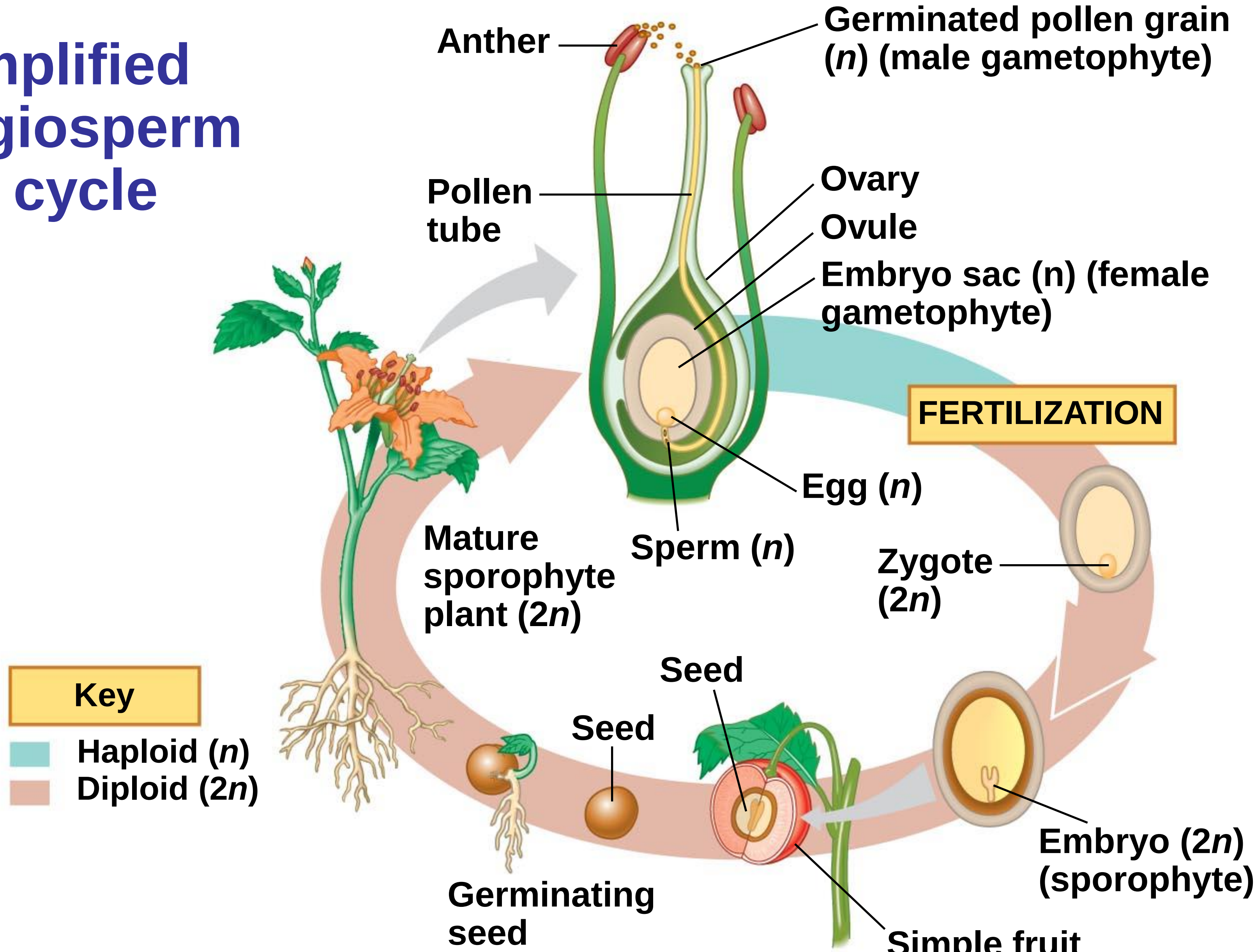
Chapter 38: Angiosperm Reproduction and Biotechnology: To Seed or Not to Seed

- The parasitic plant *Rafflesia arnoldi p*roduces huge flowers that produce up to 4 million seeds
- Many angiosperms reproduce sexually and asexually
- Since the beginning of agriculture, plant breeders have genetically manipulated traits of wild angiosperm species by artificial selection
- In angiosperms, the sporophyte is the dominant generation, the large plant that we see
- The gametophytes are reduced in size and depend on the sporophyte for nutrients
- Male gametophytes (pollen grains) and female gametophytes (embryo sacs) develop within flowers

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Simplified angiosperm life cycle

