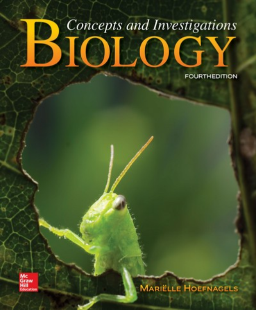


Chapter 24

Reproduction and Development of Flowering Plants

(bee keeper) ©Liu Jin/AFP/Getty Images; (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.

©Stephen Dalton/Science Source

Angiosperms seeds develop from fertilized egg cells

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

a.

(a): ©Rod Planck/Science Source

Figure 24.11

Sexual reproduction results in genetically unique offspring

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

©Stephen Dalton/Science Source

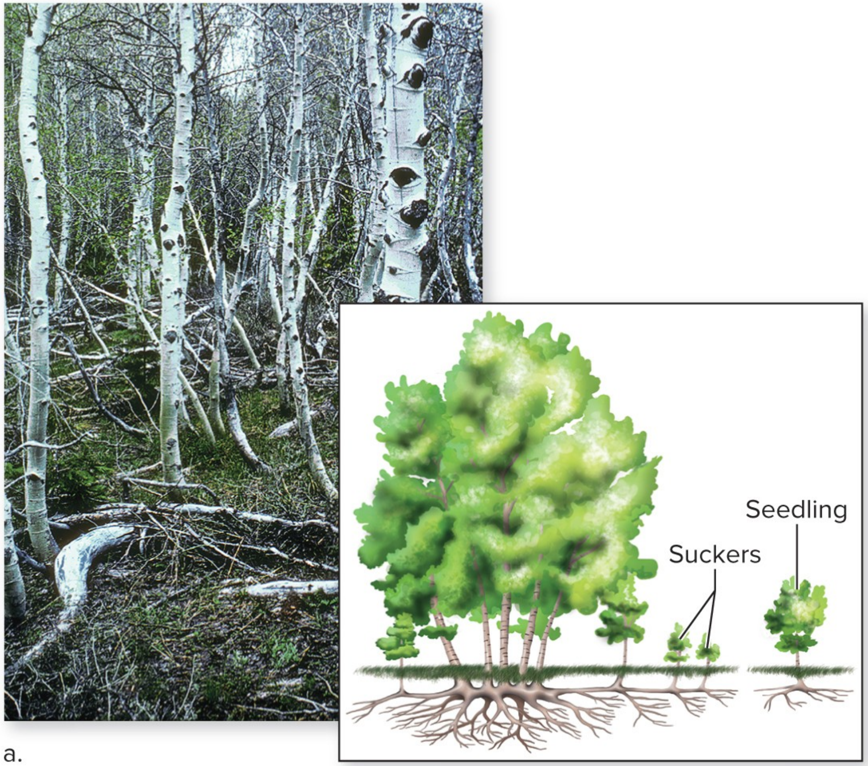
a.

(a): ©Rod Planck/Science Source

Figure 24.11

Some angiosperms reproduce asexually

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



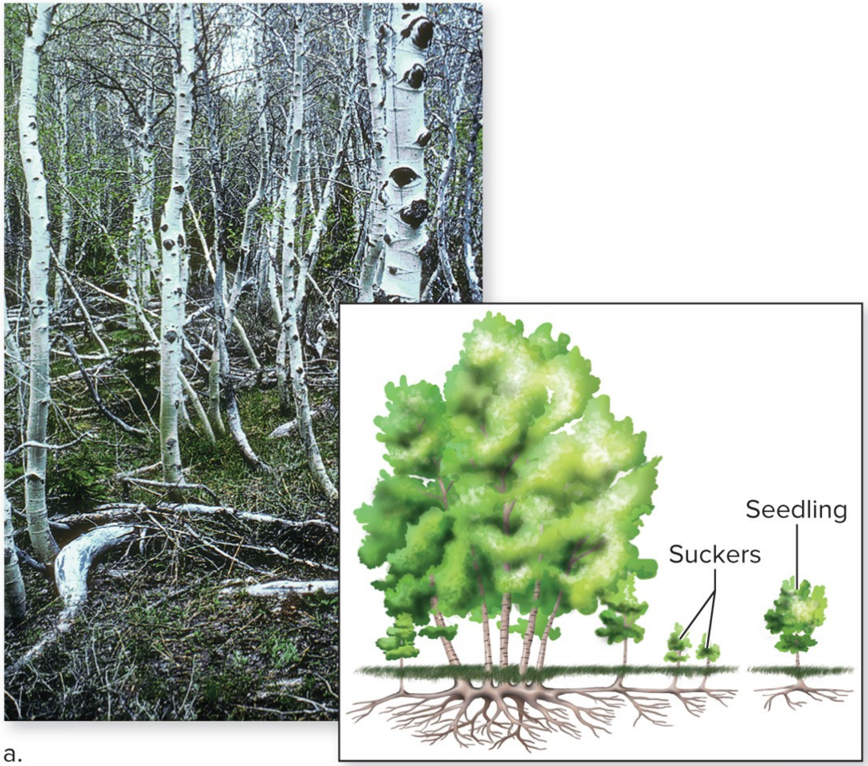
a.

(a): ©Steven P. Lynch RF

Figure 24.1

Asexual reproduction produces clones

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

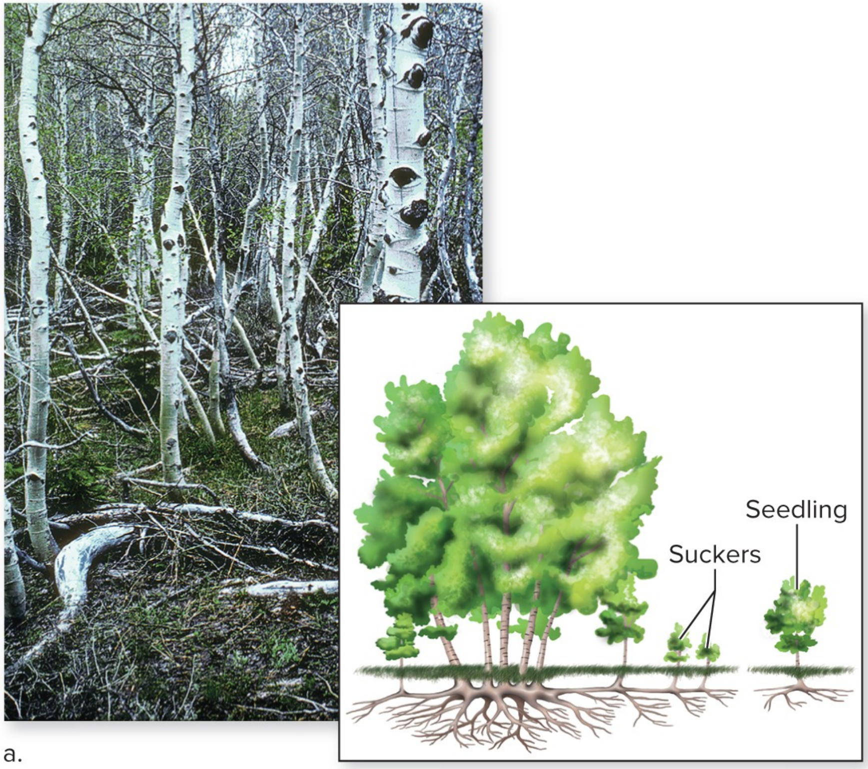


(a): ©Steven P. Lynch RF

Figure 24.1

Some angiosperms can reproduce sexually or asexually

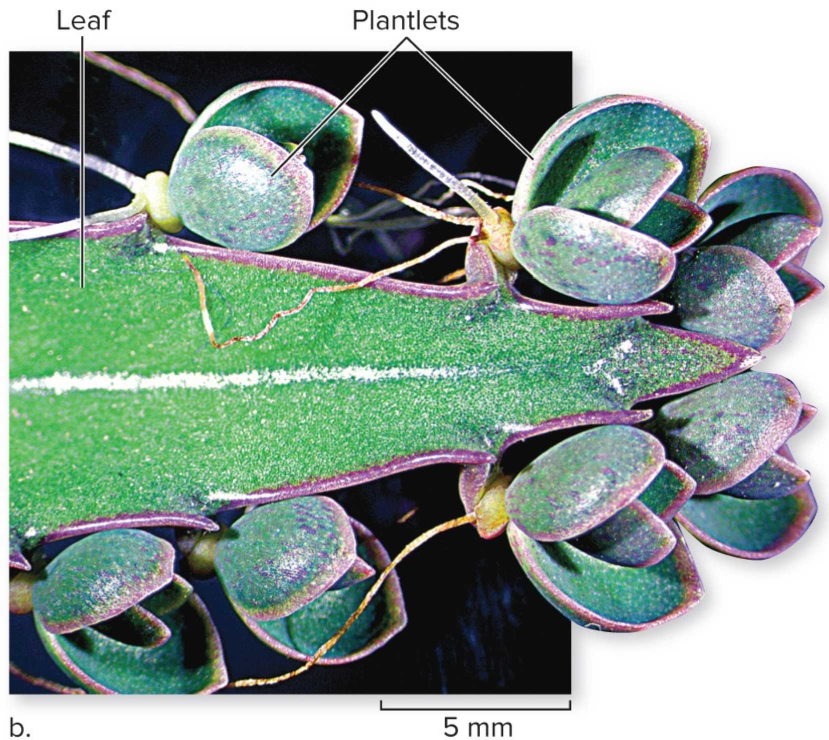
These aspen trees can reproduce either asexually, as suckers grow from roots, or sexually via seeds.



(a): ©Steven P. Lynch RF

An example of asexual reproduction

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



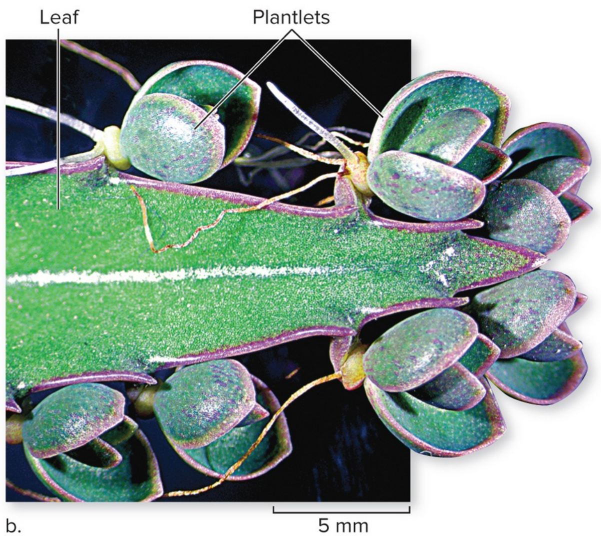
(b): ©Steven P. Lynch RF

Figure 24.1

Advantages of asexual and sexual reproduction

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.



(b): ©Steven P. Lynch RF

(a): ©Rod Planck/Science Source

Figures 24.1
24.11

Section 24.1

24.1 Mastering concepts

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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.

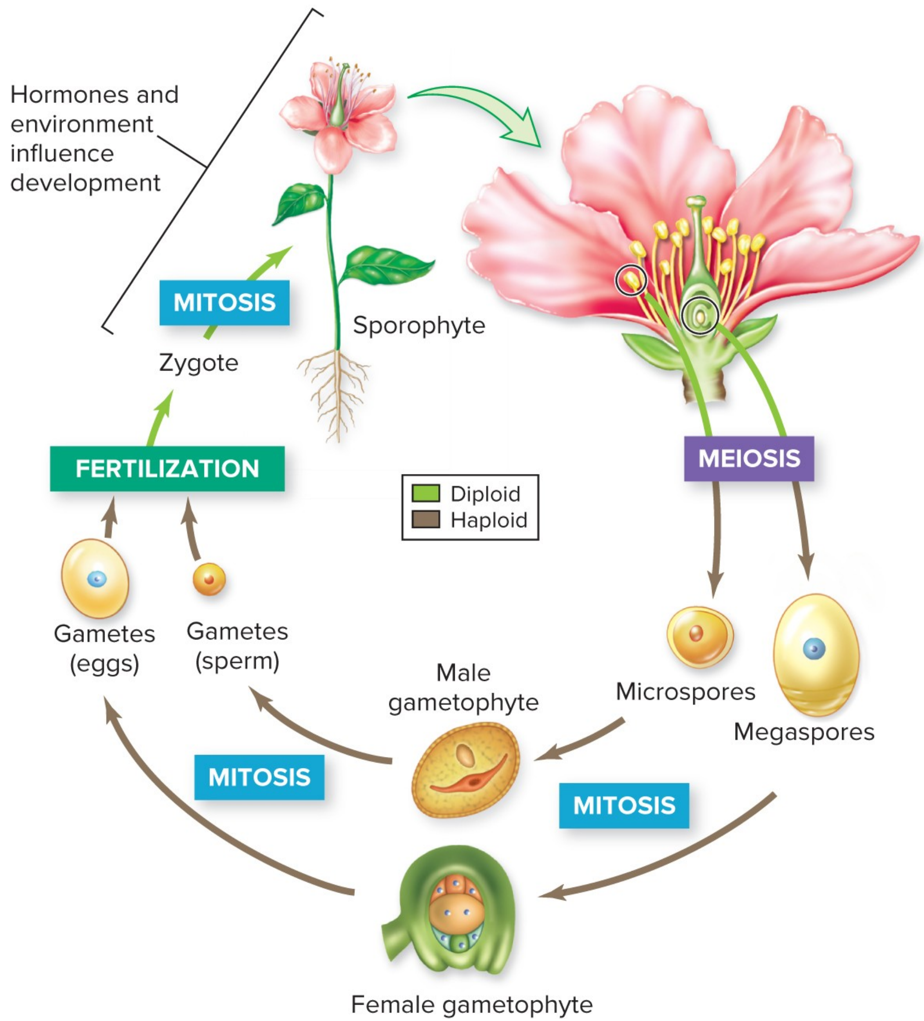


Figure 24.3

Alternation of generations

This diagram is an overview of the angiosperm life cycle.

Let's start with the flower.

