Chapter 19
Plants

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Plants have changed the world

Members of kingdom **Plantae** are nearly everywhere.

Plants harness the energy that sustains ecosystems. They also release O_2, which consumers use for respiration.

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Plants are essential for life

On land and in water, plants provide habitats and food to countless species of microbes, fungi, and animals.

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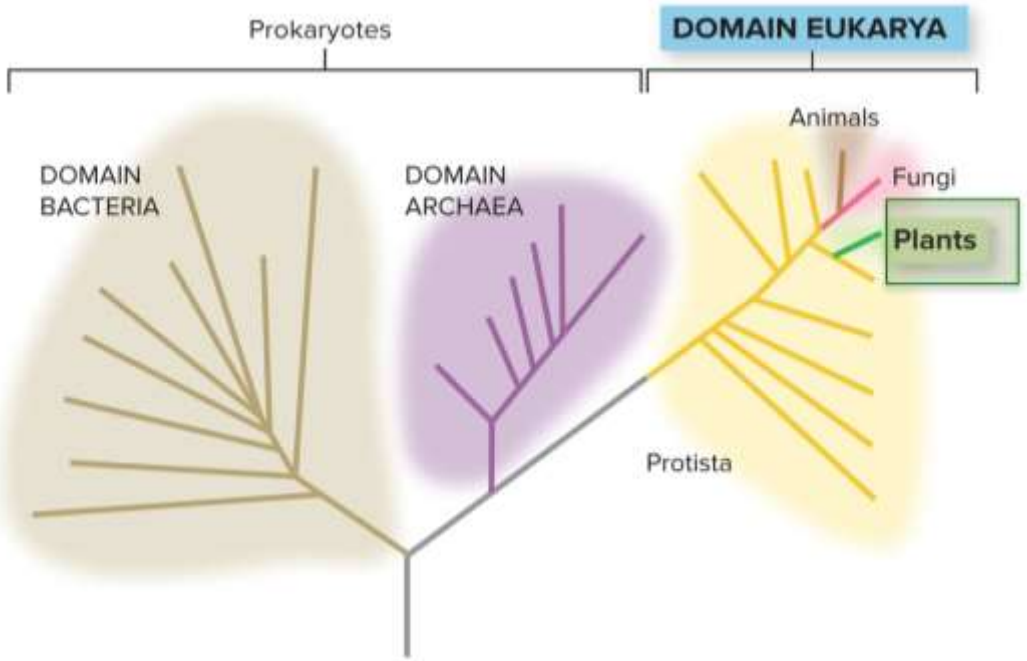
Plants share a lineage with protists

All plants are multicellular, autotrophic eukaryotes that use photosynthesis to obtain energy.



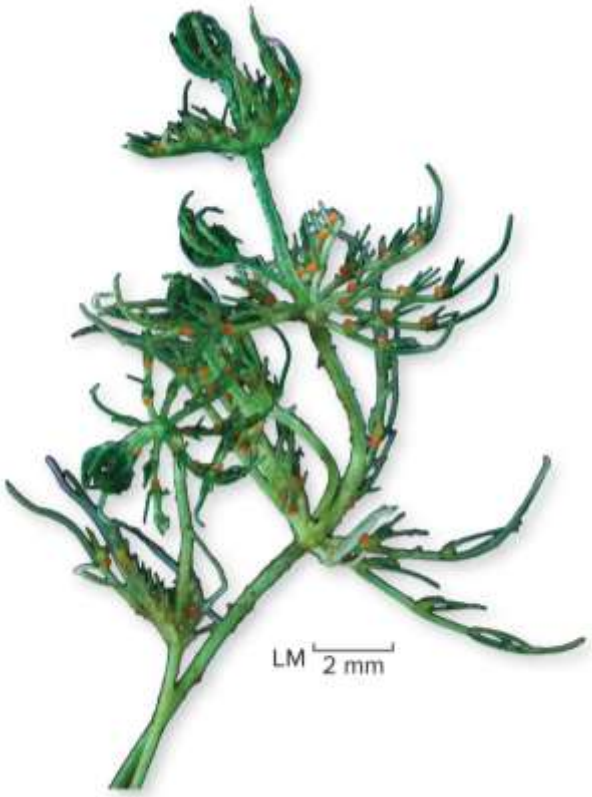
Section 19.1

Figure 19.3

Green algae are the closest relatives of plants

Charophytes are a group of modern green algae.

Biologists believe they are similar to the ancestors of plants.



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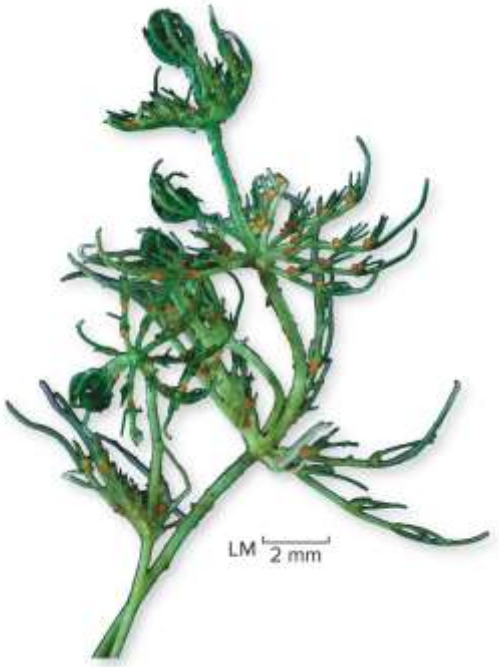
Green algae share many molecular features with plants

DNA sequences reveal a close evolutionary relationship.

Chloroplasts contain the same pigments.

Cell walls contain cellulose.

Both use starch as a storage molecule.



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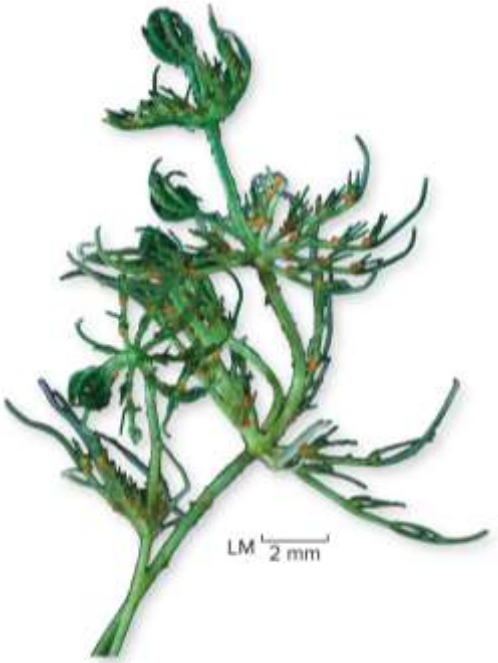
Green algae live in water, plants on land

The different environments select for different body types and reproductive strategies.



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Plants are divided into four groups

Plants arose during the Paleozoic era and diversified into thousands of different species.

Modern-day plants include

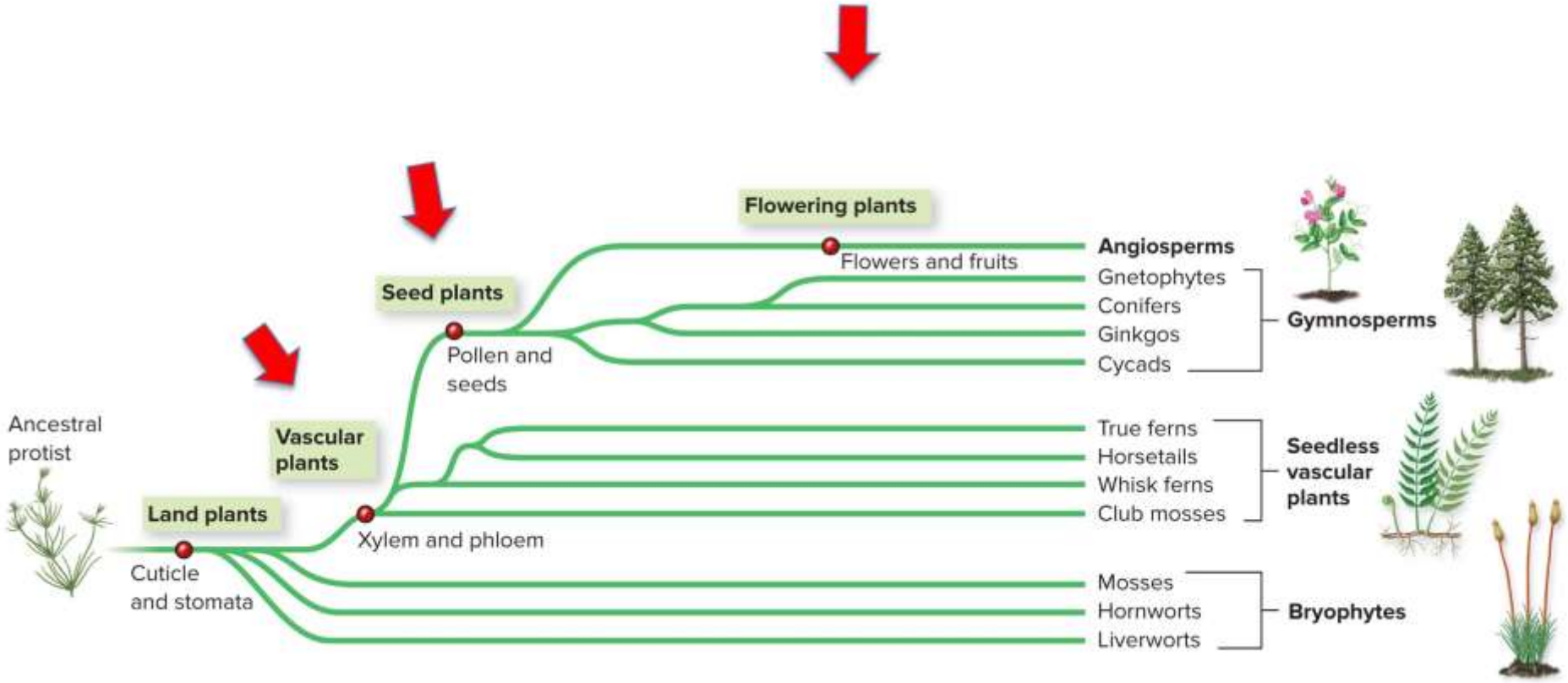
- Bryophytes
- Seedless vascular plants
- Gymnosperms
- Angiosperms

TABLE 19.1 Phyla of Plants

Phylum	Examples	Number of Existing Species
Nonvascular plants		
Marchantiophyta	Liverworts 	9000
Anthocerotophyta	Hornworts 	100
Bryophyta 	True mosses	15,000
Seedless vascular plants		
Lycopodiophyta	Club mosses, spike mosses 	1200
Pteridophyta 	Whisk ferns, true ferns, horsetails	11,500
Gymnosperms		
Cycadophyta	Cycads	130
Ginkgophyta	Ginkgo 	1
Pinophyta 	Pines, firs, and other conifers	630
Gnetophyta	Gnetophytes 	80
Angiosperms		
Magnoliophyta 	All flowering plants, including roses, grasses, fruit trees, maples, and oaks	> 260,000

Plants evolved key adaptations

The four plant groups are defined by a series of features that plants developed over time, including having vascular tissue, seeds, and flowers/fruits.



Section 19.1

Figure 19.3

Clicker question #1

A newly discovered plant in the rain forest has vascular tissues and seeds, but no flowers. What is it?

A. a bryophyte
B. a seedless vascular plant
C. a gymnosperm
D. an angiosperm

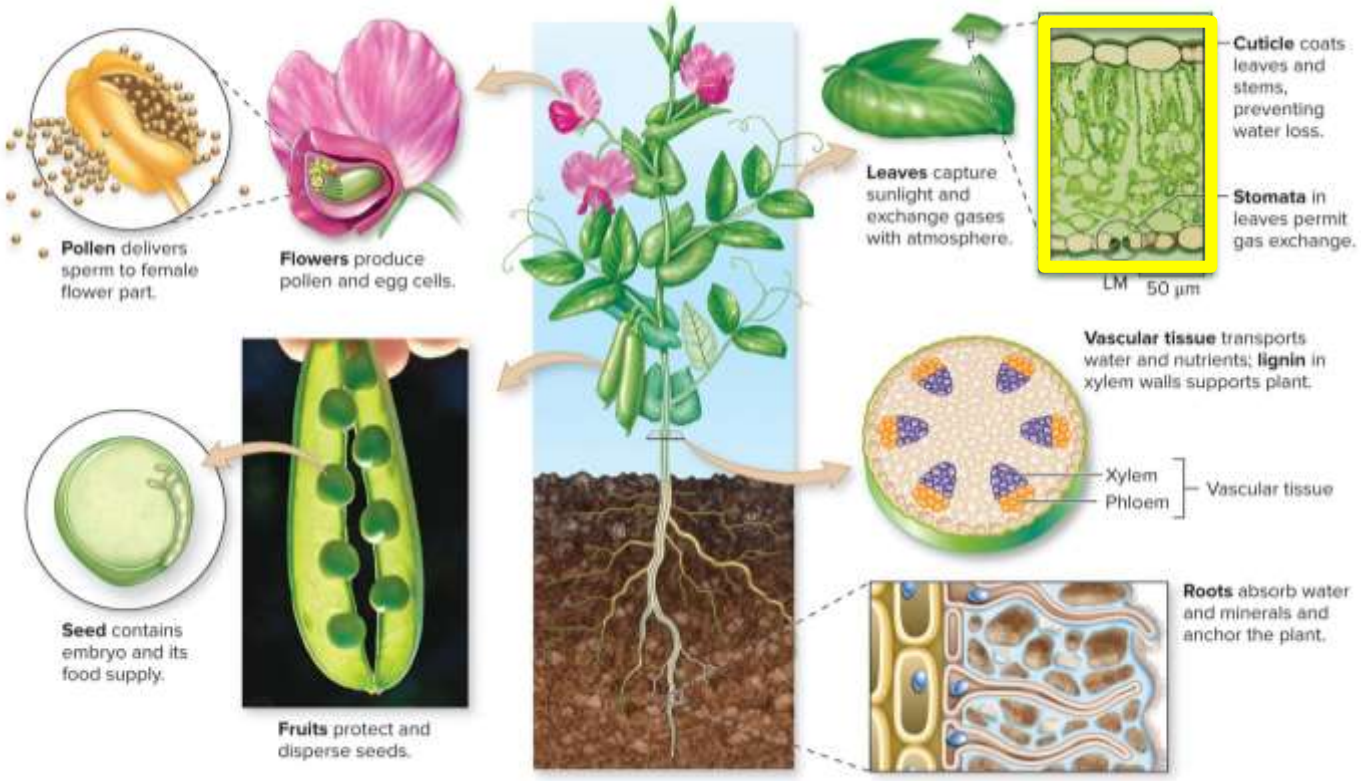
Clicker question #1, solution

A newly discovered plant in the rain forest has vascular tissues and seeds, but no flowers. What is it?

C. a gymnosperm

A leaf is an adaption to life on land

Leaves capture sunlight and CO_2 for photosynthesis. Plant leaves have evolved a **cuticle** to keep from drying out and **stomata** to allow gas exchanges.



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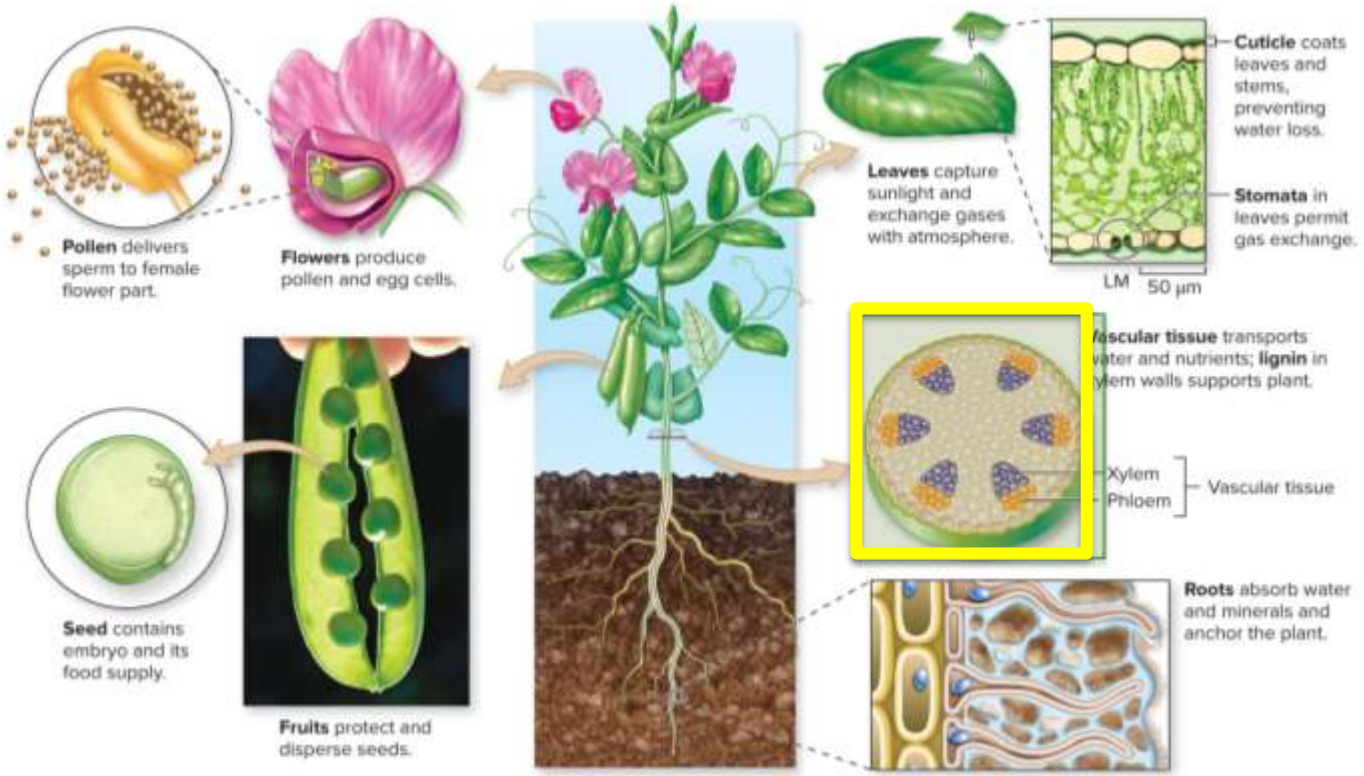
Vascular tissue is an adaption to life on land

Plant **vascular tissue** is a bundle of tubes that transports water, minerals, and sugar throughout the plant.



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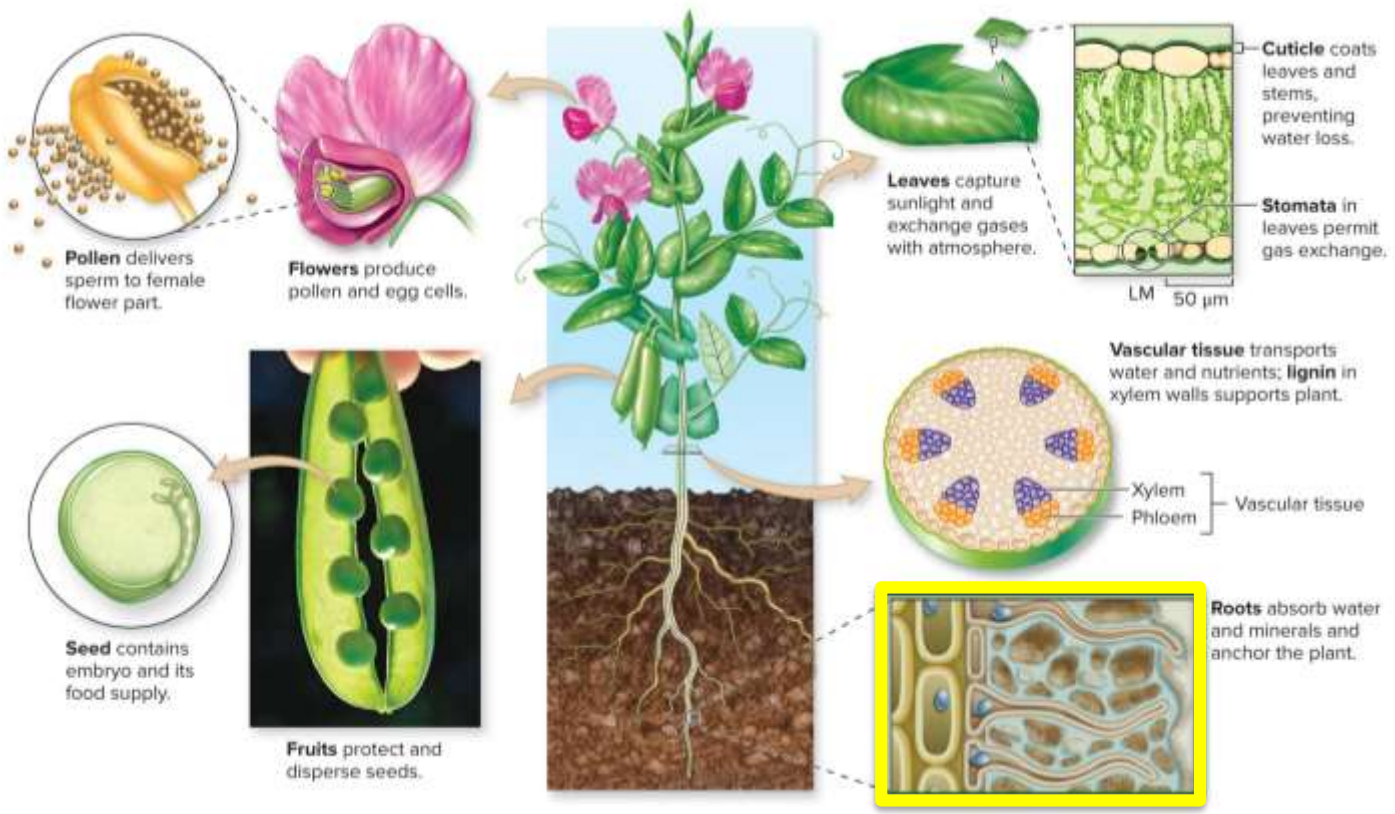
A root is an adaption to life on land

Roots below the ground absorb water and minerals while anchoring the plant in the soil.



