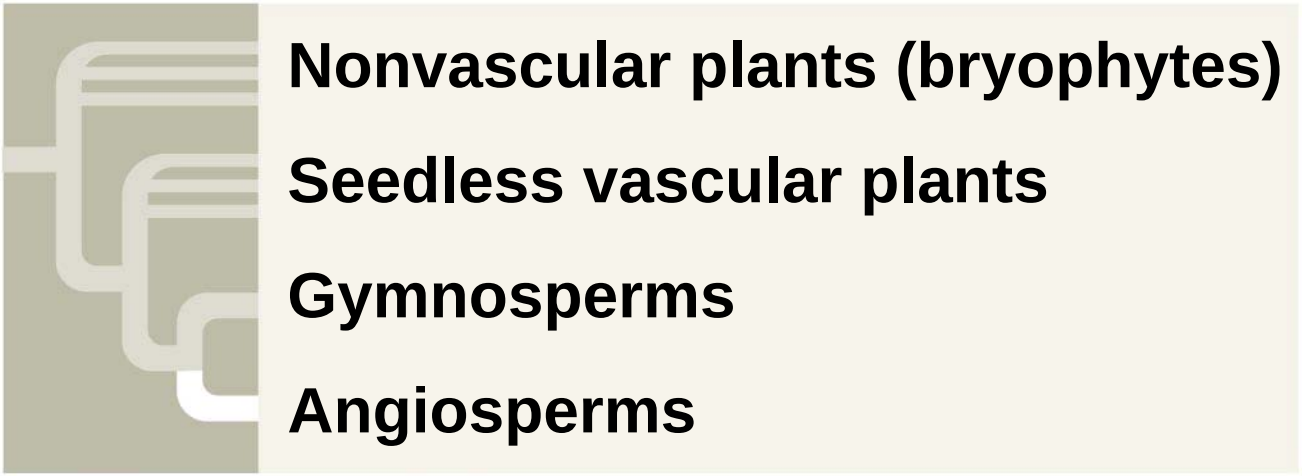
Fig. 30-6-4



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

- Angiosperms are seed plants with reproductive structures called flowers and fruits
- They are the most widespread and diverse of all plants

Fig. 30-UN2



Characteristics of Angiosperms

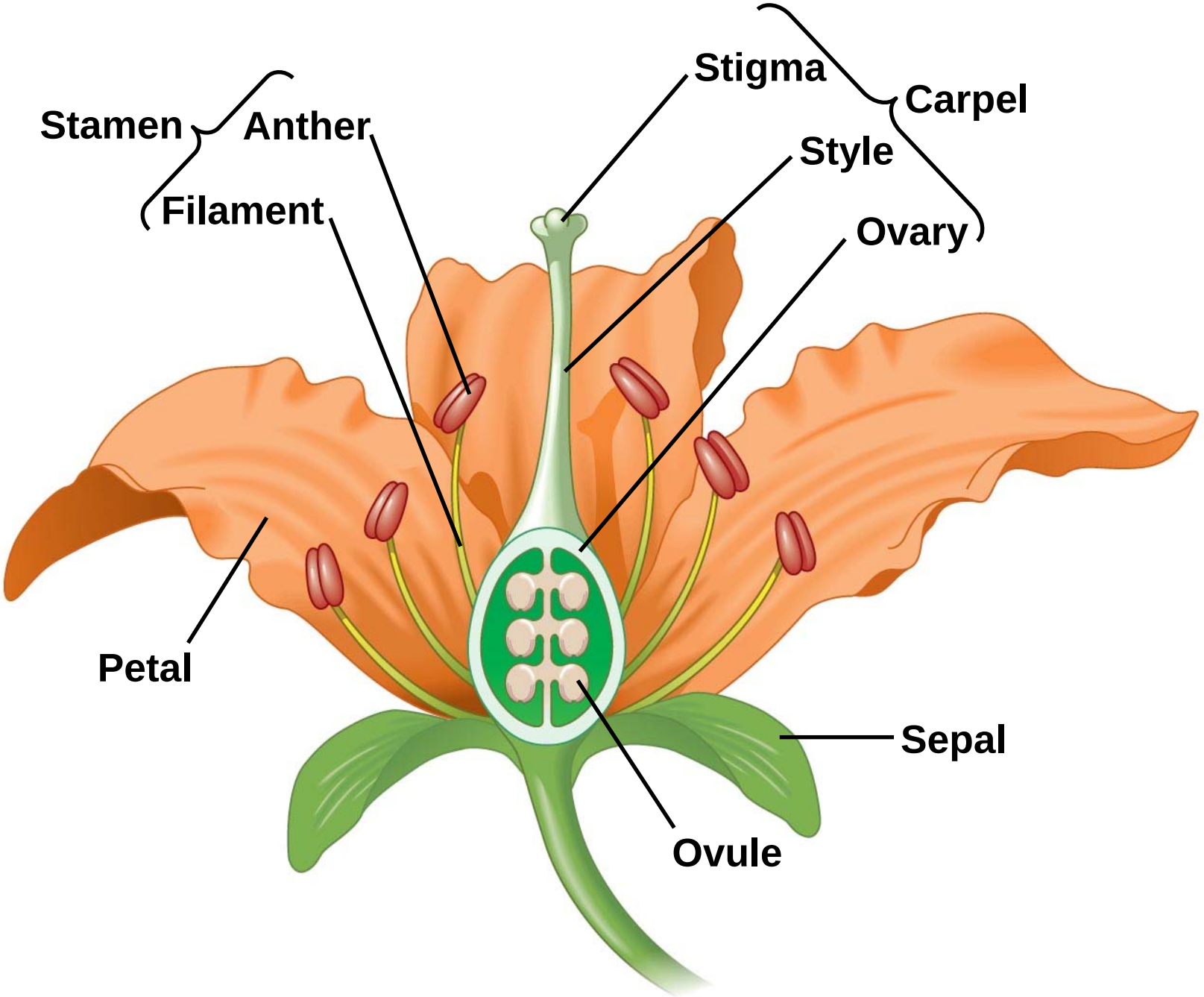
- All angiosperms are classified in a single phylum, Anthophyta
- The name comes from the Greek *anthos,* flower

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:
  - **Sepals**, which enclose the flower
  - **Petals**, which are brightly colored and attract pollinators
  - **Stamens**, which produce pollen on their terminal **anthers**
  - **Carpels**, which produce ovules

Fig. 30-7



- A carpel consists of an **ovary** at the base and a **style** leading up to a **stigma**, where pollen is received

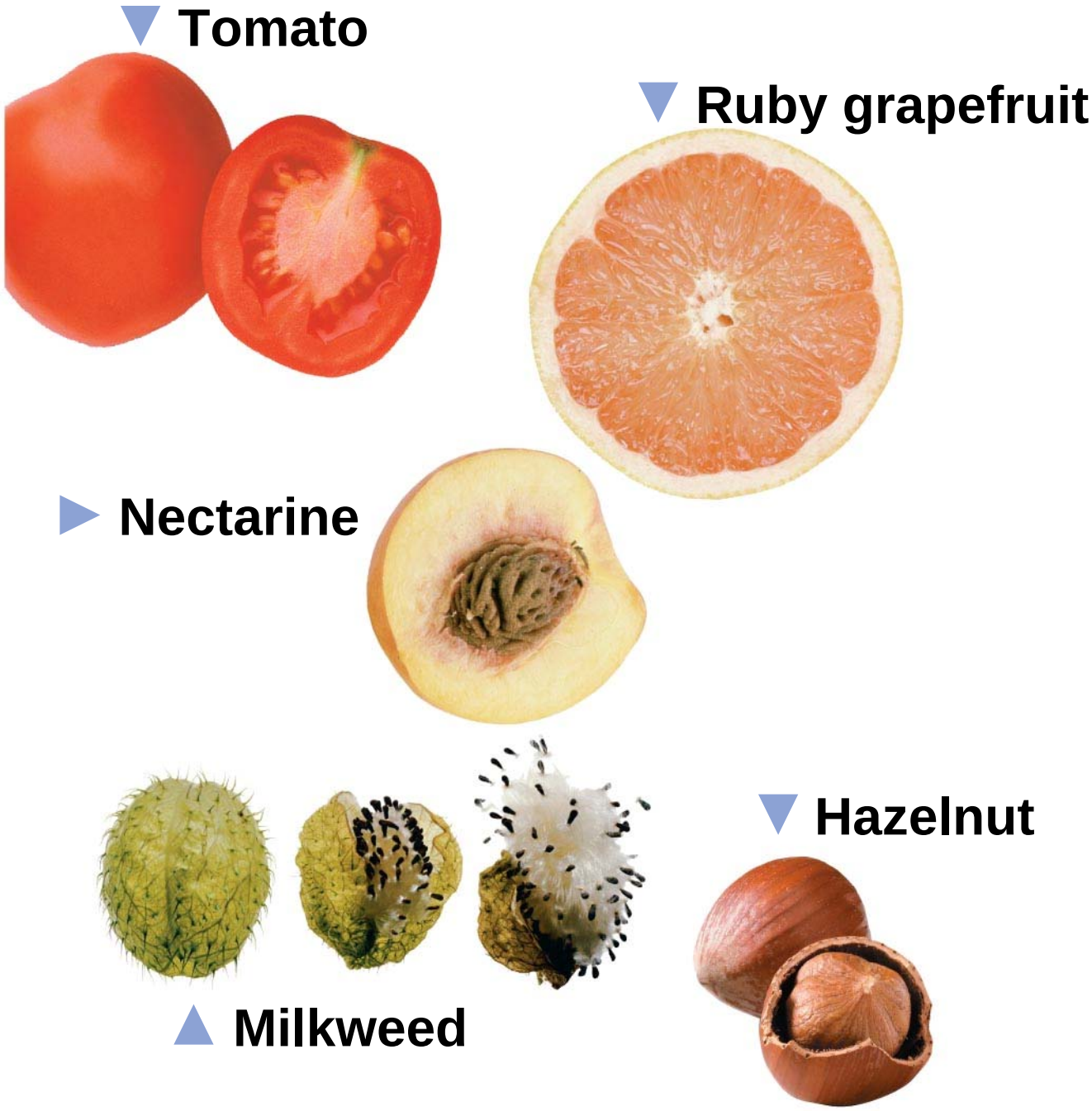
PLAY Video: Flower Blooming (time lapse)

