Chapter 38

Angiosperm Reproduction and Biotechnology

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Flowers of Deceit

- Angiosperm flowers can attract pollinators using visual cues and volatile chemicals
- Many angiosperms reproduce sexually and asexually
- Symbiotic relationships are common between plants and other species
- Since the beginning of agriculture, plant breeders have genetically manipulated traits of wild angiosperm species by artificial selection

Fig. 38-1

Concept 38.1: Flowers, double fertilization, and fruits are unique features of the angiosperm life cycle

- Diploid (2*n*) sporophytes produce spores by meiosis; these grow into haploid (*n*) gametophytes
- Gametophytes produce haploid (*n*) gametes by mitosis; **fertilization** of gametes produces a sporophyte

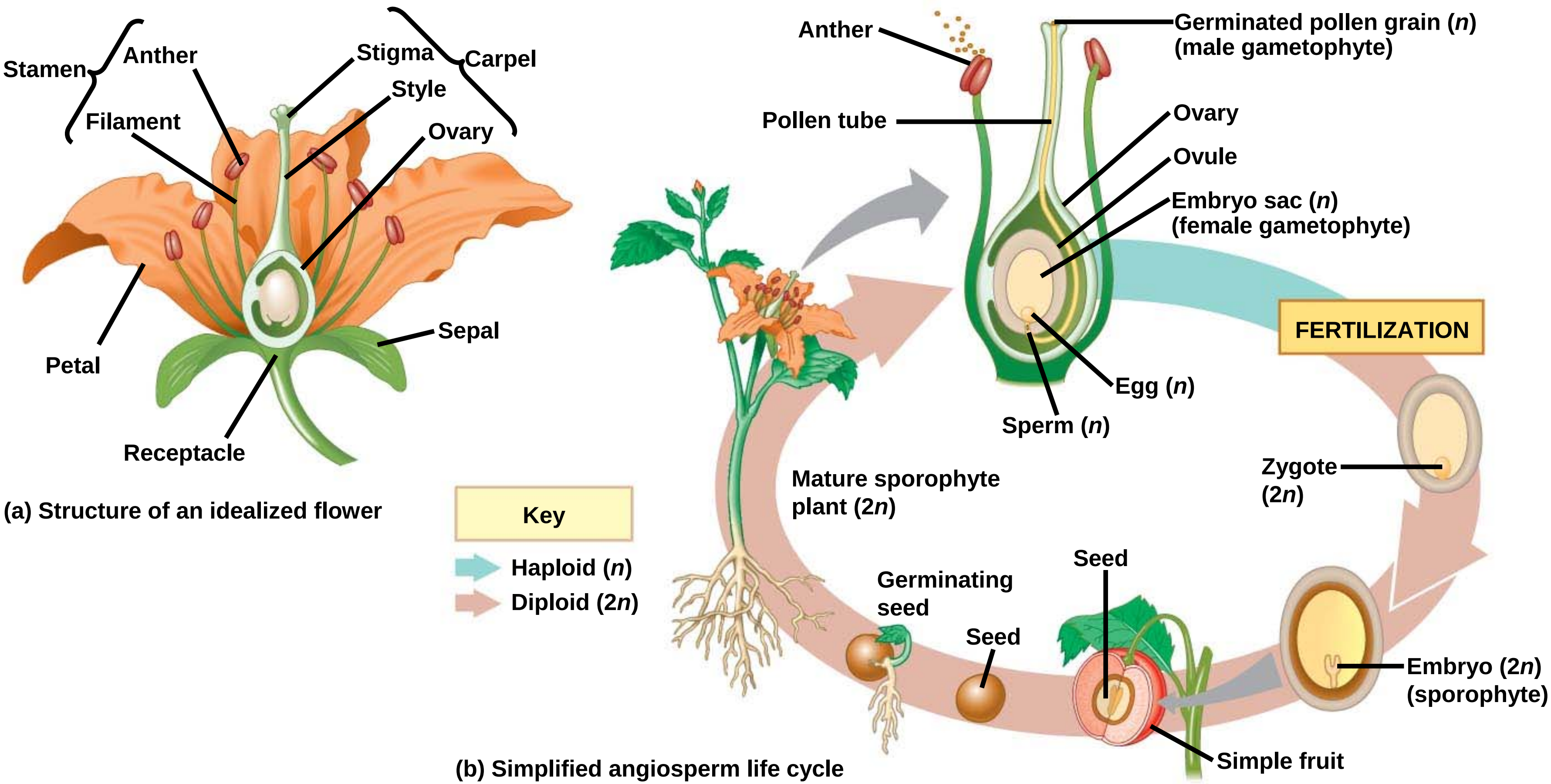
PLAY

Video: Flower Blooming (time lapse)

- 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
- The angiosperm life cycle is characterized by "three Fs": *f*lowers, double *f*ertilization, and *f*ruits

PLAY **Video: Flower Plant Life Cycle (time lapse)**

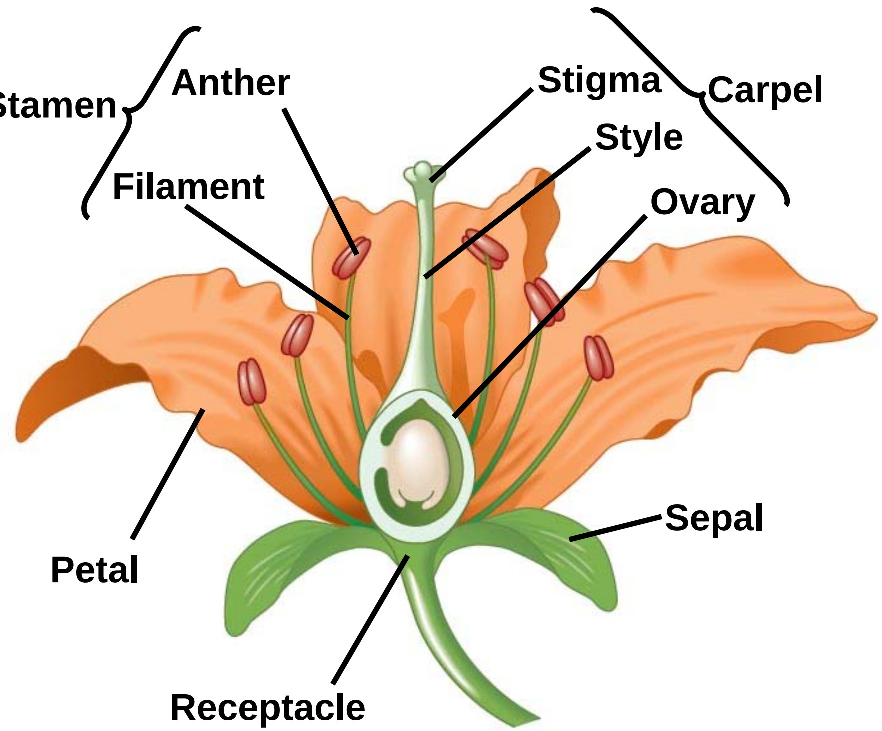
Fig. 38-2



(a) Structure of an idealized flower

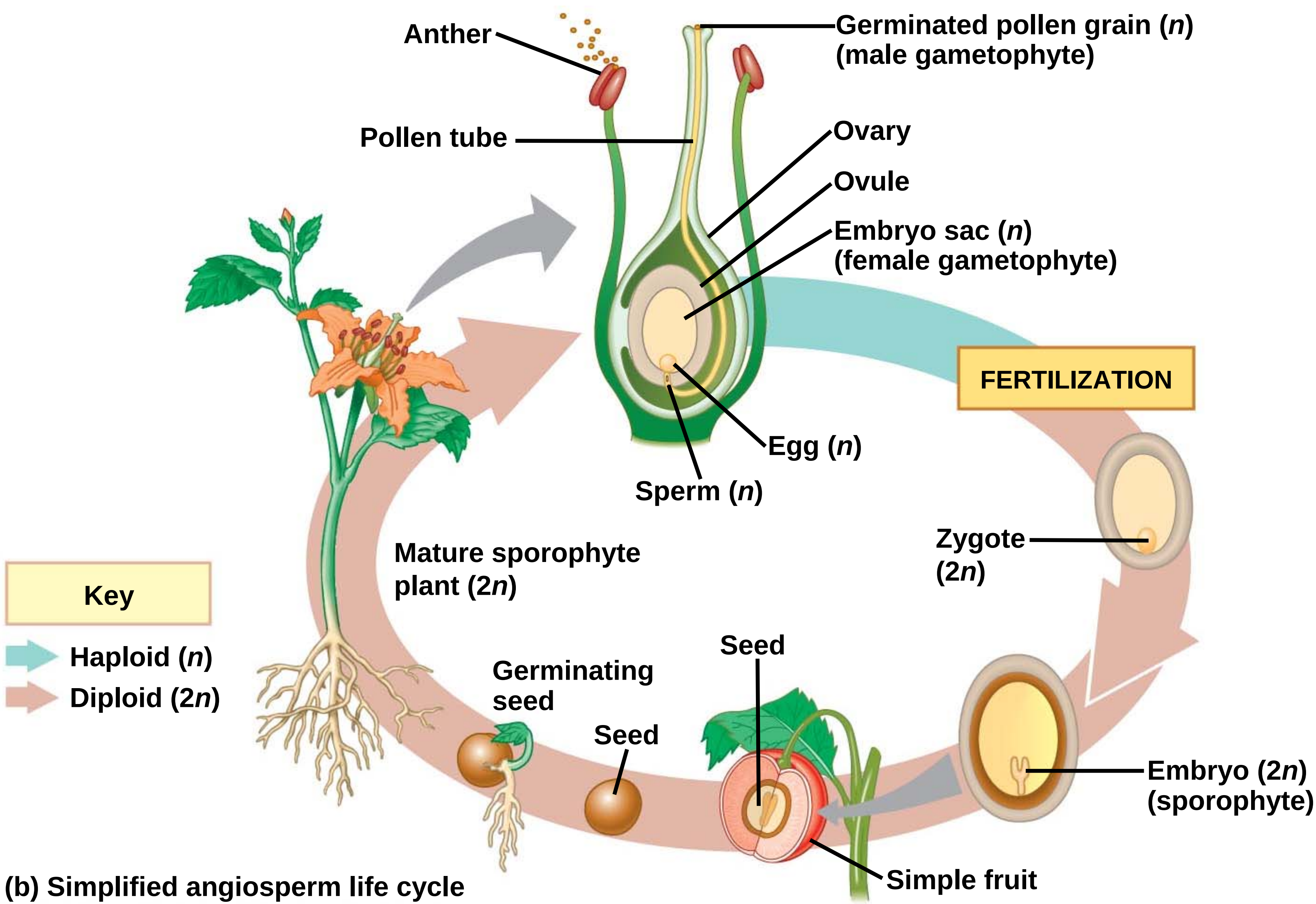
(b) Simplified angiosperm life cycle

Fig. 38-2a



(a) Structure of an idealized flower

Fig. 38-2b



(b) Simplified angiosperm life cycle

Flower Structure and Function

- Flowers are the reproductive shoots of the angiosperm sporophyte; they attach to a part of the stem called the **receptacle**
- Flowers consist of four floral organs: **sepals**, **petals**, **stamens**, and **carpels**

- A stamen consists of a filament topped by an **anther** with pollen sacs that produce pollen
- A carpel has a long **style** with a **stigma** on which pollen may land
- At the base of the style is an **ovary** containing one or more **ovules**
- A single carpel or group of fused carpels is called a **pistil**

- **Complete flowers** contain all four floral organs
- **Incomplete flowers** lack one or more floral organs, for example stamens or carpels
- Clusters of flowers are called **inflorescences**

Development of Male Gametophytes in Pollen Grains

- Pollen develops from **microspores** within the microsporangia, or pollen sacs, of anthers
- If pollination succeeds, a **pollen grain** produces a **pollen tube** that grows down into the ovary and discharges sperm near the embryo sac
- The pollen grain consists of the two-celled male gametophyte and the spore wall