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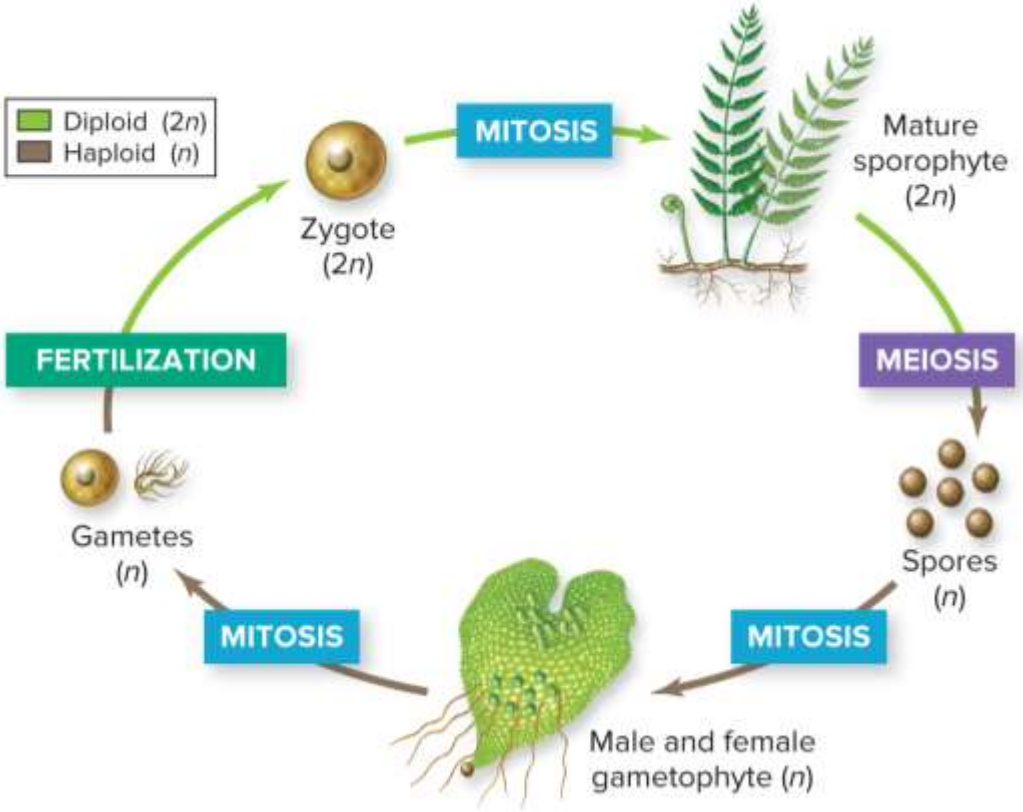
All plants have similar life cycles

The similarity among plant life cycles is evidence that all plants share a common ancestor.

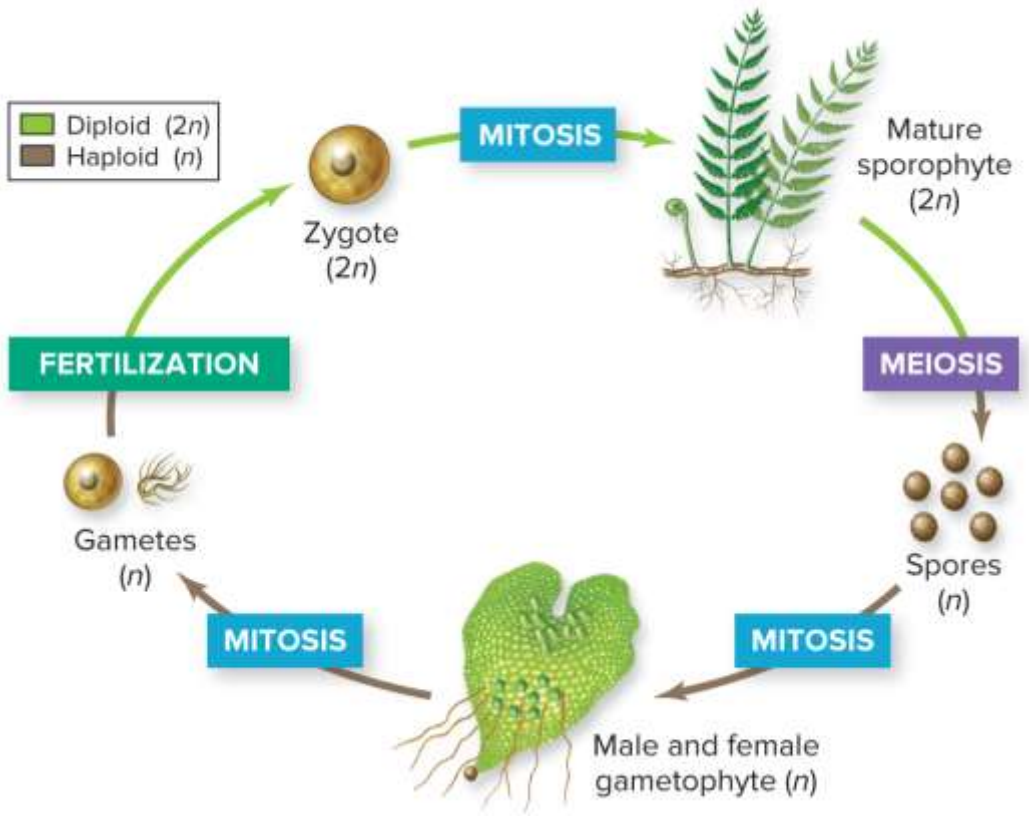


Section 19.1

Figure 19.5

Plant reproduction is complex

Plant gametes and zygotes can both grow into adult organisms and reproduce.



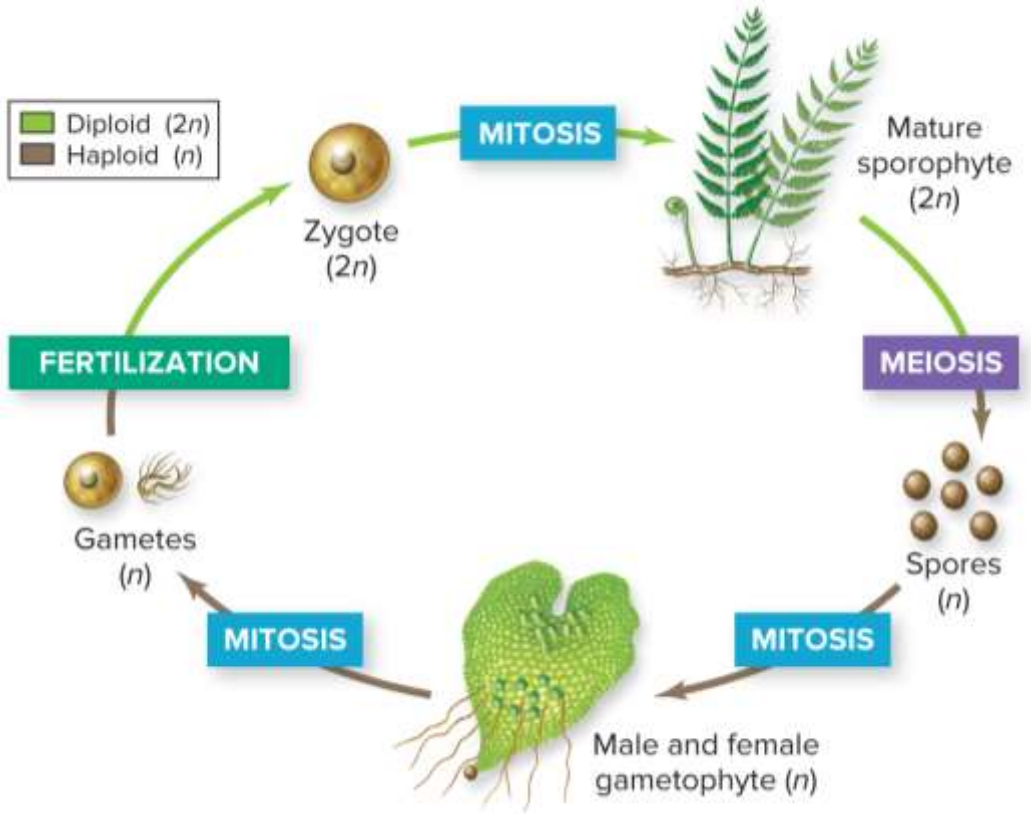
Section 19.1

Figure 19.5

Plants alternate generations

The plant life cycle is called **alternation of generations**.

A multicellular diploid stage alternates with a multicellular haploid stage.



Section 19.1

Figure 19.5

Sporophyte generation is diploid

A fertilized egg forms a diploid zygote, which develops by mitotic cell division into a multicellular, diploid plant called a **sporophyte**.

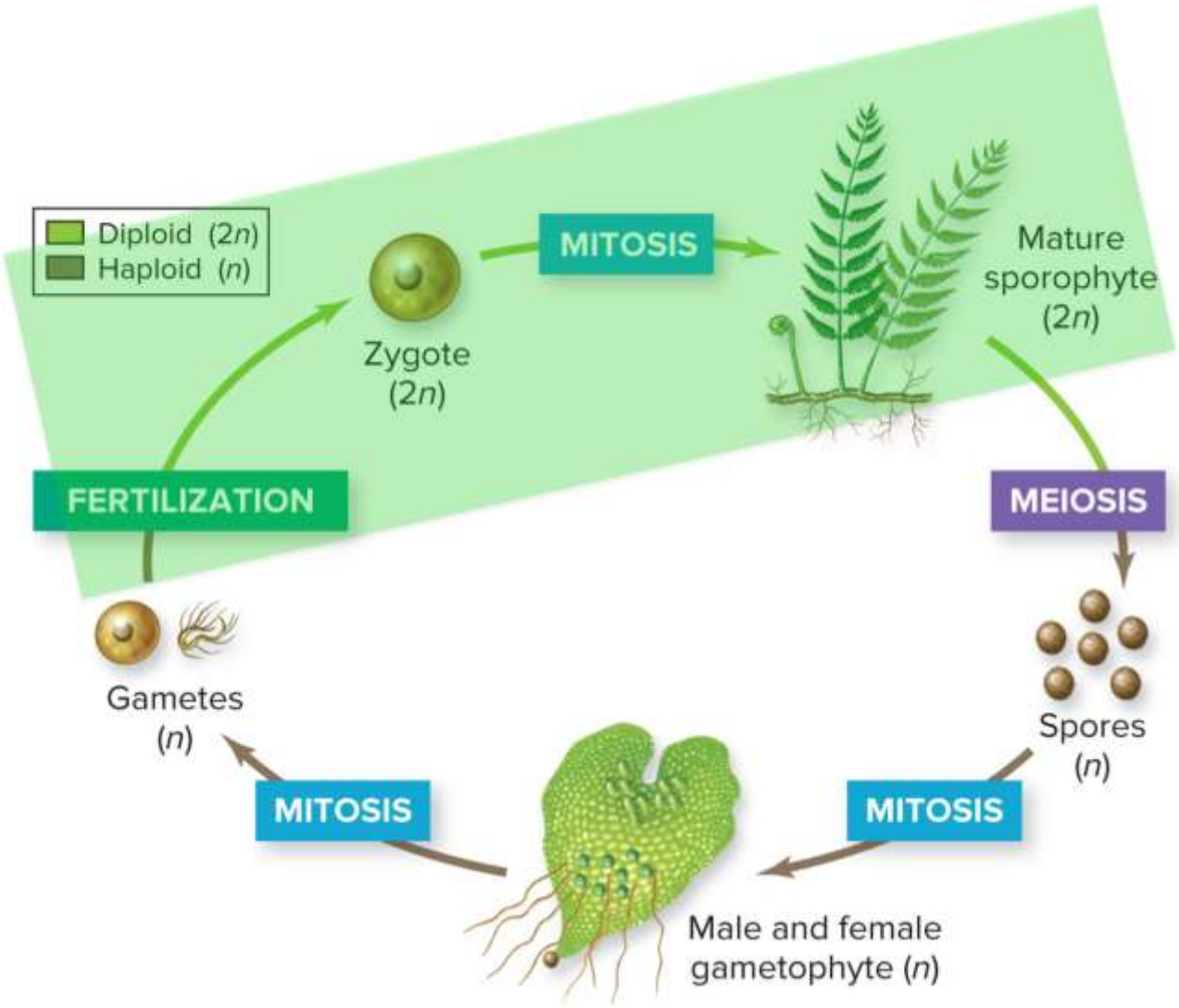
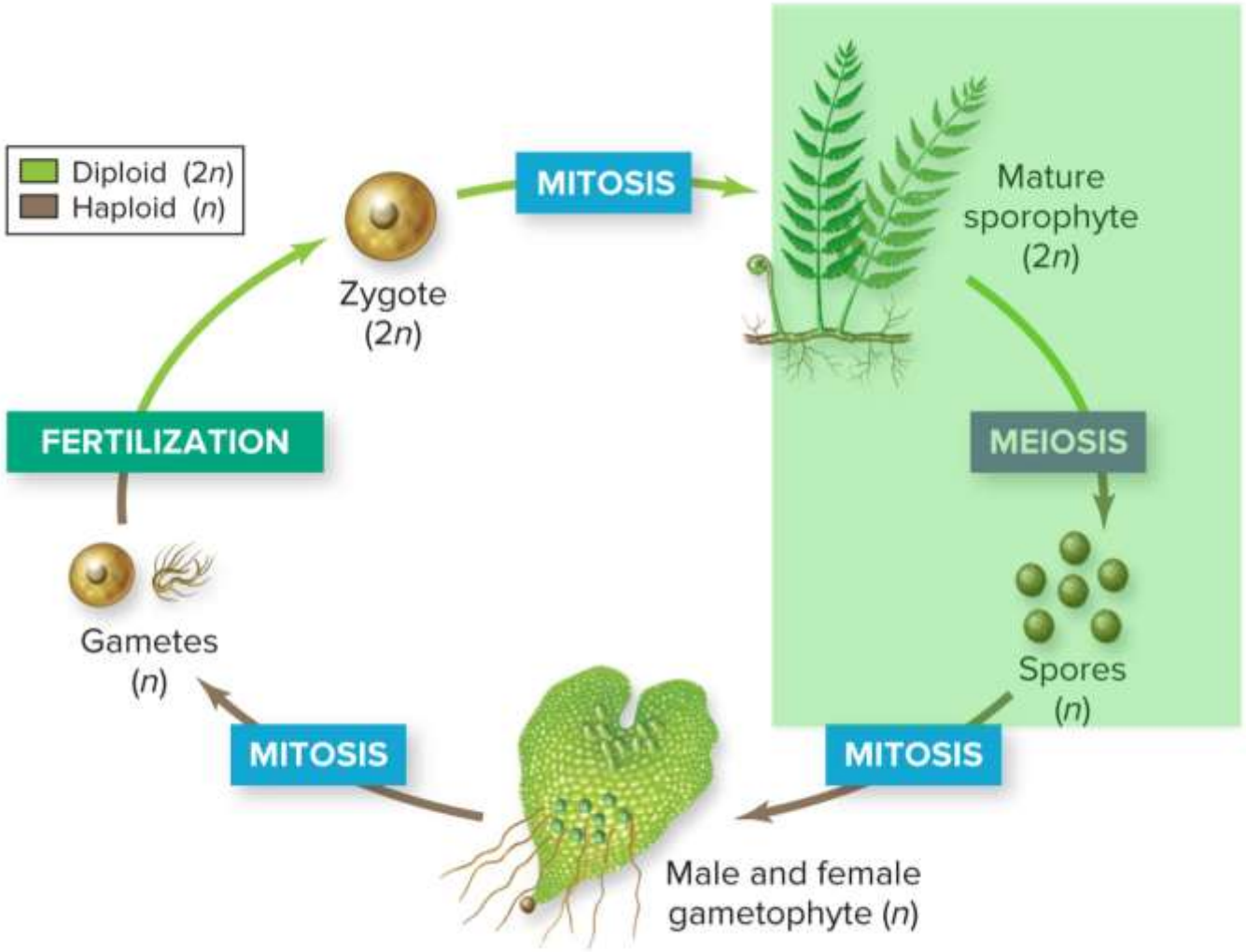


Figure 19.5

Sporophytes produce spores

The sporophyte plant produces haploid **spores** by meiosis.

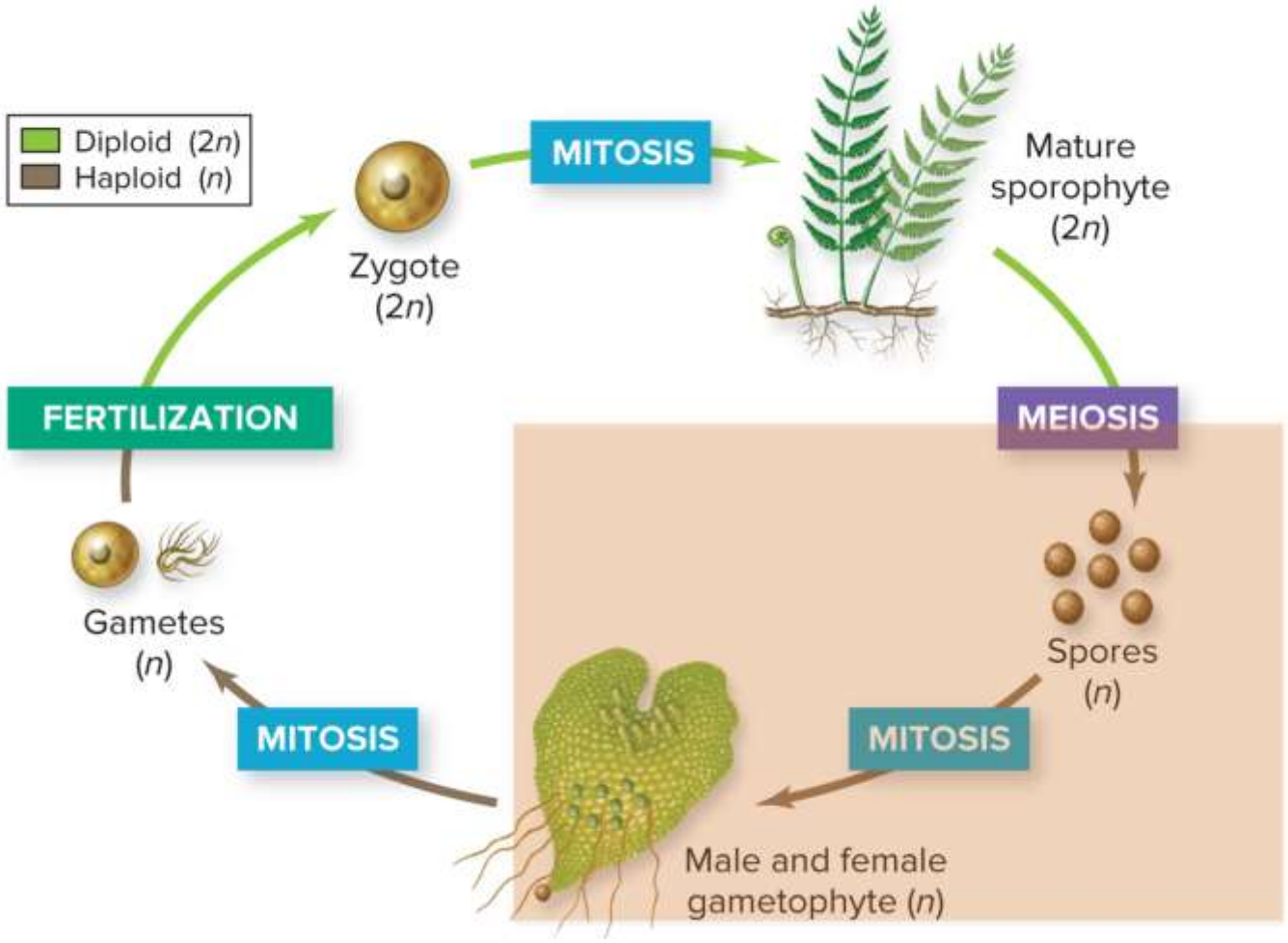


Section 19.1

Figure 19.5

Gametophyte generation is haploid

Spores divide by mitosis into a multicellular, haploid **gametophyte**.