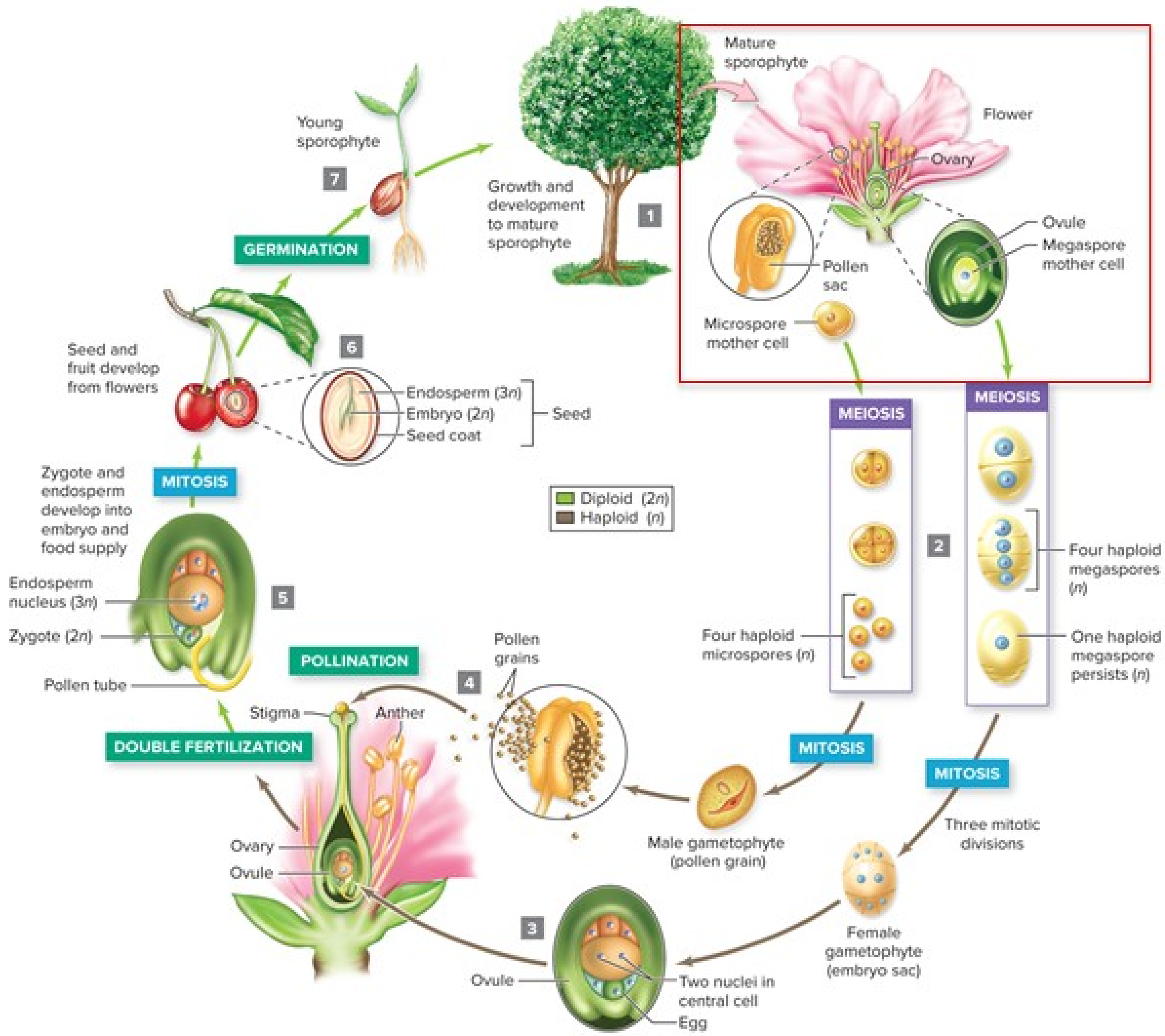


Figure 24.4

Angiosperm sex: Flowers

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

Figure 24.5

Angiosperm flower structures

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

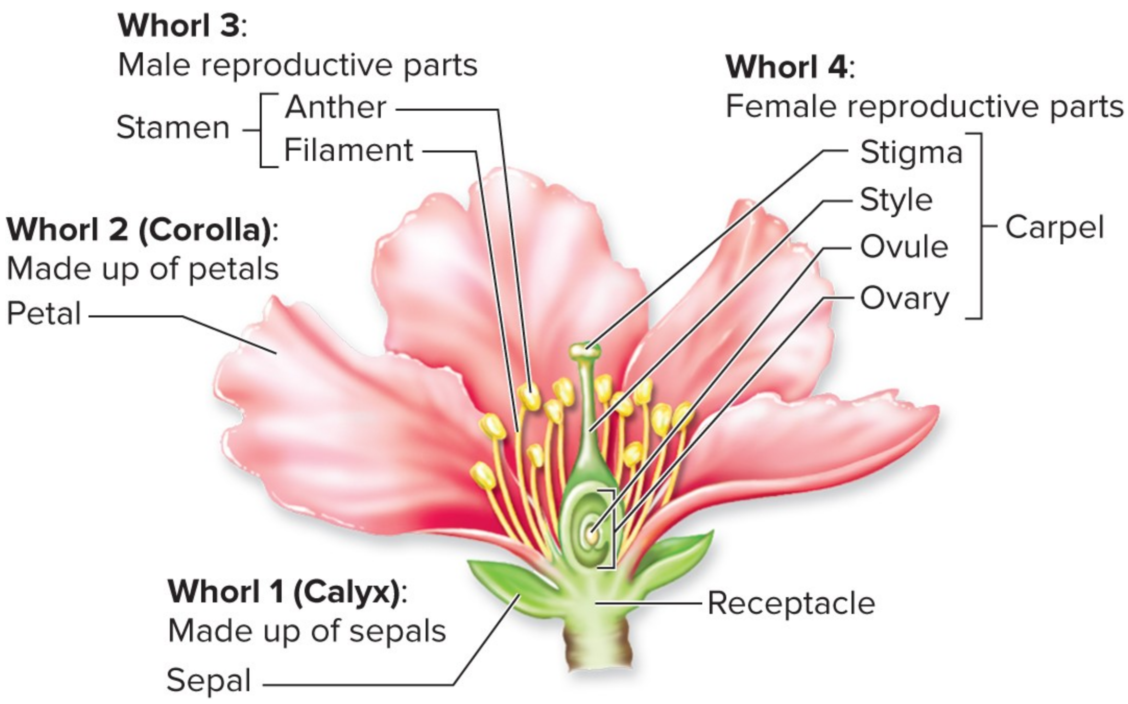


Figure 24.5

Angiosperm flower structures: Calyx

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

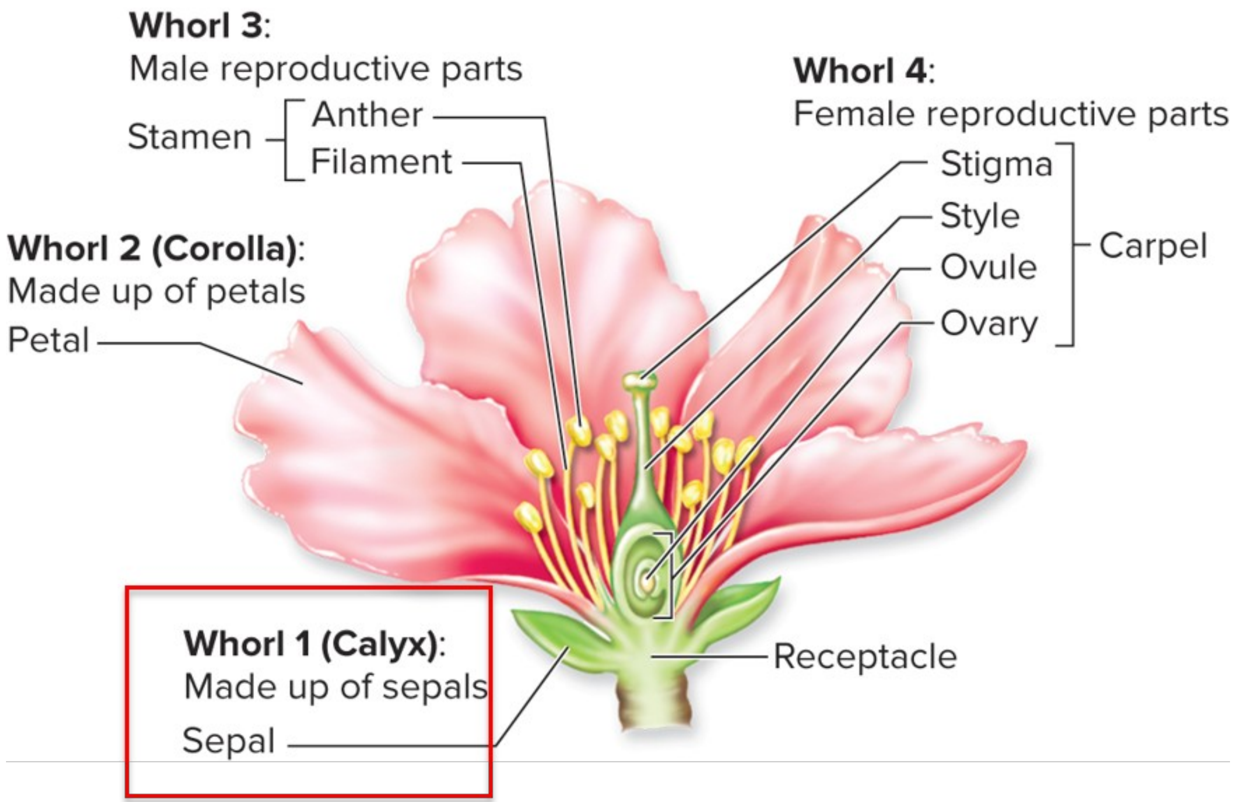


Figure 24.5

Angiosperm flower structures: Corolla

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

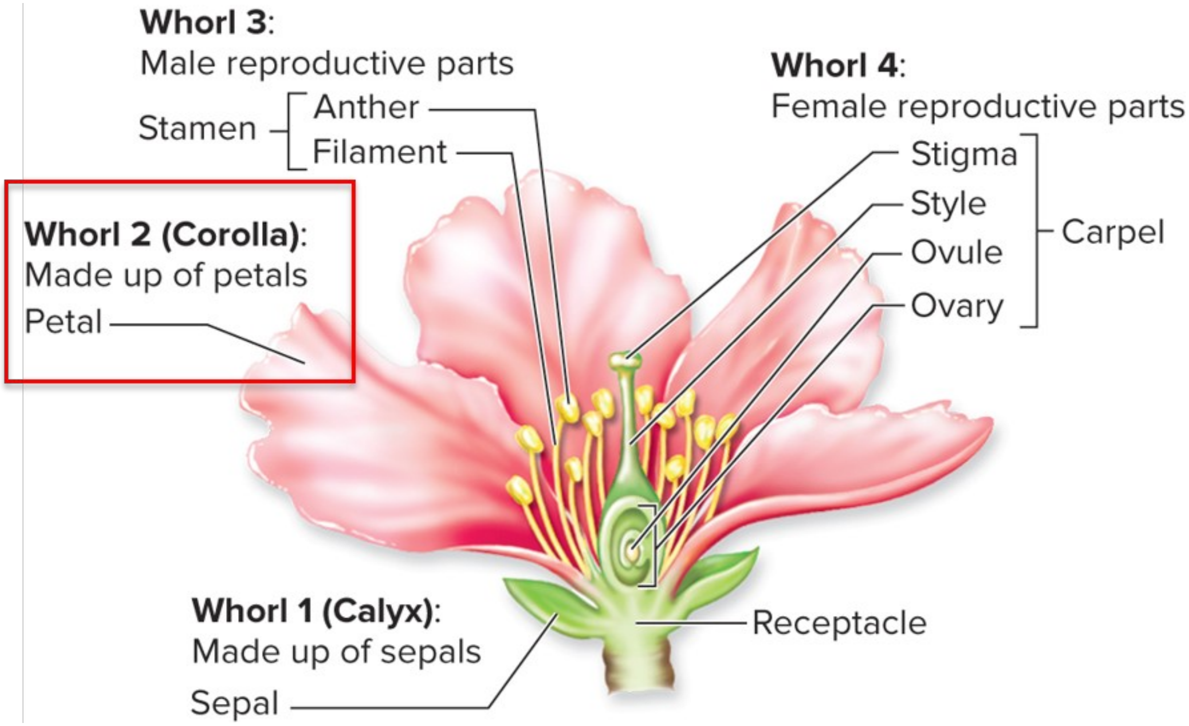


Figure 24.5

Angiosperm flower structures: Stamen

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

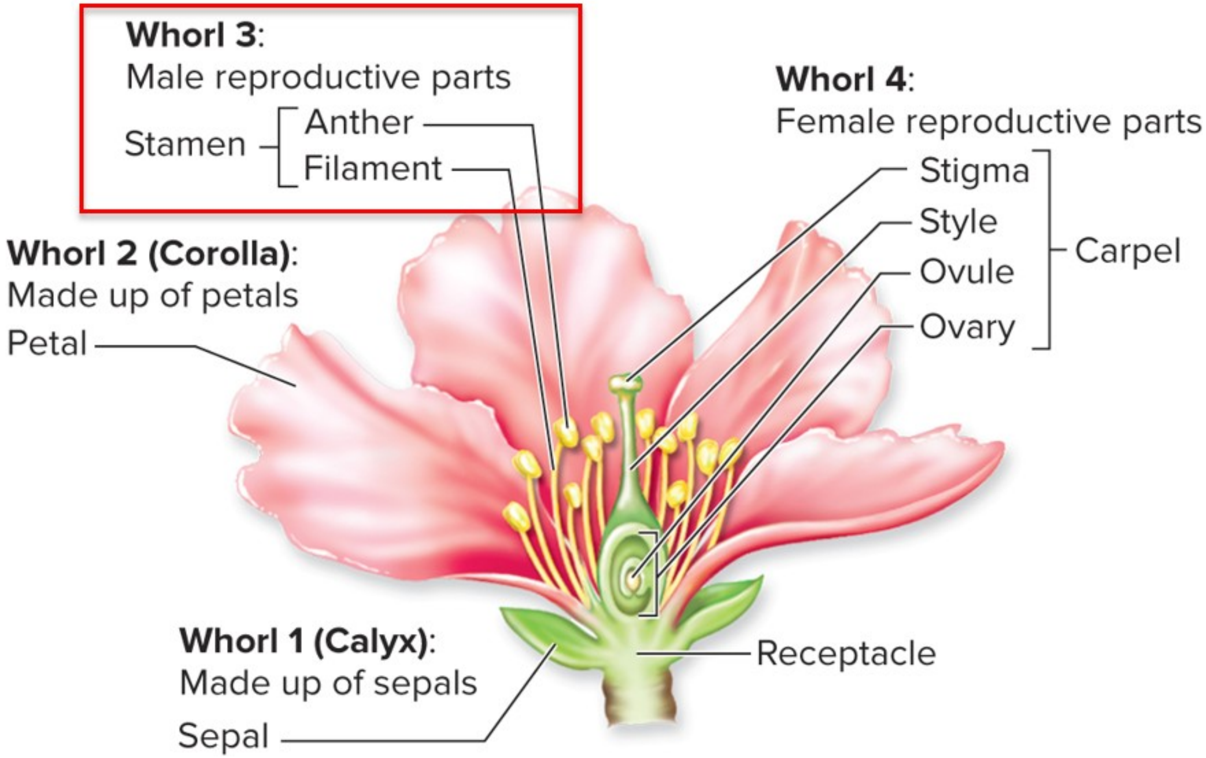


Figure 24.5

Angiosperm flower structures: Carpel

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.

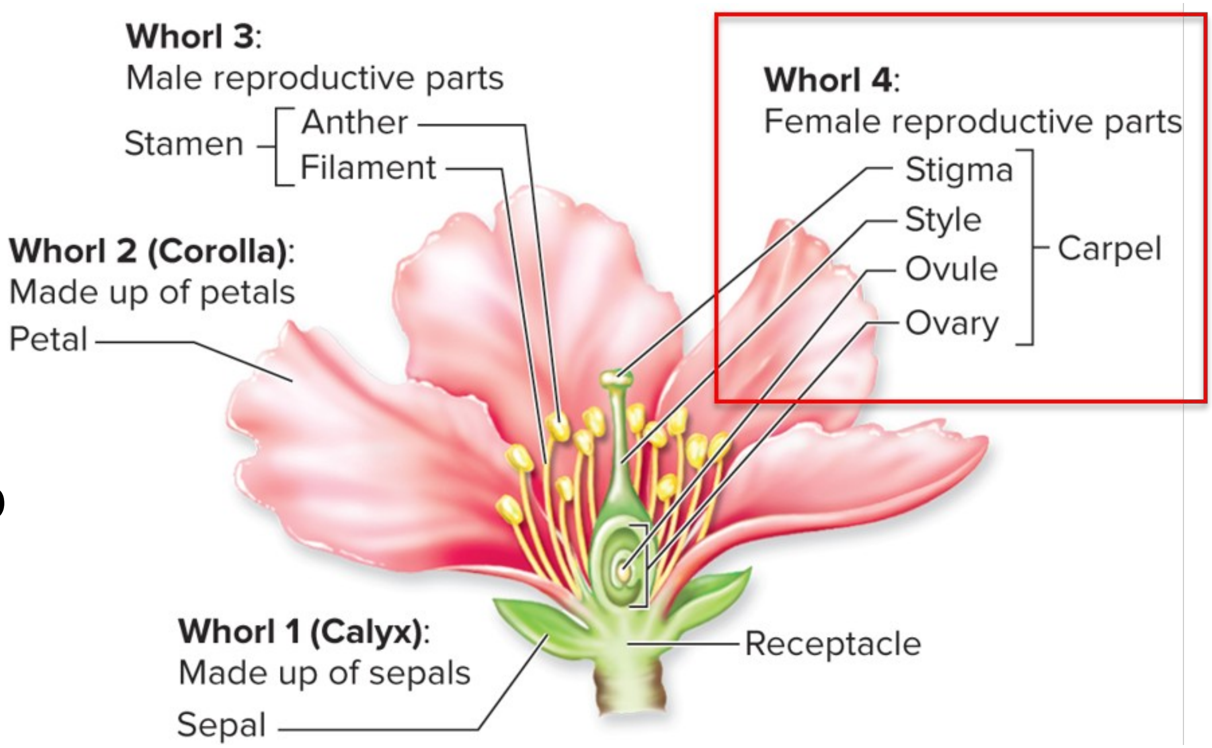


Figure 24.5

Inside the flower: Meiosis

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

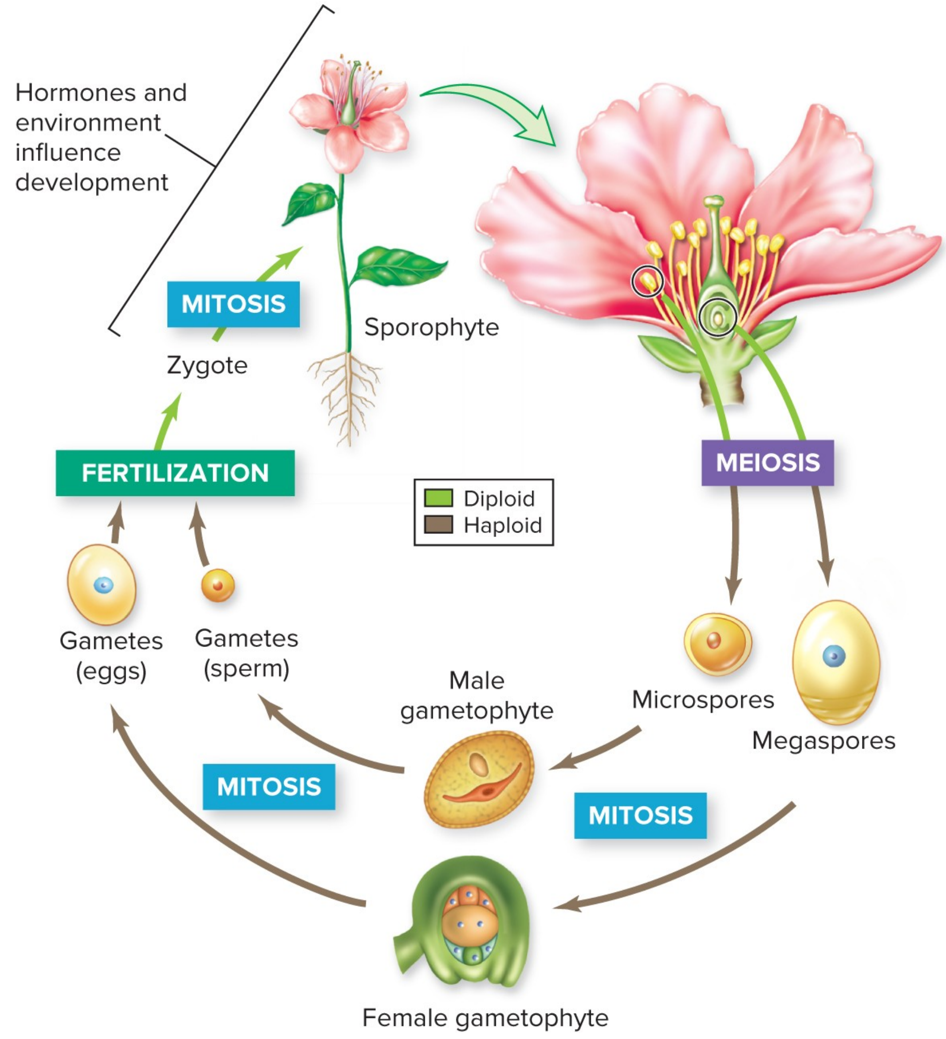


Figure 24.3

Inside the flower: Microspores and megaspores

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

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

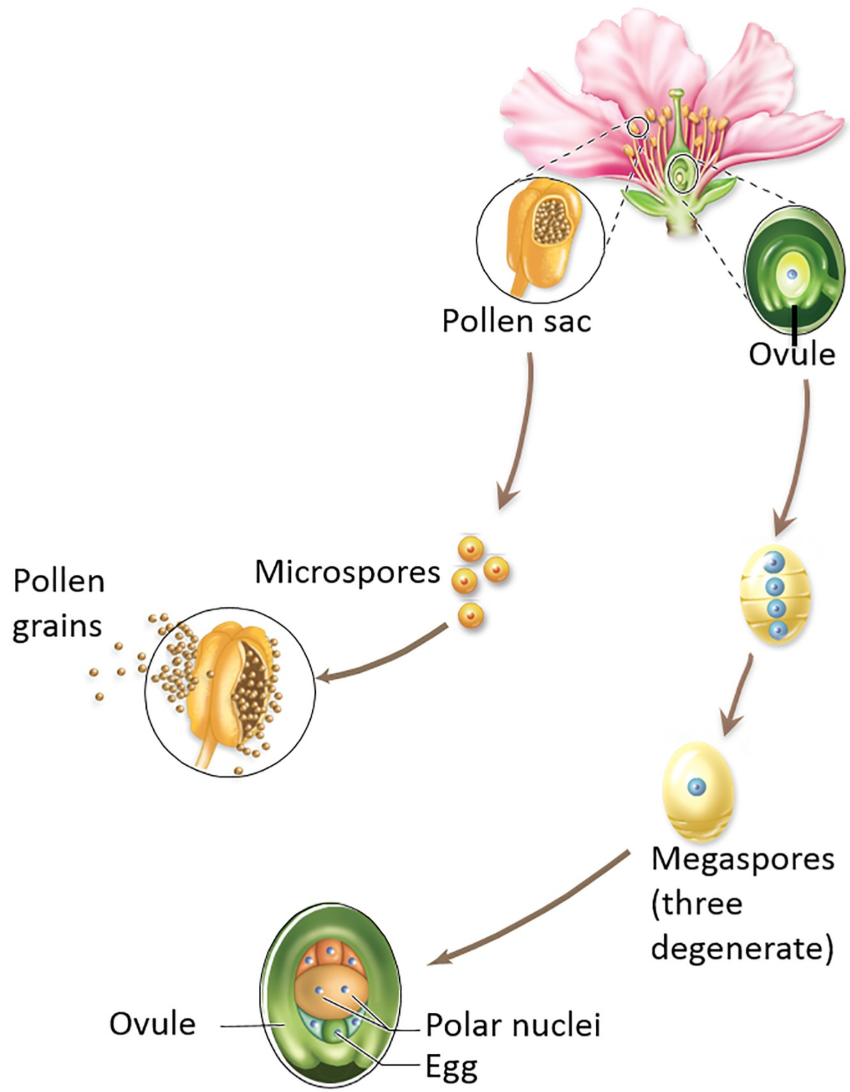


Figure 24.4

Modes of pollen dispersal: Wind

Some flowers release pollen grains in the wind.

©Dr. Jeremy Burgess/Science Source

Figure 24.6

Modes of pollen dispersal: Animals

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

c.

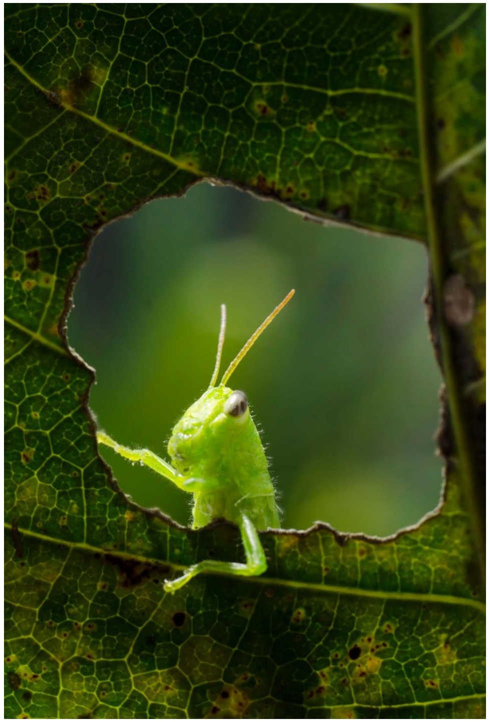
(a): ©Corbis RF; (b): ©MedioImages/Getty Images RF;
(c): ©Merlin D. Tuttle/Bat Conservation International/Science Source

Plant and pollinator: A mutualistic relationship

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

Figure 24.6

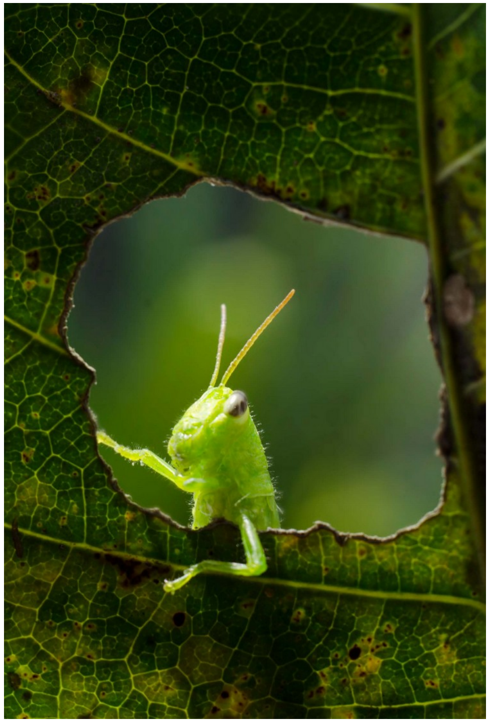
Clicker question #1



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.

Clicker question #1, solution



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

E.Both an embryo sac and egg cells are correct.