PLAY Video: Bee Pollinating

PLAY Video: Bat Pollinating Agave Plant

Fig. 38-3

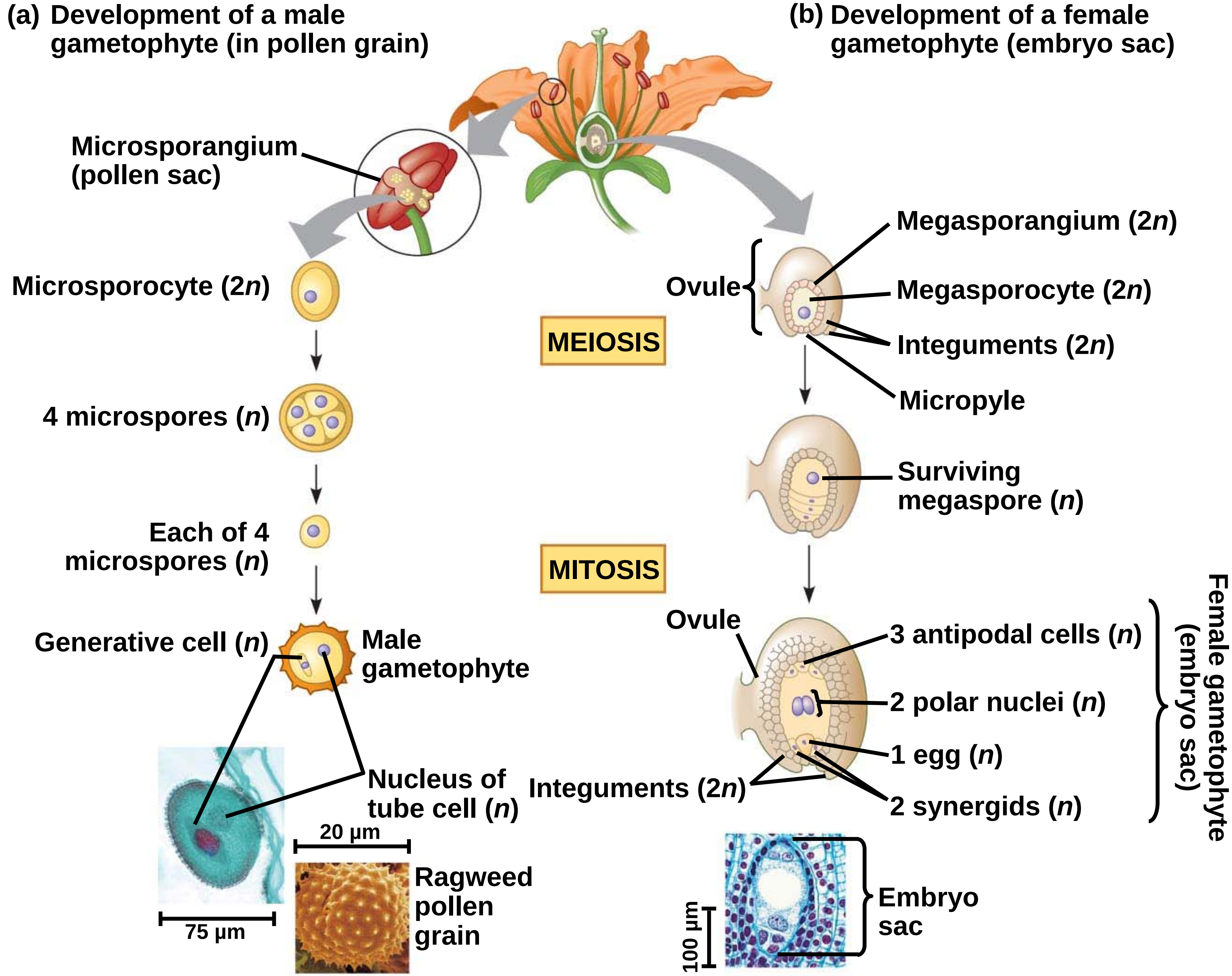
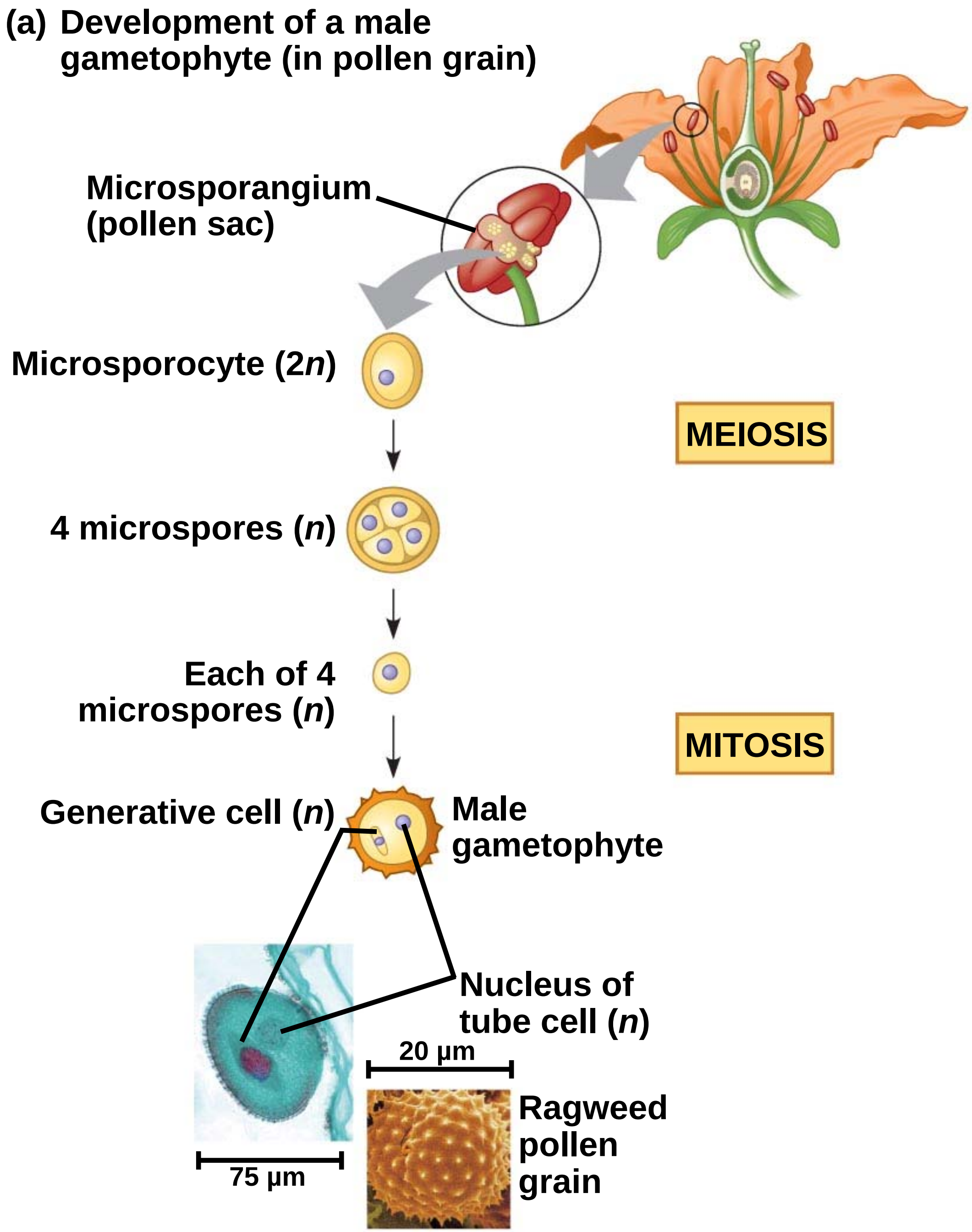

(a) Development of a male gametophyte (in pollen grain)
(b) Development of a female gametophyte (embryo sac)
Microsporangium (pollen sac)
Microsporocyte (2n)
4 microspores (n)
Each of 4 microspores (n)
Generative cell (n)
Male gametophyte
Nucleus of tube cell (n)
75 µm
20 µm
Ragweed pollen grain
MEIOSIS
MITOSIS
Ovule
Megasporangium (2n)
Megasporocyte (2n)
Integuments (2n)
Micropyle
Surviving megaspore (n)
Ovule
3 antipodal cells (n)
2 polar nuclei (n)
1 egg (n)
2 synergids (n)
Integuments (2n)
Female gametophyte (embryo sac)
Embryo sac
100 µm

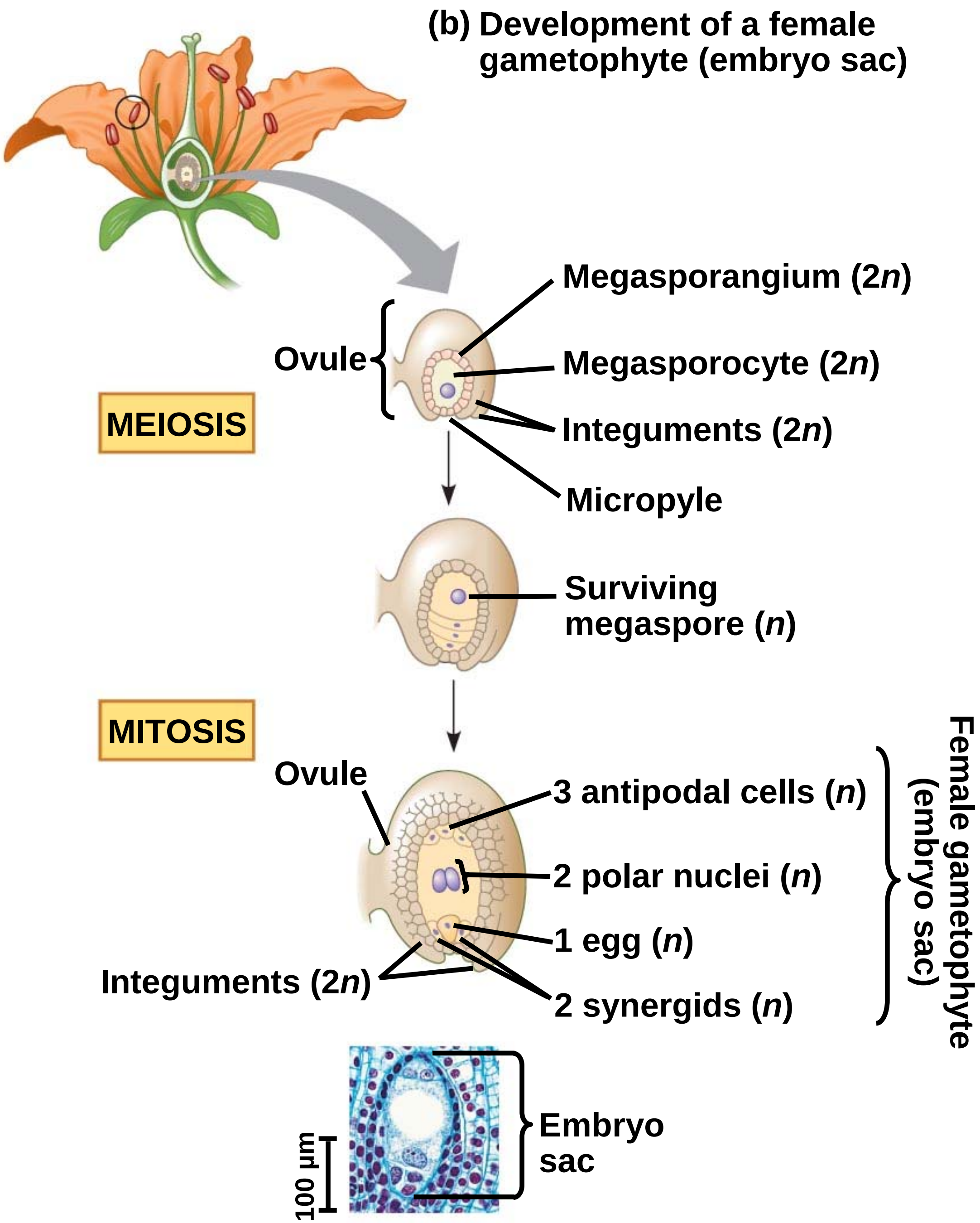
Fig. 38-3a


(a) Development of a male gametophyte (in pollen grain)
Microsporangium (pollen sac)
Microsporocyte (2n)
MEIOSIS
4 microspores (n)
Each of 4 microspores (n)
MITOSIS
Generative cell (n)
Male gametophyte
Nucleus of tube cell (n)
20 µm
75 µm
Ragweed pollen grain

Development of Female Gametophytes (Embryo Sacs)

- Within an ovule, **megaspores** are produced by meiosis and develop into **embryo sacs,** the female gametophytes

Fig. 38-3b



(b) Development of a female gametophyte (embryo sac)
Megasporangium (2n)
Ovule
Megasporocyte (2n)
MEIOSIS
Integuments (2n)
Micropyle
Surviving megaspore (n)
MITOSIS
Ovule
3 antipodal cells (n)
2 polar nuclei (n)
1 egg (n)
Integuments (2n)
2 synergids (n)
Female gametophyte (embryo sac)
100 µm
Embryo sac

Pollination

- In angiosperms, **pollination** is the transfer of pollen from an anther to a stigma
- Pollination can be by wind, water, bee, moth and butterfly, fly, bird, bat, or water

Fig. 38-4a

Abiotic Pollination by Wind

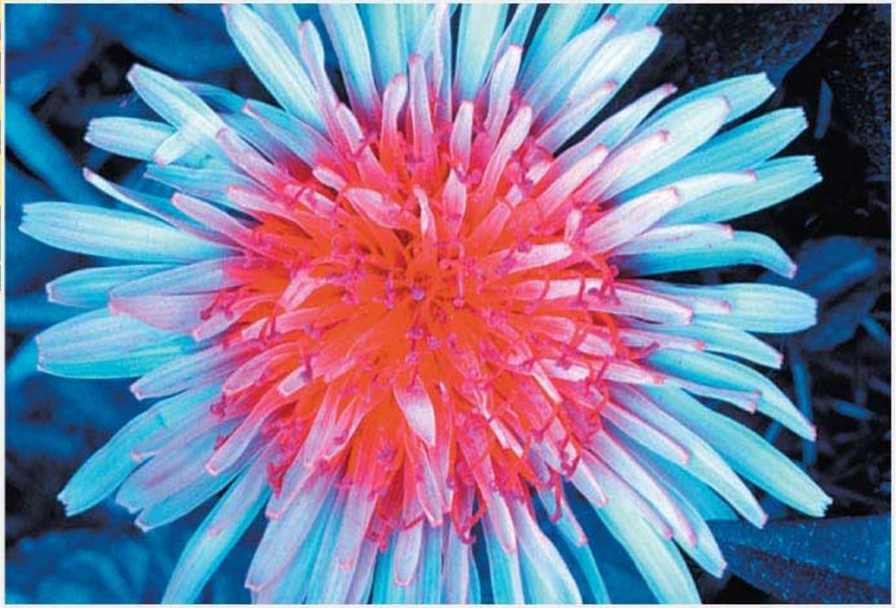
▲ **Hazel staminate flowers (stamens only)**