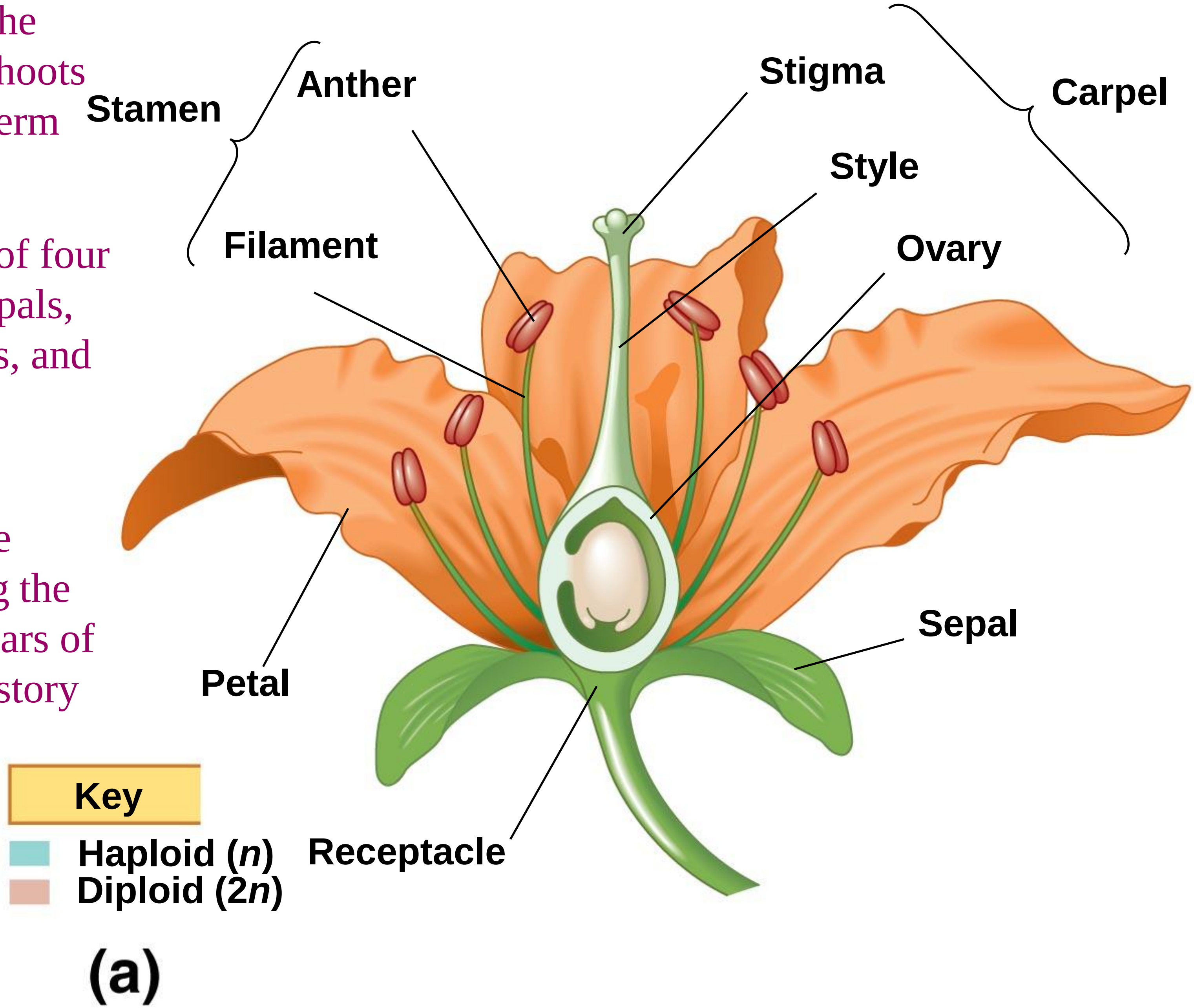


(b)

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

An idealized flower

- **Flowers** are the reproductive shoots of the angiosperm sporophyte
- They consist of four floral parts: sepals, petals, stamens, and carpels
- Many flower variations have evolved during the 140 million years of angiosperm history



Flower Structure

- **How are flowers different from other flowers?**
  - Symmetry of flower is radial or bilateral
  - The location of the ovary in relation to the receptacle
    - Superior ovary is above the receptacle
    - Inferior ovary is encased in the receptacle
    - Semi-inferior ovary is partially within the receptacle
  - How are the flowers distributed – is there one flower or many different small flowers coming together?

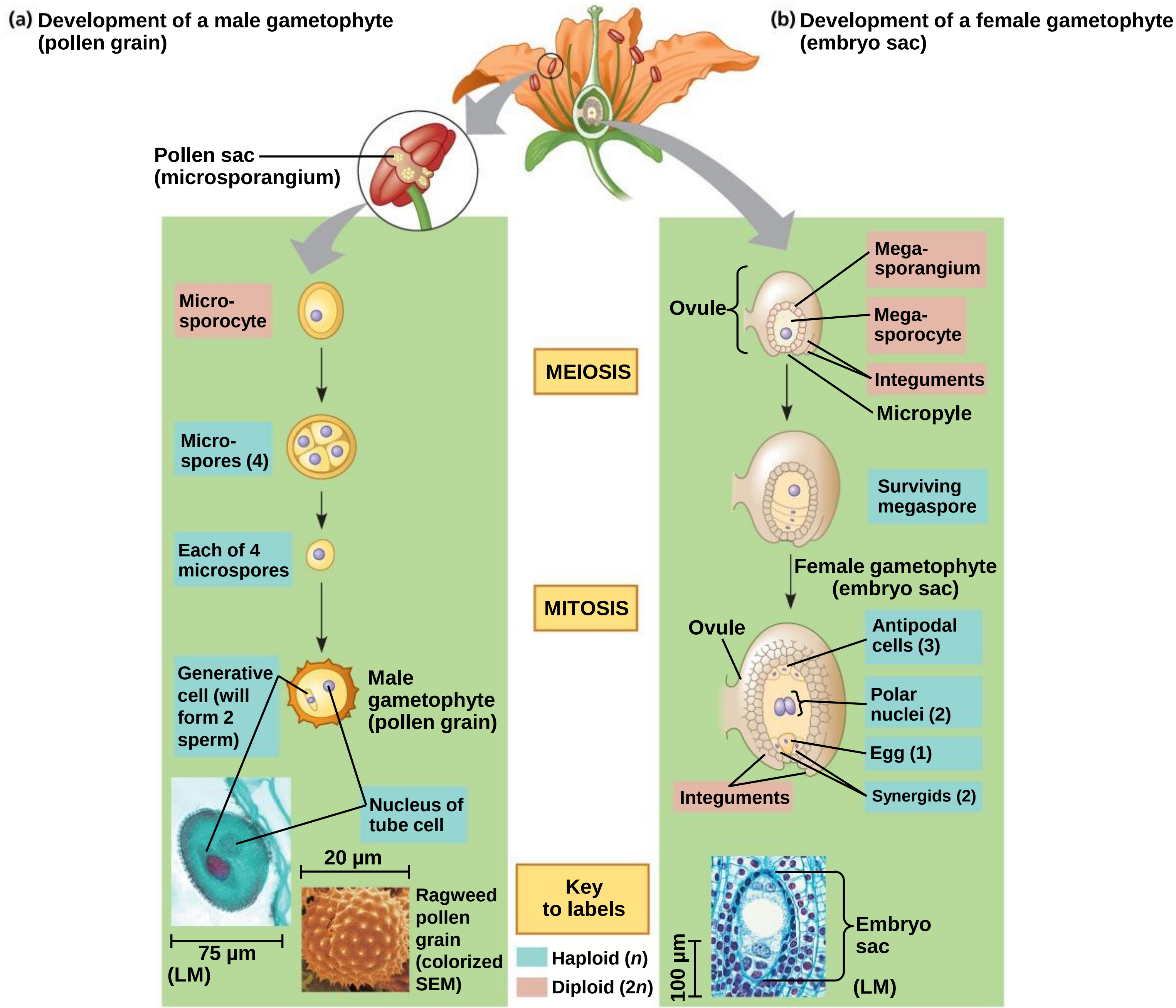
Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Gametophyte Development and Pollination

- In angiosperms, pollination is the transfer of pollen from an anther to a stigma
- If pollination succeeds, a pollen grain produces a pollen tube that grows down into the ovary and discharges sperm near the embryo sac
- Pollen develops from microspores within the sporangia of anthers
- Embryo sacs develop from megaspores within ovules

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Gametophyte Development and Pollination



Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

Mechanisms That Prevent Self-Fertilization

- Many angiosperms have mechanisms that make it difficult or impossible for a flower to self-fertilize
- The most common is self-incompatibility, a plant's ability to reject its own pollen
  - Researchers are unraveling the molecular mechanisms involved in self-incompatibility
  - Some plants reject pollen that has an *S*-gene matching an allele in the stigma cells
  - Recognition of self pollen triggers a signal transduction pathway leading to a block in growth of a pollen tube
- The second way of preventing self-fertilization is by spatially separating the anthers and the stigma – this is not a perfect way to prevent self-fertilization!
- A third way is by being **dioecious** – having flowers that are either male (have stamens), or female (have carpels)

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Spatial separation of stigma and Anthers may regulate self fertilization

Thrum flower

Pin flower

(b) *Oxalis alpina* flowers

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

Preventing self fertilization: a dioceous flower

(a) ***Sagittaria latifolia*** **staminate flower (left) and carpellate flower (right)**