Angiosperm sex: Pollination

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

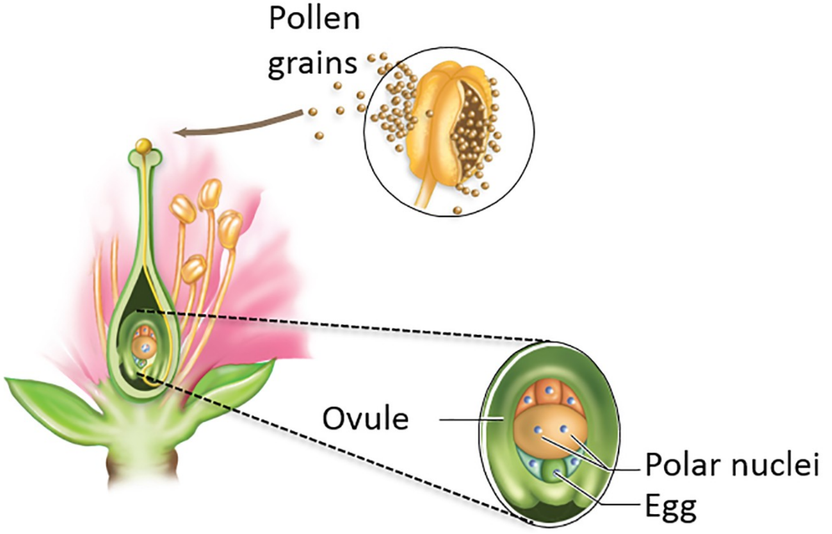


Figure 24.4

Angiosperm sex: Pollen tube

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

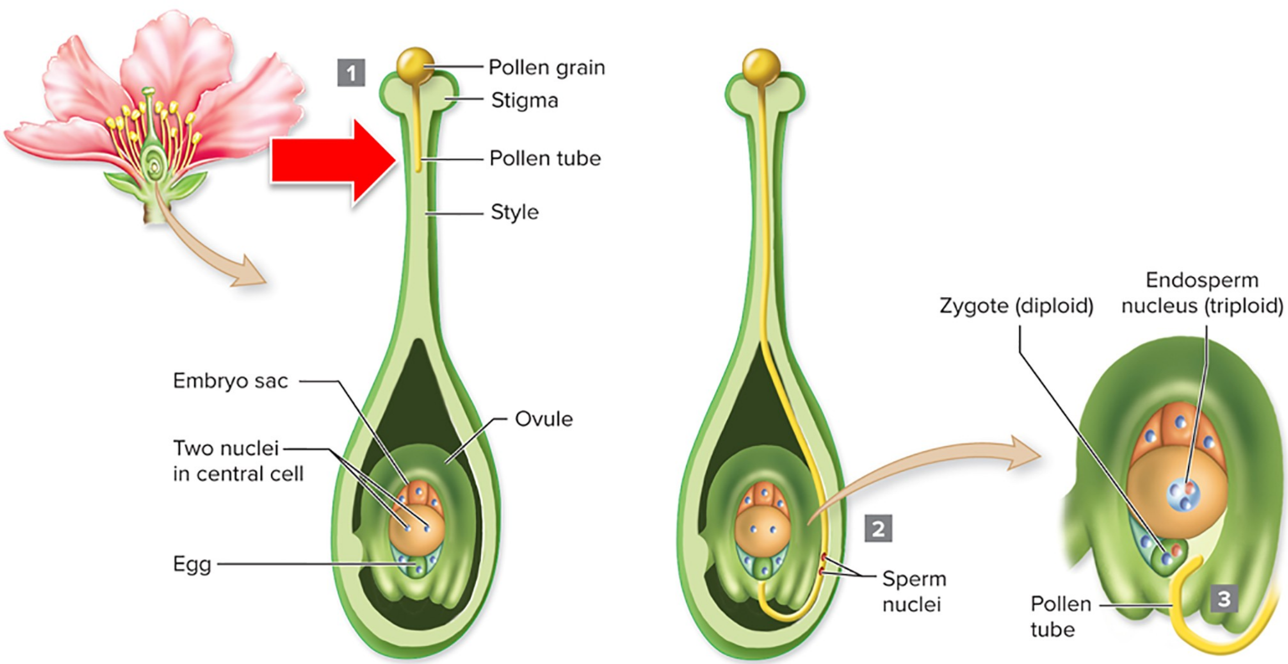


Figure 24.7

Angiosperm sex: Two sperm nuclei

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

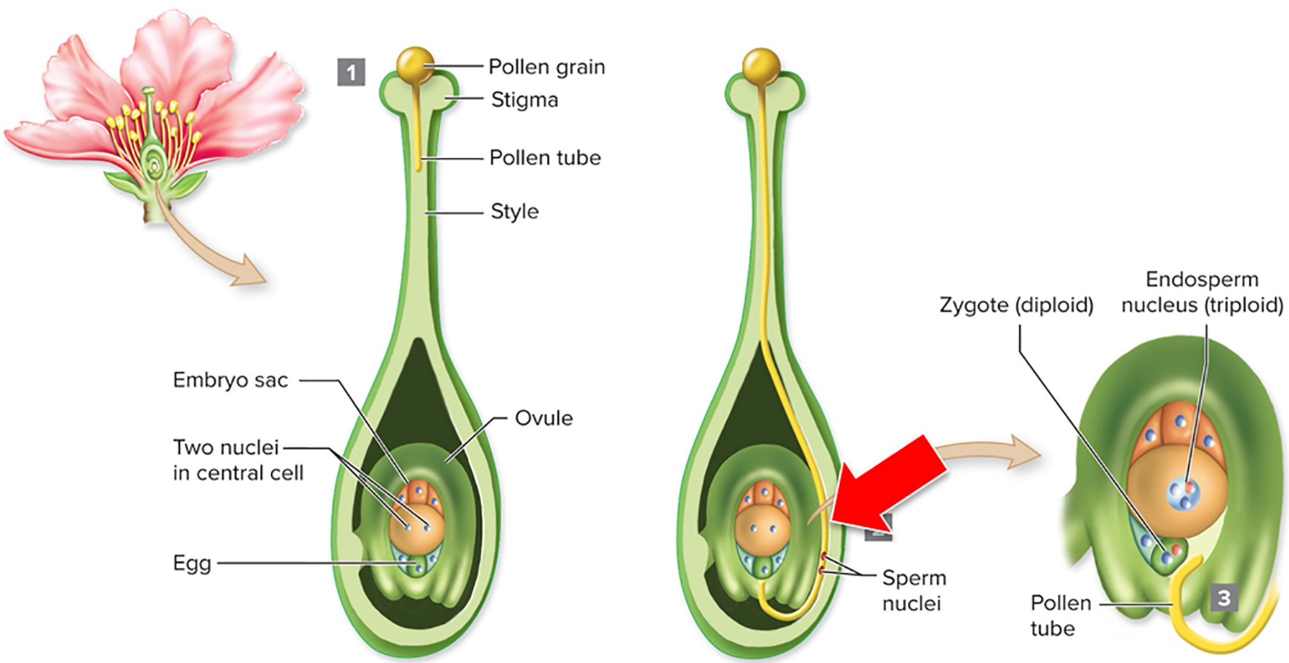


Figure 24.7

Angiosperm sex: Fertilization

The stage is now set for fertilization.

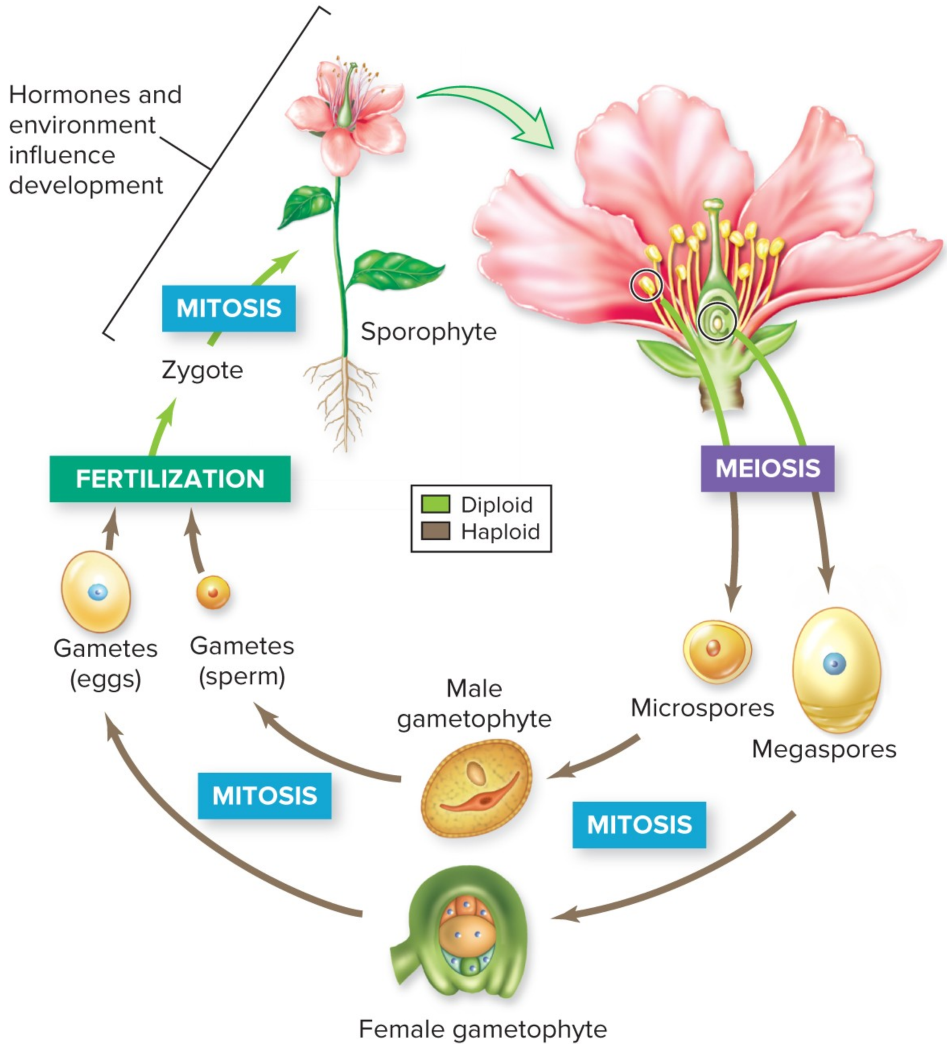
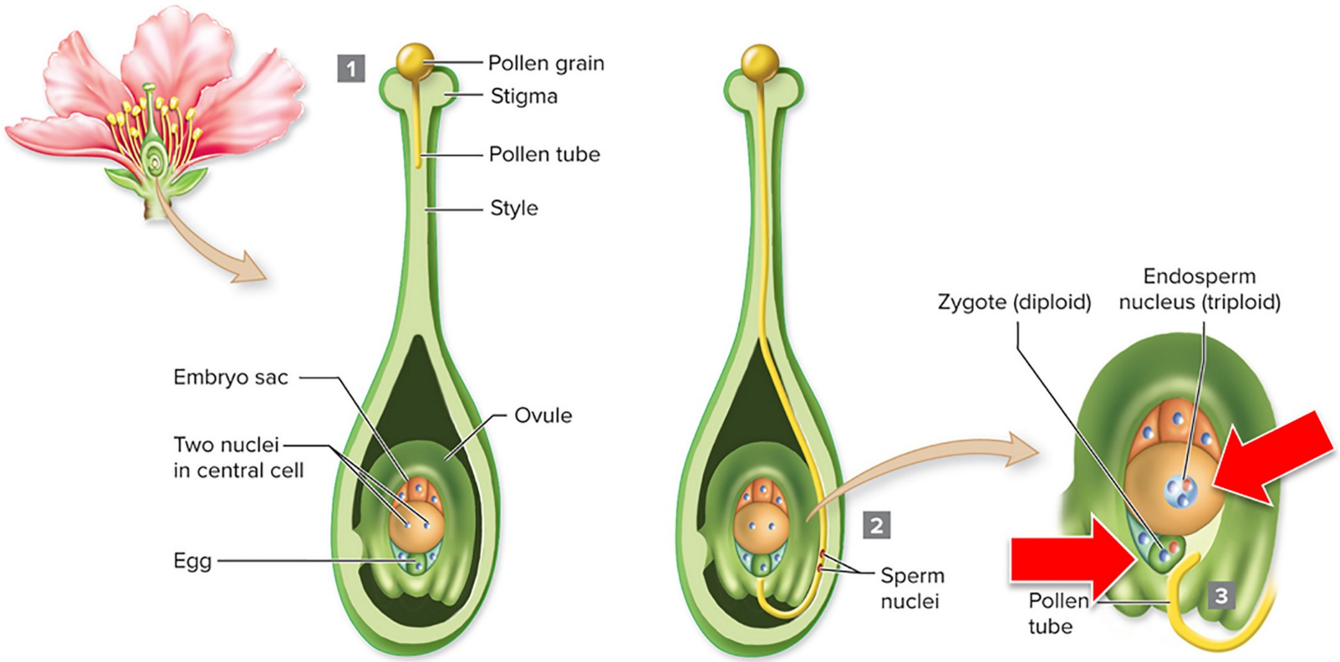


Figure 24.3

Angiosperm sex: Double fertilization

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



Section 24.2

Figure 24.7

Angiosperm sex: Triploid endosperm

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

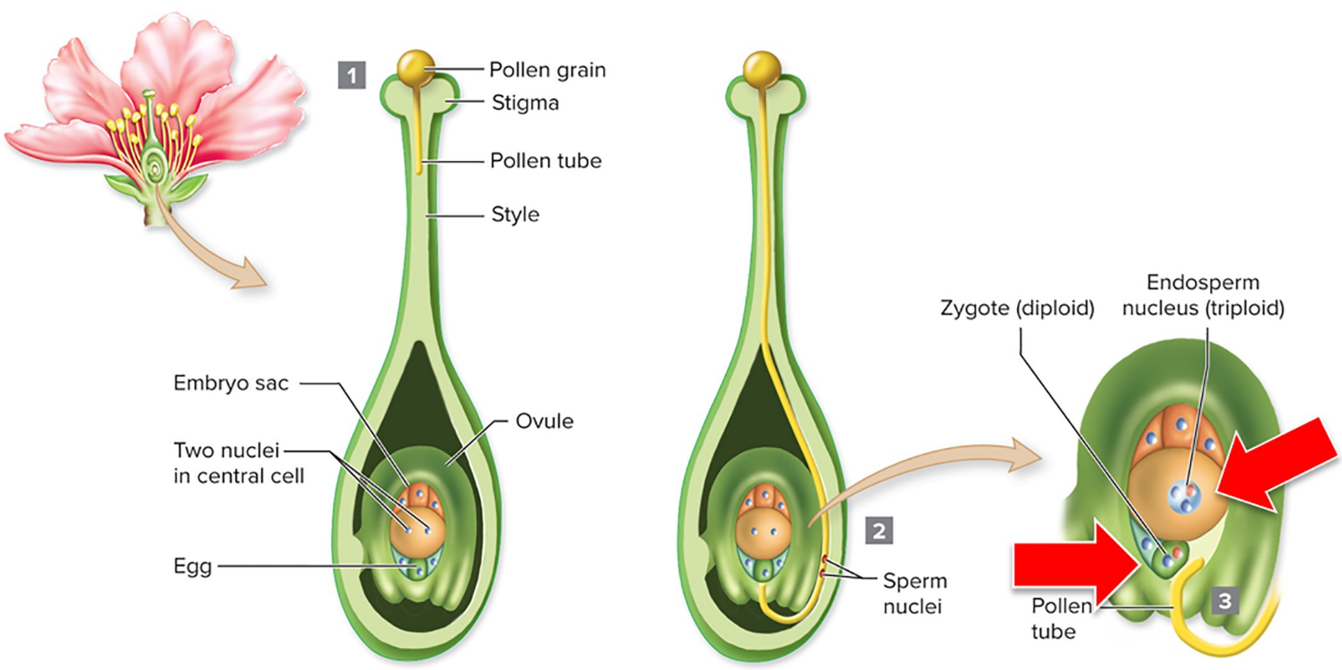
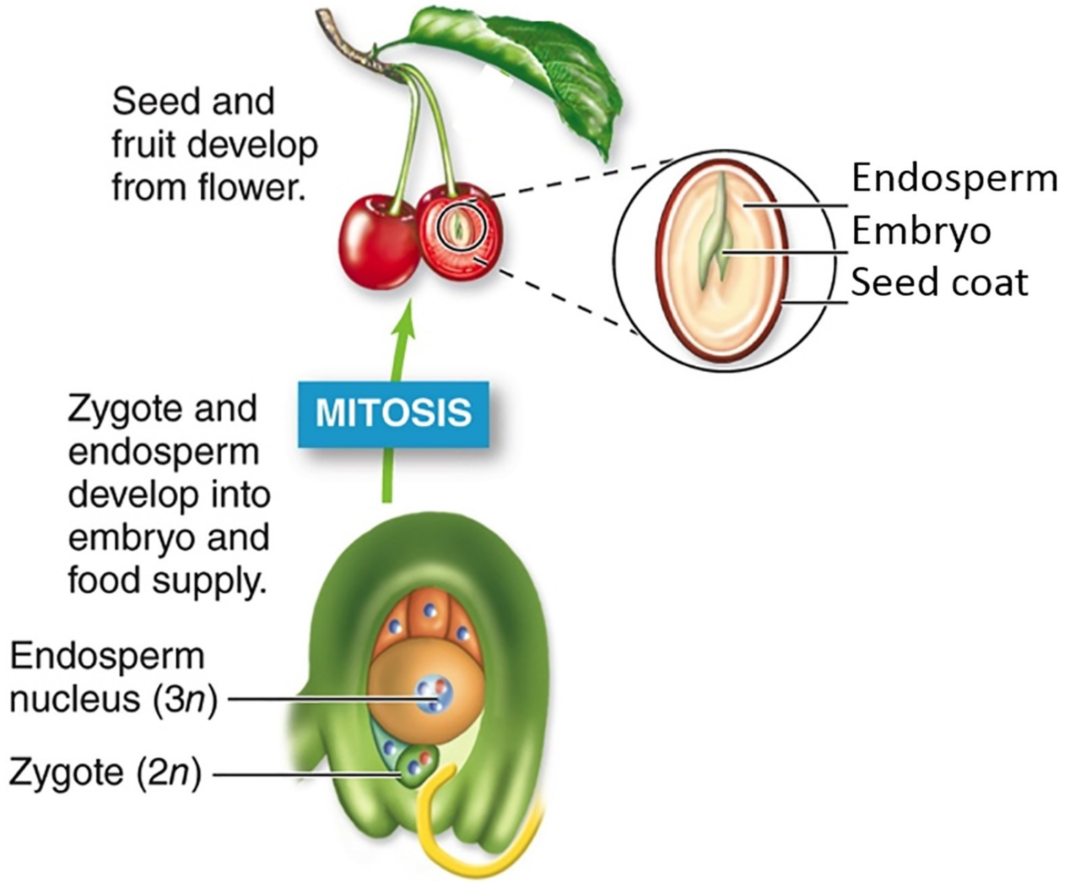


Figure 24.7

Angiosperm sex: Seeds



After fertilization, the seed starts to develop.

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

Figure 24.4

Seeds contain an embryo

The zygote develops from a single cell into an embryo.