◄ **Hazel carpellate flower (carpels only)**

Fig. 38-4b

Pollination by Bees

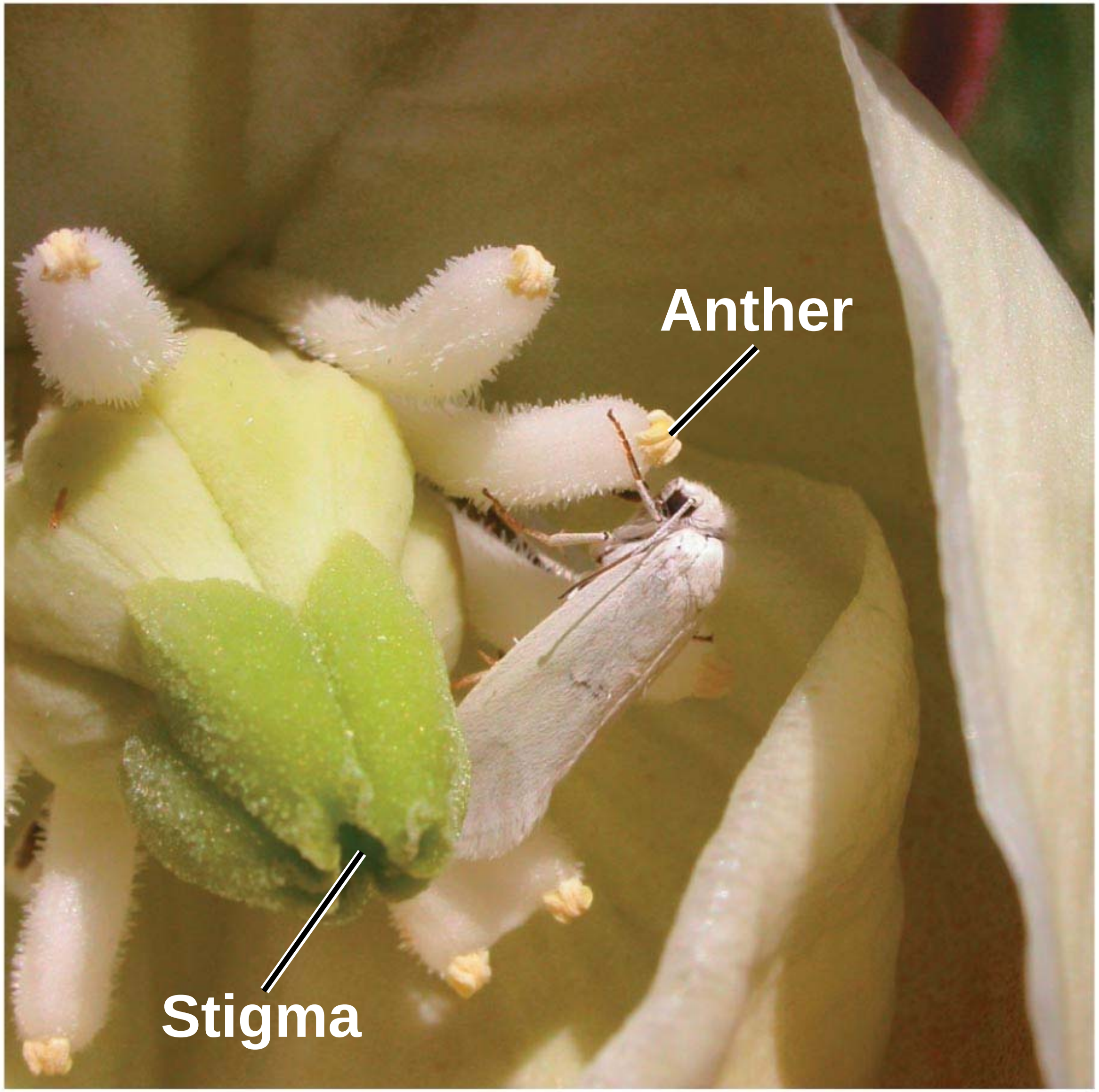
Common dandelion under normal light



Common dandelion under ultraviolet light

Fig. 38-4c

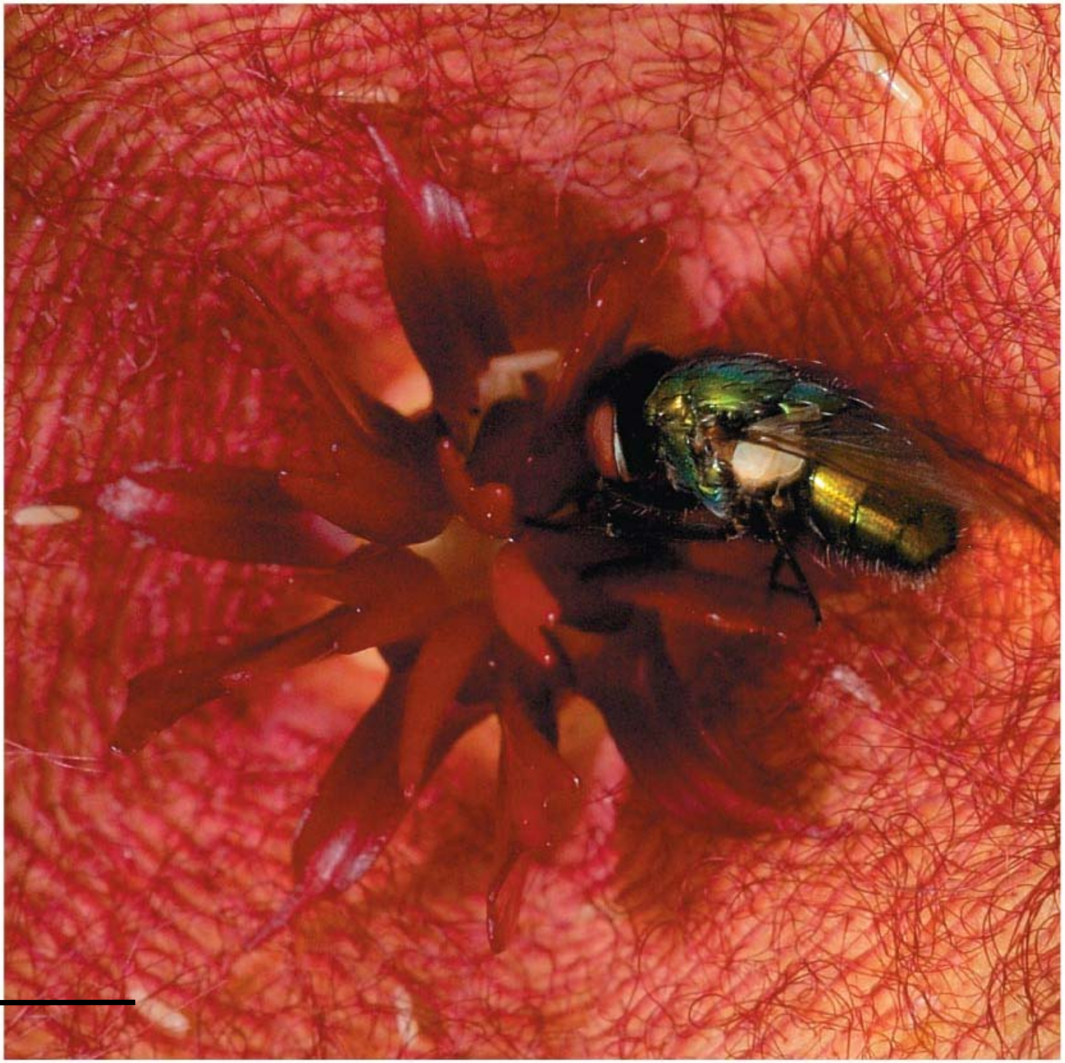
Pollination by Moths and Butterflies



Moth on yucca flower

Fig. 38-4d

Pollination by Flies



Fly egg

Blowfly on carrion flower

Fig. 38-4e

Pollination by Birds

Hummingbird drinking nectar of poro flower

Fig. 38-4f

Pollination by Bats

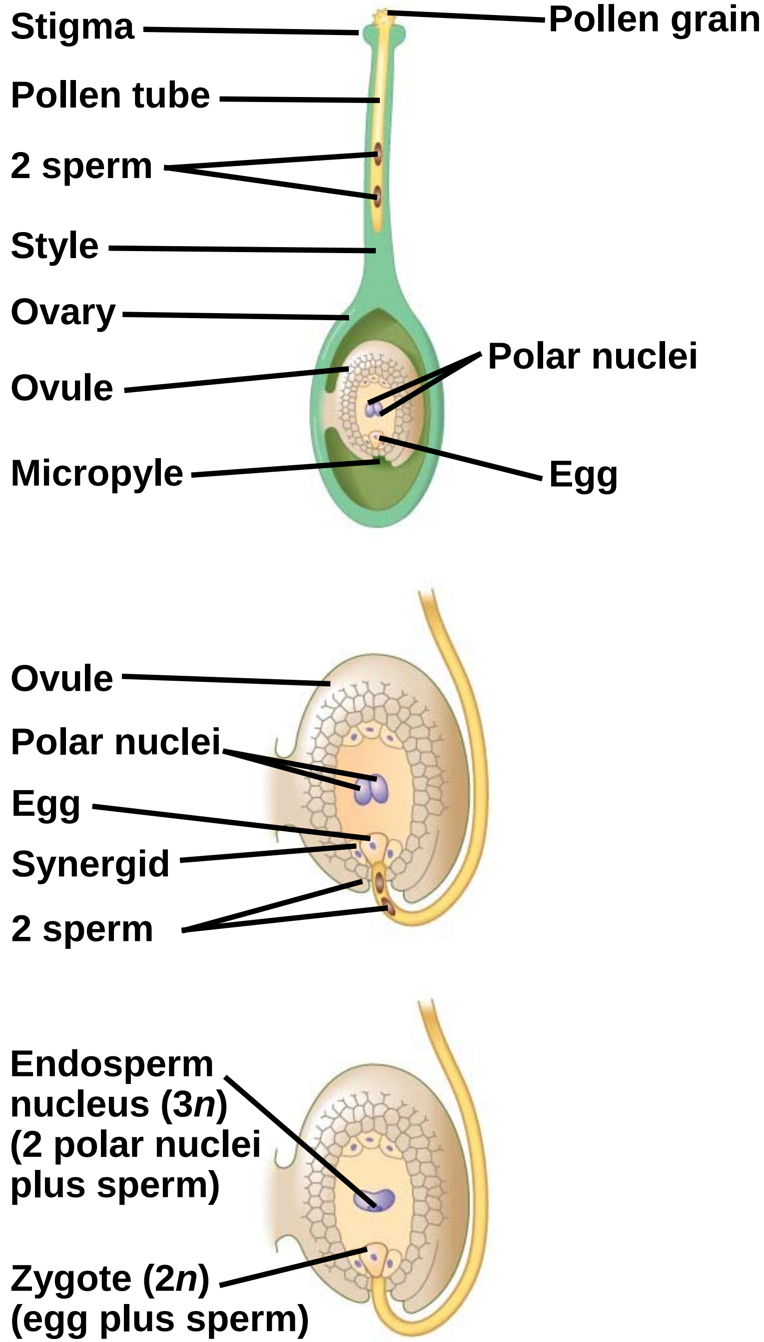
Long-nosed bat feeding on cactus flower at night

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
- **Double fertilization** results from the discharge of two sperm from the pollen tube into the embryo sac
- One sperm fertilizes the egg, and the other combines with the polar nuclei, giving rise to the triploid (3*n*) food-storing **endosperm**

PLAY Animation: Plant Fertilization

Fig. 38-5



Stigma
Pollen grain
Pollen tube
2 sperm
Style
Ovary
Polar nuclei
Ovule
Egg
Micropyle
Ovule
Polar nuclei
Egg
Synergid
2 sperm
Endosperm nucleus (3*n*) (2 polar nuclei plus sperm)
Zygote (2*n*) (egg plus sperm)

Fig. 38-5a

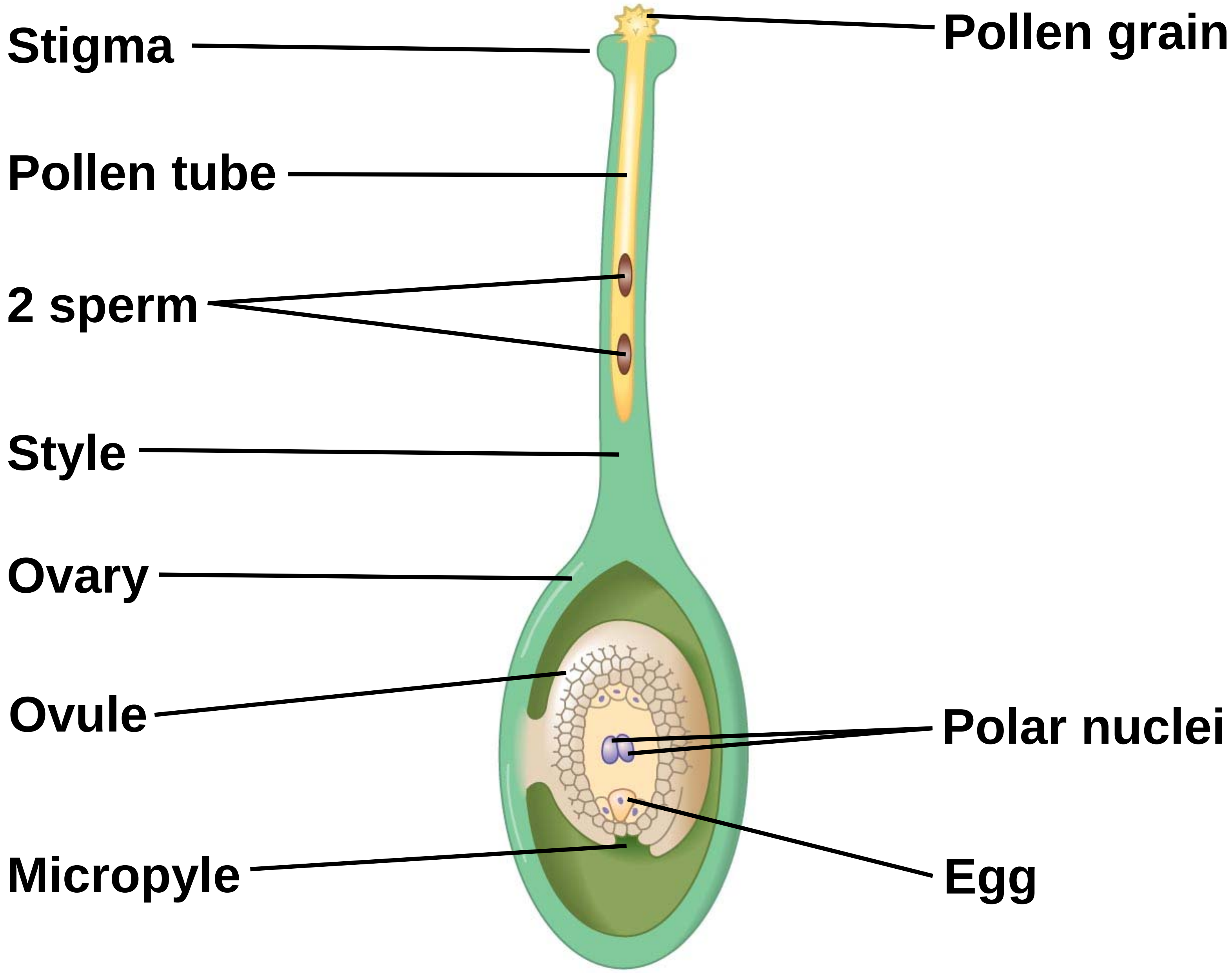

Stigma
Pollen grain
Pollen tube
2 sperm
Style
Ovary
Ovule
Polar nuclei
Micropyle
Egg