Fruits

- A **fruit** typically consists of a mature ovary but can also include other flower parts
- Fruits protect seeds and aid in their dispersal
- Mature fruits can be either fleshy or dry

PLAY Animation: Fruit Development

Fig. 30-8



- Various fruit adaptations help disperse seeds
- Seeds can be carried by wind, water, or animals to new locations

Fig. 30-9

Wings

Seeds within berries

Barbs

The Angiosperm Life Cycle

- The flower of the sporophyte is composed of both male and female structures
- Male gametophytes are contained within pollen grains produced by the microsporangia of anthers
- The female gametophyte, or **embryo sac**, develops within an ovule contained within an ovary at the base of a stigma
- Most flowers have mechanisms to ensure **cross-pollination** between flowers from different plants of the same species

- A pollen grain that has landed on a stigma germinates and the pollen tube of the male gametophyte grows down to the ovary
- The ovule is entered by a pore called the **micropyle**
- **Double fertilization** occurs when the pollen tube discharges two sperm into the female gametophyte within an ovule

- One sperm fertilizes the egg, while the other combines with two nuclei in the central cell of the female gametophyte and initiates development of food-storing **endosperm**
- The endosperm nourishes the developing embryo
- Within a seed, the embryo consists of a root and two seed leaves called **cotyledons**

