Evolution of seed plants

What are the derived traits of seed plants?

Gymnosperm groups

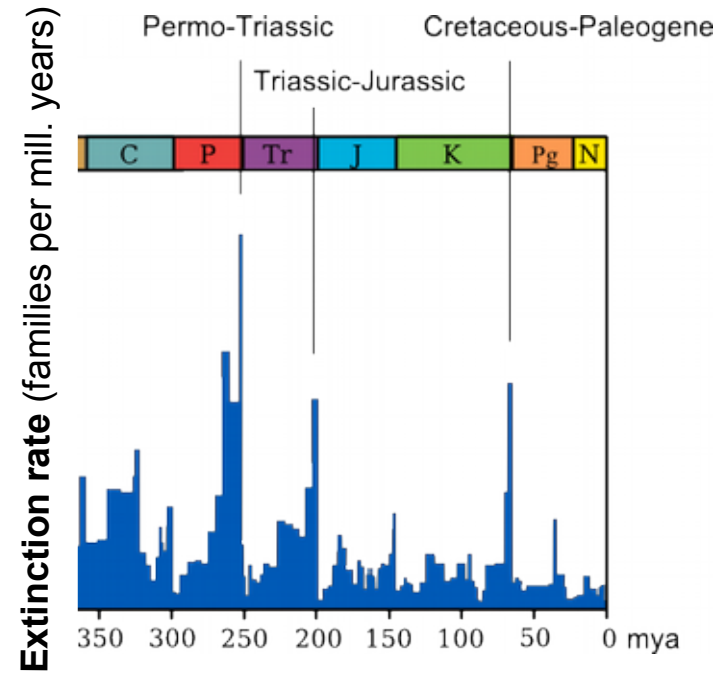
Life cycles that include heterospory and pollen...

Evolutionary advantages of seeds

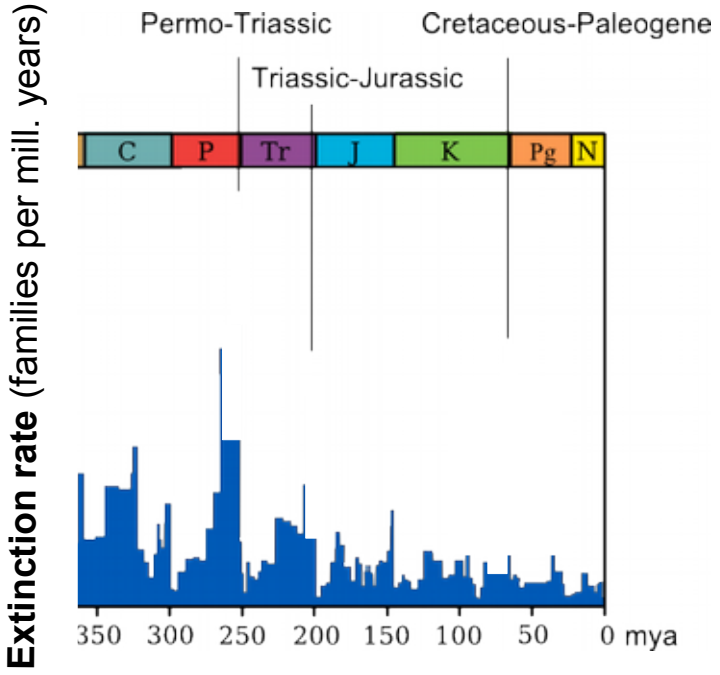
Angiosperm double fertilization

Chapter 30 Plant Diversity II: The Evolution of Seed Plants

Extinction rates

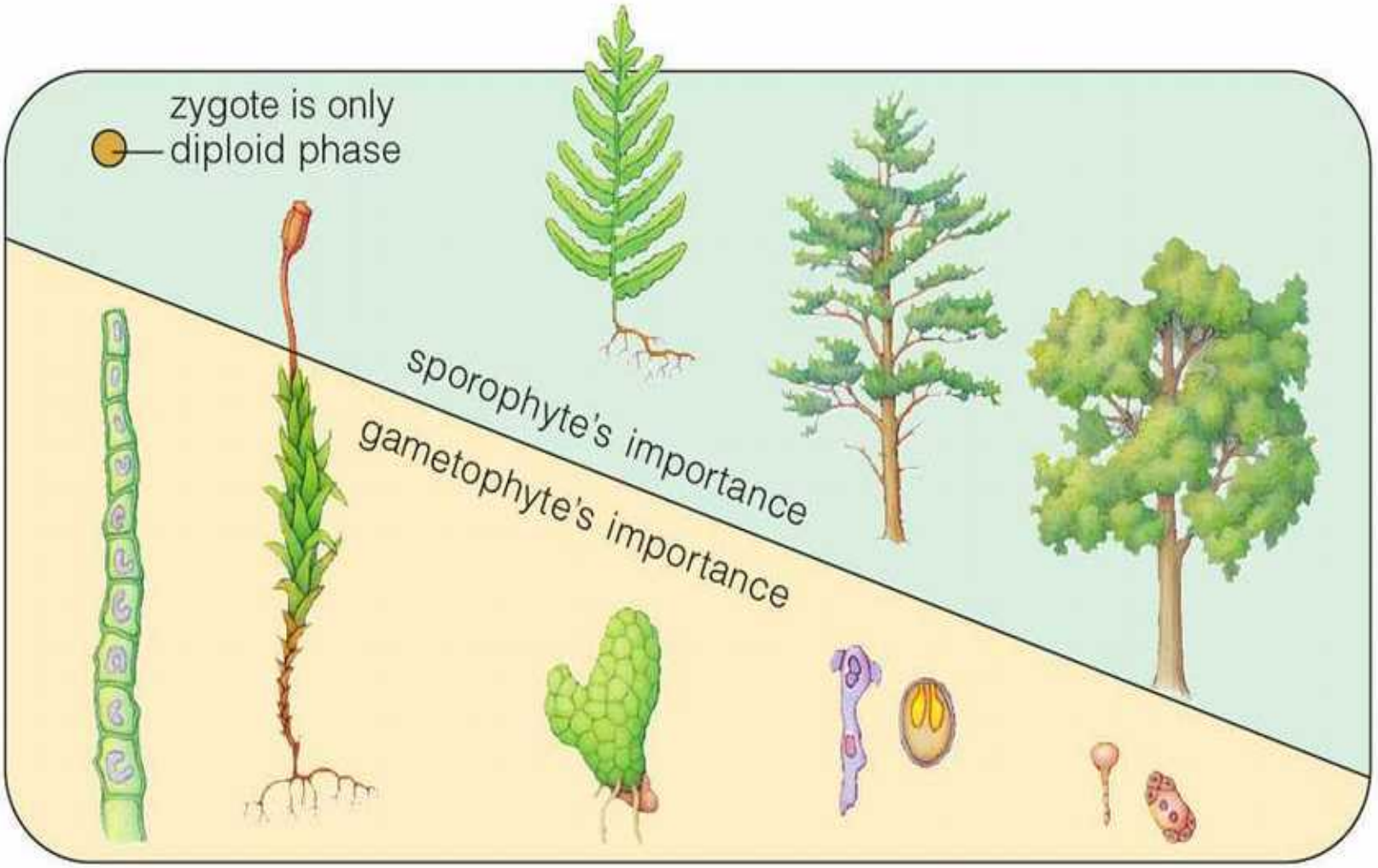


Animals



Plants

Evolutionary Trends in Plant Life Cycles



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

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**

Fig. 30-2

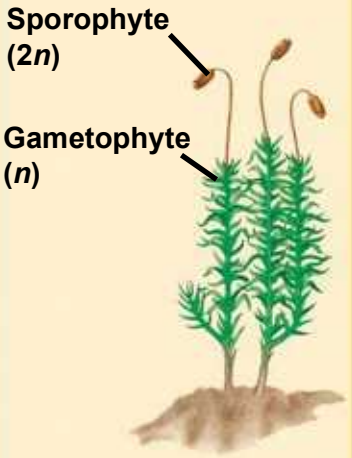
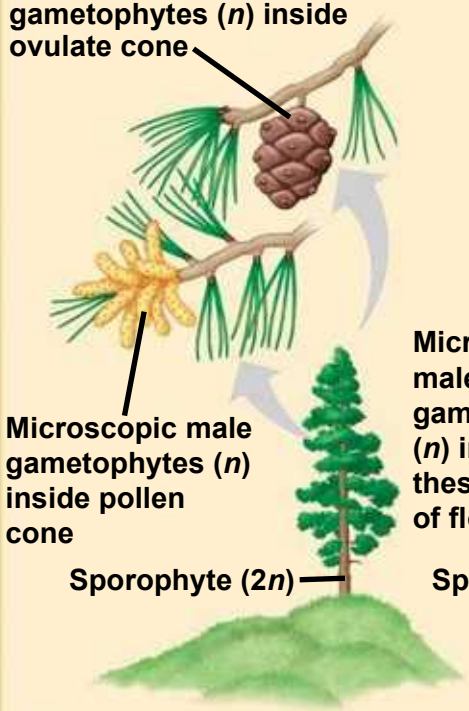
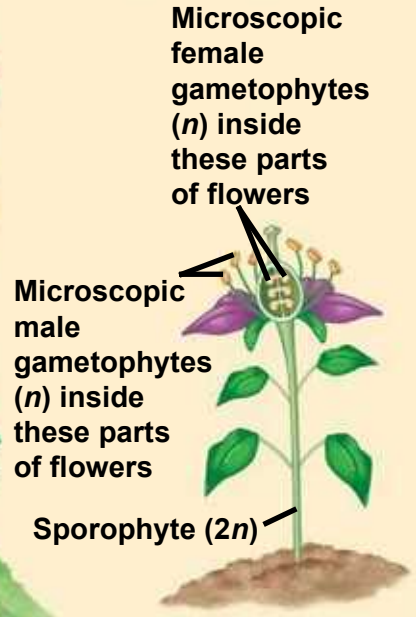
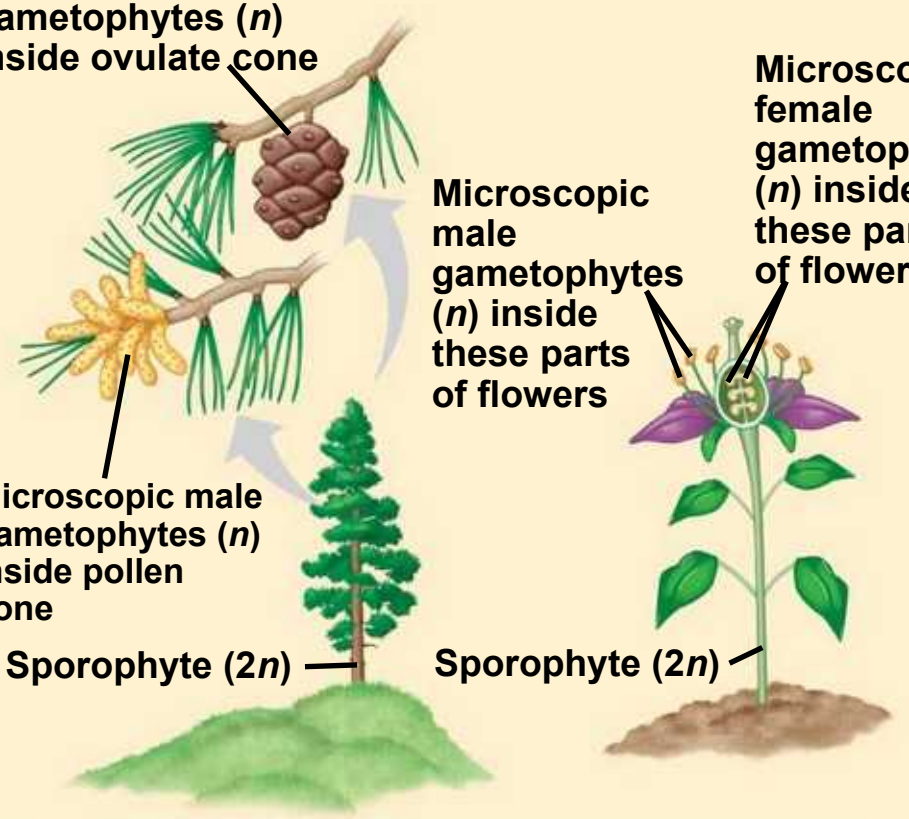
	PLANT GROUP		
	Mosses and other nonvascular plants	Ferns and other seedless vascular plants	Seed plants (gymnosperms and angiosperms)
Gametophyte	Dominant	Reduced, independent (photosynthetic and free-living)	Reduced (usually microscopic), dependent on surrounding sporophyte tissue for nutrition
Sporophyte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

Fig. 30-2c

	Seed plants (gymnosperms and angiosperms)
Gametophyte	Reduced (usually microscopic), dependent on surrounding sporophyte tissue for nutrition
Sporophyte	Dominant
Example	Gymnosperm Microscopic female gametophytes (*n*) inside ovulate cone Microscopic male gametophytes (*n*) inside pollen cone Sporophyte (2*n*) Angiosperm Microscopic male gametophytes (*n*) inside these parts of flowers Microscopic female gametophytes (*n*) inside these parts of flowers Sporophyte (2*n*)

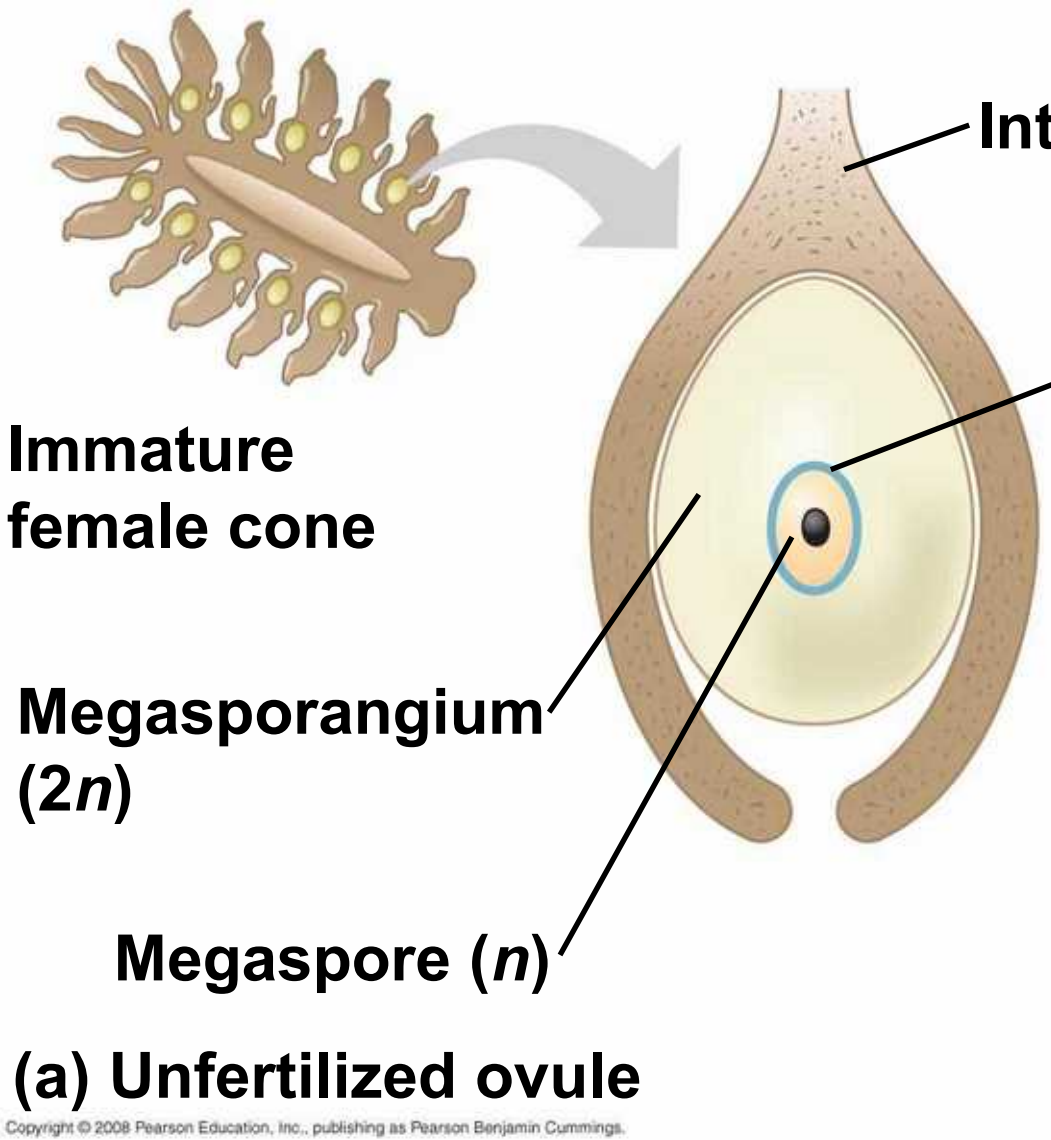


- Living seed plants can be divided into two clades: gymnosperms and angiosperms
- Gymnosperms appear early in the fossil record and dominated the Mesozoic terrestrial ecosystems
- Gymnosperms were better suited than nonvascular plants to drier conditions
- Angiosperms evolved from the gymnosperms