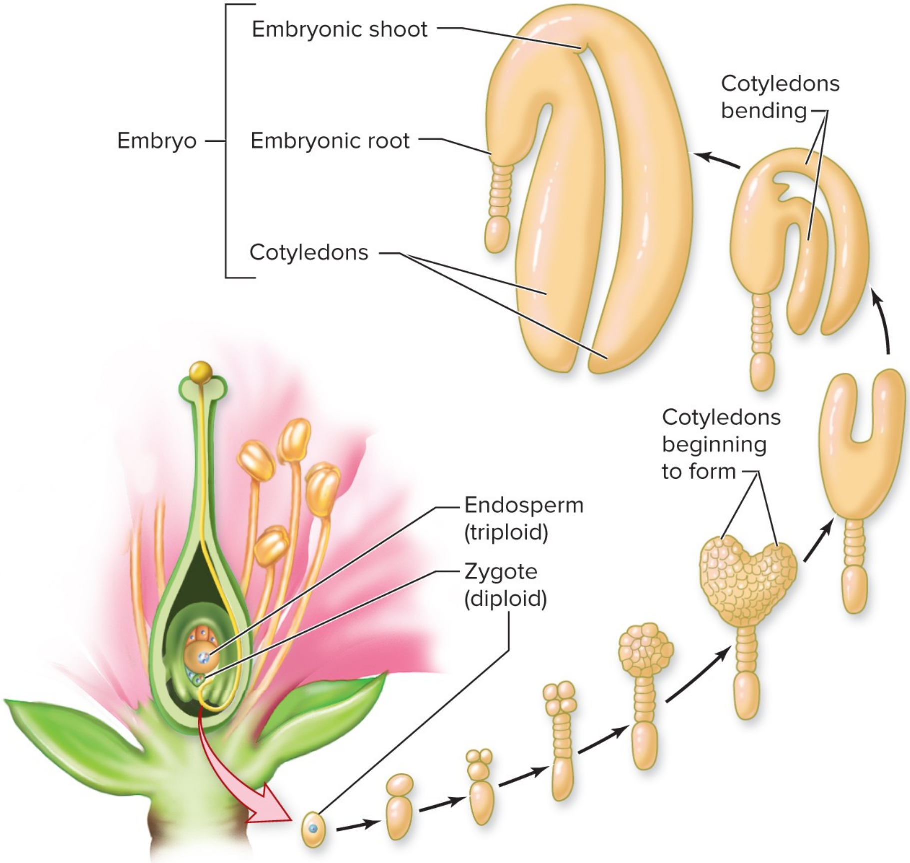


Figure 24.8

Seeds contain cotyledons

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

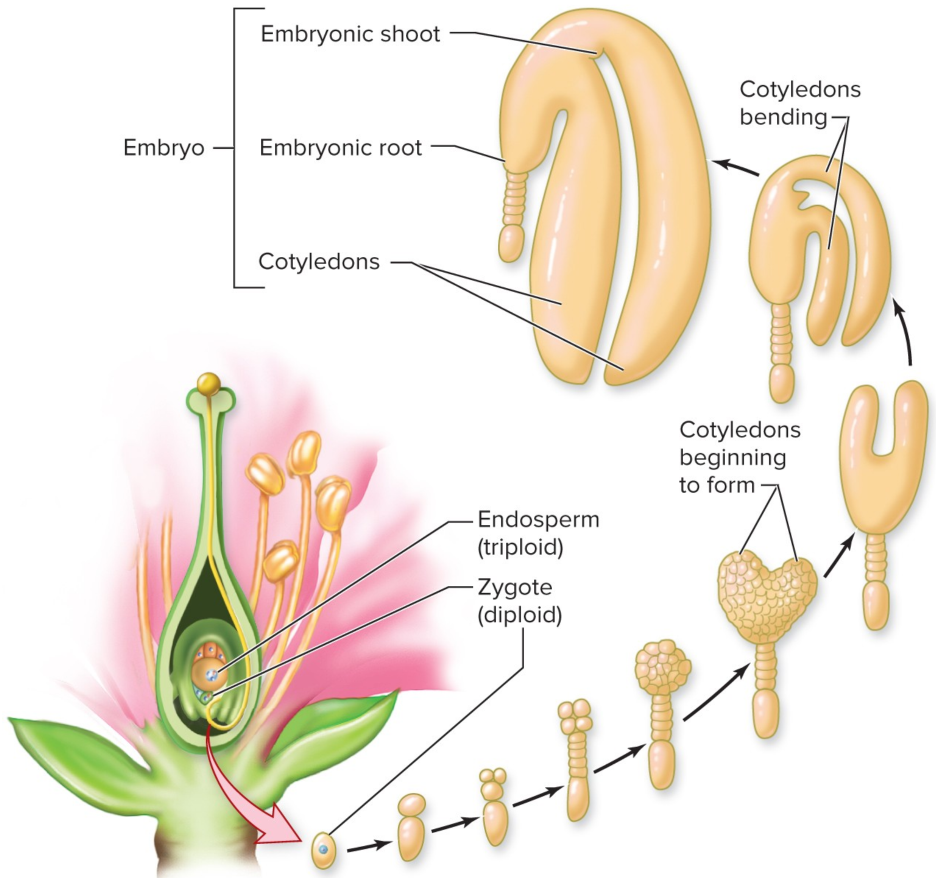
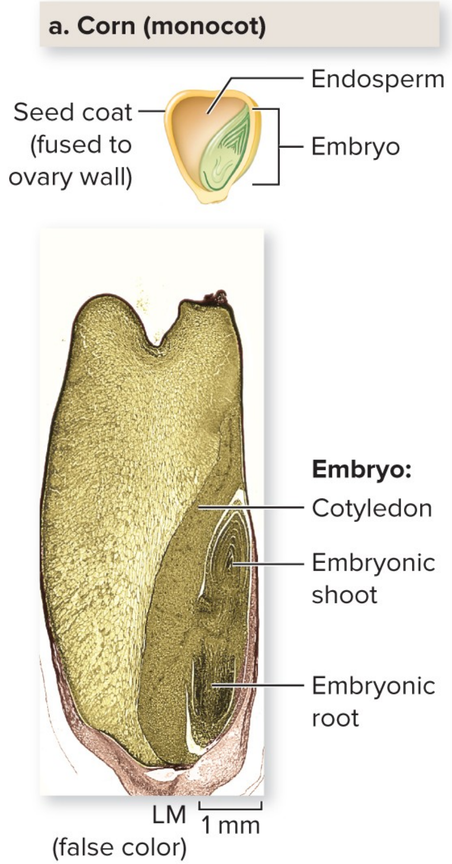


Figure 24.8

Endosperm feeds the embryo

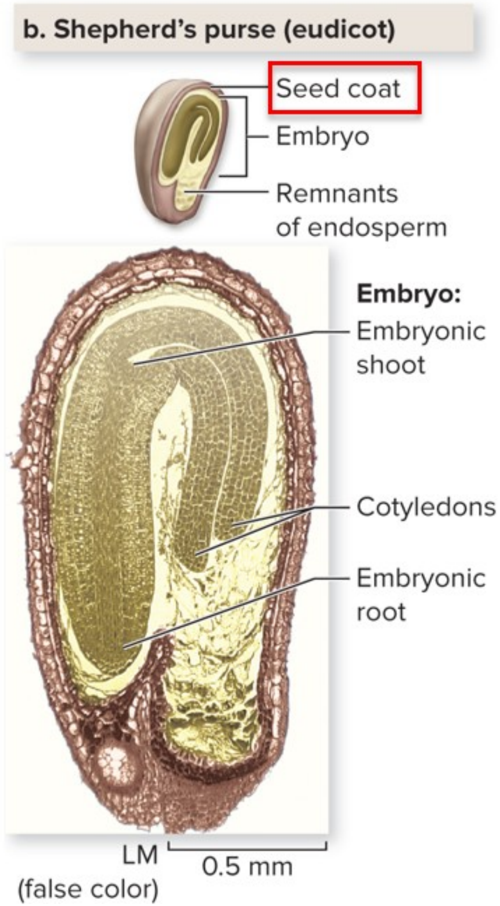
Endosperm cells divide rapidly and nourish the embryo.



(a): ©Steven P. Lynch/McGraw-Hill Education

The seed coat

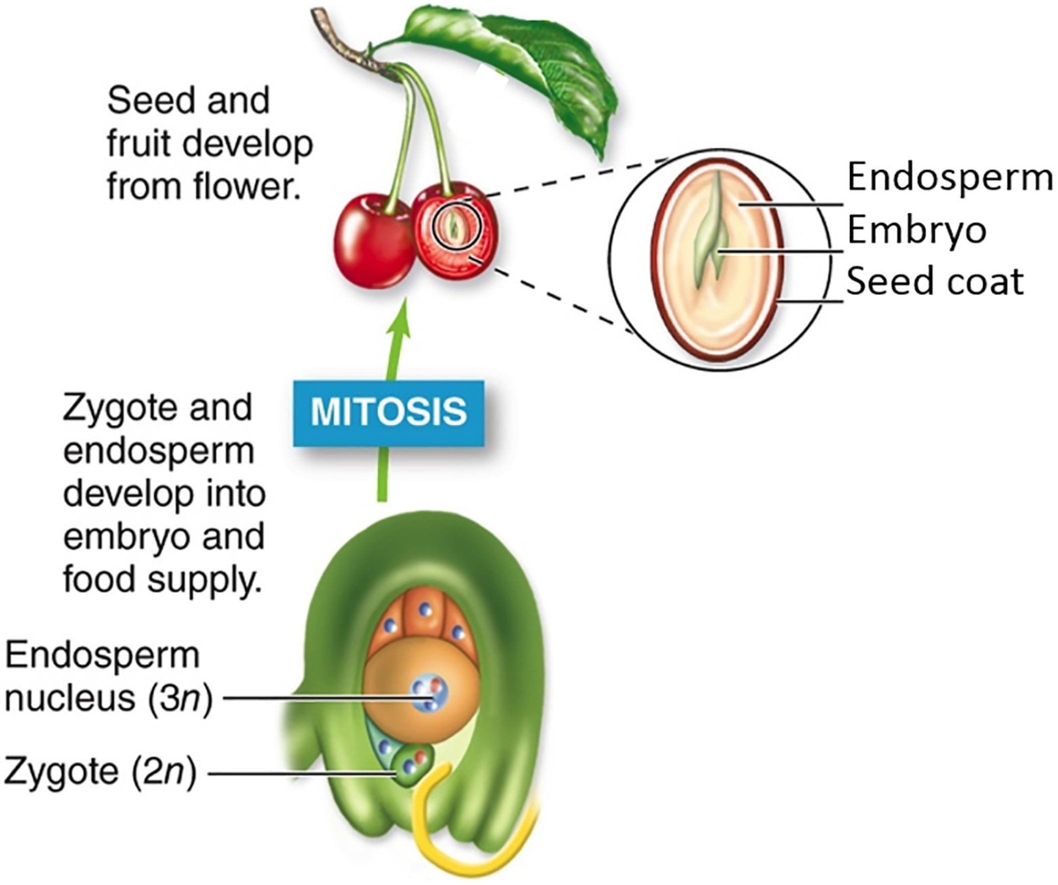
The **seed coat** is a tough outer layer that protects the embryo from damage, dehydration, and predators.



(b): ©Steven P. Lynch RF

Figure 24.9

Angiosperm sex: Fruits

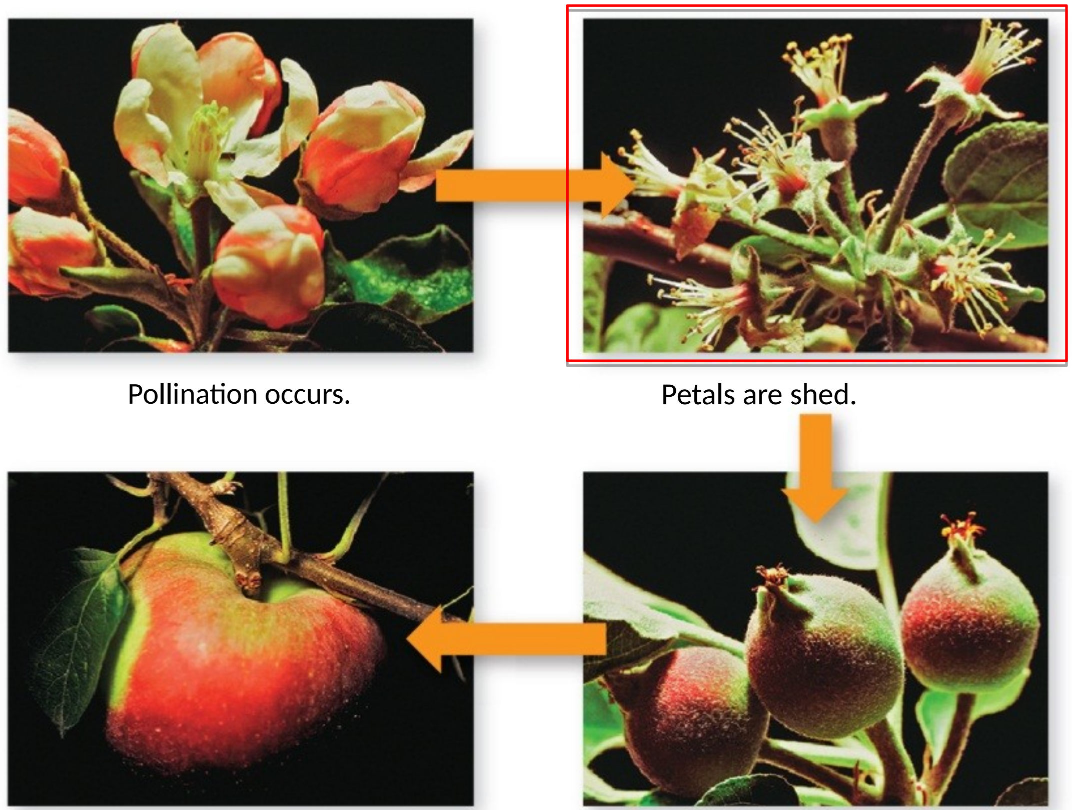


At the same time, a **fruit** develops from the ovary enclosing the developing seed(s).

Figure 24.4

Fruit formation

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



(all): ©Brent Seabrook

Figure 24.10

Hormones and fruit formation

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

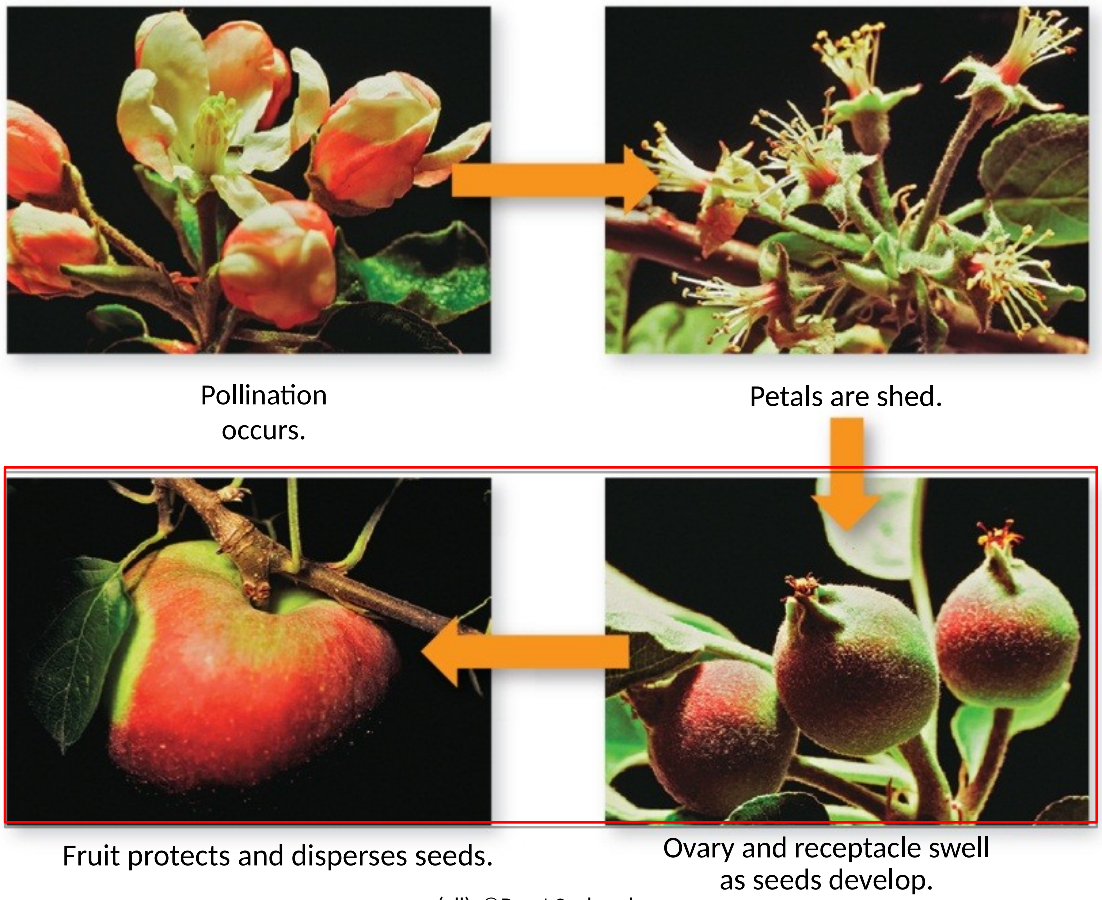


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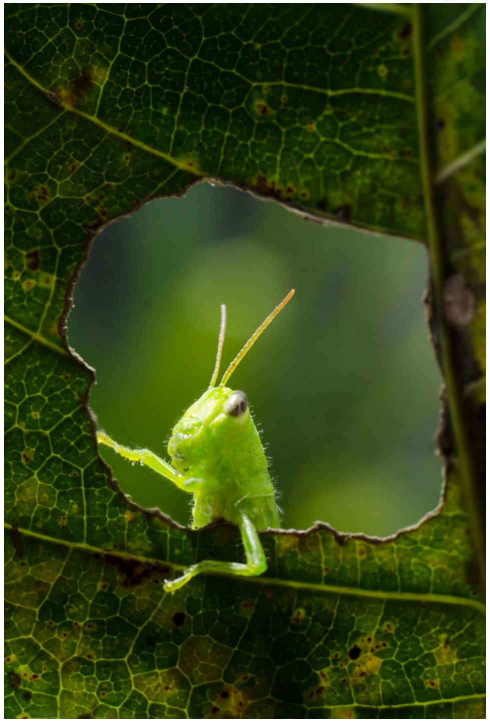
Figure 24.10

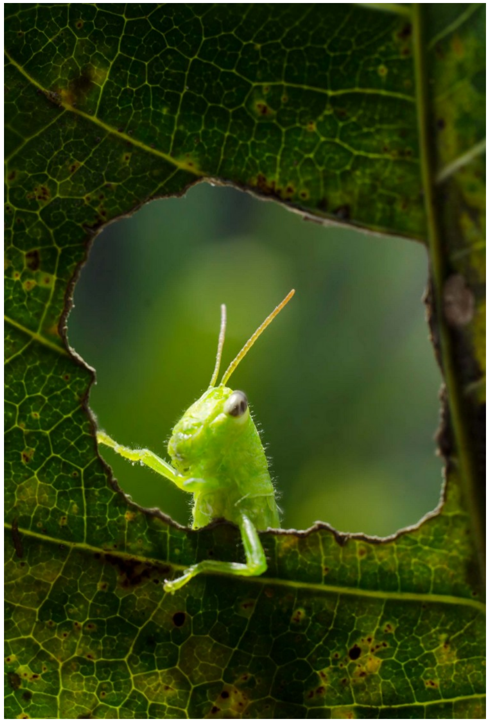
Clicker question #2



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.

Clicker question #2, solution



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

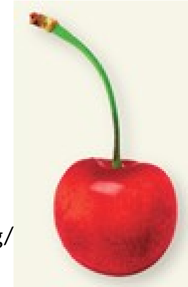
A.sexual intercourse; growth of the fetus

Flower: © Doug Sherman/Geofile/RF

There are many types of fruit

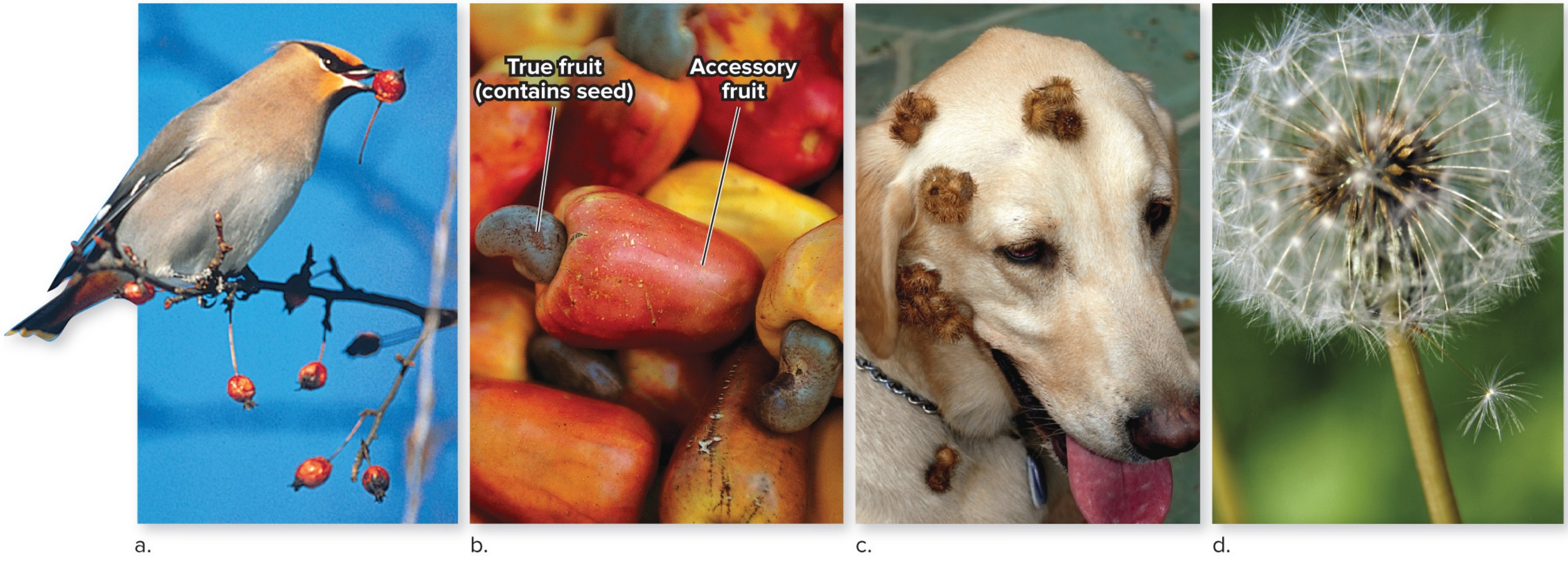
Fruits come in many forms.

T A B L E 24.1 Types of Fruits: A Summary

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

The function of fruit

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



(a): ©Rod Planck/Science Source; (b): ©Barry Barker/McGraw-Hill Education; (C) ©Scott Camazine/Science Source; (d): ©Ingram Publishing/SuperStock RF

Section 24.2

Figure 24.11

When does fruit ripen?

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

(a): ©Rod Planck/Science Source; (b): ©Barry Barker/McGraw-Hill Education; (C) ©Scott Camazine/Science Source; (d): ©Ingram Publishing/SuperStock RF

Figure 24.11

Prickly fruits

Prickly fruits stick to feathers or fur.