Fig. 30-10-1

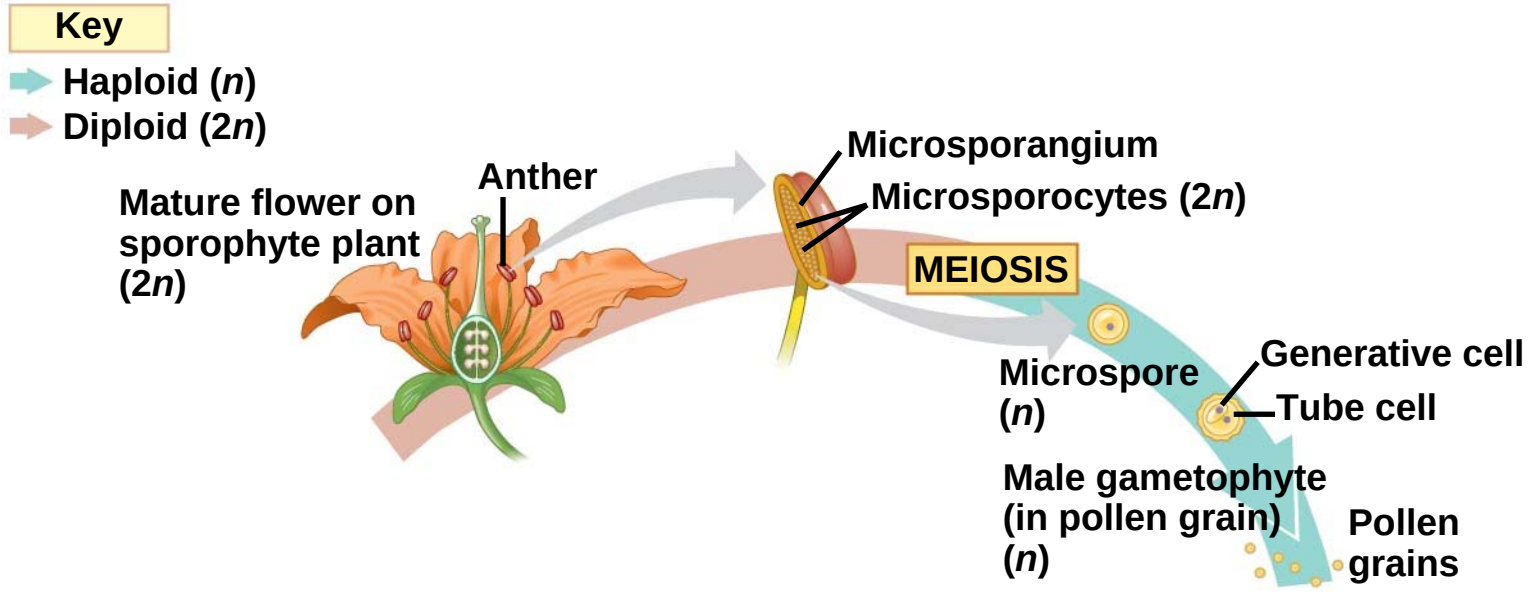


Fig. 30-10-2

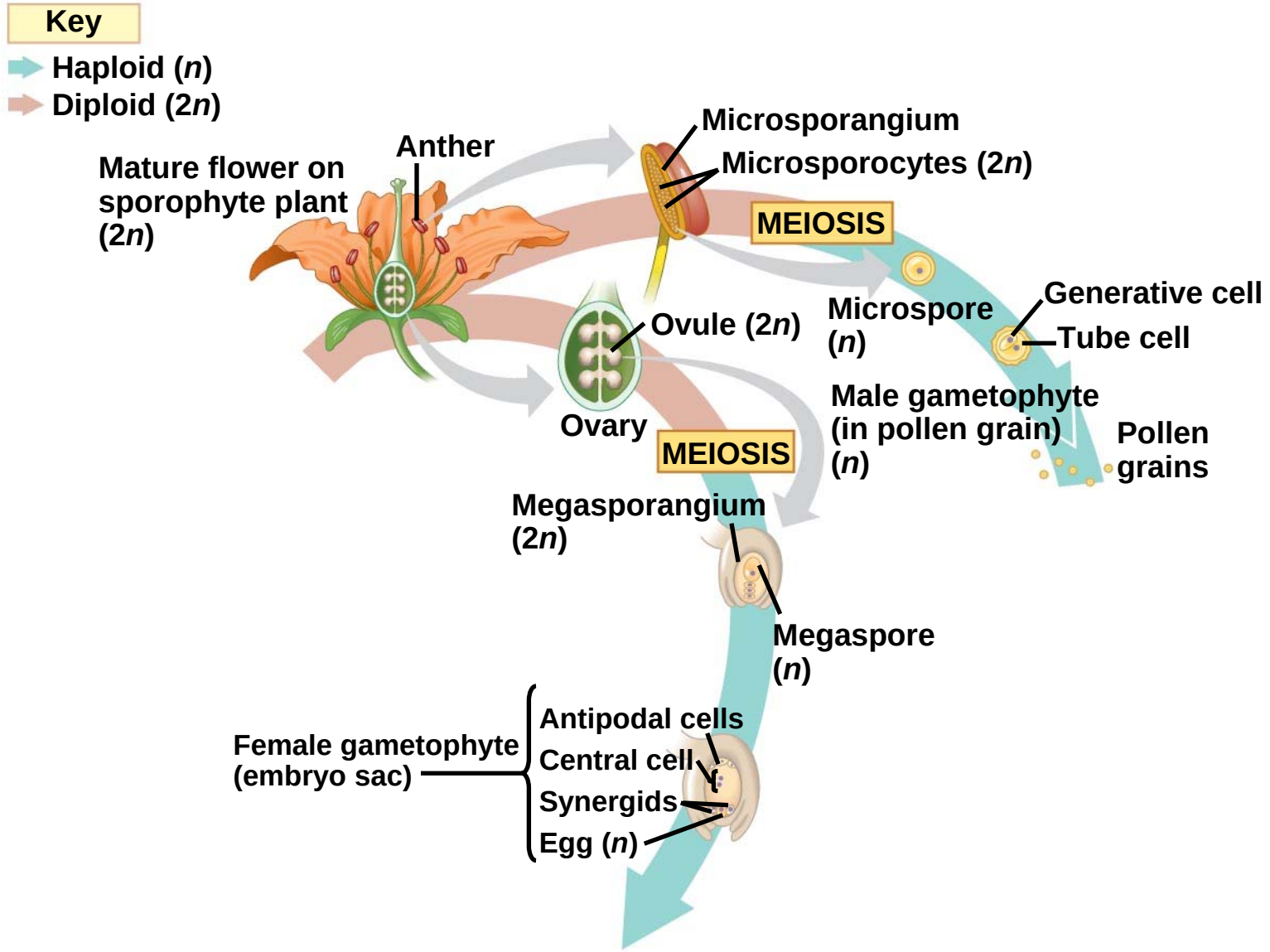


Fig. 30-10-3

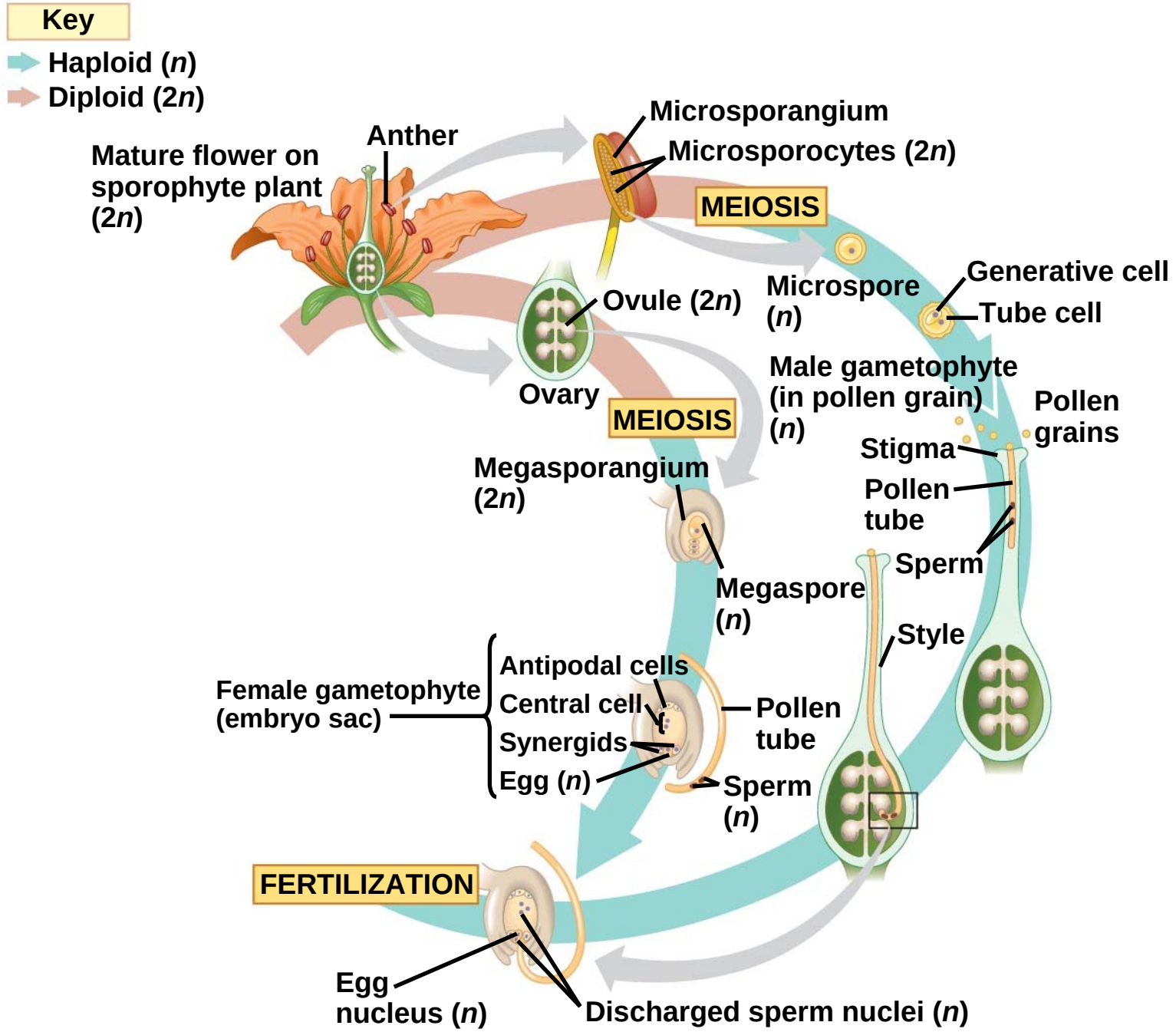
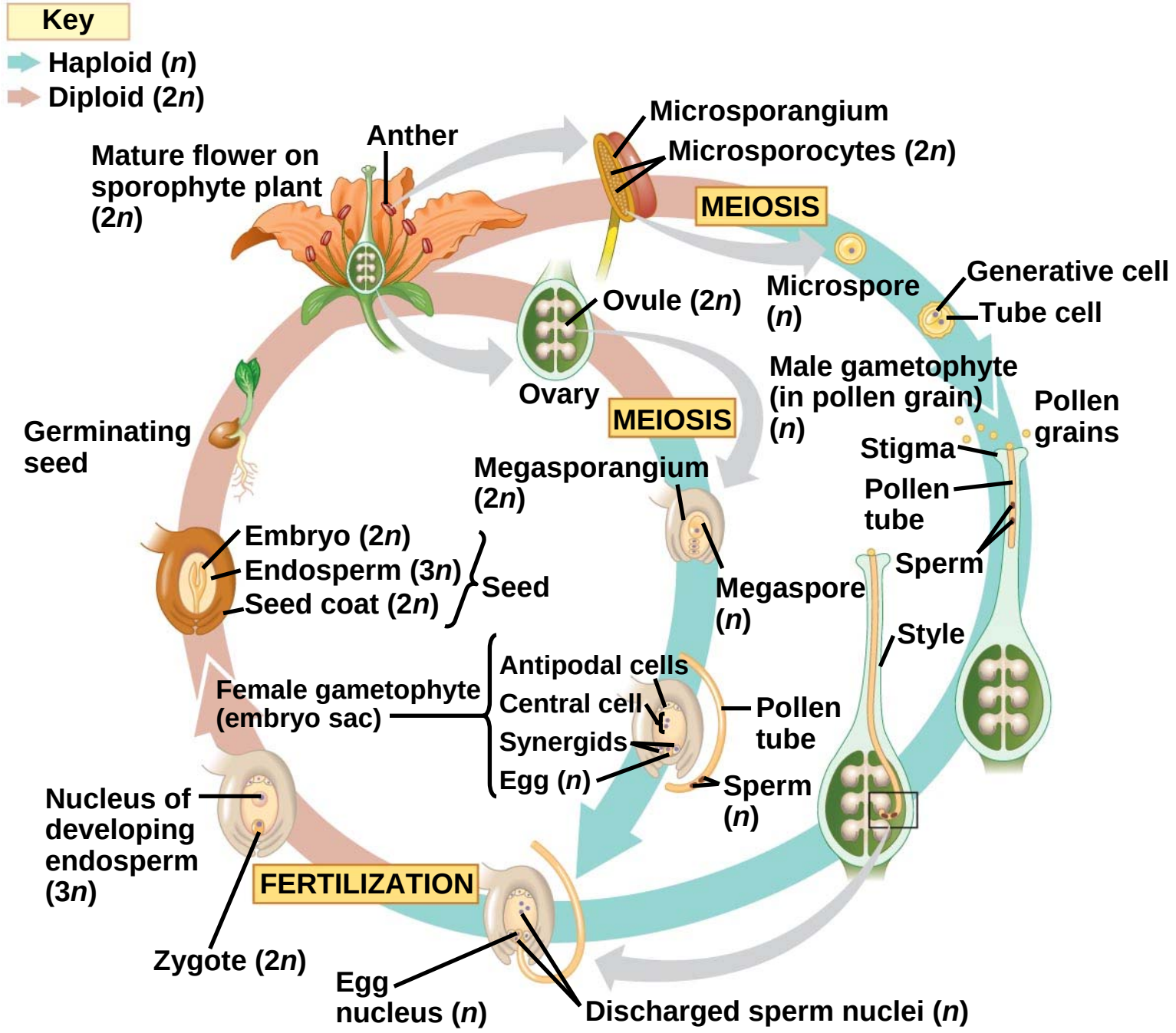


Fig. 30-10-4



PLAY Animation: Plant Fertilization

PLAY Animation: Seed Development

PLAY Video: Flowering Plant Life Cycle (time lapse)

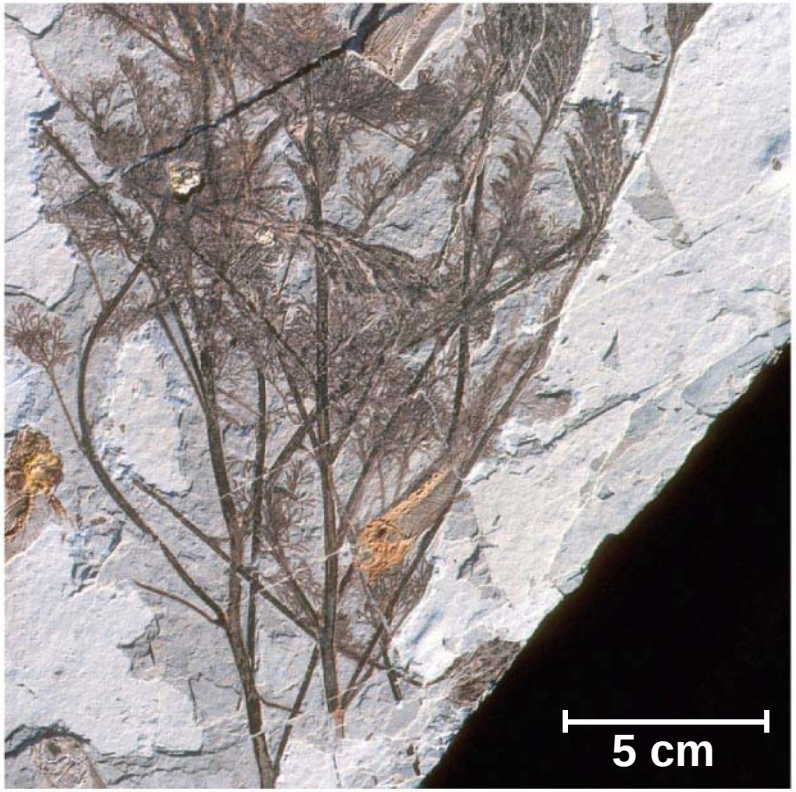
Angiosperm Evolution

- Clarifying the origin and diversification of angiosperms poses fascinating challenges to evolutionary biologists
- Angiosperms originated at least 140 million years ago
- During the late Mesozoic, the major branches of the clade diverged from their common ancestor

