Chapter 24

Reproduction and Development of Flowering Plants

Beekeeper: ©Liu Jin/AFP/Getty Images; honey bee: ©Stephen Dalton/Science Source

Most Angiosperms Reproduce Sexually

Flowers are the sex organs of angiosperms. This bee is gathering pollen that might deliver sperm to the next flower it visits.

Most Angiosperms Reproduce Sexually

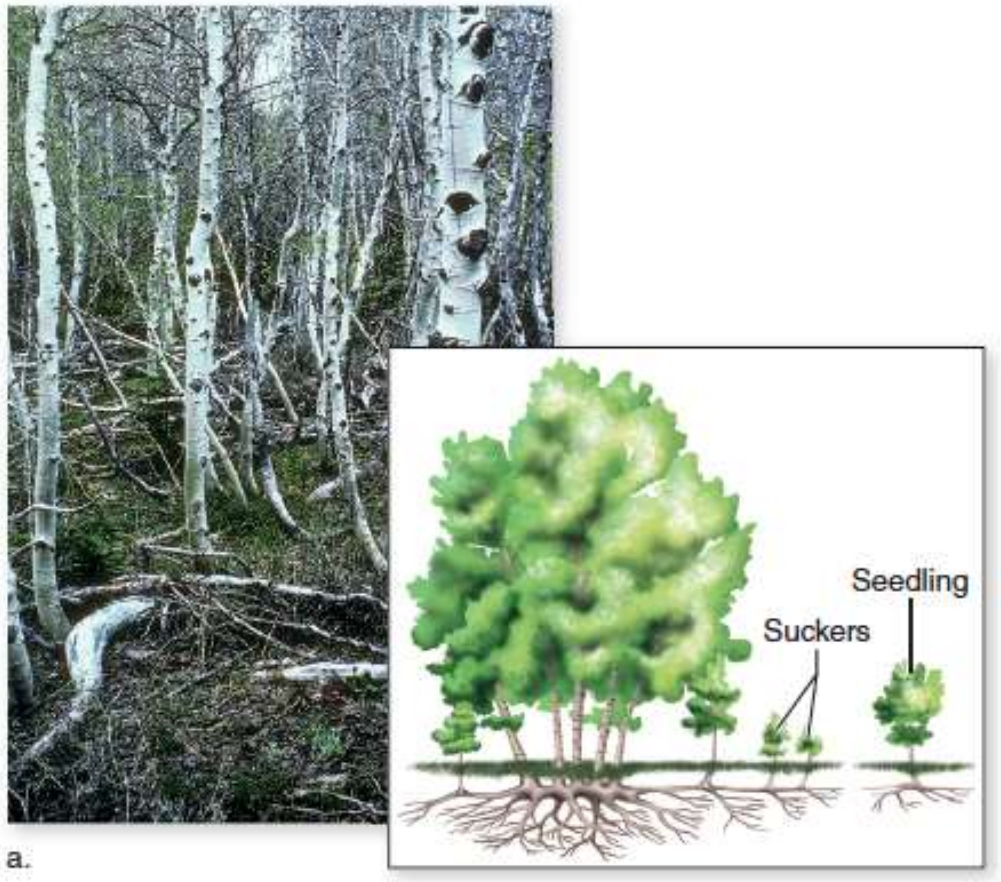
This ant is carrying a seed, which developed from a fertilized egg cell.

Most Angiosperms Reproduce Sexually

Flowers and seeds are produced by angiosperms that **sexually reproduce**, yielding genetically unique offspring with traits derived from two parents.

Most Angiosperms Reproduce Sexually

Some species of angiosperms also reproduce **asexually**, forming new individuals by mitotic division.



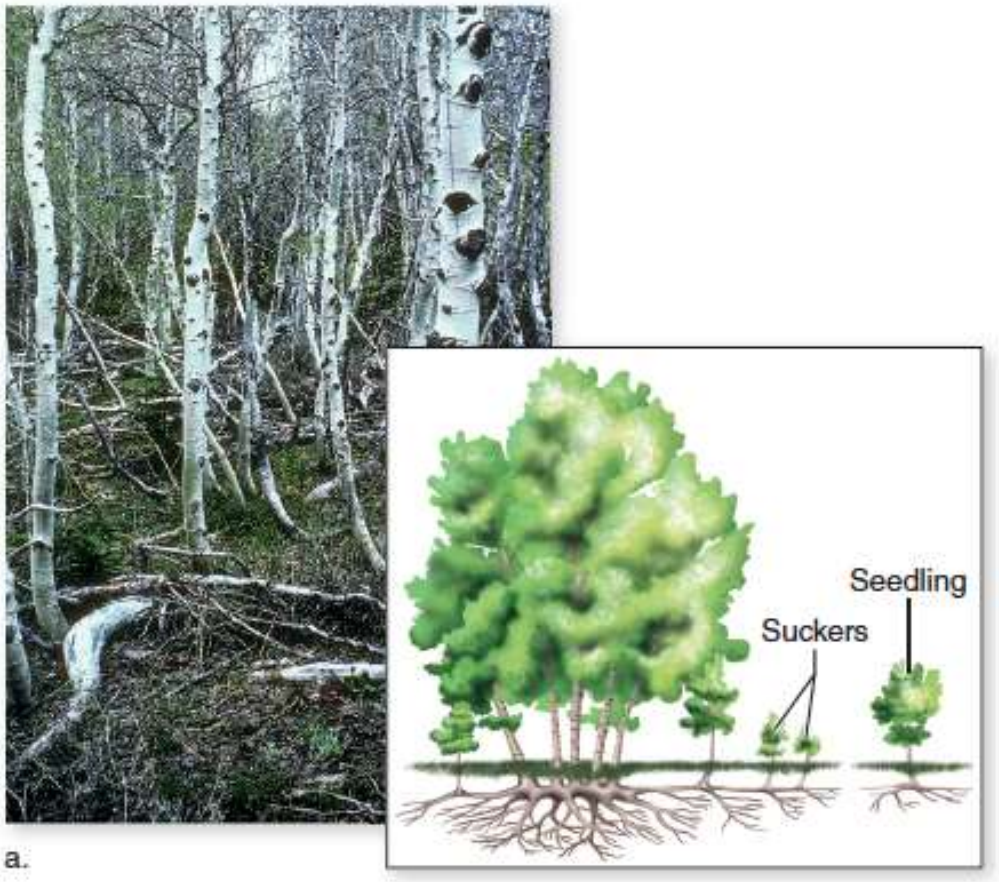
Section 24.1

Aspens: © Steven P. Lynch/The McGraw-Hill Companies

Figure 24.1

Most Angiosperms Reproduce Sexually

Offspring produced asexually are genetically identical to each other and to their parents.



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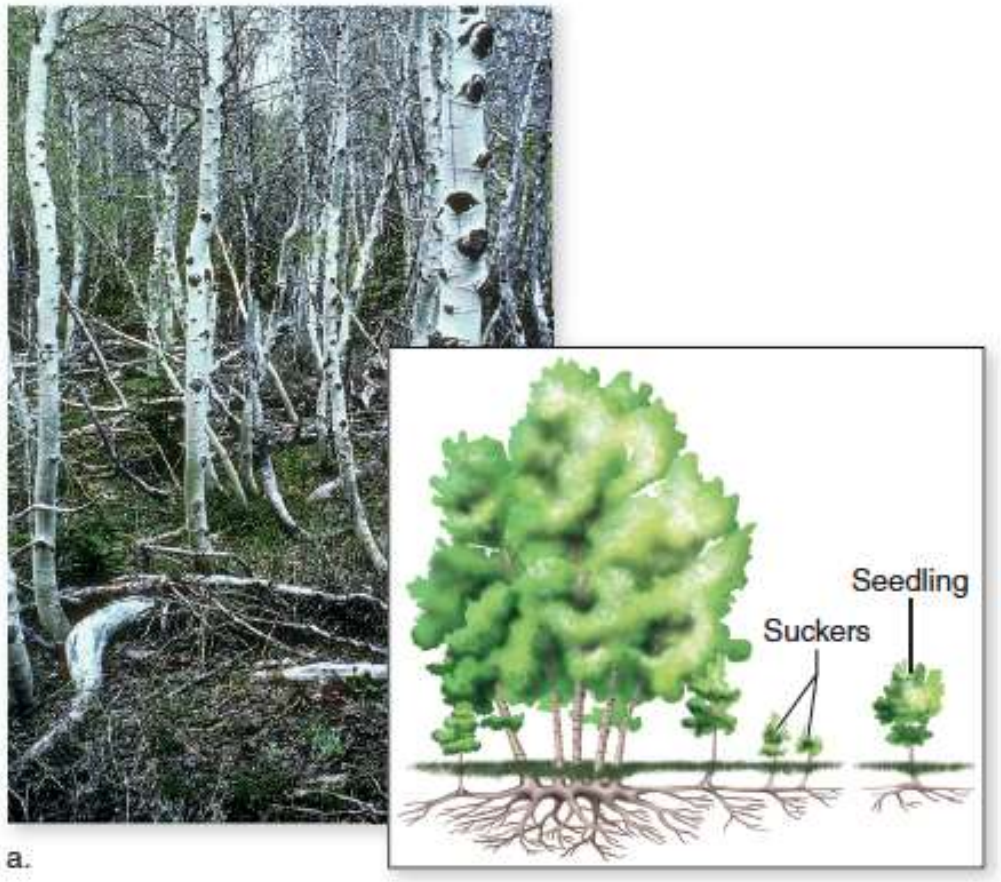
Aspens: © Steven P. Lynch/The McGraw-Hill Companies

Figure 24.1

Most Angiosperms Reproduce Sexually

These aspen trees can reproduce either asexually, as suckers grow from roots, or sexually via seeds.



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Aspens: © Steven P. Lynch/The McGraw-Hill Companies

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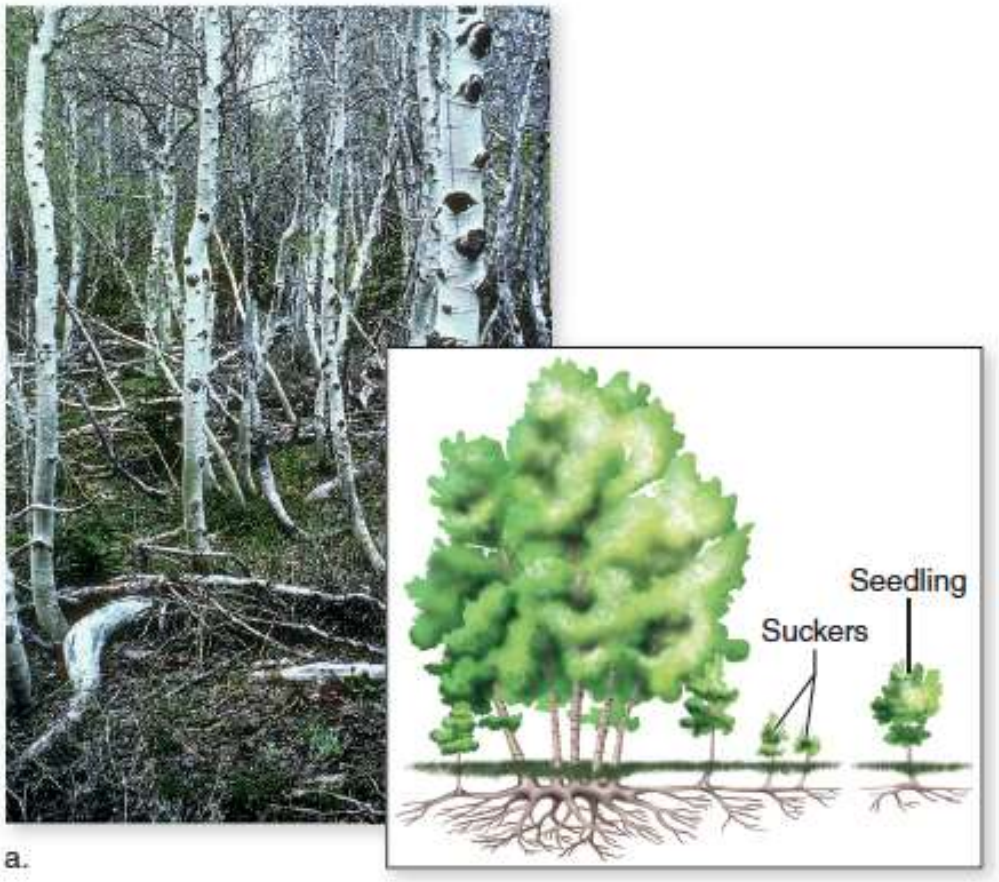


Section 24.1

Aspens: © Steven P. Lynch/The McGraw-Hill Companies

Figure 24.1

Most Angiosperms Reproduce Sexually

Similarly, the leaves of this kalanchoe plant produce genetically identical plantlets.

Section 24.1

Kalanchoe: ©R Koenig/age fotostock

Figure 24.1

Most Angiosperms Reproduce Sexually

Asexual reproduction is advantageous when conditions are stable and plants are well-adapted to their surroundings.

Sexual reproduction produces variable offspring, increasing reproductive success in a changing world.




Section 24.1

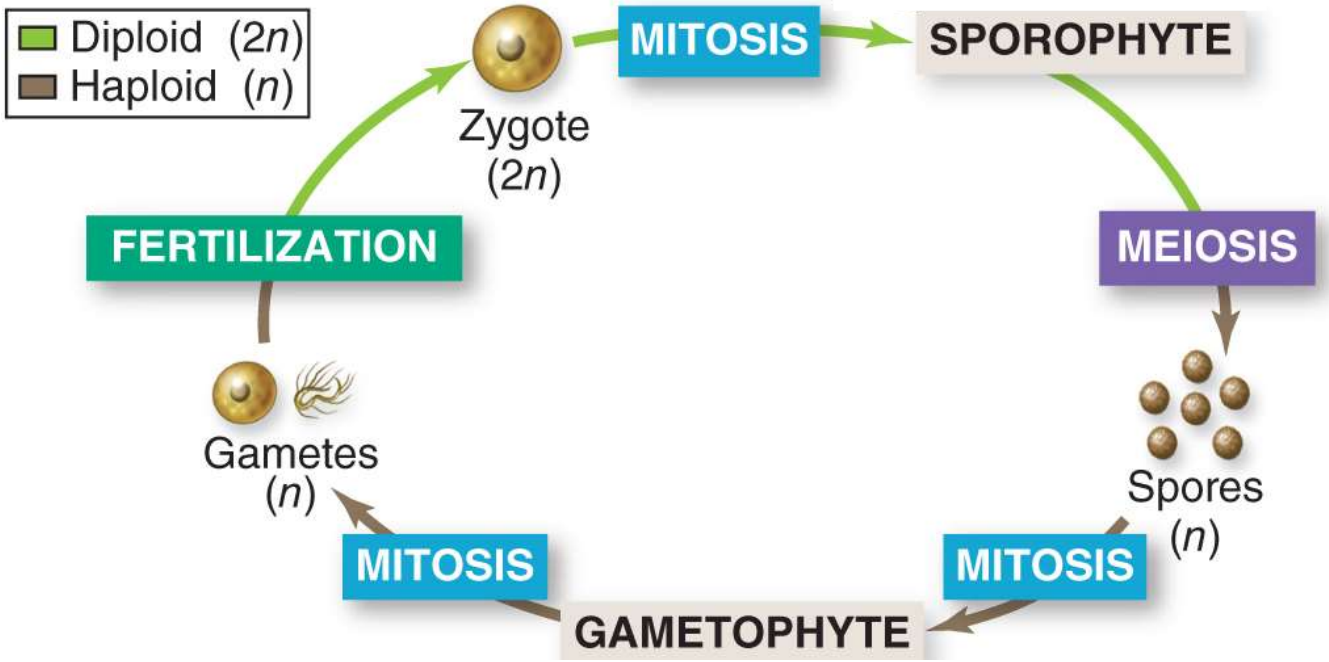
Figure 24.1

24.1 Mastering Concepts

When are sexual and asexual reproduction each adaptive?

Angiosperm Sex: Flowers, Fruits, and Seeds

The angiosperm life cycle is an alternation of generations with multicellular diploid and haploid stages.



Angiosperm Sex: Flowers, Fruits, and Seeds

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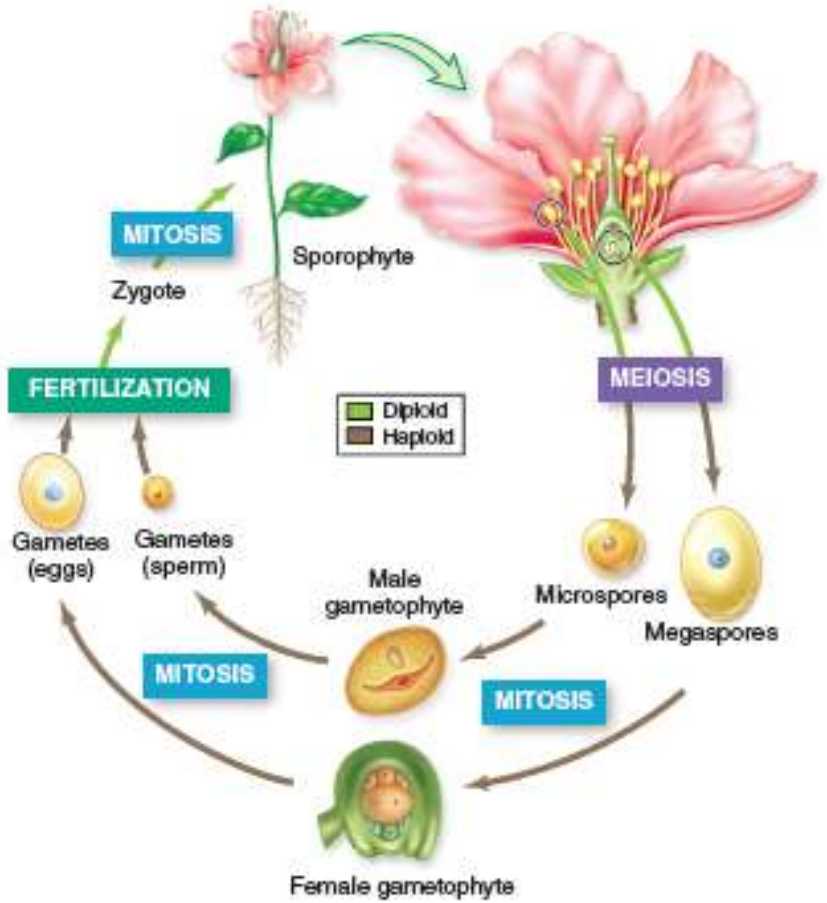