Heterospory: The Rule Among Seed Plants

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

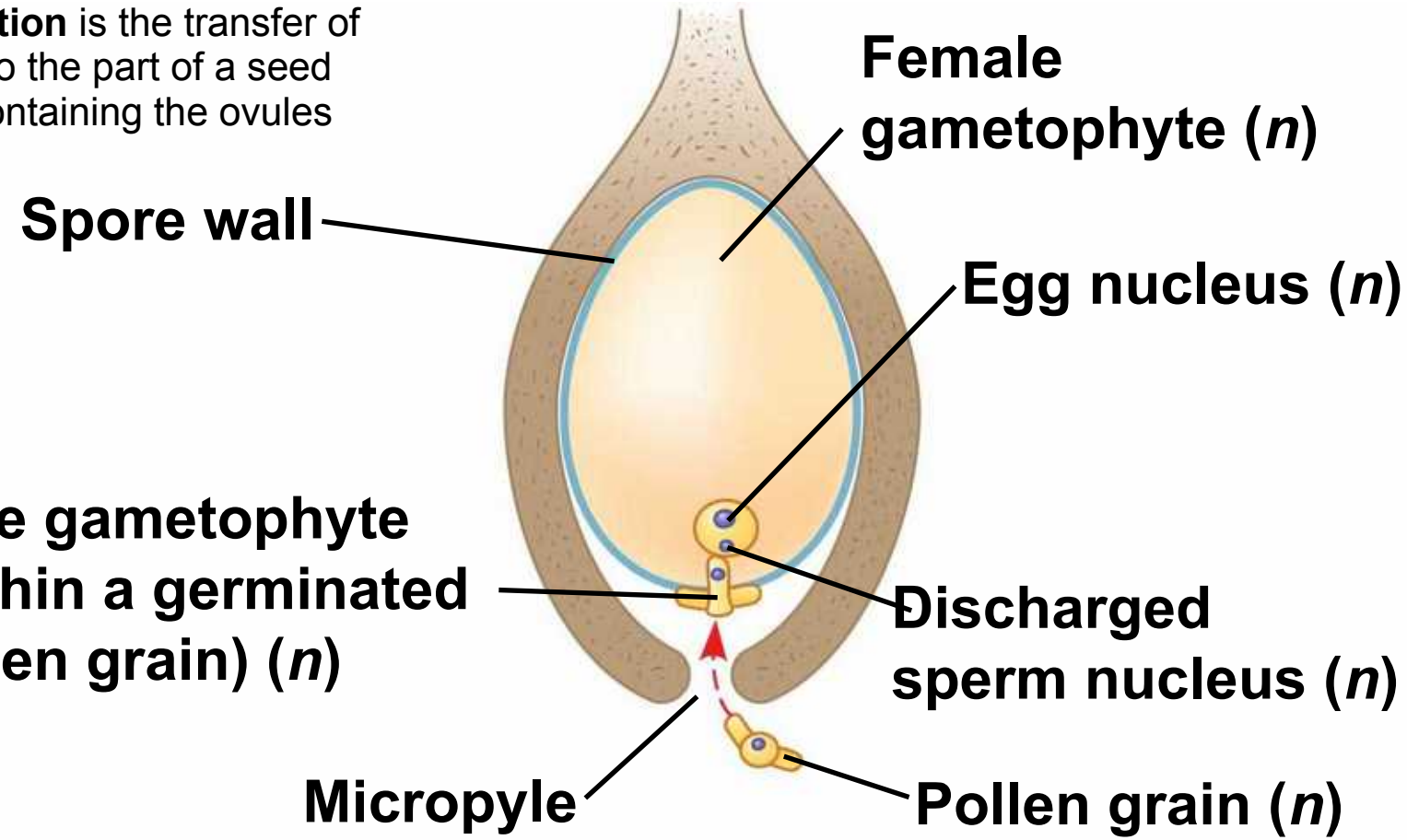
Fig. 30-3-1



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

- 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 and Production of Sperm

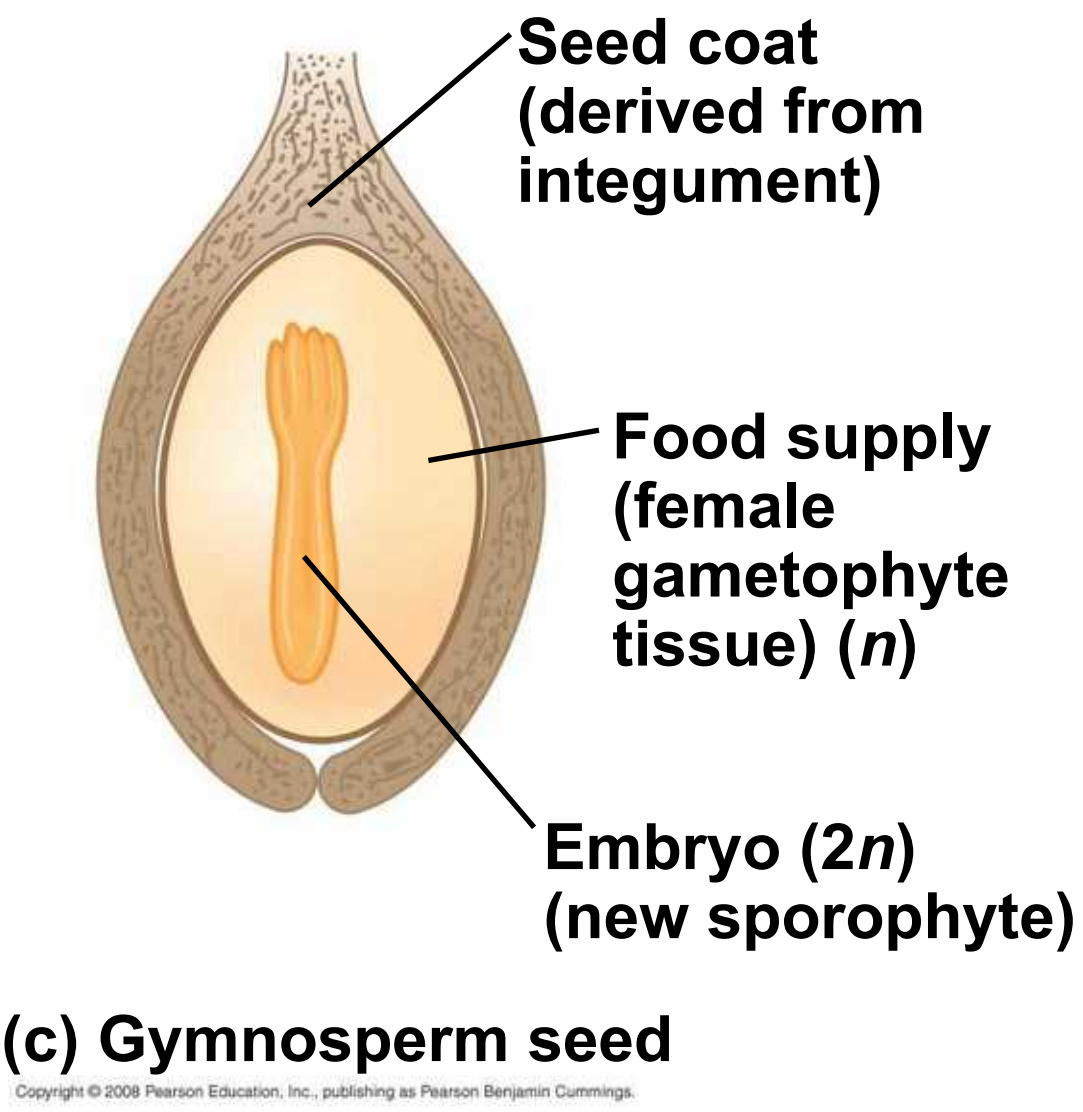


(b) Fertilized ovule

The Evolutionary Advantage of Seeds

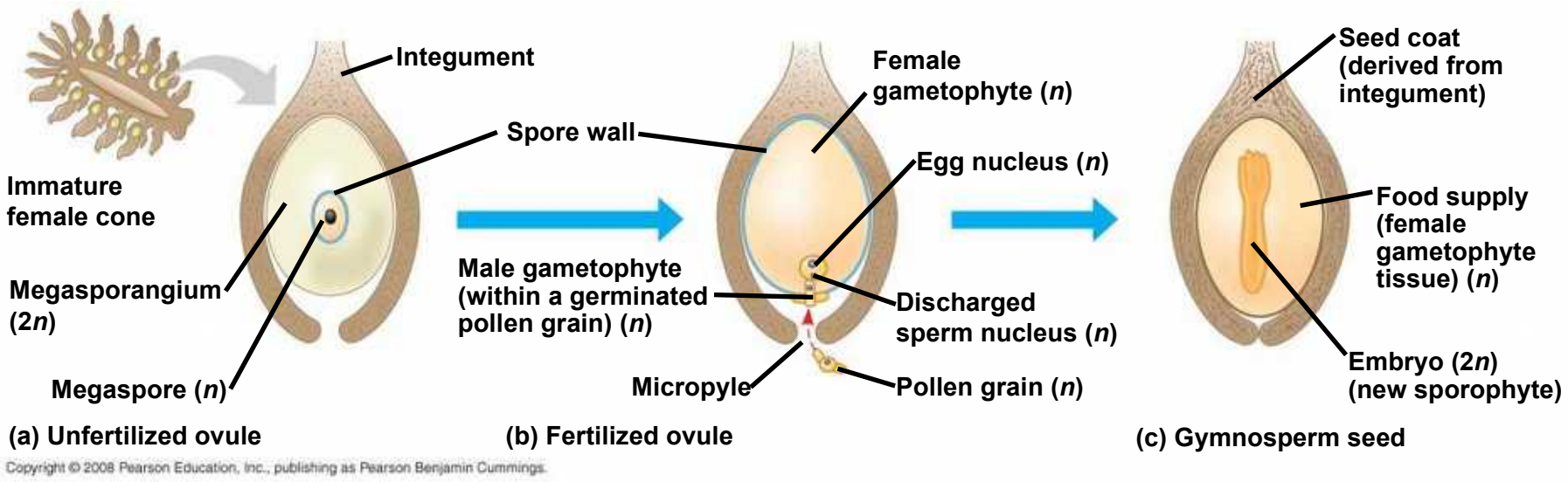
- A seed develops from the whole ovule
- A seed is a sporophyte embryo, along with its food supply, packaged in a protective coat
- Seeds provide some evolutionary advantages over spores:
  - They may remain dormant for days to years, until conditions are favorable for germination
  - They may be transported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

Sporophyte embryo is DEPENDENT on gametophyte tissue!



(c) Gymnosperm seed

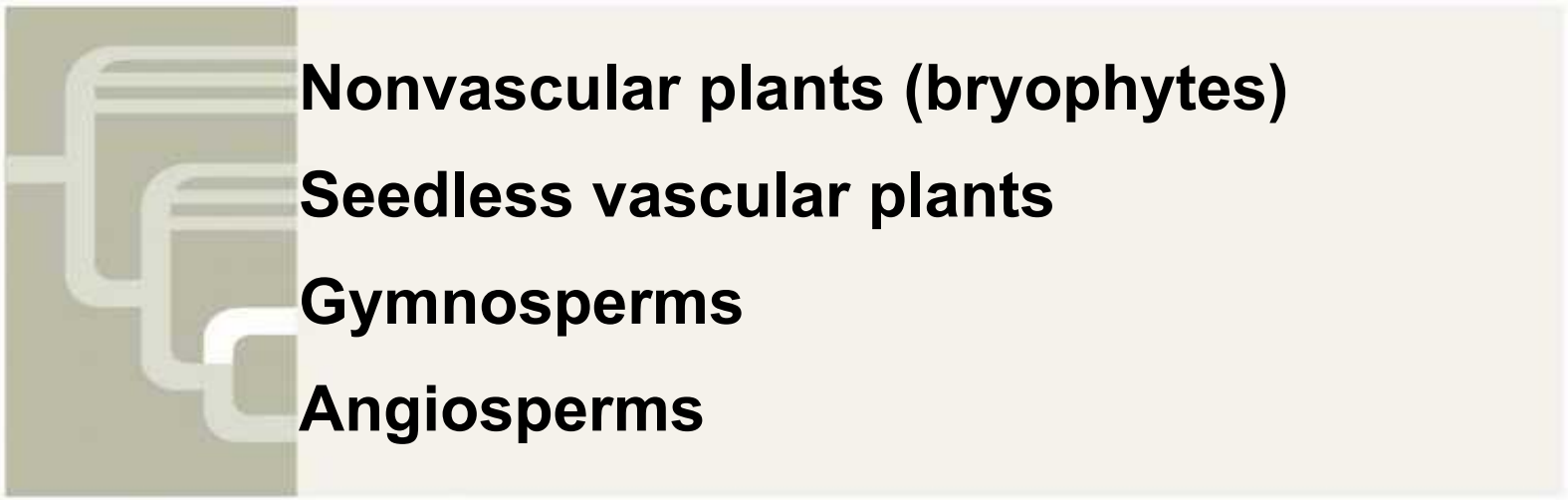
Fig. 30-3-4

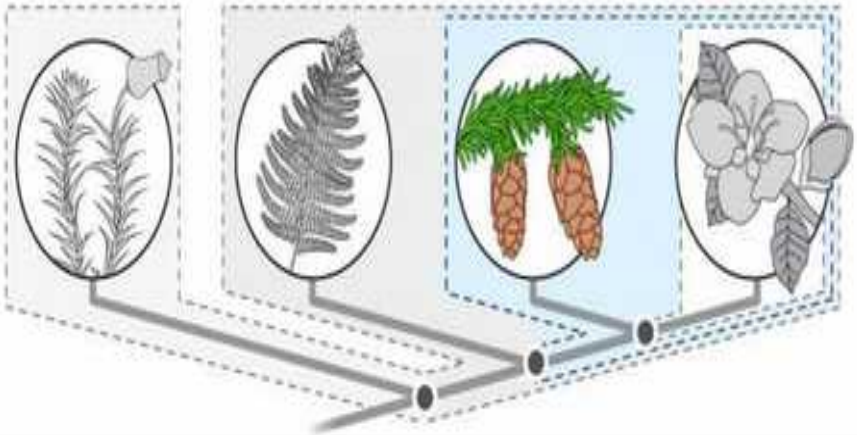


Concept 30.2: Gymnosperms bear "naked" seeds, typically on cones

- **The gymnosperms have "naked" seeds not enclosed by ovaries and consist of four phyla:**
  - **Cycadophyta (cycads)**
  - **Ginkgophyta (one living species: *Ginkgo biloba*)**
  - **Gnetophyta (three genera: *Gnetum, Ephedra, Welwitschia*)**
  - **Coniferophyta (conifers, such as pine, fir, and redwood)**