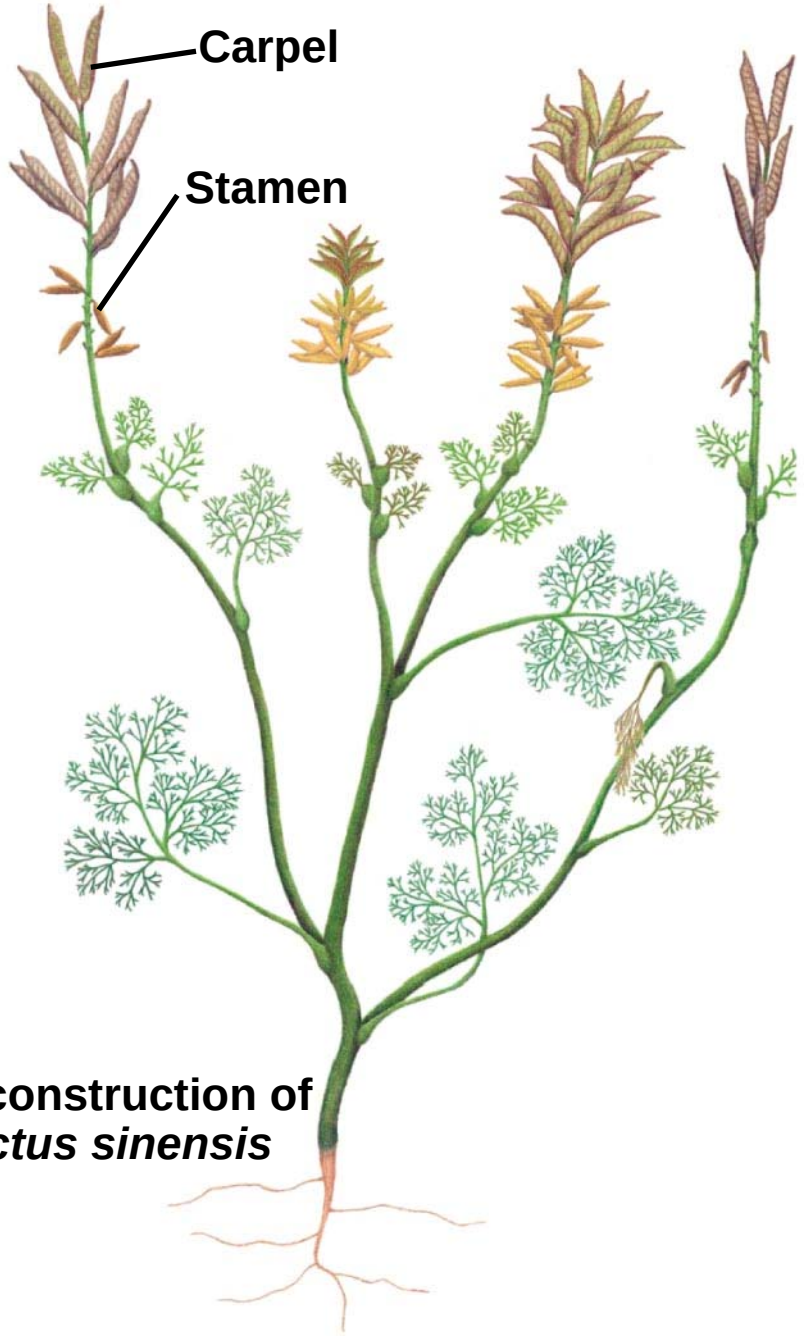
Fossil Angiosperms

- Primitive fossils of 125-million-year-old angiosperms display derived and primitive traits
- *Archaefructus sinensis,* for example, has anthers and seeds but lacks petals and sepals

Fig. 30-11



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

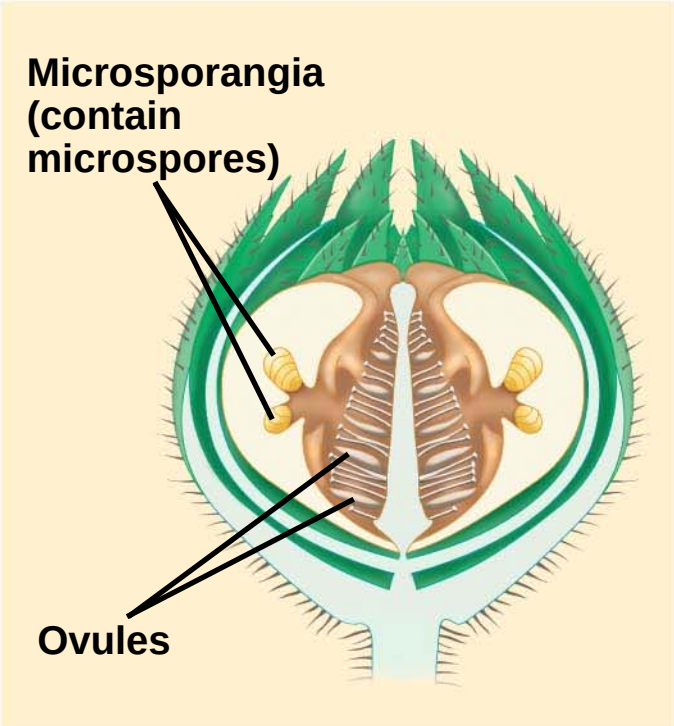


(b) Artist's reconstruction of *Archaefructus sinensis*

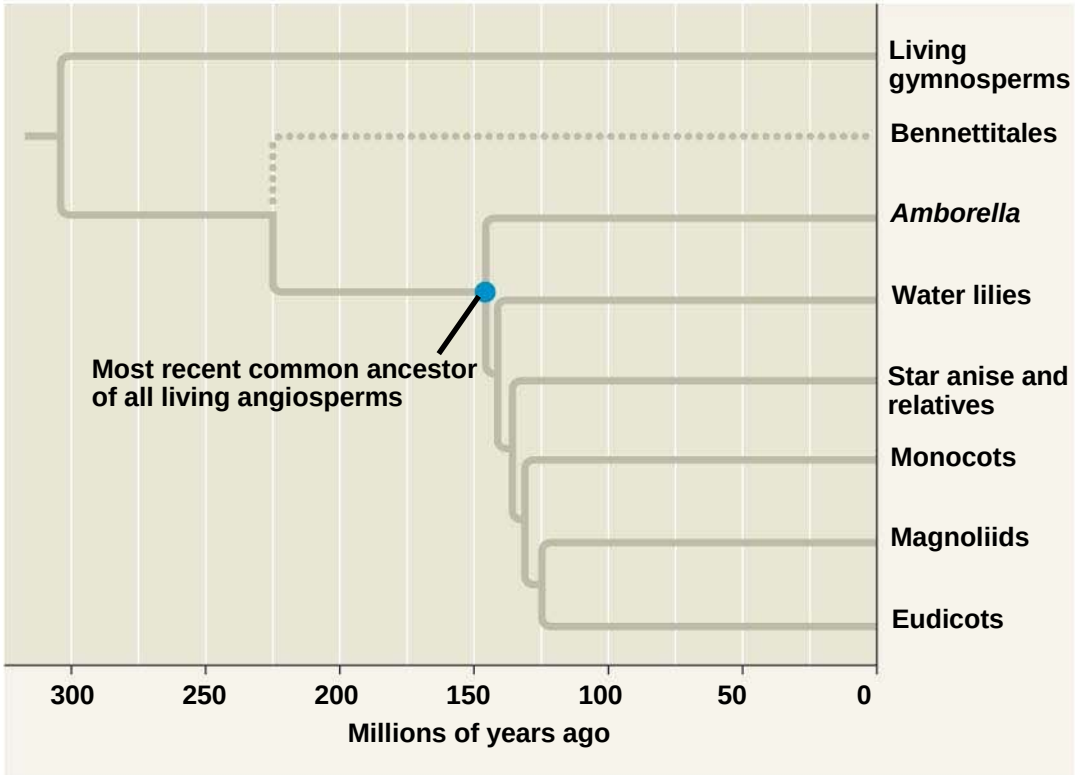
Angiosperm Phylogeny

- The ancestors of angiosperms and gymnosperms diverged about 305 million years ago
- Angiosperms may be closely related to Bennettitales, extinct seed plants with flowerlike structures
- *Amborella* and water lilies are likely descended from two of the most ancient angiosperm lineages