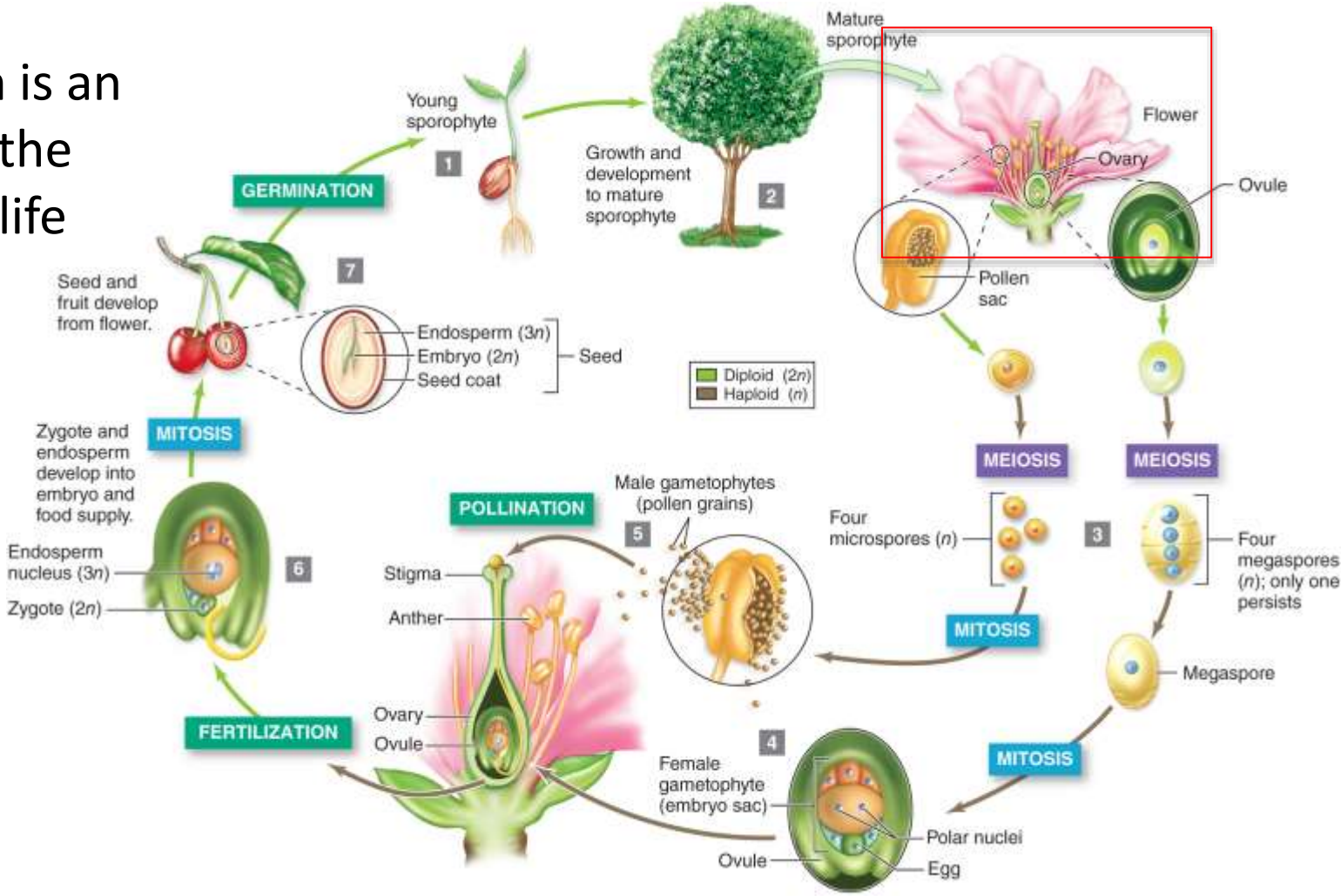
Section 24.2

Figure 24.3

Angiosperm Sex: Flowers, Fruits, and Seeds

This diagram is an overview of the angiosperm life cycle.

Let's start with the flower.



Section 24.2

Figure 24.4

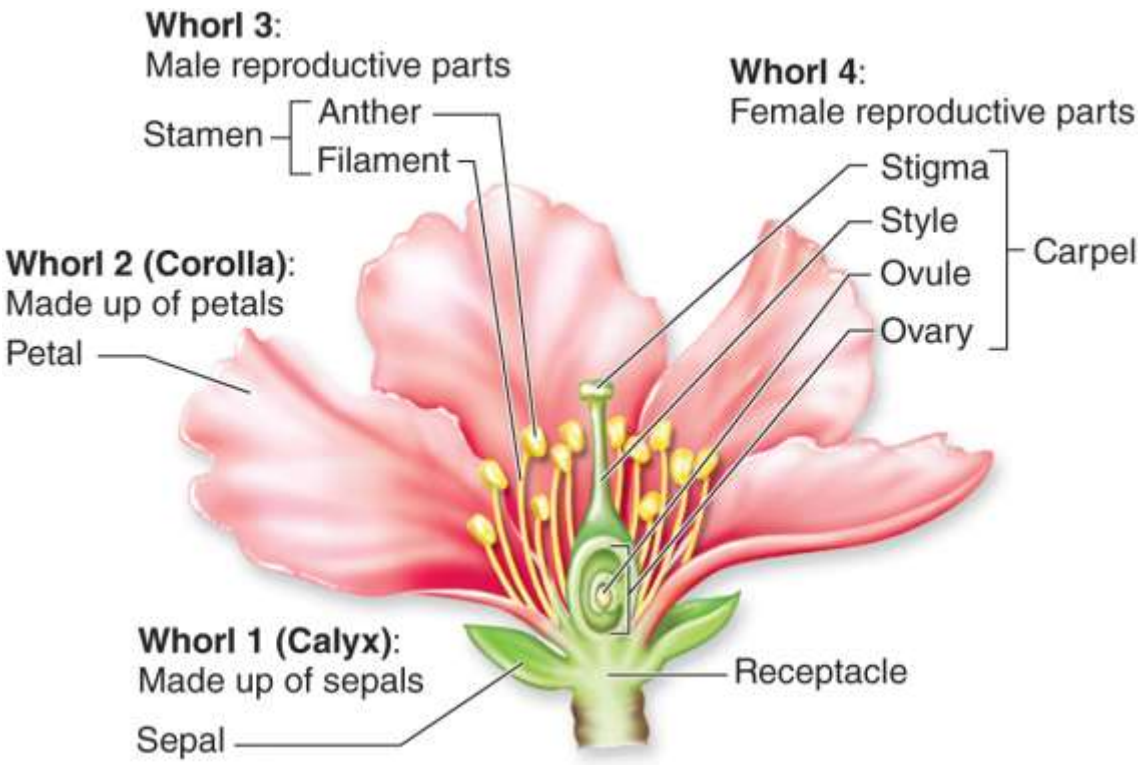
Angiosperm Sex: Flowers, Fruits, and Seeds

The first step in angiosperm reproduction is the formation of flowers on the mature sporophyte.

Figure 24.5

Angiosperm Sex: Flowers, Fruits, and Seeds

A typical flower has four whorls of structures, all of which are modified leaves.

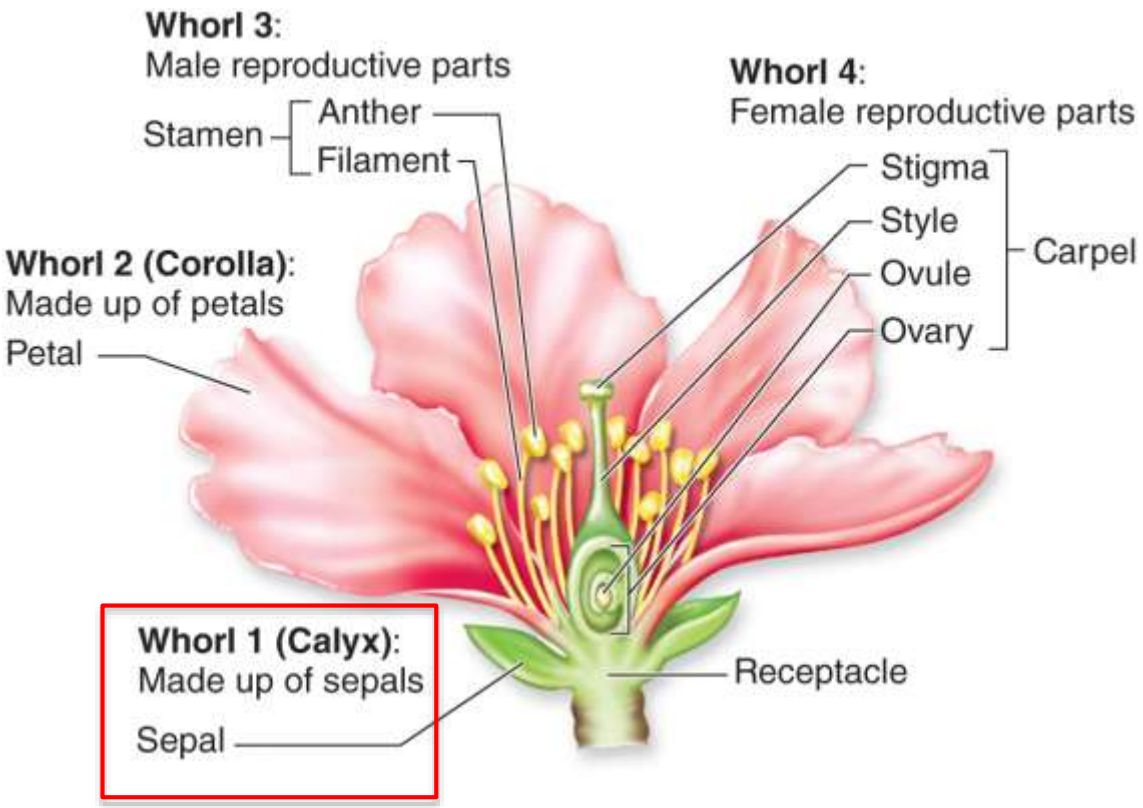


Section 24.2

Figure 24.5

Angiosperm Sex: Flowers, Fruits, and Seeds

The outer whorl is the **calyx**. It consists of sepals, which enclose and protect the inner floral parts.

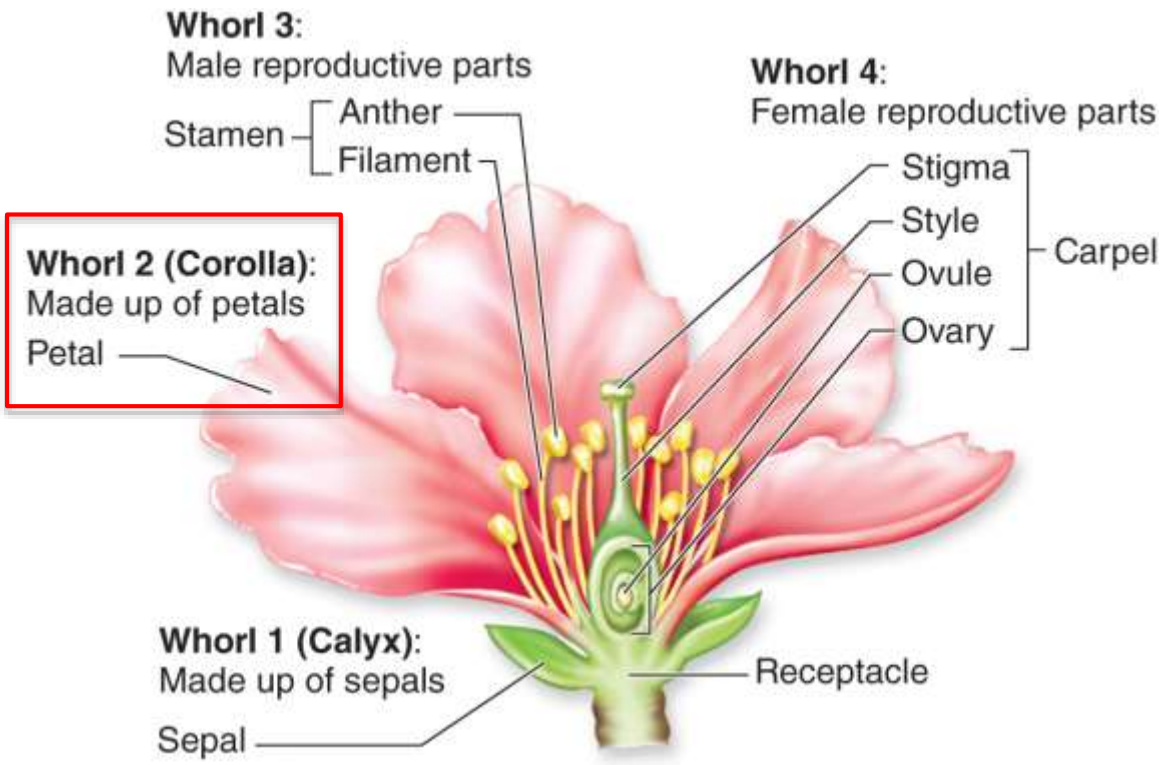


Section 24.2

Figure 24.5

Angiosperm Sex: Flowers, Fruits, and Seeds

The second whorl is the **corolla**, which is made of petals.

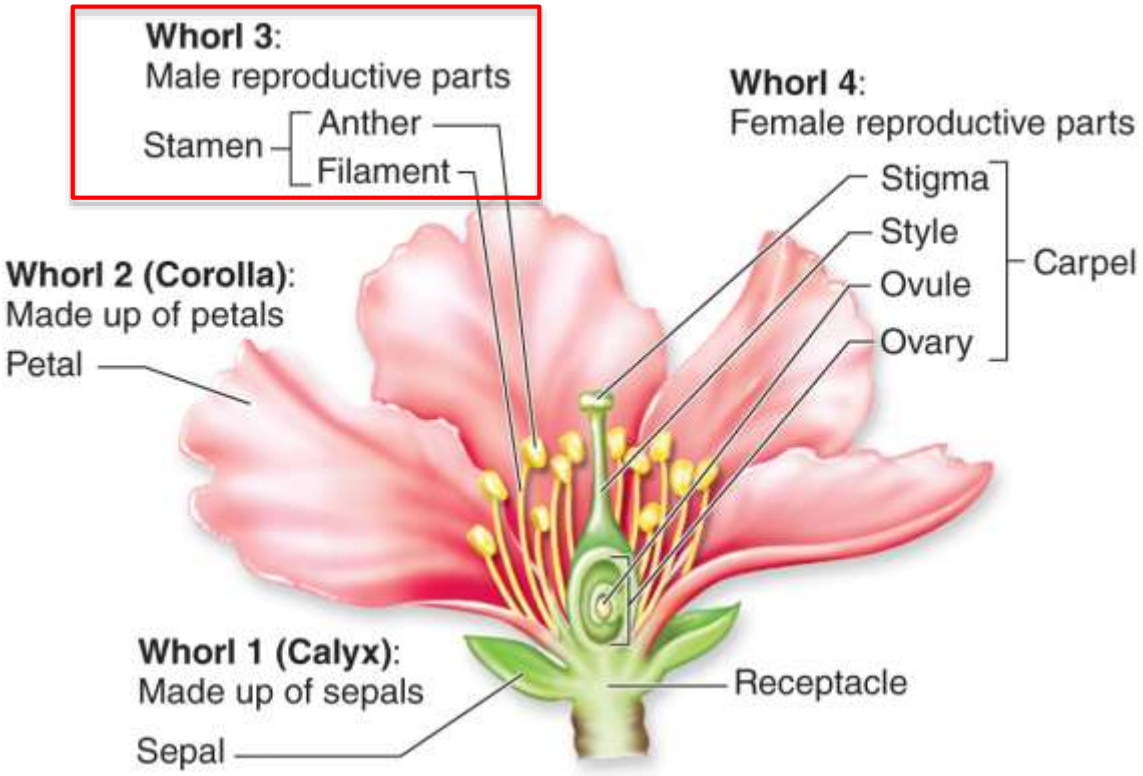


Section 24.2

Figure 24.5

Angiosperm Sex: Flowers, Fruits, and Seeds

The third whorl is the male reproductive parts. **Stamens** are filaments with pollen-producing anthers on top.

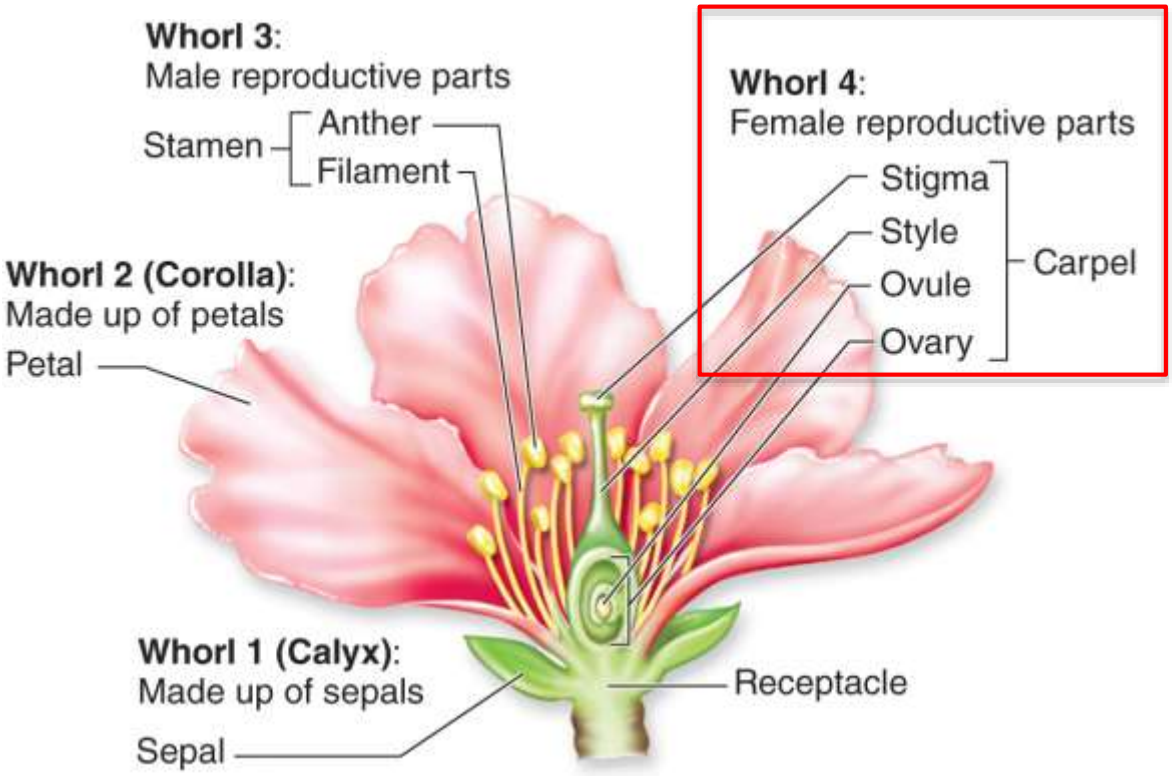


Section 24.2

Figure 24.5

Angiosperm Sex: Flowers, Fruits, and Seeds

The fourth whorl is the female reproductive parts. A **carpel** includes:
-the ovary, which encloses one or more ovules.
-a stalklike style. The top of the style, called the stigma, receives pollen.