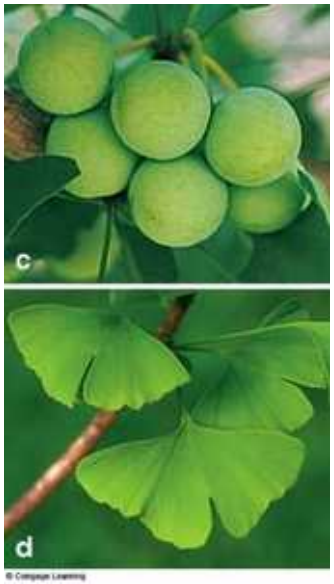
Fig. 30-UN1





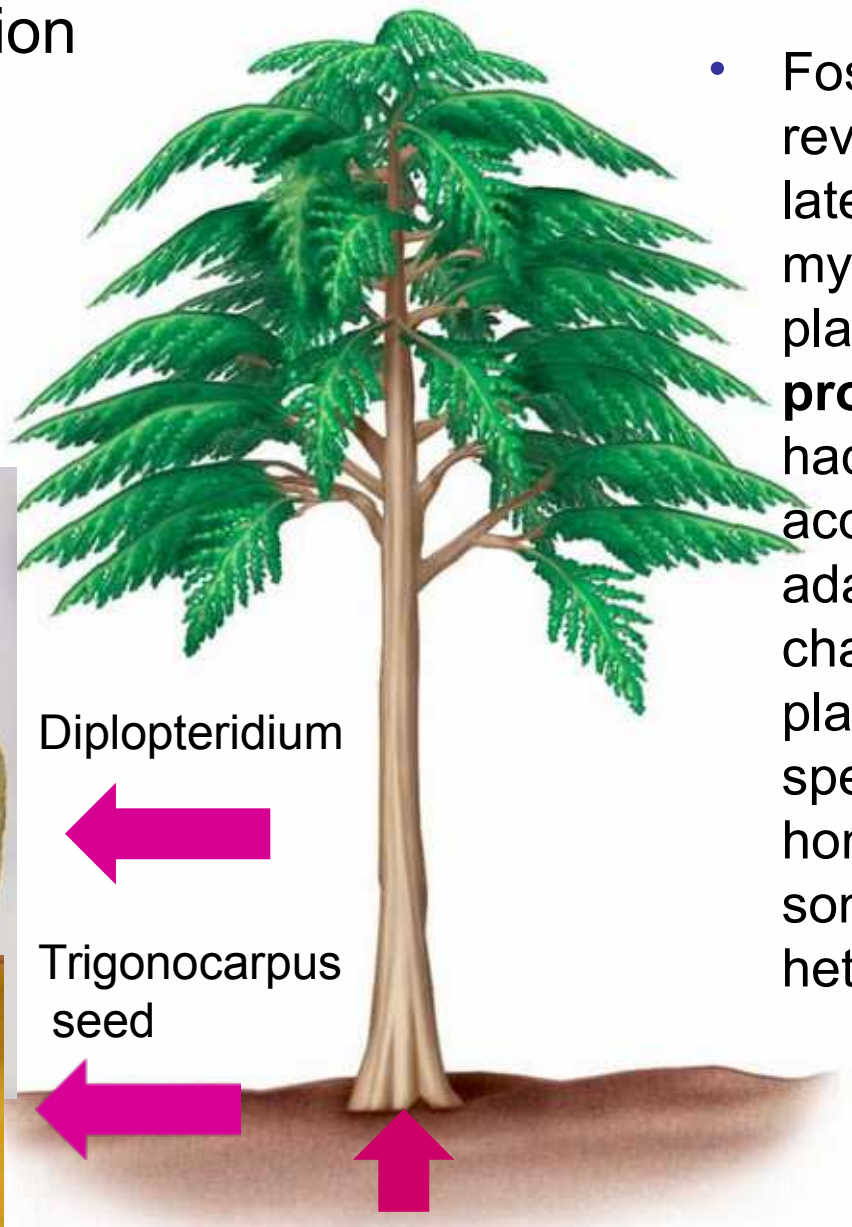
THE GYMNOSPERMS

Gymnosperms



Gymnosperm Evolution

In the late Devonian, there were also ancient gymnosperms called seed ferns, or Pteridospermales.



- Fossil evidence reveals that by the late Devonian (370 mya) period some plants, called **progymnosperms**, had begun to acquire some adaptations that characterize seed plants. Some species were homosporous and some were heterosprous.

***Archaeopteris*, a progymnosperm**

Phylum Cycadophyta

- Individuals have large cones and palmlike leaves, tracheids, ovulate and microsporangia cones on separate plants
- These thrived during the Mesozoic, but relatively few species exist today, (Dinosaur food)
- Their sperm is multiflagellated, and some actually have insects such as beetles help pollinate them (they eat pollen). So in this way, they are like angiosperms.

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, tracheids, ovules and microsporangia on separate plants
- Sperm is also multiflagellated
- The fleshy seed coat has a vile odor from butanoic and hexanoic acids. Fatty acids found in rancid butter and Romano cheese.

Fig. 30-5b

Ginkgo biloba
pollen-producing tree

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
- Tracheids and vessel elements, no motile sperm, ovulate and microsporangiate cones on separate plants, ephedra has double fertilization like angiosperms, but produces extra embryos instead of 3n endosperm

Fig. 30-5d

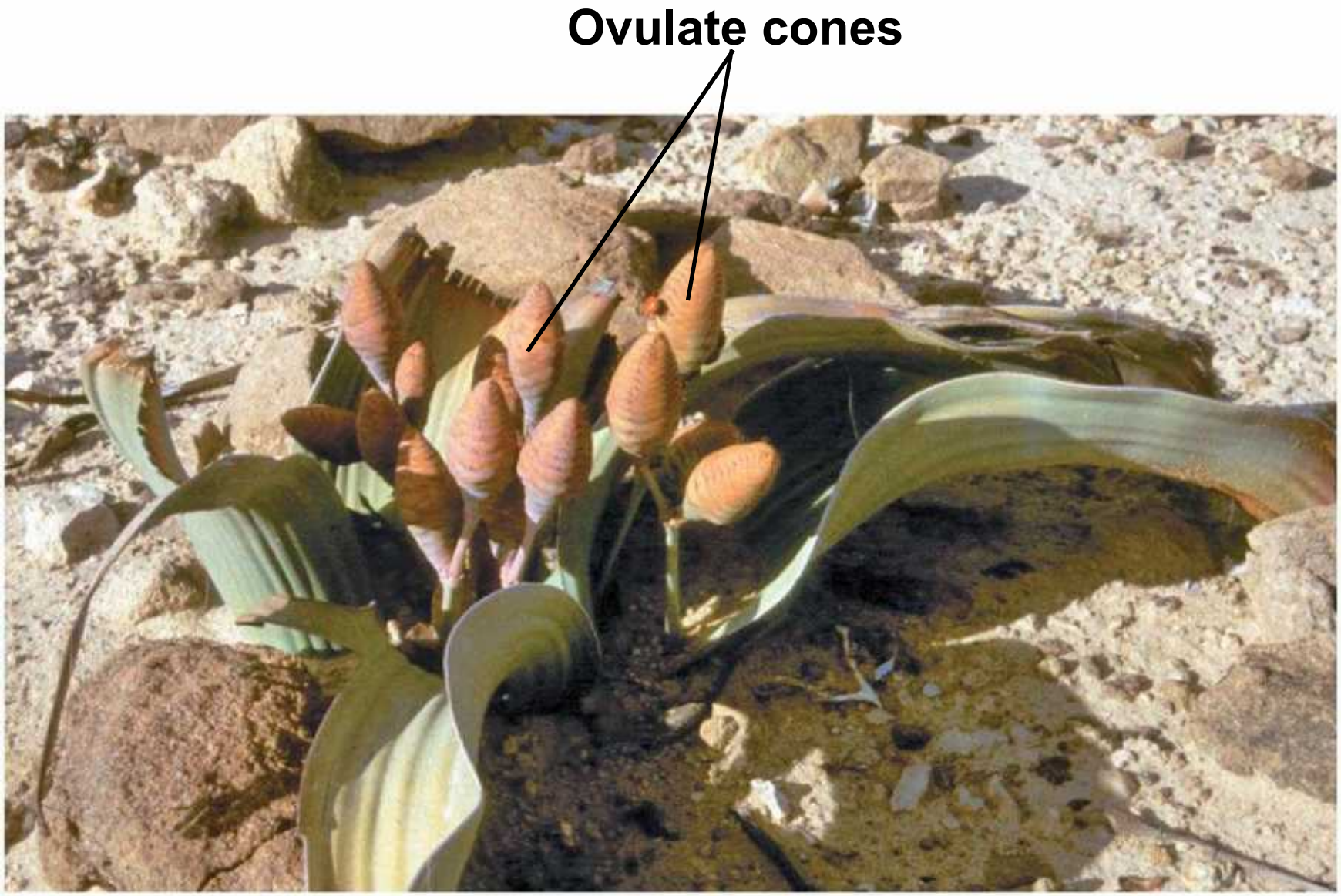
Gnetum

Ephedra

Ephedra

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, tracheids, no motile sperm, ovate and microsporangiate cones on same plant
- Usually, pine trees disperse their offspring by using windblown seeds
- The cones are modified leaves

CONES

MALE CONES
The male cone releases pollen grains that require wind to reach a female cone.

FEMALE CONE
The female cone has ovules on the protruding scales. They produce seeds when fertilized by pollen.

Wind dispersal of pollen is highly inefficient. For each grain that fertilizes an egg, billions of pollen grains are wasted. Nonetheless, pines have been using wind pollination successfully for more than 200 million years.