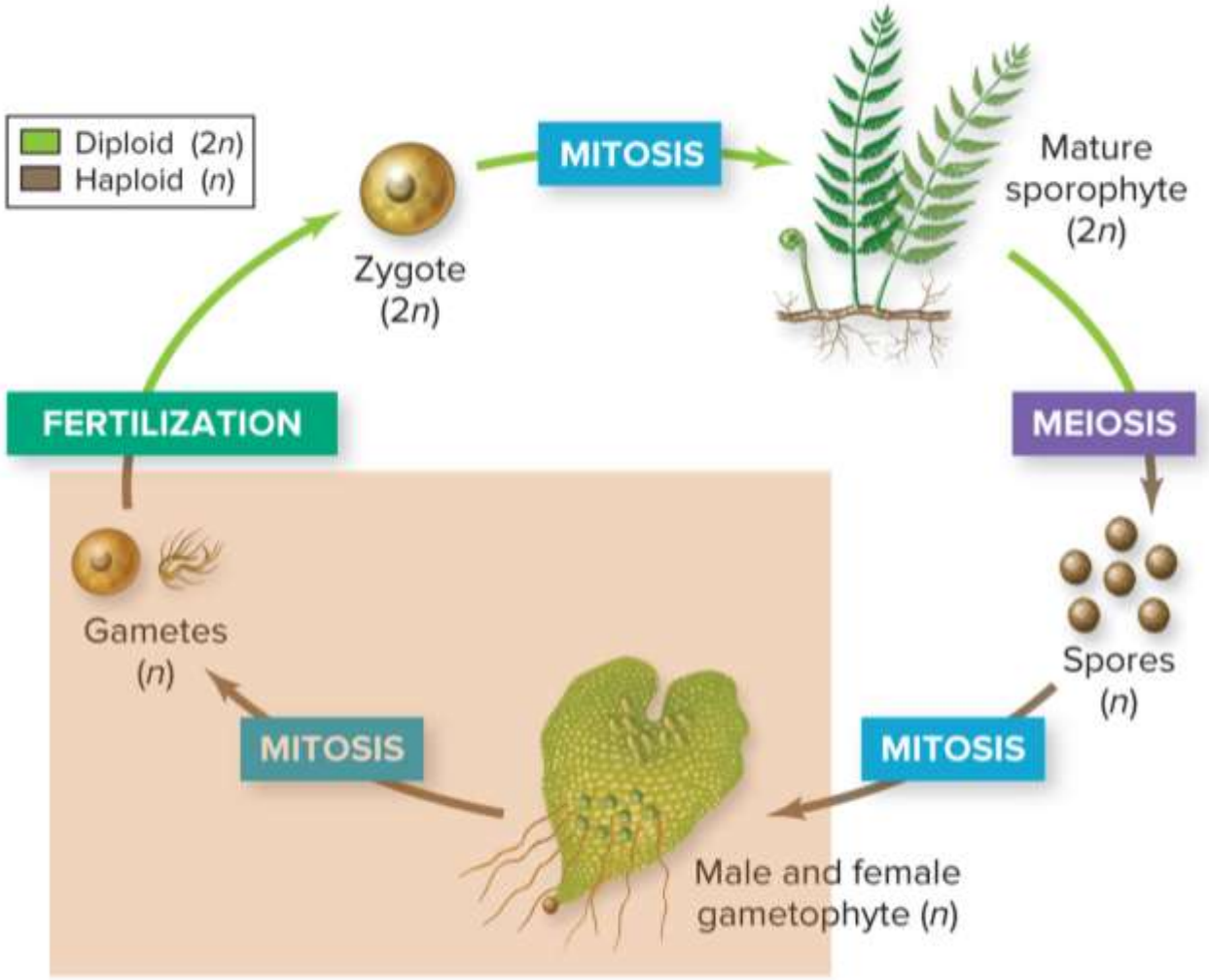


Section 19.1

Figure 19.5

Gametophytes produce gametes

The haploid gametophyte produces **gametes** by mitosis.

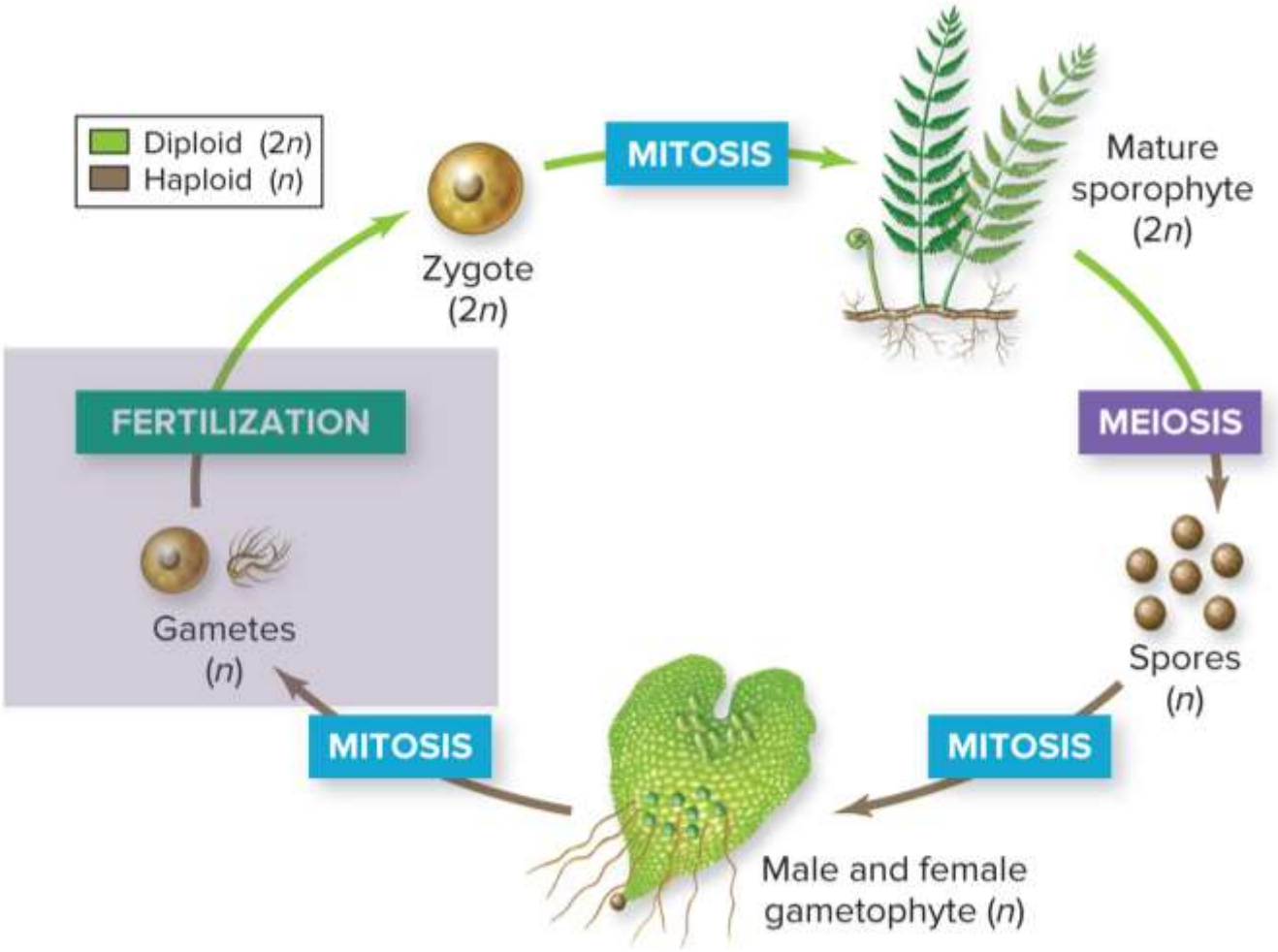


Section 19.1

Figure 19.5

Fertilization forms a zygote

The gametes fuse at fertilization, forming a diploid zygote and starting the cycle again.



Section 19.1

Figure 19.5

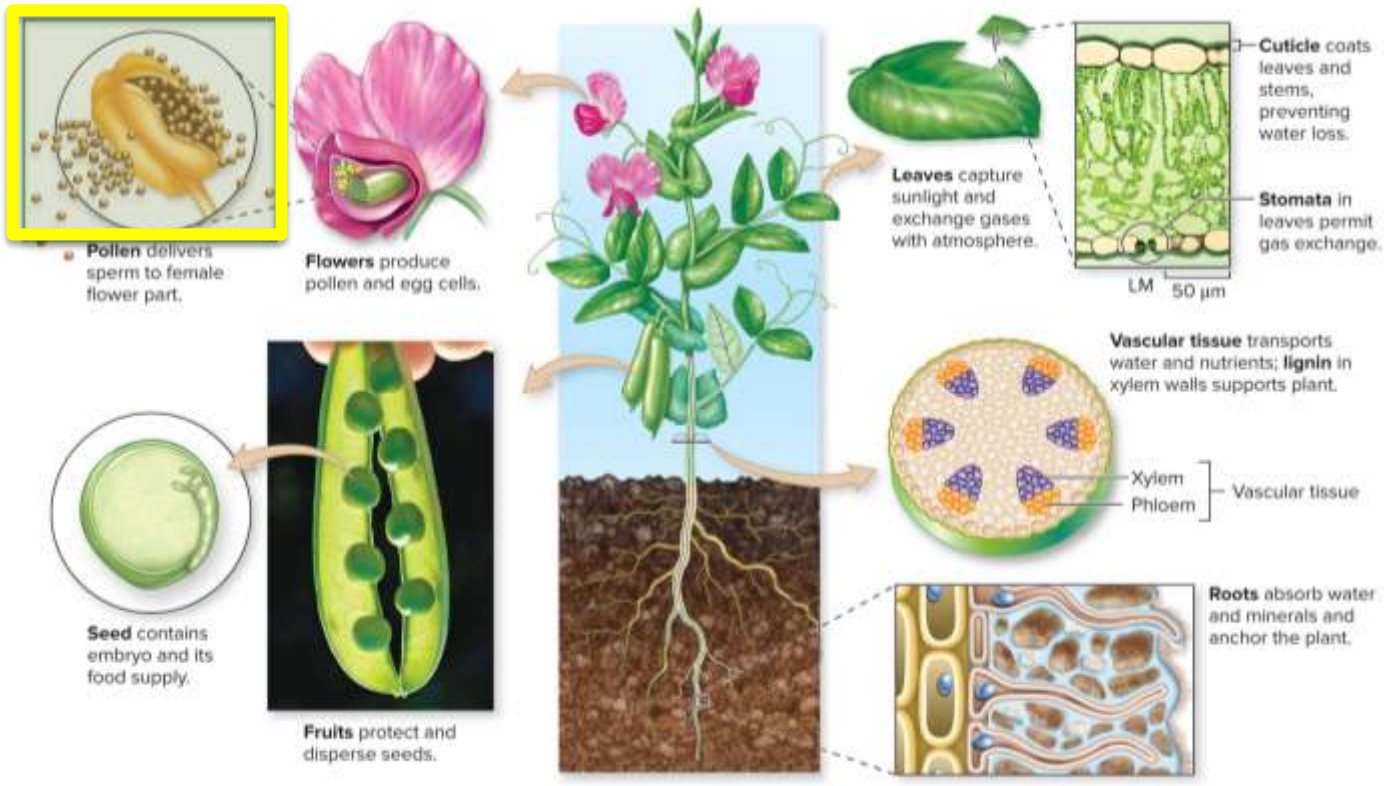
The lifestyle of gametophytes varies through plant phyla

In simpler plants the gametophyte is larger and less dependent on the sporophyte; in more complex plants the reverse is true.

	Bryophytes	Seedless Vascular Plants	Gymnosperms	Angiosperms
Gametophyte (haploid generation)				
Size relative to sporophyte?	Varies	Small	Microscopic	Microscopic
Depends on sporophyte for nutrition?	No	No	Yes	Yes
Sporophyte (diploid generation)				
Size relative to gametophyte?	Varies	Large	Large	Large
Depends on gametophyte for nutrition?	Yes	No	No	No

Pollen is an adaption to life on land

Seed plants produce **pollen**, which contains the male gametophyte. Pollination can occur without water, and often animals help spread the pollen to new plants.



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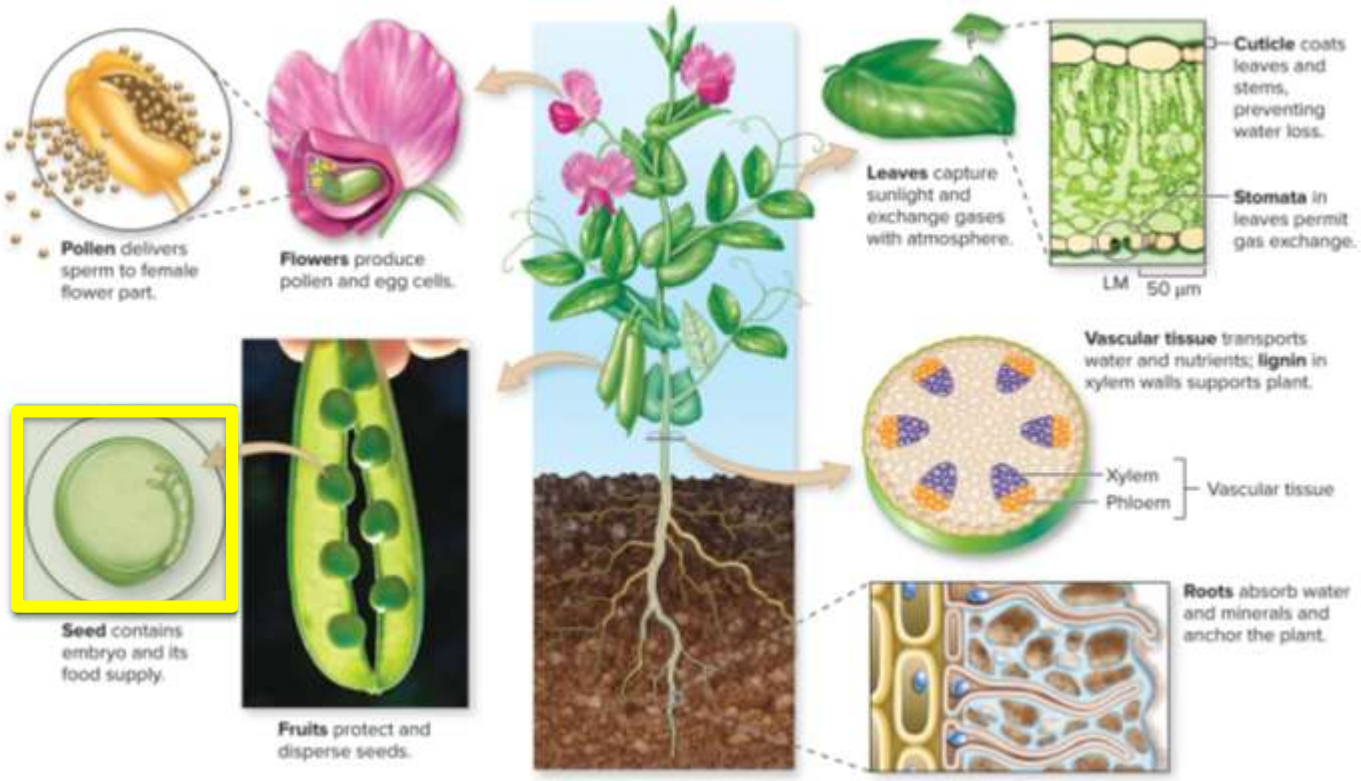
Section 19.1

Figure 19.4

A seed is an adaption to life on land

Seeds carry dormant plant embryos packaged with a food supply and protected from drying out. They can be dispersed long distances and remain dormant until conditions are favorable.



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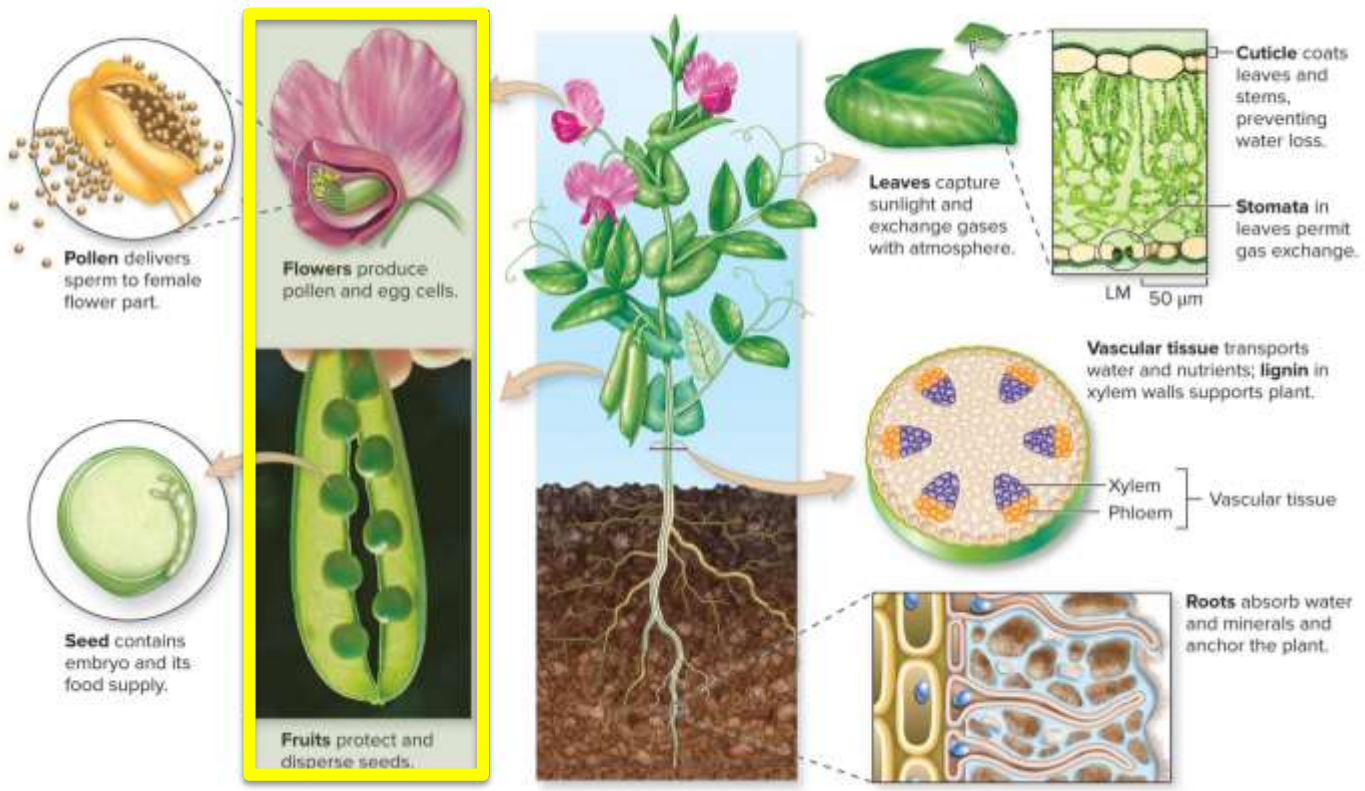
Flowers and fruit are adaptions to life on land

Flowers produce pollen and egg cells. Fruits develop after fertilization, to protect and disperse the plant offspring.



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Clicker question #2

How many of the items in the following list are haploid?

zygote, gamete, sporophyte, spore, gametophyte

A. one
B. two
C. three
D. four
E. five

Clicker question #2, solution

How many of the items in the following list are haploid?

zygote, gamete, sporophyte, spore, gametophyte

C. three

19.1 Mastering concepts

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What is the evidence that plants are closely related to green algae? Which adaptations set plants apart from green algae?

Bryophytes are the simplest plants

There are about 24,000 existing species of **bryophytes**, or "nonvascular" plants.

Mosses, hornworts, and liverworts are bryophytes.