Fig. 38-5b

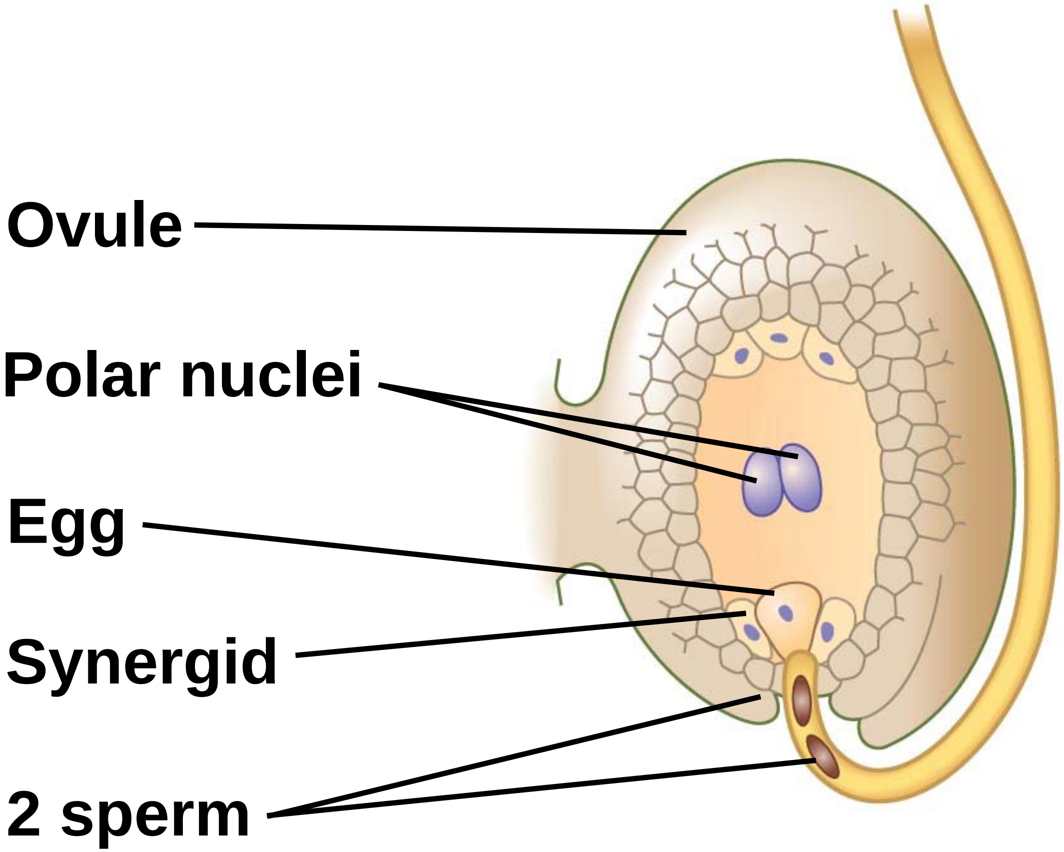


Fig. 38-5c

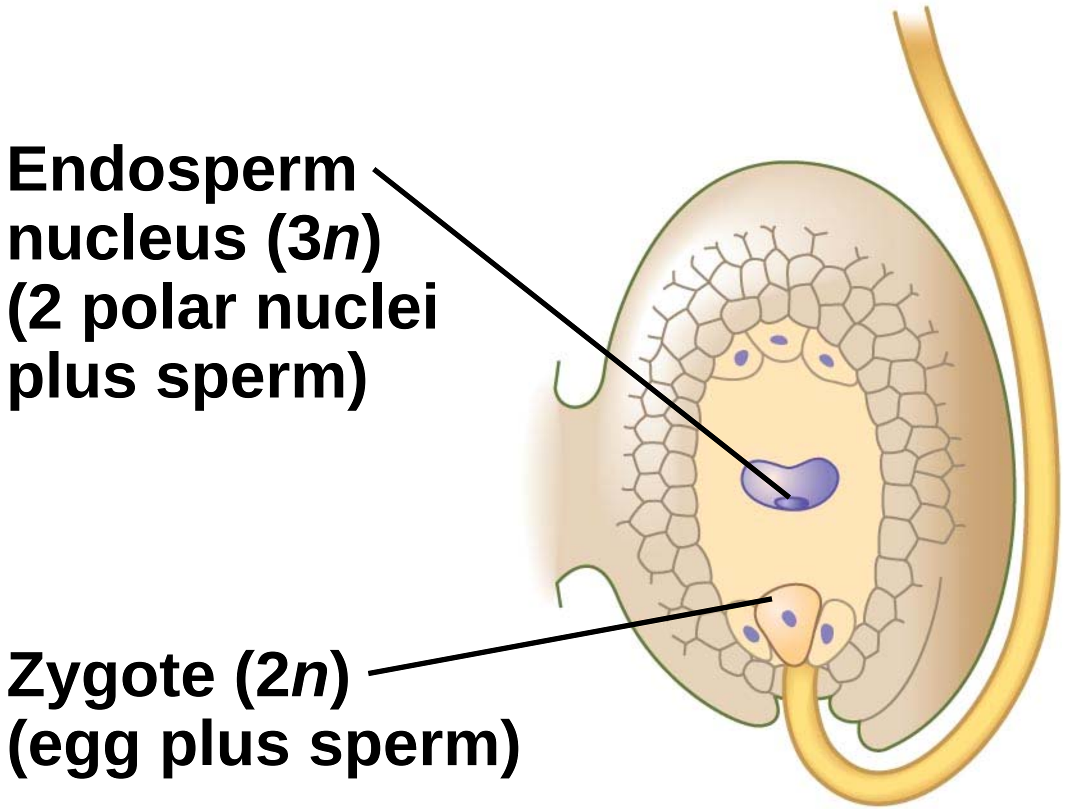
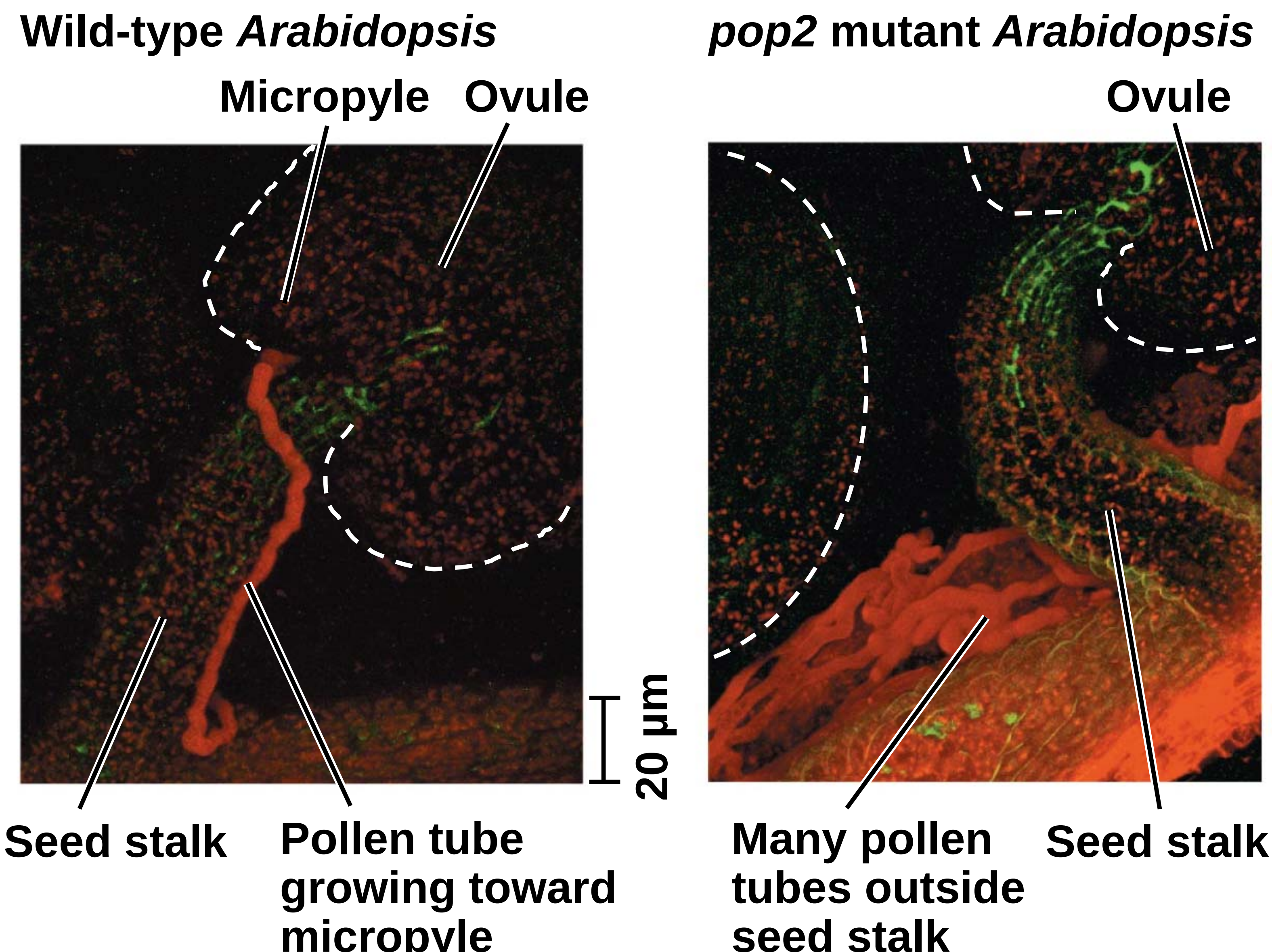

Endosperm nucleus (3*n*) (2 polar nuclei plus sperm)
Zygote (2*n*) (egg plus sperm)

Fig. 38-6

EXPERIMENT



Seed Development, Form, and Function

- After double fertilization, each ovule develops into a seed
- The ovary develops into a fruit enclosing the seed(s)

Endosperm Development

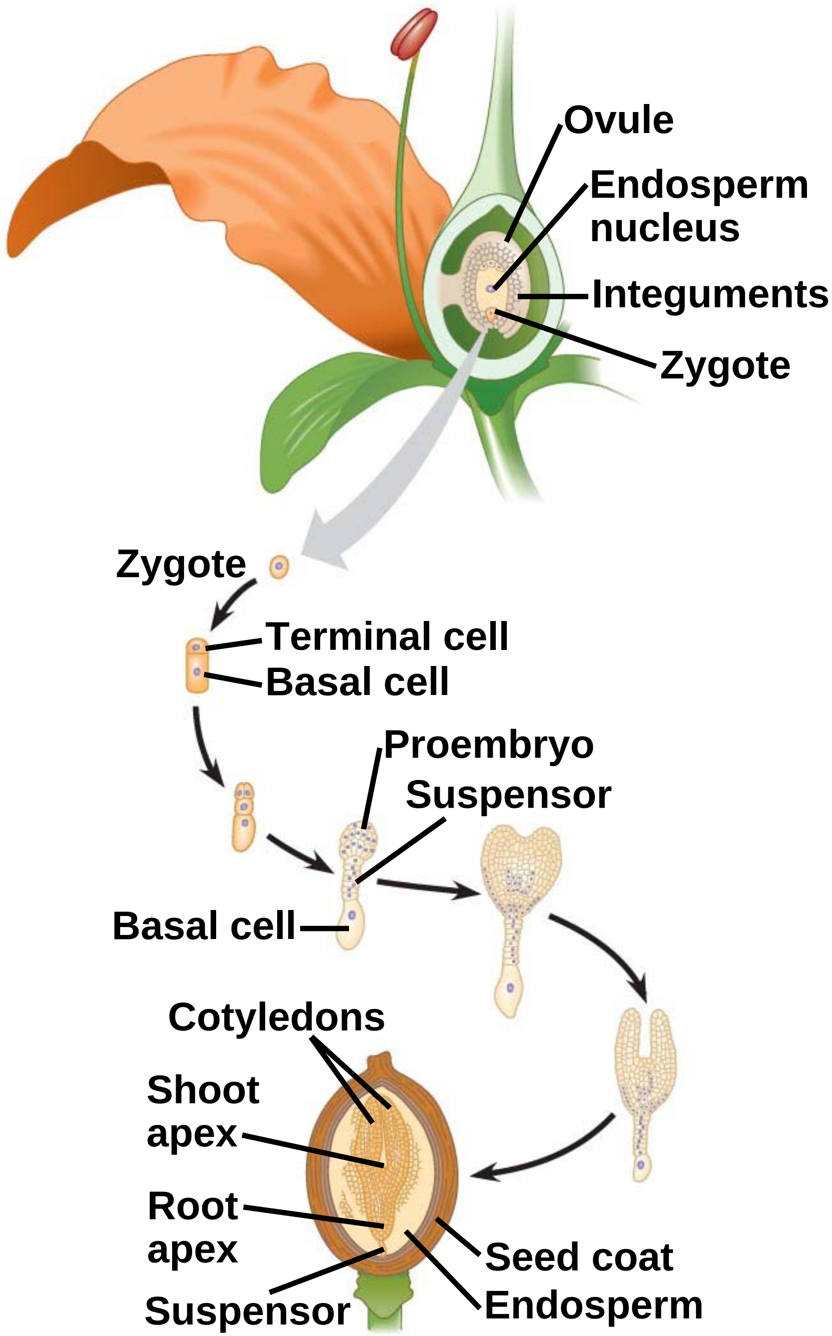
- Endosperm development usually precedes embryo development
- In most monocots and some eudicots, endosperm stores nutrients that can be used by the seedling
- In other eudicots, the food reserves of the endosperm are exported to the cotyledons

Embryo Development

- The first mitotic division of the zygote is transverse, splitting the fertilized egg into a basal cell and a terminal cell

PLAY **Animation: Seed Development**

Fig. 38-7

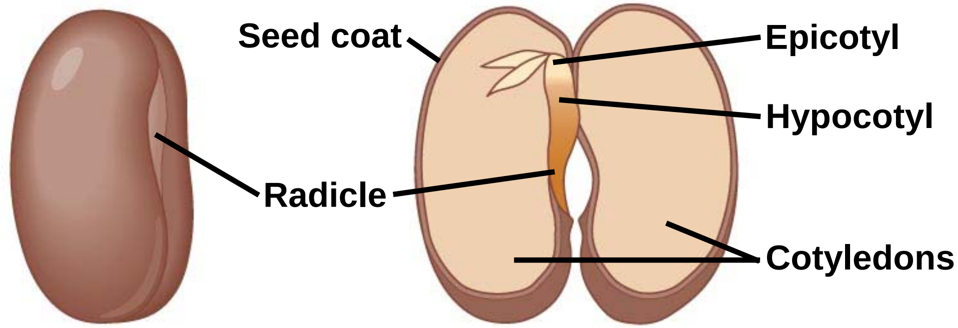

Ovule
Endosperm nucleus
Integuments
Zygote
Zygote
Terminal cell
Basal cell
Proembryo
Suspensor
Basal cell
Cotyledons
Shoot apex
Root apex
Suspensor
Seed coat
Endosperm

Structure of the Mature Seed

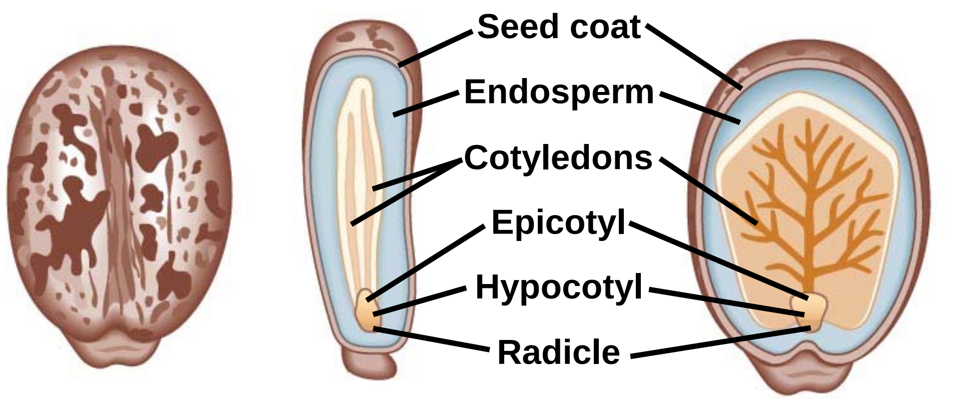
- The embryo and its food supply are enclosed by a hard, protective **seed coat**
- The seed enters a state of **dormancy**

- In some eudicots, such as the common garden bean, the embryo consists of the embryonic axis attached to two thick cotyledons (seed leaves)
- Below the cotyledons the embryonic axis is called the **hypocotyl** and terminates in the **radicle** (embryonic root); above the cotyledons it is called the **epicotyl**