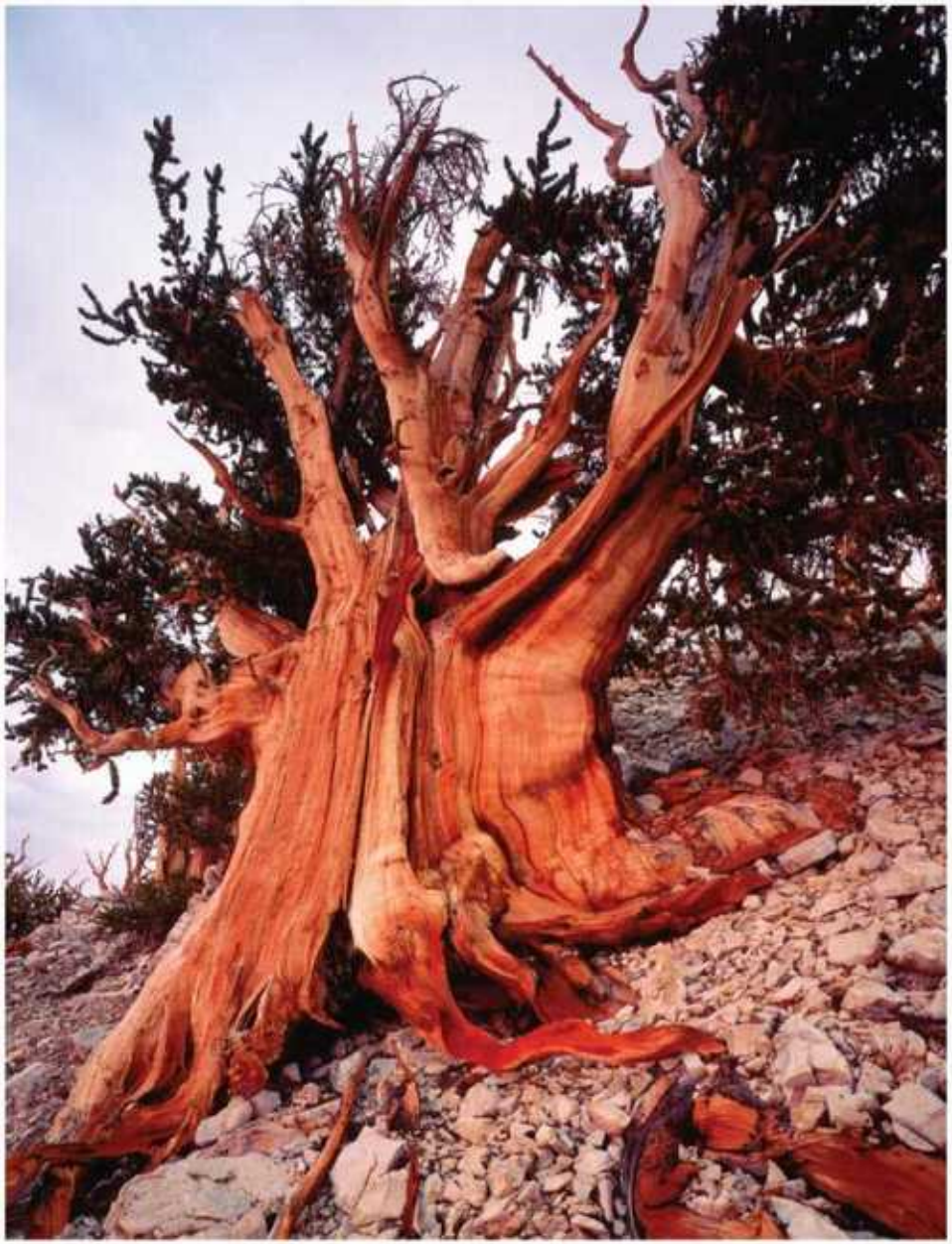
Fig. 30-5h

Douglas fir

Fig. 30-5i

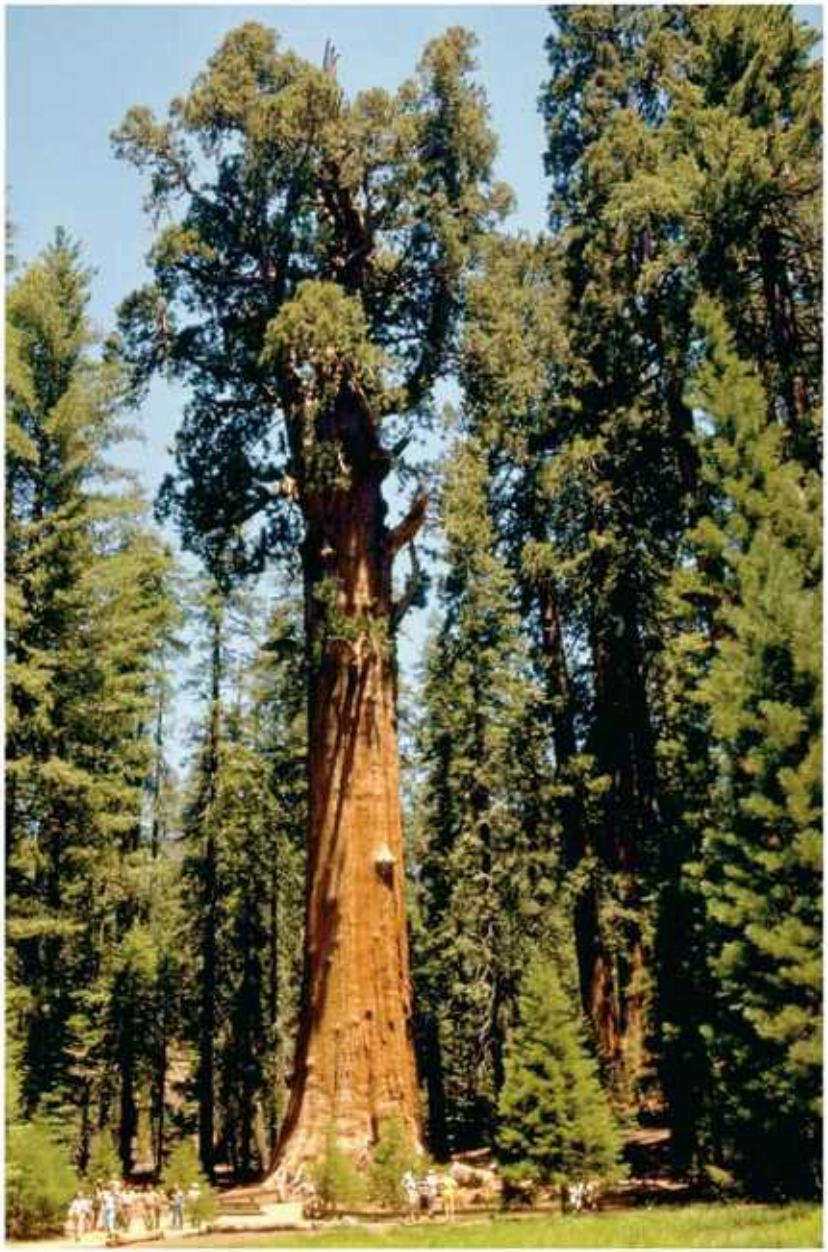
European larch

Fig. 30-5j



Bristlecone pine

Fig. 30-5k

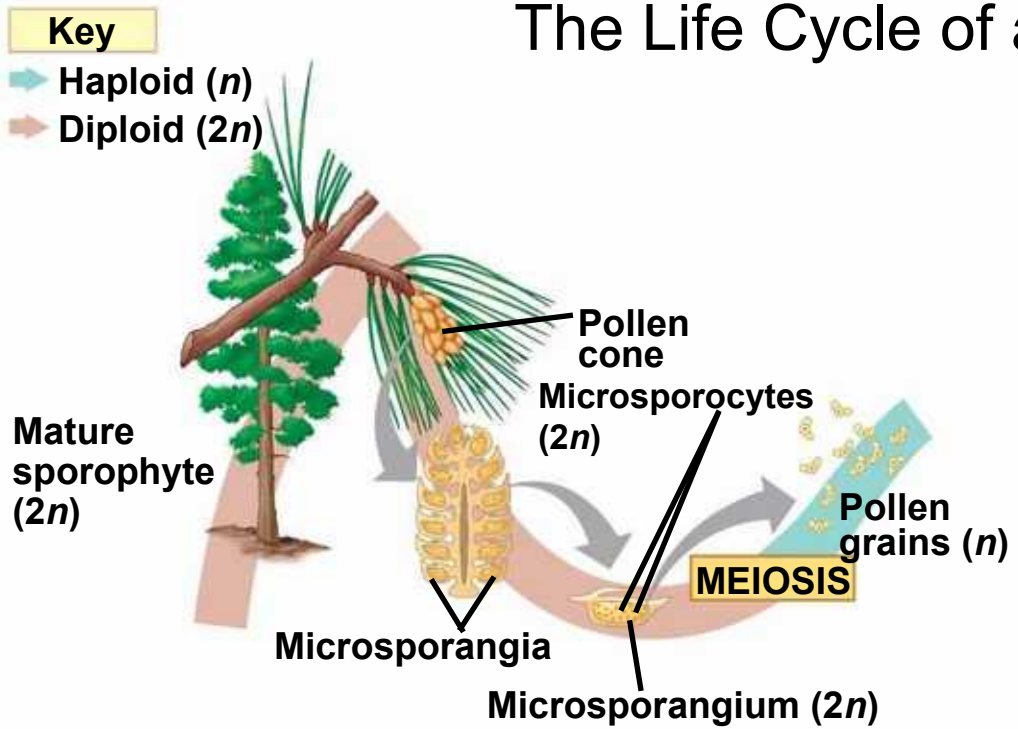


Sequoia

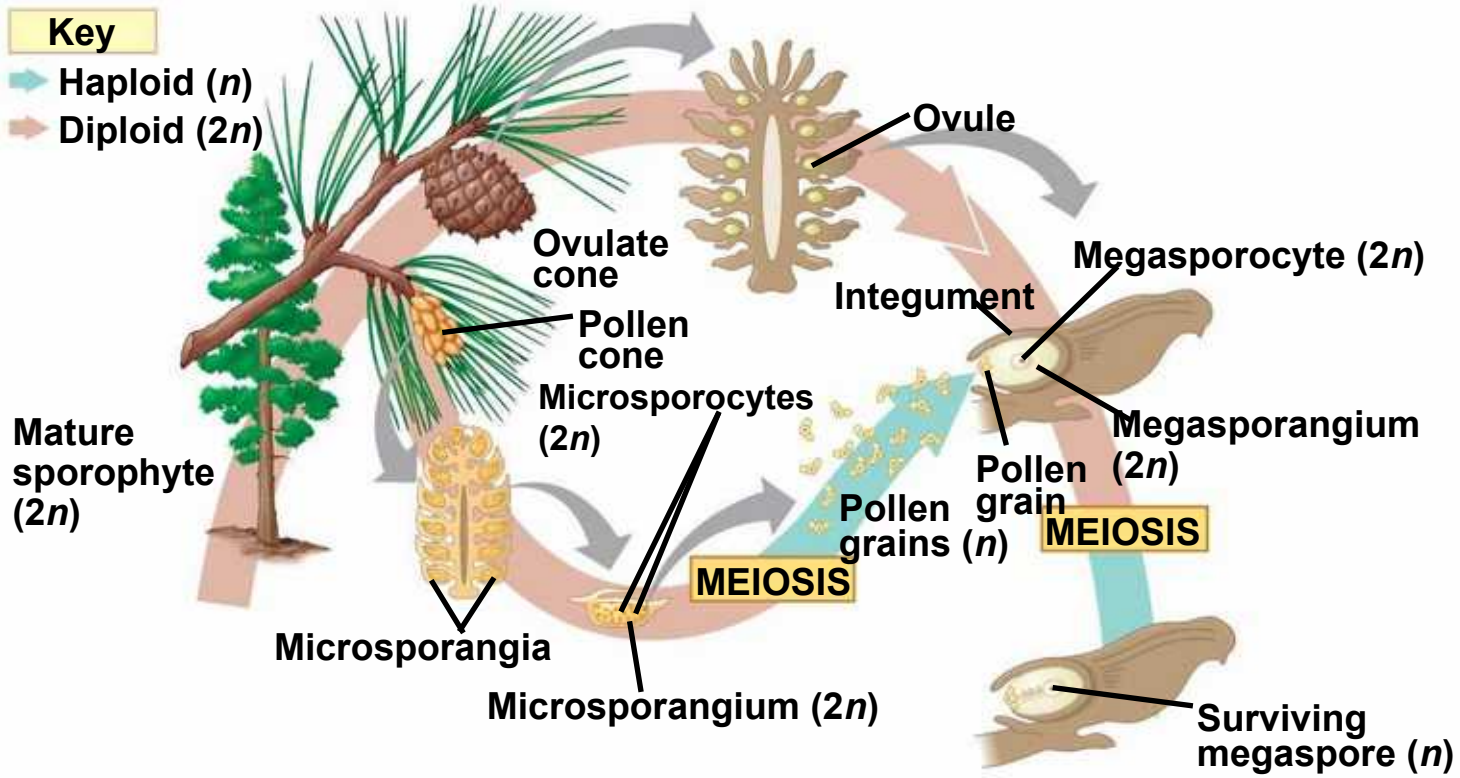
Fig. 30-5m

Common juniper

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



- 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 and can be dispersed by the wind



- 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. 30-6-3

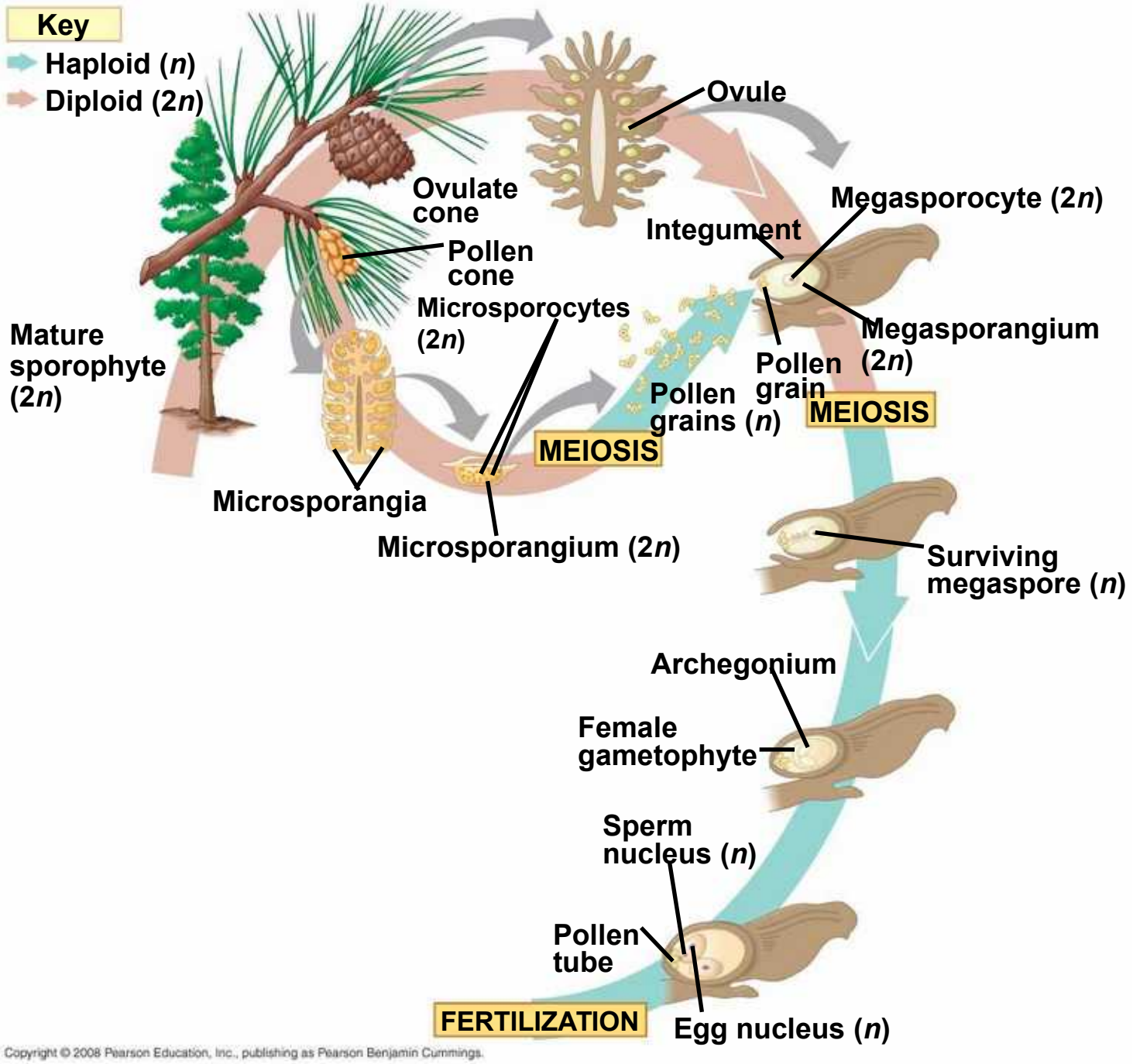
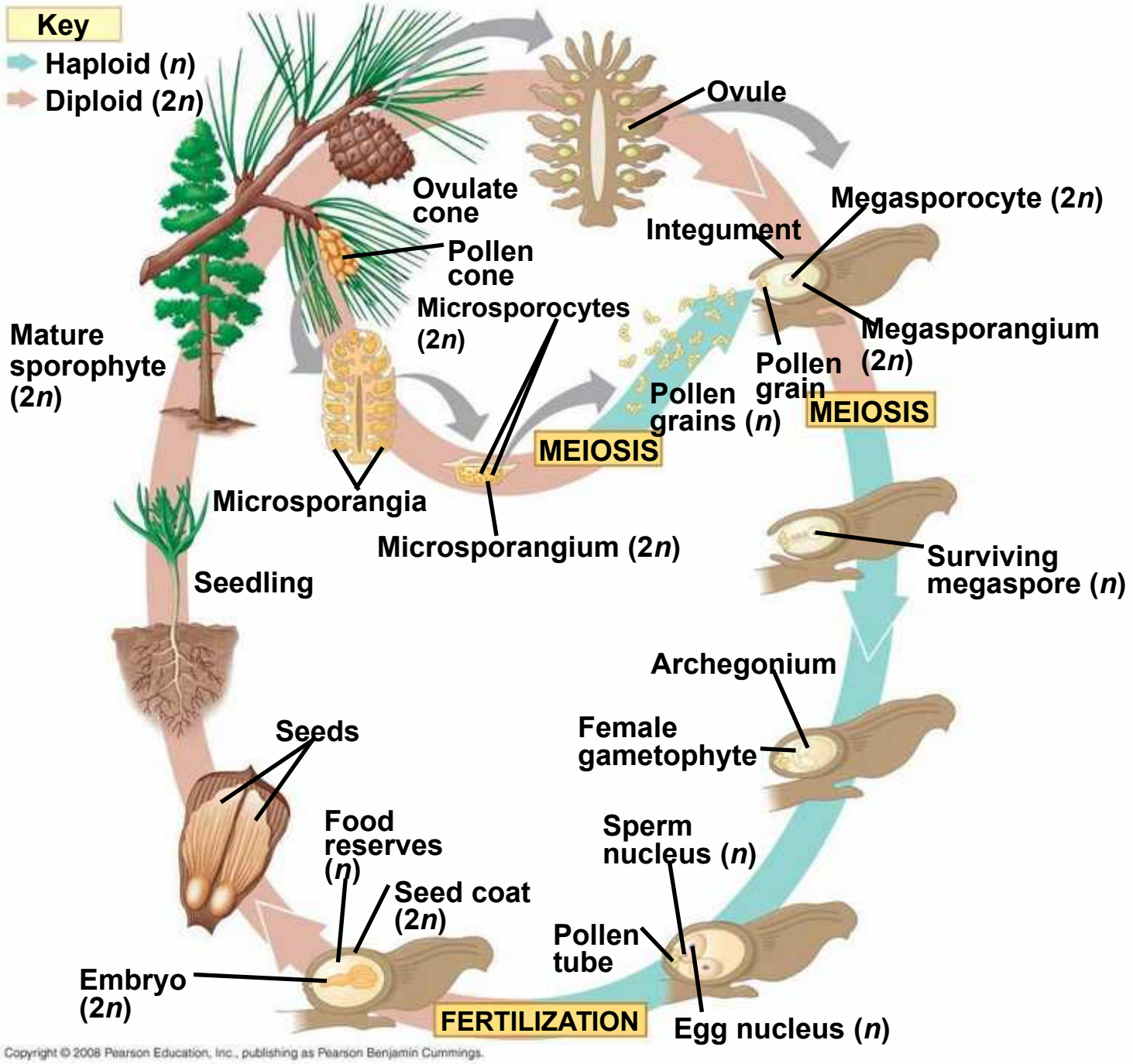
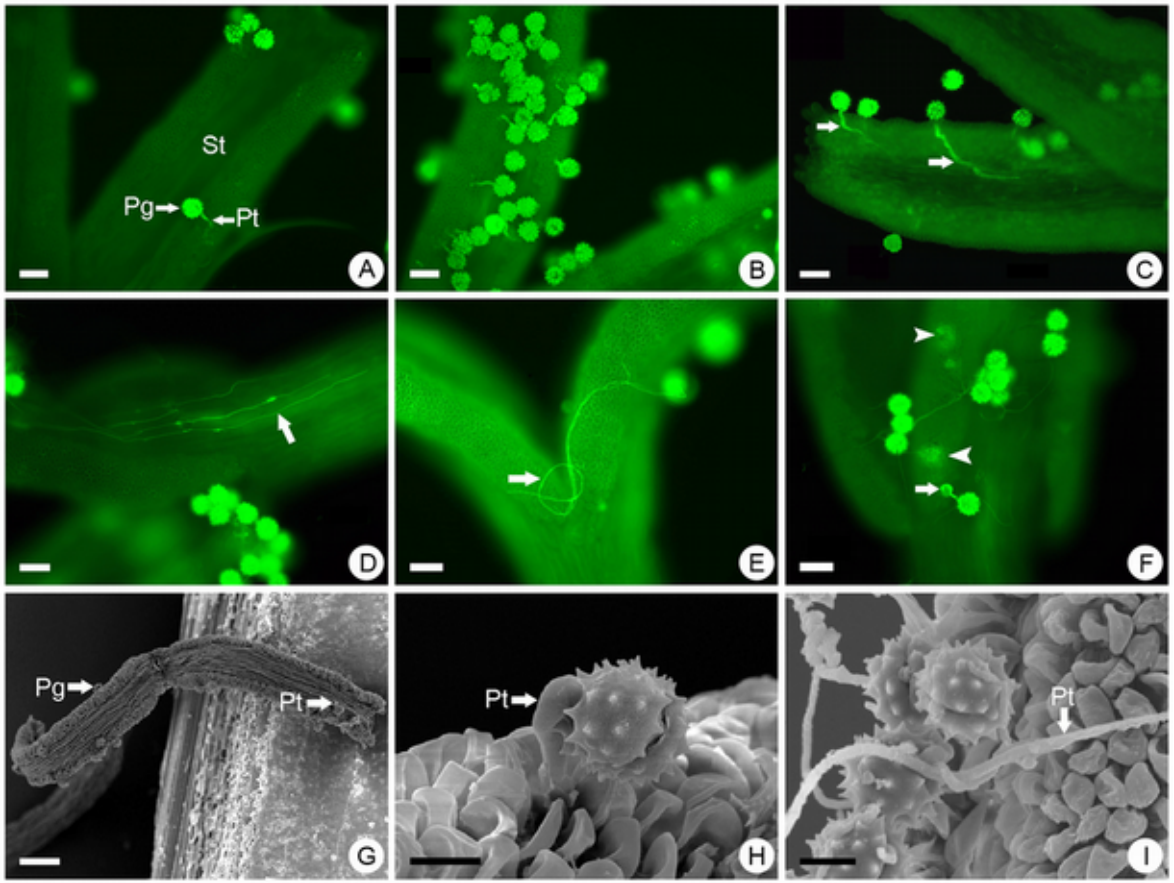


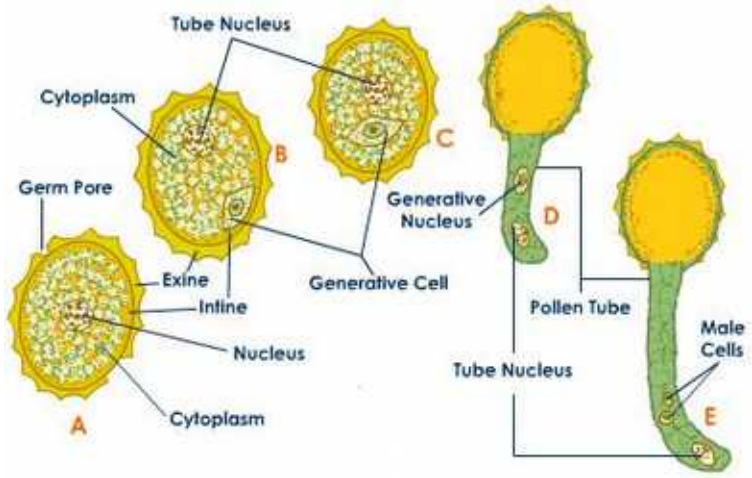
Fig. 30-6-4

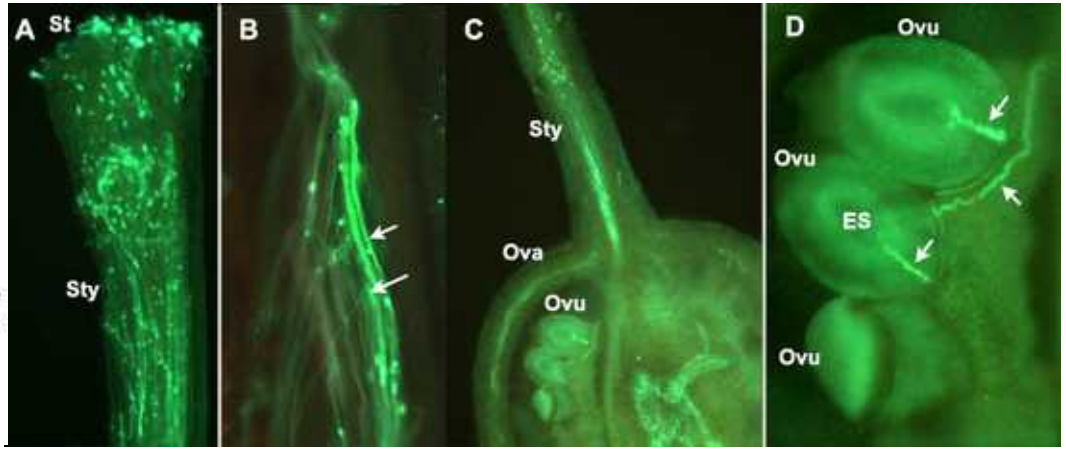


Pollen

Pollen tube growth







Conifers such as these redwoods can reach up to 380 feet tall.