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Phylum	Examples	Number of Existing Species
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Marchantiophyta	Liverworts	9000
Anthocerotophyta	Hornworts	100
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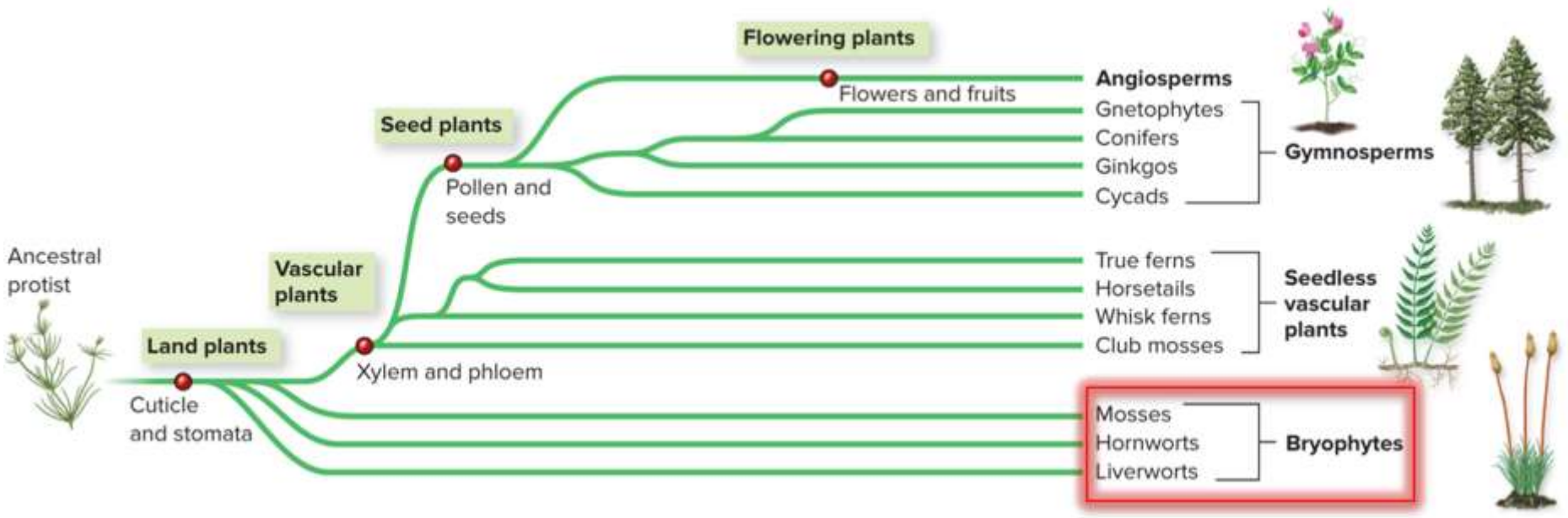
Gnetophyta	Gnetophytes	80
Angiosperms		
Magnoliophyta	All flowering plants, including roses, grasses, fruit trees, maples, and oaks	> 260,000

Bryophytes are nonvascular and seedless

The earliest plants probably resembled modern bryophytes. Bryophytes have no vascular tissue, roots, leaves, seeds, or flowers.



Section 19.2

Figure 19.3

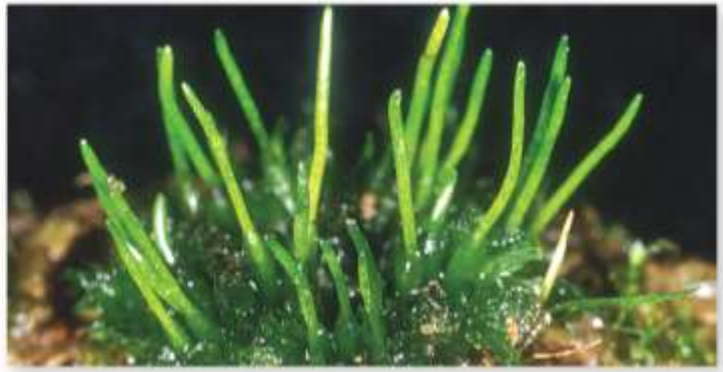
Bryophytes are small, compact plants

Without vascular tissue and lignin (which strengthens the cell wall), bryophytes lack physical support.

Materials move from cell to cell within the plant by diffusion and osmosis.

They live in moist shady habitats where they will not dry out.

a. Liverwort



b. Hornwort

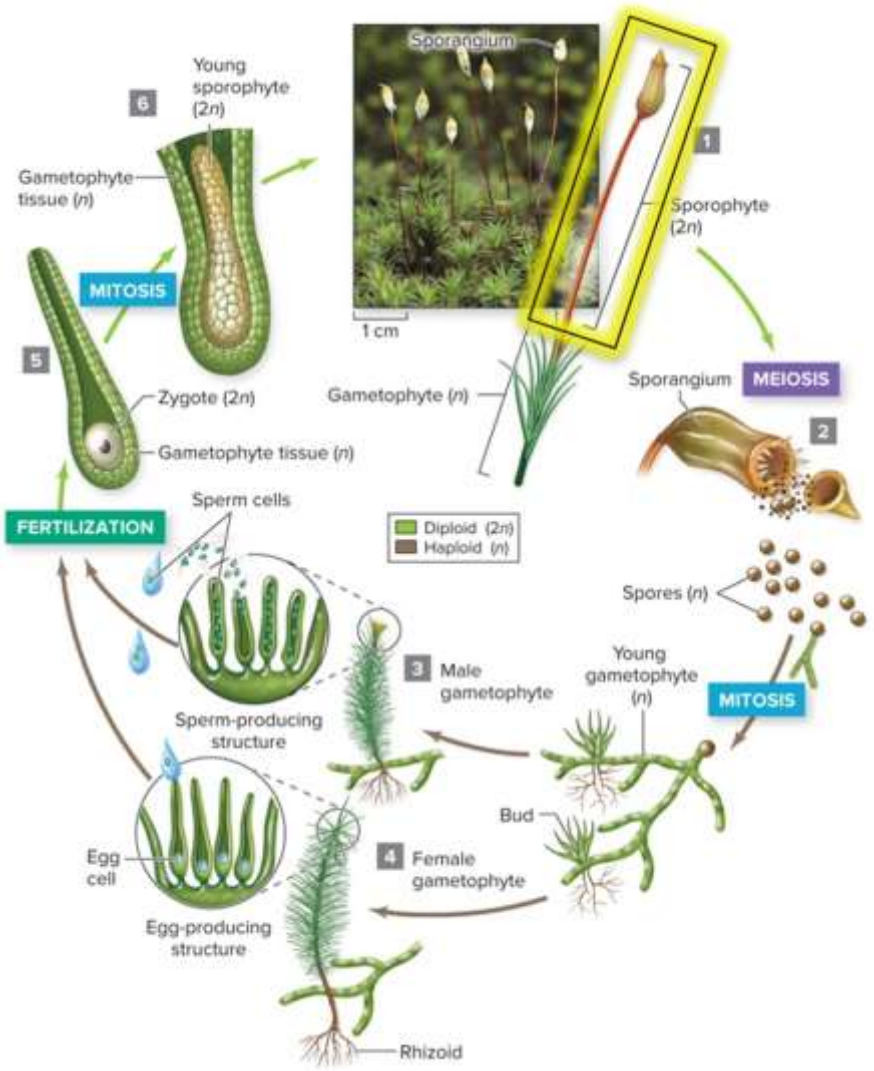
c. Moss

(a): ©Dr. Jeremy Burgess/Science Source; (b, c): ©Steven P. Lynch RF

Bryophytes have a small sporophyte

The sporophyte is a stalk attached to the gametophyte.

The sporophyte produces spores that grow into new haploid gametophyte plants.



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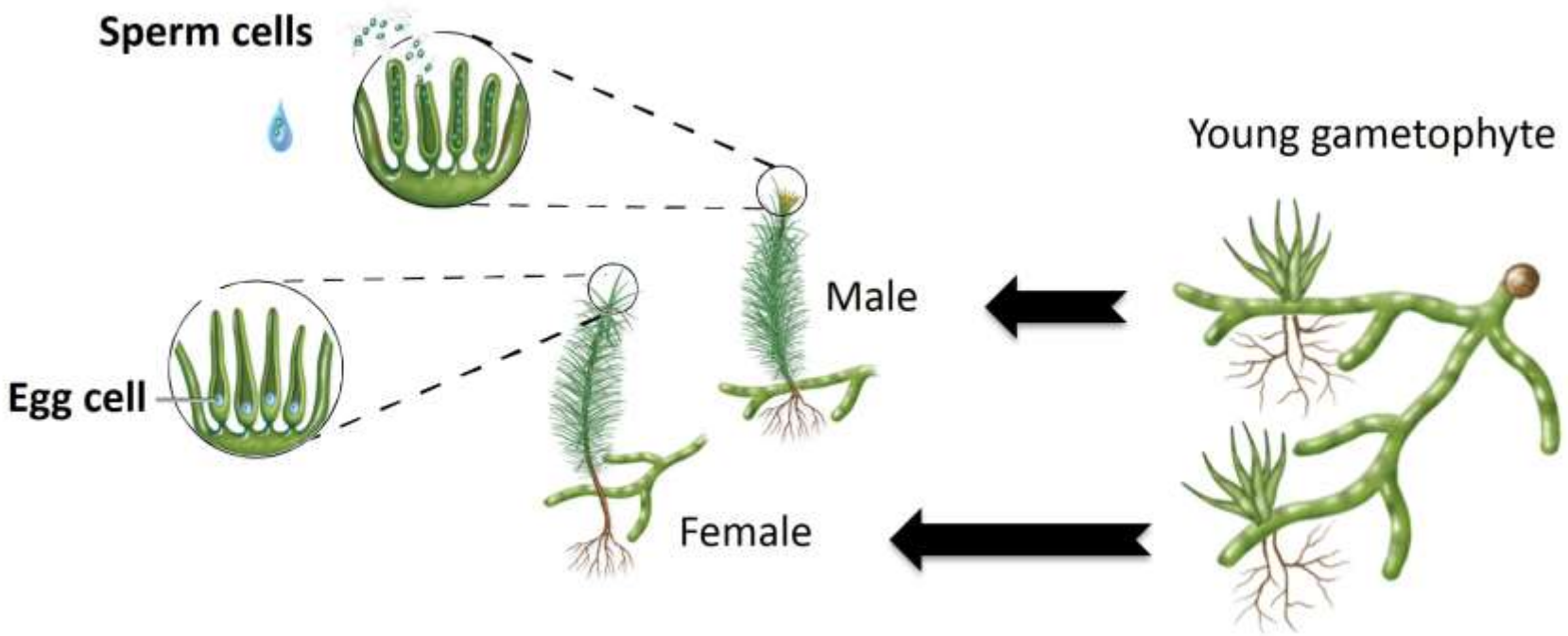
Sporophyte

Bryophyte sexual reproduction requires water

Gametophytes have male and female structures that produce gametes (eggs and sperm). The sperm swim to the eggs.



Section 19.2

Figure 19.9

Bryophytes also reproduce asexually

Mosses and liverworts produce structures called gemmae, which are small pieces of tissue that detach from the gametophyte and grow into new plants.

Clicker question #3

What does the structure indicated by the arrow produce?

A. spores
B. phloem
C. gametes
D. pollen

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Figure 19.7

Clicker question #3, solution

What does the structure indicated by the arrow produce?

A. spores

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Figure 19.7

19.2 Mastering concepts

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Name two reasons mosses usually live in moist, shady habitats.

Seedless vascular plants have no seeds

There are about 12,700 existing species of plants with vascular tissue, but no seeds.

This phylum is composed of ferns and their close relatives.

TABLE 19.1 Phyla of Plants

Phylum	Examples	Number of Existing Species
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Gymnosperms		
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Ginkgophyta	Ginkgo	1
Pinophyta	Pines, firs, and other conifers	630
Gnetophyta	Gnetophytes	80
Angiosperms		
Magnoliophyta	All flowering plants, including roses, grasses, fruit trees, maples, and oaks	> 260,000

Seedless vascular plants have true roots, stems, and leaves

Vascular tissue allowed these plants to grow much larger than bryophytes, which gave them an edge in competing for sunlight.

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There are four groups of seedless vascular plants

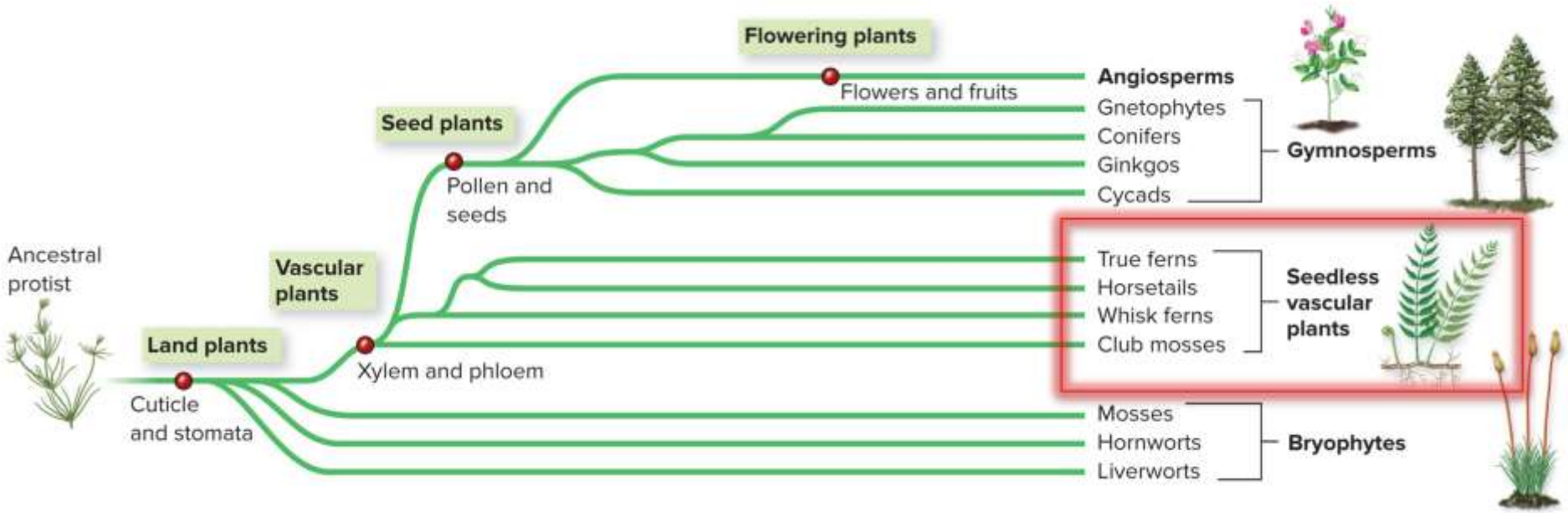
Seedless vascular plants include:

- **Club mosses**
- **Whisk ferns**
- **Horsetails**
- **True ferns**

(a): ©ImageBROKER/Alamy RF; (b): ©Howard Rice/Garden Picture Library/Getty Images; (c): ©Biosphoto/Superstock;(d): ©Ed Reschke/Photolibrary/Getty Images; (e): ©Rod Planck/Science Source

The earliest seedless vascular plants were probably modern club mosses

Fossil evidence suggests the first vascular plants originated around 425 million years ago. Club mosses are different from true mosses, which are bryophytes. They are placed in their own phylum.

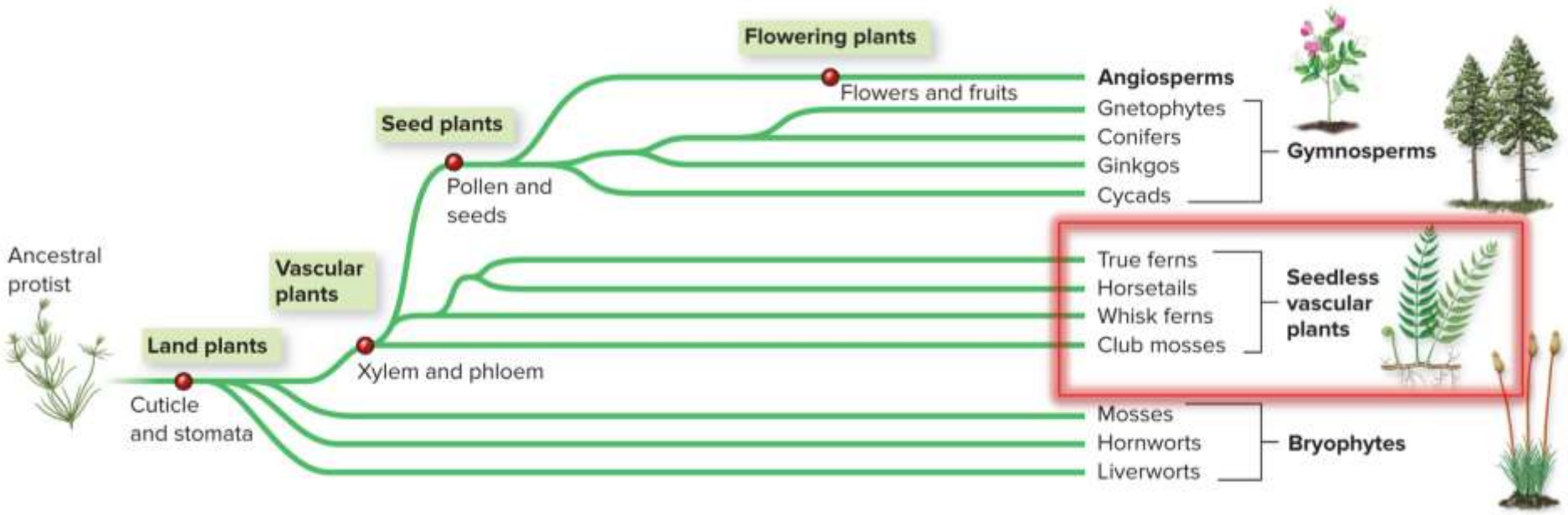


Section 19.3

Figure 19.3

Ferns and their relatives evolved later

Whisk ferns, horsetails, and true ferns make up a second phylum of seedless vascular plants that first appeared around 375 million years ago. Most, but not all, of these species live on land.



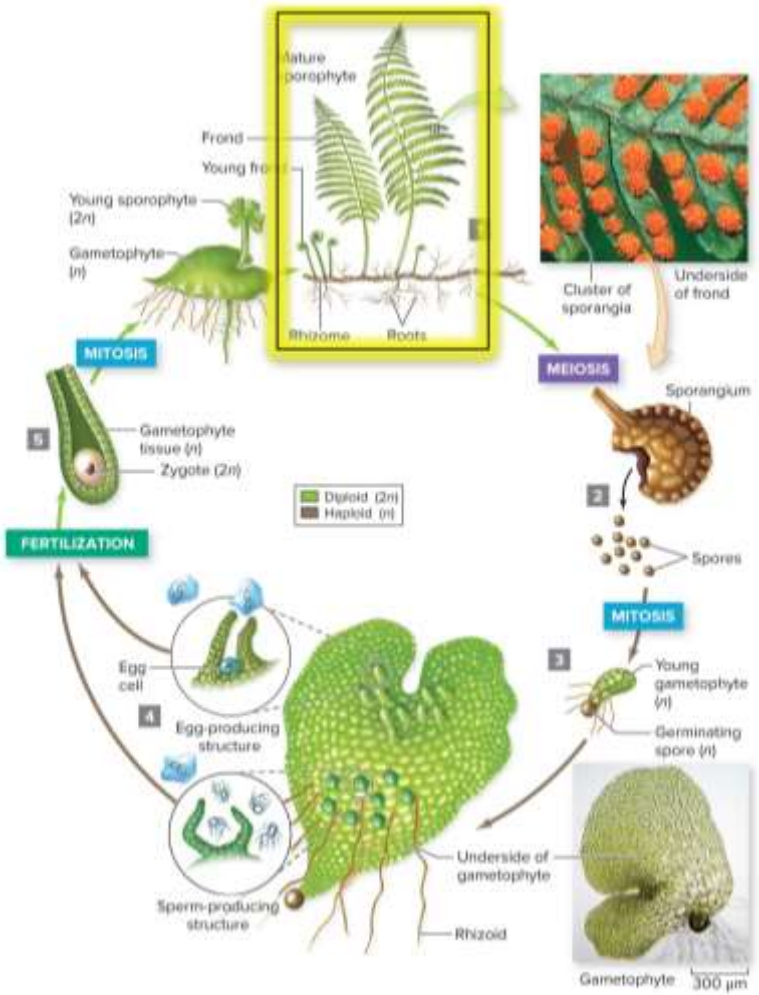
Section 19.3

Figure 19.3

Seedless vascular plants have a conspicuous sporophyte

The sporophyte develops from a zygote, then grows up and out of the gametophyte.

As it matures, the sporophyte detaches and grows separately from the gametophyte.