Fig. 30-12

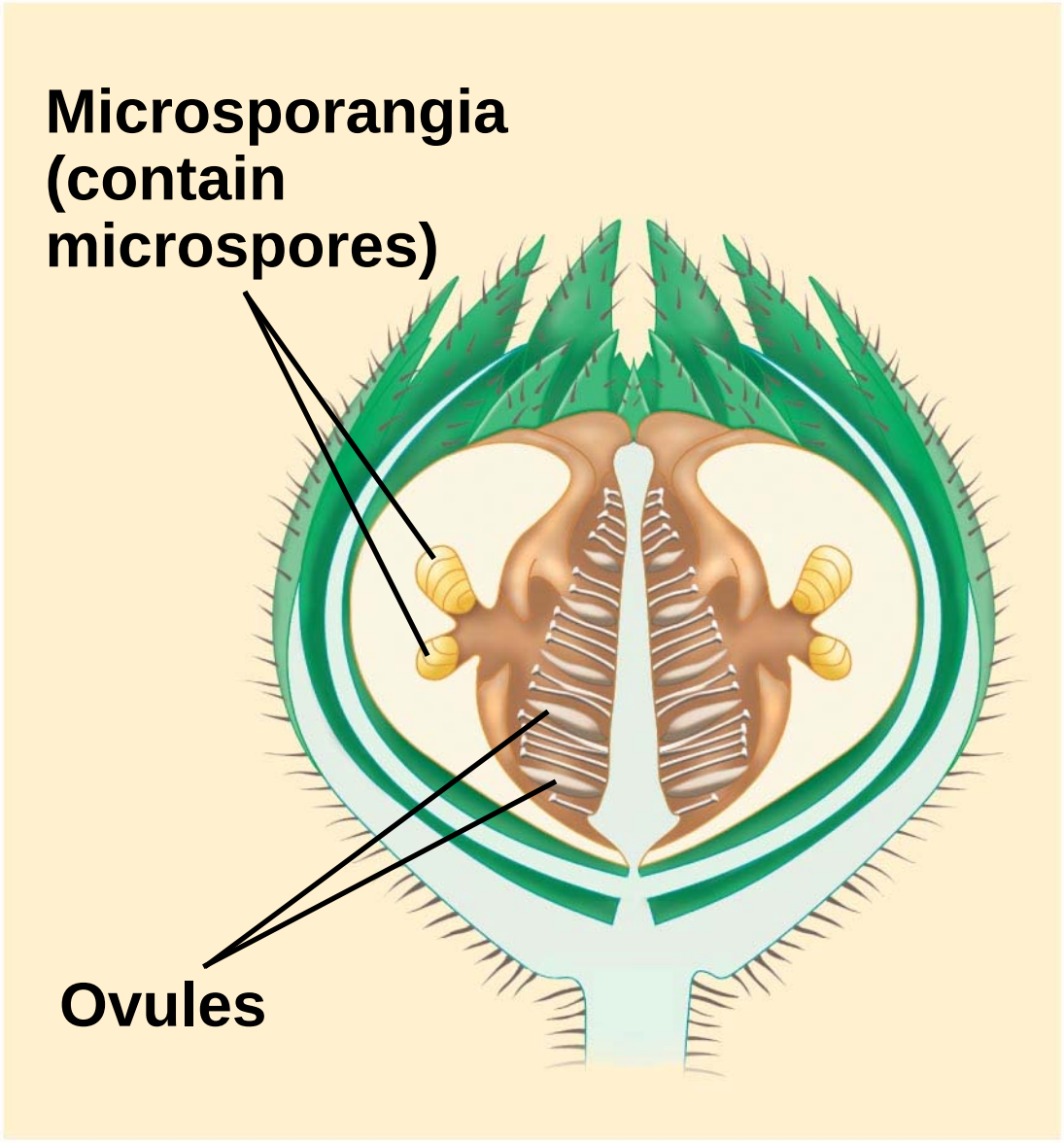


(a) A possible ancestor of the angiosperms?



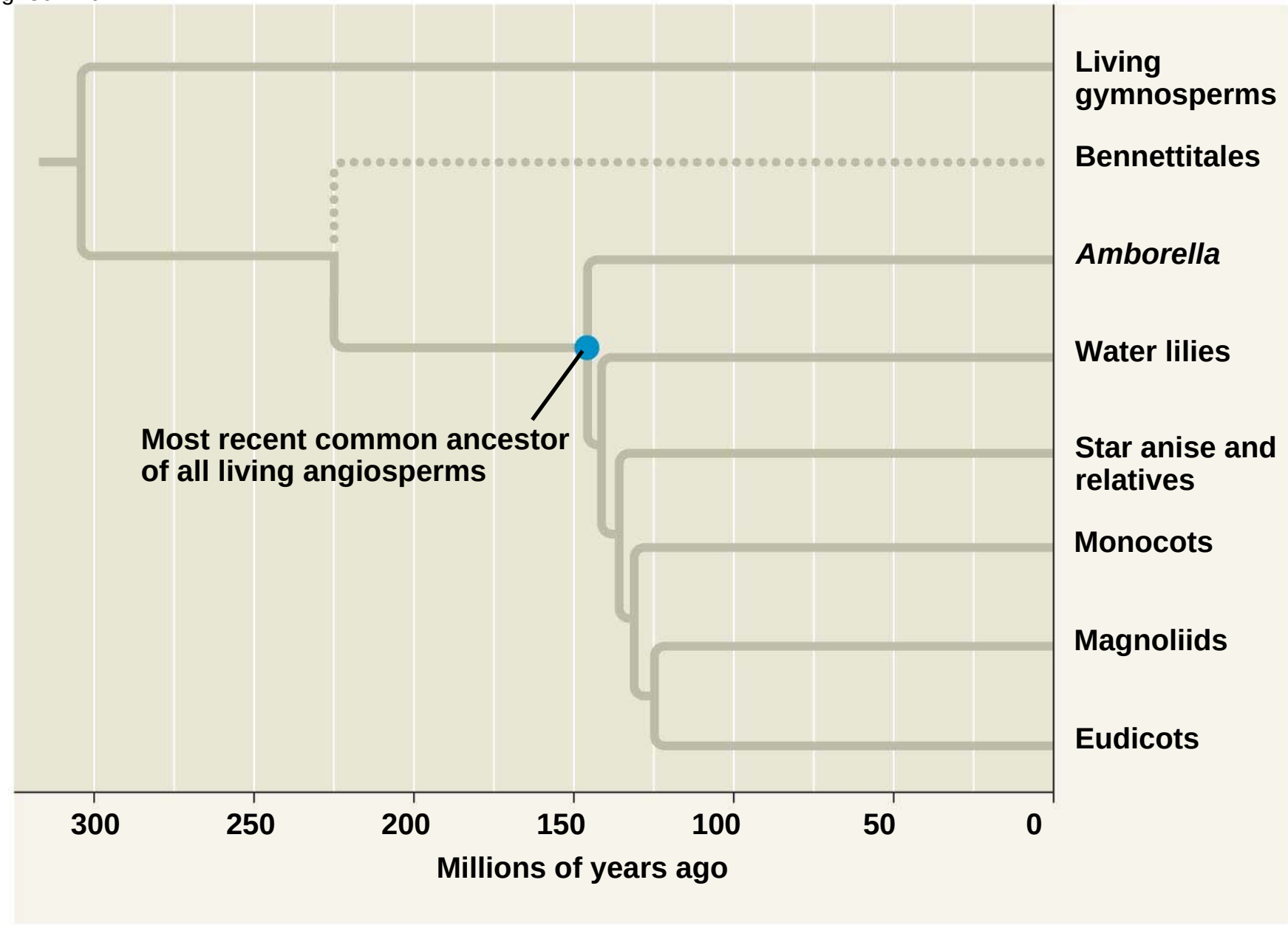
(b) Angiosperm phylogeny

Fig. 30-12a



(a) A possible ancestor of the angiosperms?

Fig. 30-12b



(b) Angiosperm phylogeny

Developmental Patterns in Angiosperms

- Egg formation in the angiosperm *Amborella* resembles that of the gymnosperms
- Researchers are currently studying expression of flower development genes in gymnosperm and angiosperm species

Angiosperm Diversity

- The two main groups of angiosperms are **monocots** (one cotyledon) and **eudicots** ("true" dicots)
- The clade eudicot includes some groups formerly assigned to the paraphyletic **dicot** (two cotyledons) group

- **Basal angiosperms** are less derived and include the flowering plants belonging to the oldest lineages
- **Magnoliids** share some traits with basal angiosperms but are more closely related to monocots and eudicots

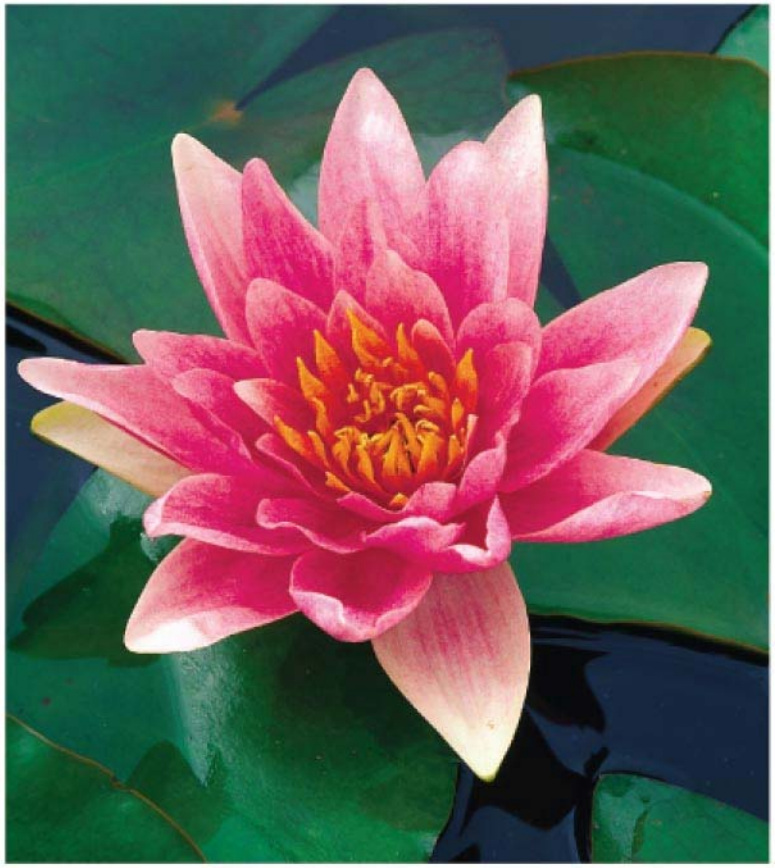
Basal Angiosperms

- Three small lineages constitute the basal angiosperms
- These include *Amborella trichopoda*, water lilies, and star anise

Fig. 30-13a

Amborella trichopoda

Fig. 30-13b



Water lily

Fig. 30-13c

Star anise

Magnoliids

- Magnoliids include magnolias, laurels, and black pepper plants
- Magnoliids are more closely related to monocots and eudicots than basal angiosperms