Conifers such as these bristlecone pines can live for more than 4,800 years.

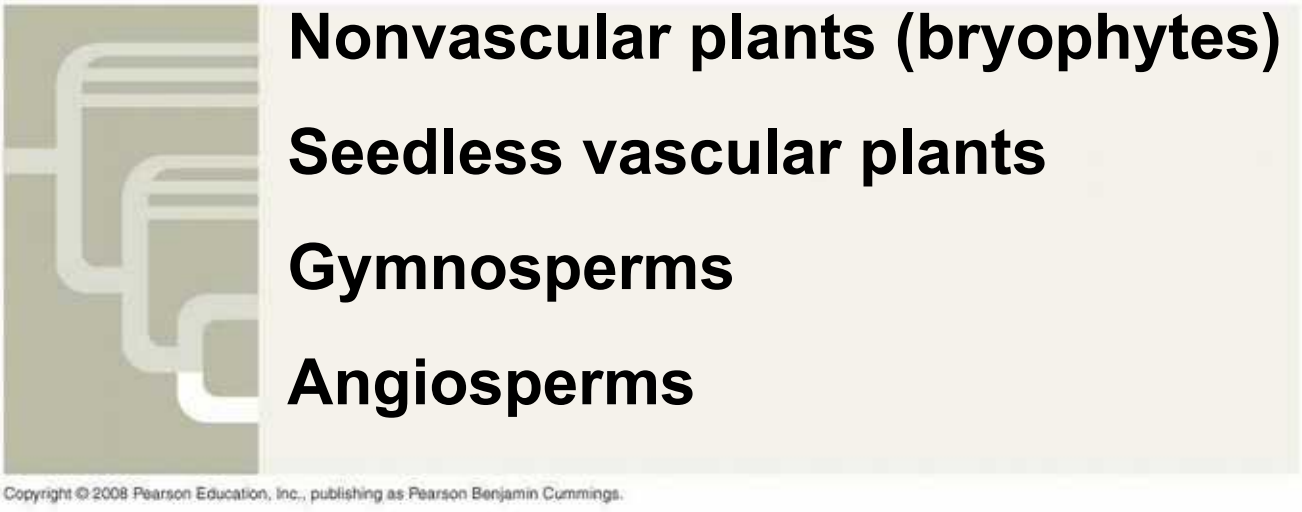
Conifers have grown taller and reached older ages than any other plants.

Old Tjikko

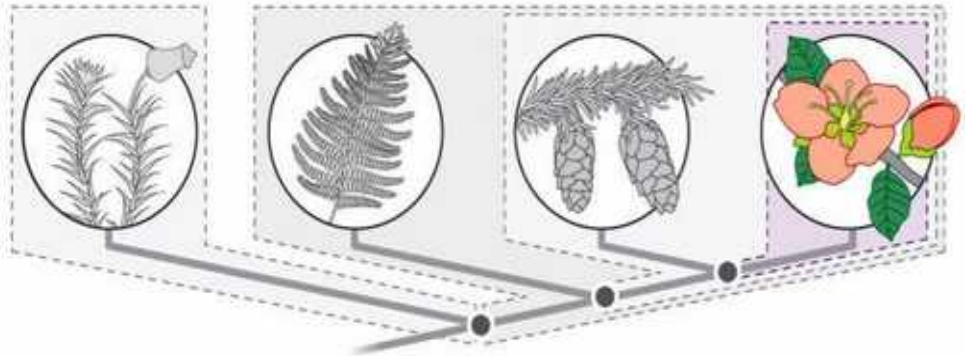
The trunk of this tree is less than 600 years old—but its roots date back to 9,558 years ago, making it the world's oldest known living tree, The Norway Spruce in Sweden.

~3000 years prior to the invention of writing

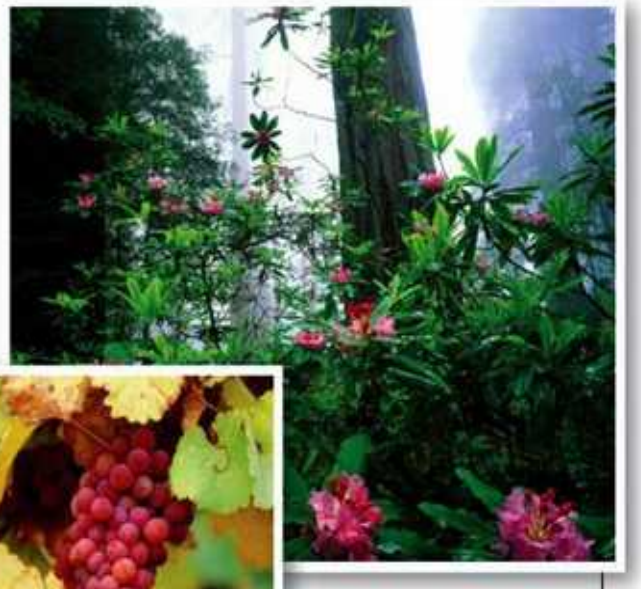
Concept 30.3: The reproductive adaptations of angiosperms (vessel seeds) include flowers and fruits



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



THE ANGIOSPERMS



Characteristics of Angiosperms

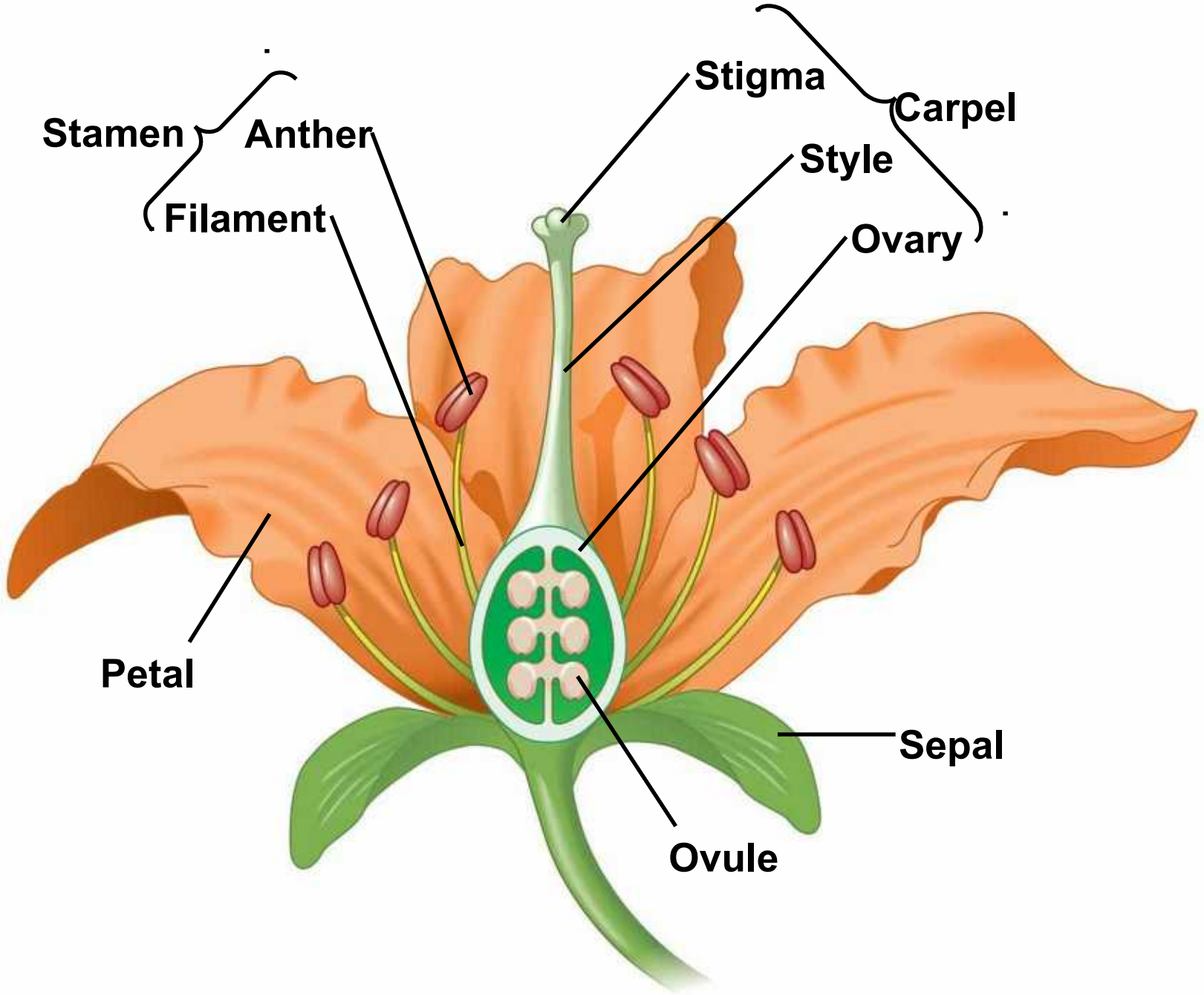
- All angiosperms are classified in a single phylum, Anthophyta (Magnoliophyta)
- The name comes from the Greek *anthos*, flower

Flowers

- The **flower** is an angiosperm structure specialized for sexual reproduction
- Many species are pollinated by insects or vertebrate animals, while some species are wind-pollinated and others can sometimes use water as a vector of transport

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

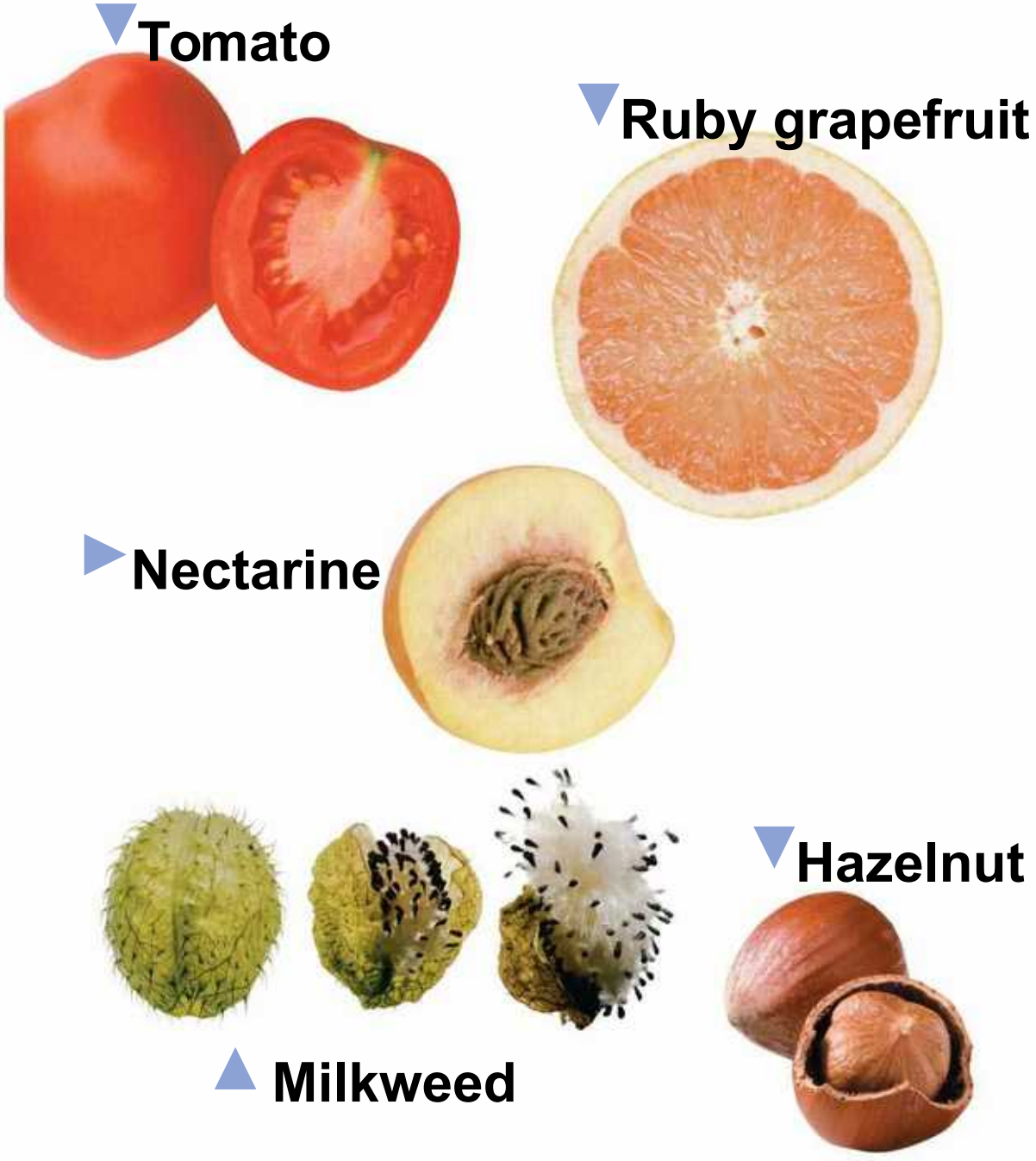
Fig. 30-7



- A **fruit (the ovary)** typically consists of a mature ovary but can also include other flower parts

- Fruits protect seeds and aid in their dispersal

- **Seeds (the ovules)** can be carried by wind, water, or animals to new locations



Frugivourous (fruit eating) animals have coevolved unique adaptations. Seed coats need to be protected going through the digestive track. Some seeds are resistant to digestive enzymes and some seed coats can also withstand low pH's. Some seeds actually need disruption of the seed coat to germinate, whether it is by acid or enzyme action or scarification (scratching of the seed coat) to start the formation of the seedling.

Wings

Seeds within berries

Barbs

Nectar and brightly colored reproductive parts will attract animal dispersers easily.