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

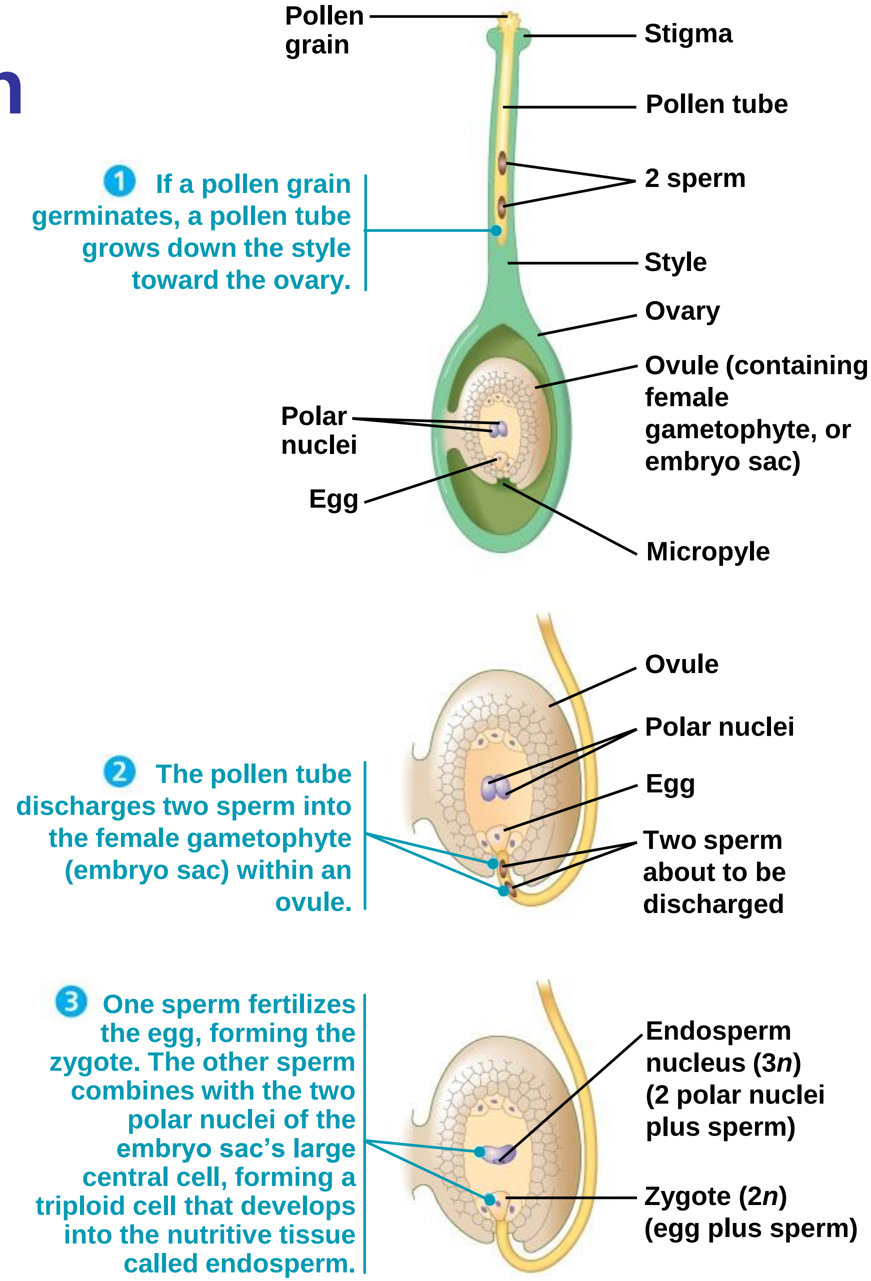
Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

After fertilization, ovules develop into seeds and ovaries into fruits

- In angiosperms, the products of fertilization are seeds and fruits
- Fertilization is actually a double fertilization:
  - After landing on a receptive stigma, a pollen grain produces a pollen tube that extends between the cells of the style toward the ovary
  - The pollen tube then discharges two sperm into the embryo sac
  - One sperm fertilizes the egg to give rise to the diploid zygote, and the other combines with the polar nuclei, giving rise to the triploid food-storing endosperm

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Double fertilization



Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

From Ovule to Seed

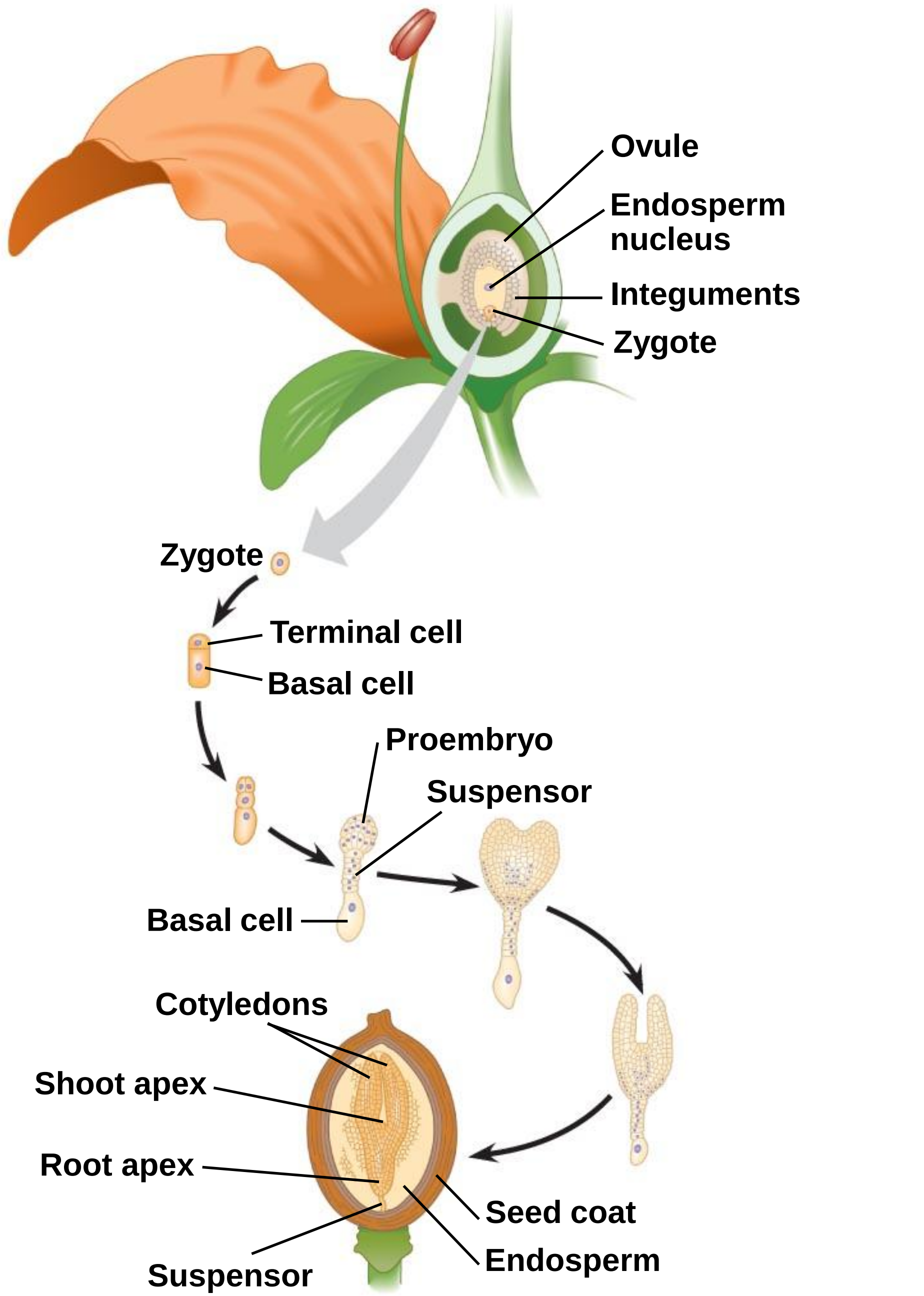
- After double fertilization, each ovule develops into a seed
- The ovary develops into a fruit enclosing the seed(s)
- Endosperm development usually precedes embryo development
- In most monocots and some eudicots, endosperm stores nutrients that can be used by the seedling
- In other eudicots, the food reserves of the endosperm are exported to the cotyledons
- The first mitotic division of the zygote is transverse, splitting the fertilized egg into a basal cell and a terminal cell