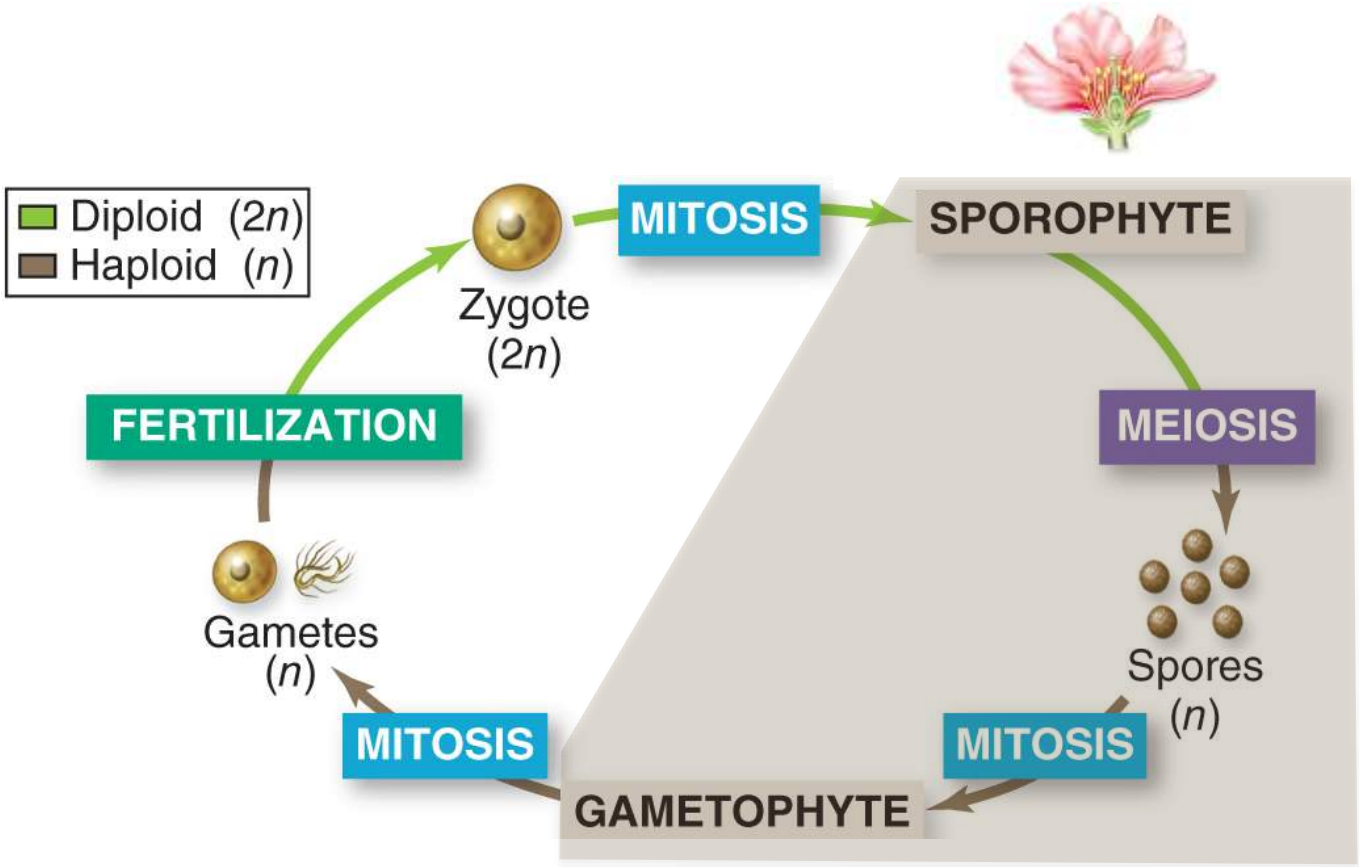


Section 24.2

Figure 24.5

Angiosperm Sex: Flowers, Fruits, and Seeds

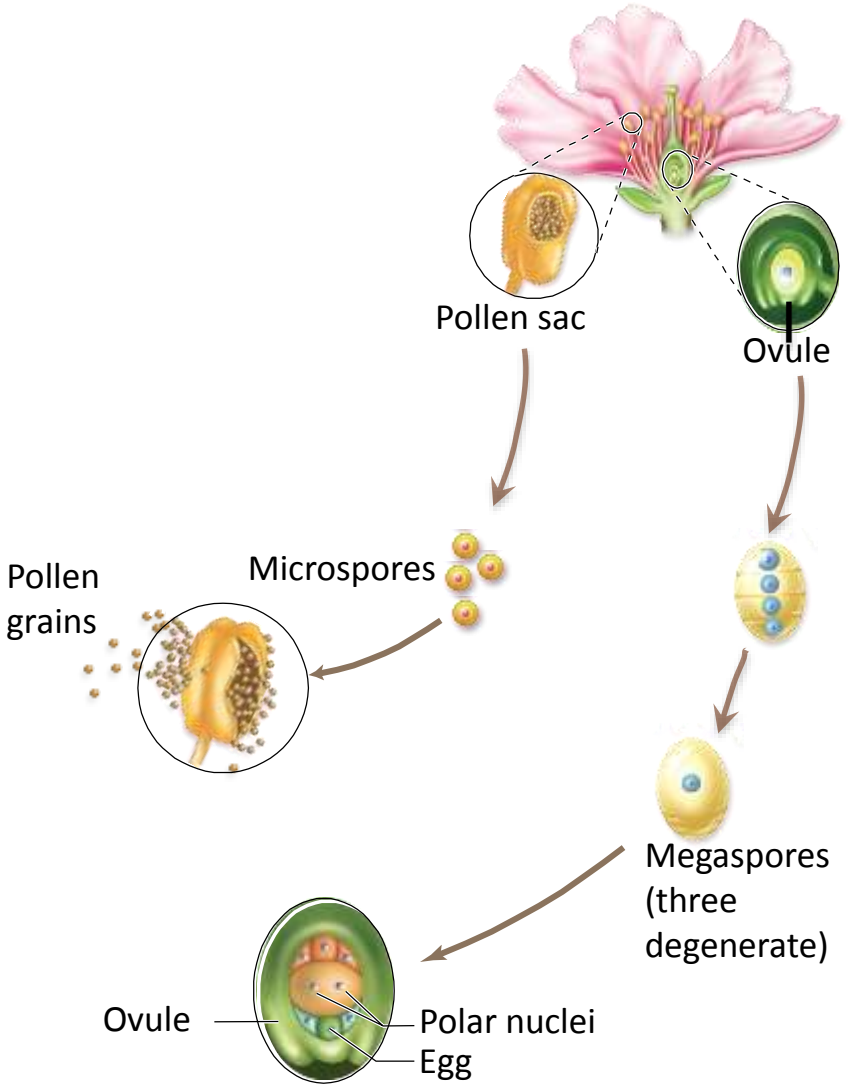
Inside the flower, meiosis produces haploid spores that develop into gametophytes.



Angiosperm Sex: Flowers, Fruits, and Seeds

Anthers produce **microspores**, which divide into male gametophytes (**pollen grains**).

Ovules produce **megaspores**, which divide into female gametophytes (**embryo sacs**).



Section 24.2

Figure 24.4

Angiosperm Sex: Flowers, Fruits, and Seeds

Some flowers release pollen grains in the wind.

Figure 24.6

Angiosperm Sex: Flowers, Fruits, and Seeds

Other flowers attract animal pollinators, which unwittingly carry pollen between plants.

Angiosperm Sex: Flowers, Fruits, and Seeds

Often, the pollinator benefits from its association with plants—animals use plants for food, shelter, or a mating ground.

Section 24.2

Hummingbird: © Corbis RF; butterfly: © MedioImages/Getty Images RF; bat: © Merlin D. Tuttle/Bat Conservation International/Science Source

Figure 24.6

Clicker Question #1

An “imperfect” flower is one that lacks either male or female parts. A flower lacking male parts would still produce

A. pollen.
B. anthers.
C. an embryo sac.
D. egg cells.
E. Both an embryo sac and eggs cells are correct.

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A. pollen.
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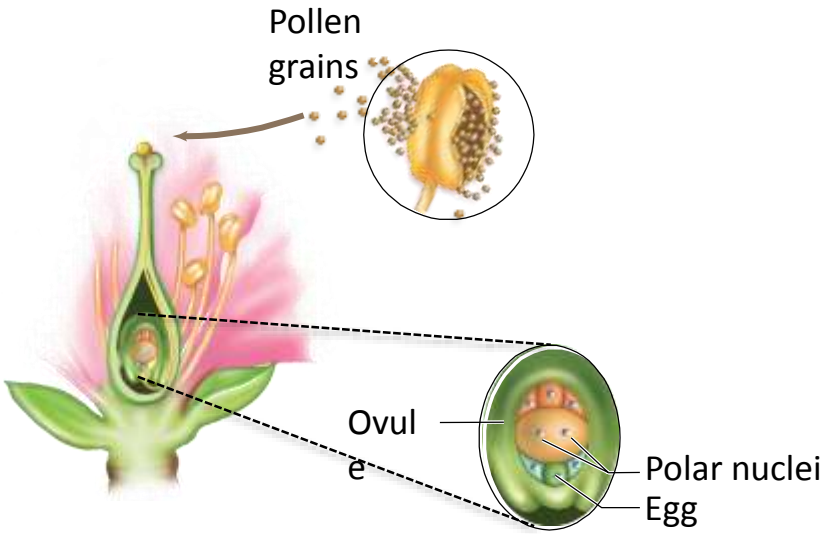
Angiosperm Sex: Flowers, Fruits, and Seeds

If a pollen grain lands on a receptive stigma, **pollination** occurs.

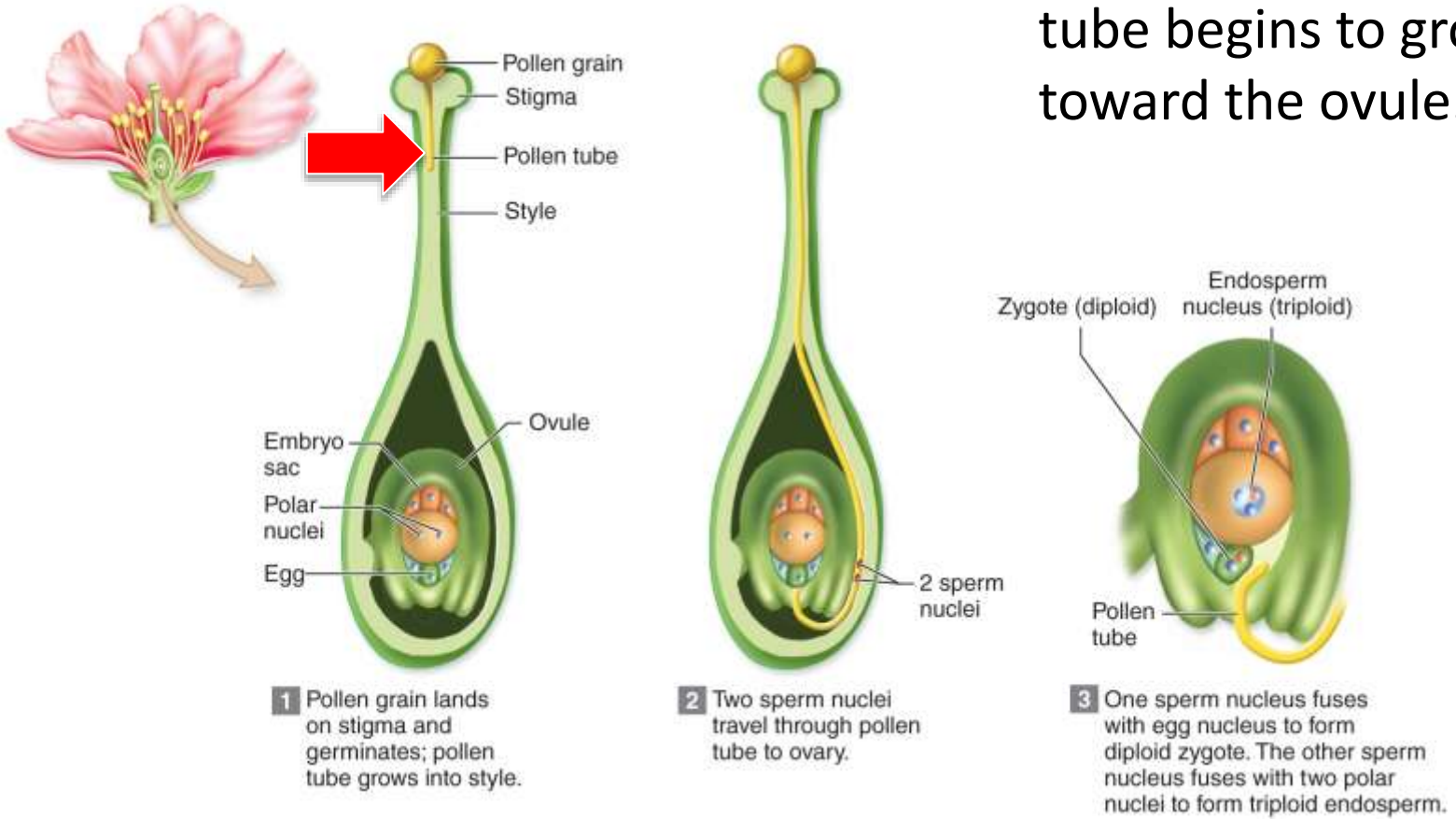


Section 24.2

Figure 24.4

Angiosperm Sex: Flowers, Fruits, and Seeds

When the pollen grain germinates, a pollen tube begins to grow toward the ovule.

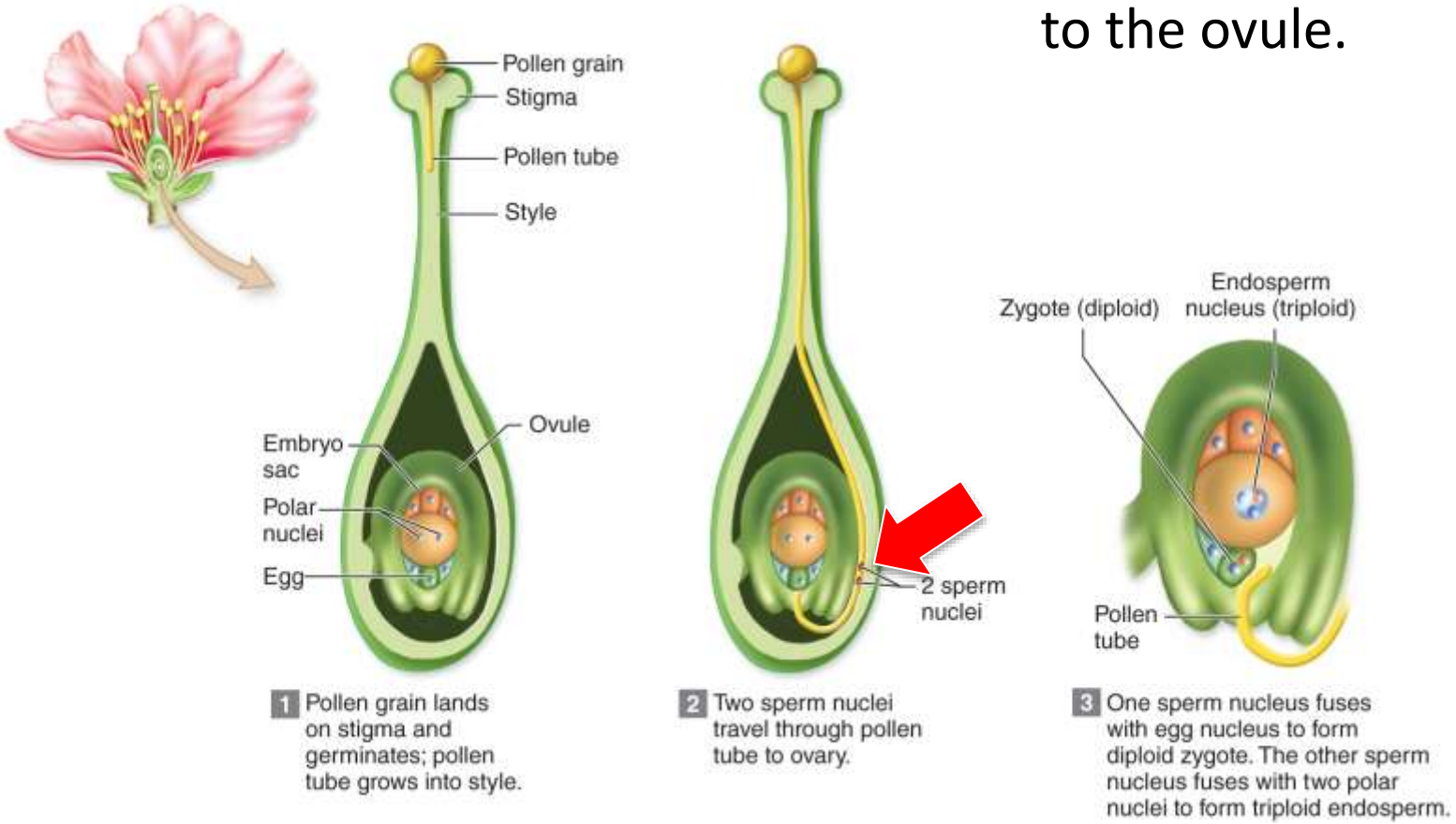


Section 24.2

Figure 24.7

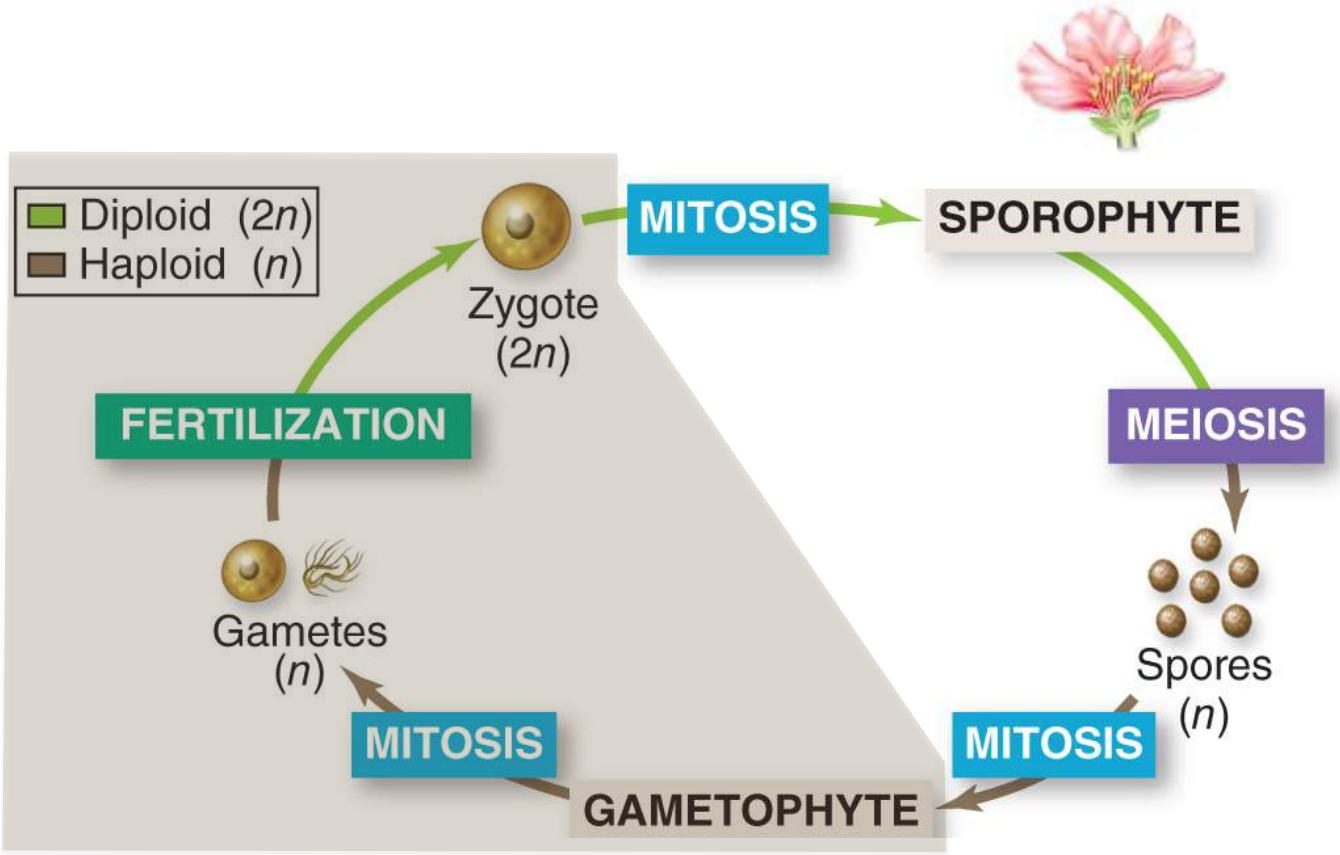
Angiosperm Sex: Flowers, Fruits, and Seeds

Two sperm nuclei travel through the pollen tube to the ovule.