Many mammals have skins and mucous membranes that are sensitive to phenolic secretions of plants like poison ivy. These secondary compounds are primarily adaptations that inhibit herbivory (Coevolution)

COEVOLUTION: FLOWERS AND THEIR POLLINATORS

COLORS AND PATTERNS

WHITE: Nocturnal pollinators, such as moths and bats

BRIGHT: Visually oriented, diurnal pollinators, such as birds, butterflies, and bees

FLOWER STRUCTURE

TUBE: Pollinators with long tongues, such as moths

INTRICATE/CLOSED: Pollinators such as bees

ODORS

SWEET: Pollinators with a good sense of smell, such as moths, butterflies, and bees

STINKY: Pollinators, such as flies, looking for rotten meat on which to lay eggs

NO ODOR: Pollinators with a poor sense of smell, such as birds

NECTAR

ABUNDANT: Pollinators with high energy needs, such as bees, birds, and butterflies

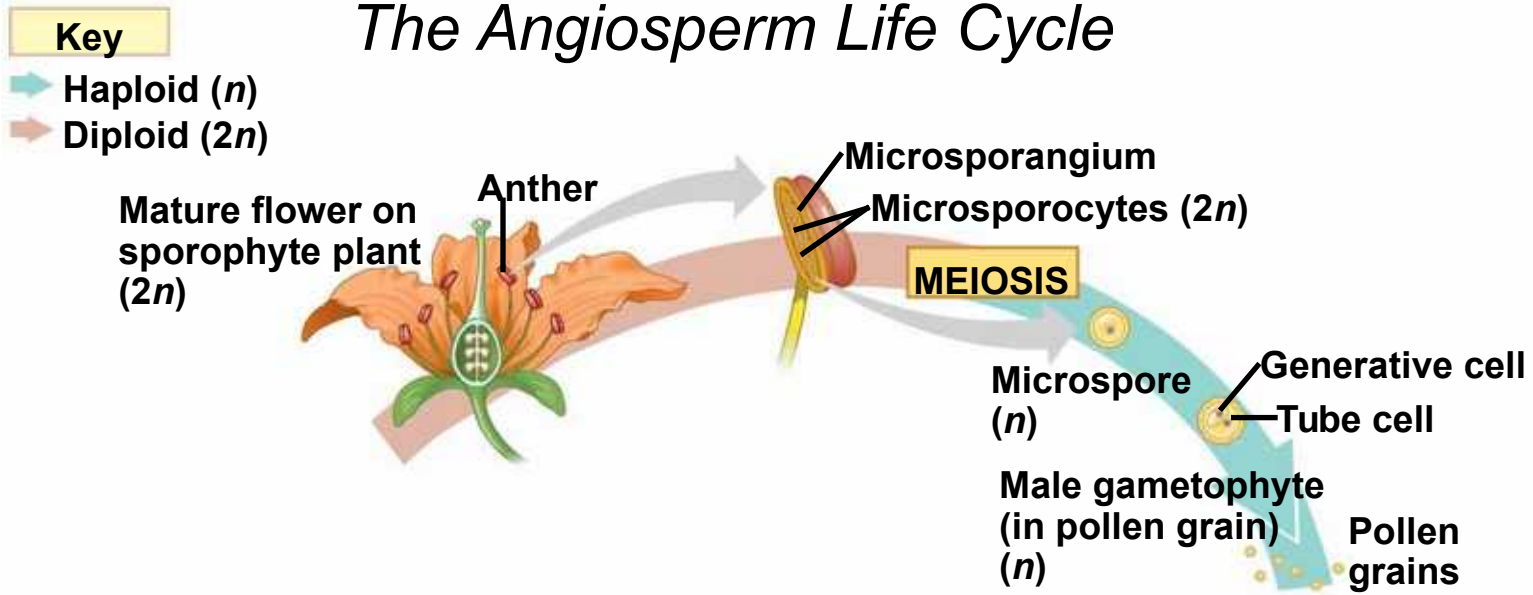
NO NECTAR: Pollinators, such as flies, looking for a place to lay eggs, or such as beetles, looking for petals, pollen, and other parts to eat

How a bee sees a flower

(c)

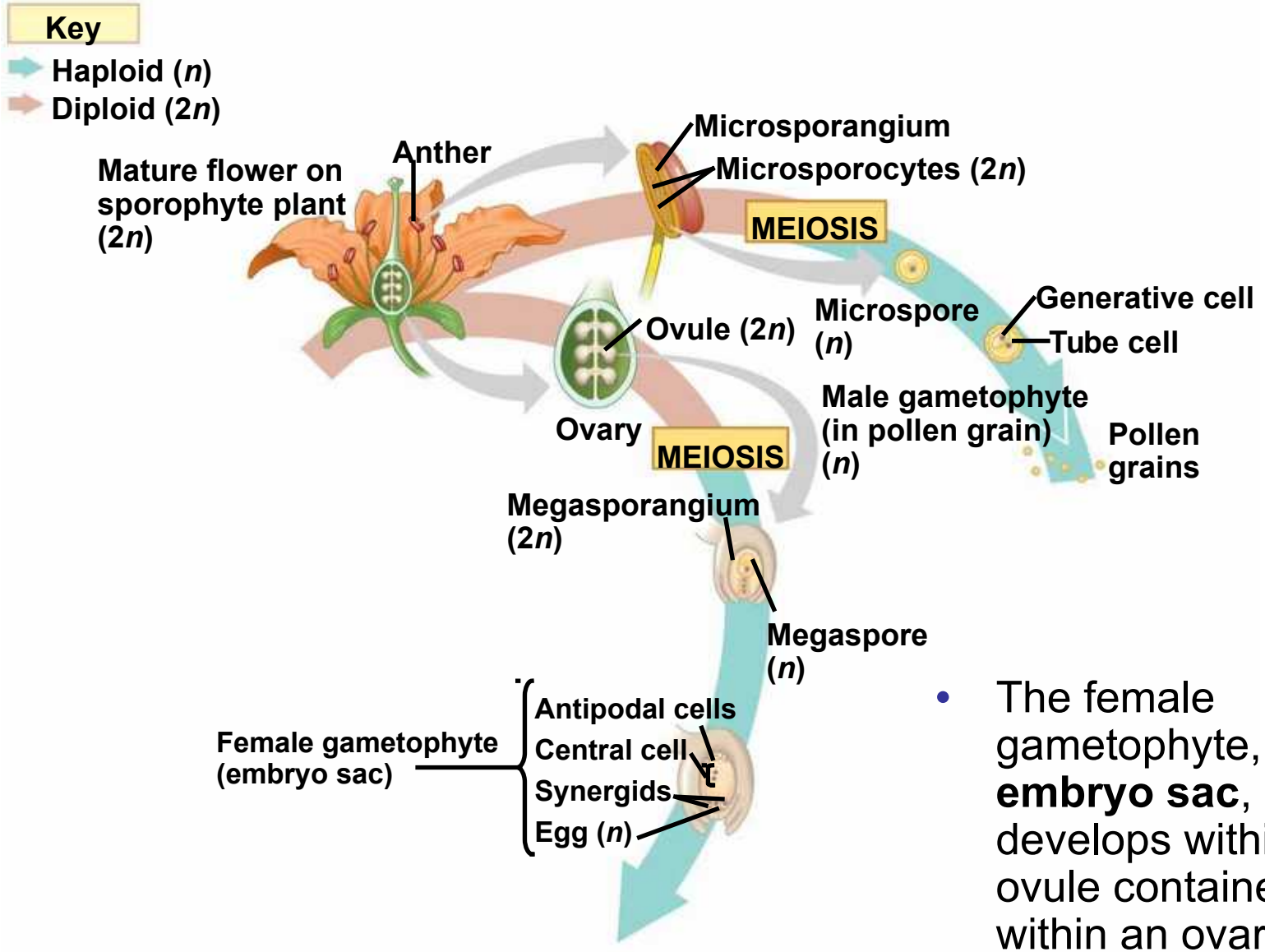
Bee covered in pollen

The Angiosperm Life Cycle



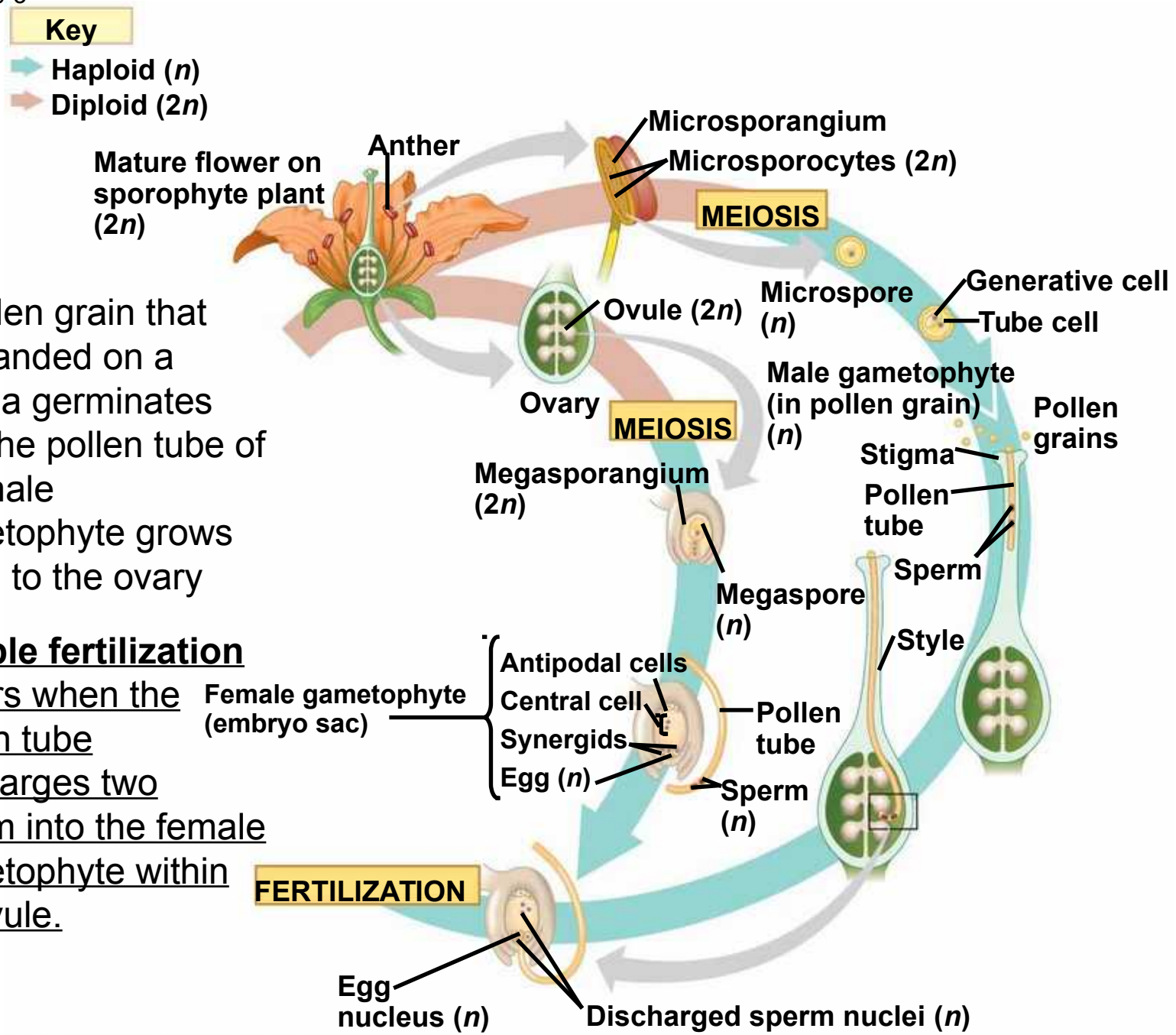
- The flower of the sporophyte is composed of both male and female structures
- Male gametophytes are contained within pollen grains produced by the microsporangia of anthers
- Most flowers have mechanisms to ensure **cross-pollination** between flowers from different plants of the same species

Fig. 30-10-2



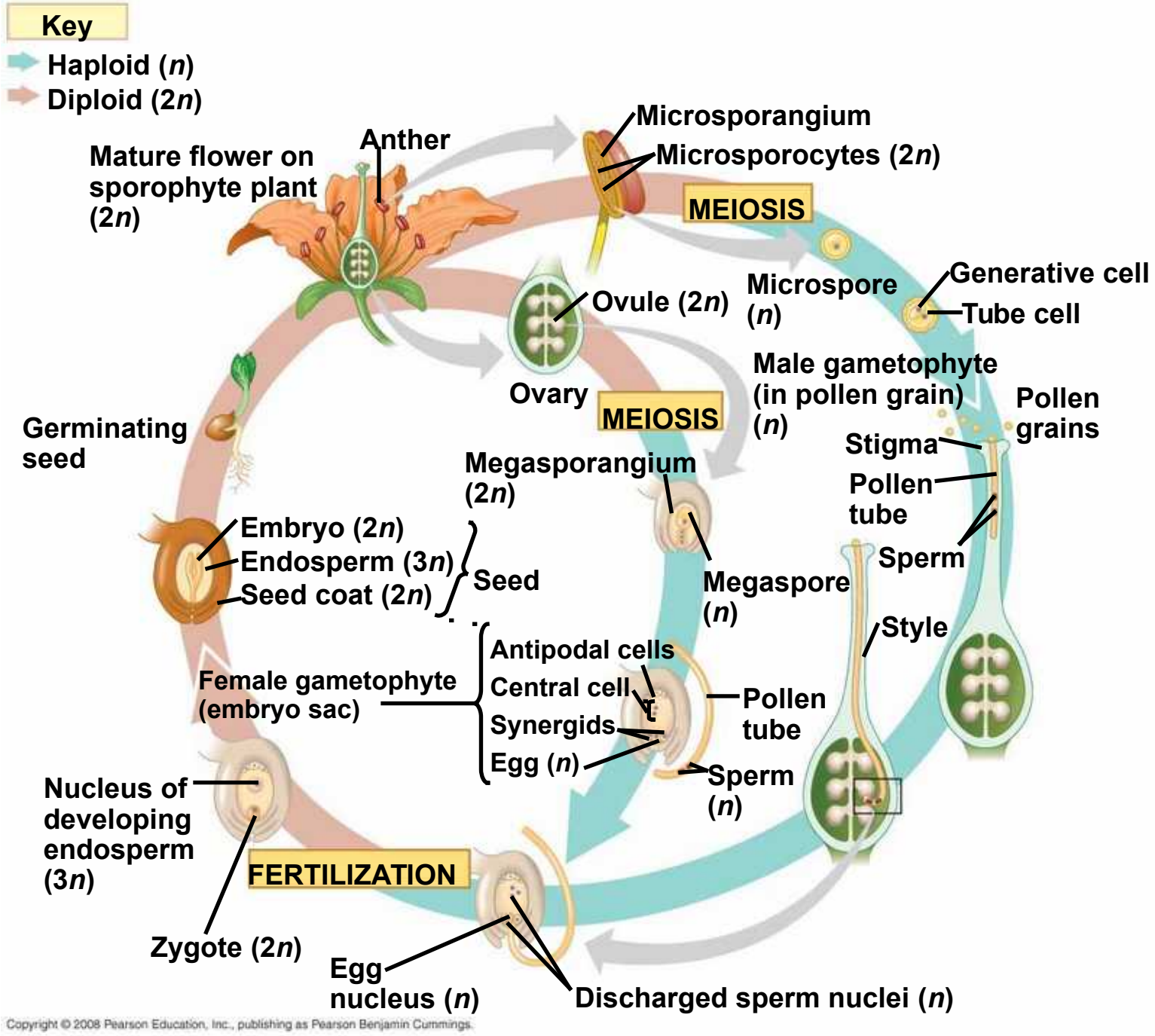
- The female gametophyte, or **embryo sac**, develops within an ovule contained within an ovary at the base of a stigma

Fig. 30-10-3

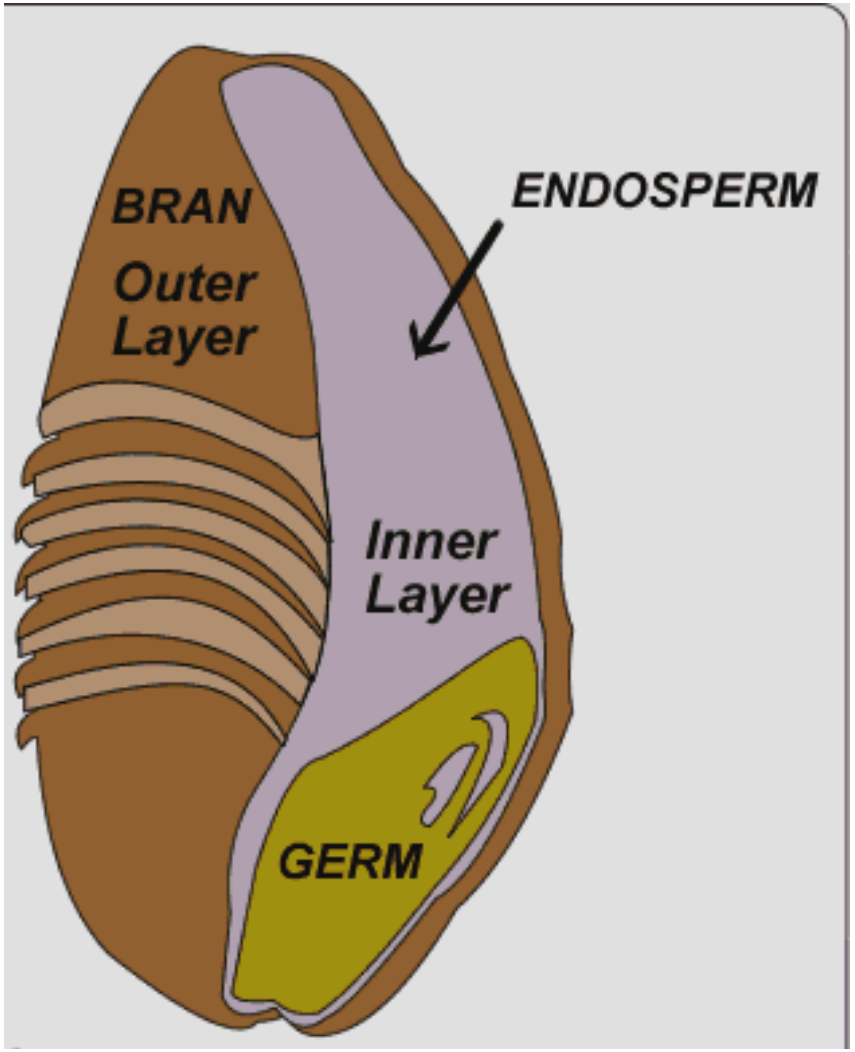


- A pollen grain that has landed on a stigma germinates and the pollen tube of the male gametophyte grows down to the ovary
- **Double fertilization** occurs when the pollen tube discharges two sperm into the female gametophyte within an ovule.