Fig. 30-13d

Southern magnolia

Monocots

- More than one-quarter of angiosperm species are monocots

Fig. 30-13e

Orchid

Fig. 30-13e1

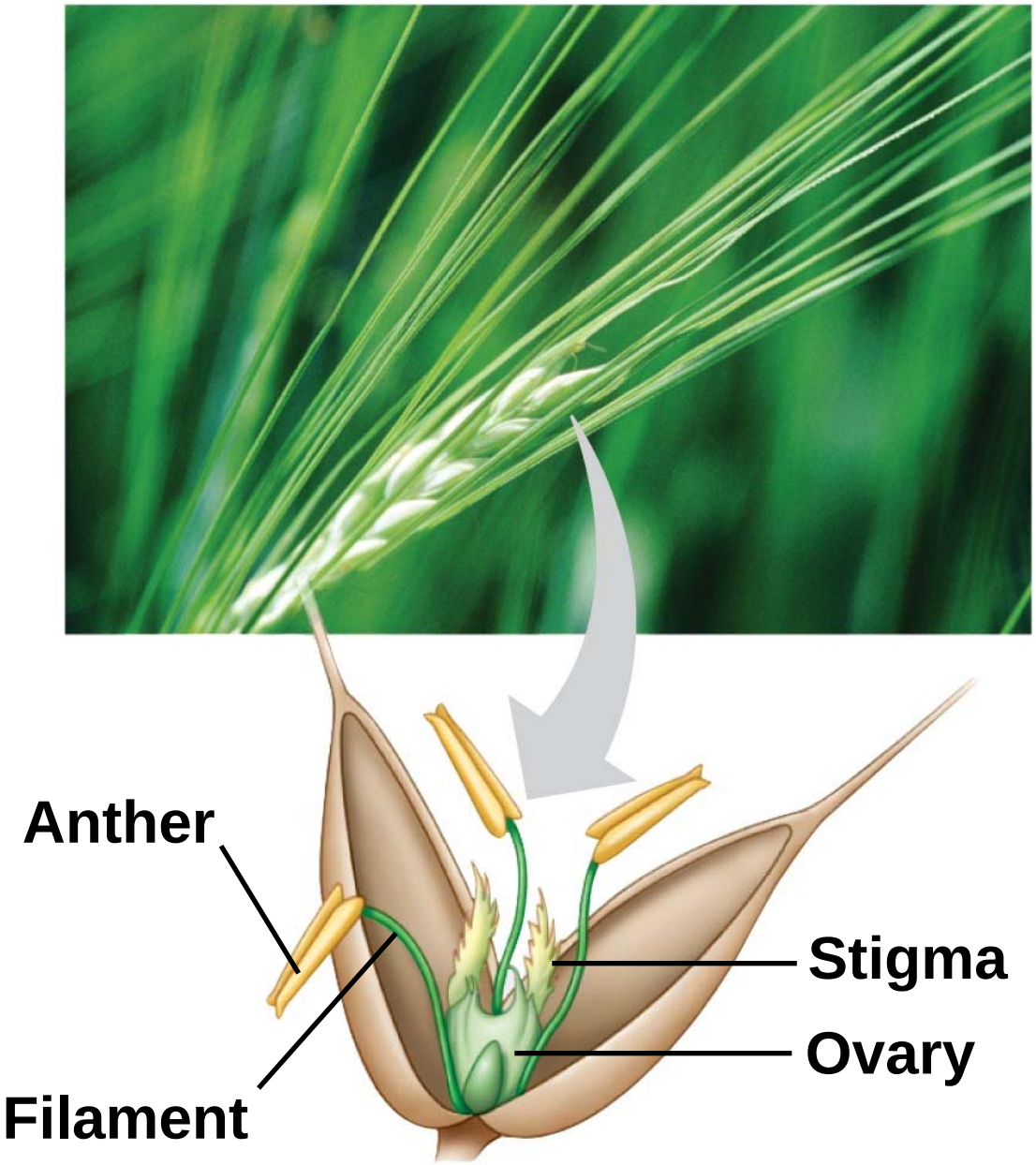
Pygmy date palm (*Phoenix roebelenii*)

Fig. 30-13f

Lily

Fig. 30-13g

Barley



Eudicots

- More than two-thirds of angiosperm species are eudicots

Fig. 30-13h

California poppy

Fig. 30-13i

Pyrenean oak

Fig. 30-13j

Dog rose

Fig. 30-13k

Snow pea

Fig. 30-13l

Zucchini flowers

Fig. 30-13m

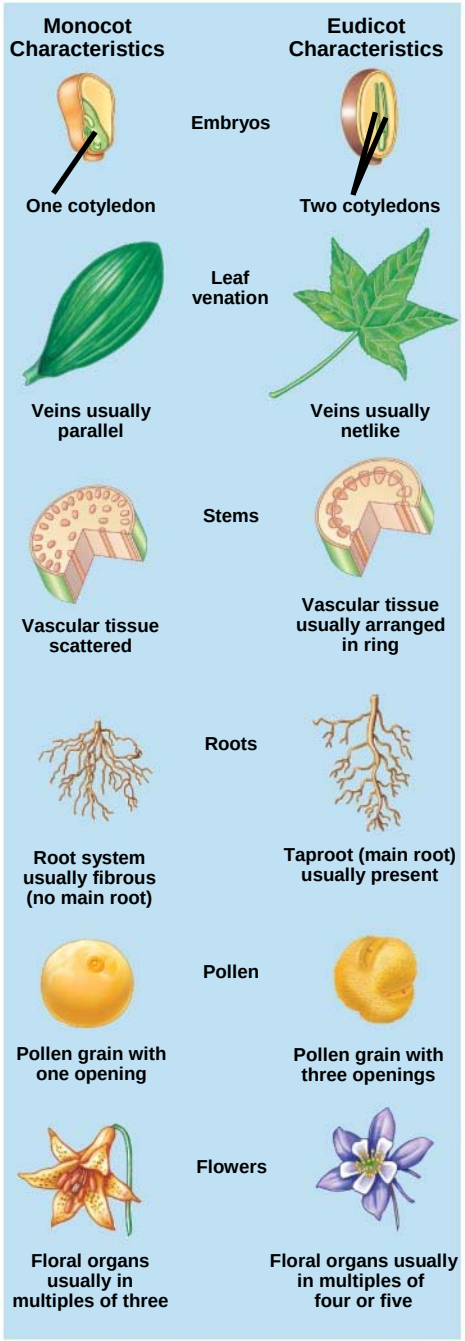


Fig. 30-13n

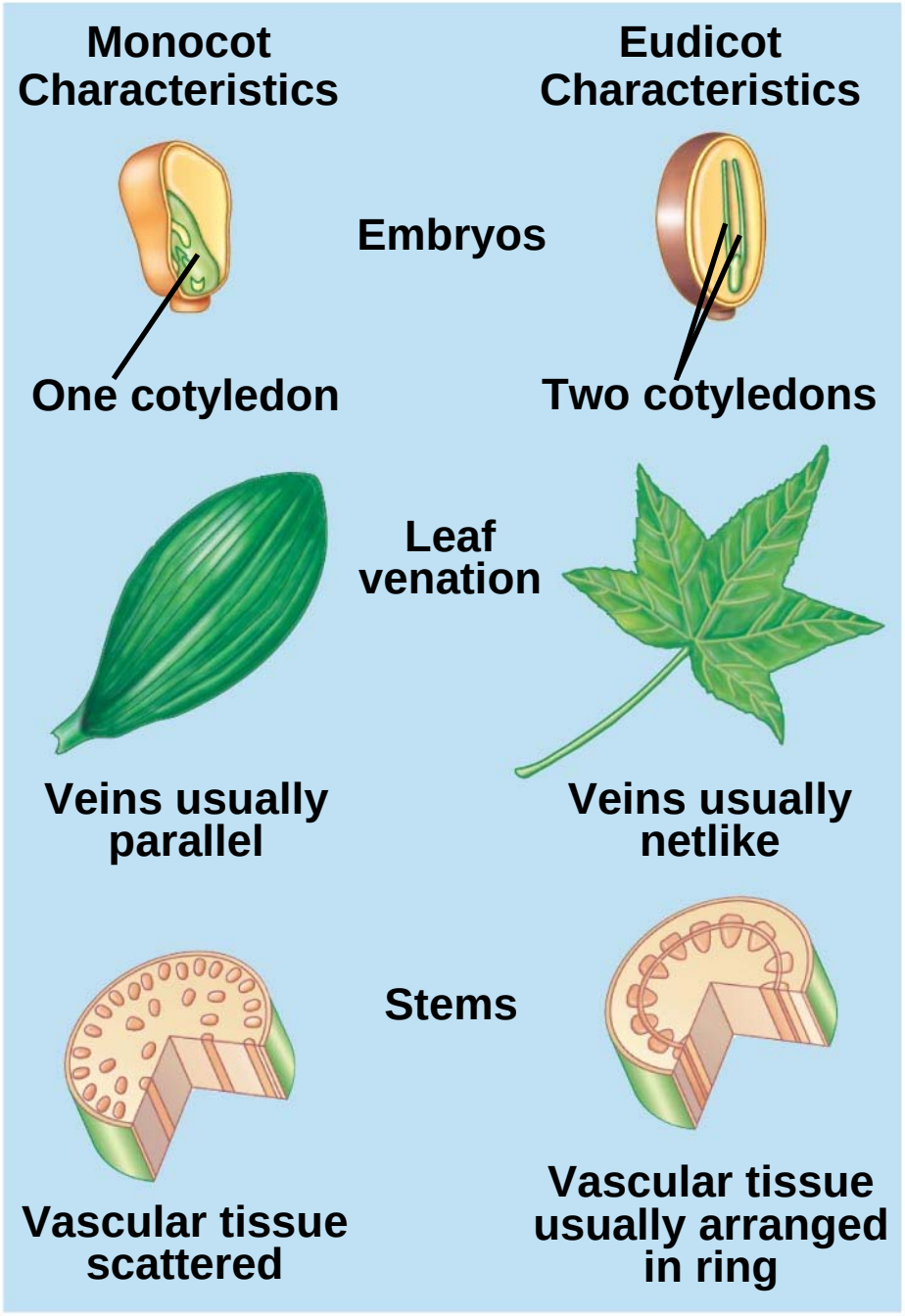
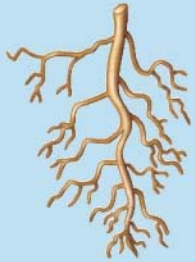