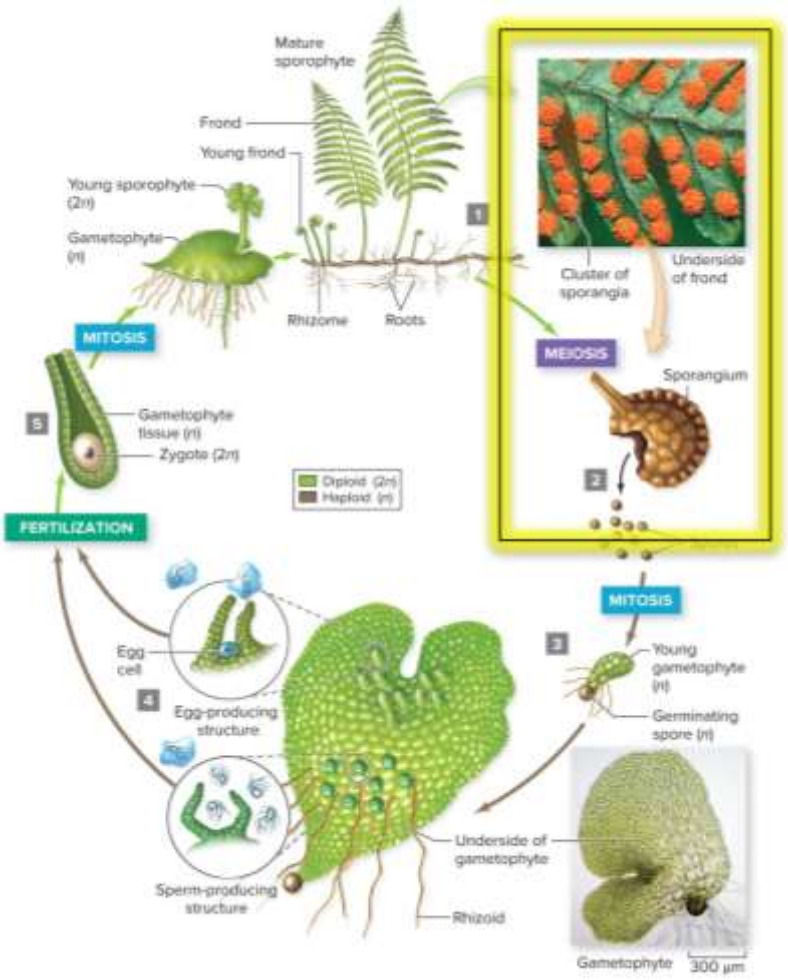
(spores): ©Ed Reschke/Photolibrary/Getty Images; (gametophyte): ©Les Hickok and Thomas Warne, C-Fern

Figure 19.11

Spores form under the leaves of the sporophyte

Haploid spores grow on the underside of sporophyte leaves.

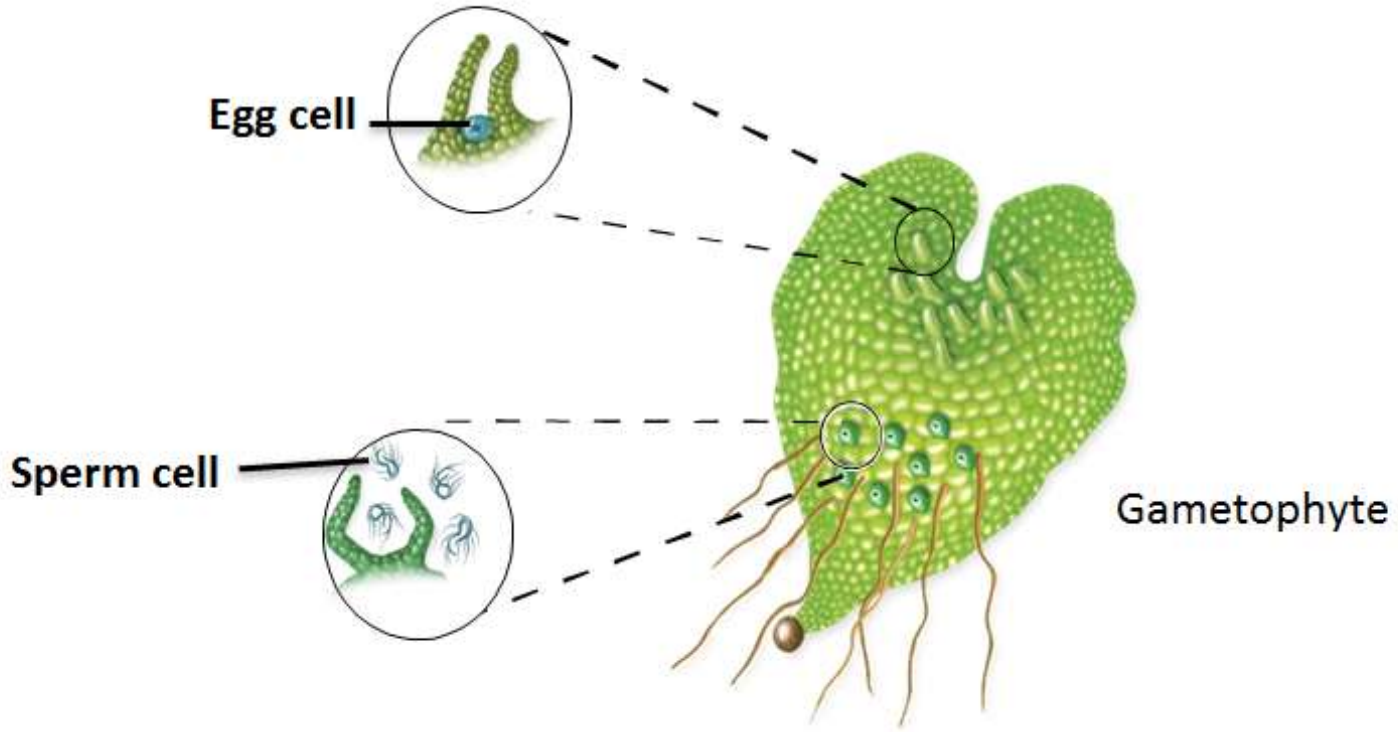
The spores form by meiosis and then develop into gametophytes.



(spores): ©Ed Reschke/Photolibrary/Getty Images; (gametophyte): ©Les Hickok and Thomas Warne, C-Fern

Seedless vascular plants require water for reproduction

Gametophytes produce male and female gametes. Sperm swim to the eggs in water.



Section 19.3

Figure 19.11

19.3 Mastering concepts

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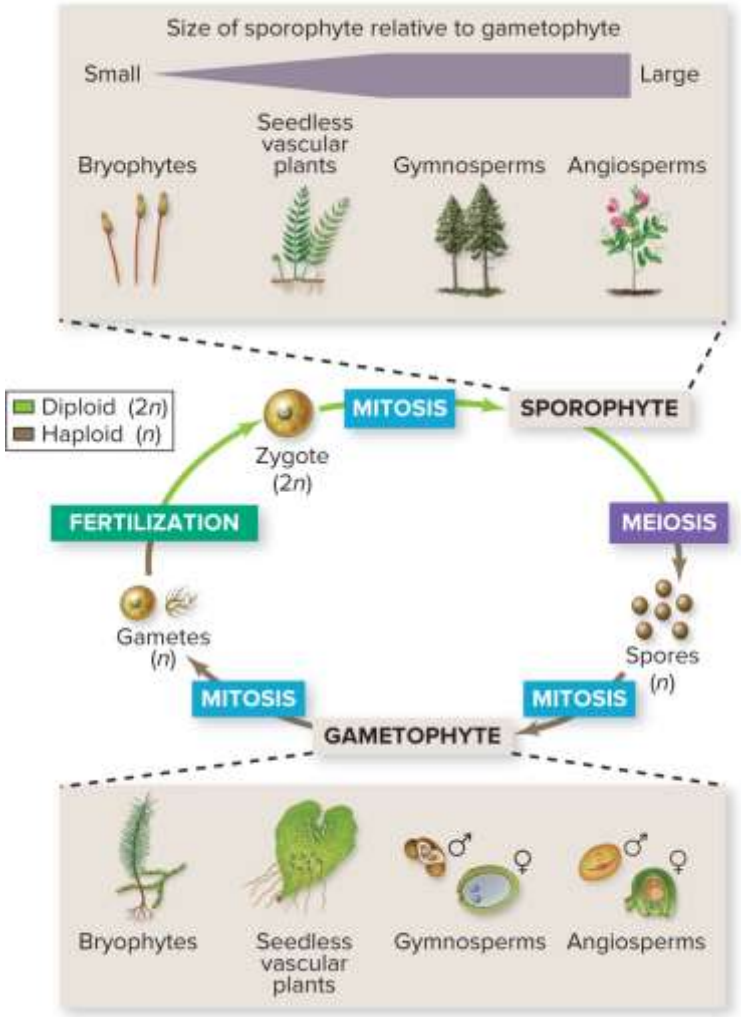
How are seedless vascular plants similar to and different from bryophytes?

All plants alternate generations

In bryophytes and seedless vascular plants, the gametophyte is more prominent than the sporophyte.

In gymnosperms and angiosperms, the sporophyte is much more prominent than the gametophyte.



Section 19.1

Figure 19.19

Gymnosperms have pollen and seeds

There are about 850 existing species of gymnosperms.

They evolved about 300 million years ago.

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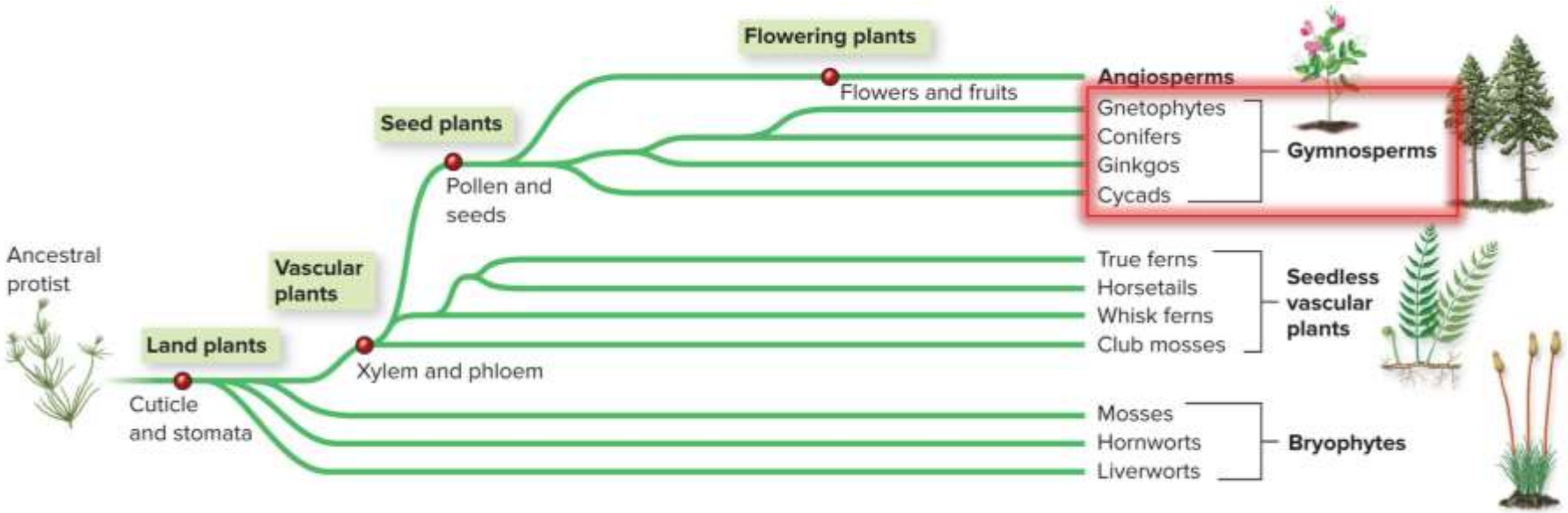
Angiosperms		
Magnoliophyta	All flowering plants, including roses, grasses, fruit trees, maples, and oaks	> 260,000

Gymnosperms are "naked seed" plants

New reproductive adaptations allowed gymnosperms to outcompete seedless vascular plants in many habitats. Gymnosperms produce seeds but do not enclose them in fruit.

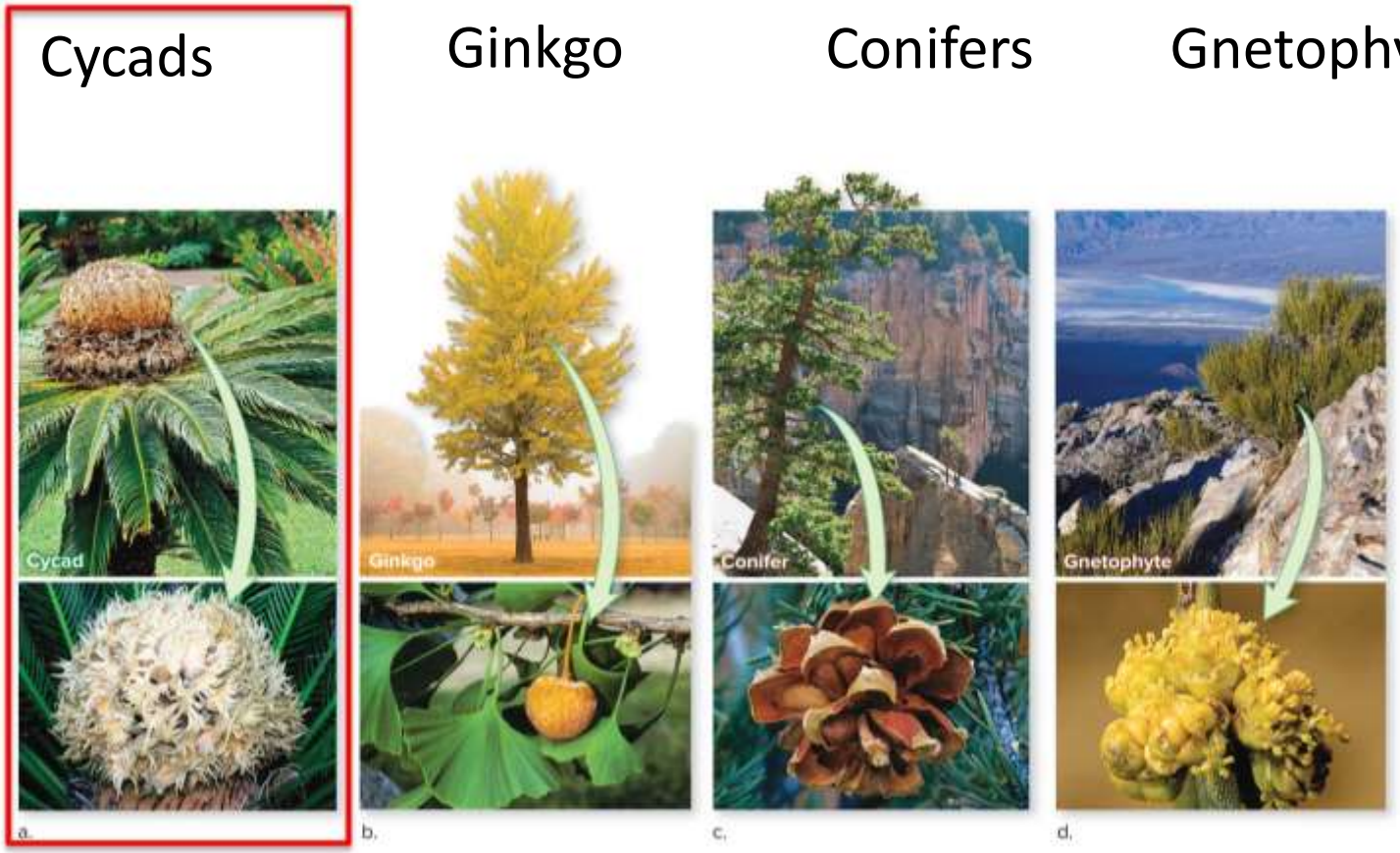


Section 19.4

Figure 19.3

Gymnosperms include cycads

Cycads were prevalent in the Mesozoic era, but many species are near extinction in the wild today. They have palmlike leaves and produce large cones.



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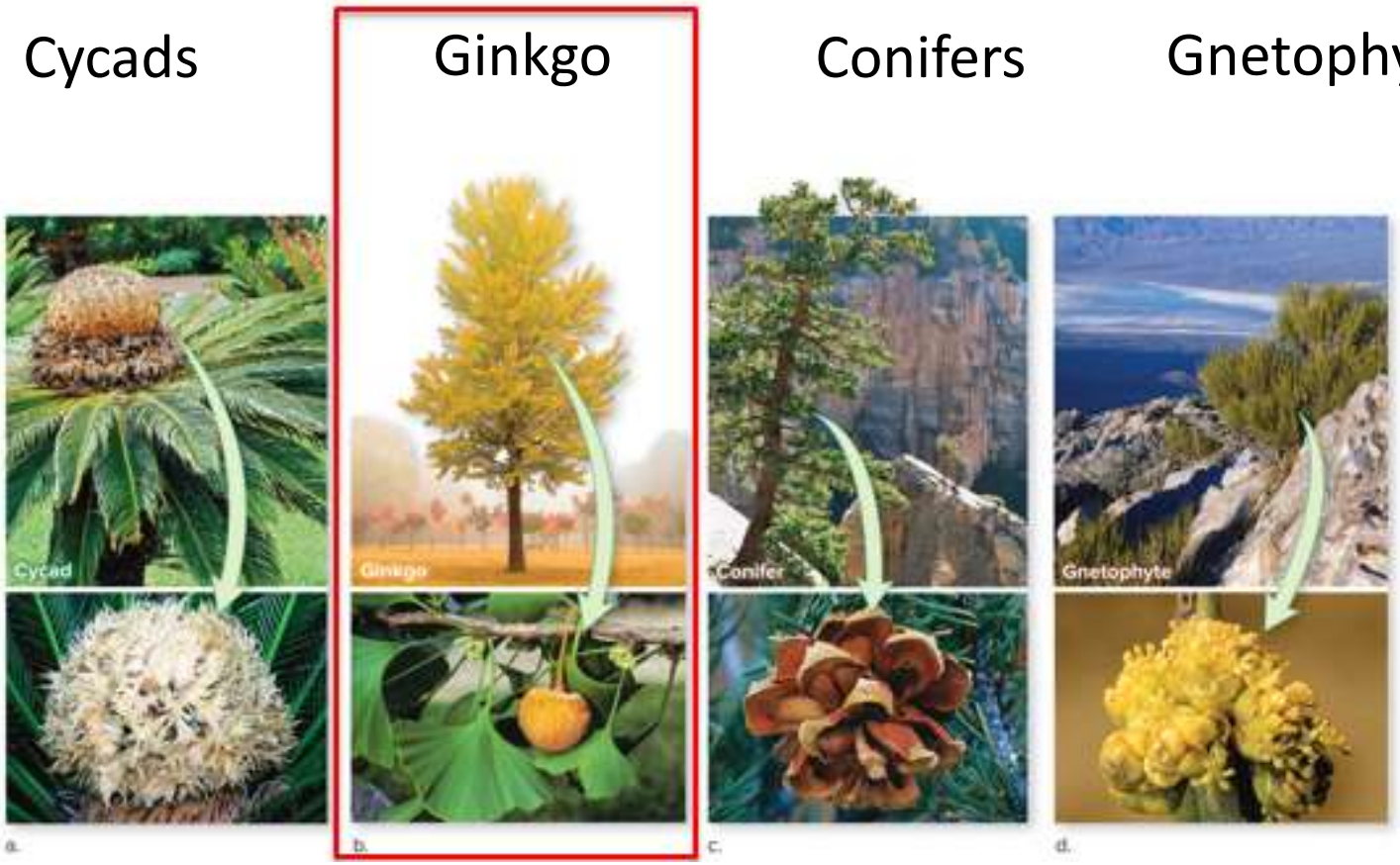
Gymnosperms include the ginkgo

Only one species exists today, and it no longer grows wild in nature. The ginkgo tree has distinctive, fan-shaped leaves.