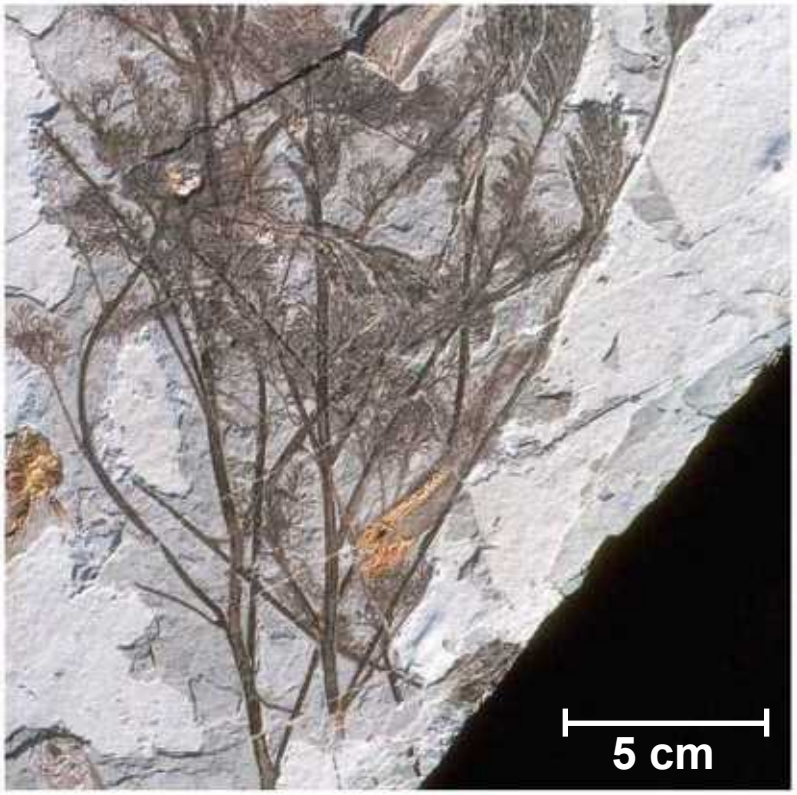
Fig. 30-10-4



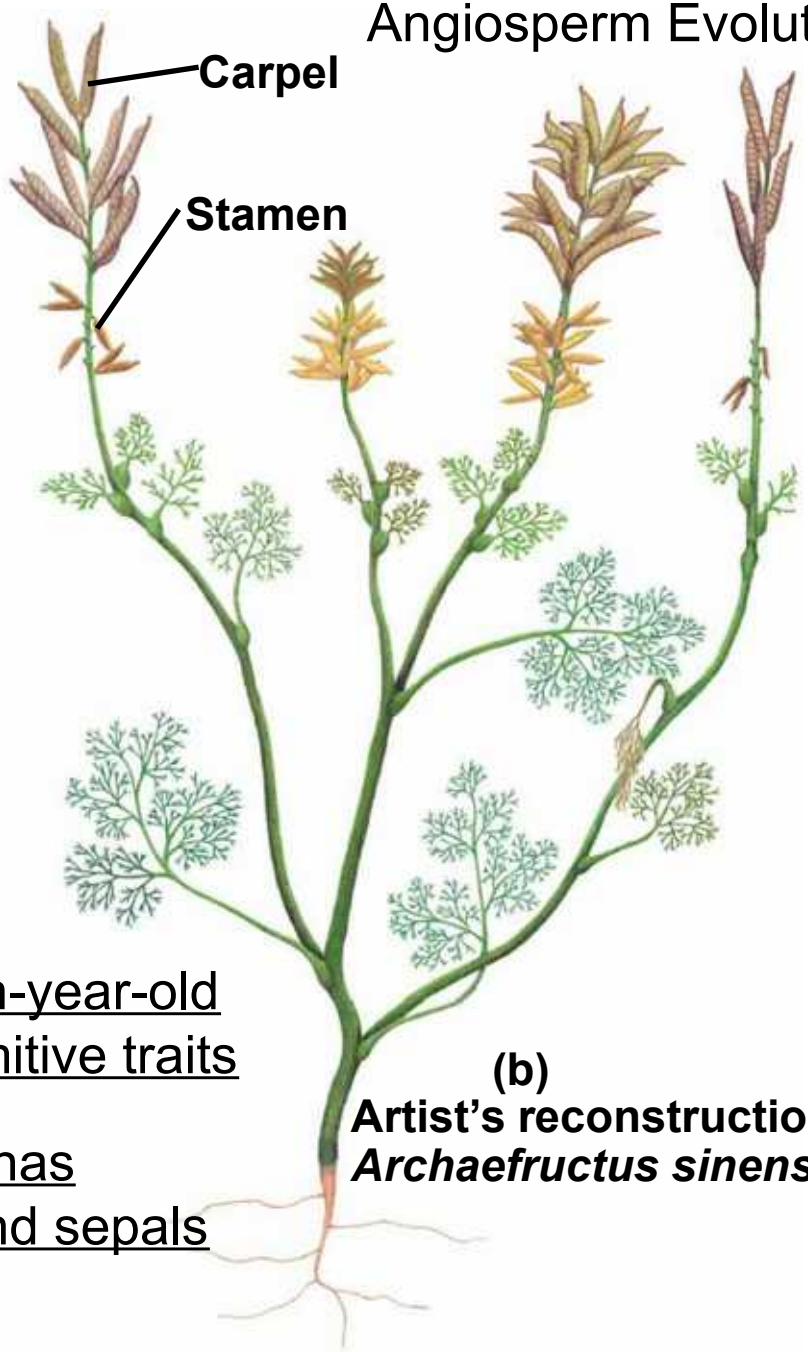
- One sperm fertilizes the egg, while the other combines with two nuclei in the central cell of the female gametophyte and initiates development of food-storing **endosperm**
- The endosperm nourishes the developing embryo
- Not all flowers have extensive endosperm reserves (such as Orchids) and have the smallest seeds of any angiosperm, and germinate very soon after being released from the ovary.
- Within a seed, the embryo consists of a root and two seed leaves called **cotyledons**



Angiosperm Evolution

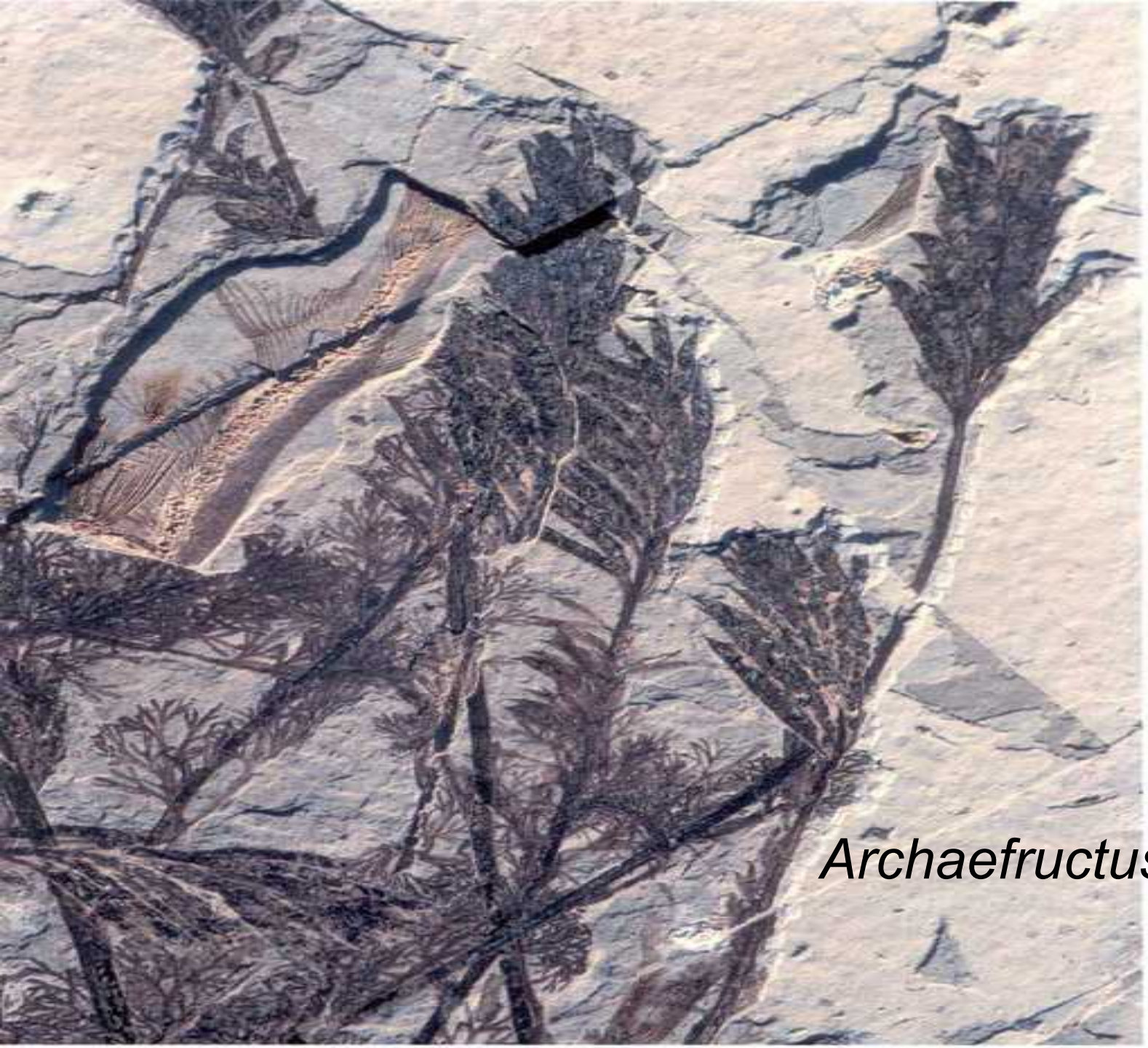


(a) ***Archaefructus sinensis*, a 125-million-year-old fossil**



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

- Primitive fossils of 122.6-125.8-million-year-old angiosperms display derived and primitive traits
- *Archaefructus sinensis,* for example, has anthers and seeds but lacks petals and sepals

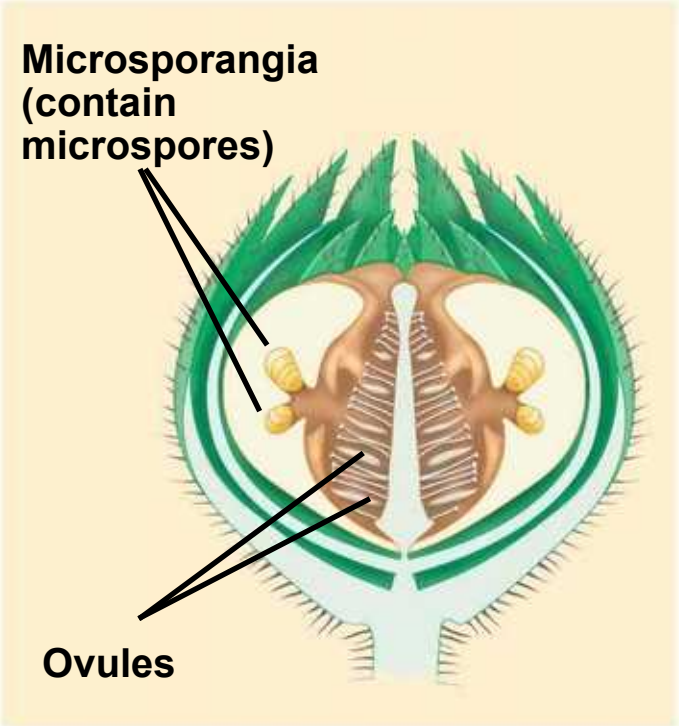


Archaefructus sinensis

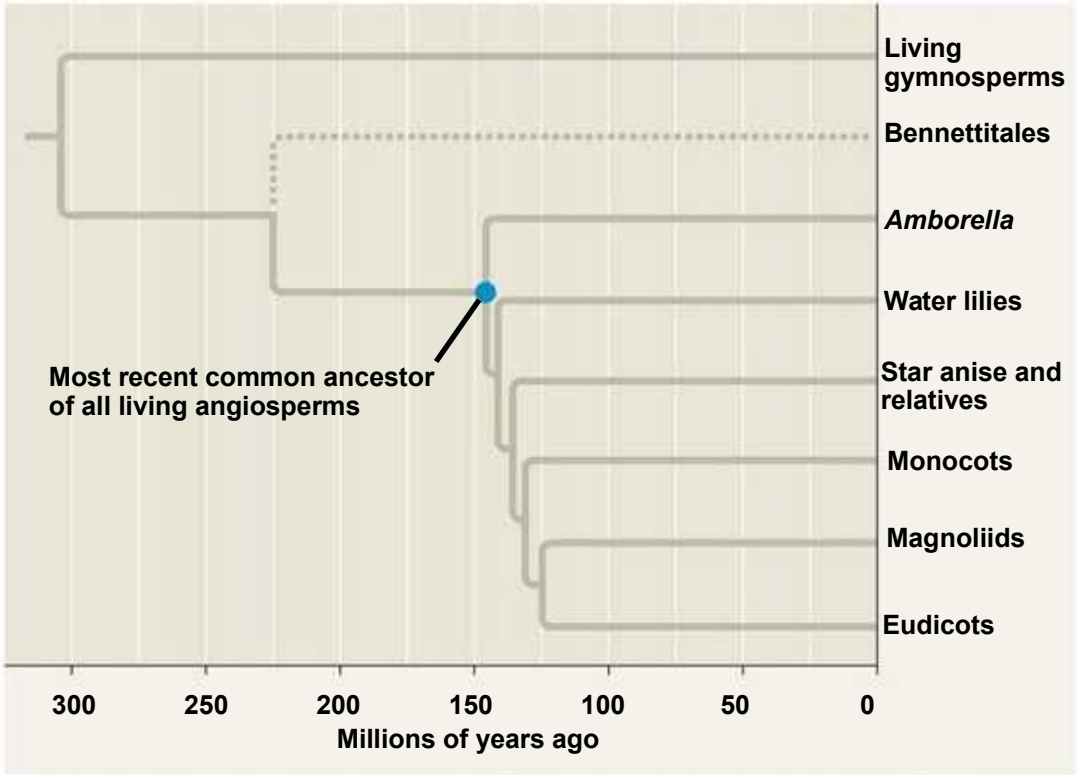
***Archaefructus lianoningensis*, china 124.3-128.7 mya**

Leefructus mirus
122.6-125.8 mya, China.
A eudicot of the Early Cretaceous Period.
Morphological characters suggest it has affinities with *Ranunculaceae* (buttercup family)