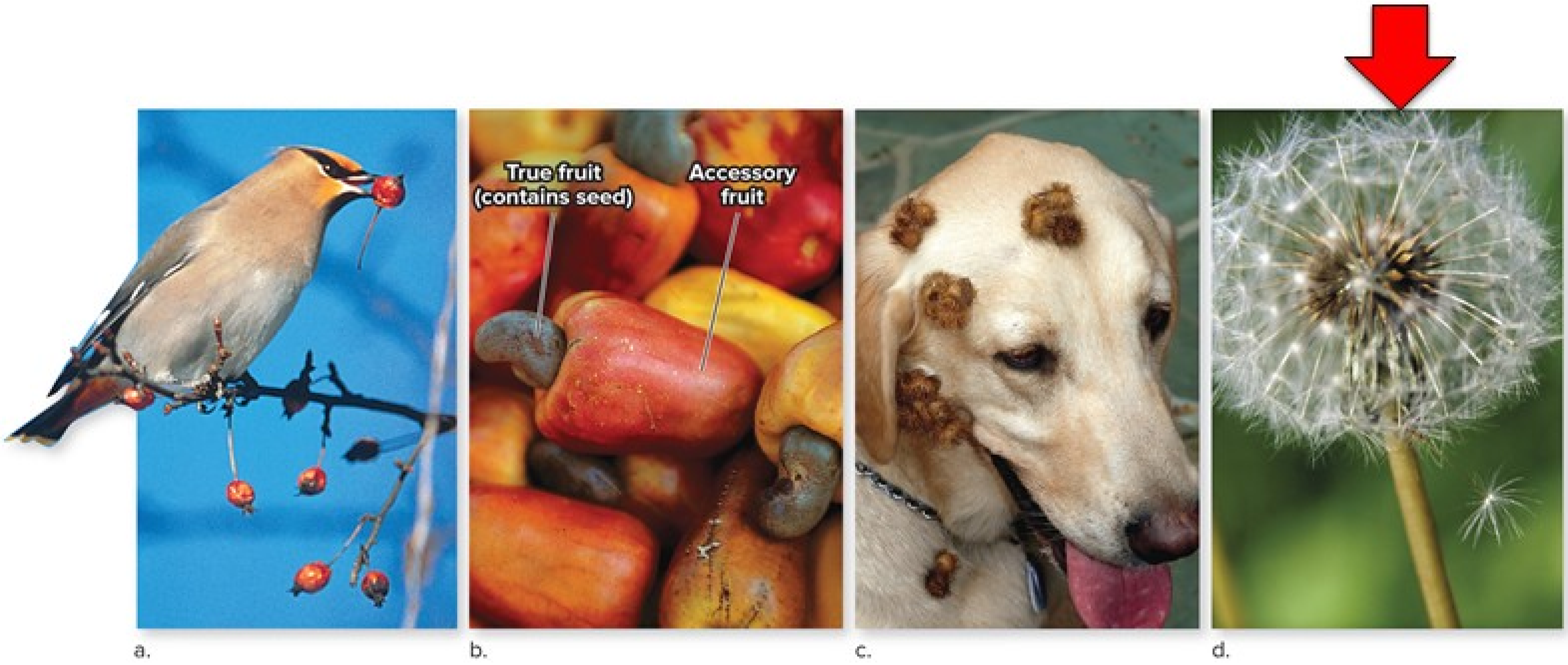
a. b. c. d.

(a): ©Rod Planck/Science Source; (b): ©Barry Barker/McGraw-Hill Education; (c) ©Scott Camazine/Science Source; (d): ©Ingram Publishing/SuperStock RF

Figure 24.11

Flying and floating fruit

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



(a): ©Rod Planck/Science Source; (b): ©Barry Barker/McGraw-Hill Education; (C) ©Scott Camazine/Science Source; (d): ©Ingram Publishing/SuperStock RF

24.2 Mastering concepts

(bee keeper): ©Liu Jin/AFP/Getty Images; (bee): ©Stephen Dalton/Science Source

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?

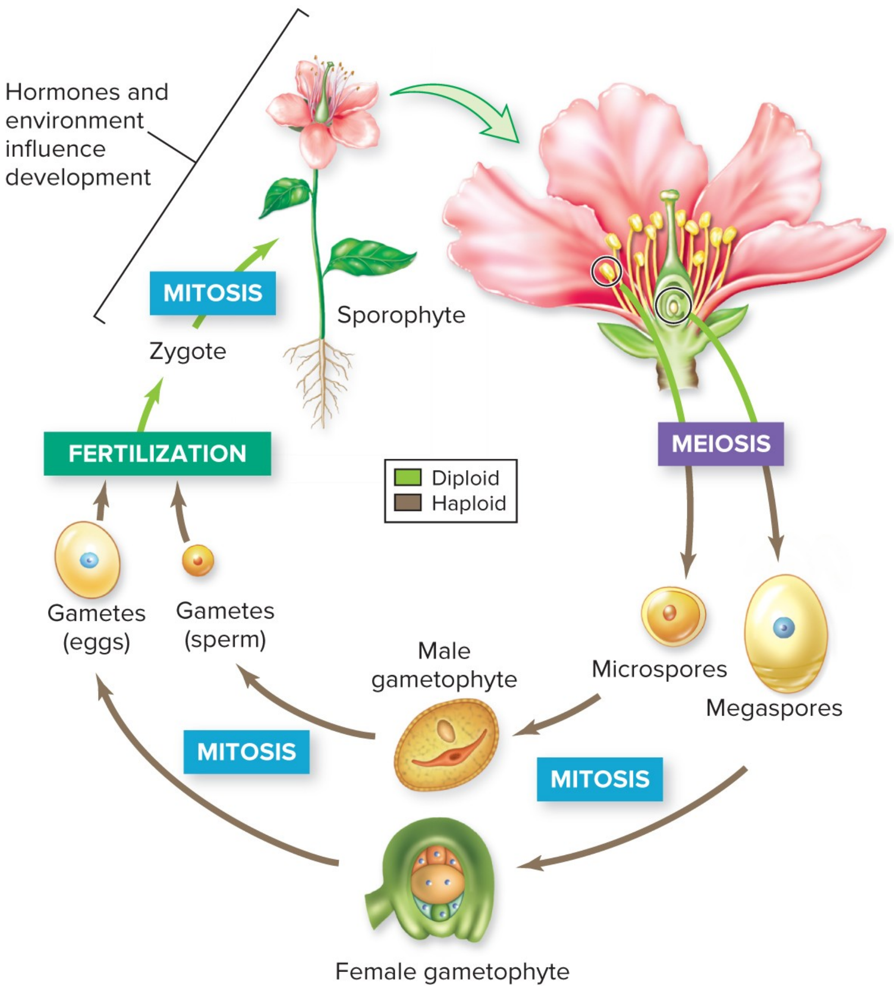
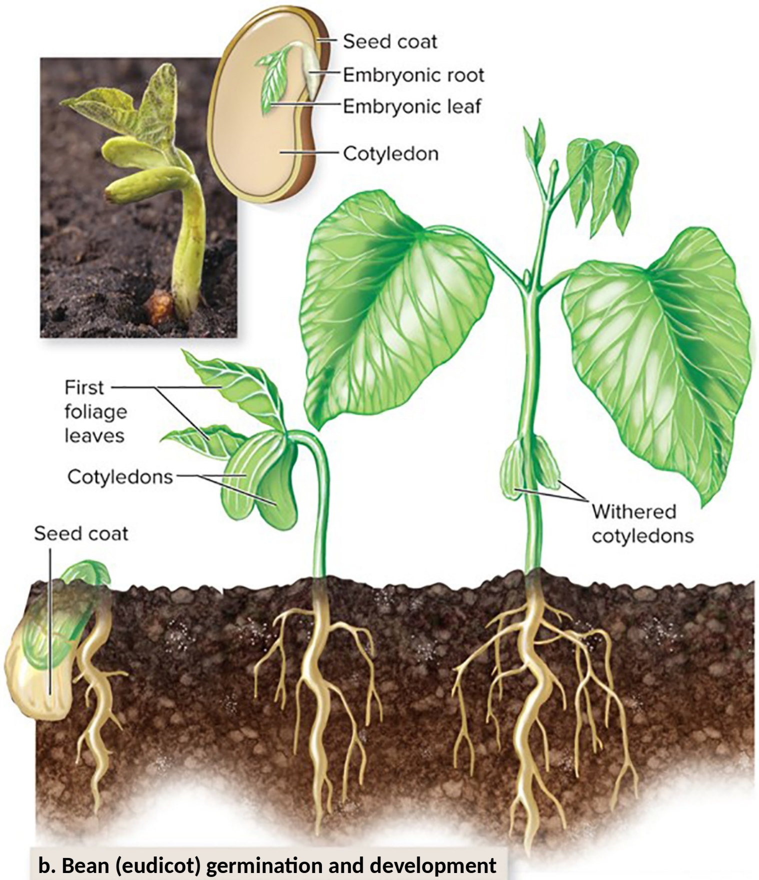


Figure 24.3

Seed germination



b. Bean (eudicot) germination and development

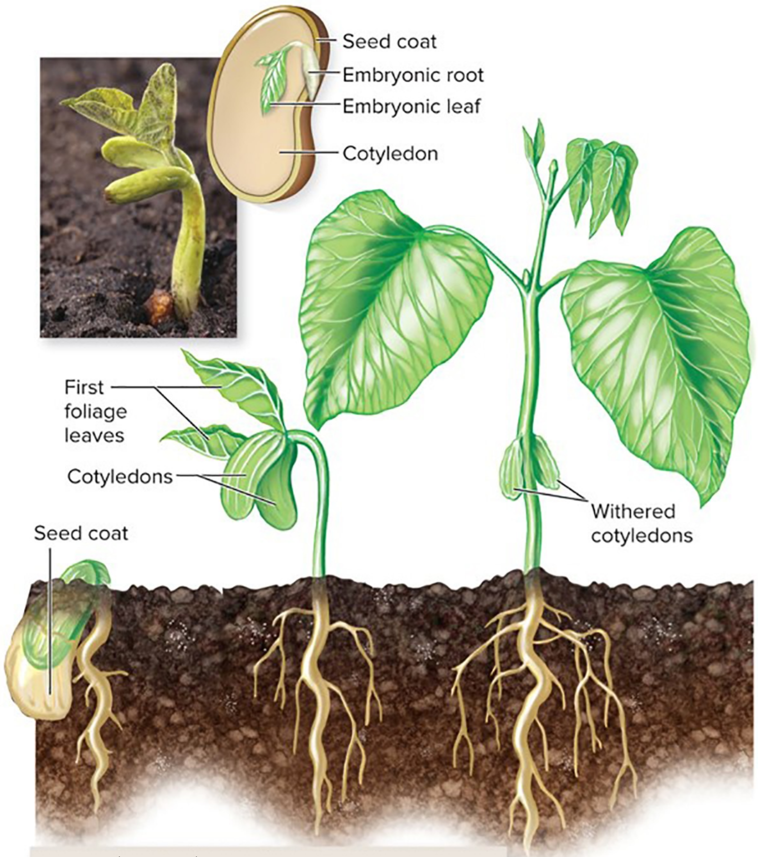
(b): ©Ed Reschke/Photolibrary/Getty Images

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

Germination requires water, , and a favorable temperature.

Figure 24.12

Seed germination: Rupturing the seed coat

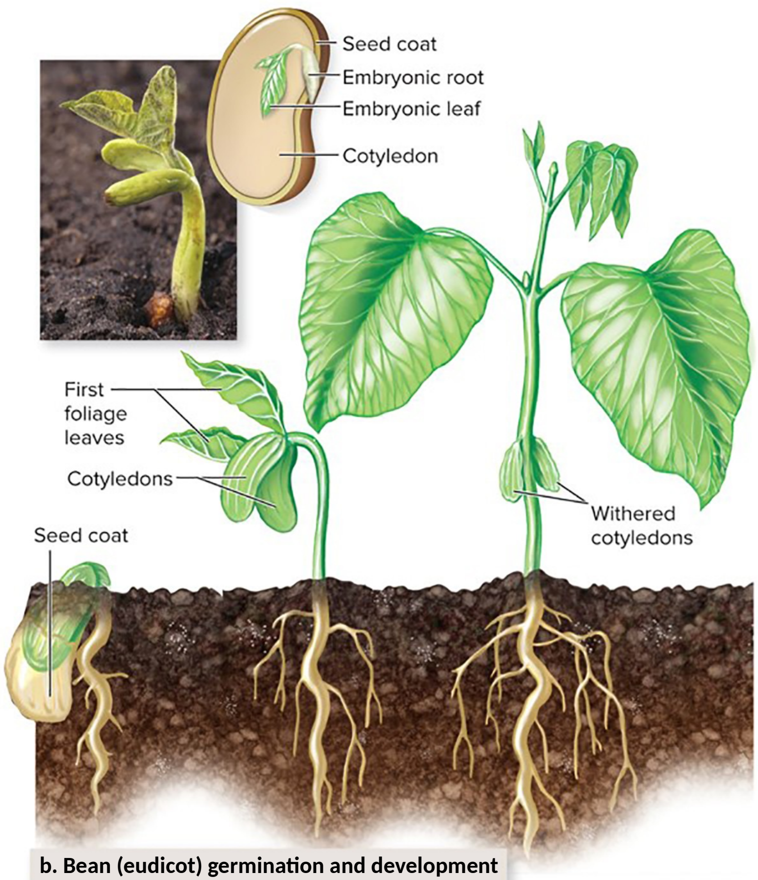


b. Bean (eudicot) germination and development

(b): ©Ed Reschke/Photolibrary/Getty Images

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

Seed germination: Endosperm fuels the growth of the embryo



b. Bean (eudicot) germination and development

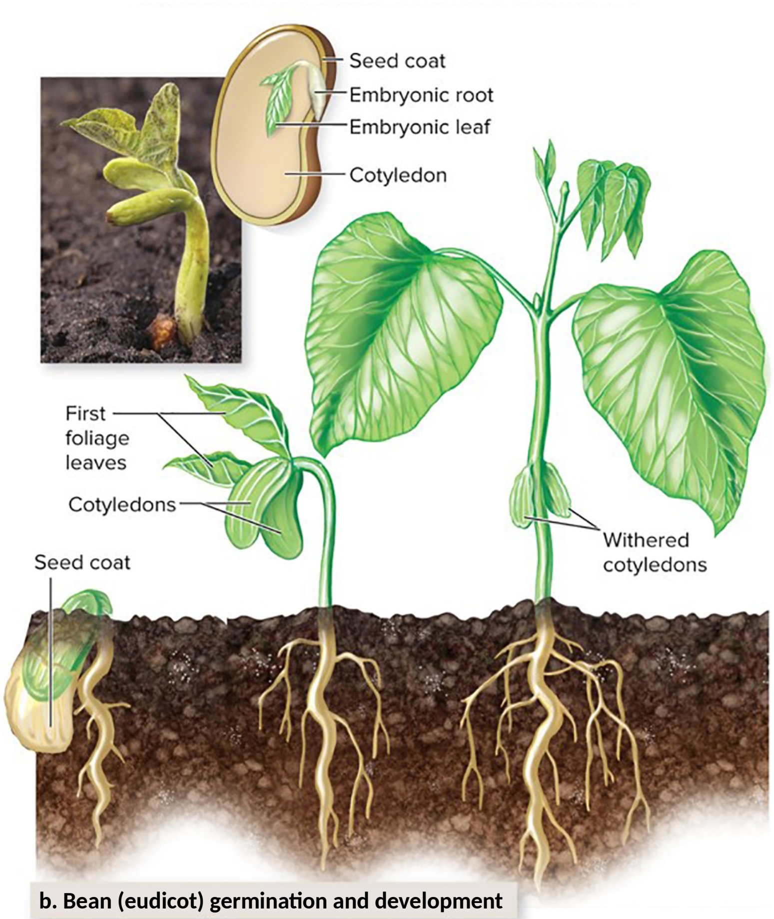
(b): ©Ed Reschke/Photolibrary/Getty Images

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

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

Figure 24.12

Plant growth before photosynthesis

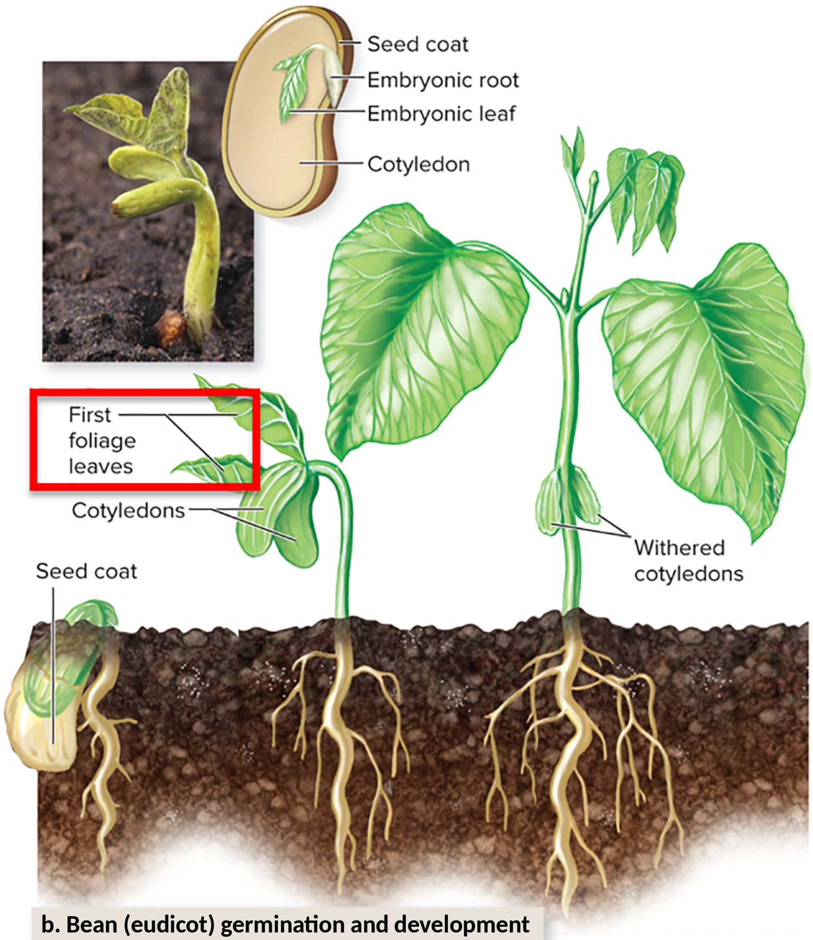


b. Bean (eudicot) germination and development

(b): ©Ed Reschke/Photolibrary/Getty Images

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

Photosynthesis takes over



(b): ©Ed Reschke/Photolibrary/Getty Images

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

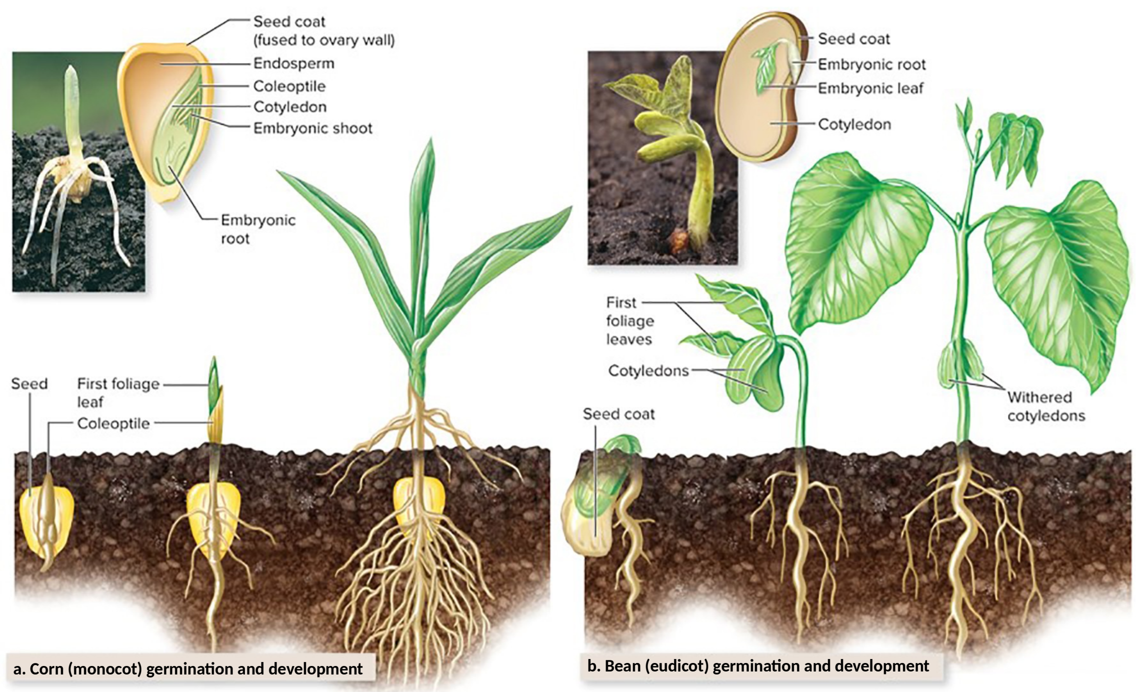
Figure 24.12

Seed germination in monocots and dicots

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

Monocot development

Eudicot development

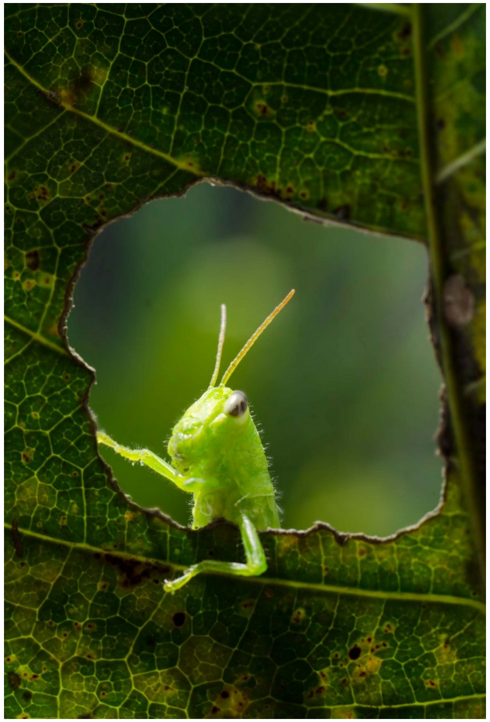


(a): ©Dwight Kuhn; (b): ©Ed Reschke/Photolibrary/Getty Images

Section 24.3

Figure 24.12

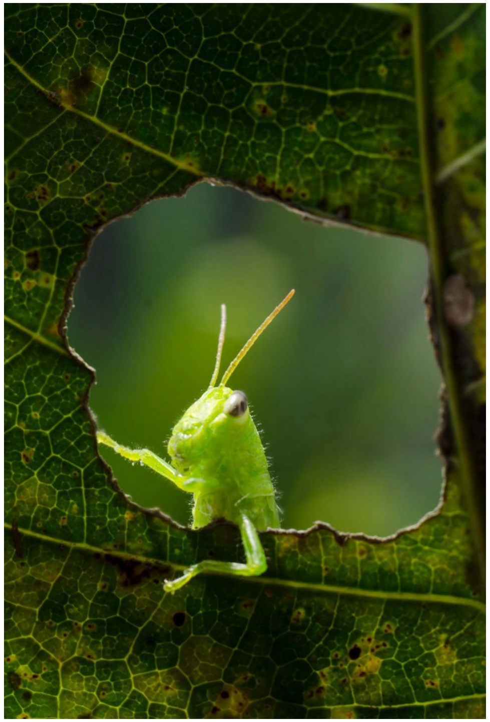
Clicker question #3



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, solution



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

D. water.

24.3 Mastering concepts

(bee keeper): ©Liu Jin/AFP/Getty Images; (bee): ©Stephen Dalton/Science Source

What are the events of early seedling development?