Fig. 30-13o

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

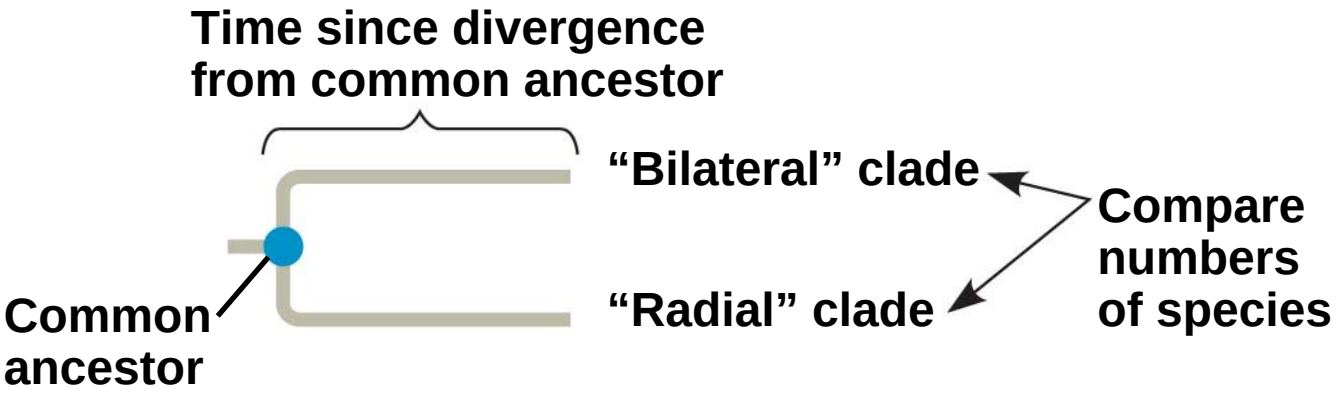
- Pollination of flowers and transport of seeds by animals are two important relationships in terrestrial ecosystems
- Clades with bilaterally symmetrical flowers have more species than those with radially symmetrical flowers
- This is likely because bilateral symmetry affects the movement of pollinators and reduces gene flow in diverging populations

PLAY Video: Bee Pollinating

PLAY Video: Bat Pollinating Agave Plant

Fig. 30-14

EXPERIMENT



RESULTS

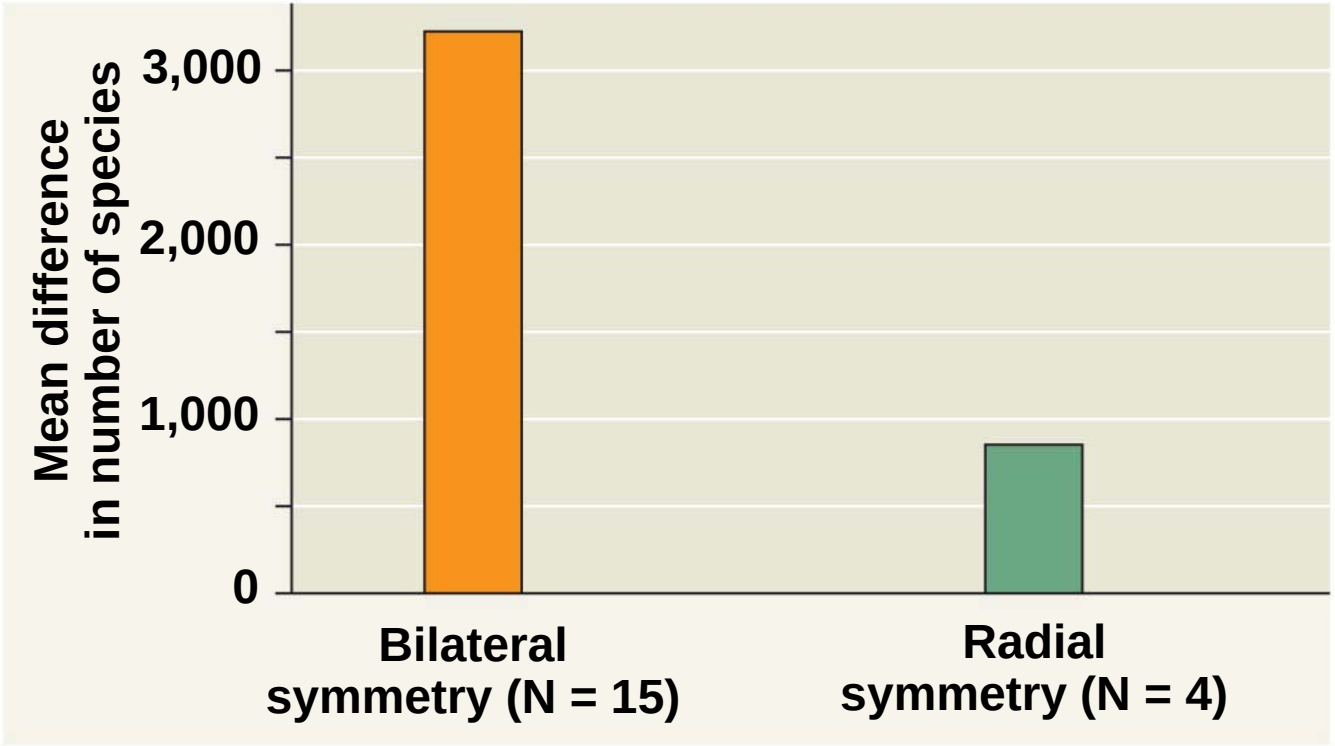


Fig. 30-14a

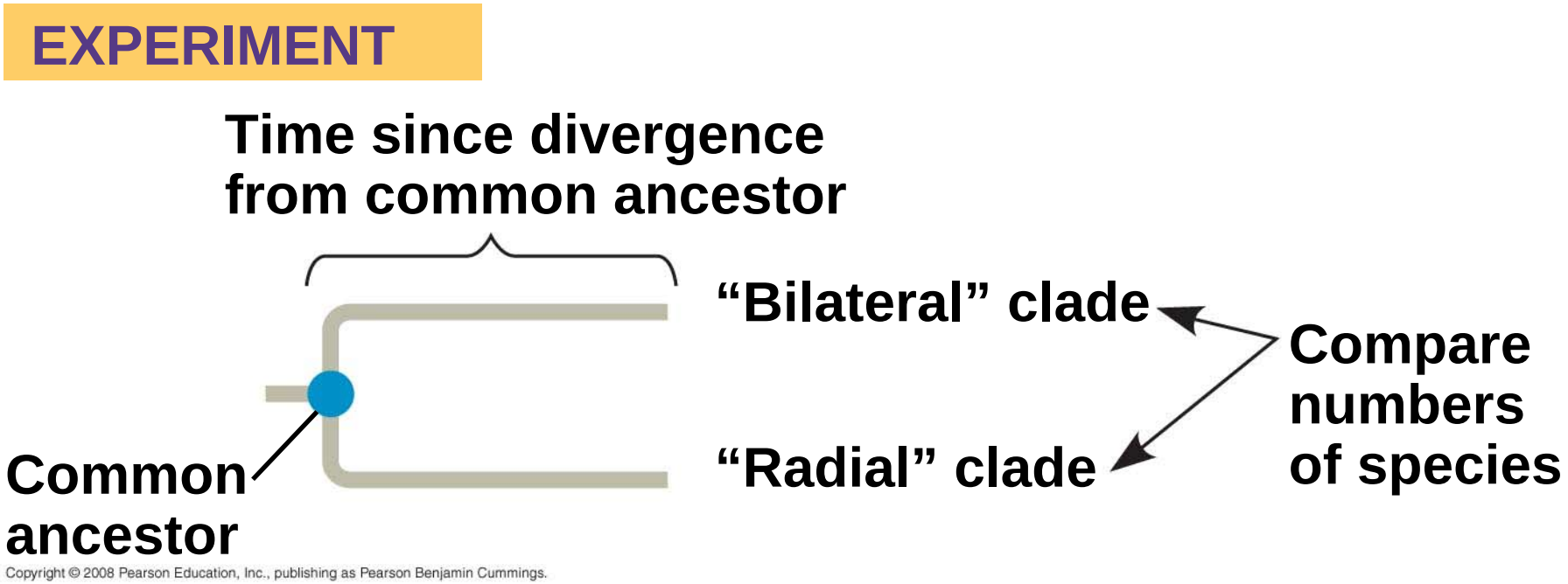
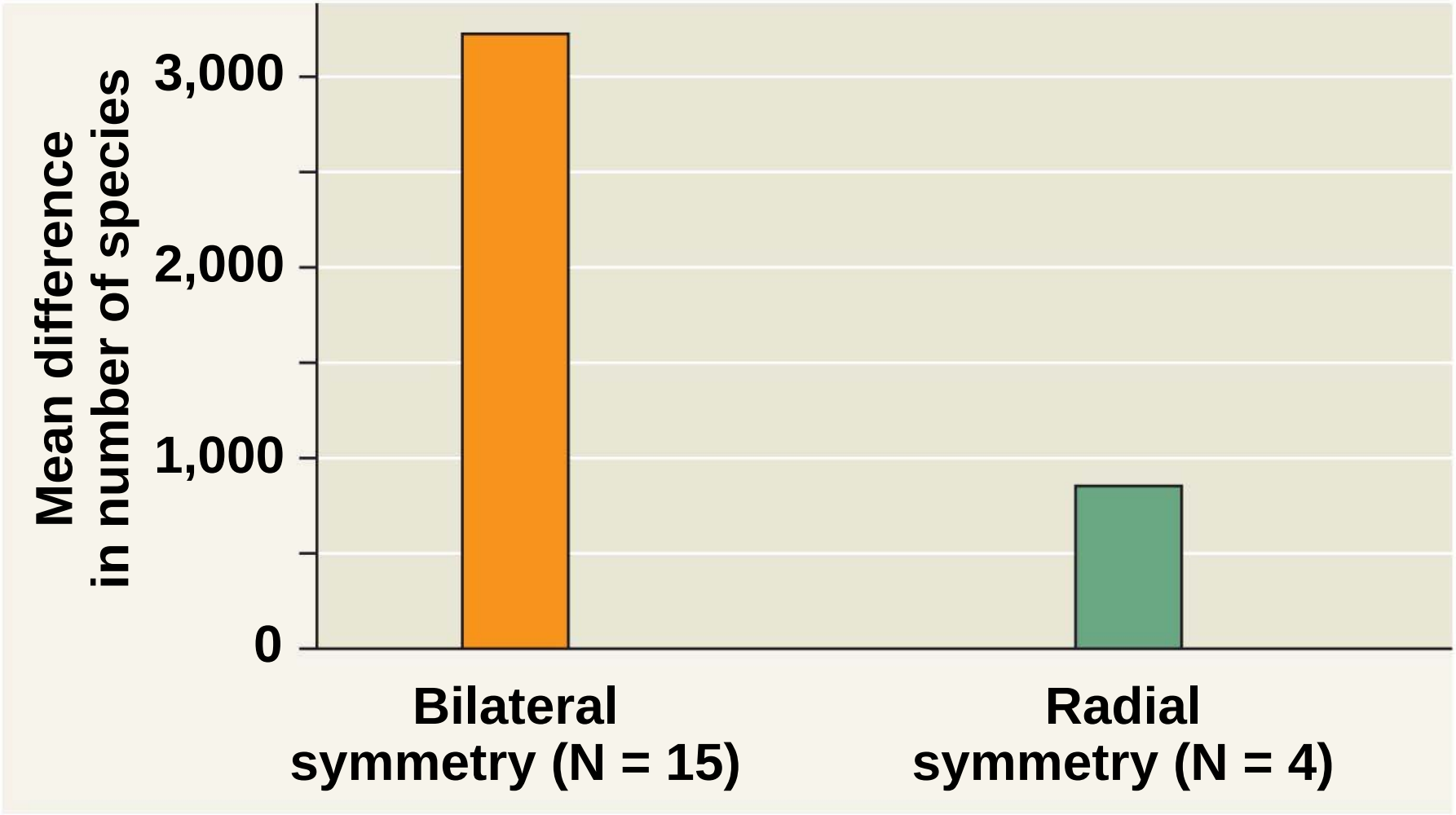