Angiosperm Phylogeny



(a) **A possible ancestor of the angiosperms?**



(b) **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

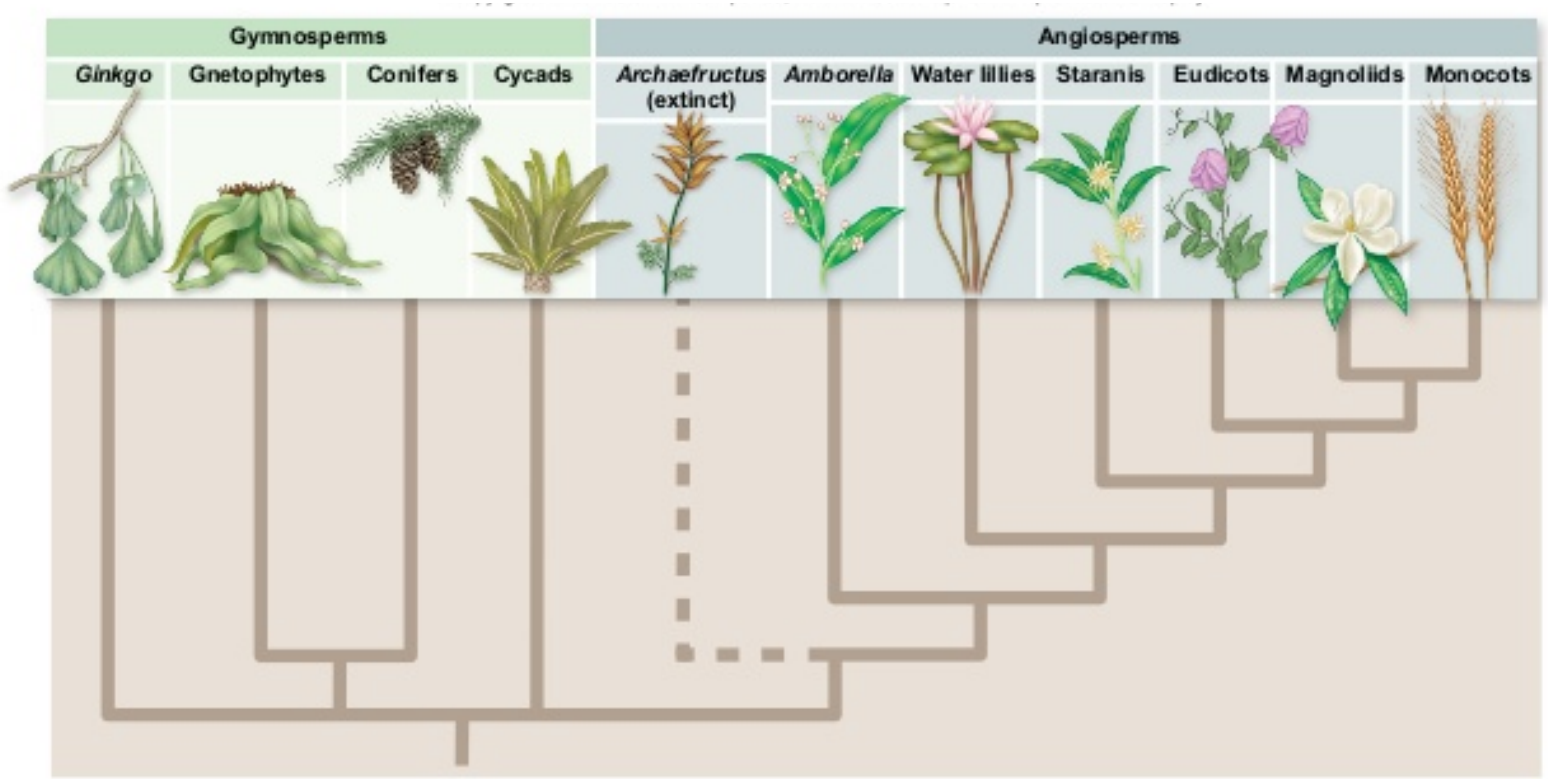
Angiosperm Diversity

- The two main groups of angiosperms are **dicots** evolving into **eudicots**(“true”dicots, two cotyledons)(Magnoliopsida) and evolving from the dicot root, **monocots** (one cotyledon)(Liliopsida)

Basal Angiosperms

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

Angiosperms



Archaefructus may be the sister clade to all other angiosperms

Eudicots

- More than two-thirds of angiosperm species are eudicots

California poppy

Monocots

- More than one-quarter of angiosperm species are monocots

Orchid

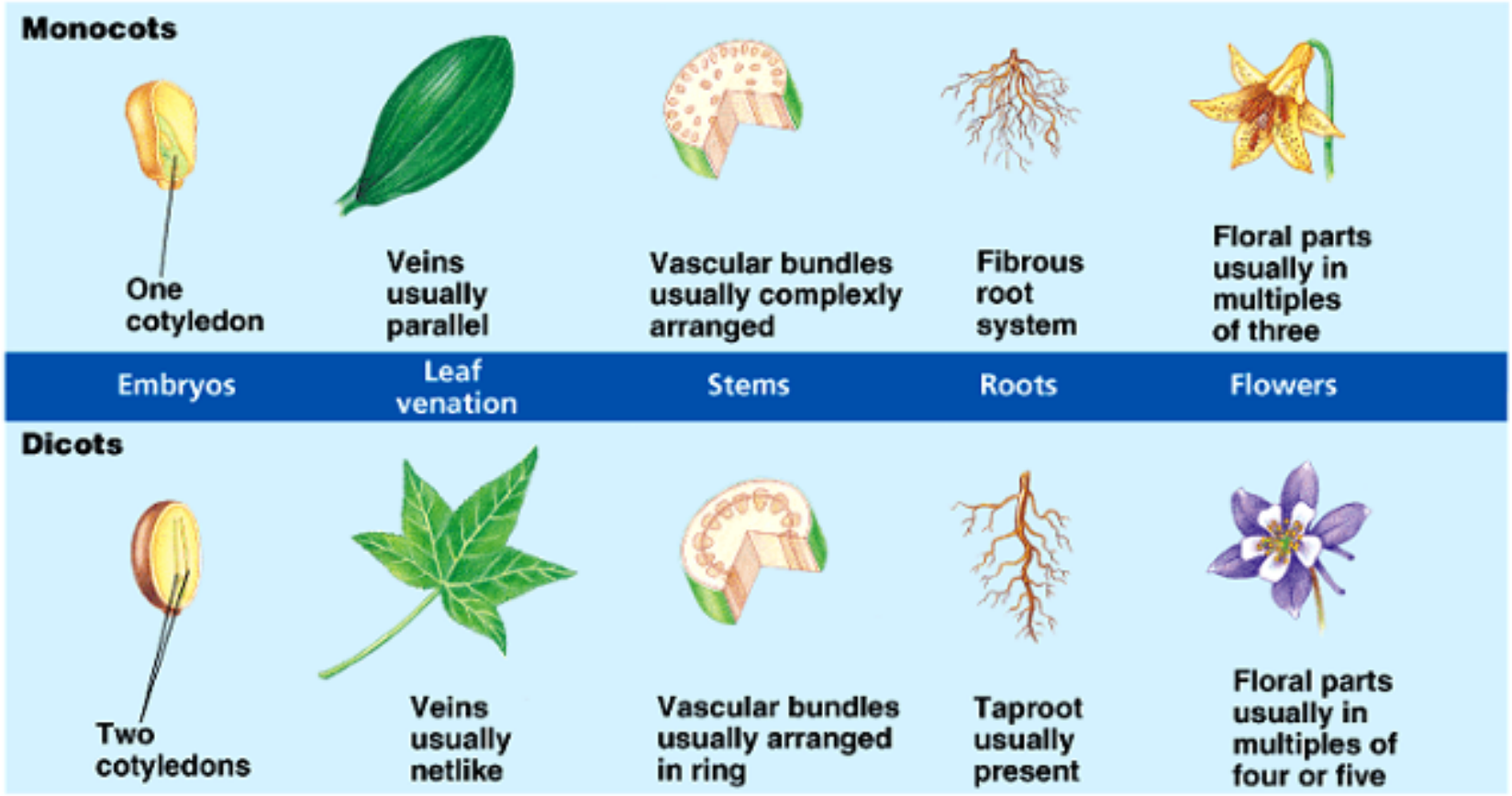


Fig. 30-UN3

Five Derived Traits of Seed Plants

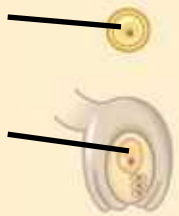
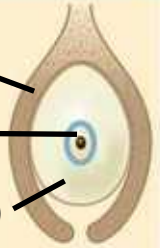
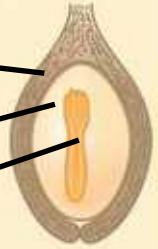
Reduced gametophytes	**Microscopic male and female gametophytes (*n*) are nourished and protected by the sporophyte (2*n*)**  **Male gametophyte** **Female gametophyte**
Heterospory	**Microspore (gives rise to a male gametophyte)** **Megaspore (gives rise to a female gametophyte)** 
Ovules	**Ovule (gymnosperm)** **Integument (2*n*)** **Megaspore (2*n*)** **Megasporangium (2*n*)** 
Pollen	**Pollen grains make water unnecessary for fertilization** 
Seeds	**Seeds: survive better than unprotected spores, can be transported long distances** **Integument** **Food supply** **Embryo** 

Fig. 36-2-3

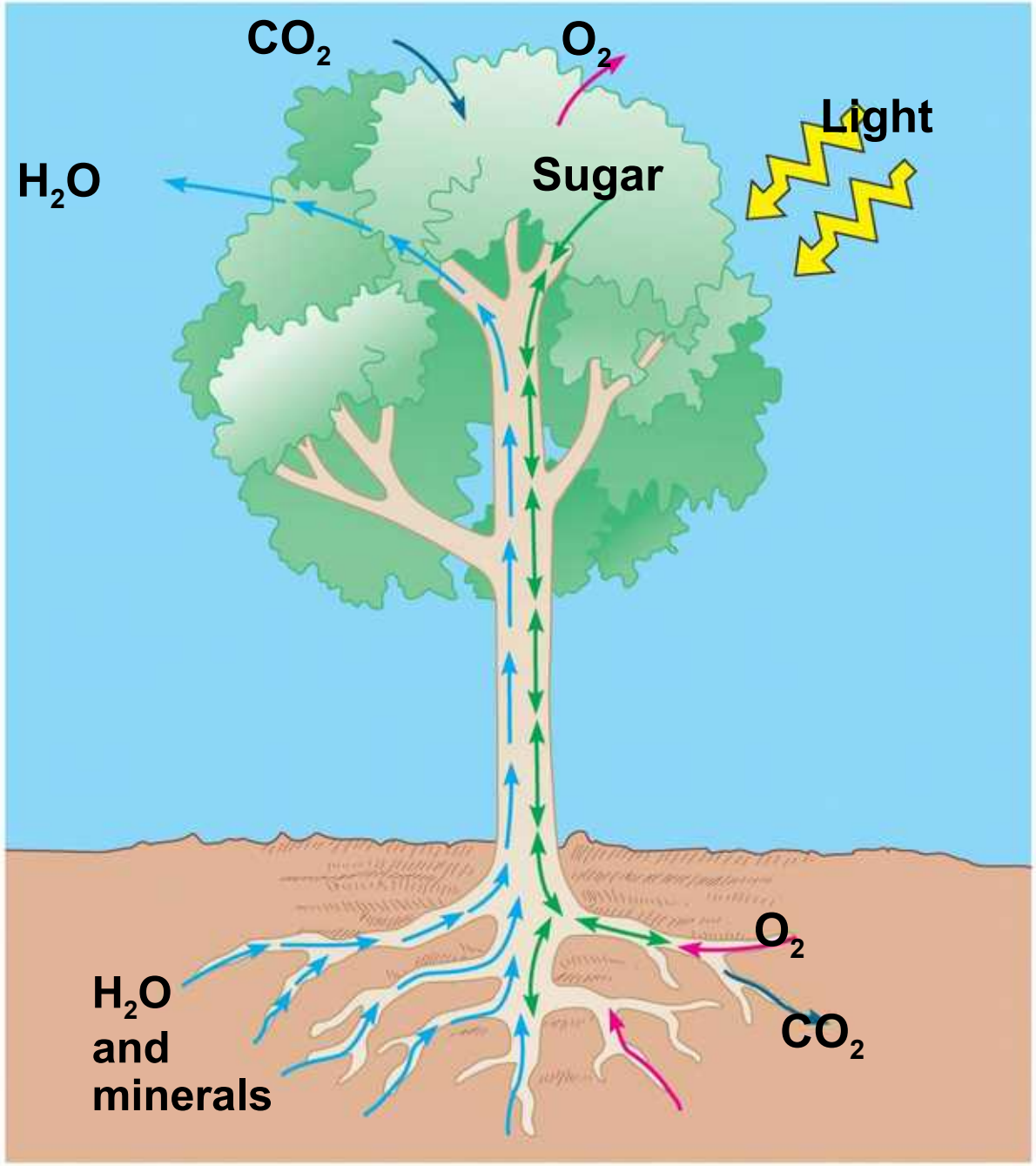
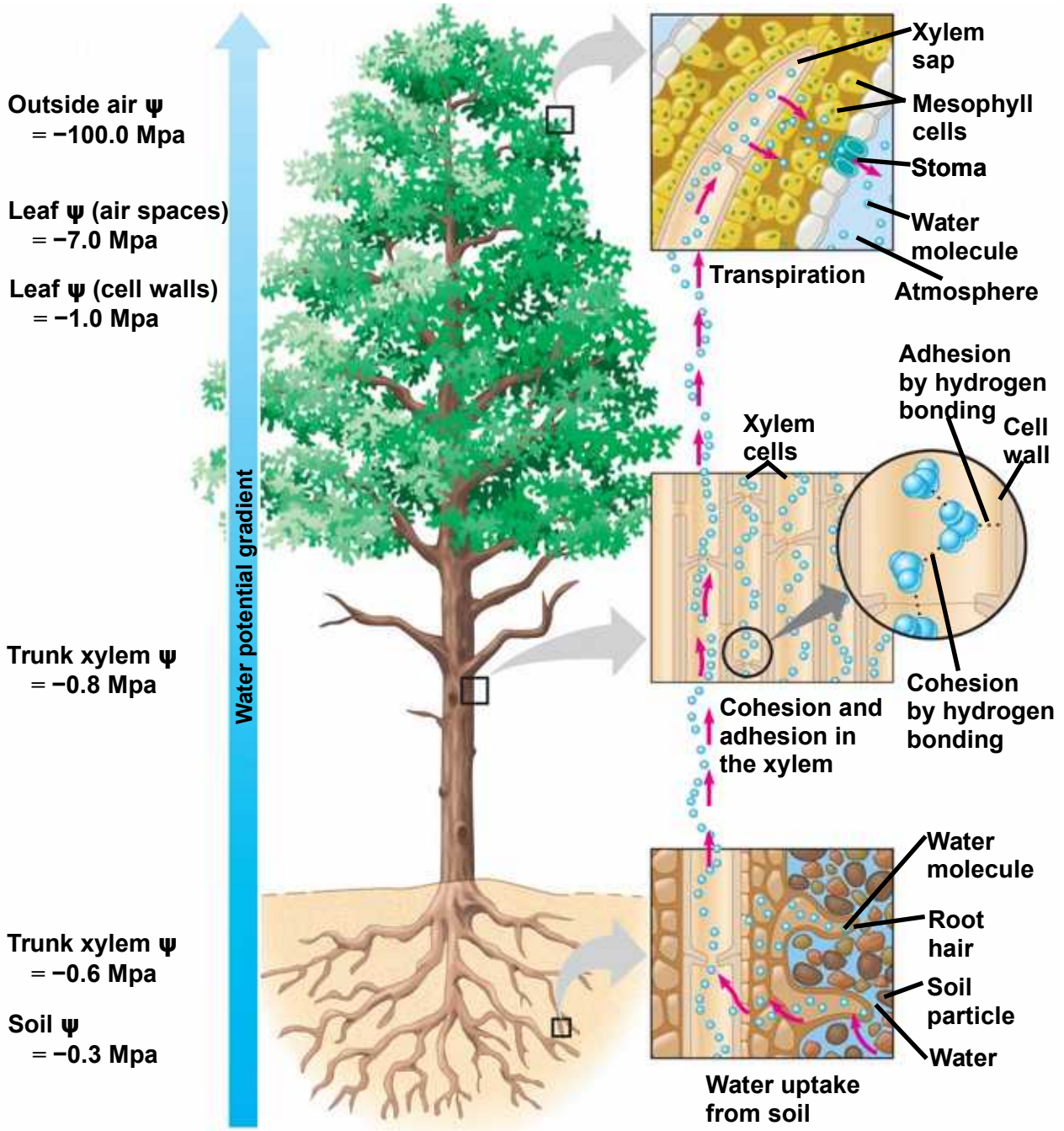


Fig. 36-15



Explain how the images on the left relate to the figure on the right.