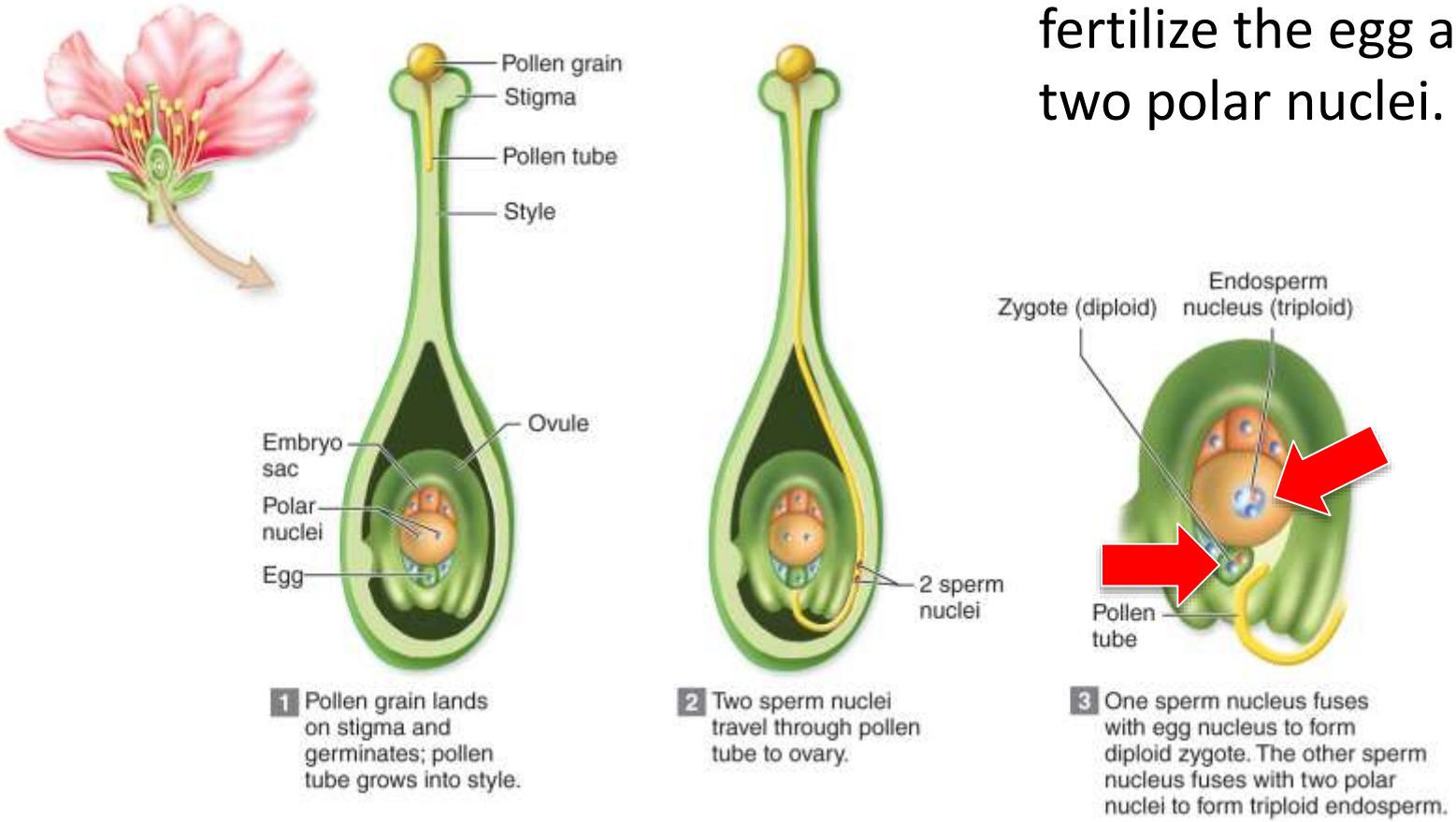
Angiosperm Sex: Flowers, Fruits, and Seeds

The stage is now set for fertilization.



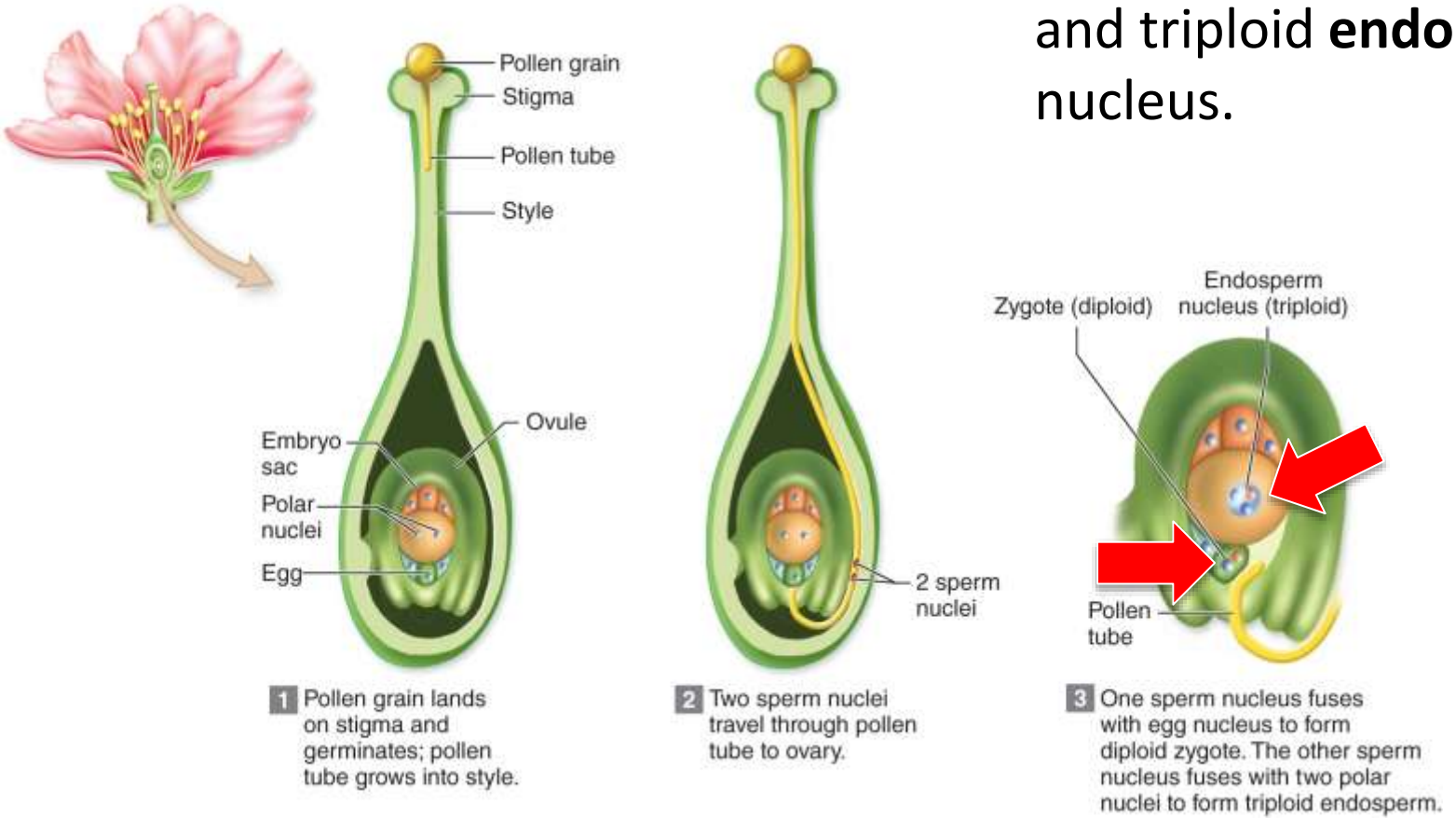
Angiosperm Sex: Flowers, Fruits, and Seeds

In **double fertilization**, these sperm nuclei fertilize the egg and the two polar nuclei.

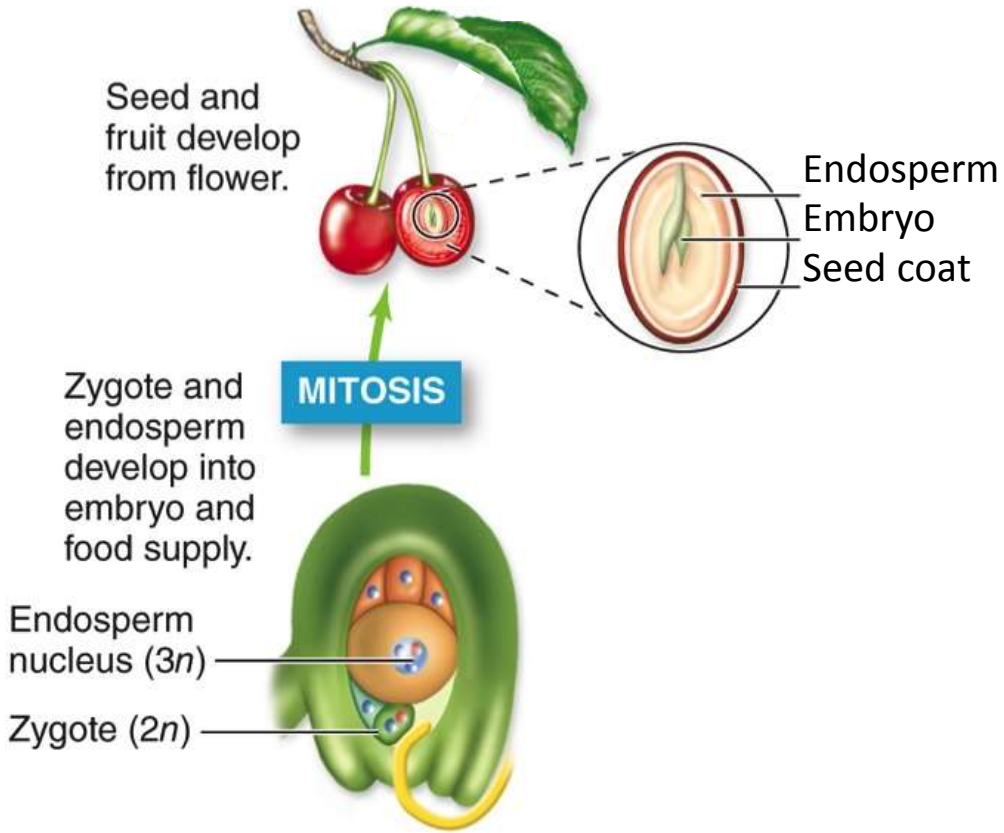


Angiosperm Sex: Flowers, Fruits, and Seeds

Double fertilization results in a diploid zygote and triploid **endosperm** nucleus.



Angiosperm Sex: Flowers, Fruits, and Seeds



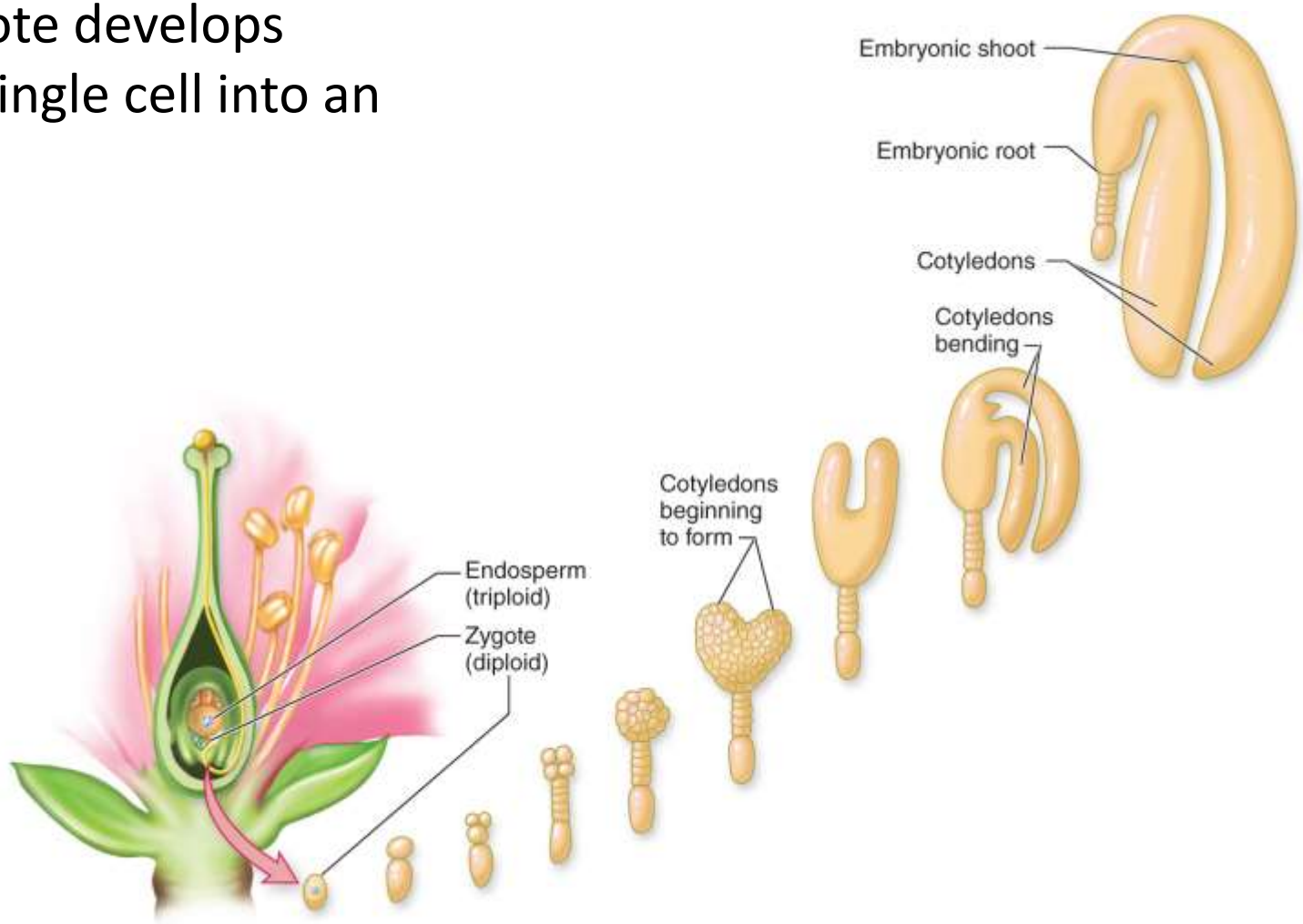
After fertilization, the seed starts to develop.

A **seed** consists of an embryo, endosperm, and seed coat.

Figure 24.4

Angiosperm Sex: Flowers, Fruits, and Seeds

The zygote develops from a single cell into an embryo.

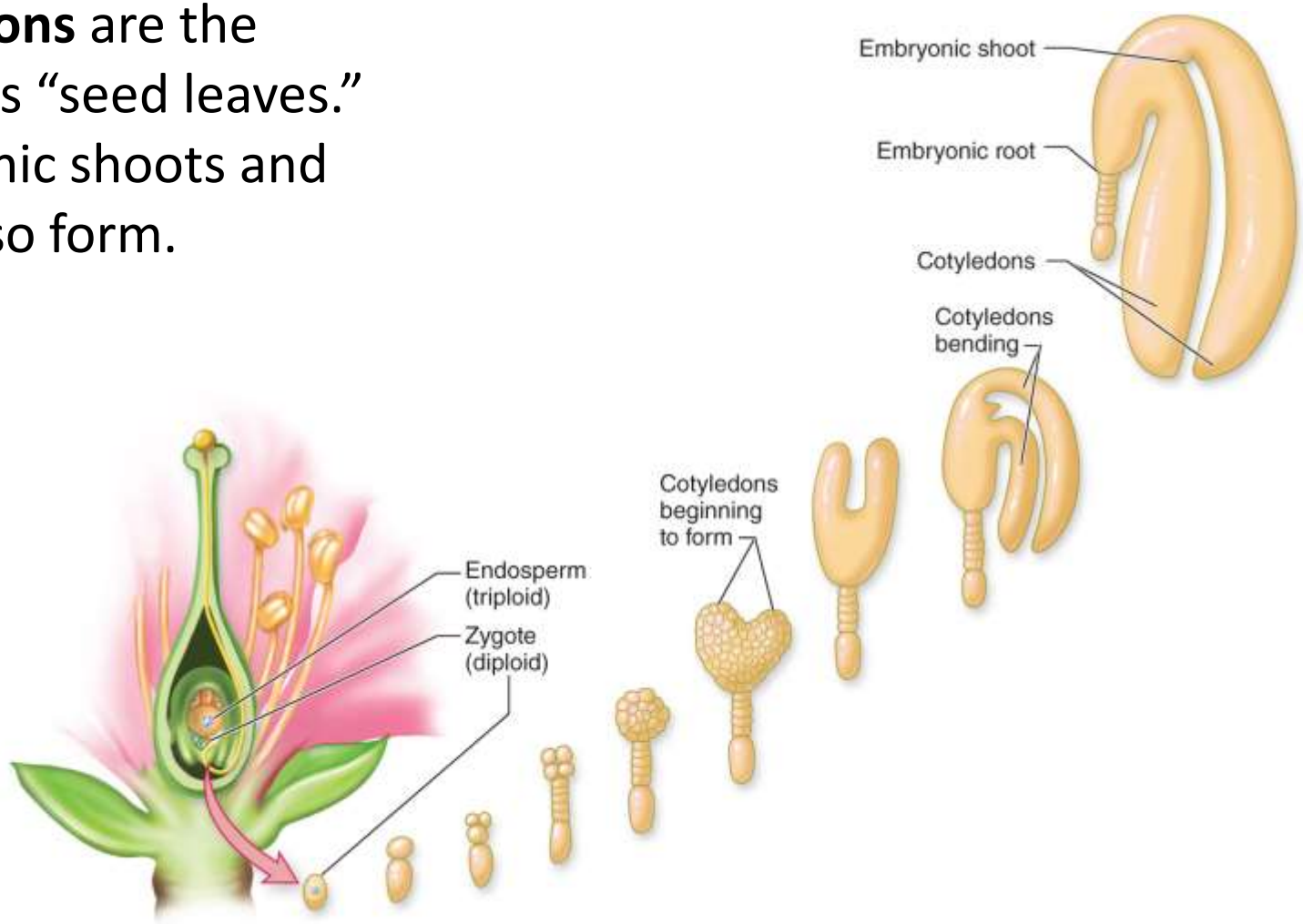


Section 24.2

Figure 24.9

Angiosperm Sex: Flowers, Fruits, and Seeds

Cotyledons are the embryo's "seed leaves." Embryonic shoots and roots also form.