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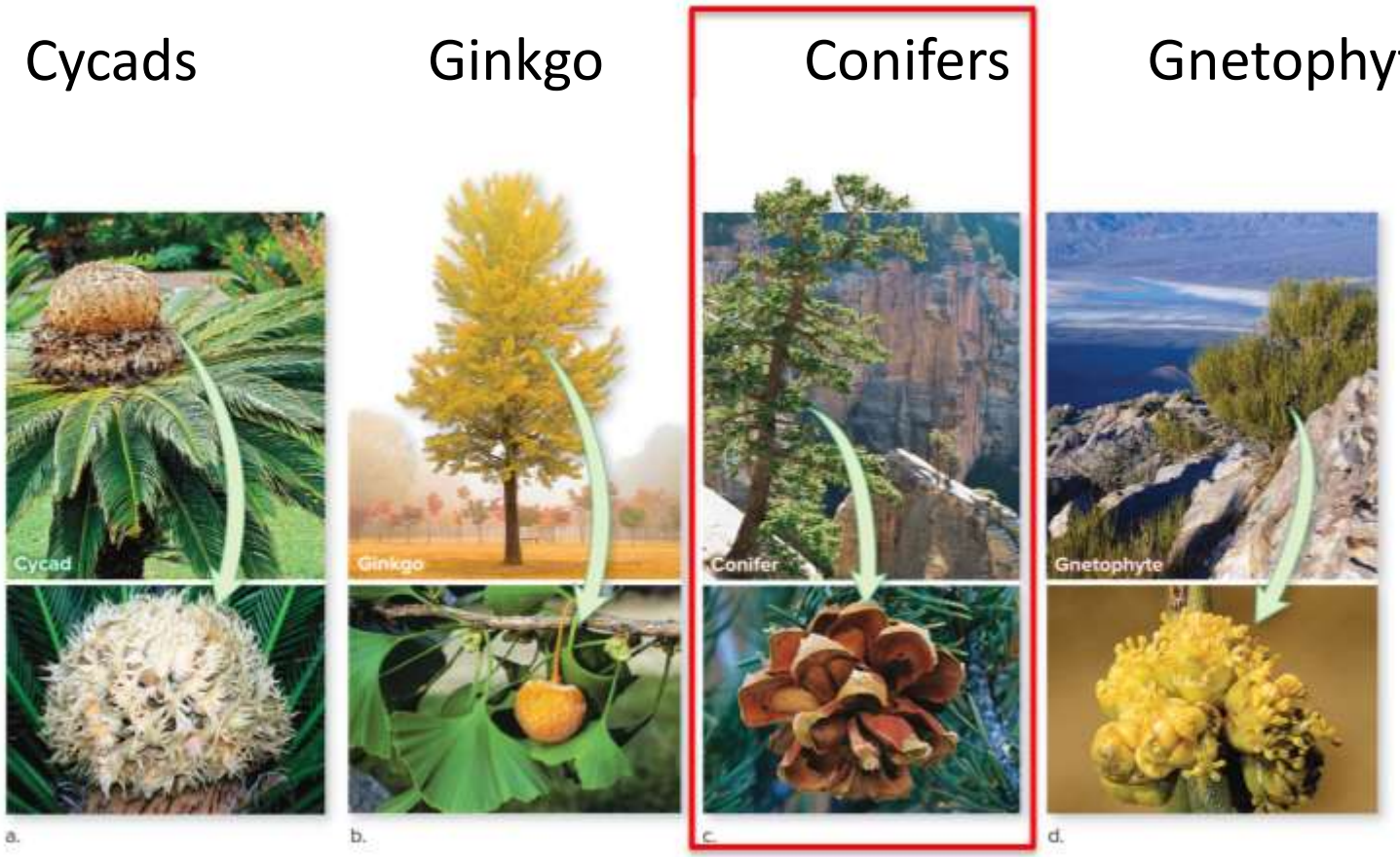
Gymnosperms include conifers

Conifers such as pine trees are familiar gymnosperms. Their leaves are needlelike and they produce egg cells and pollen in cones.



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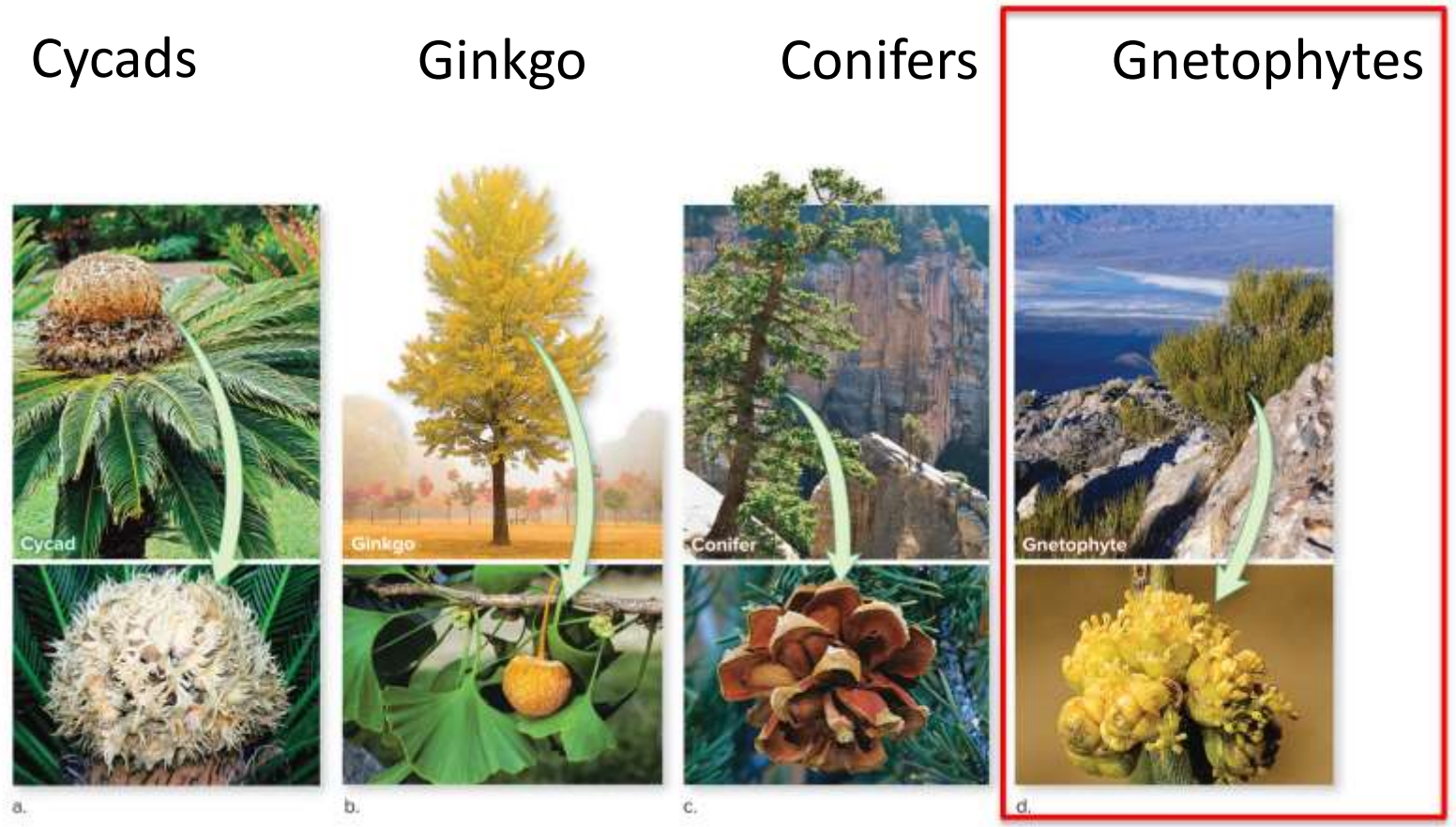
Gymnosperms include gnetophytes

These plants have a mixture of traits that make them difficult to classify. *Ephedra,* shown here, has cones that resemble tiny flowers.



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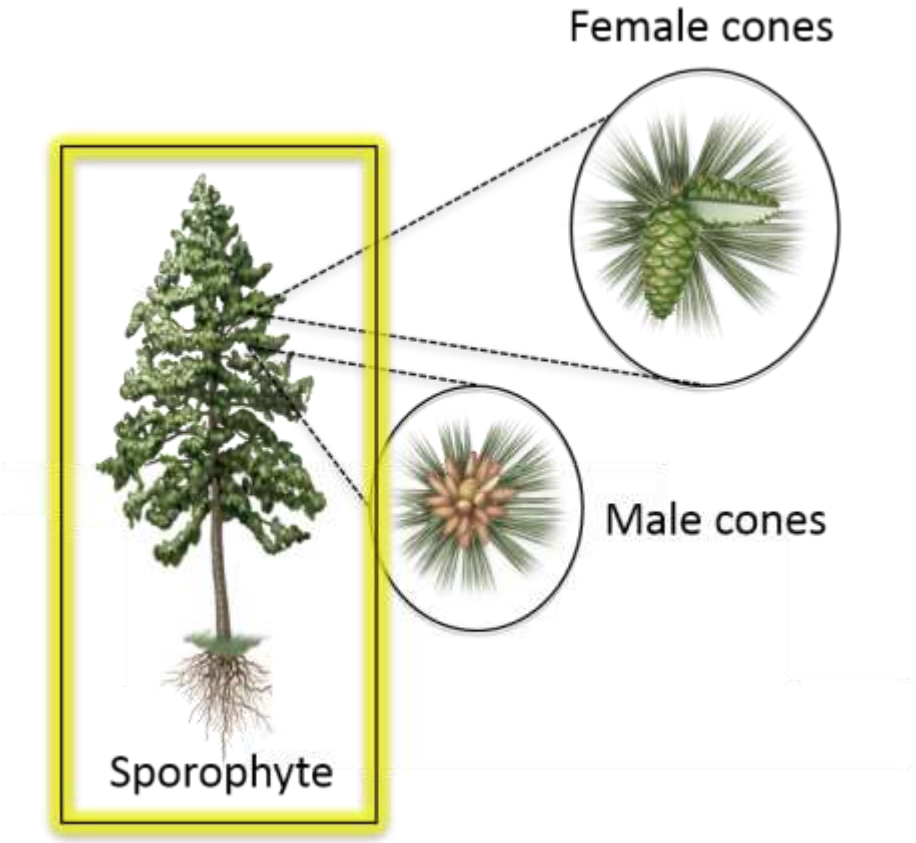
Gymnosperm sporophytes are large and conspicuous

The sporophytes of most gymnosperms are woody trees or shrubs. Reproductive structures and leaf types are diverse.

Sporophytes produce both male and female **cones**, where spores form by meiosis.



Gymnosperm sporophytes produce spores in cones

Male cones produce microspores on cone scales.

Ovules on female cone scales produce megaspores.

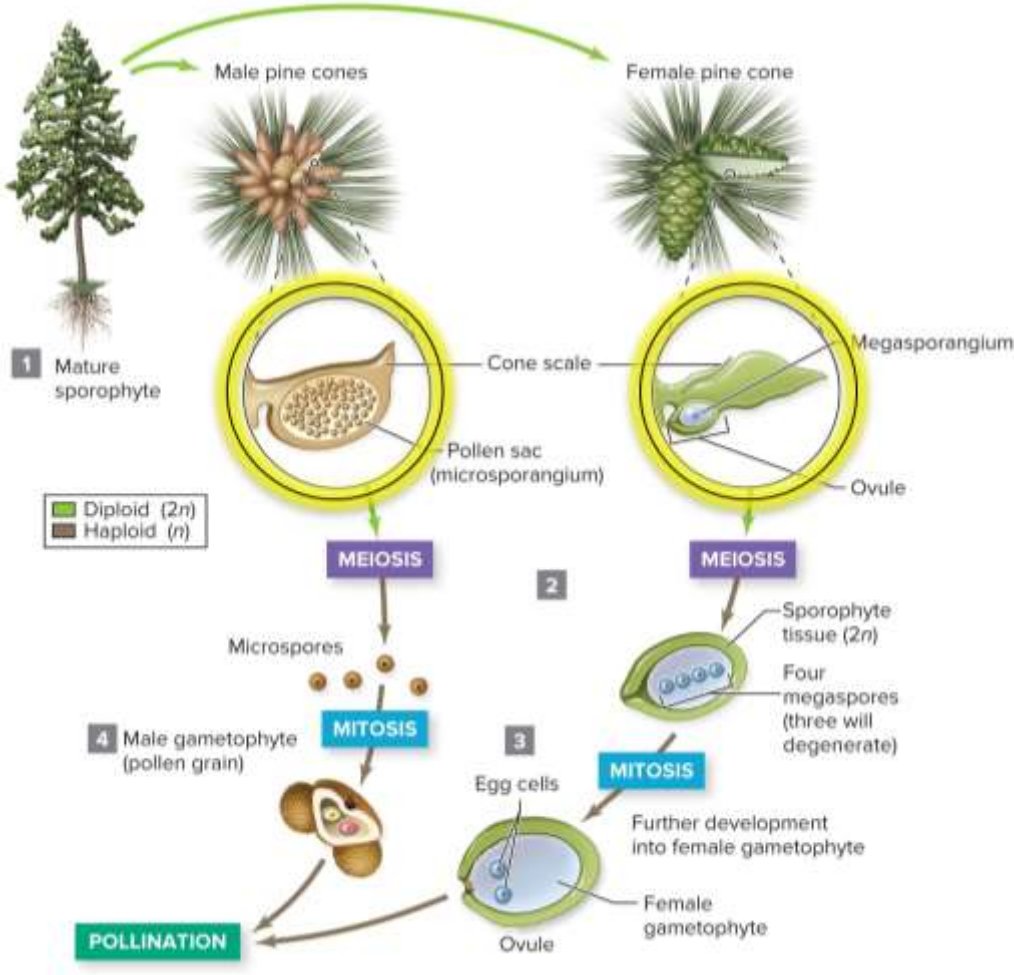


Figure 19.13

Gymnosperm gametophytes are microscopic

Male gametophytes are enclosed inside grains of pollen. Pollen can be dispersed by wind to settle on new plants.

The tiny female gametophytes stay in the cone, enclosed inside the ovule.

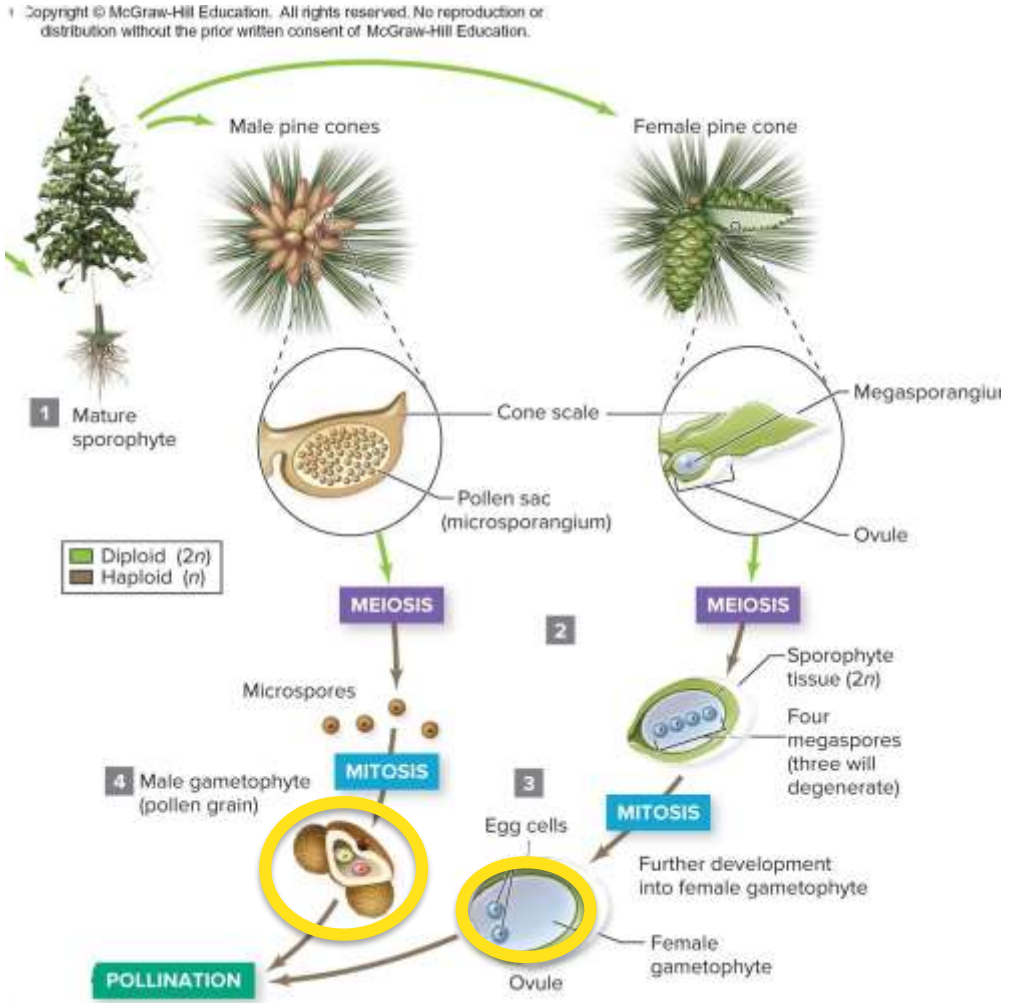
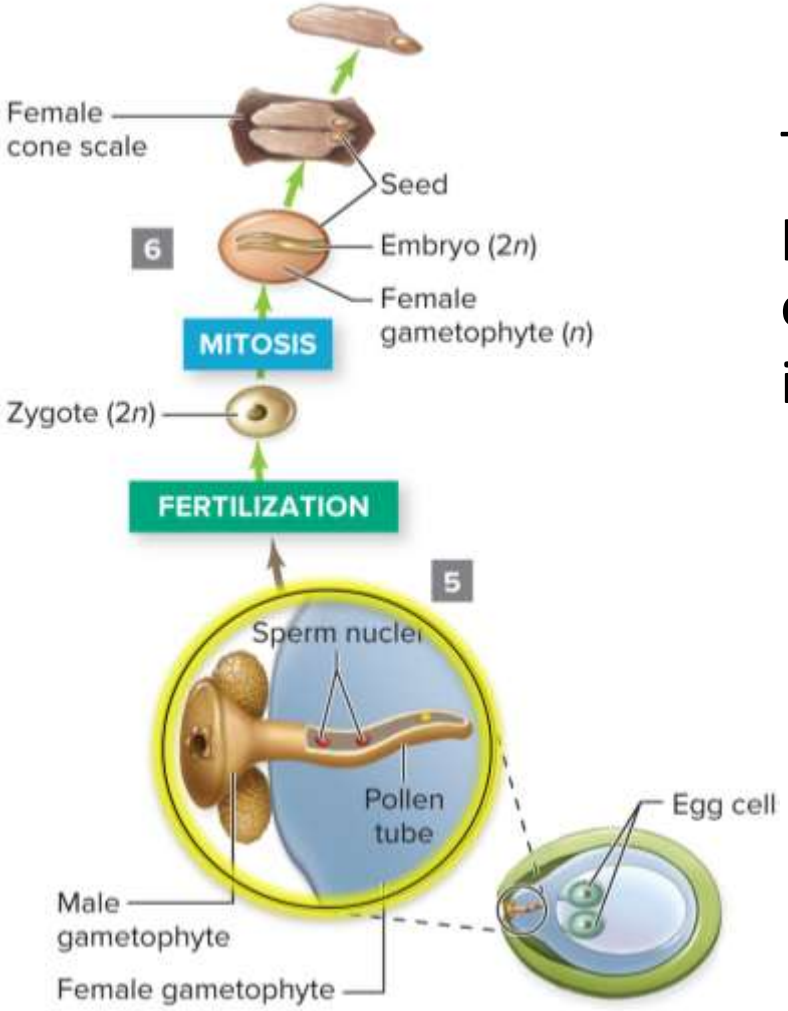


Figure 19.13

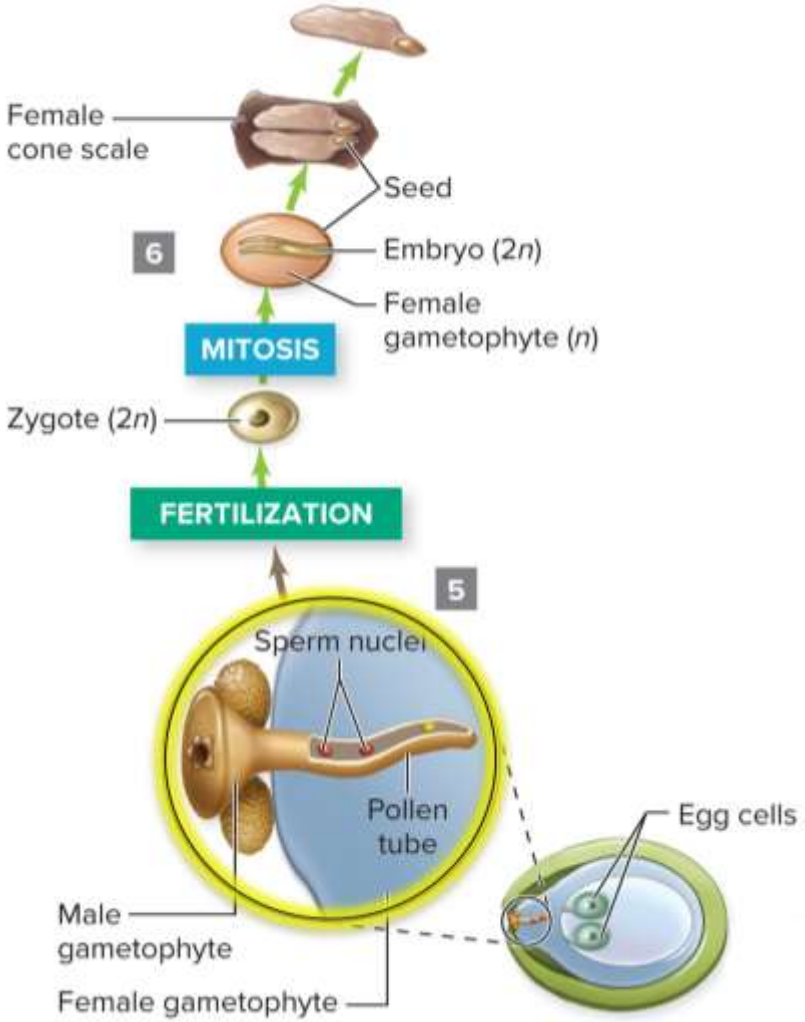
Pollination gets male and female gametophytes together



The male gametophyte produces a pollen tube that grows through the ovule until it reaches the egg cells inside.