Fig. 30-14b

RESULTS



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

Products from Seed Plants

- 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
- Many seed plants provide wood
- Secondary compounds of seed plants are used in medicines

Table 30-1a

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

Table 30-1b

Cinchona bark, source of quinine

Threats to Plant Diversity

- Destruction of habitat is causing extinction of many plant species
- 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

Fig. 30-UN3

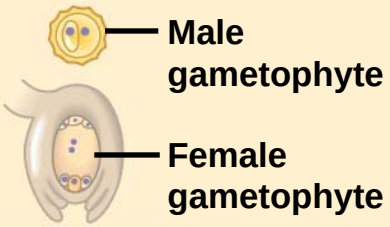
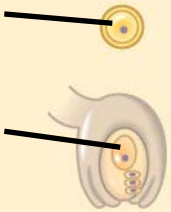
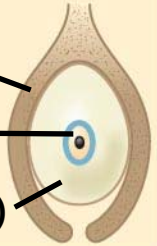
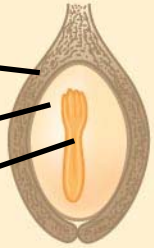
Five Derived Traits of Seed Plants	
Reduced gametophytes	Microscopic male and female gametophytes (*n*) are nourished and protected by the sporophyte (2*n*) 
Heterospory	Microspore (gives rise to a male gametophyte) Megaspore (gives rise to a female gametophyte) 
Ovules	Ovule (gymnosperm) 
Pollen	Pollen grains make water unnecessary for fertilization 
Seeds	Seeds: survive better than unprotected spores, can be transported long distances 

Fig. 30-UN4

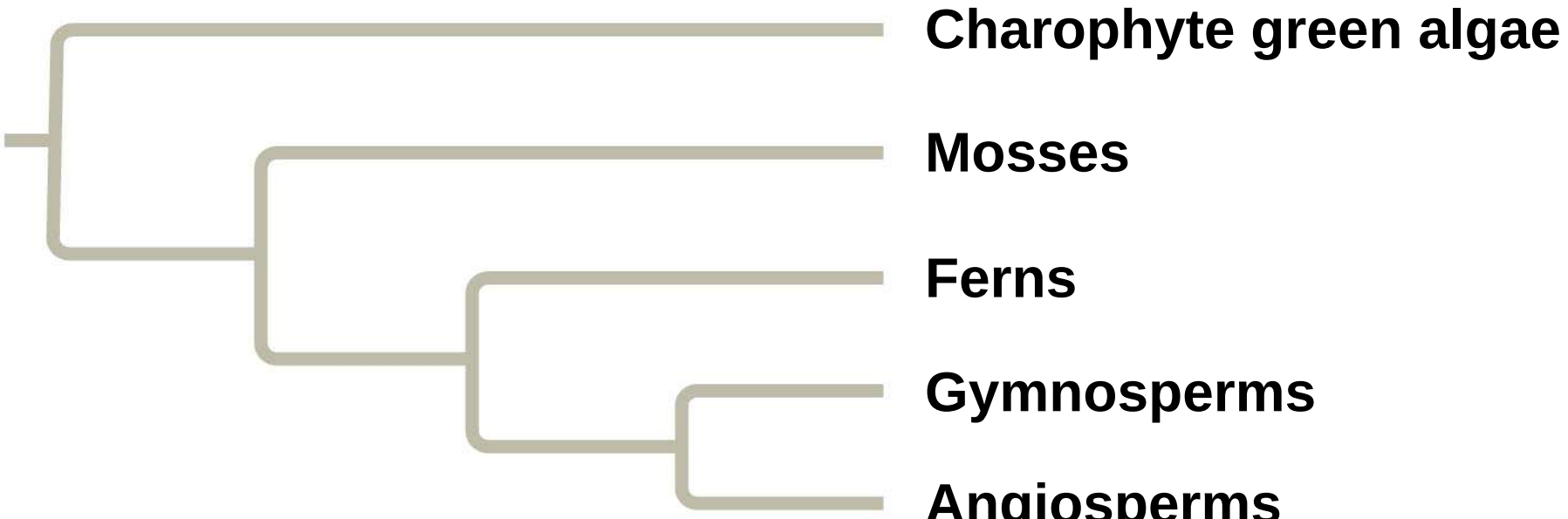
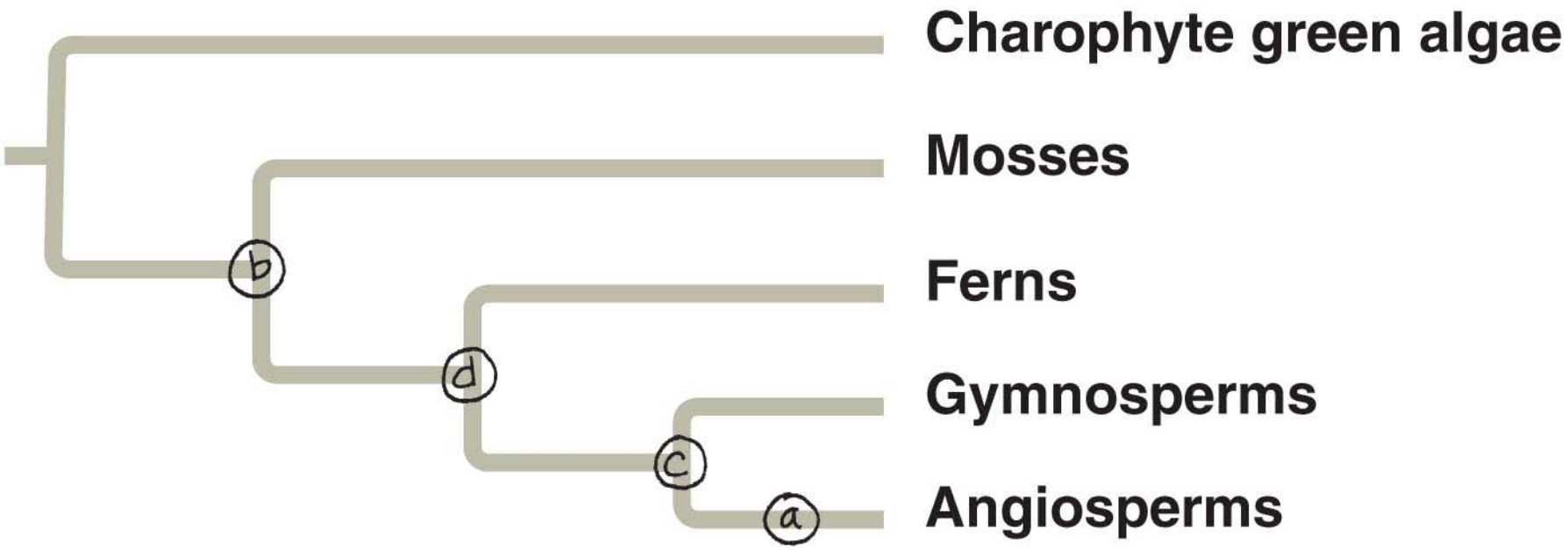


Fig. 30-UN5



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