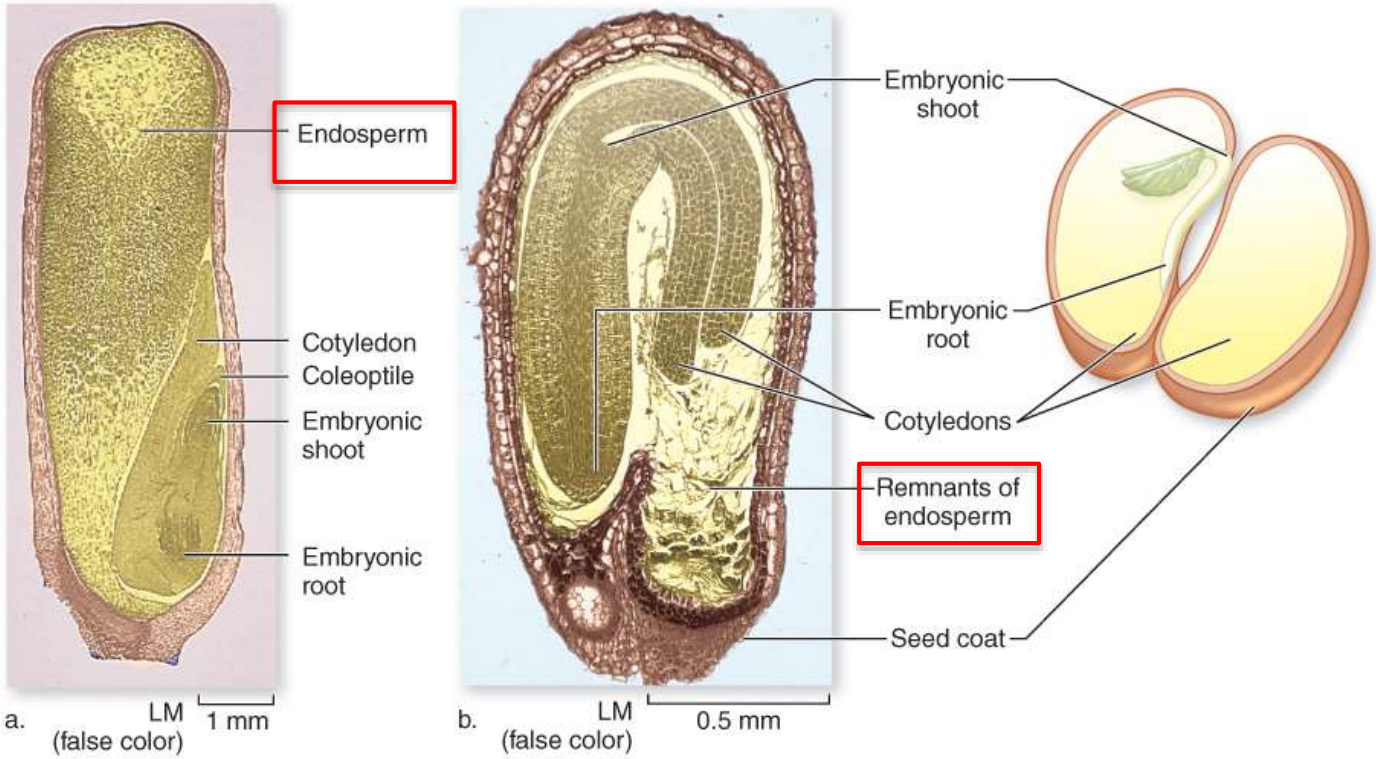


Section 24.2

Figure 24.9

Angiosperm Sex: Flowers, Fruits, and Seeds

Endosperm cells divide rapidly and nourish the embryo.

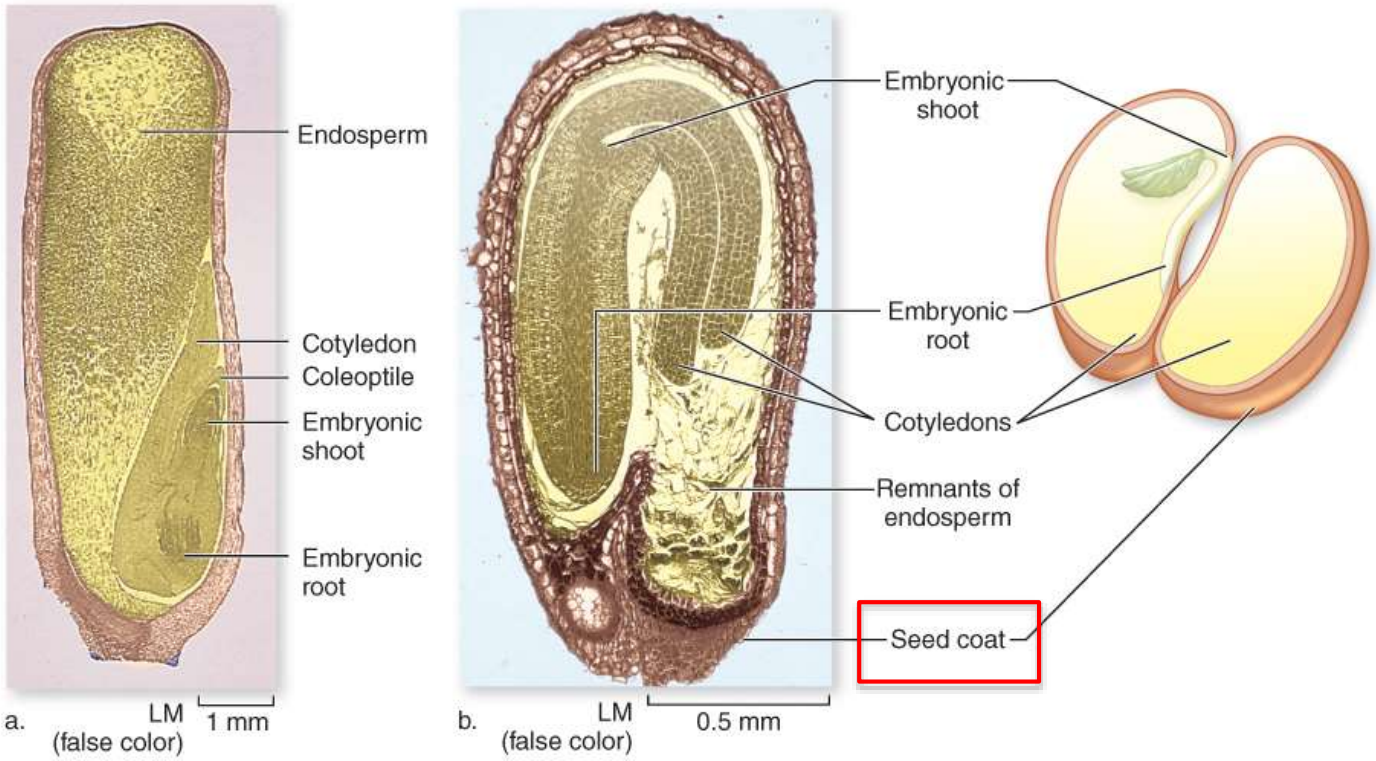


Section 24.2

Figure 24.8

Angiosperm Sex: Flowers, Fruits, and Seeds

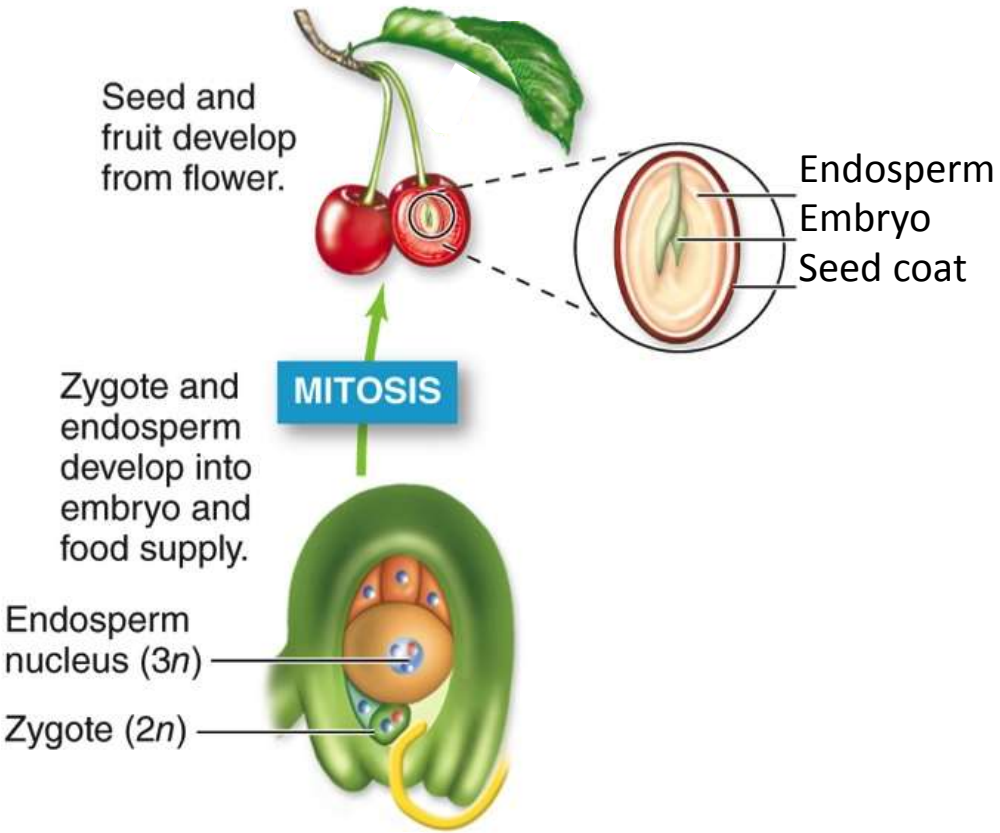
The **seed coat** is a tough outer layer that protects the embryo from damage, dehydration, and predators.



Section 24.2

Figure 24.8

Angiosperm Sex: Flowers, Fruits, and Seeds



At the same time, a **fruit** develops from the ovary enclosing the developing seed(s).

Section 24.2

Figure 24.4

Angiosperm Sex: Flowers, Fruits, and Seeds

These photos show how the fruit forms.
After pollination, the flower loses its petals.

Section 24.2

Photos: © Brent Seabrook

Figure 24.10

Angiosperm Sex: Flowers, Fruits, and Seeds

A developing seed releases hormones that trigger fruit formation. The ovary swells.

Figure 24.10

Clicker Question #2

Angiosperms and humans reproduce sexually. Pollination in plants is analogous to ___ in humans; seed development in plants is analogous to ___ in humans.

A. sexual intercourse; growth of the fetus
B. dating; going through puberty
C. fertilization; early childhood
D. gamete formation; birth
E. None of the choices is correct.

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Angiosperm Sex: Flowers, Fruits, and Seeds

Fruits come in many forms.

Fruit Type	Characteristics	Example(s)
Simple 	Derived from one flower with one carpel	Olive, cherry, peach, plum, coconut, grape, tomato, pepper, eggplant, apple, pear
Aggregate 	Derived from one flower with many separate carpels	Blackberry, strawberry, raspberry, magnolia
Multiple 	Derived from tightly clustered flowers whose ovaries fuse as the fruit develops	Pineapple

Section 24.2

Table 24.1

Angiosperm Sex: Flowers, Fruits, and Seeds

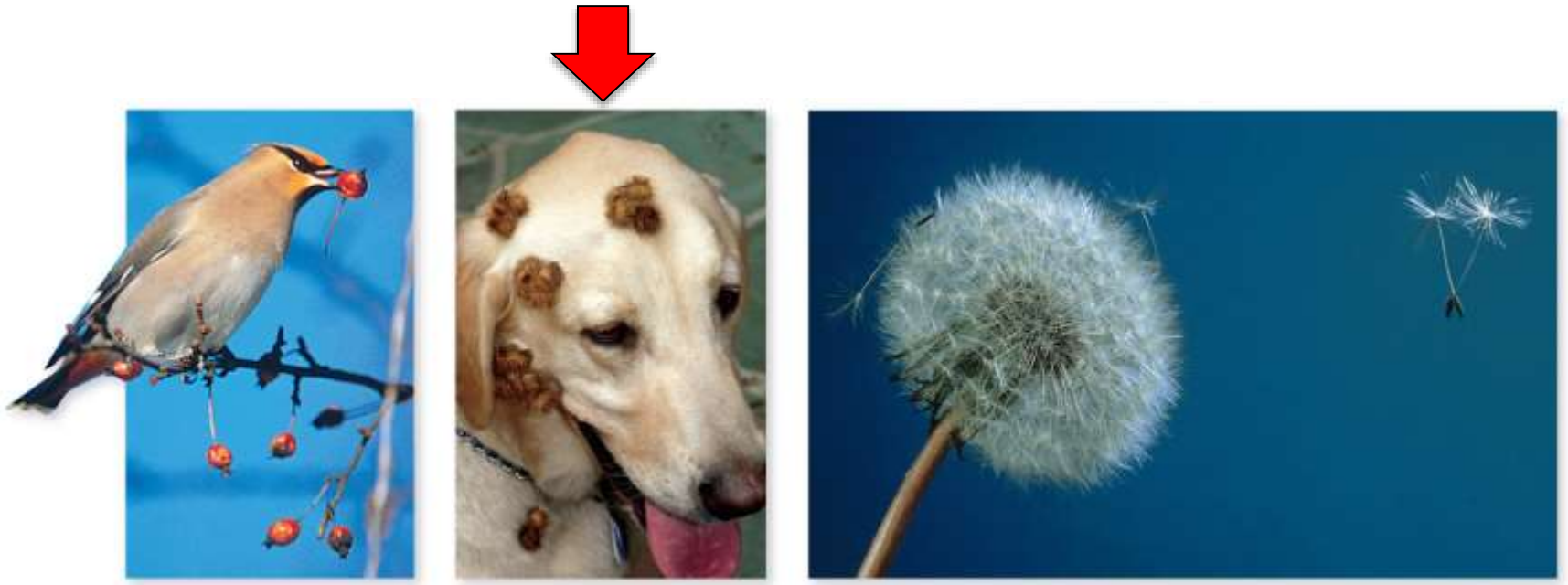
Fruits protect and disperse seeds.
Seeds carried away from parent plants decrease the chance of competition among parents, offspring, and siblings.

Angiosperm Sex: Flowers, Fruits, and Seeds

Unripe fruits, which contain immature seeds, are usually distasteful. Ripe fruits are tasty; mature seeds are deposited in droppings.

Angiosperm Sex: Flowers, Fruits, and Seeds

Prickly fruits stick to feathers or fur.



Angiosperm Sex: Flowers, Fruits, and Seeds

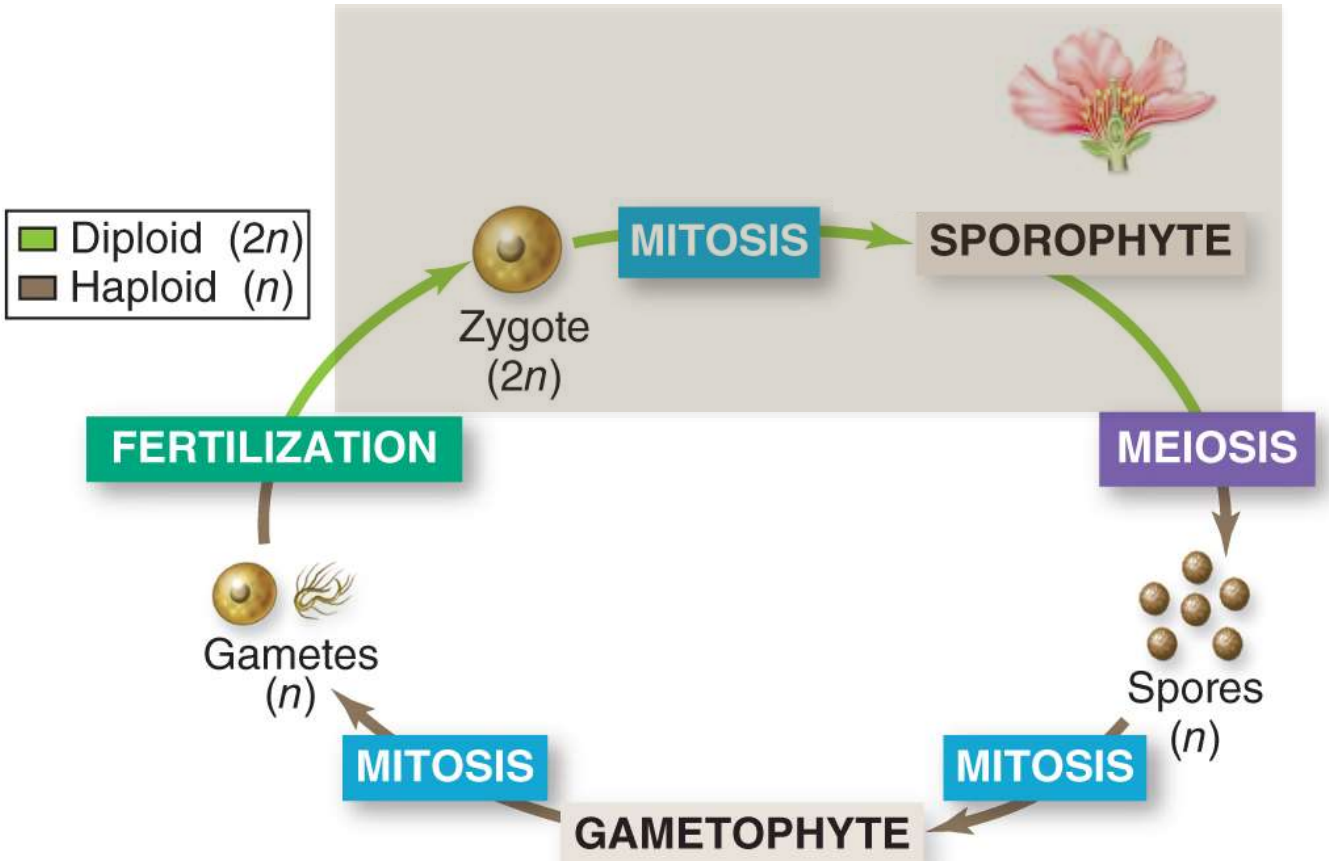
Some fruits catch the wind with tufts of fluff.
Still others float in water currents.