Figure 19.13

Fertilization in gymnosperms does not require water

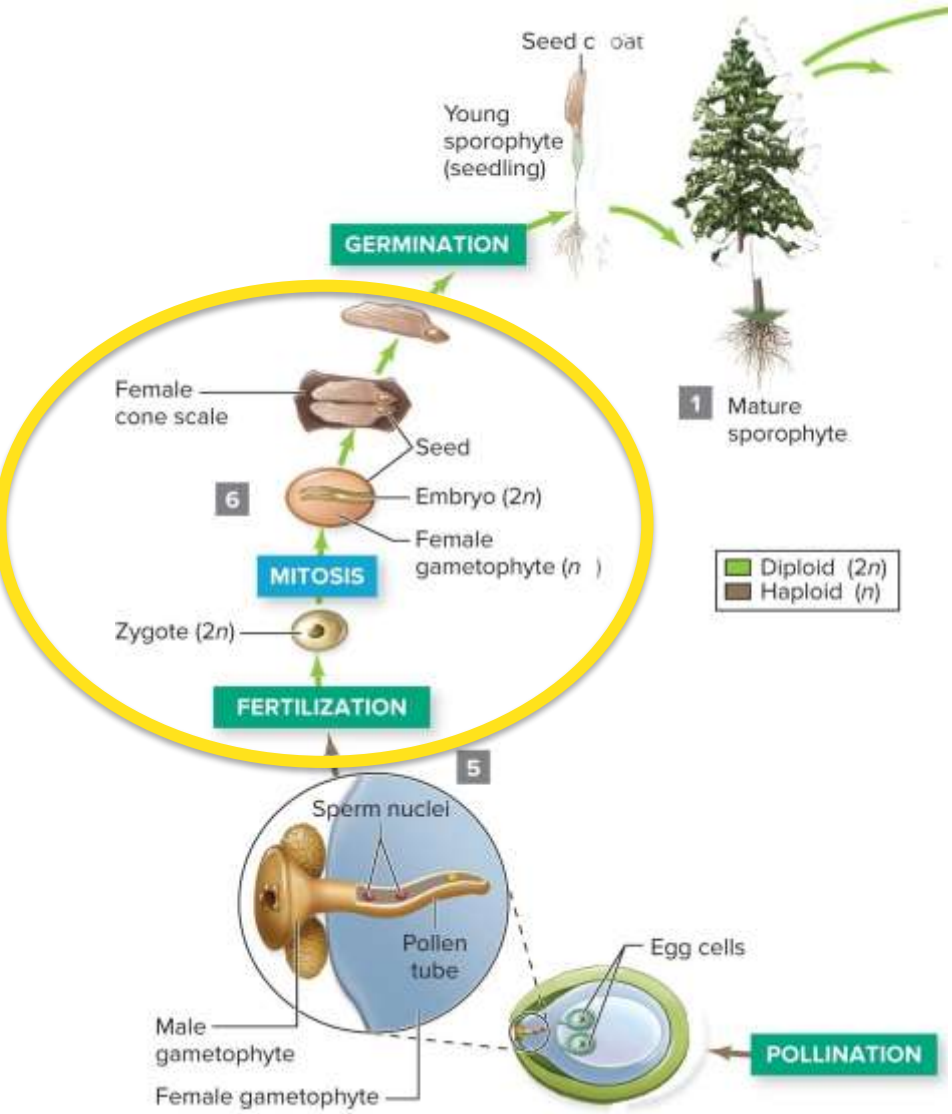


Sperm do not need to swim through water to eggs for fertilization.

Section 19.4

Figure 19.13

Gymnosperms zygotes stay inside seeds



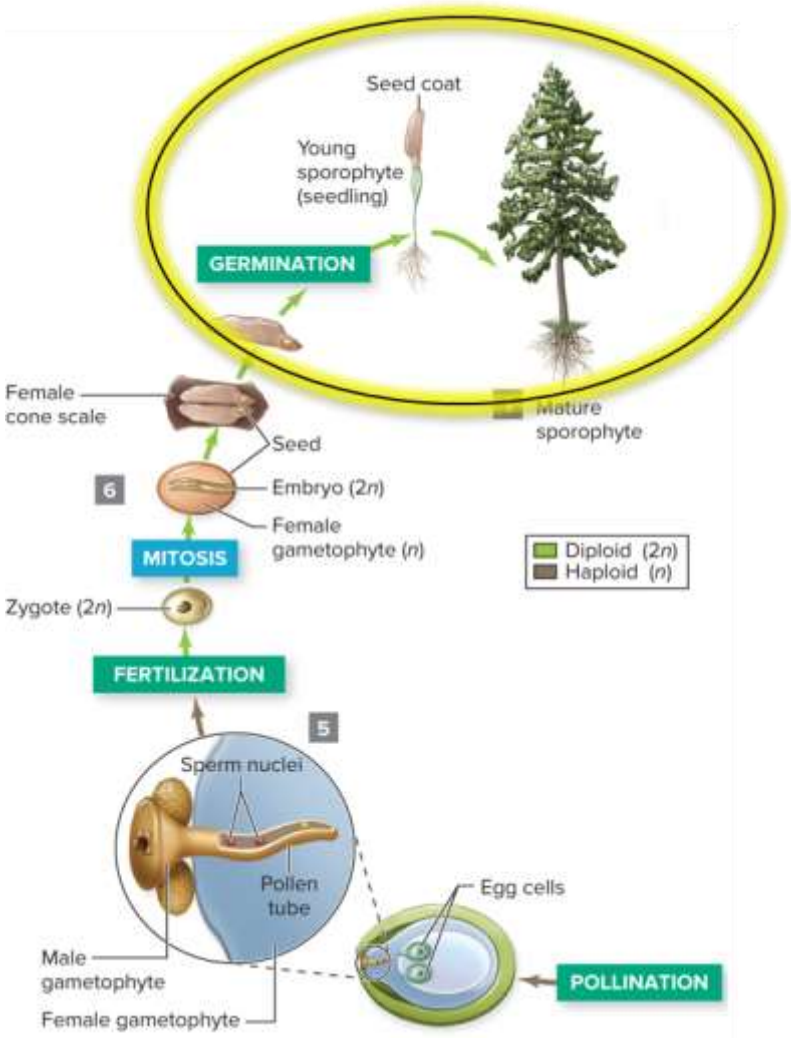
The zygote is the first cell of the sporophyte.

It grows mitotically into an embryo, inside a seed, on a female cone scale.

Section 19.4

Figure 19.13

Seeds protect sporophyte embryos



Gymnosperm seeds have a tough outer coat and can be dispersed by wind or animals.

When conditions are favorable they will germinate into seedlings, which develop into mature sporophyte trees.

Clicker question #4

How is gymnosperm reproduction different from that of ferns?

A. Gymnosperms produce seeds; ferns don't.
B. Gymnosperms produce swimming sperm; ferns don't.
C. Gymnosperms produce zygotes; ferns don't.
D. Gymnosperms don't produce spores; ferns do.

Clicker question #4, solution

How is gymnosperm reproduction different from that of ferns?

A. Gymnosperms produce seeds; ferns don’t.

19.4 Mastering concepts

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What happens during and after pollination in gymnosperms?

Angiosperms have flowers and fruit

95% of all living plant species are angiosperms.

They evolved about 144 million years ago and rapidly diversified into over 260,000 different species.

TABLE 19.1 Phyla of Plants

Phylum	Examples	Number of Existing Species
Nonvascular plants		
Marchantiophyta	Liverworts	9000
Anthocerotophyta	Hornworts	100
Bryophyta	True mosses	15,000
Seedless vascular plants		
Lycopodiophyta	Club mosses, spike mosses	1200
Pteridophyta	Whisk ferns, true ferns, horsetails	11,500
Gymnosperms		
Cycadophyta	Cycads	130
Ginkgophyta	Ginkgo	1
Pinophyta	Pines, firs, and other conifers	630
Gnetophyta	Gnetophytes	80
Angiosperms		
Magnoliophyta	All flowering plants, including roses, grasses, fruit trees, maples, and oaks	> 260,000

Angiosperms produce seeds in fruits

Angiosperms produce pollen and egg cells in flowers, which develop into fruit after fertilization.

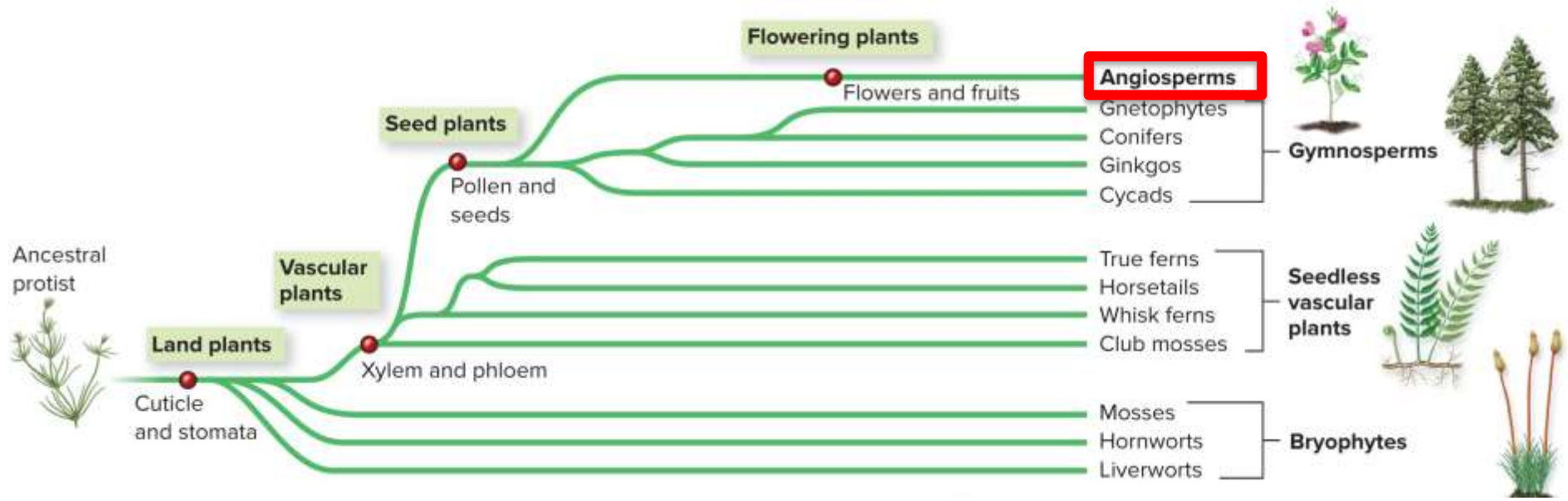
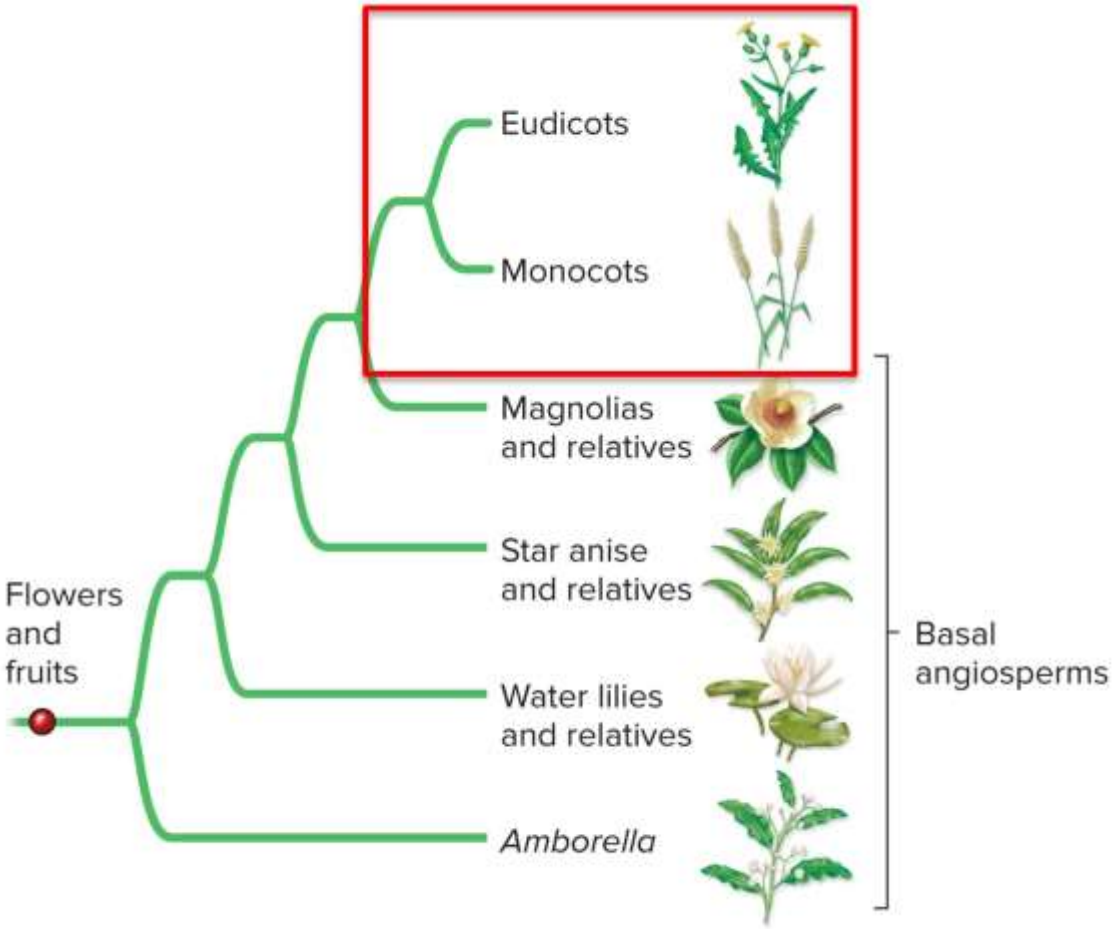


Figure 19.3

97% of angiosperms are either eudicots or monocots

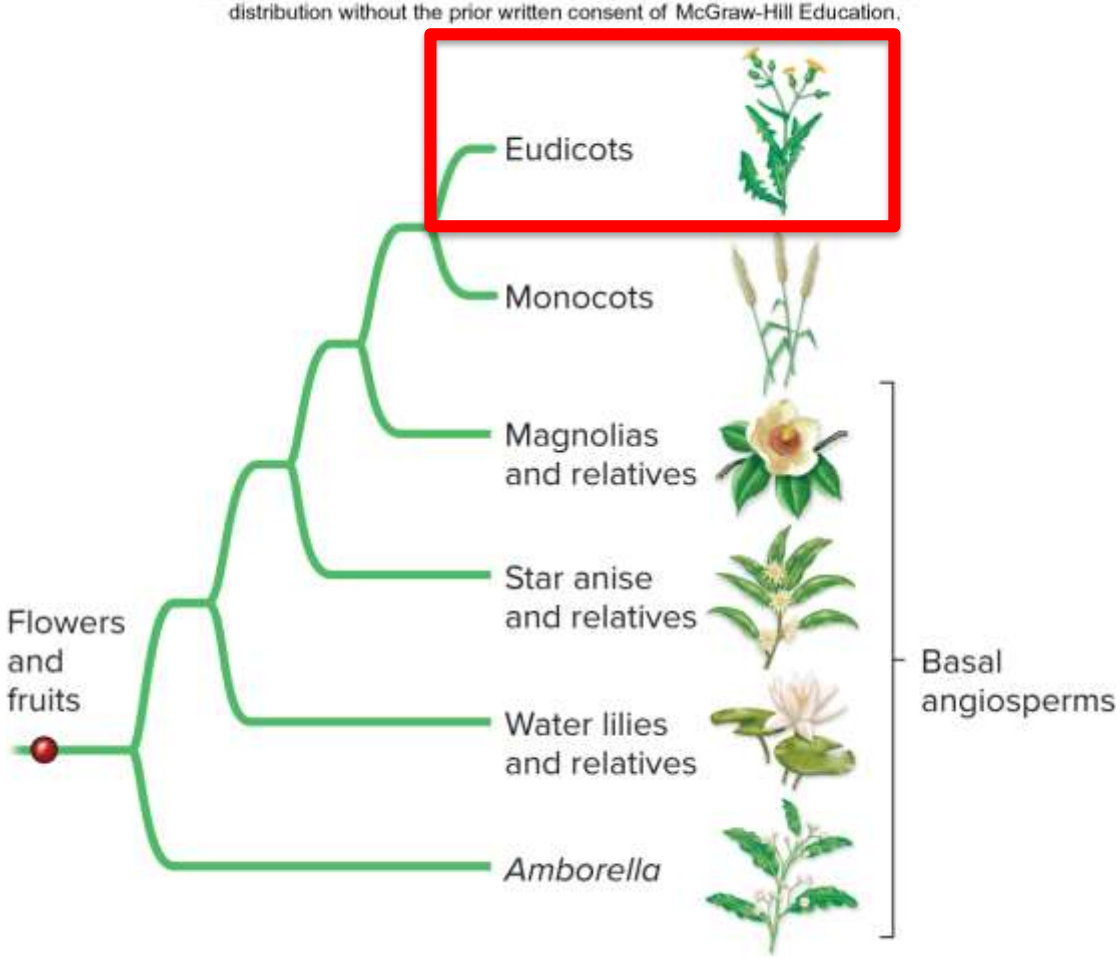


Scientists classify the diverse angiosperms into several groups, notably the **eudicots** and **monocots**.

The other 3% of angiosperms are a paraphyletic group called basal angiosperms.

Figure 19.14

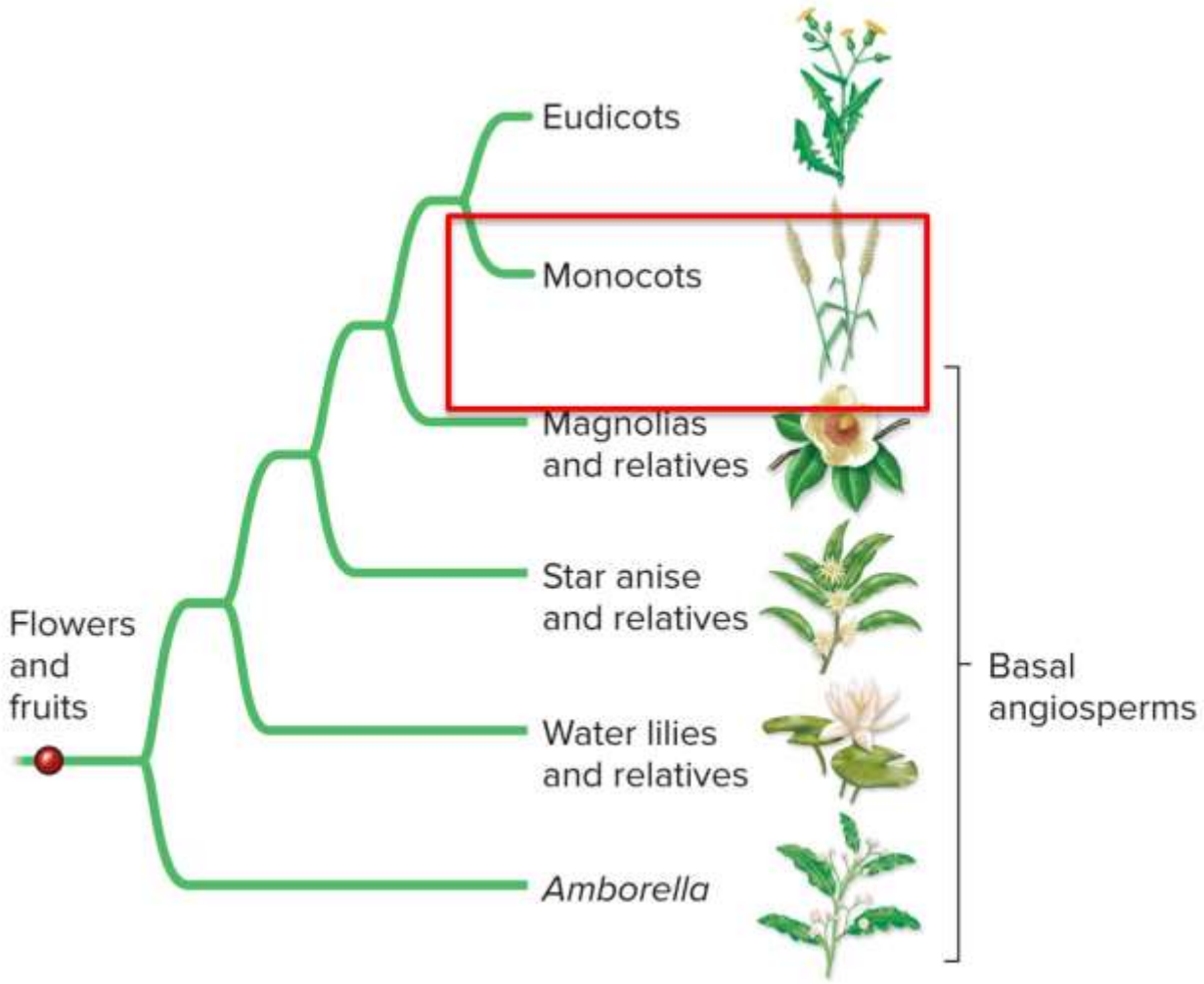
Most angiosperms are eudicots



Eudicots have two cotyledons, which are the first leaves to emerge during germination. Their pollen grains have three pores.