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

From Ovule to Seed

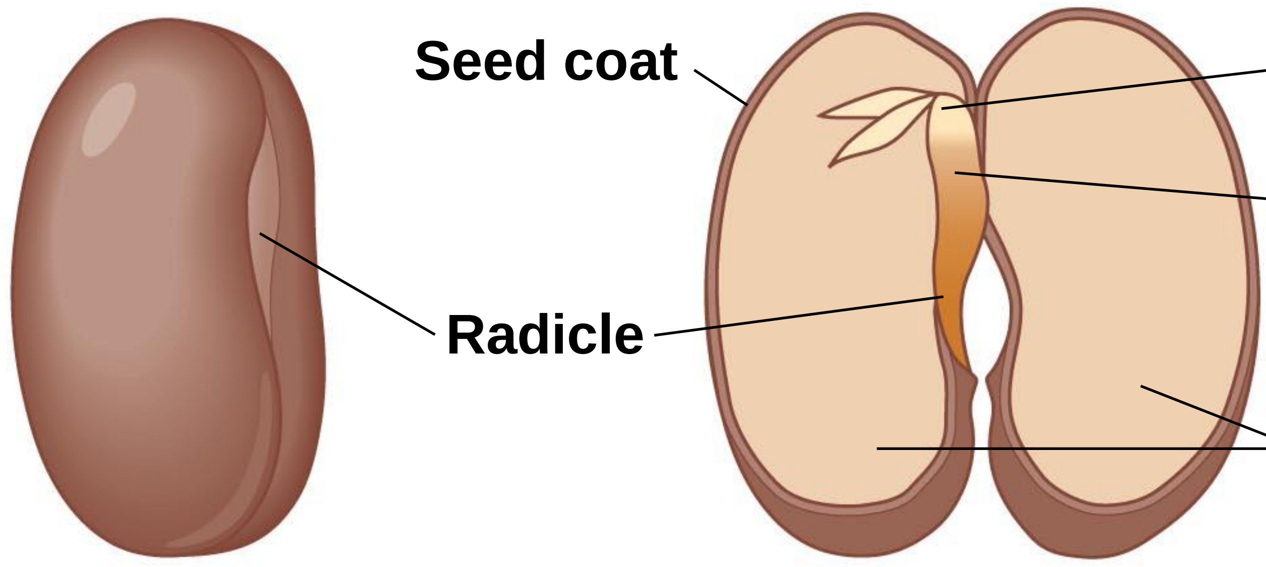
•The embryo and its food supply are enclosed by a hard, protective seed coat

•In some eudicots, such as the common garden bean, the embryo consists of the **hypocotyl** (the growing plant), **radicle** (embryonic root), and thick **cotyledons** (seed leaves)



Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights

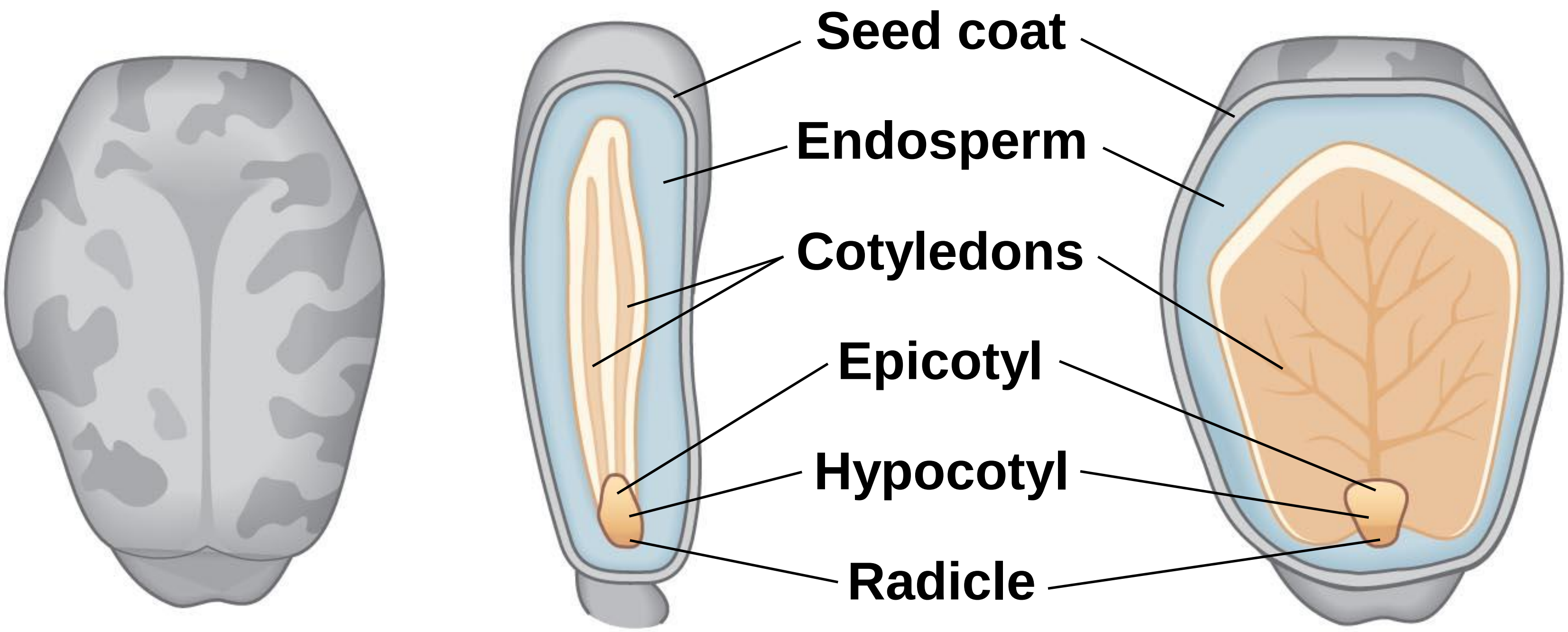
Seed structure - eudicot



(a) Common garden bean, a eudicot with thick cotyledons

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

The seeds of some eudicots, such as castor beans, have thin cotyledons

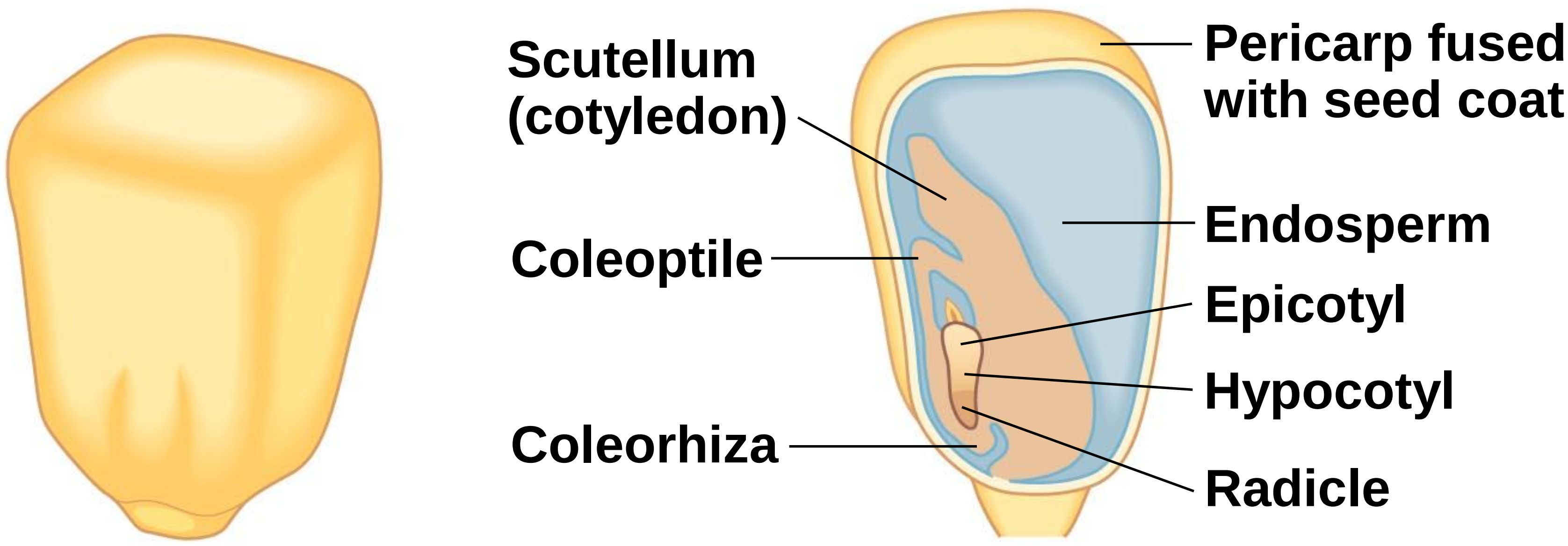


(b) Castor bean, a eudicot with thin cotyledons

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

A monocot embryo has one cotyledon

- Grasses, such as maize and wheat, have a special cotyledon called a **scutellum**
- Two sheathes enclose the embryo of a grass seed: a **coleoptile** covering the young shoot and a **coleorhiza** covering the young root



(c) Maize, a monocot

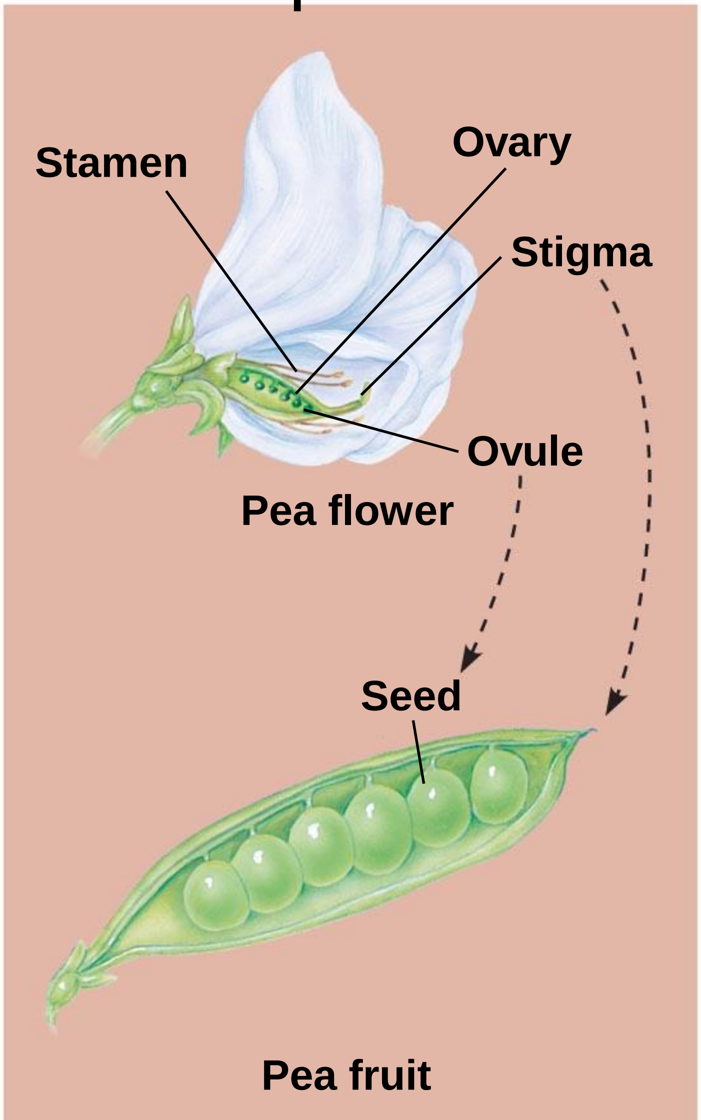
Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

From Ovary to Fruit

- A fruit develops from the ovary
- It protects the enclosed seeds and aids in seed dispersal by wind or animals
- Depending on developmental origin, fruits are classified as simple, aggregate, or multiple