22.2 Mastering Concepts

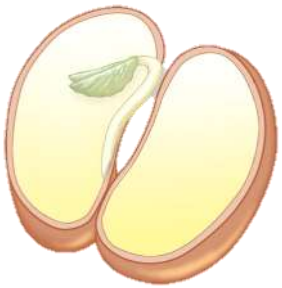
How does pollen move from one flower to another, and why is this process essential for sexual reproduction?

Plant Growth Begins With Seed Germination

How does the embryo continue developing into a mature sporophyte?



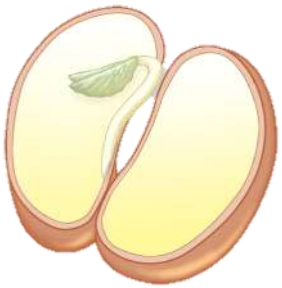
Plant Growth Begins With Seed Germination



Continued development requires seed **germination,** the resumption of growth and development after a period of seed dormancy.

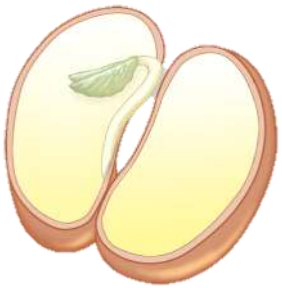
Germination requires water, O_2, and a favorable temperature.

Plant Growth Begins With Seed Germination



The seed absorbs water and swells, rupturing the seed coat and exposing the embryo to O_2.

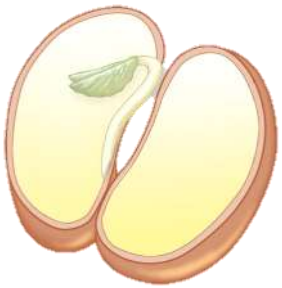
Plant Growth Begins With Seed Germination



Meanwhile, enzymes break down the endosperm's starch into sugars.

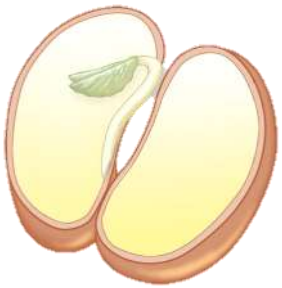
The availability of O_2 and sugars means cellular respiration can resume in the embryo. Cell division at apical meristems rapidly lengthens the young roots and shoot.

Plant Growth Begins With Seed Germination



At first, the only energy source is fuel stored in the endosperm.

Plant Growth Begins With Seed Germination



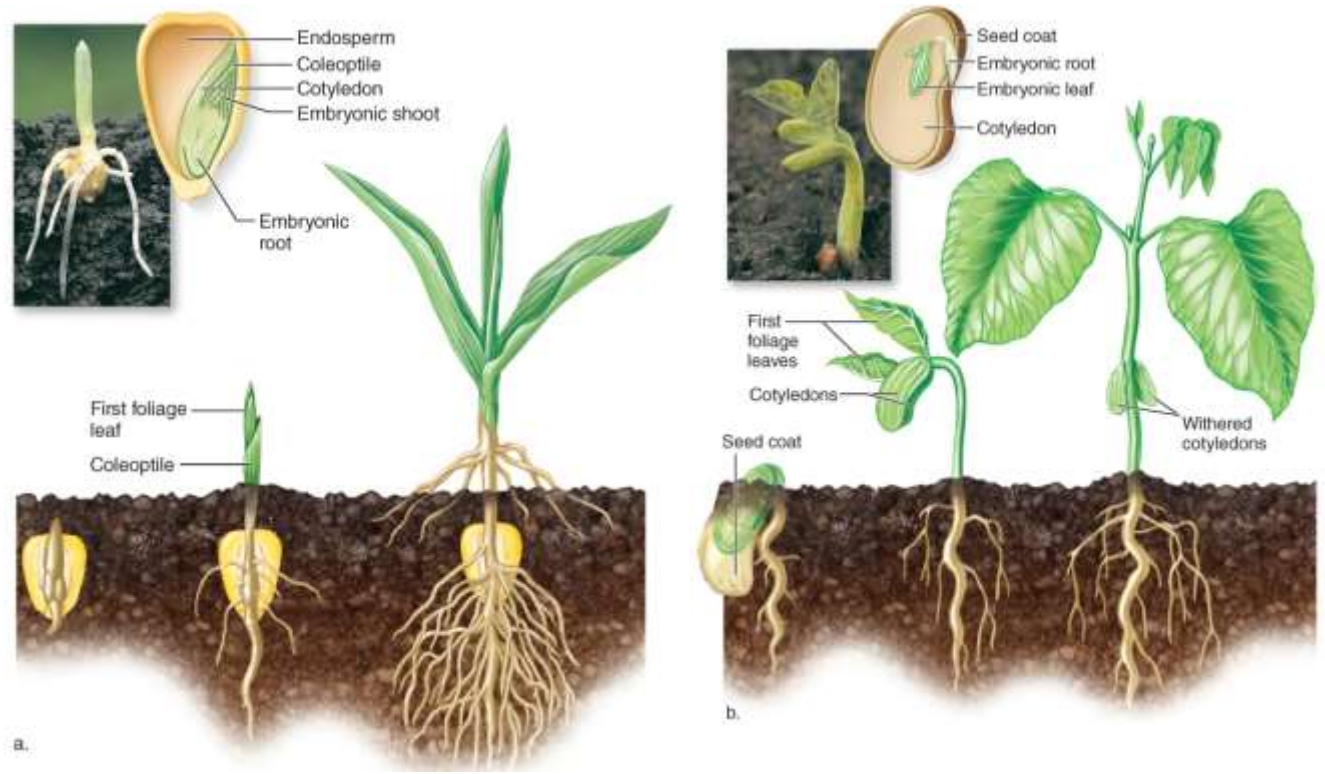
After the shoot emerges from the ground and the first leaves unfold, photosynthesis begins.

Plant Growth Begins With Seed Germination

Monocots and eudicots, two groups of plants, have slightly different development patterns.

Monocot development

Eudicot development



Section 24.3

Corn sprout: ©Dwight Kuhn; bean sprout: ©Ed Reschke

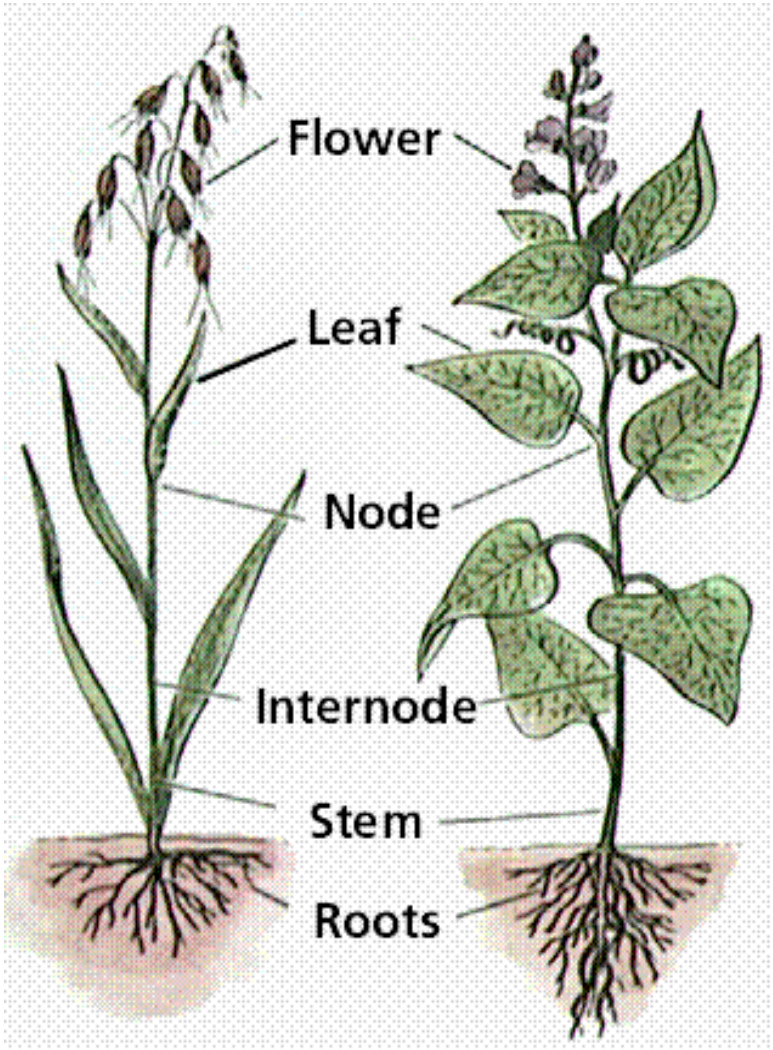
Figure 24.12

Angiosperm Anatomy

Angiosperm Categories

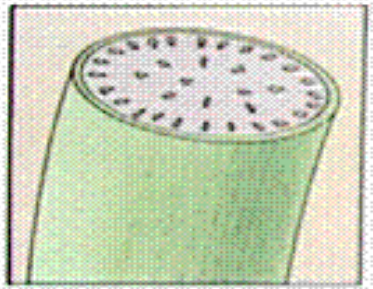
Angiosperms (flowering plants) are divided into two types:
Monocots and Dicots

They differ based on a number of characteristics

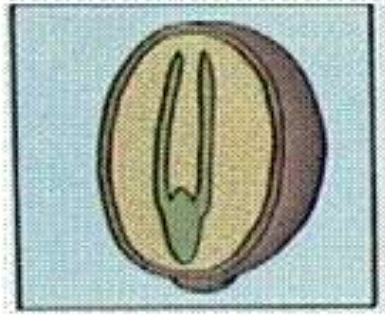
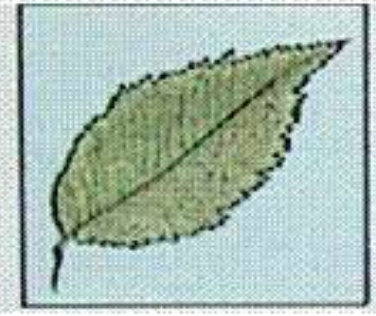
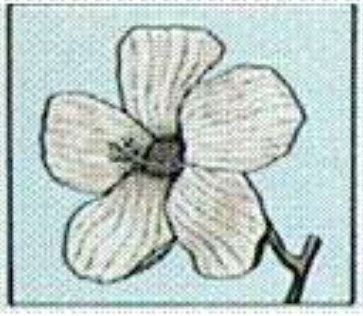
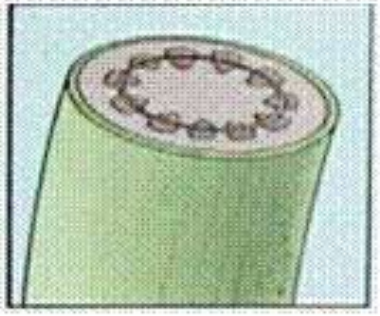


Monocot and Dicot Characteristics

MONOCOTS

Cotyledons	Veins in leaves	Flower parts	Arrangement of primary vascular bundles in stem
			
One cotyledon	Usually Parallel	Usually in multiples of three	Scattered

DICOTS

Two cotyledons	Usually netlike	Usually in fours or fives	In a ring
			

Tissues of the Plant

Dermal tissue: Analogous to our skin

Vascular tissue: Vaguely like a circulatory system

Ground tissue: Support tissue

Dermal Tissue System

Function:

Protection from the environment and water loss

Tissues:

Epidermis - outermost single layer off cells on herbaceous plant parts. May be covered by waxy **cuticle**

Bark - a corky tissue that replaces epidermis on woody plant parts

Vascular Tissue System

Function:

Translocation of water, nutrients, sugars and hormones throughout the plant

Tissues:

Xylem - conducts water and nutrients up roots to stems and leaves

Phloem - conducts water, sugar, hormones, etc. down to roots

Ground Tissue System

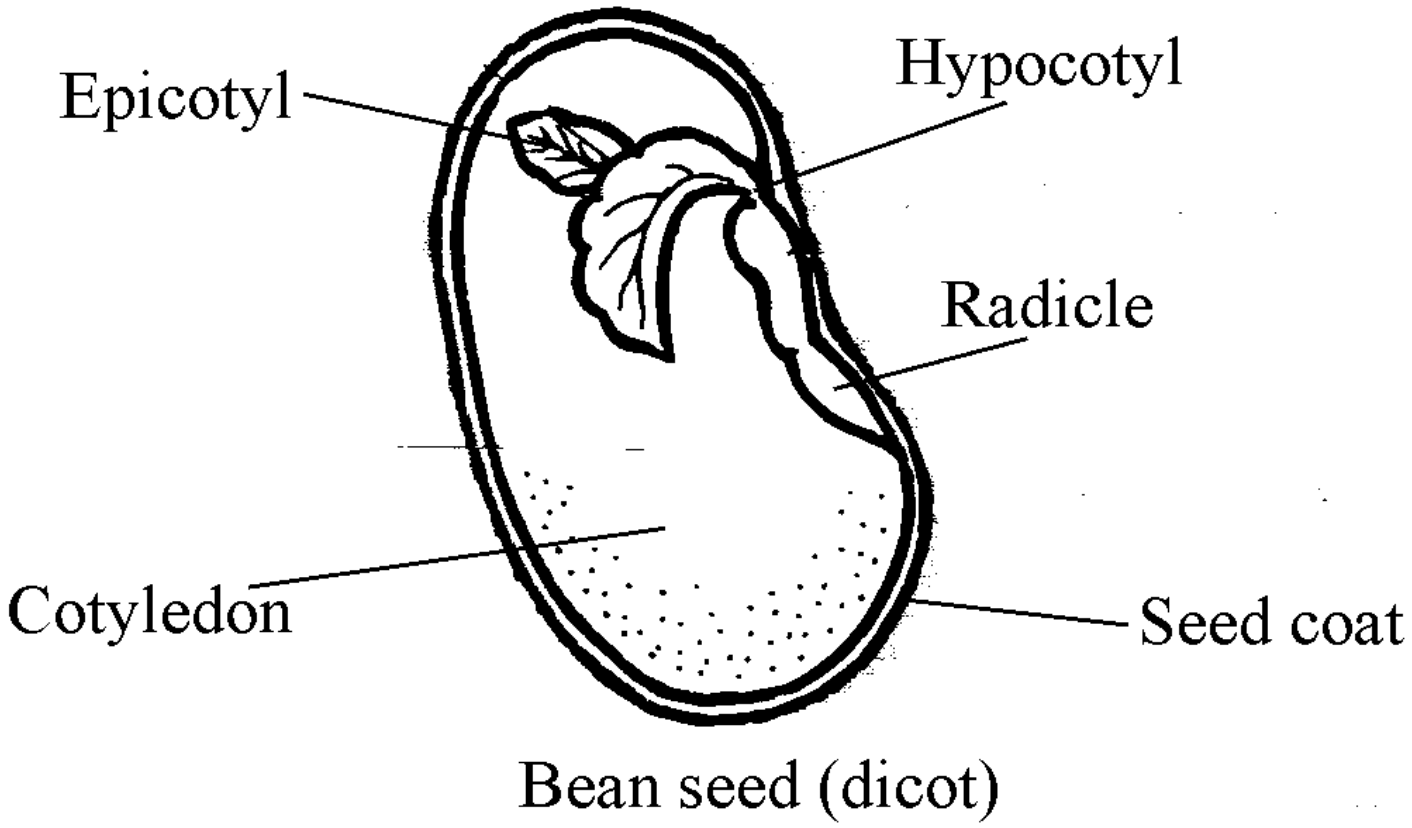
Function:

Storage, support, filler tissue and site of some photosynthesis.

Plant Structure

- Seed and Seedling Structure
- Growth Tissues (Meristems)
- Root Structure
- Stem Structure
- Leaf Structure
- Flower Structure

Seed Structure



Bean seed (dicot)

Seed Structure

Seed coat or **testa** protects the seed from the environment

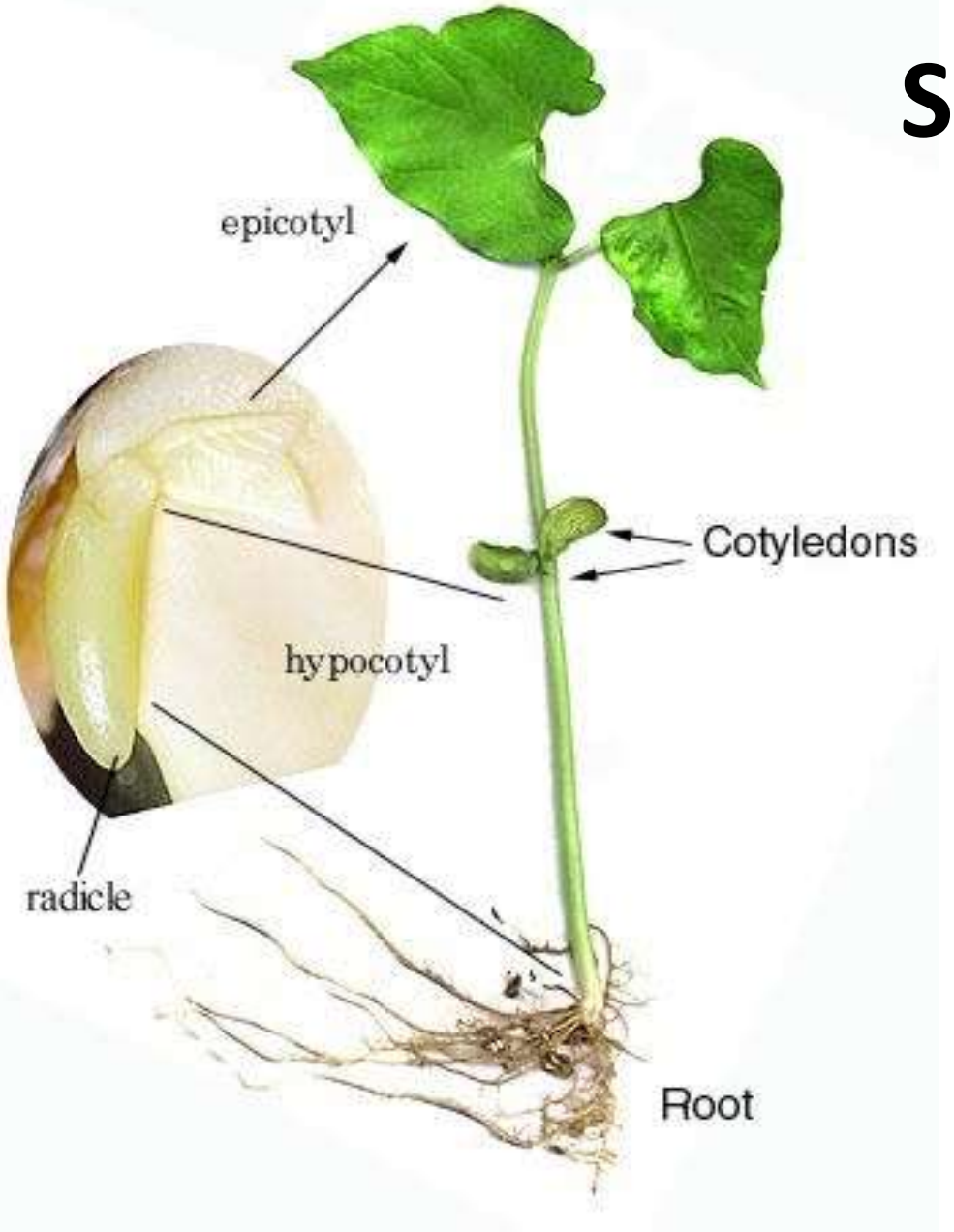
Cotyledons contain the endosperm, a nutritive tissue that accumulates starch, protein, and fats to provide for the growth of the embryo