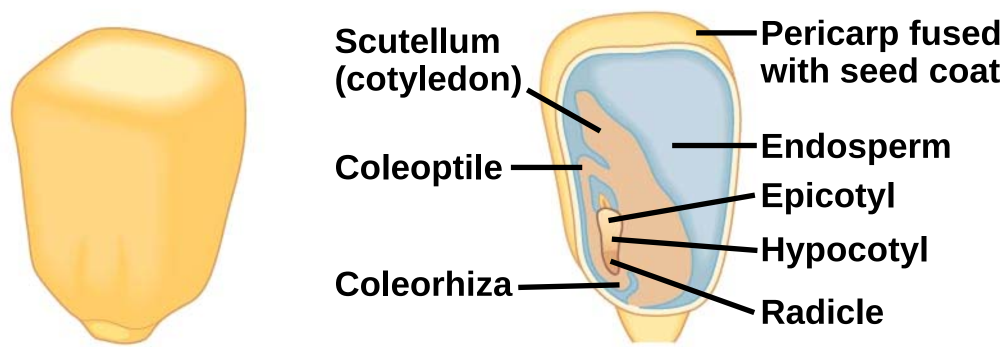
Fig. 38-8



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

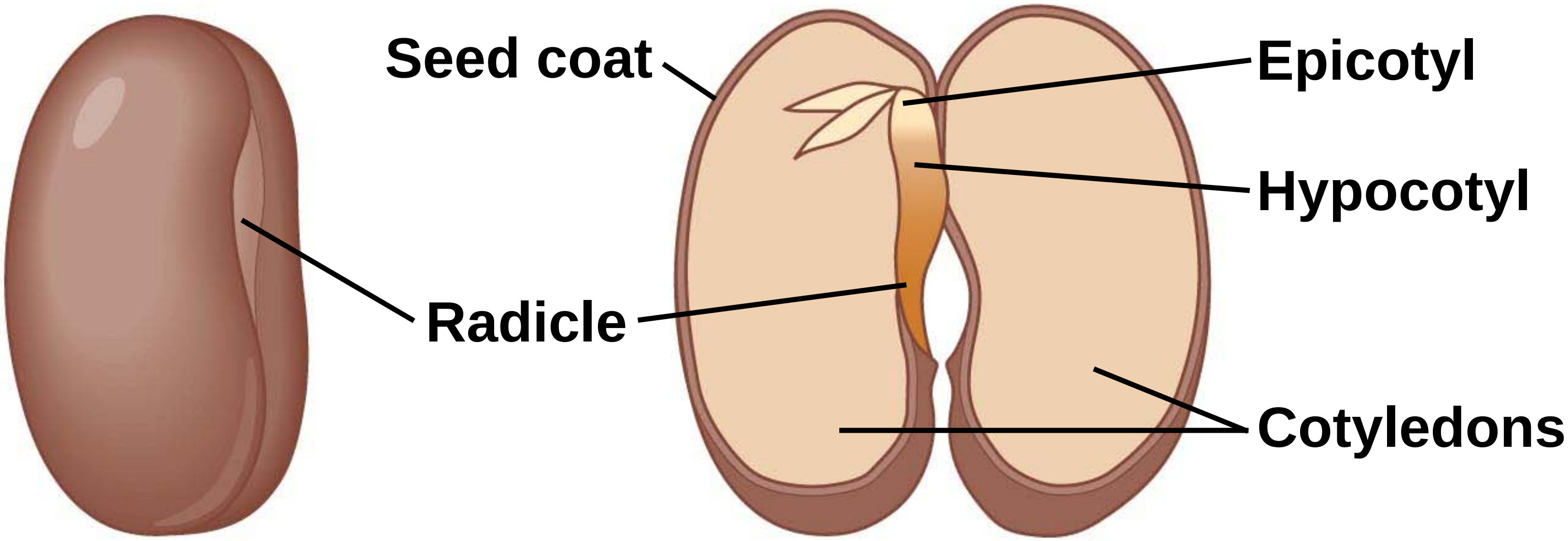


(b) Castor bean, a eudicot with thin cotyledons



(c) Maize, a monocot

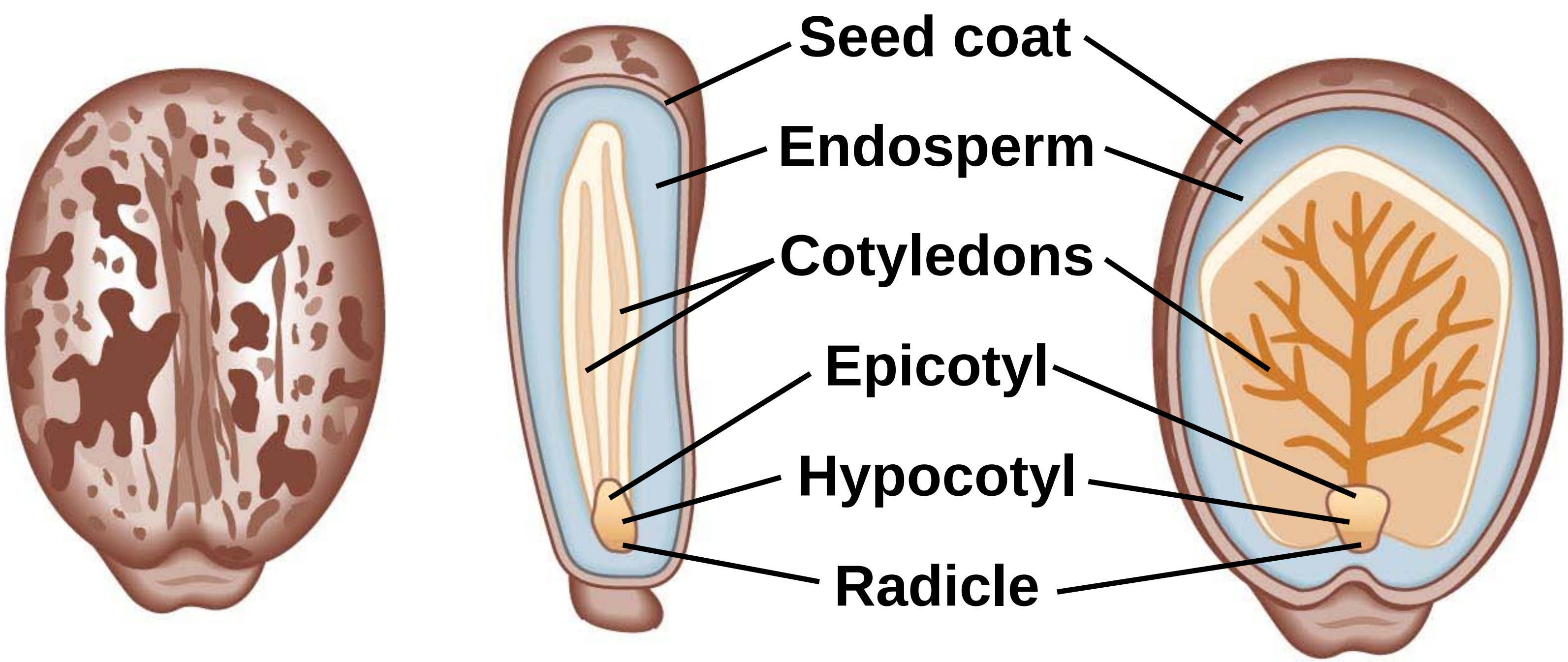
Fig. 38-8a



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

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

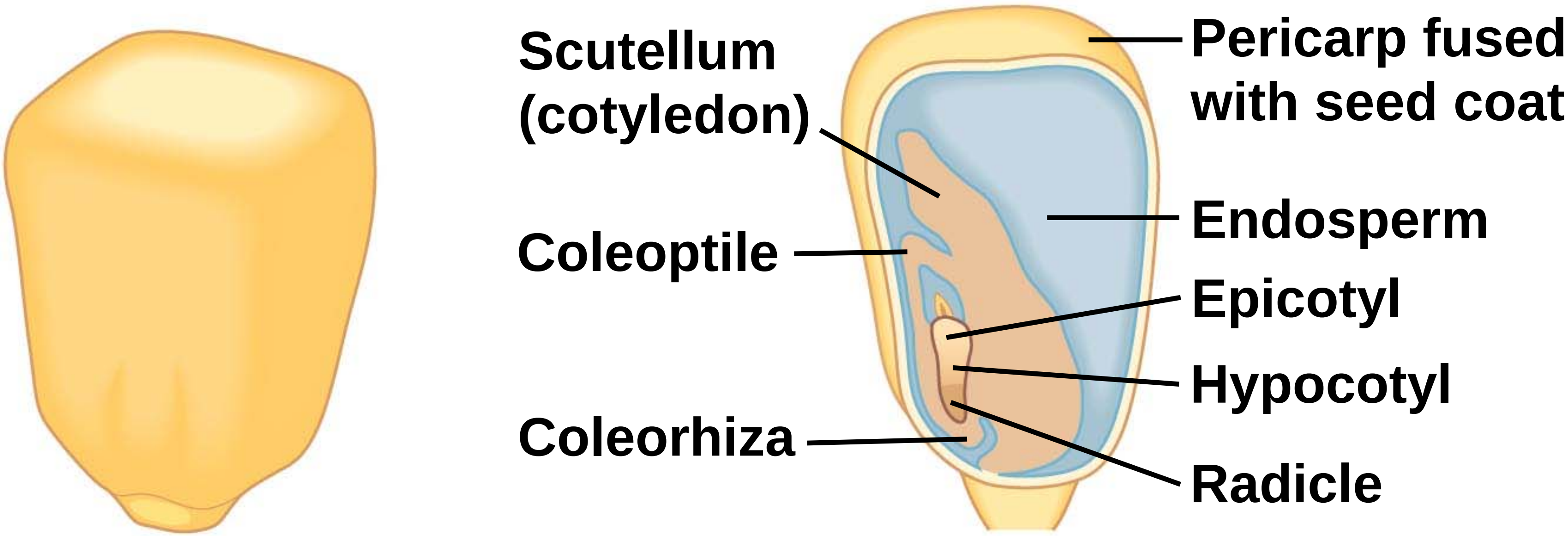
Fig. 38-8b



(b) Castor bean, a eudicot with thin cotyledons

- 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

Fig. 38-8c



(c) Maize, a monocot

Seed Dormancy: An Adaptation for Tough Times

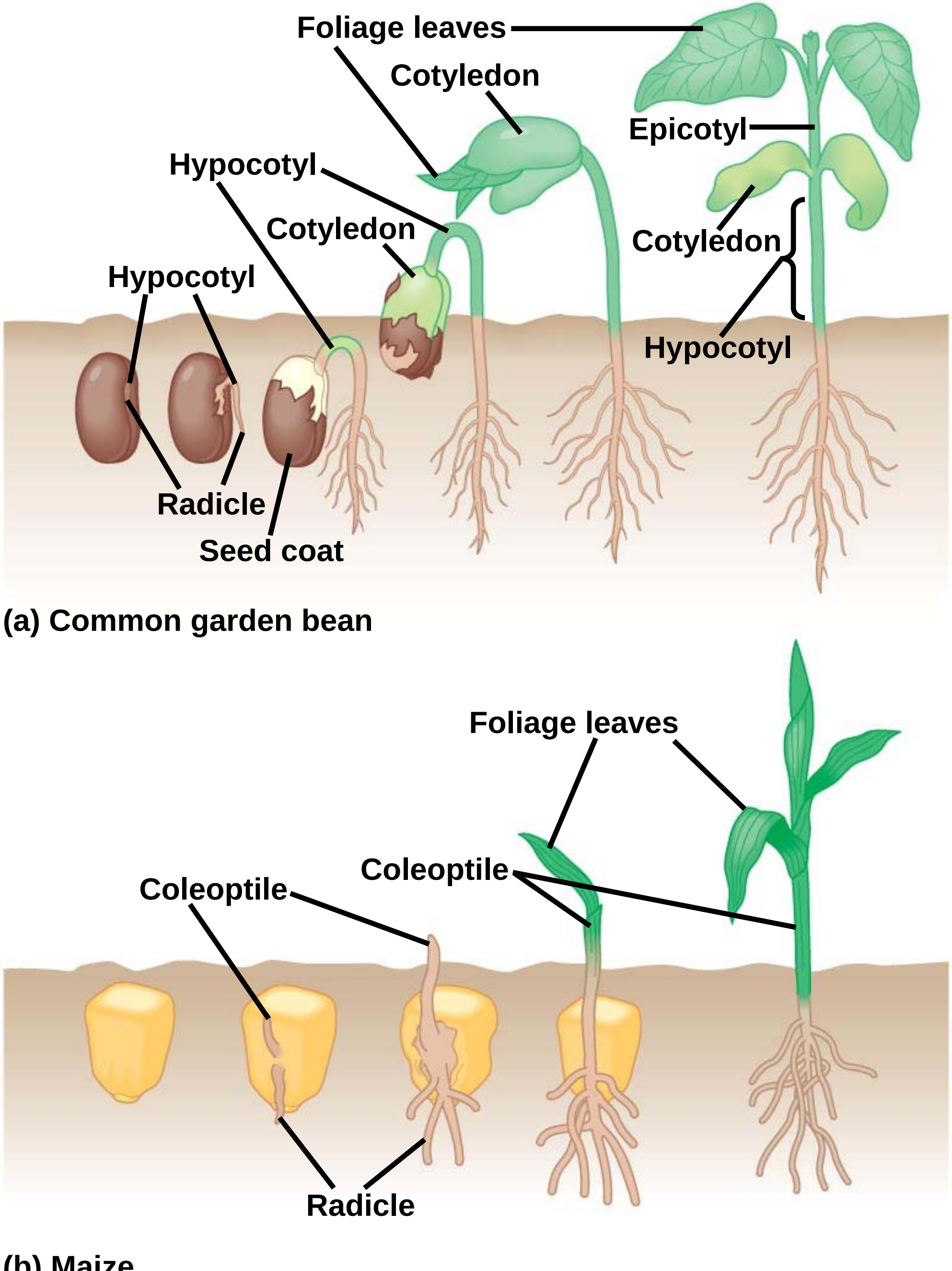
- Seed dormancy increases the chances that germination will occur at a time and place most advantageous to the seedling
- The breaking of seed dormancy often requires environmental cues, such as temperature or lighting changes

Seed Germination and Seedling Development

- Germination depends on **imbibition**, the uptake of water due to low water potential of the dry seed
- The radicle (embryonic root) emerges first
- Next, the shoot tip breaks through the soil surface

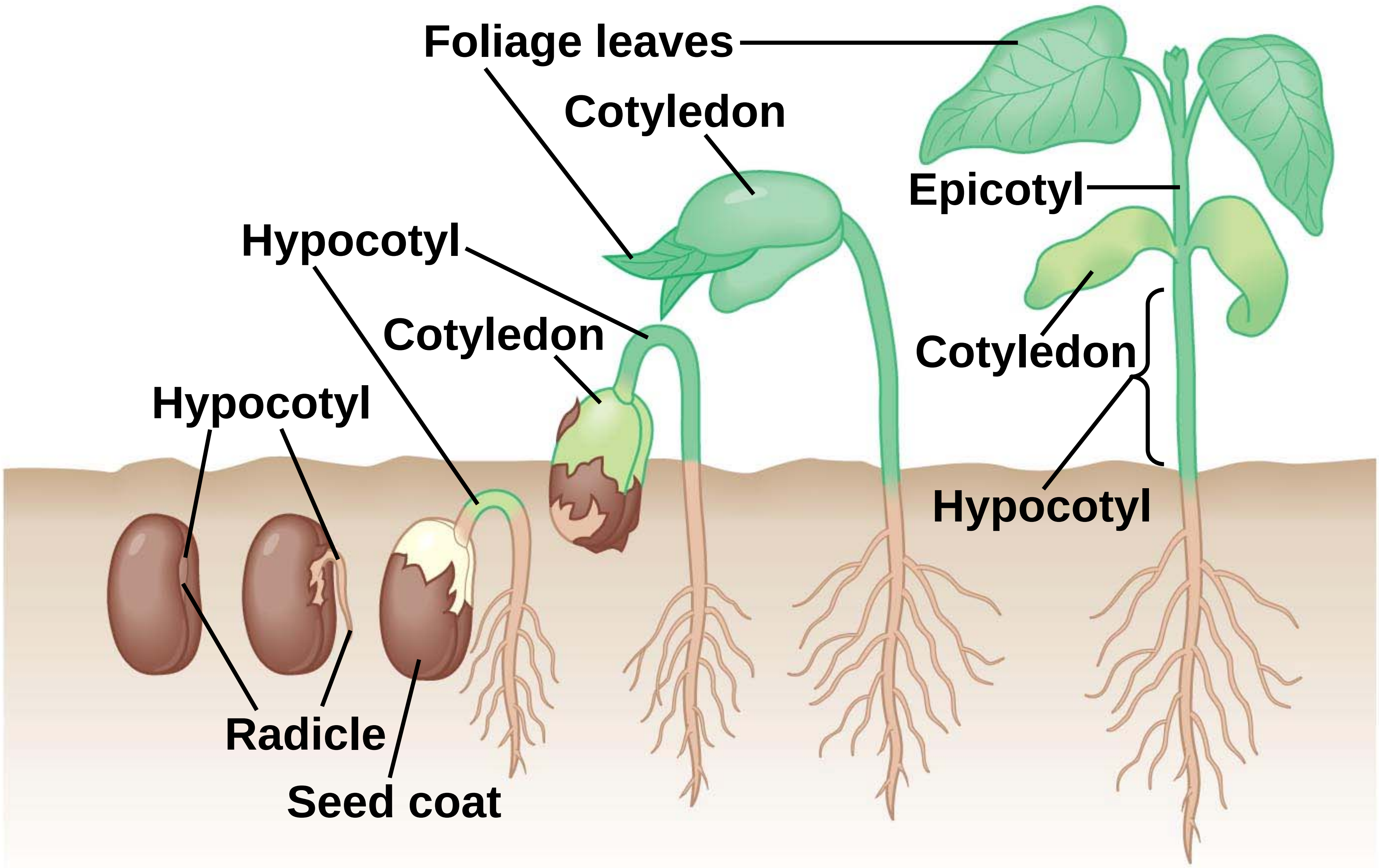
- In many eudicots, a hook forms in the hypocotyl, and growth pushes the hook above ground
- The hook straightens and pulls the cotyledons and shoot tip up

Fig. 38-9



Foliage leaves
Cotyledon
Epicotyl
Hypocotyl
Cotyledon
Cotyledon
Hypocotyl
Hypocotyl
Radicle
Seed coat
(a) Common garden bean
Foliage leaves
Coleoptile
Coleoptile
Radicle
(b) Maize