Hormones regulate plant growth

©Nigel Cattlin/Alamy

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

Figure 24.14

Five hormones regulate most plant growth

©Nigel Cattlin/Alamy

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

- auxins,
- cytokinins,
- gibberellins,
- ethylene,
- abscisic acid.

Figure 24.14

Hormones regulate plant growth: Auxin

©Nigel Cattlin/Alamy

Auxins control plant responses to light and gravity, promote elongation of cells in a stem, and suppress the growth of lateral buds.

Figure 24.14

Hormones regulate plant growth: Cytokinins

©Nigel Cattlin/Alamy

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

Figure 24.14

Apical dominance

©Nigel Cattlin/Alamy

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.**

The role of auxin

Apical dominance

©Nigel Cattlin/Alamy

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

The role of cytokinins

©Nigel Cattlin/Alamy

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

The plant's growth becomes bushier.

Figure 24.14

Hormones regulate plant growth: Gibberellins

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

Figure 24.15

Hormones regulate plant growth: Ethylene

©Kent Knudson/PhotoLink/Getty Images RF

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

Figure 24.16

The effects of ethylene

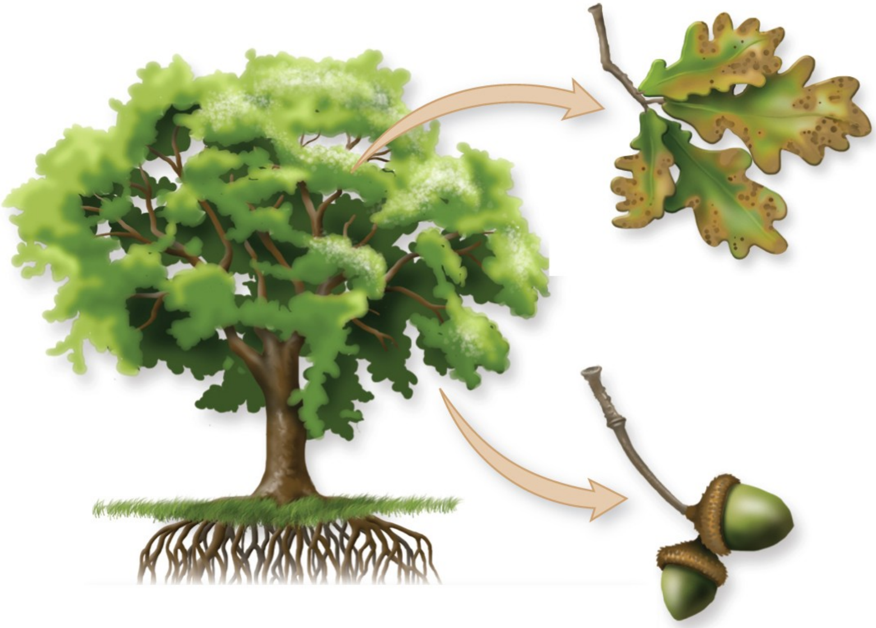
©Kent Knudson/PhotoLink/Getty Images RF

Ethylene is the hormone responsible for the changes in texture, softening, color, and other processes involved in ripening. Ethylene gas is used commercially to ripen tomatoes. If the tomatoes on the left were exposed to ethylene, they would turn red.

Section 24.4

Figure 24.16

Hormones regulate plant growth: Abscisic acid



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

A summary of hormones and plant growth

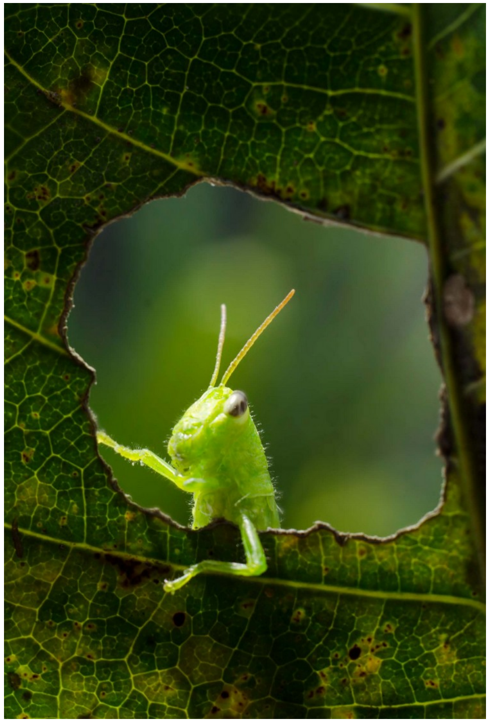
This table summarizes how hormones affect plant germination and development.

TABLE 24.2 The "Classic Five" Plant Hormones: A Summary

Class	Synthesis Site(s)	Mode of Transport	Selected Actions
Auxins	Shoot apical meristem, developing leaves and fruits	Diffusion between parenchyma cells associated with vascular tissue	•Stimulate elongation of cells in stem •Control phototropism, gravitropism, thigmotropism •Stimulate growth of adventitious roots from stem cuttings •Suppress growth of lateral buds in stem (apical dominance)
Cytokinins	Root apical meristem	In xylem	• Stimulate cell division in seeds, roots, young leaves, fruits • Delay leaf senescence • Stimulate cell division in stem's lateral buds when auxin concentrations are low
Gibberellins	Young shoot, developing seeds	In xylem and phloem	• Stimulate cell division and elongation in roots, shoots, young leaves • Break seed dormancy
Ethylene	All parts, especially under stress, aging, or ripening	Diffusion of gas	• Hastens fruit ripening • Stimulates leaf and flower senescence • Stimulates leaf and fruit abscission (shedding) • Participates in thigmotropism
Abscisic acid	Mature leaves, especially in plants under drought or freezing stress	In xylem and phloem	• Inhibits shoot growth and maintains bud dormancy • Induces and maintains seed dormancy • Stimulates closure of stomata

Table 24.2

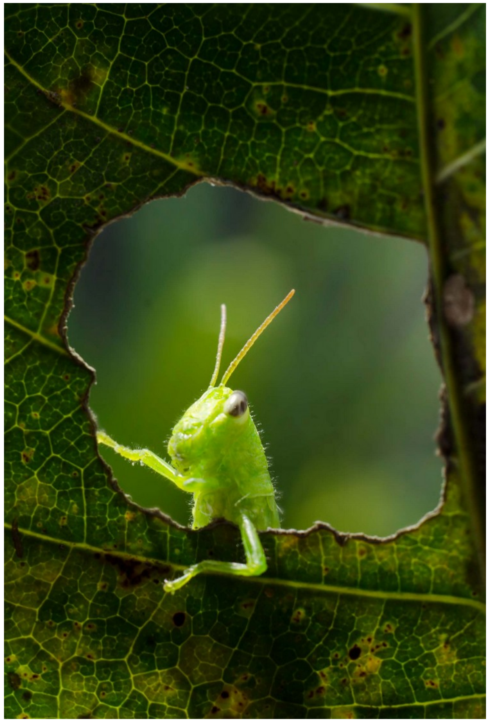
Clicker question #4



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, solution



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?

B. The plants were abnormally tall.

24.4 Mastering concepts

(bee keeper): ©Liu Jin/AFP/Getty Images; (bee): ©Stephen Dalton/Science Source

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

Light is a powerful influence on plant life

Many plants grow toward light.

©Martin Shields/Science Source

Phototropism

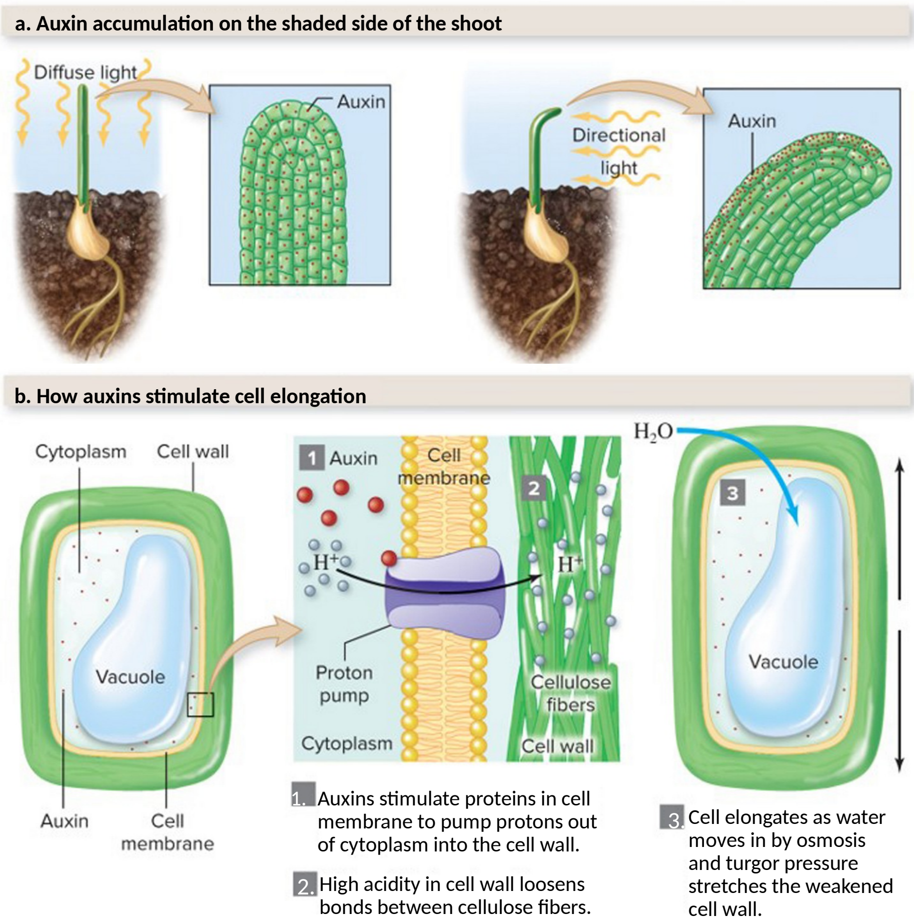
Phototropism is a plant's tendency to grow toward or away from light. How does this process occur?

©Martin Shields/Science Source

Light and auxin

©Martin Shields/Science Source

The hormone auxin has a role in phototropism. As auxin molecules migrate away from light, they accumulate on the shaded side of a stem.



Figs. 24.17, 24.18

Auxin and phototropism

Auxin binds to proton pumps, which transport hydrogen ions out of the cell. As the acidity in the cell wall increases, the bonds between cellulose fibers loosen.

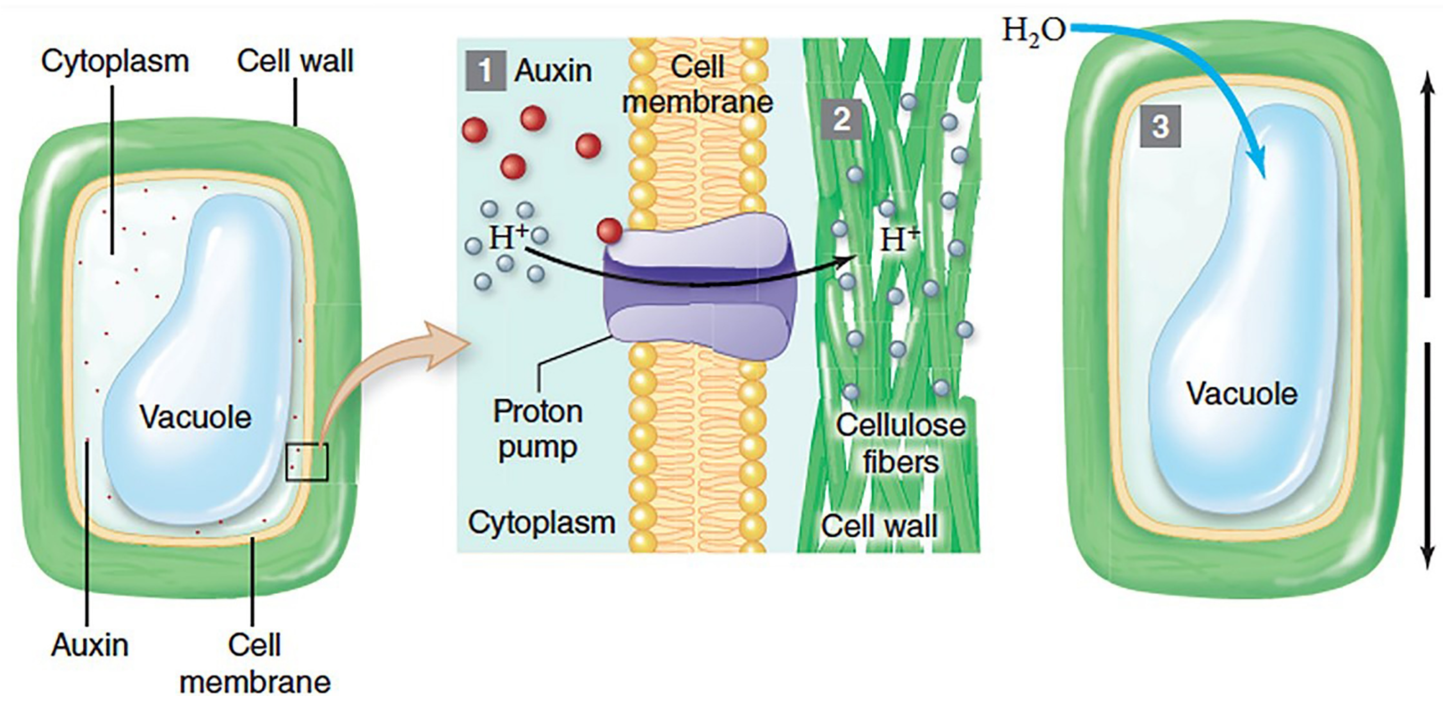


Figure 24.18

Auxin and phototropism, continued

Water enters cells on the shaded side of the stem by osmosis. Since the cell wall is less rigid, inflowing water causes the cells elongate.

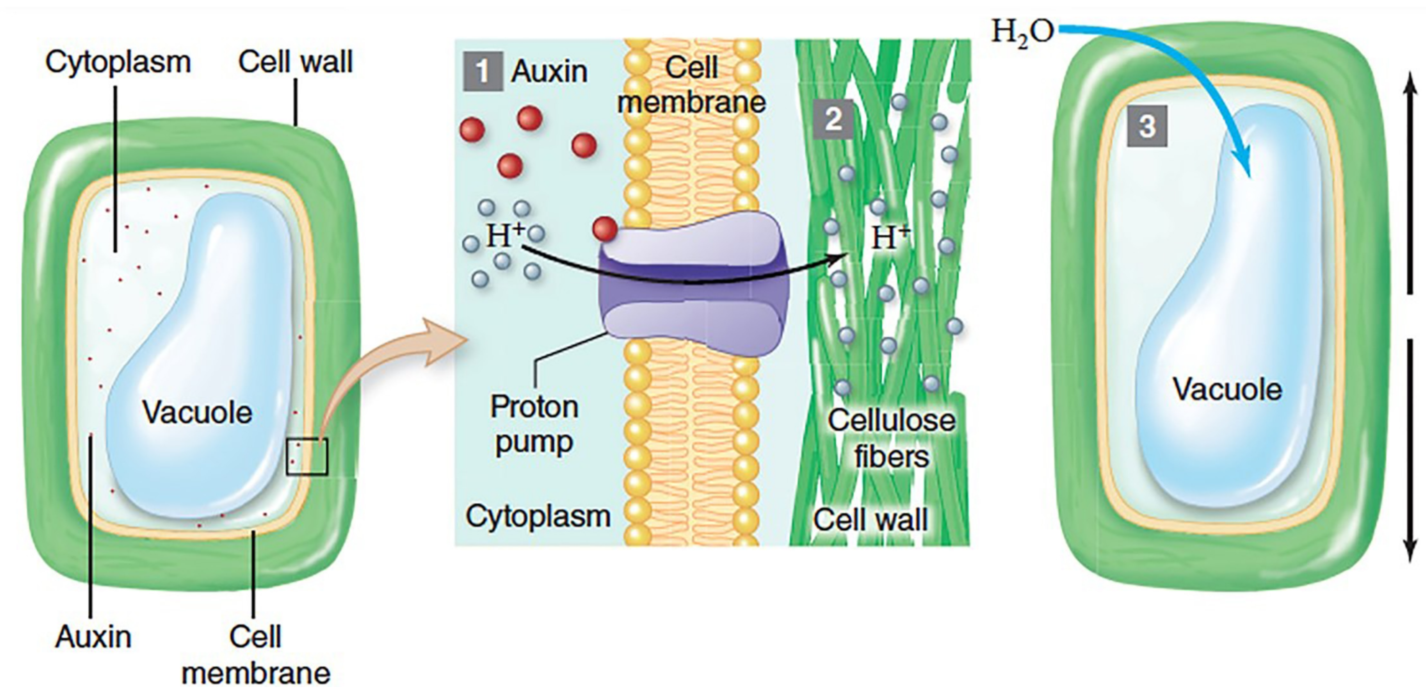
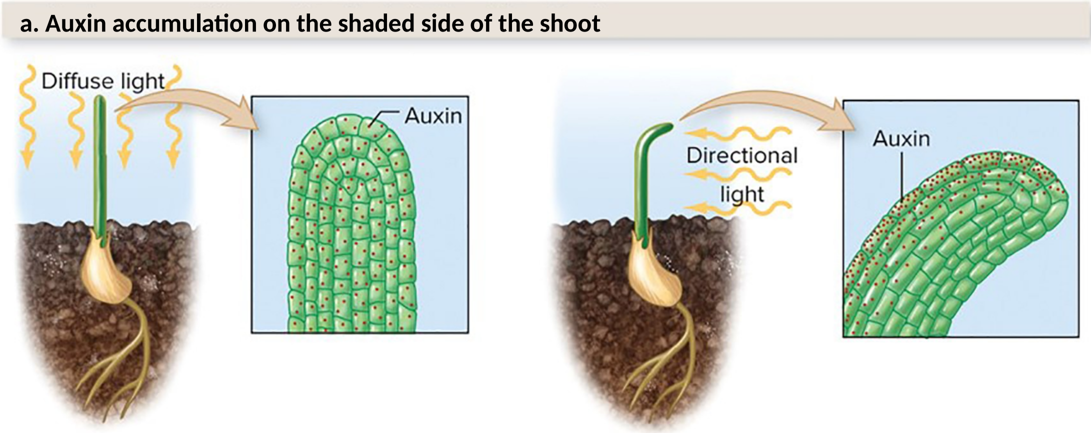


Figure 24.18

The effect of phototropism

©Martin Shields/Science Source

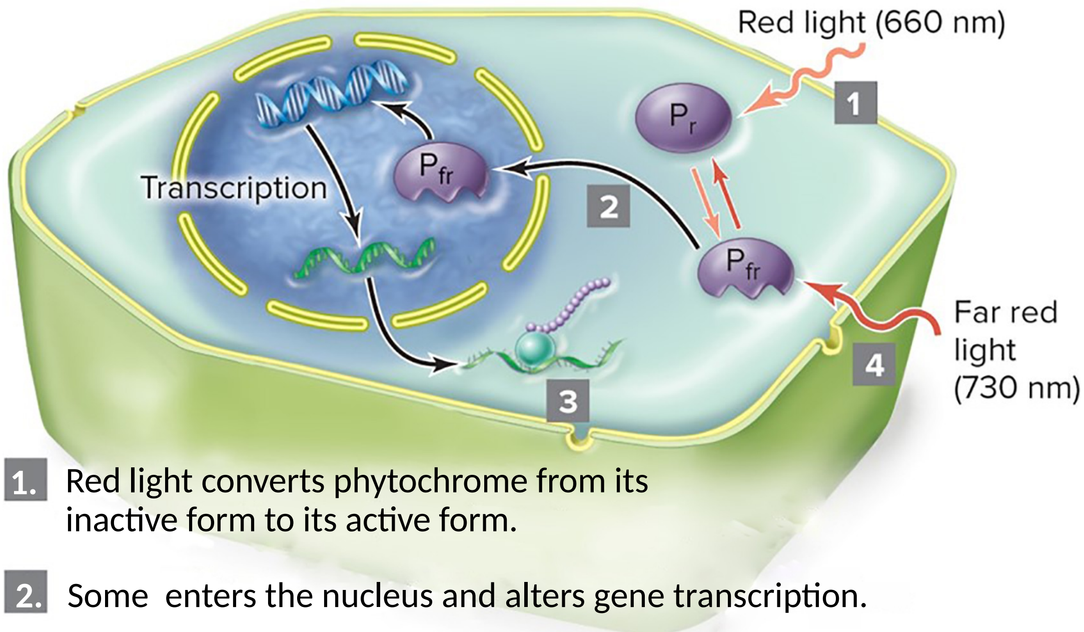
Elongation of these cells causes the stem to bend toward the light.