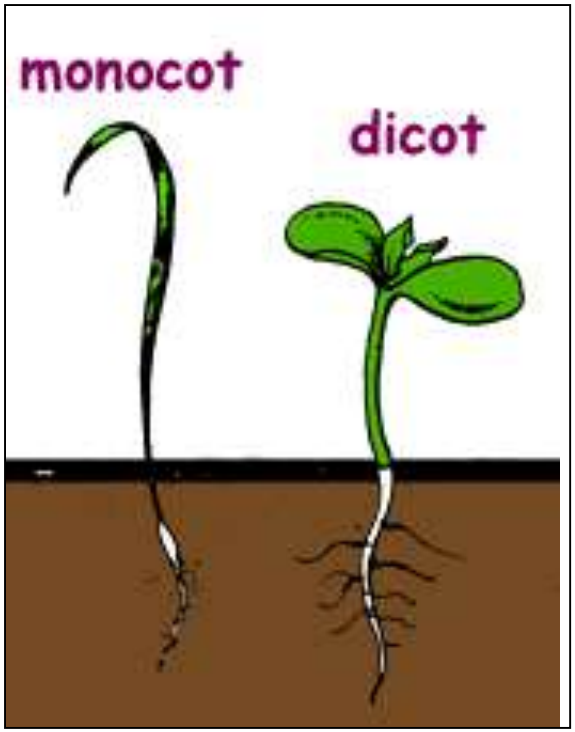
Epicotyl in most plants develop into the leaves

Hypocotyl develops into the stem

Radicle first to emerge from the seed and develops into the root

Seedling Parts



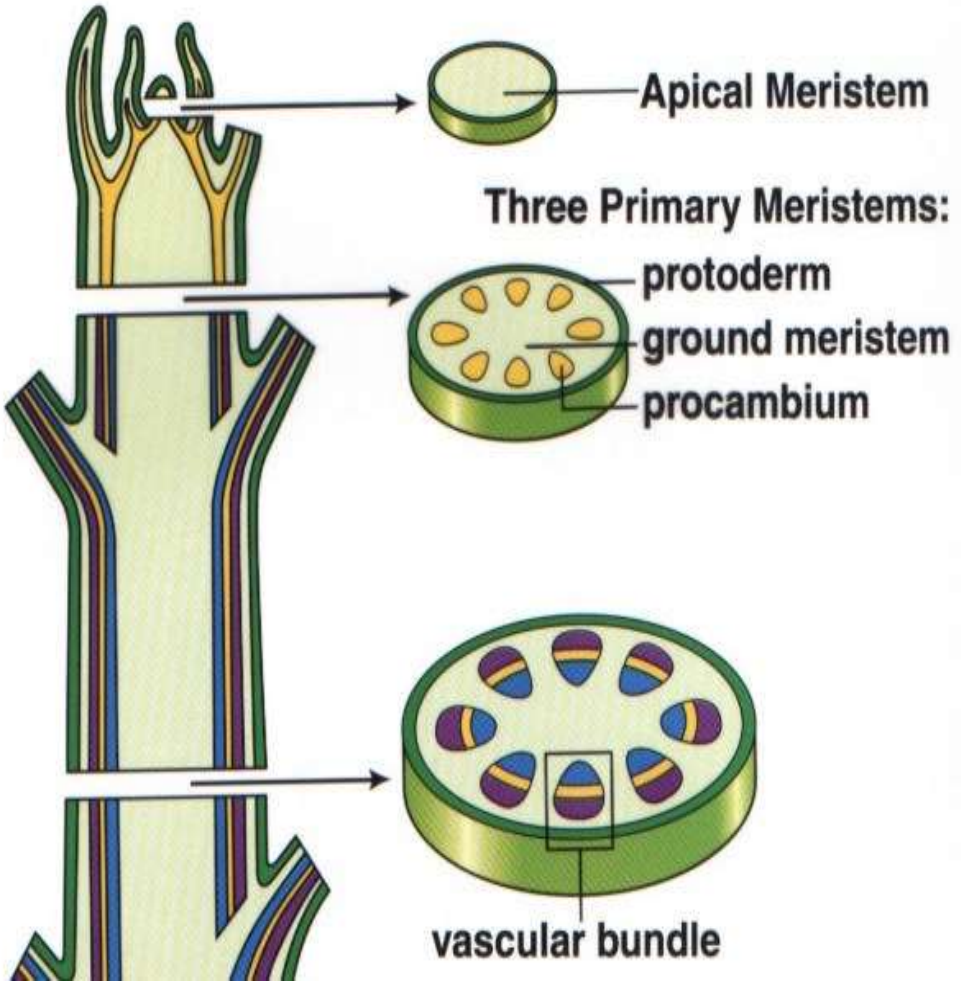


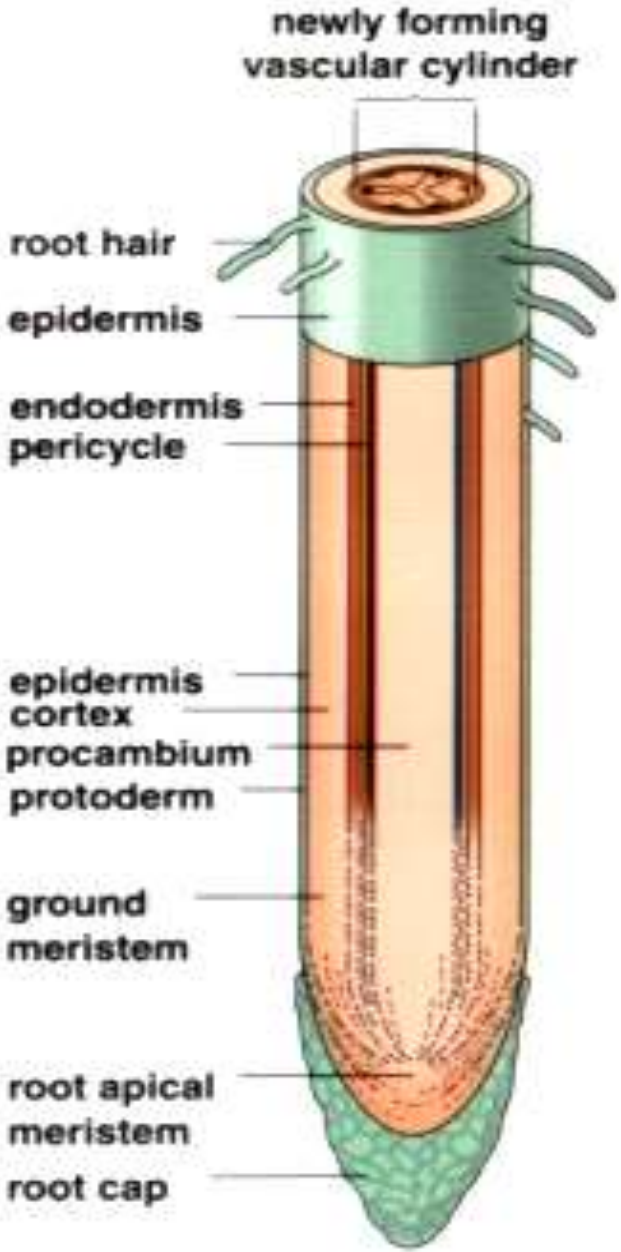
Meristem (Growth Tissue)

Plants grow from localized areas called **meristems**.

They are discrete regions or groups of cells that have the ability to continue cell division for the life of the plant.

Meristem Location





Stem Functions

Functions:

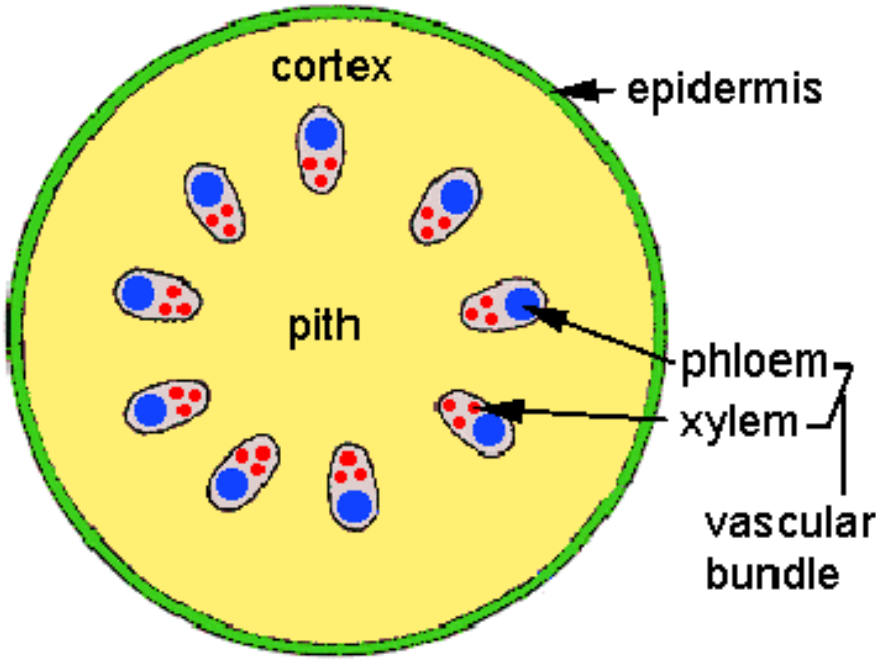
Anchorage: secures plant to ground or for epiphytes to branches

Absorption: water and nutrients from soil

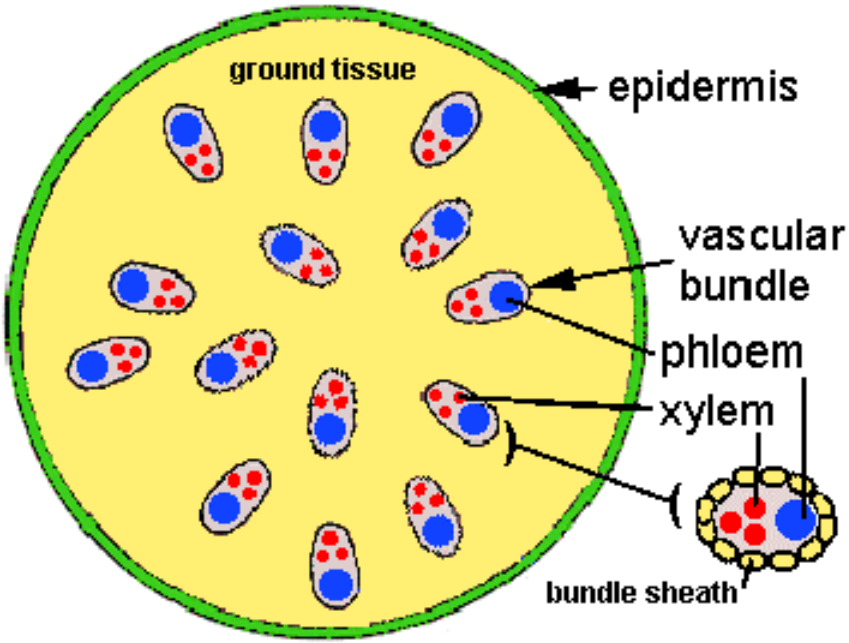
Storage: ex.. sweet potato, carrot, etc.

Propagation: ex. dahlia or sweet potato tuberous roots, blackberry

Stems and the Vascular System



Dicot Stem



Monocot Stem

Xylem cells are dead, they carry water and dissolved nutrients from the roots to the leaves.

Phloem cells are living, they conduct food from the leaves to the roots.

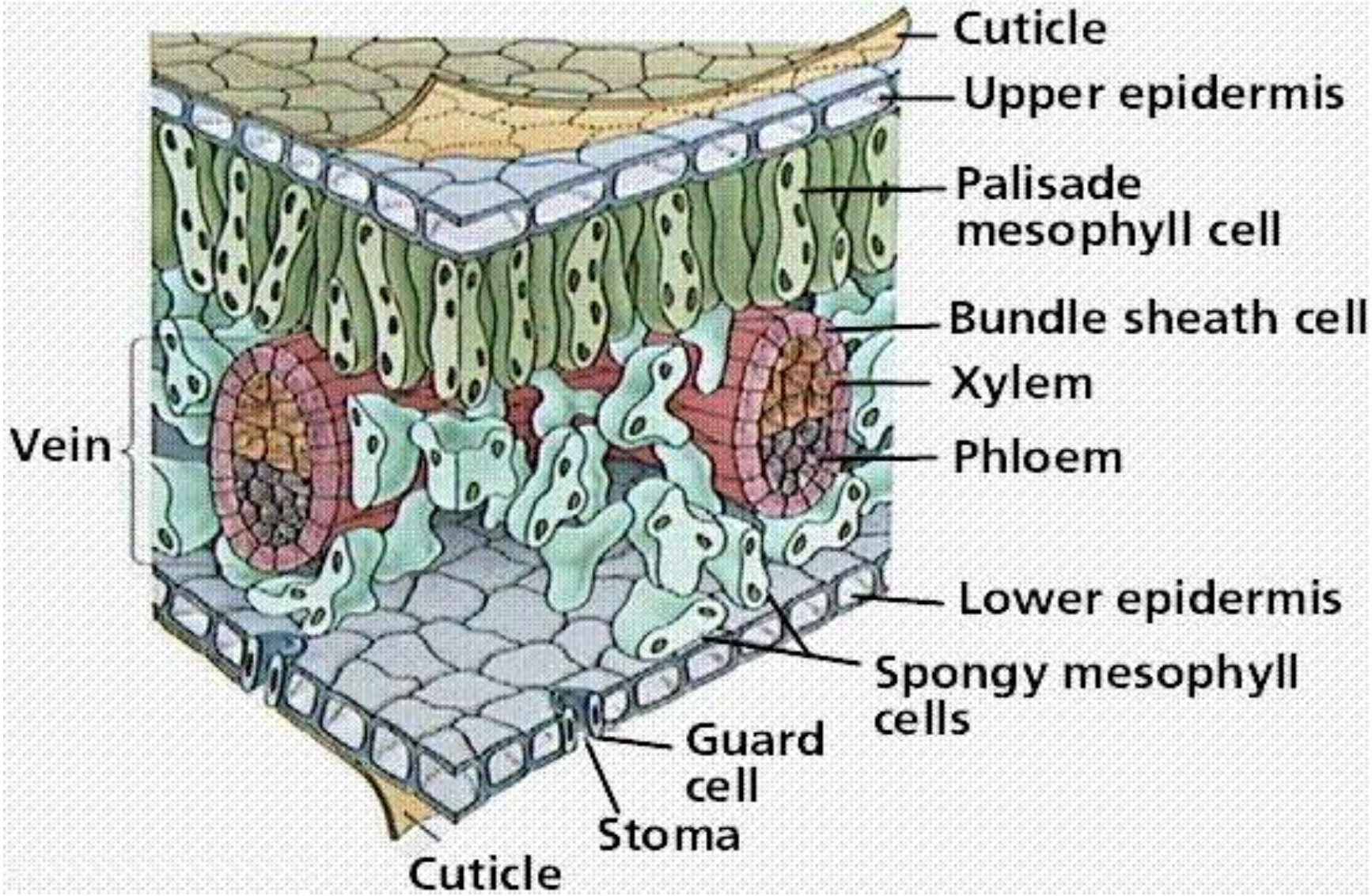
Stem Functions

Bud - an un-elongated stem containing primordial leaves and/or flowers
Terminal bud - a bud at the tip off a stem
Axillary or Latteral bud - buds along the side off a stem that grow out to form a side branches
Flower bud - a bud that develops into flowers; usually larger than vegetative buds
Leaf scar - marks the former attachment point off a leaf or petiole to the stem
Node - part off stem where leaves, flowers, fruits, buds and other stems are attached

Leaf Functions

Photosynthesis: it mainly occurs in leaves
Regulate water loss: by opening and closing guard cells
Storage: ex. carbohydrates & water in chives
Support: ex. tendrils on grape
Protection: ex. spines on cacti
Attraction: ex. bracts on poinsettia
Propagation: ex. piggyback plant with plantlets on leaves

Leaf Interior



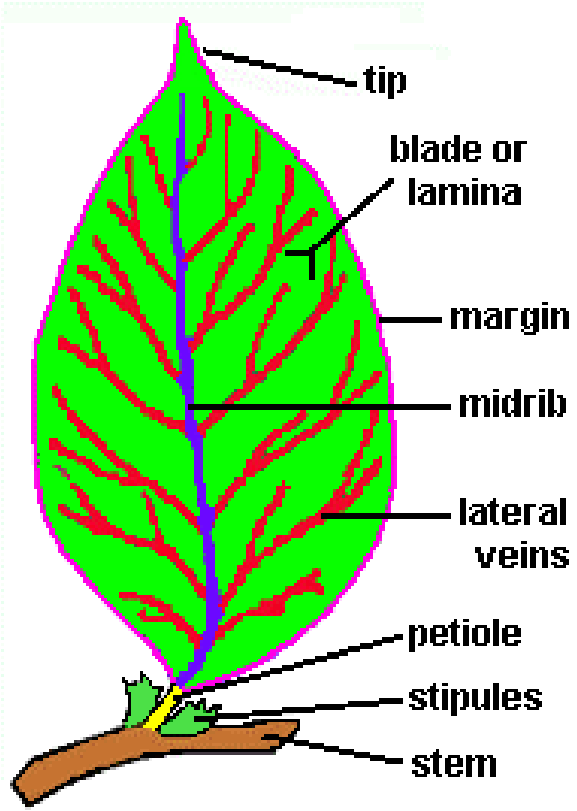
Leaf Arrangement

Alternate - one leaf attached per node, usually staggered (spiral) along stem.