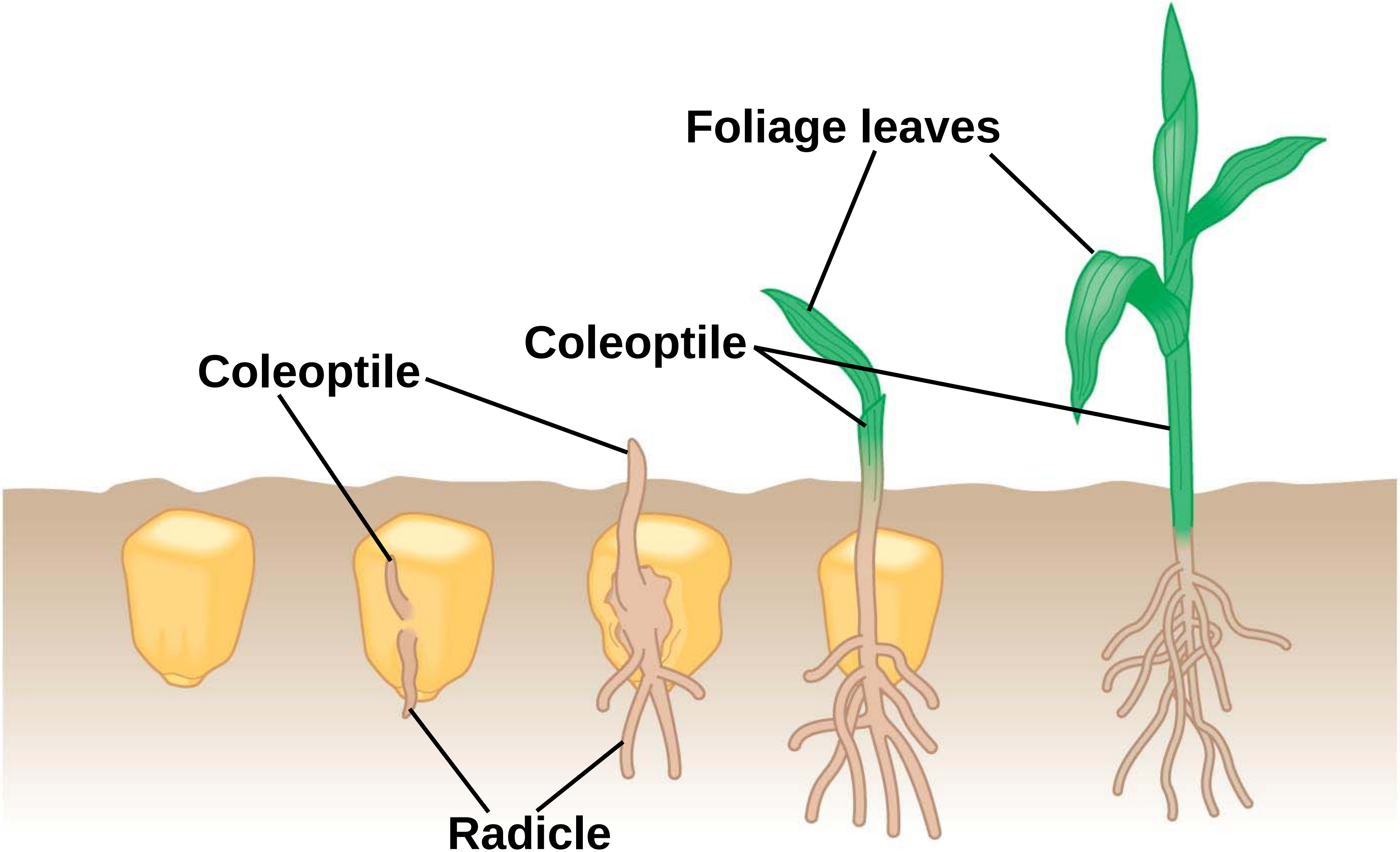
Fig. 38-9a



(a) Common garden bean

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

Fig. 38-9b



(b) Maize

Fruit Form and Function

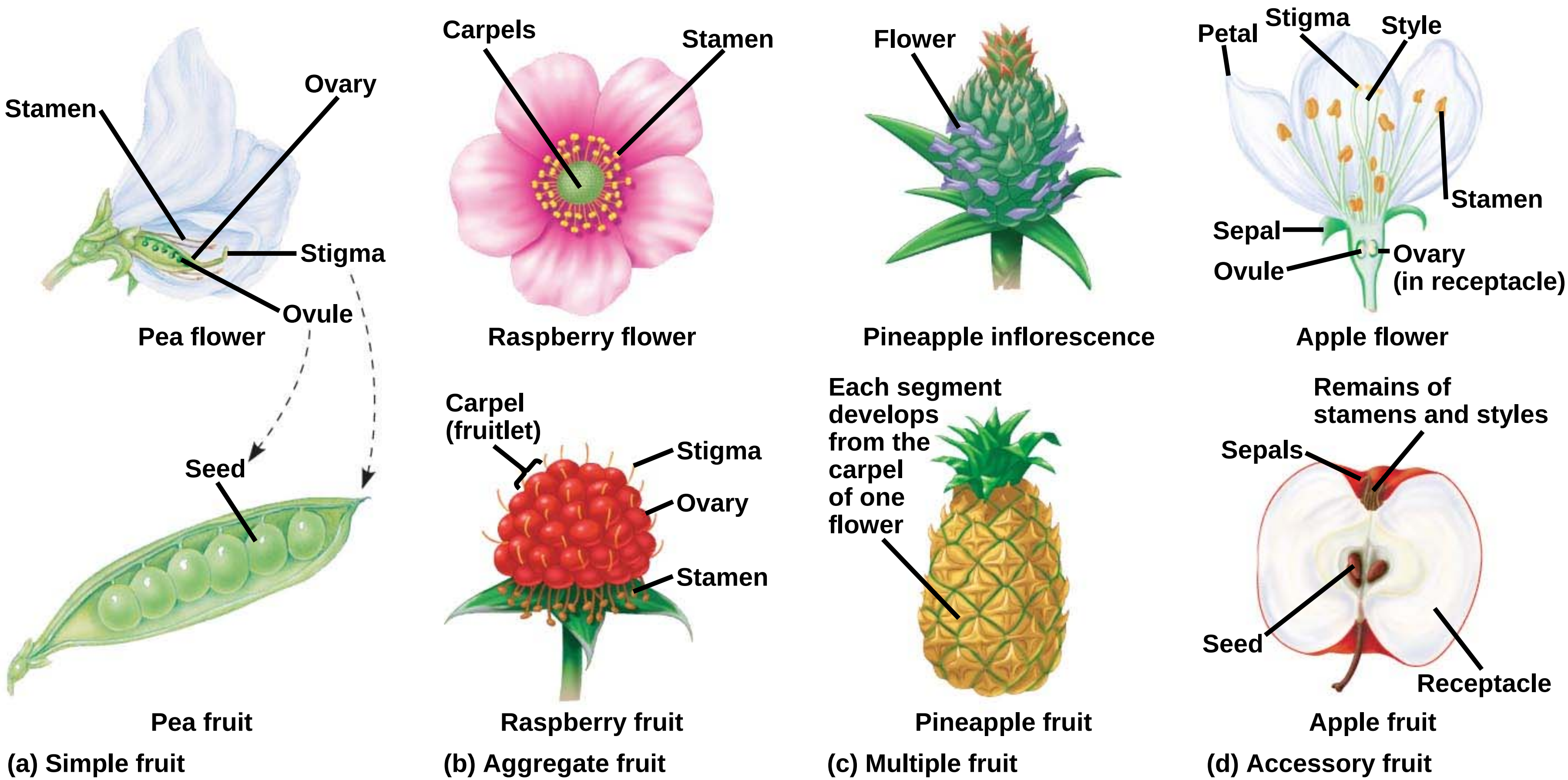
- A **fruit** develops from the ovary
- It protects the enclosed seeds and aids in seed dispersal by wind or animals
- A fruit may be classified as dry, if the ovary dries out at maturity, or fleshy, if the ovary becomes thick, soft, and sweet at maturity

PLAY

Animation: Fruit Development

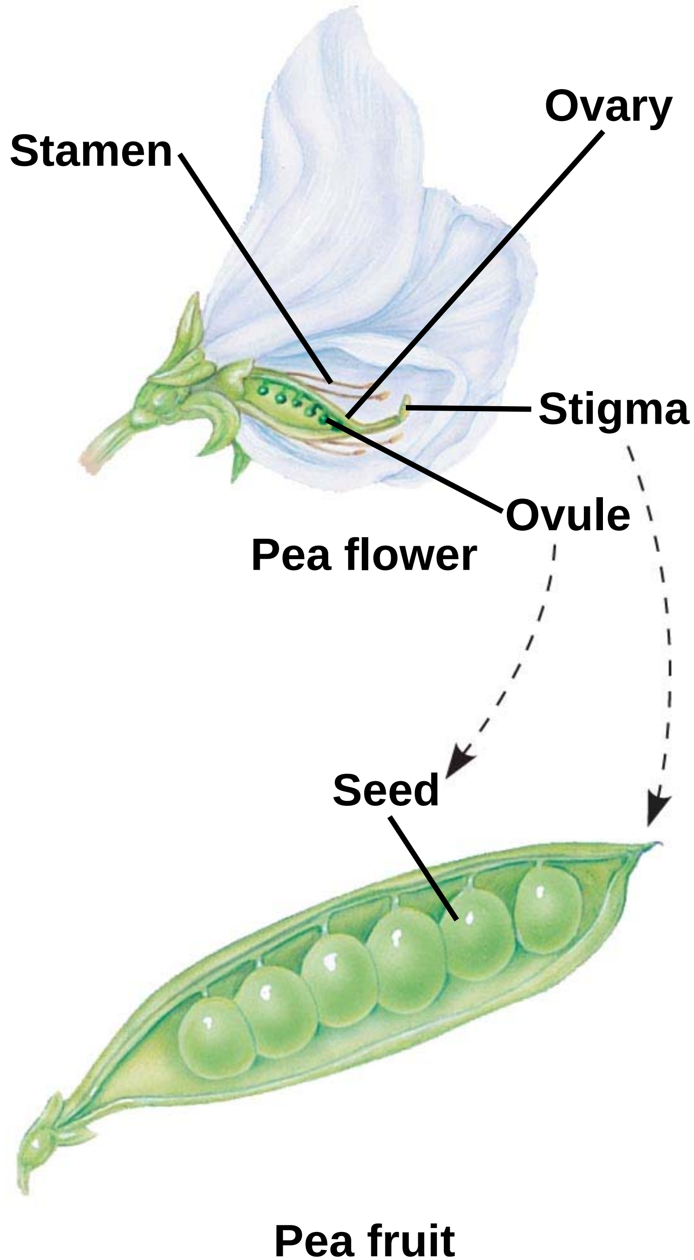
- Fruits are also classified by their development:
  - **Simple**, a single or several fused carpels
  - **Aggregate,** a single flower with multiple separate carpels
  - **Multiple,** a group of flowers called an inflorescence

Fig. 38-10



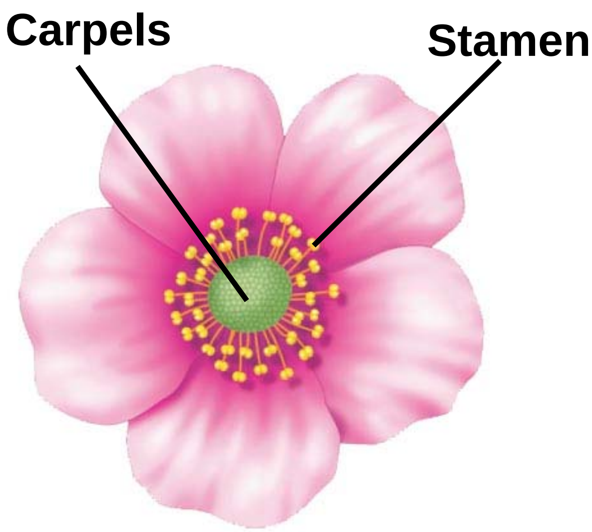
Stamen
Ovary
Stigma
Ovule
Pea flower
Seed
Pea fruit
(a) Simple fruit
Carpels
Stamen
Raspberry flower
Carpel
(fruitlet)
Stigma
Ovary
Stamen
Raspberry fruit
(b) Aggregate fruit
Flower
Pineapple inflorescence
Each segment
develops
from the
carpel
of one
flower
Pineapple fruit
(c) Multiple fruit
Petal
Stigma
Style
Stamen
Sepal
Ovule
Ovary
(in receptacle)
Apple flower
Remains of
stamens and styles
Sepals
Seed
Receptacle
Apple fruit
(d) Accessory fruit