Figs. 24.17, 24.18

Light and phytochrome

Light also regulates seed germination, daily rhythms, and flowering by means of a photoreceptor in plants called **phytochrome**.

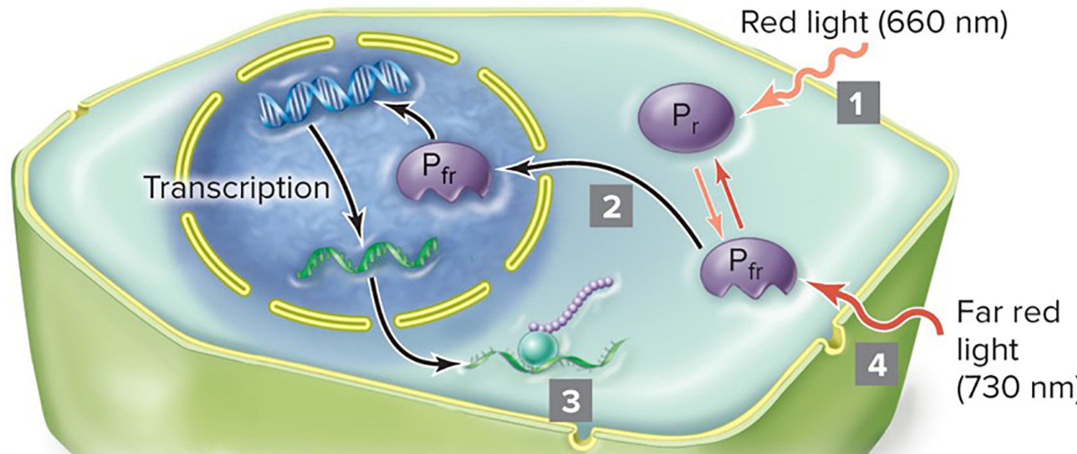


1. Red light converts phytochrome from its inactive form to its active form.
2. Some enters the nucleus and alters gene transcription.
3. Translation produces proteins controlling seed germination, flowering, etc.
4. Far red light converts back to . also slowly converts to in darkness.

Figure 24.19

Phytochrome

Phytochrome transforms to its active form when it absorbs red light.



1. Red light converts phytochrome from its inactive form to its active form.
2. Some enters the nucleus and alters gene transcription.
3. Translation produces proteins controlling seed germination, flowering, etc.
4. Far red light converts back to . also slowly converts to in darkness.

Figure 24.19

The effects of phytochrome

Phytochrome helps plants sense day length. Plants flower when periods of darkness meet certain thresholds.

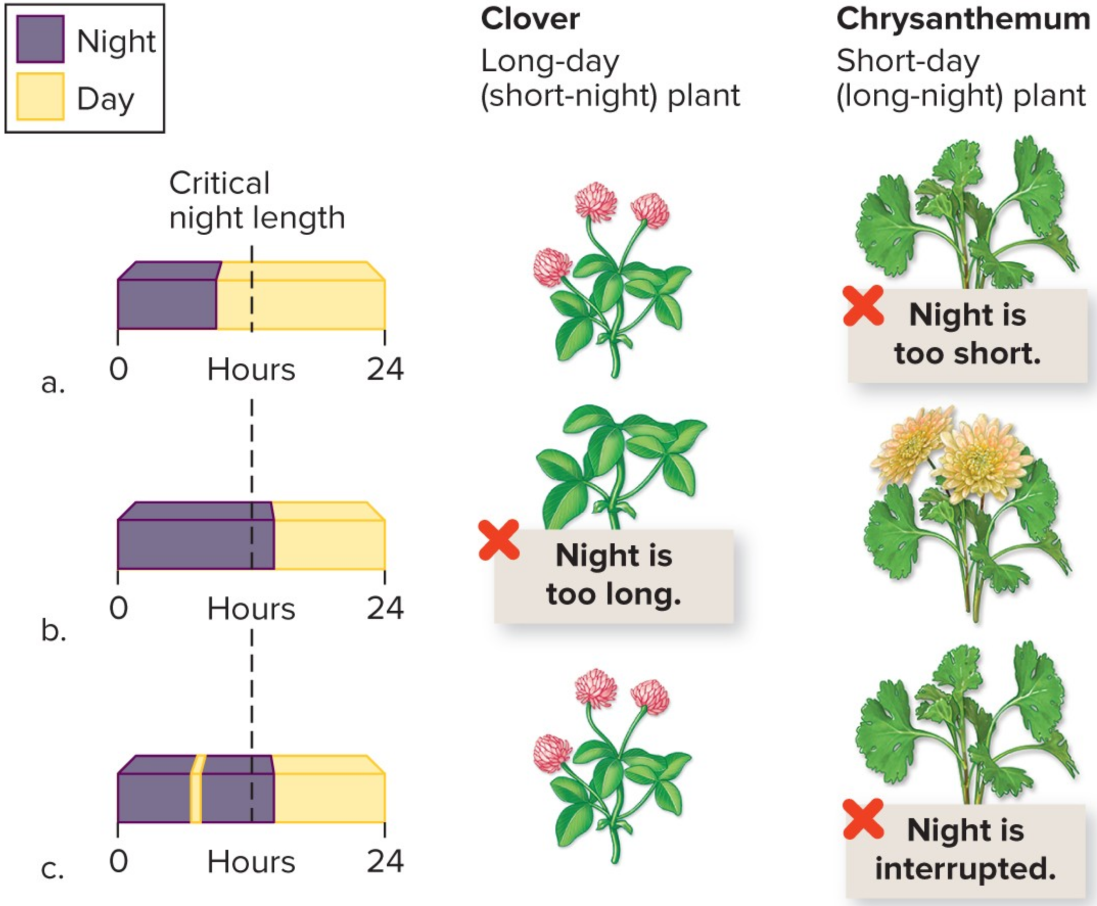


Figure 24.22

Phytochrome and flowering

The dominant form of phytochrome determines whether flowering will occur. In this experiment, the last flash of light determines the prevalent form of phytochrome.

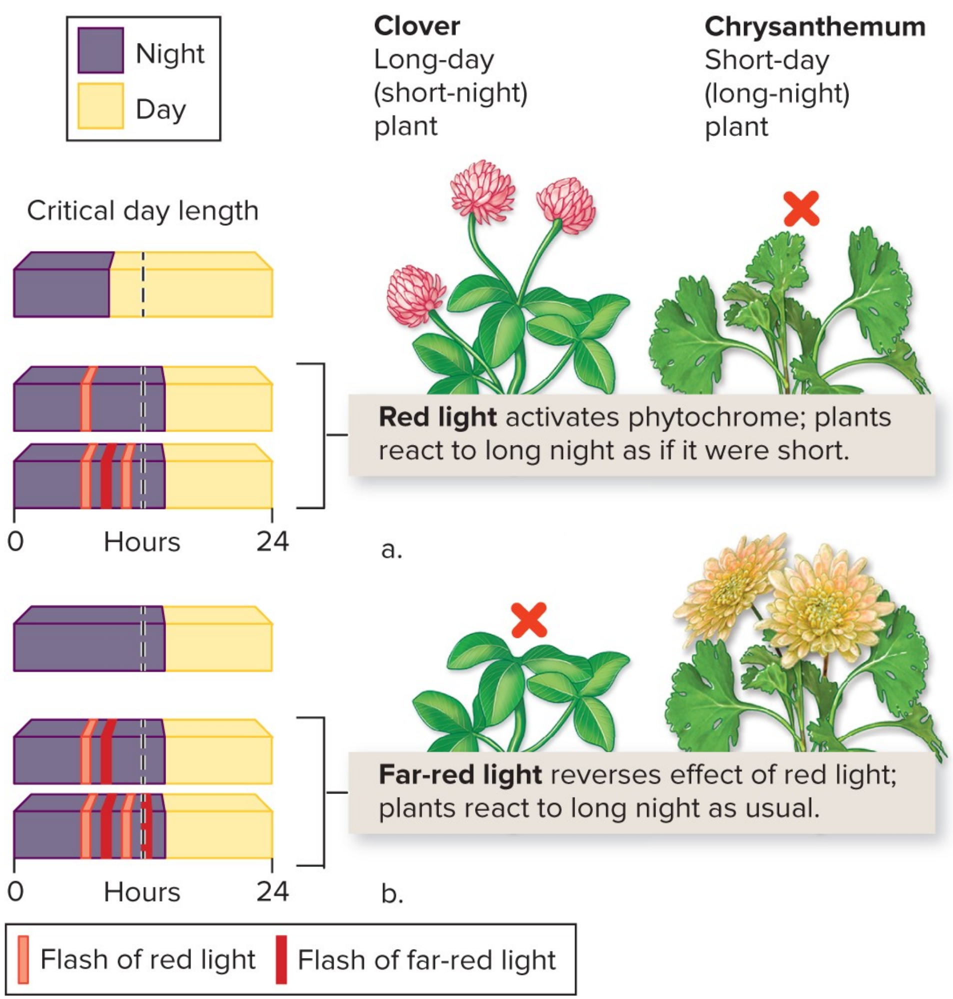


Figure 24.23

24.5 Mastering concepts

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What is auxin’s role in phototropism?

Plants respond to gravity and touch

Gravity is another important environmental cue.

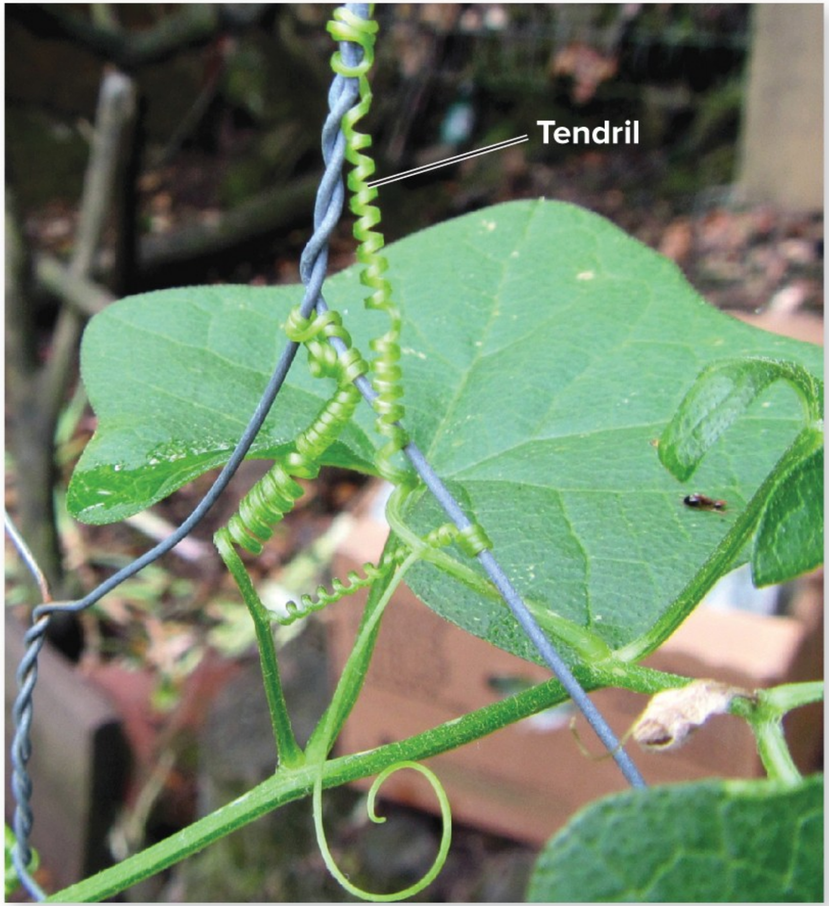

Figure 24.25

Gravitropism

Gravitropism is directional growth in response to gravity. Shoots always grow upward.

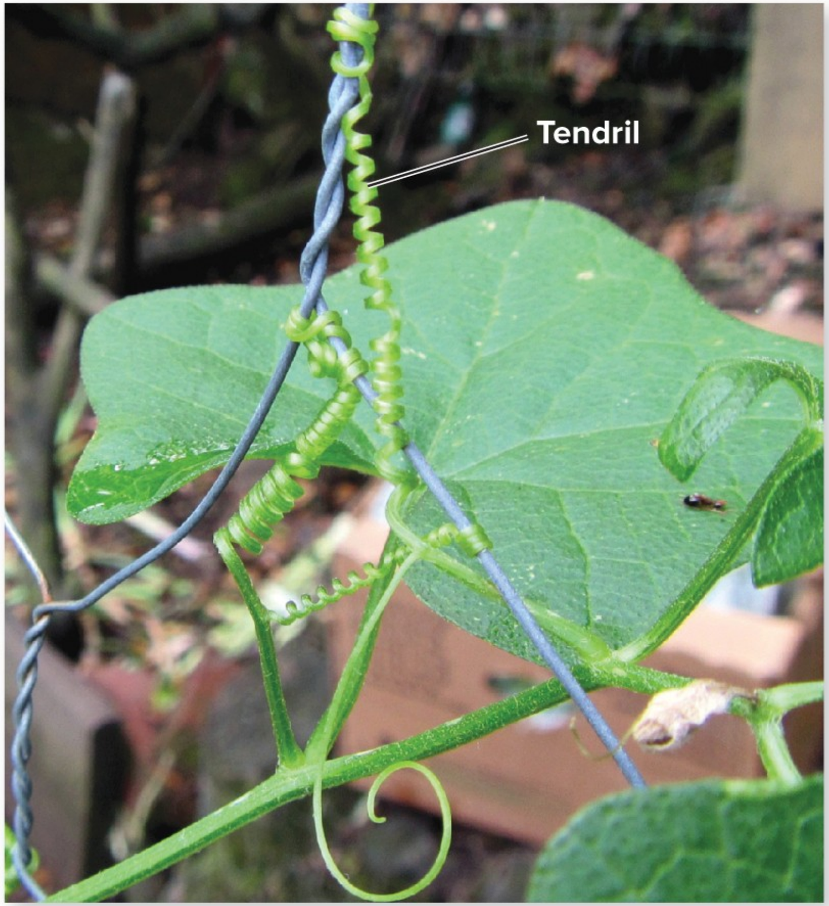

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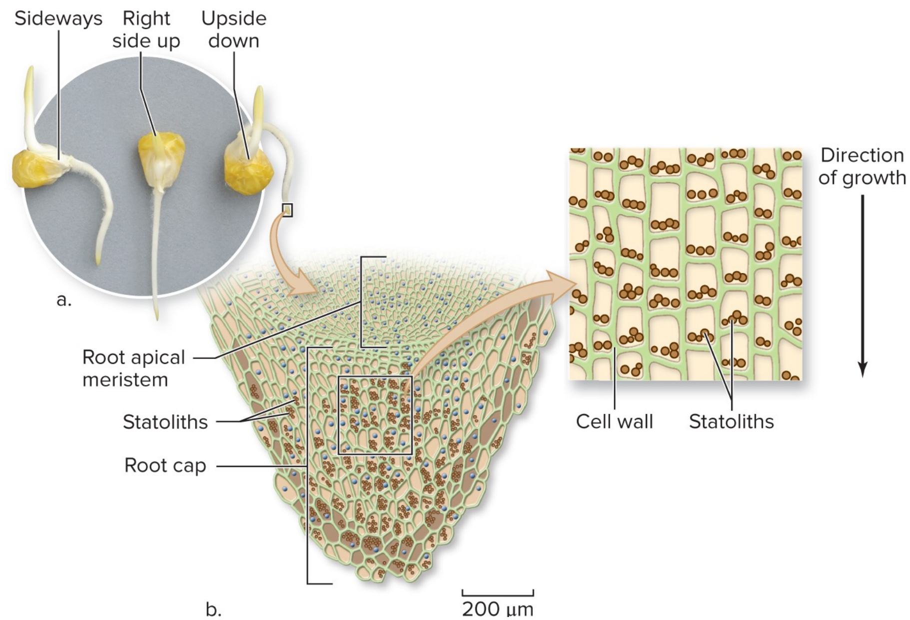
Figure 24.25

Gravitropism and statoliths

Roots always grow downward. **Statoliths** sink to the bottom of cells and therefore might help plants detect gravity.



(a): ©Martin Shields/Science Source

Figure 24.24

Thigmotropism

Plants also respond to touch, a reaction called **thigmotropism**.

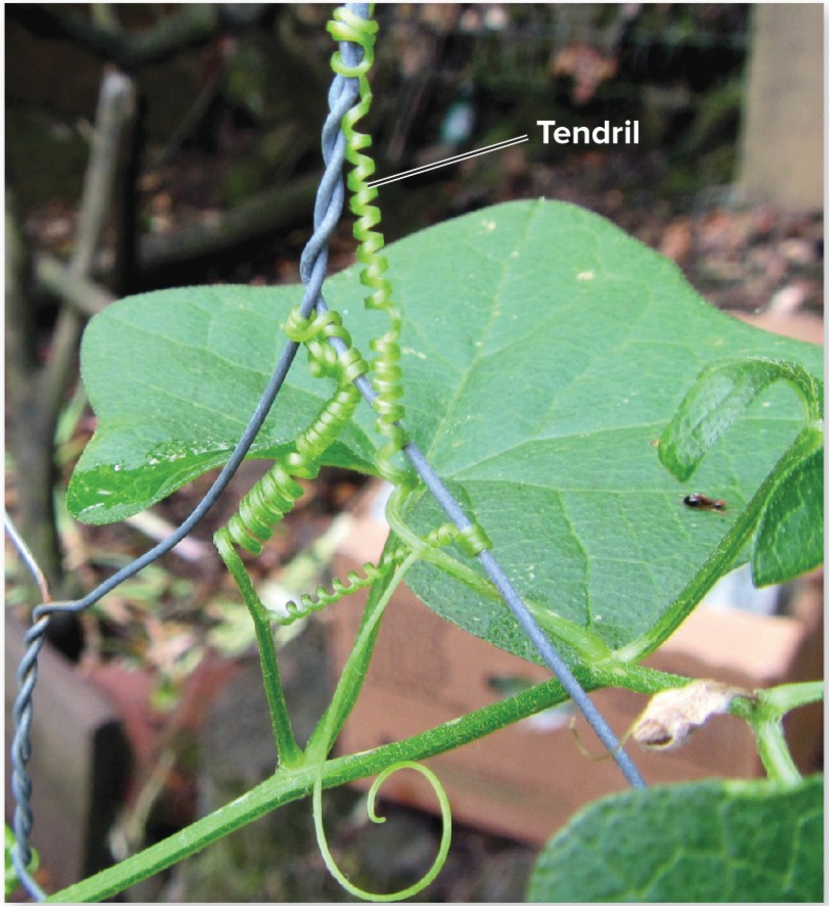


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Figure 24.25

An example of thigmotropism

Specialized epidermal cells detect contact with an object, which stimulates the tendril to bend.