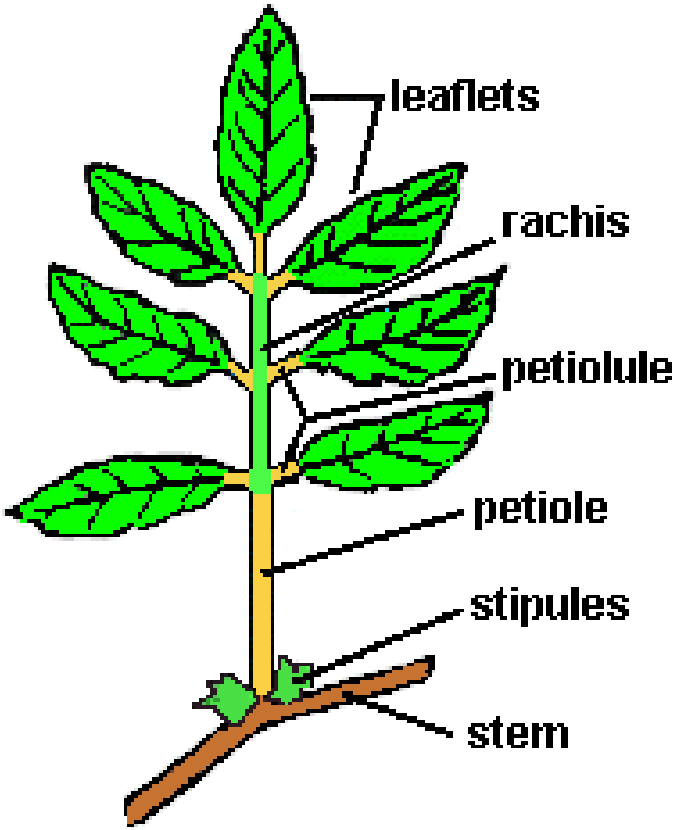
Opposite - two leaves (a pair) attached per node, usually opposite each other.

Whorled - three or more leaves attached per node, usually equally spaced around the node.

Simple and Compound Leaves

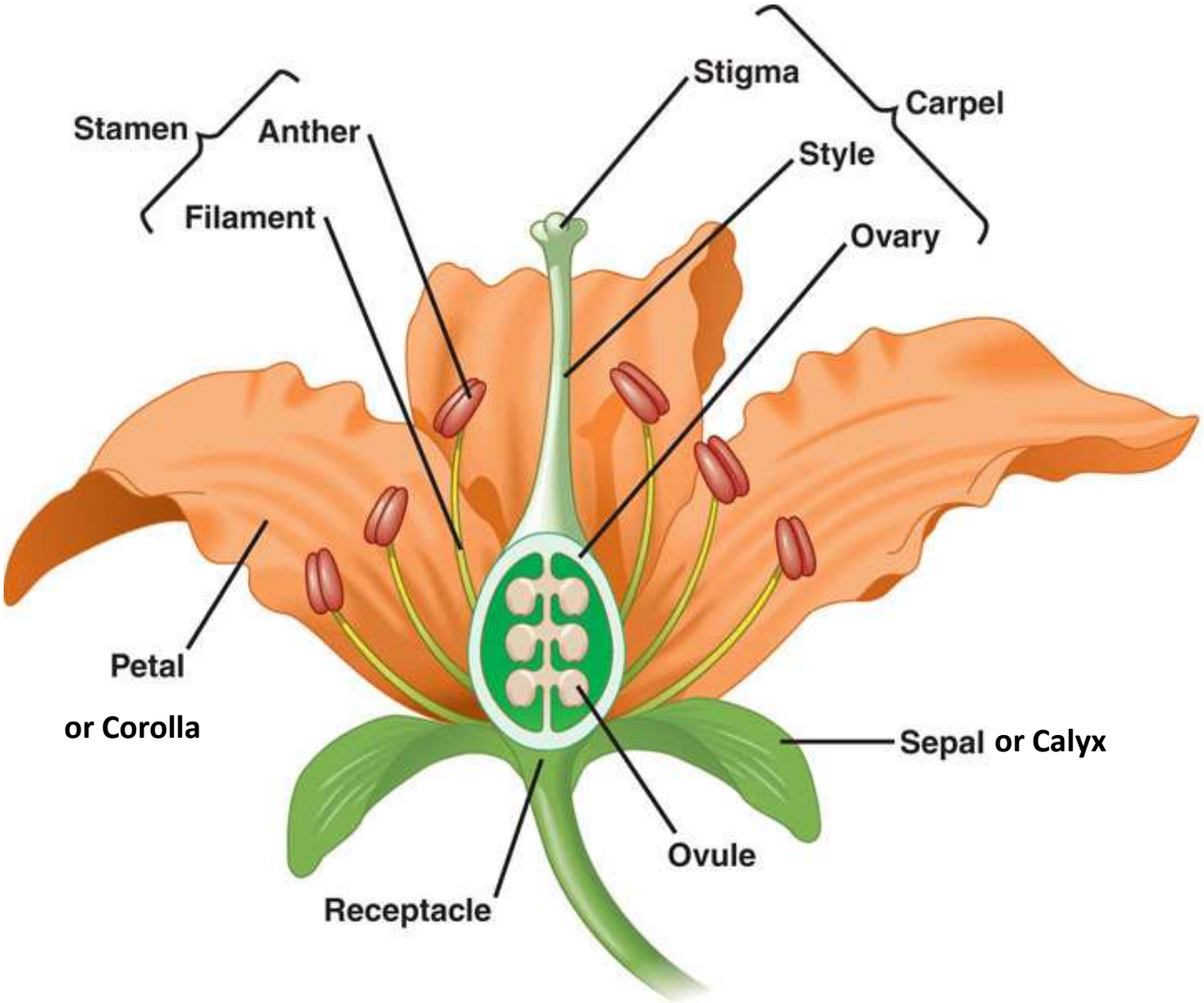


Simple Leaf



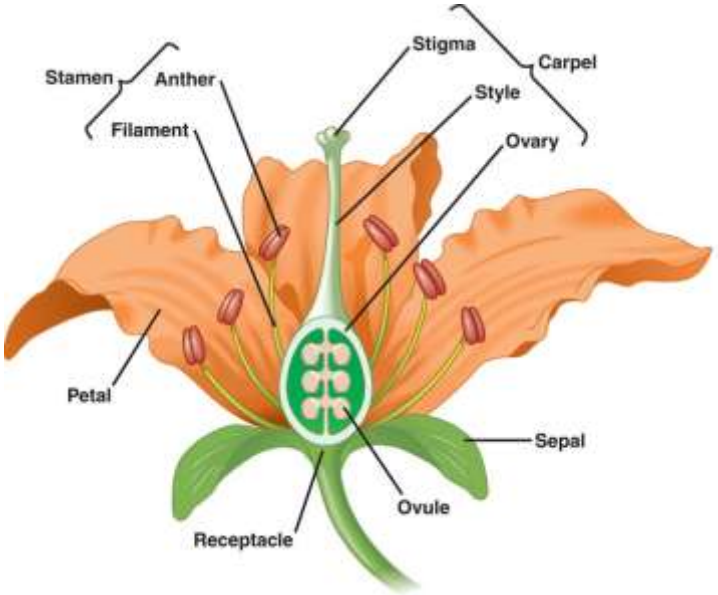
Compound Leaf

Flower Structure

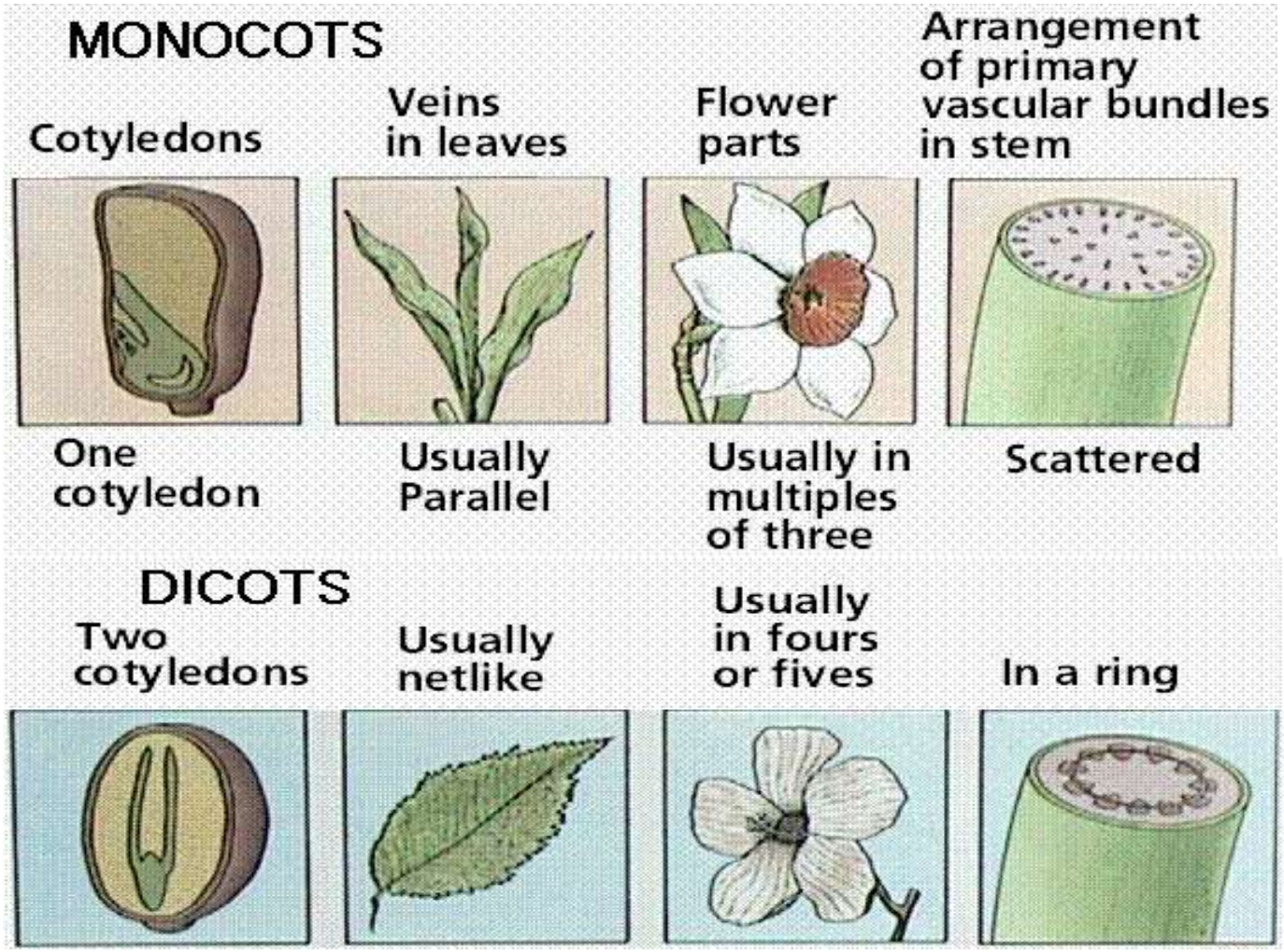


Receptacle – swollen end of stem that supports flower
Sepal – protective parts around flower bud
Petal –Colorful parts to attract pollinators
Stamen – male part of flower
- **Anther** produces pollen
- **Filament** elevates anther

Carpel – female part of flower
- **Stigma** – end that receives pollen
- **Style** – elevates stigma
- **Ovary** – contains ovules (eggs)



Monocot Vs. Dicot Plants



Root Diversity

Taproot (m)

Fibrous root system(d)

Clicker Question #3

A seed that lands on dry pavement is unlikely to germinate because it does not receive enough

A. light.
B. oxygen.
C. food.
D. water.

Clicker Question #3

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A. light.
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D. water.

22.3 Mastering Concepts

What are the events of early seedling development?

Hormones Regulate Plant Growth

Chemicals called **hormones** travel between cells and regulate many aspects of plant growth.

Section 24.4

Figure 24.14

Hormones Regulate Plant Growth

Five hormones cue many of the major changes in plant growth and development:

- Auxins
- Cytokinins
- Gibberellins
- Ethylene
- Abscisic acid

Section 24.4

Apical dominance: © Nigel Cattlin/Visuals Unlimited

Figure 24.14

Hormones Regulate Plant Growth

Auxins stimulate fruit development, control elongation of cells in a stem, and suppress growth of lateral buds.

Section 24.4

Apical dominance: © Nigel Cattlin/Visuals Unlimited

Figure 24.14

Hormones Regulate Plant Growth

Cytokinins stimulate cell division in many plant parts, delay shedding of leaves, and stimulate growth of lateral buds.

Section 24.4

Apical dominance: © Nigel Cattlin/Visuals Unlimited

Figure 24.14

Hormones Regulate Plant Growth

Auxins are primarily released from the shoot tip, and cytokinins are primarily released from the roots. The counteracting effect of these hormones is called **apical dominance**.

Section 24.4

Apical dominance: © Nigel Cattlin/Visuals Unlimited

Figure 24.14

Hormones Regulate Plant Growth

Apical dominance

If the shoot tip is in place, auxins suppress the growth of lateral buds.

Section 24.4

Apical dominance: © Nigel Cattlin/Visuals Unlimited

Figure 24.14

Hormones Regulate Plant Growth

Apical dominance

Removing the shoot tip reduces the auxin concentration. Cytokinins stimulate cell division in lateral buds.

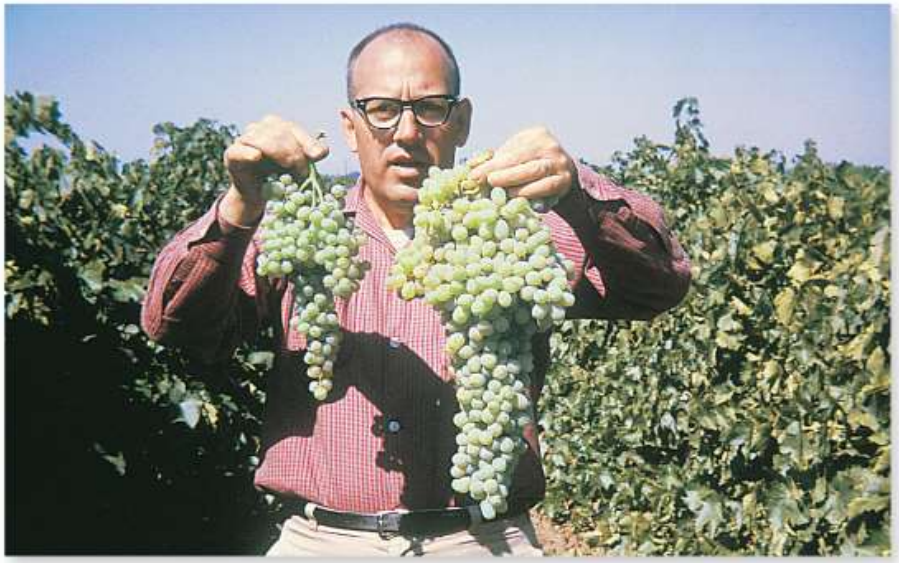
The plant's growth becomes bushier.

Section 24.4

Apical dominance: © Nigel Cattlin/Visuals Unlimited

Figure 24.14

Hormones Regulate Plant Growth



Gibberellins also stimulate shoot elongation. Farmers use these hormones to stimulate stem elongation and fruit growth.

Section 24.4

Grapes: © Sylvan Wittwer/Visuals Unlimited

Figure 24.15

Hormones Regulate Plant Growth

Ethylene hastens fruit ripening and stimulates shedding of leaves, flowers, and fruits.

Section 24.4

Figure 24.A

Hormones Regulate Plant Growth

Ethylene caused the flowers on the left to wither. The flowers on the right are genetically engineered to have mutant ethylene receptor genes.

Section 24.4

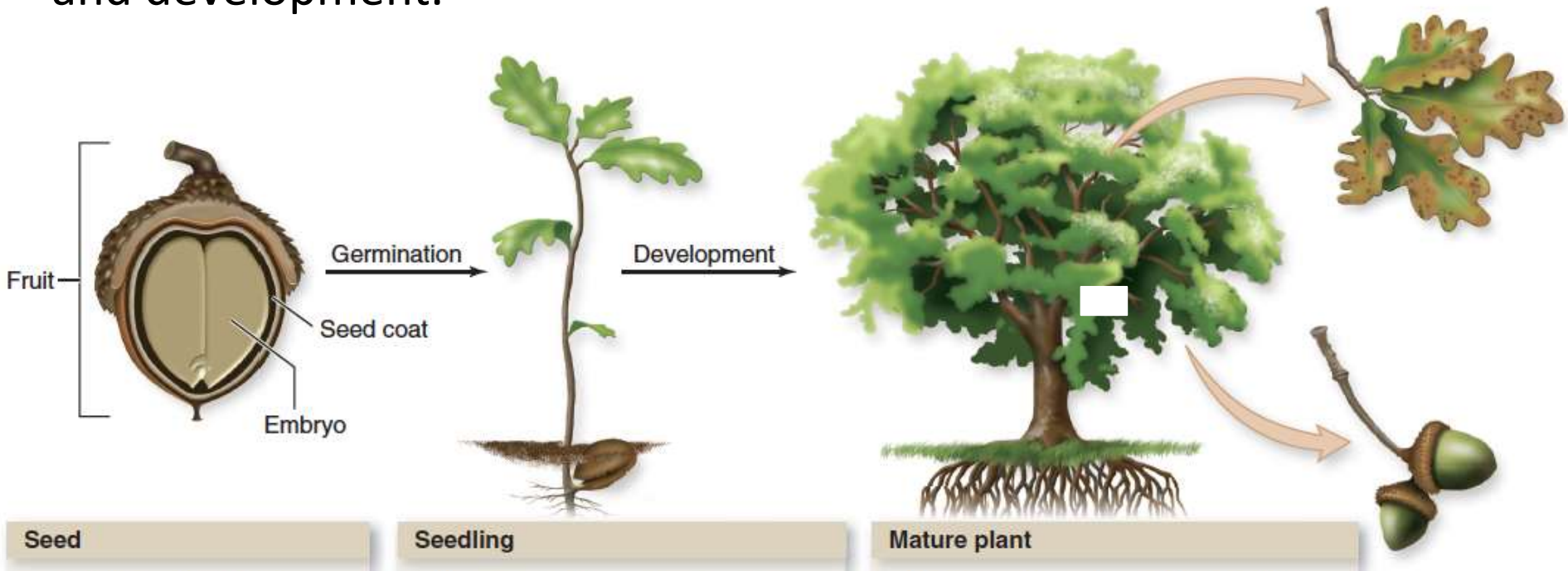
Figure 24.A

Hormones Regulate Plant Growth

Abscisic acid inhibits shoot growth, maintains seed dormancy, and stimulates closure of stomata and shedding of plant parts.

Hormones Regulate Plant Growth

This figure summarizes how hormones affect plant germination and development.



Seed

- Abscisic acid maintains seed dormancy until favorable conditions arise.
- Gibberellins break seed dormancy.
- Cytokinins stimulate cell division in germinating seeds.

Seedling

- Auxins stimulate stem elongation, suppress lateral bud growth (apical dominance), and control tropisms.
- Gibberellins and cytokinins stimulate cell division in shoot and roots.
- Cytokinins stimulate lateral bud growth.

Mature plant

- Hormones active in seedling are still active in mature plant.
- Abscisic acid inhibits shoot growth and maintains bud dormancy.
- Cytokinins delay leaf senescence.
- Ethylene hastens fruit ripening and promotes leaf abscission.

Clicker Question #4

Researchers first discovered gibberellins in diseased rice plants. A gibberellin-producing fungus infected the plants, causing abnormal growth. How do you think the researchers could identify the infected plants in the field?

A. The plants were abnormally short.
B. The plants were abnormally tall.
C. The plants shed their leaves.

Clicker Question #4

Researchers first discovered gibberellins in diseased rice plants. A gibberellin-producing fungus infected the plants, causing abnormal growth. How do you think the researchers could identify the infected plants in the field?

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22.4 Mastering Concepts

List the major classes of plant hormones and name some of their functions.