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

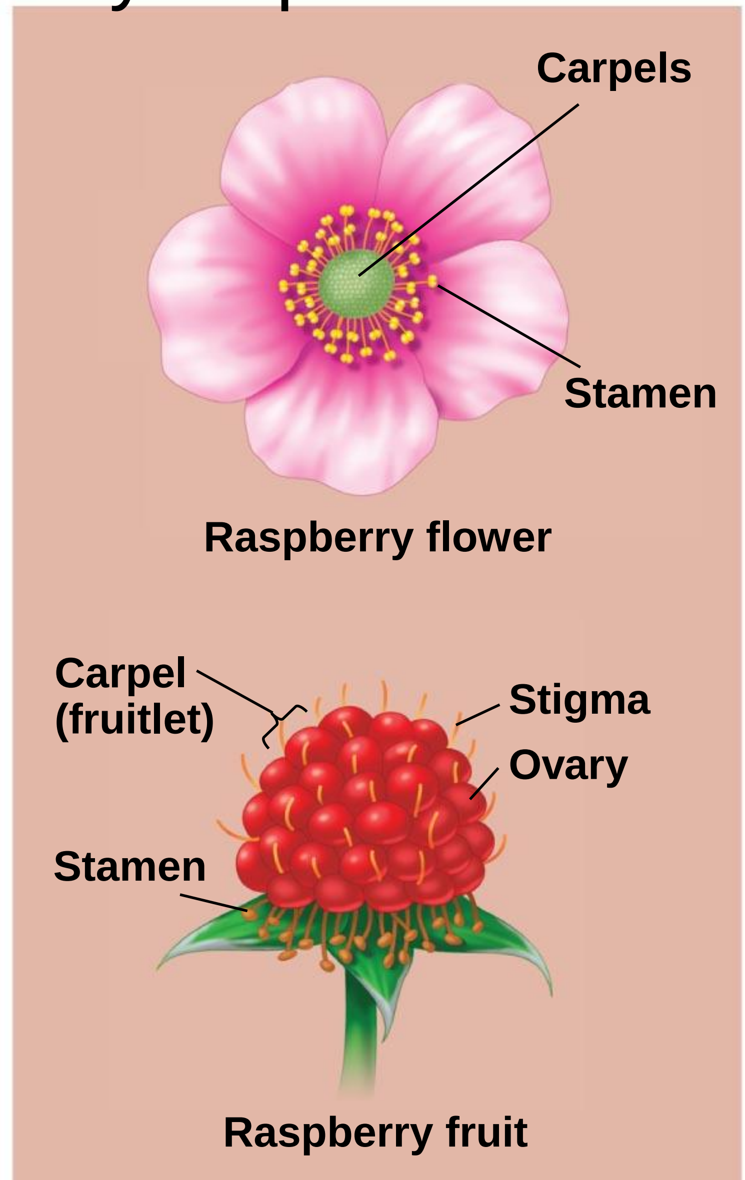
One carpel in flower



(a) Simple fruit

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummin

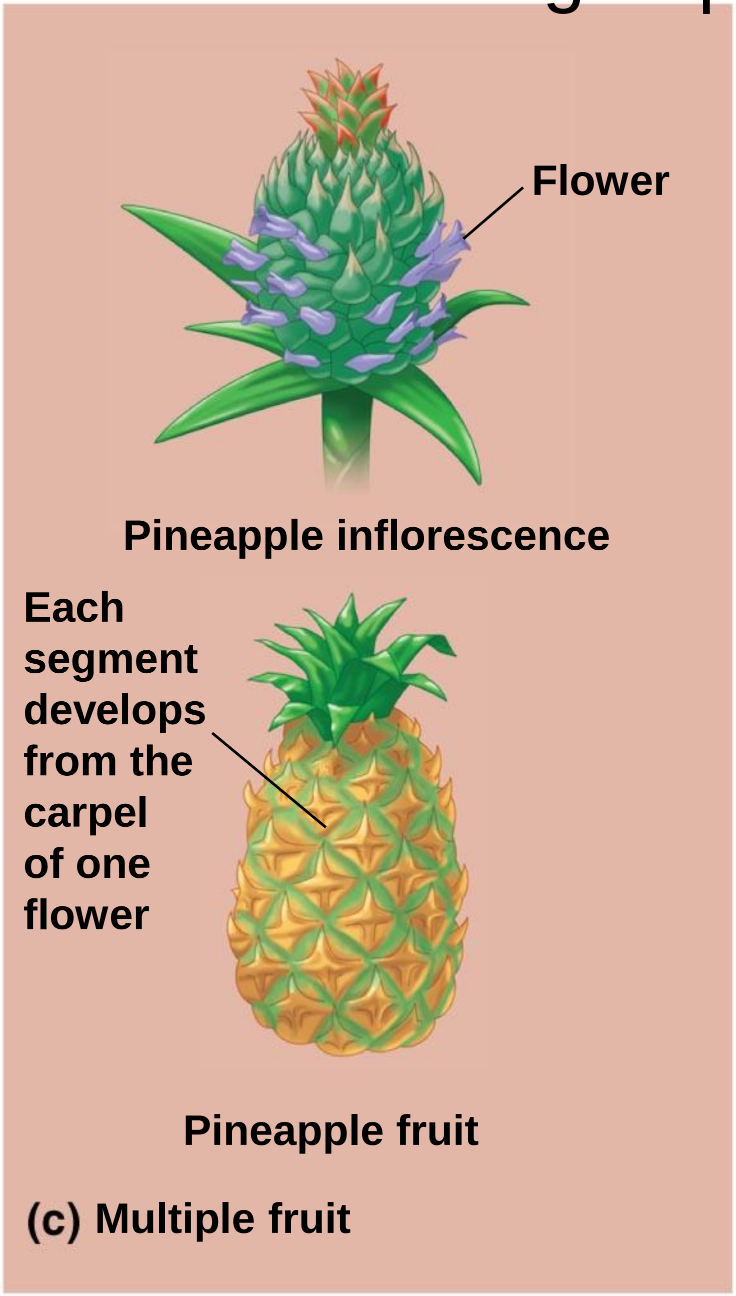
Many carpels in flower



(b) Aggregate fruit

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. A

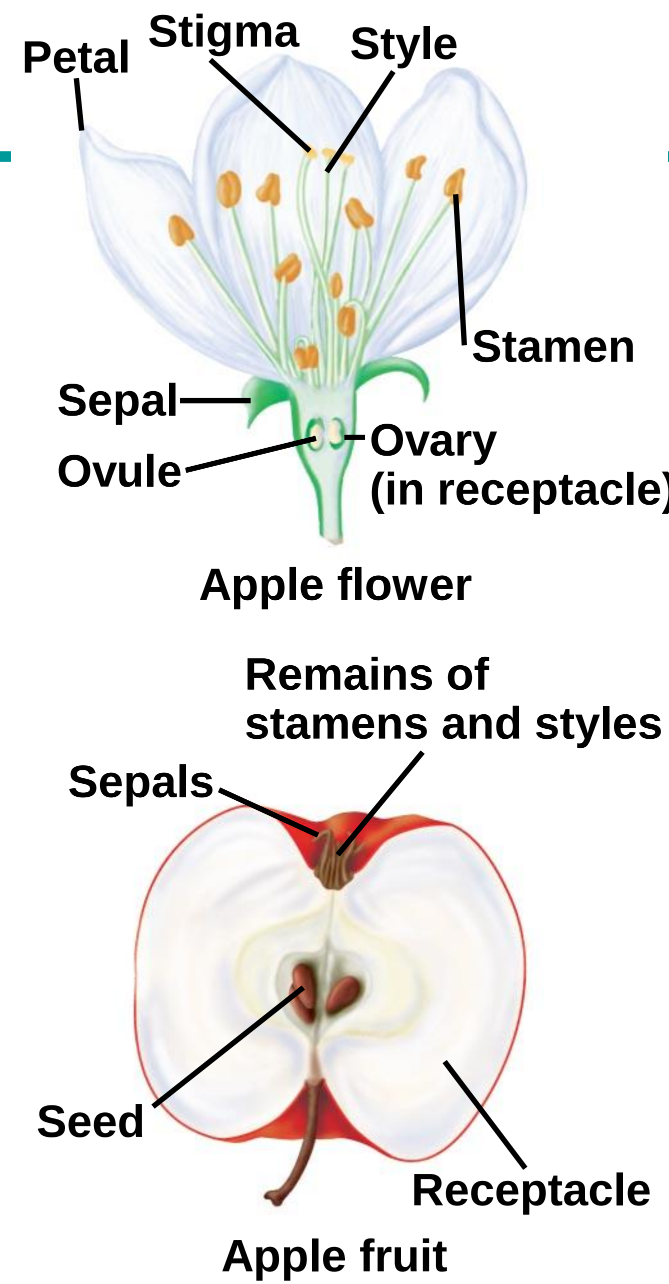
Many individual flowers grouped together



Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

Accessory fruits

- Here, the fruit we actually eat develops from material OTHER than the ovary.
- The apple fruit is from the receptacle, while the ovary surrounds the seeds (from the ovules)



(d) Accessory fruit

Copyright © 2008 Pearson Education, Inc., publishing as Pearson Benjamin Cummings.

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Seed Germination

- As a seed matures, it dehydrates and enters a phase called **dormancy**