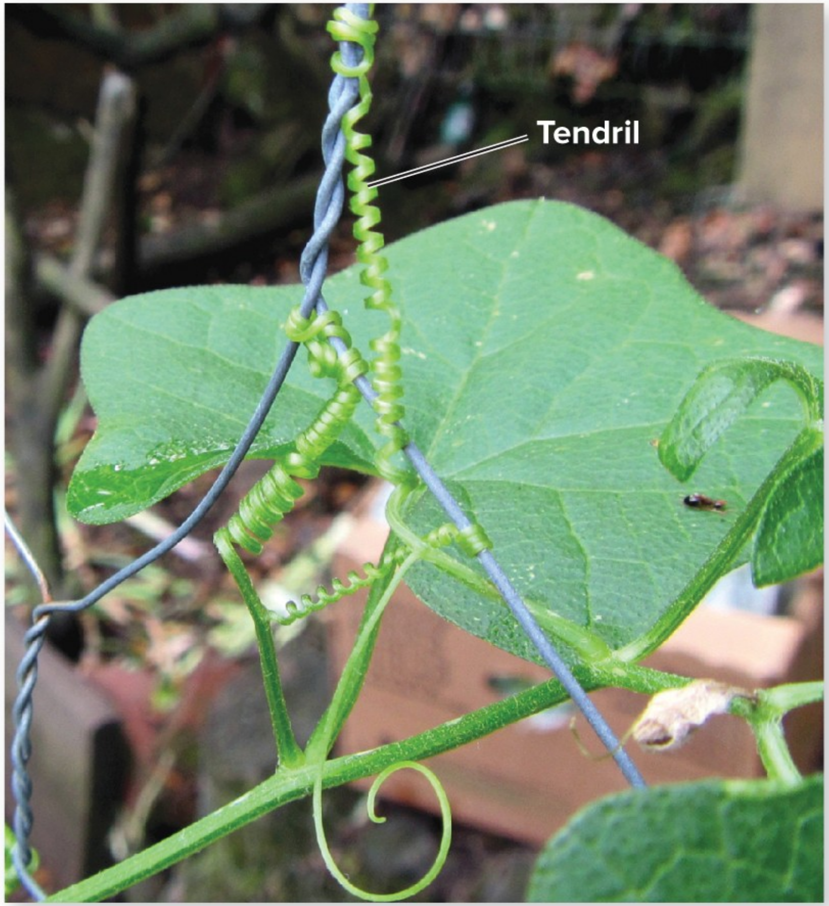

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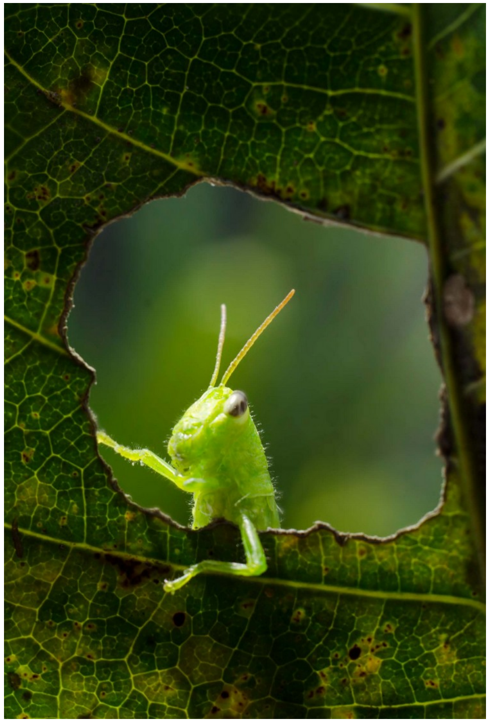
Figure 24.25

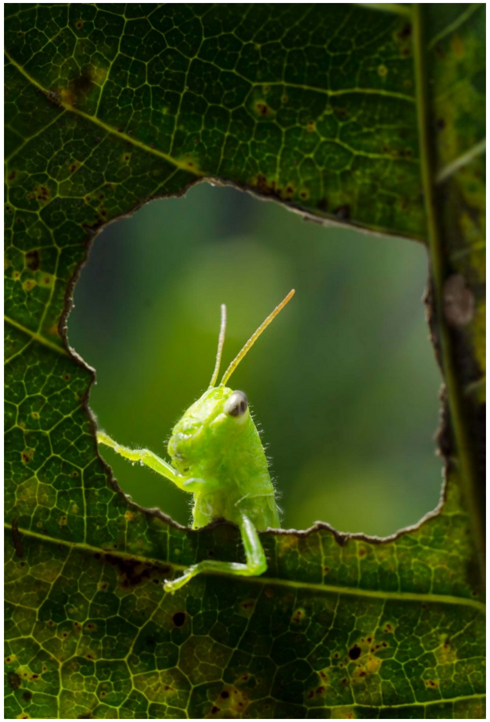
Clicker question #5



Thigmotropism allows climbing plants to wrap tendrils around a supportive structure (like a trellis). This adaptation improves the plant’s ability to

A. absorb food through their roots.
B. absorb food through their leaves.
C. absorb .
D. acquire light.
E. absorb water.

Clicker question #5, solution



Thigmotropism allows climbing plants to wrap tendrils around a supportive structure (like a trellis). This adaptation improves the plant's ability to

D. acquire light.

24.6 Mastering concepts

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How do statoliths participate in gravitropism?

Plant parts die or become dormant

During **senescence**, metabolism changes from synthesis to breakdown.

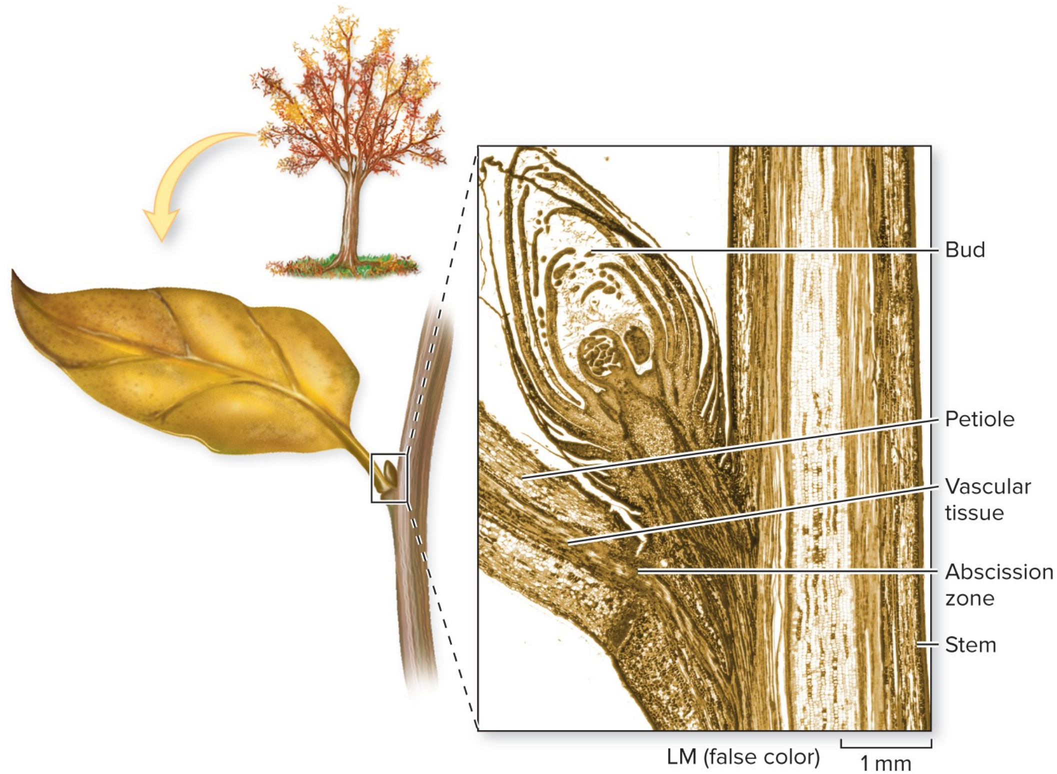

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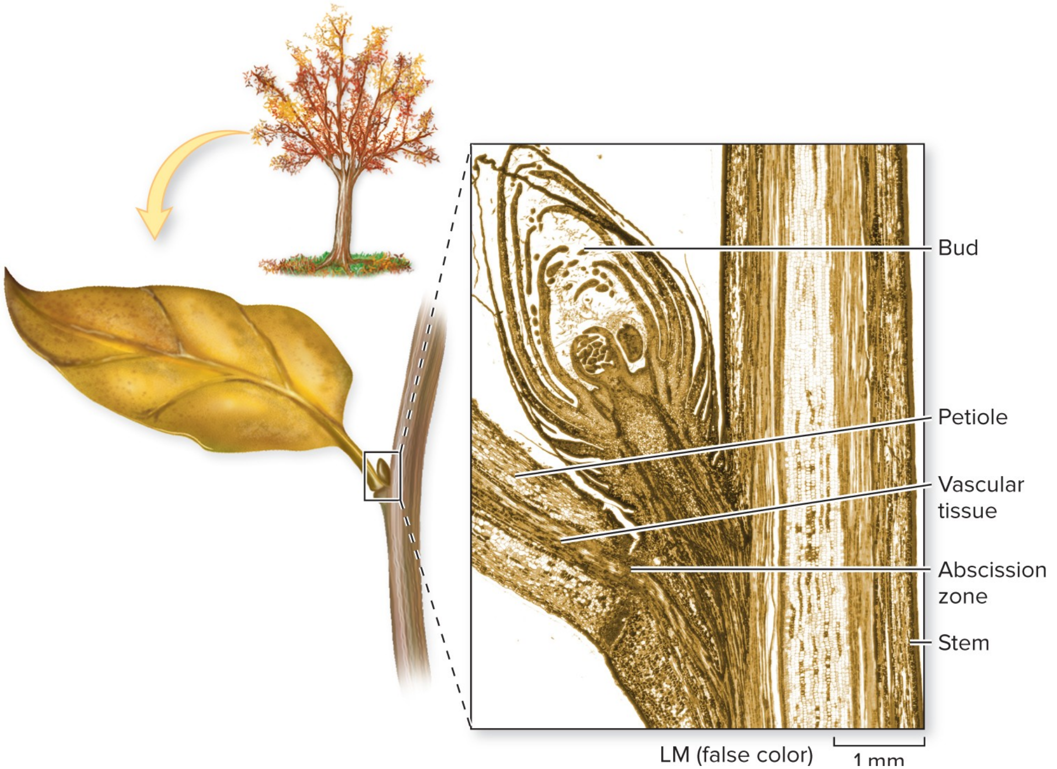
Figure 24.26

Senescence

Senescence also occurs in plants that survive for multiple growing seasons (perennial plants).



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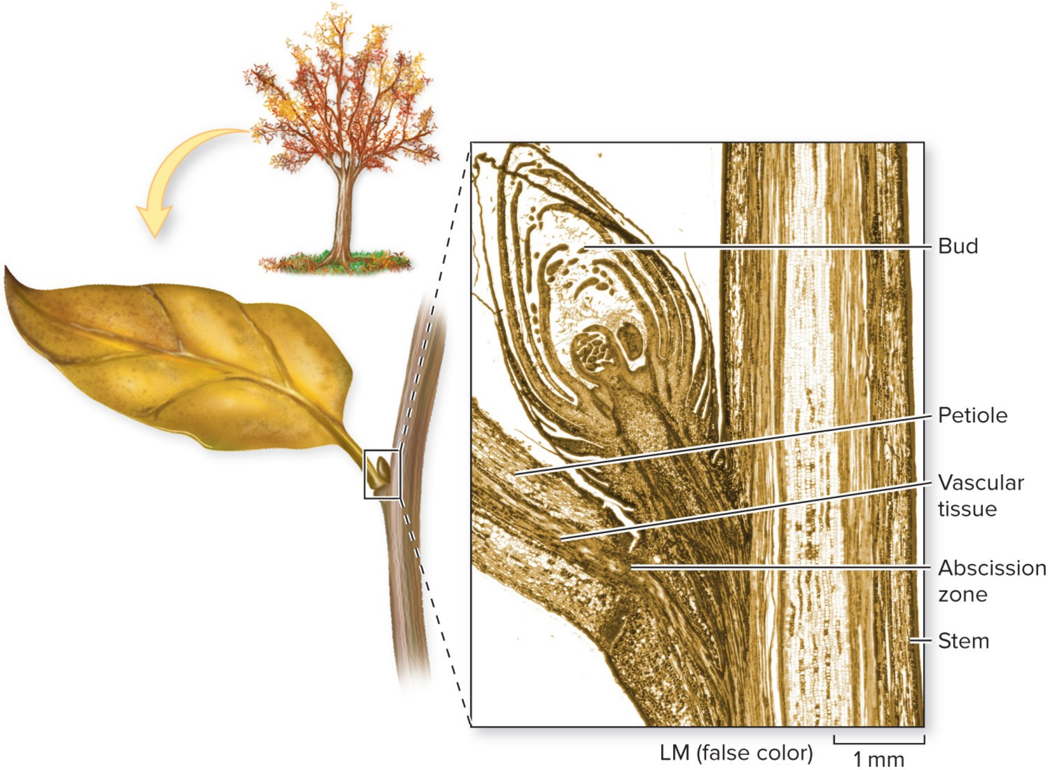
An example of senescence

Each year, deciduous trees loose their leaves.



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Ethylene and senescence

Influenced by a high level of ethylene, the leaf separates from the tree at the **abscission zone**.

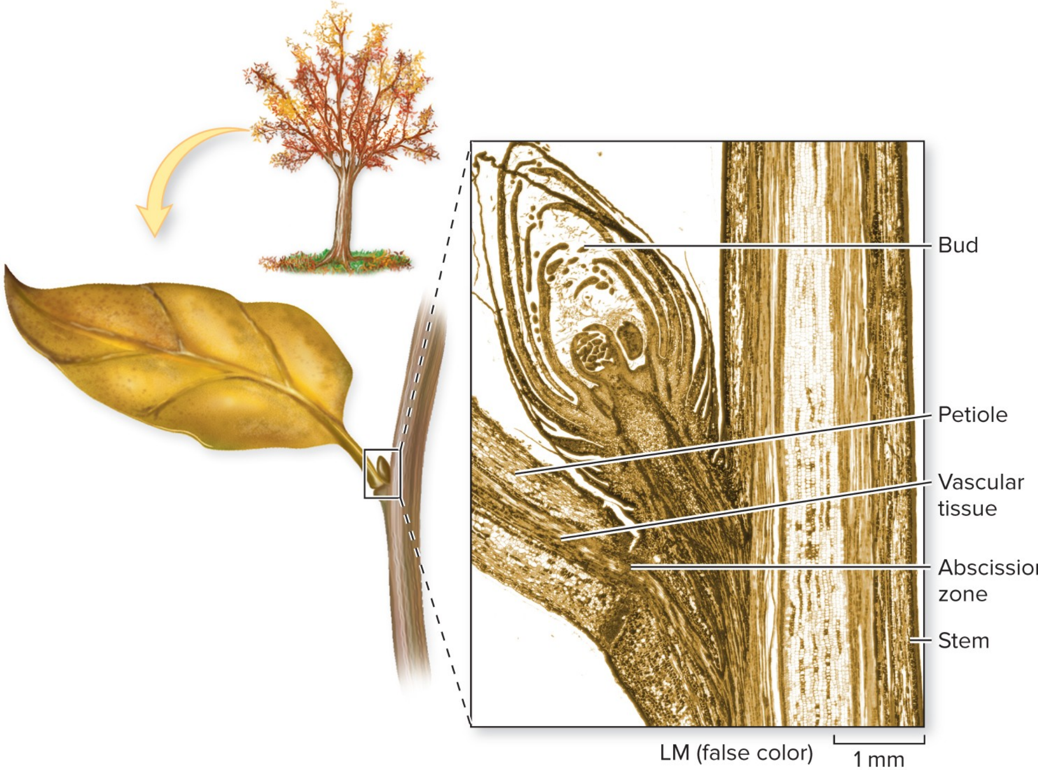

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Figure 24.26

Dormancy

During the winter, some plants enter a seasonal state of **dormancy**, during which metabolism slows down.

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24.7 Mastering concepts

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How is dormancy different from senescence?

Investigating life:

A red hot chili pepper paradox

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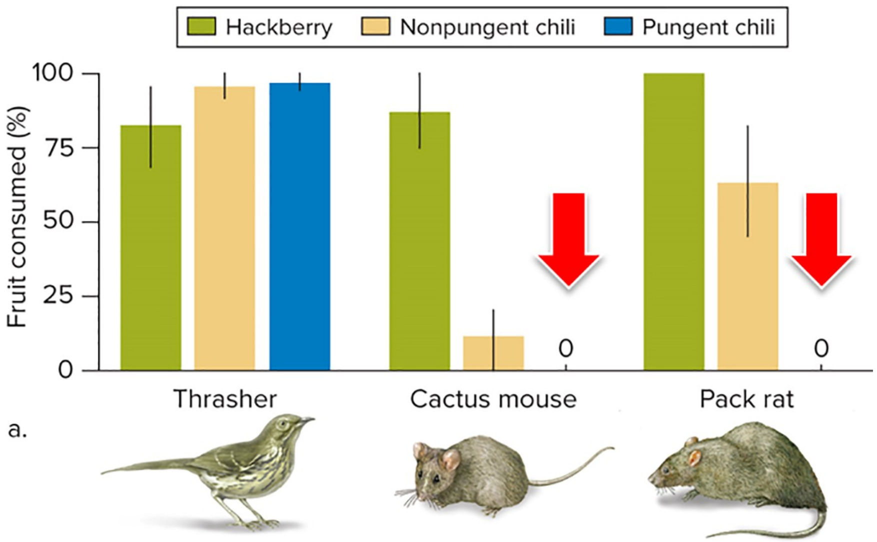
Why would natural selection favor spicy chili peppers, when one of the main function of fruits is seed dispersal?

Investigating life:

A red hot chili pepper paradox — who eats spicy food?

©Sierra Vista Herald, Jonathon Shacat/AP Images



Mammals, but not birds, avoid the spicy chemical in pungent chili peppers.

Investigating life:

A red hot chili pepper paradox—why think about digestion?

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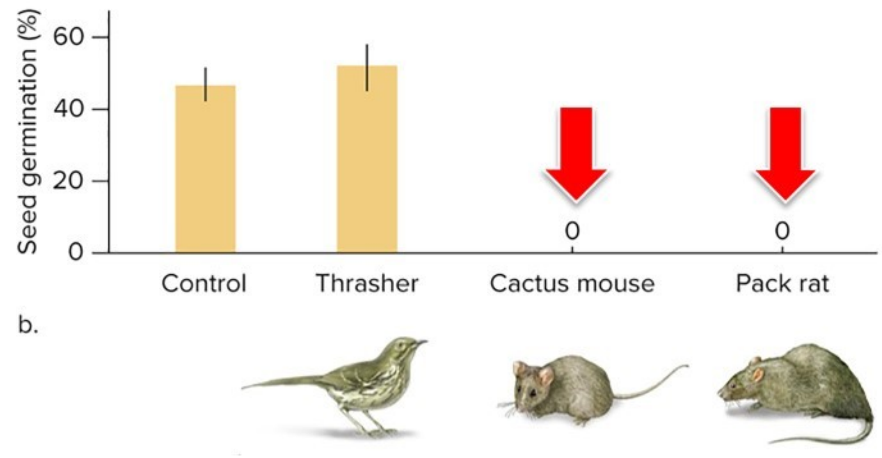
Chili seeds eaten by mice and pack rats are destroyed, but they pass through birds intact.



Figs. 24.28, 24.29

A red hot chili pepper paradox — seed destroyers vs seed dispersers

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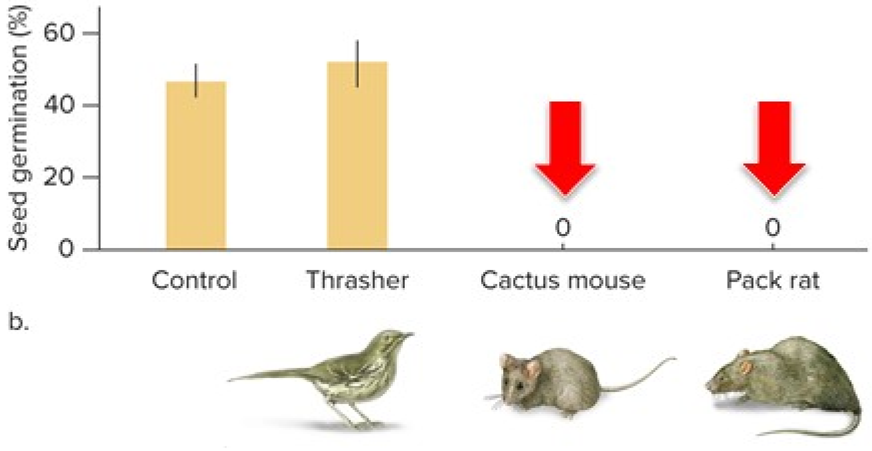

Natural selection favors adaptations that deter seed-destroyers but not beneficial dispersers.