Fig. 38-10a

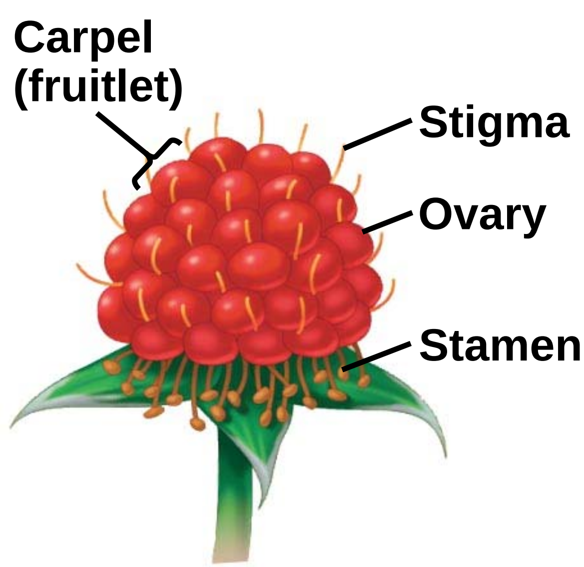


(a) Simple fruit

Fig. 38-10b



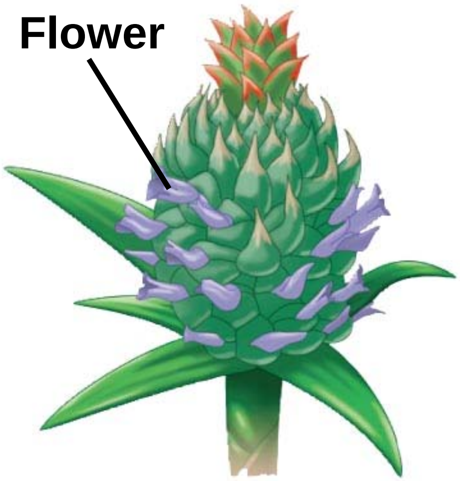
Raspberry flower



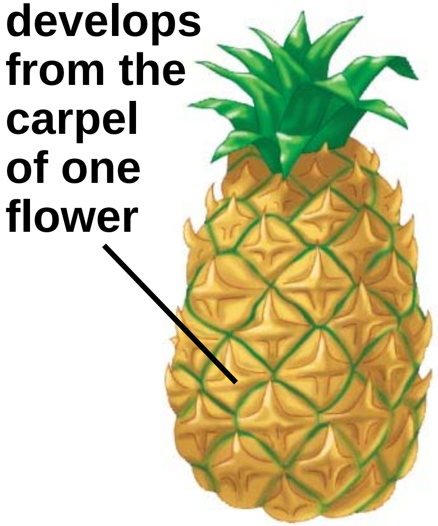
Raspberry fruit

(b) Aggregate fruit

Fig. 38-10c



Pineapple inflorescence

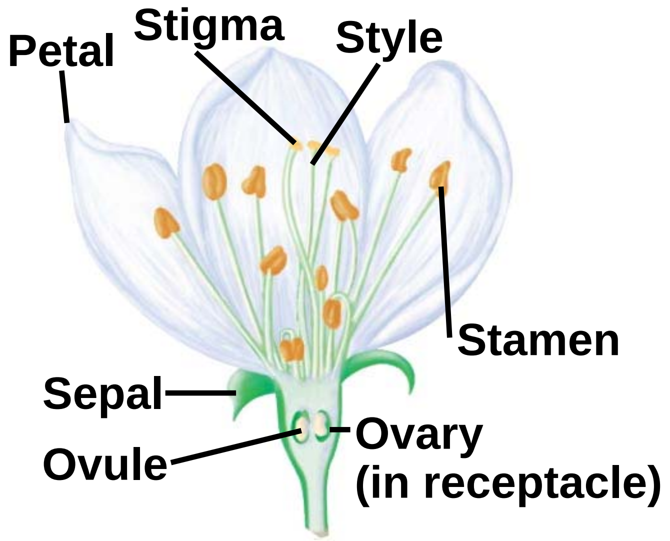


Pineapple fruit

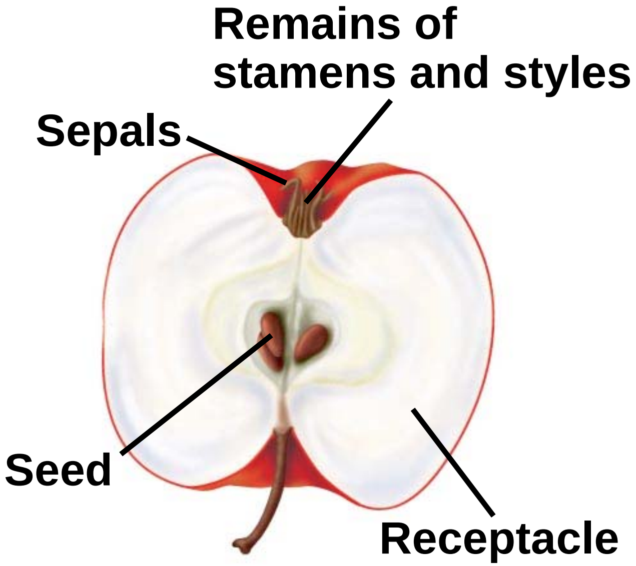
(c) Multiple fruit

- An **accessory fruit** contains other floral parts in addition to ovaries

Fig. 38-10d



Apple flower



Apple fruit

(d) Accessory fruit

- Fruit dispersal mechanisms include:
  - Water
  - Wind
  - Animals

Fig. 38-11a

Dispersal by Water

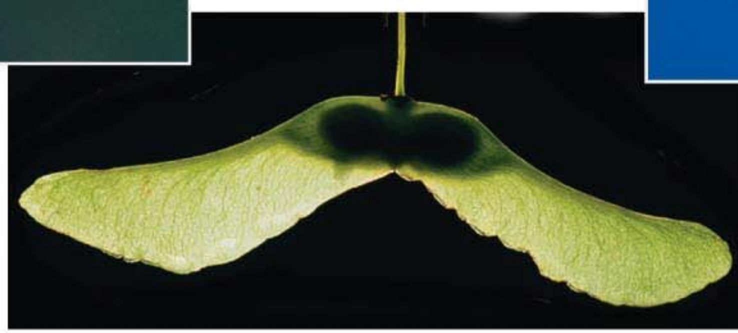
Coconut

Fig. 38-11b

Dispersal by Wind

Winged seed of Asian climbing gourd

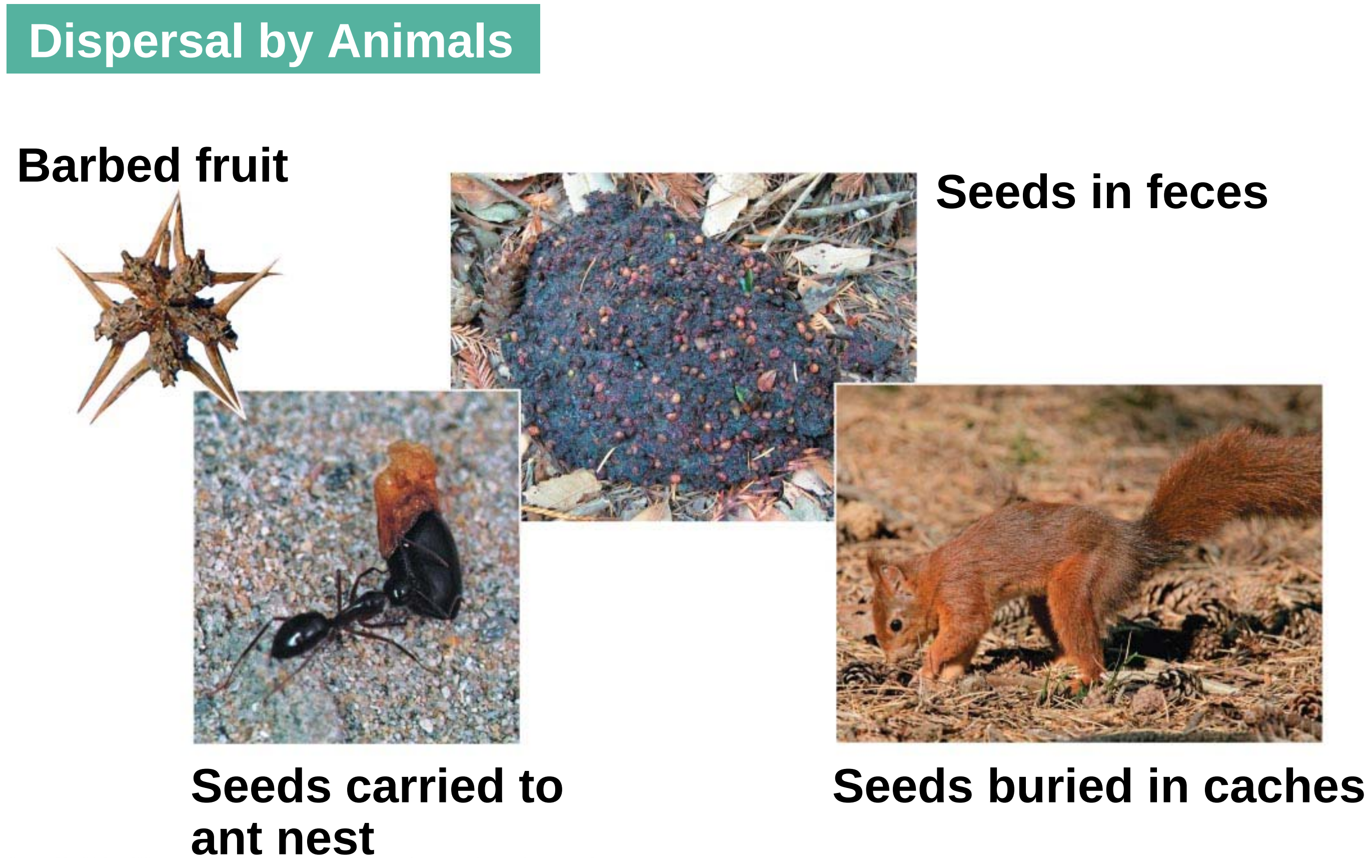
Dandelion “parachute”



Winged fruit of maple

Tumbleweed

Fig. 38-11c



Dispersal by Animals
Barbed fruit
Seeds in feces
Seeds carried to ant nest
Seeds buried in caches

Concept 38.2: Plants reproduce sexually, asexually, or both

- Many angiosperm species reproduce both asexually and sexually
- Sexual reproduction results in offspring that are genetically different from their parents
- **Asexual reproduction** results in a clone of genetically identical organisms

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

Fig. 38-12

- **Apomixis** is the asexual production of seeds from a diploid cell

Advantages and Disadvantages of Asexual Versus Sexual Reproduction

- Asexual reproduction is also called **vegetative reproduction**
- Asexual reproduction can be beneficial to a successful plant in a stable environment
- However, a clone of plants is vulnerable to local extinction if there is an environmental change

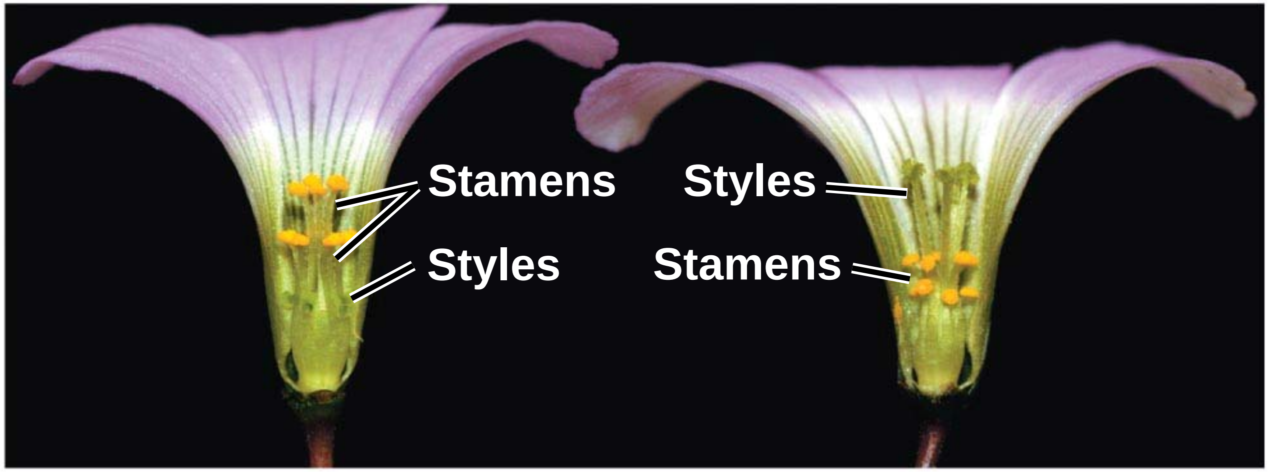
- Sexual reproduction generates genetic variation that makes evolutionary adaptation possible
- However, only a fraction of seedlings survive

Mechanisms That Prevent Self-Fertilization

- Many angiosperms have mechanisms that make it difficult or impossible for a flower to self-fertilize
- **Dioecious** species have staminate and carpellate flowers on separate plants

Fig. 38-13

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



Thrum flower **Pin flower**

(b) ***Oxalis alpina*** **flowers**

Fig. 38-13a

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

- Others have stamens and carpels that mature at different times or are arranged to prevent selfing

Fig. 38-13b

Thrum flower

Pin flower

(b) *Oxalis alpina* flowers

- 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

Vegetative Propagation and Agriculture

- Humans have devised methods for asexual propagation of angiosperms
- Most methods are based on the ability of plants to form adventitious roots or shoots

Clones from Cuttings

- Many kinds of plants are asexually reproduced from plant fragments called cuttings
- A **callus** is a mass of dividing undifferentiated cells that forms where a stem is cut and produces adventitious roots

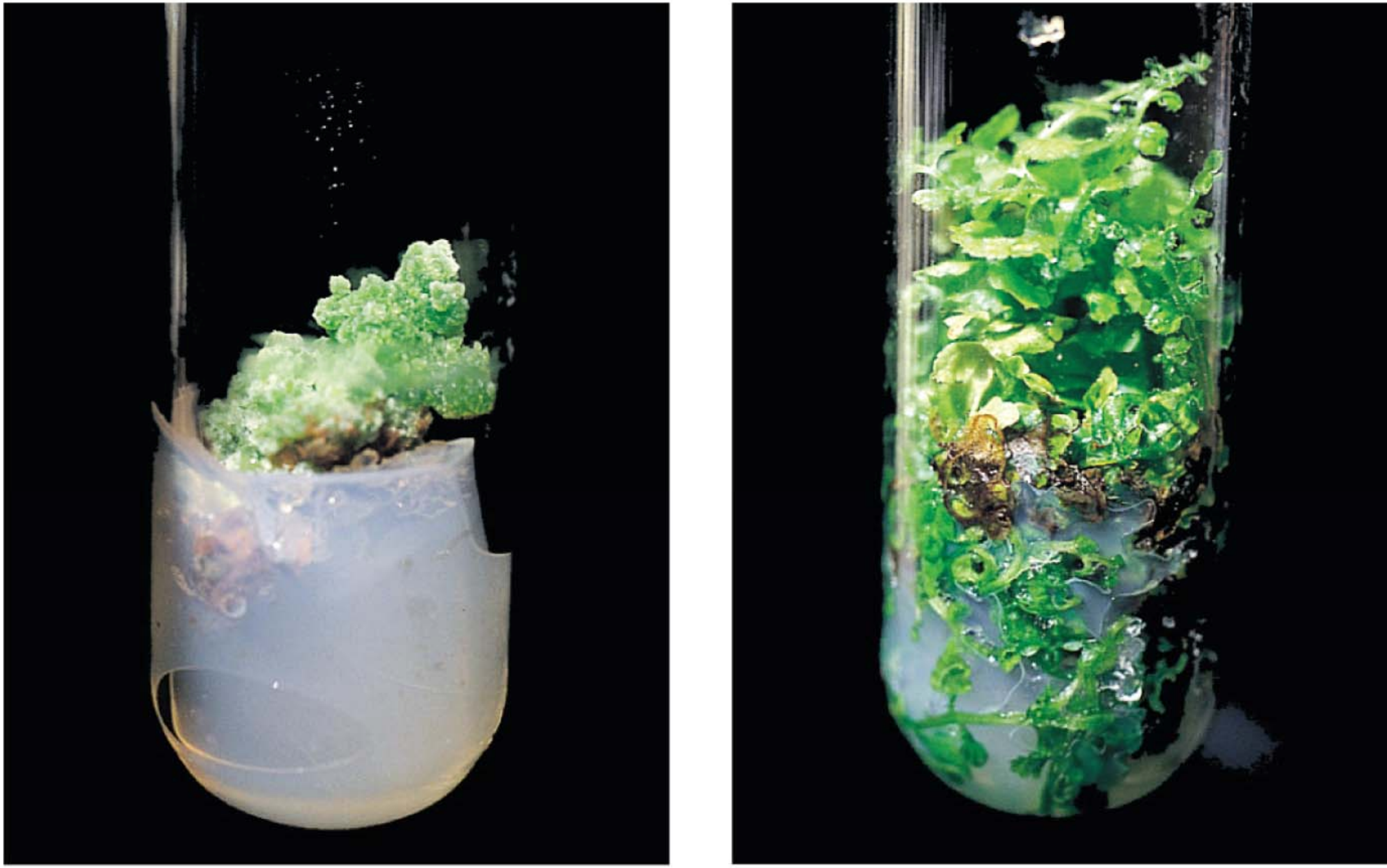
Grafting

- A twig or bud can be grafted onto a plant of a closely related species or variety
- The **stock** provides the root system
- The **scion** is grafted onto the stock

Test-Tube Cloning and Related Techniques

- Plant biologists have adopted *in vitro* methods to create and clone novel plant varieties
- **Transgenic** plants are genetically modified (GM) to express a gene from another organism