- *Seed Dormancy: Adaptation for Tough Times*
- Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling
- The breaking of seed dormancy often requires environmental cues, such as temperature or lighting changes, or even heat indicating a fire.
- Some seeds must pass through the digestive tract of animals before breaking dormancy.

- Seeds are dispersed throughout the environment by water (rivers, oceans, etc.), wind and animals

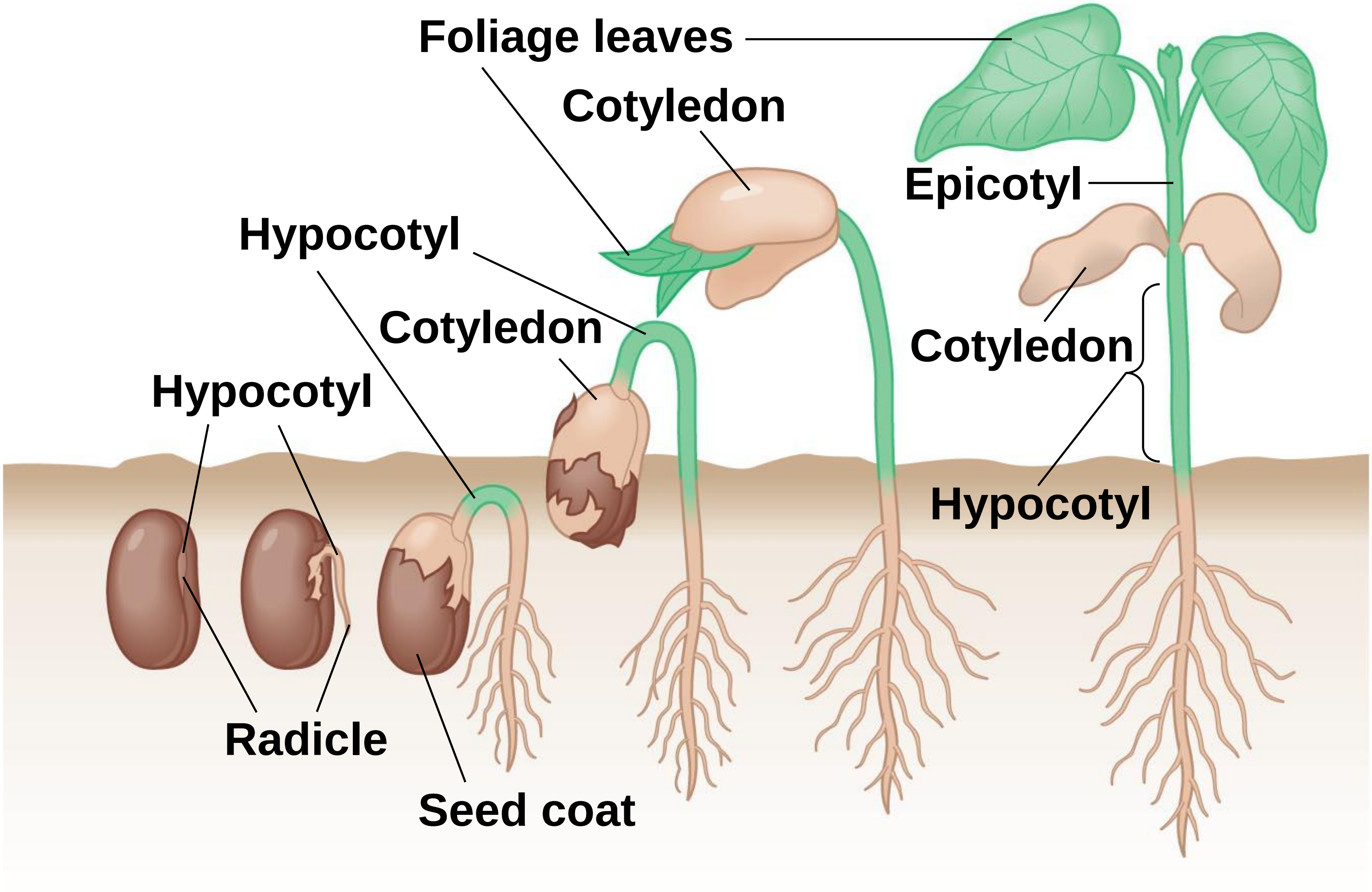
Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

From Seed to Seedling

- Germination depends on **imbibition**, the uptake of water due to low water potential of the dry seed – this is the first step of germination!!
- The **radicle** (embryonic root) emerges first
- Next, the shoot tip breaks through the soil surface
  - In many eudicots, a hook forms in the hypocotyl, and growth pushes the hook above ground