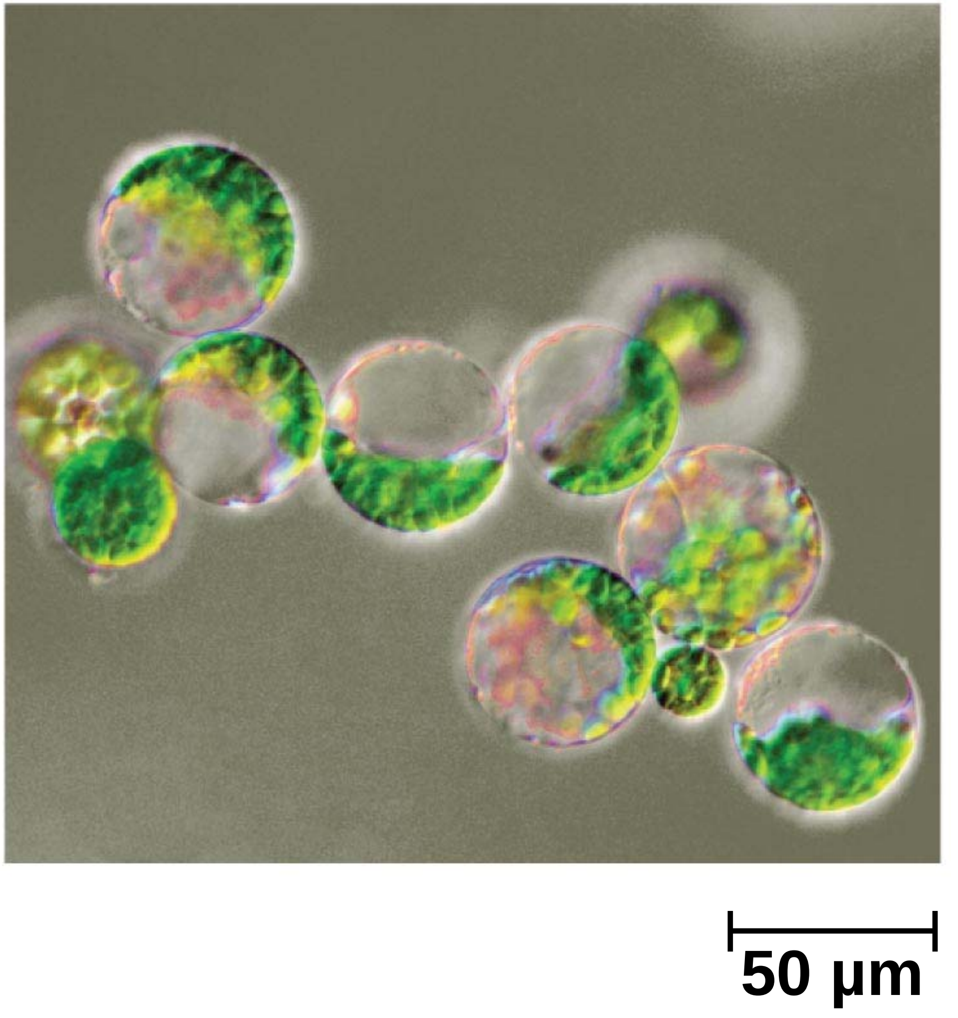
Fig. 38-14



(a) Undifferentiated carrot cells **(b) Differentiation into plant**

- **Protoplast fusion** is used to create hybrid plants by fusing protoplasts, plant cells with their cell walls removed

Fig. 38-15



Concept 38.3: Humans modify crops by breeding and genetic engineering

- Humans have intervened in the reproduction and genetic makeup of plants for thousands of years
- Hybridization is common in nature and has been used by breeders to introduce new genes
- Maize, a product of artificial selection, is a staple in many developing countries

Fig. 38-16

Plant Breeding

- Mutations can arise spontaneously or can be induced by breeders
- Plants with beneficial mutations are used in breeding experiments
- Desirable traits can be introduced from different species or genera
- The grain triticale is derived from a successful cross between wheat and rye

Plant Biotechnology and Genetic Engineering

- Plant biotechnology has two meanings:
  - In a general sense, it refers to innovations in the use of plants to make useful products
  - In a specific sense, it refers to use of GM organisms in agriculture and industry
- Modern plant biotechnology is not limited to transfer of genes between closely related species or varieties of the same species

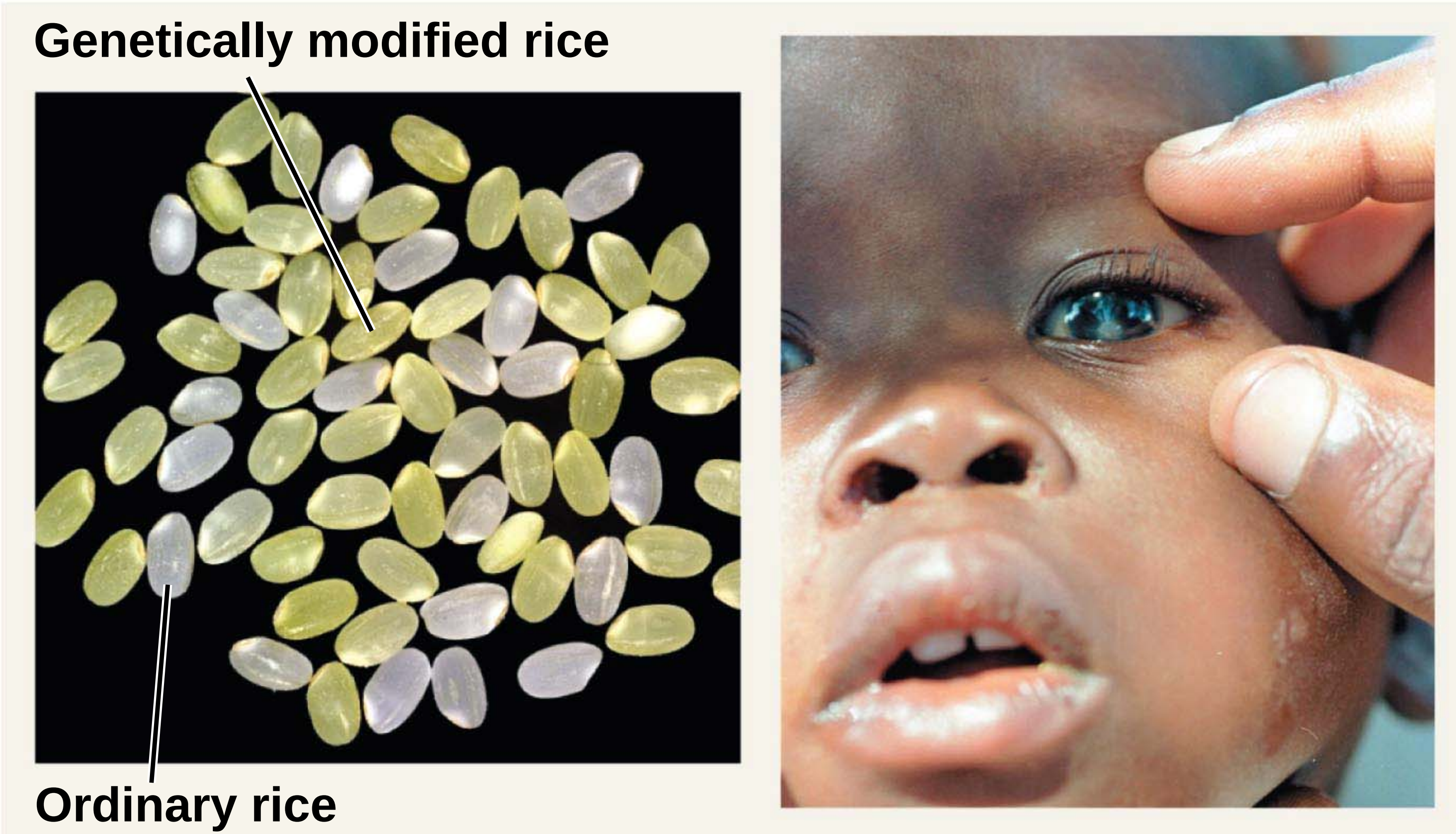
Reducing World Hunger and Malnutrition

- Genetically modified plants may increase the quality and quantity of food worldwide
- Transgenic crops have been developed that:
  - Produce proteins to defend them against insect pests
  - Tolerate herbicides
  - Resist specific diseases

Fig. 38-17

- Nutritional quality of plants is being improved
- “Golden Rice” is a transgenic variety being developed to address vitamin A deficiencies among the world’s poor

Fig. 38-18



Reducing Fossil Fuel Dependency

- **Biofuels** are made by the fermentation and distillation of plant materials such as cellulose
- Biofuels can be produced by rapidly growing crops

The Debate over Plant Biotechnology

- Some biologists are concerned about risks of releasing GM organisms into the environment

Issues of Human Health

- One concern is that genetic engineering may transfer allergens from a gene source to a plant used for food

Possible Effects on Nontarget Organisms

- Many ecologists are concerned that the growing of GM crops might have unforeseen effects on nontarget organisms

Addressing the Problem of Transgene Escape

- Perhaps the most serious concern is the possibility of introduced genes escaping into related weeds through crop-to-weed hybridization

- Efforts are underway to prevent this by introducing:
  - Male sterility
  - Apomixis
  - Transgenes into chloroplast DNA (not transferred by pollen)
  - Strict self-pollination

Fig. 38-UN1

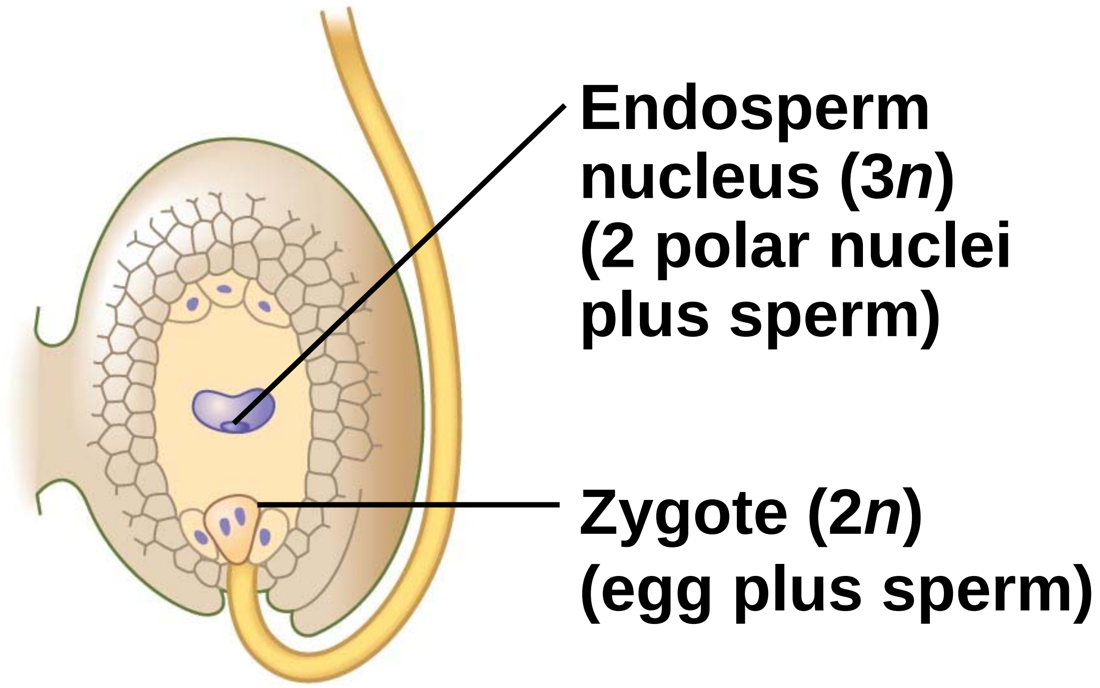
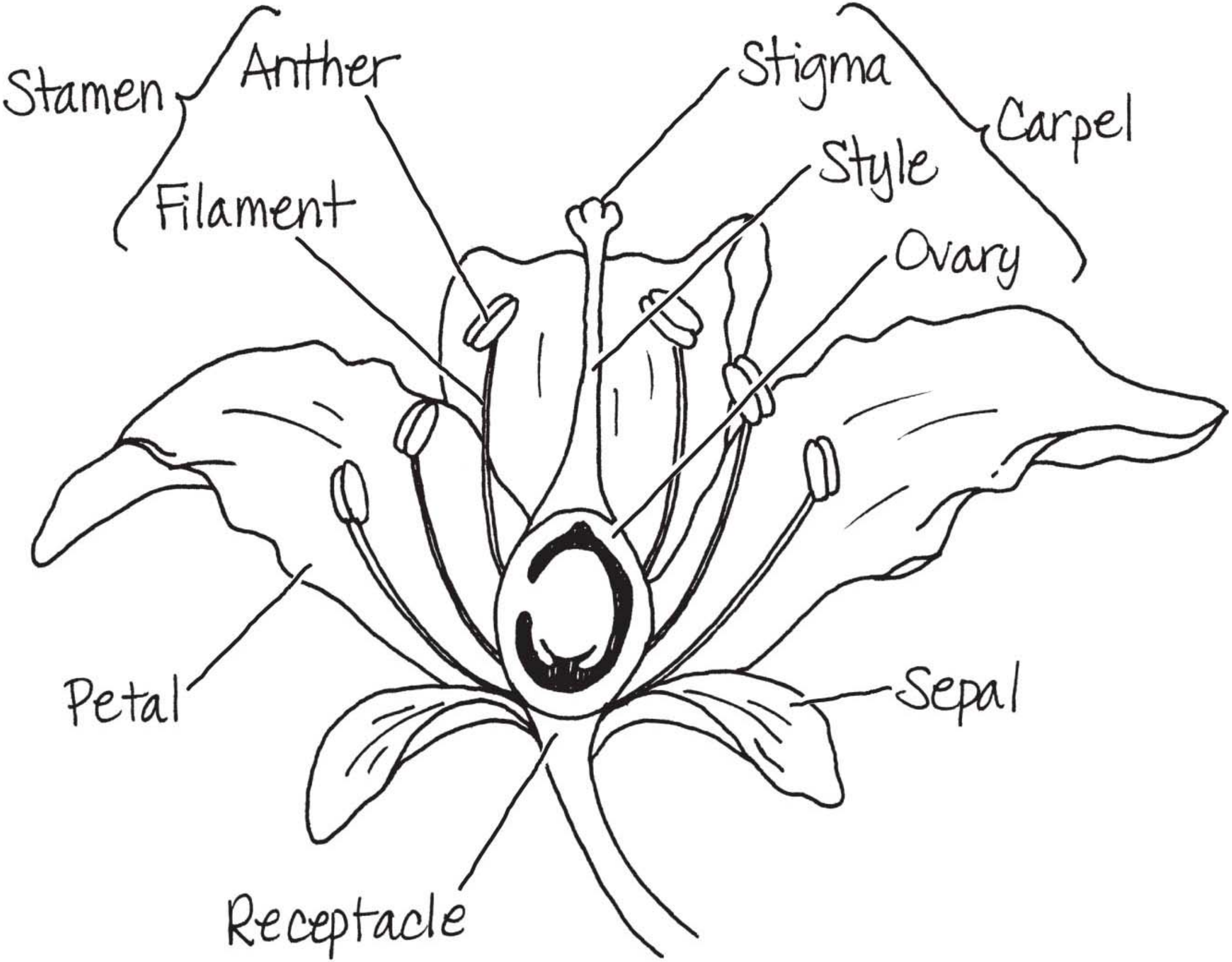

Endosperm nucleus (3*n*) (2 polar nuclei plus sperm)
Zygote (2*n*) (egg plus sperm)

Fig. 38-UN2



Stamen
Anther
Filament
Stigma
Carpel
Style
Ovary
Petal
Sepal
Receptacle

You should now be able to:

1. Describe how the plant life cycle is modified in angiosperms
2. Identify and describe the function of a sepal, petal, stamen (filament and anther), carpel (style, ovary, ovule, and stigma), seed coat, hypocotyl, radicle, epicotyl, endosperm, cotyledon

You should now be able to:

3. Distinguish between complete and incomplete flowers; bisexual and unisexual flowers; microspores and megaspores; simple, aggregate, multiple, and accessory fruit
4. Describe the process of double fertilization
5. Describe the fate and function of the ovule, ovary, and endosperm after fertilization

6. Explain the advantages and disadvantages of reproducing sexually and asexually
7. Name and describe several natural and artificial mechanisms of asexual reproduction
8. Discuss the risks of transgenic crops and describe four strategies that may prevent transgene escape