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

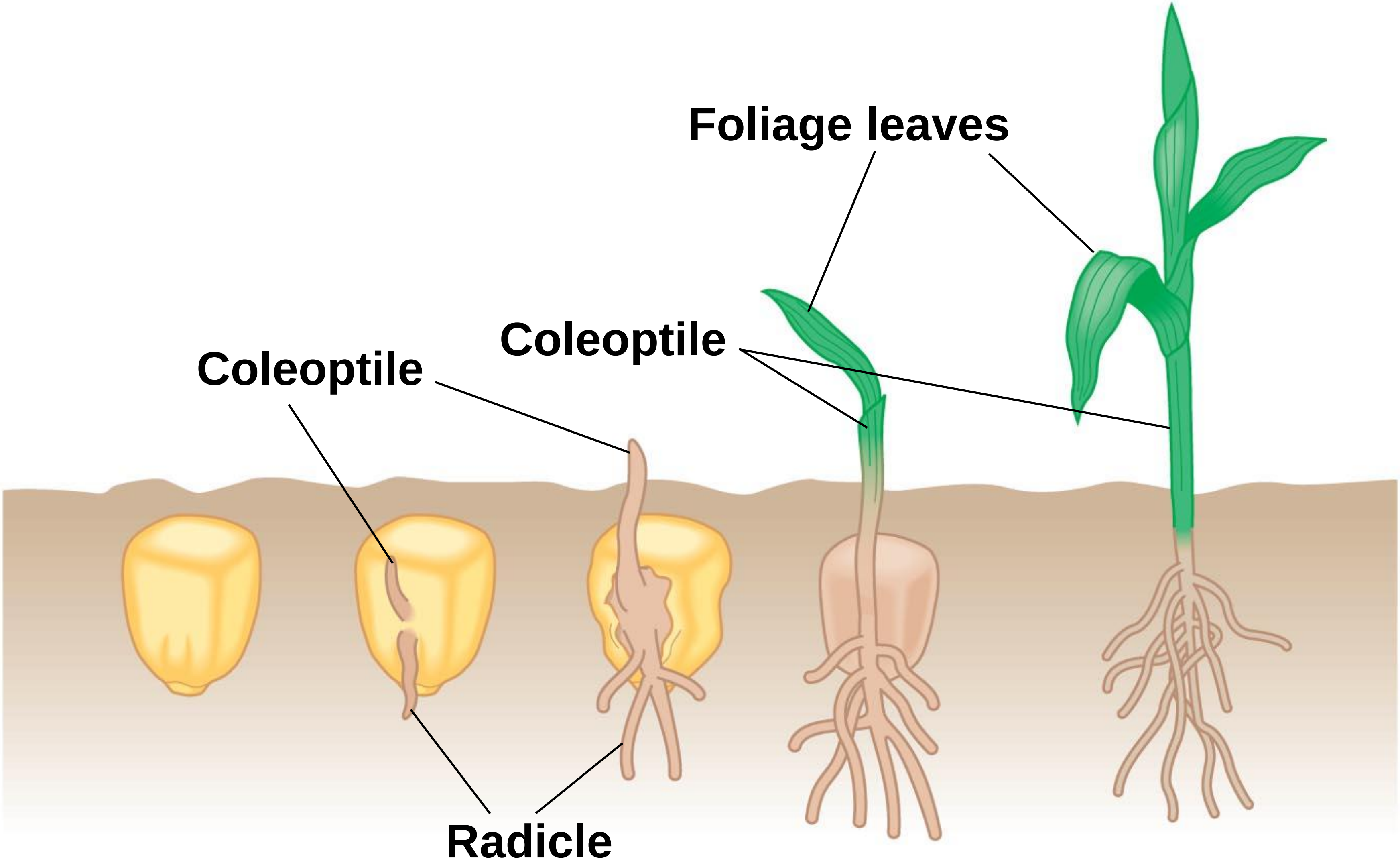
From Seed to Seedling



(a) Common garden bean

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

In maize and other grasses, which are monocots, the coleoptile pushes up through the soil



(b) Maize

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

Many flowering plants clone themselves by asexual reproduction

- Many angiosperm species reproduce both asexually and sexually
- Sexual reproduction generates genetic variation that makes evolutionary adaptation possible
- Asexual reproduction in plants is also called vegetative reproduction

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Mechanisms of Asexual Reproduction

- **Fragmentation**, separation of a parent plant into parts that develop into whole plants, is a very common type of asexual reproduction
- In some species, a parent plant's root system gives rise to adventitious shoots that become separate shoot systems
- Humans have devised methods for asexual propagation of angiosperms
  - Most methods are based on the ability of plants to form adventitious roots or shoots
  - Many kinds of plants are asexually reproduced by using plant fragments called **cuttings**
  - A twig or bud can be **grafted** onto a plant of a closely related species or variety to induce it to grow

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Test-Tube Cloning and Related Techniques

- In addition to asexual reproduction of a plant, plant biologists have adopted *in vitro* methods to create and clone novel plant varieties
  - Protoplast (cell) fusion is used to create hybrid plants by fusing **protoplasts**, plant cells with their cell walls removed
  - This could result in the production of new plants – GMOs!

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Plant growth *in vitro*

(a) Just a few parenchyma cells from a carrot gave rise to this callus, a mass of undifferentiated cells.

(b) The callus differentiates into an entire plant, with leaves, stems, and roots.

Plant biotechnology is transforming agriculture

- Plant biotechnology has two meanings:
  - In a general sense, it refers to innovations in use of plants to make useful products
  - In a specific sense, it refers to use of genetically modified organisms (GMOs) in agriculture and industry
- Humans have intervened in the reproduction and genetic makeup of plants for thousands of years
- **Hybridization** – the exchange of genetic material between closely related plant species, is common in nature and has been used by breeders to introduce new genes into plants
  - Maize (corn), a product of artificial selection, is a staple in many developing countries
- Modern plant biotechnology is not limited to transfer of genes between closely related species or varieties of the same species

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Reducing World Hunger and Malnutrition – potential benefits of GMOs

- 1) Genetically modified plants may increase the quality and quantity of food worldwide – some organisms grow larger fruits
- 2) Some fruits have been made such that they have longer shelf lives by extending their ripening time or resistance to freezing (strawberries)
- 3) Progress has been made in developing transgenic plants that tolerate herbicides – herbicide tolerance
- 4) Nutritional quality of plants is being improved by making more proteins in plants - “Golden Rice” is a **transgenic** variety being developed to address vitamin A deficiencies among the world’s poor
- 5) Some plants are being designed to express proteins that make them resistant to bacterial (pest) infections
- 6) Some plants are being designed to express proteins that make them resistant to viral infections also
- 7) Some plants are being made to be resistant to drought conditions

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings

Copyright © 2005 Pearson Education, Inc. Publishing as Pearson Benjamin Cummings. All rights reserved.

The Debate over Plant Biotechnology

- Some biologists are concerned about risks of releasing GM organisms into the environment
  - 1) Genetic engineering may transfer allergens from a gene source to a plant used for food – people's health adversely affected
  - 2) The growing of GM crops might have unforeseen effects on non-target organisms – creating super-pests – insects may become resistant to toxins
  - 3) Perhaps the most serious concern is the possibility of introduced genes escaping into related weeds through crop-to-weed hybridization – creating super-weeds
    - Efforts are underway to breed male sterility into transgenic crops
  - 4) Loss of plant diversity by growing only GM plants
  - 5) Biotechnology companies with GM plants control agriculture

Copyright © 2005 Pearson Education, Inc. publishing as Benjamin Cummings