Examples include roses, daisies, sunflowers, oak trees, beans, and the model organism *Arabidopsis*.

Many angiosperms are monocots



Monocots have one cotyledon. Their pollen grains have one pore.

Examples include orchids, lilies, grass, bananas, rice, wheat, and corn.

Figure 19.14

Angiosperm sporophytes are large and conspicuous

Trees and other familiar angiosperms we see are the sporophytes.

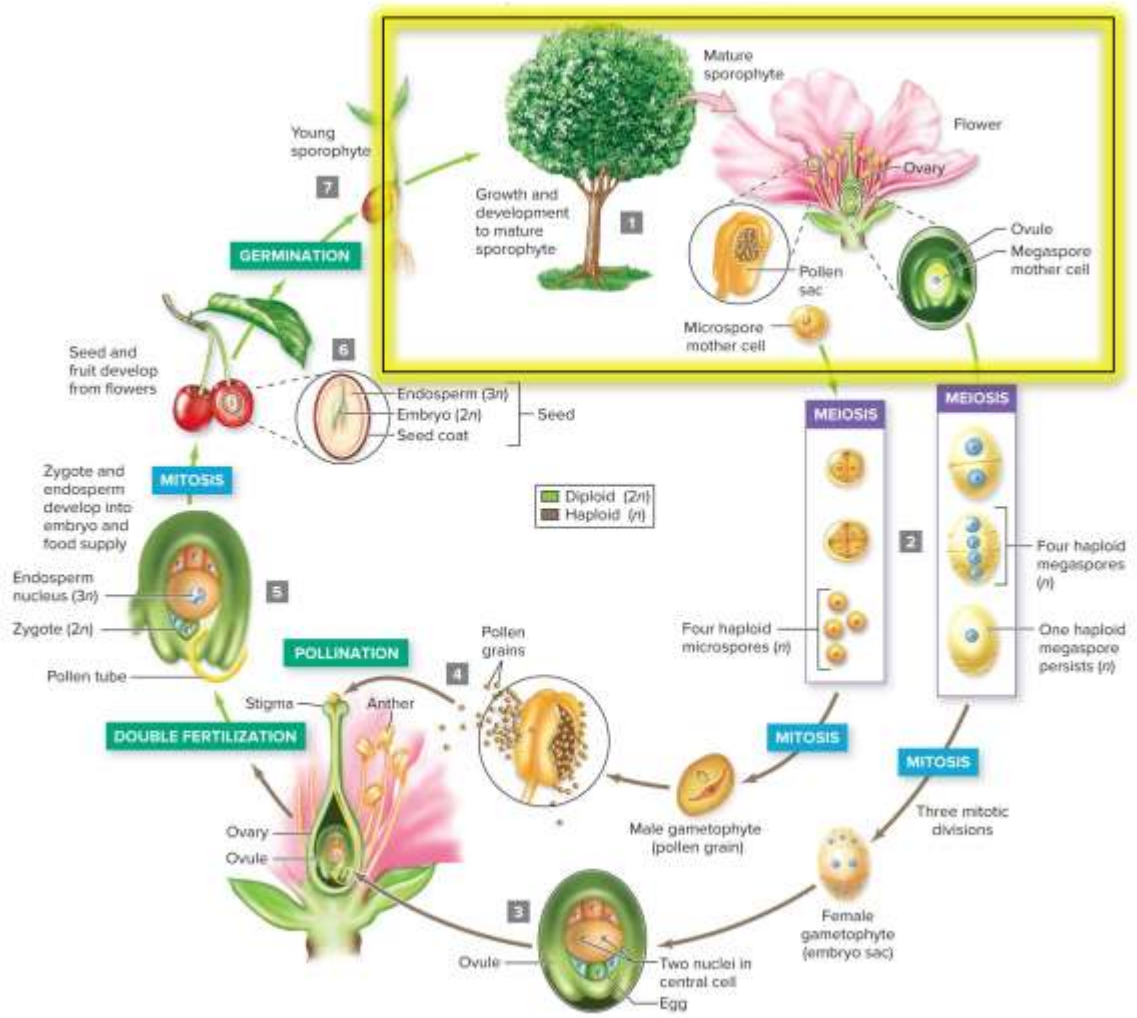
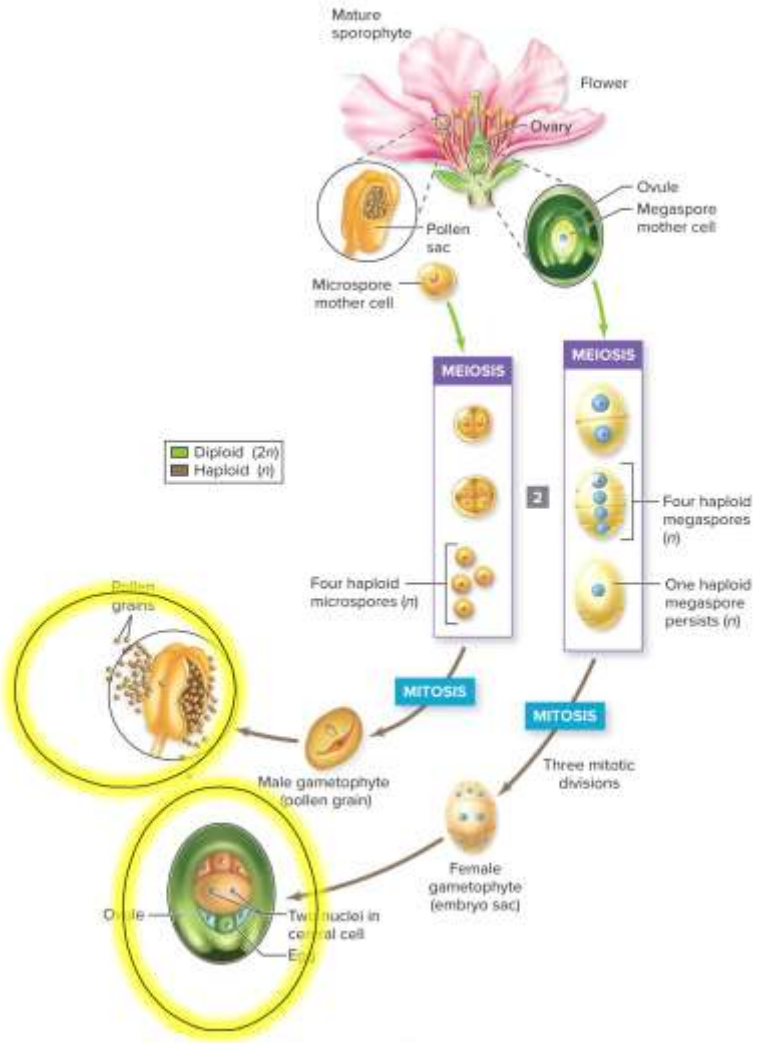


Figure 19.15

Flowers are sporophyte reproductive structures in angiosperms

Pollen sacs in flowers produce microspores that develop into male gametophytes.

The ovule in the flower produces megaspores that develop into the female gametophytes.

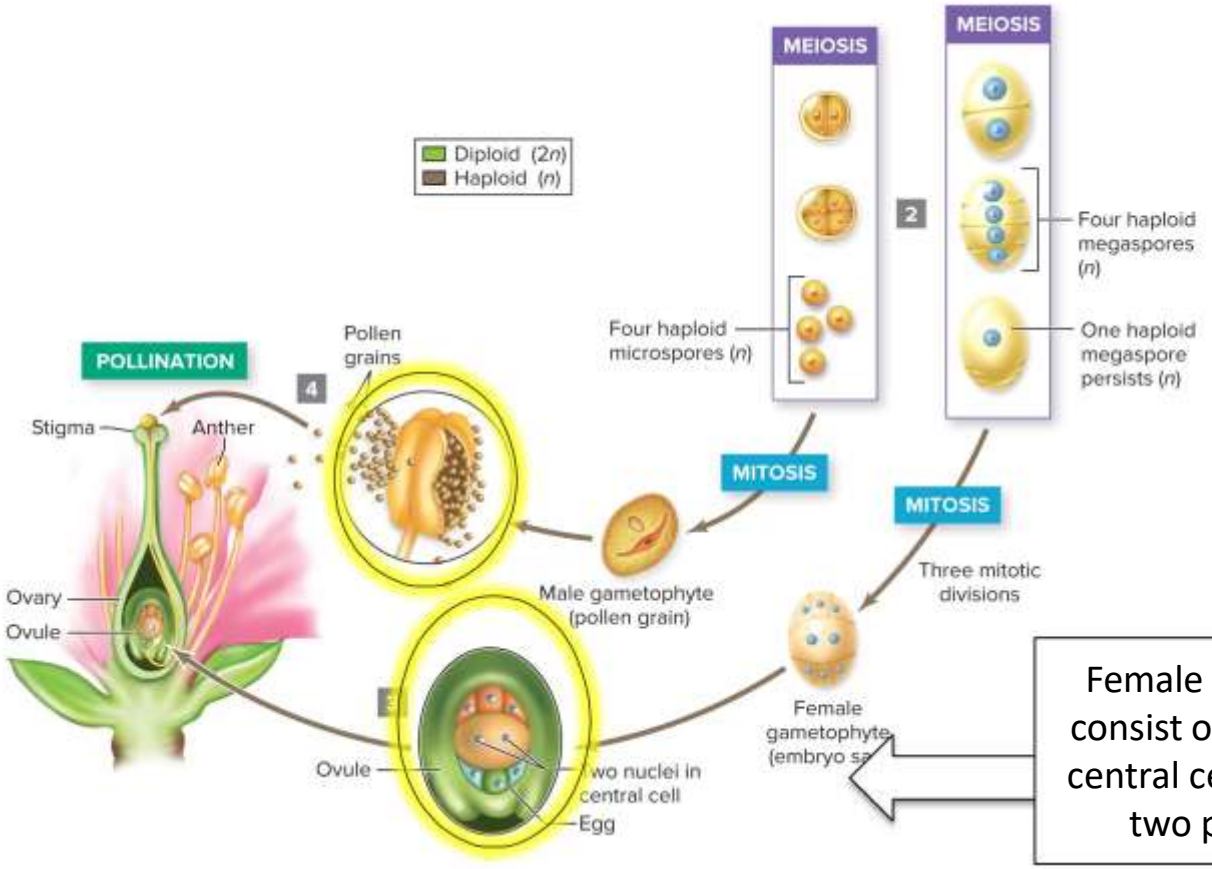


Section 19.4

Figure 19.15

Microscopic gametophytes get together at pollination

During pollination, a grain of pollen (male gametophyte) produces a pollen tube to reach the female gametophyte.



Female gametophytes consist of one egg and a central cell that contains two polar nuclei.

Section 19.5

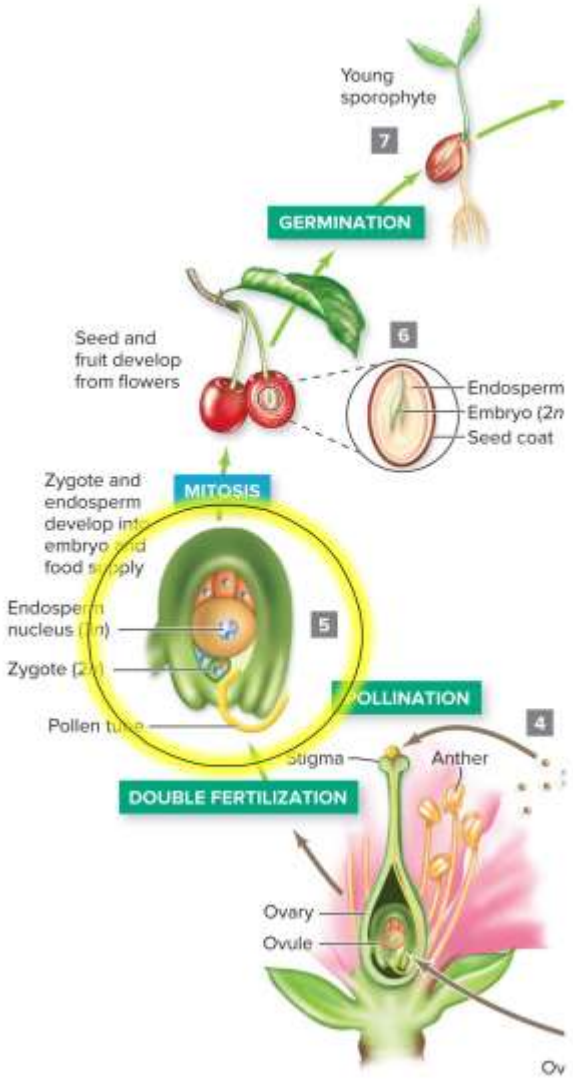
Figure 19.15

Angiosperms have double fertilization

Two sperm nuclei travel through the pollen tube.

One fertilizes the egg, forming a zygote. This is the first cell of the sporophyte.

The other sperm fertilizes the central cell's polar nuclei. This will develop into the endosperm, which feeds the embryo inside the seed.

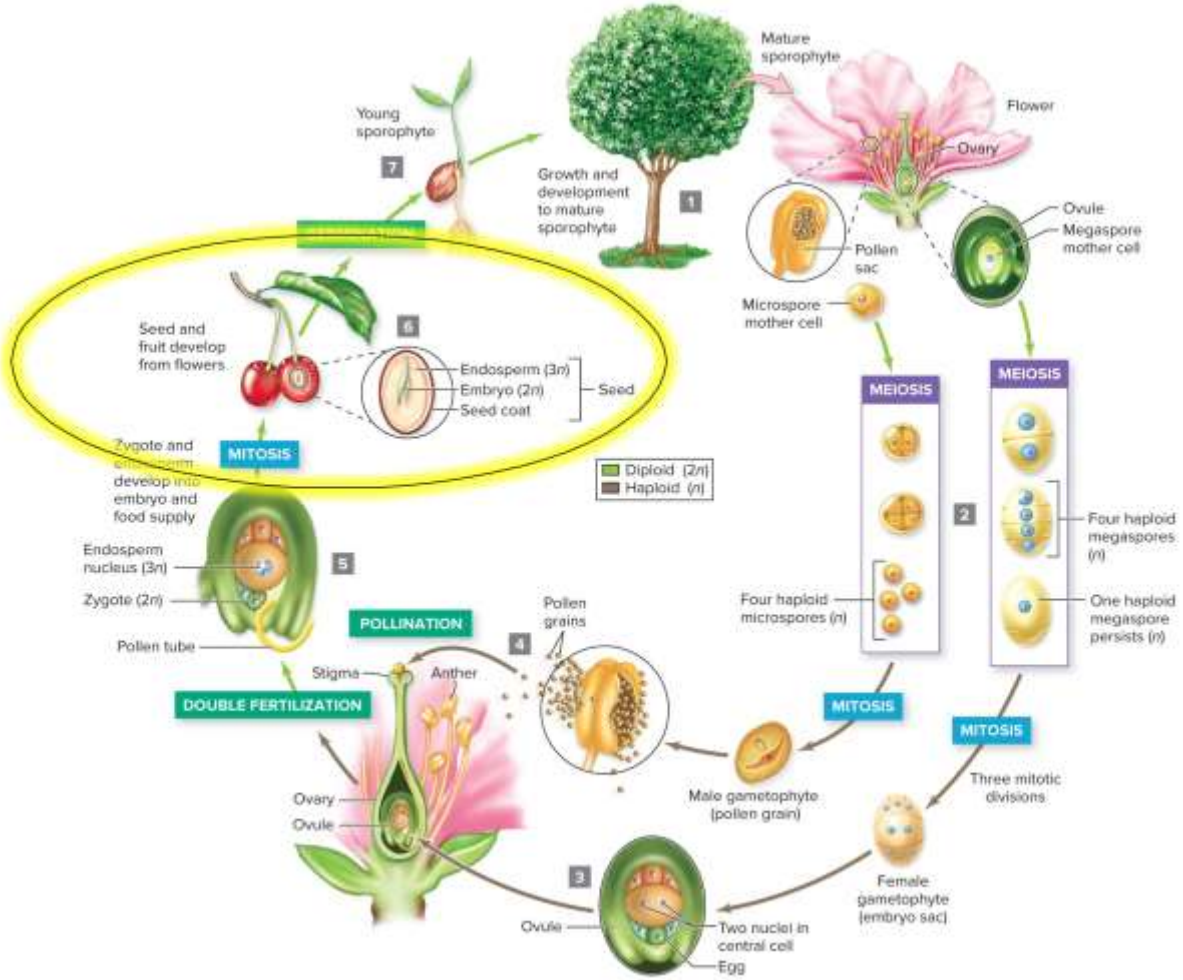


Section 19.5

Figure 19.15

Seeds contain embryo and endosperm

In angiosperms, the ovule develops into a seed. At the same time, the ovary that surrounds the ovule develops into a fruit.

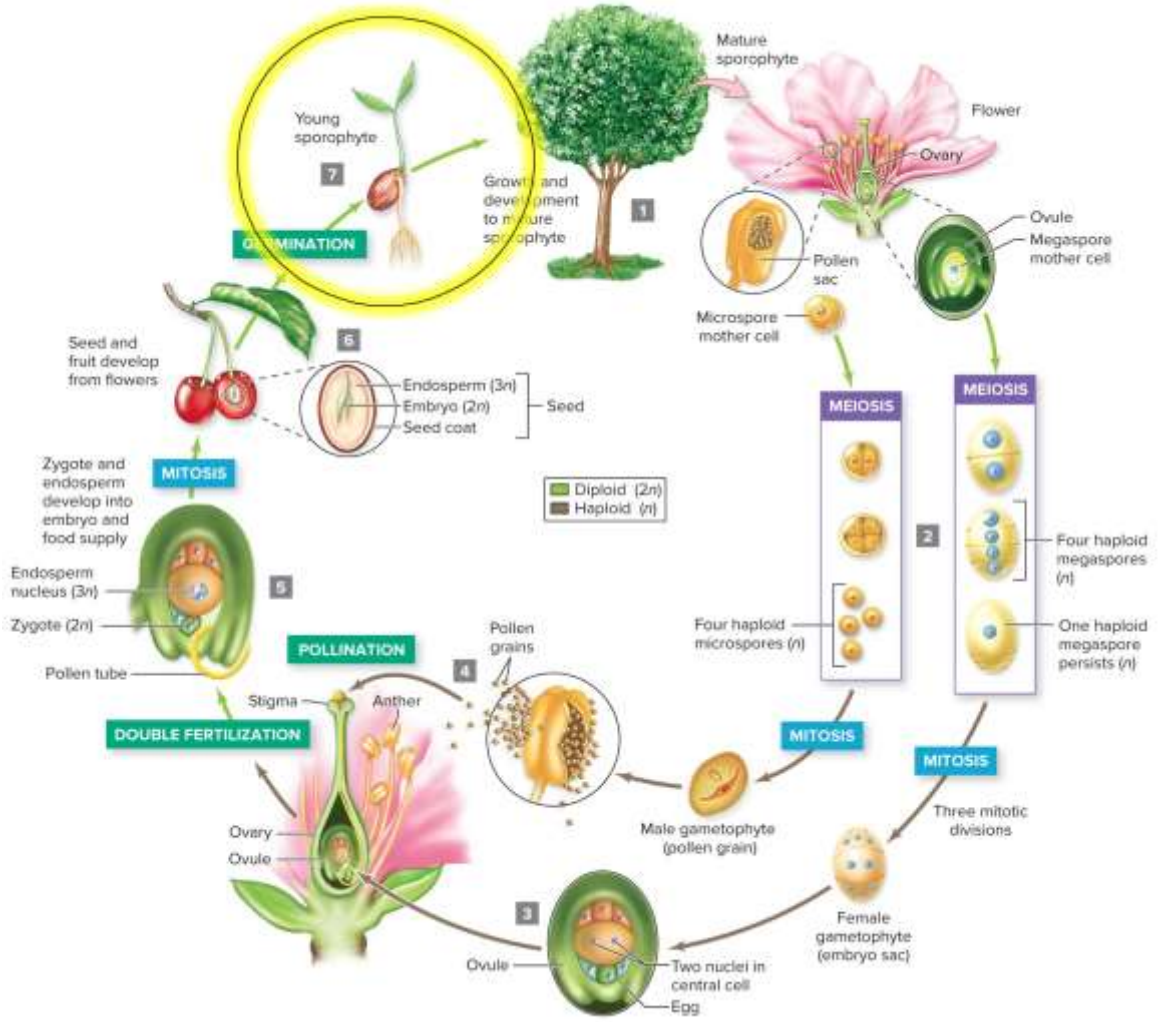


Section 19.5

Figure 19.15

Angiosperm seeds germinate when conditions are favorable

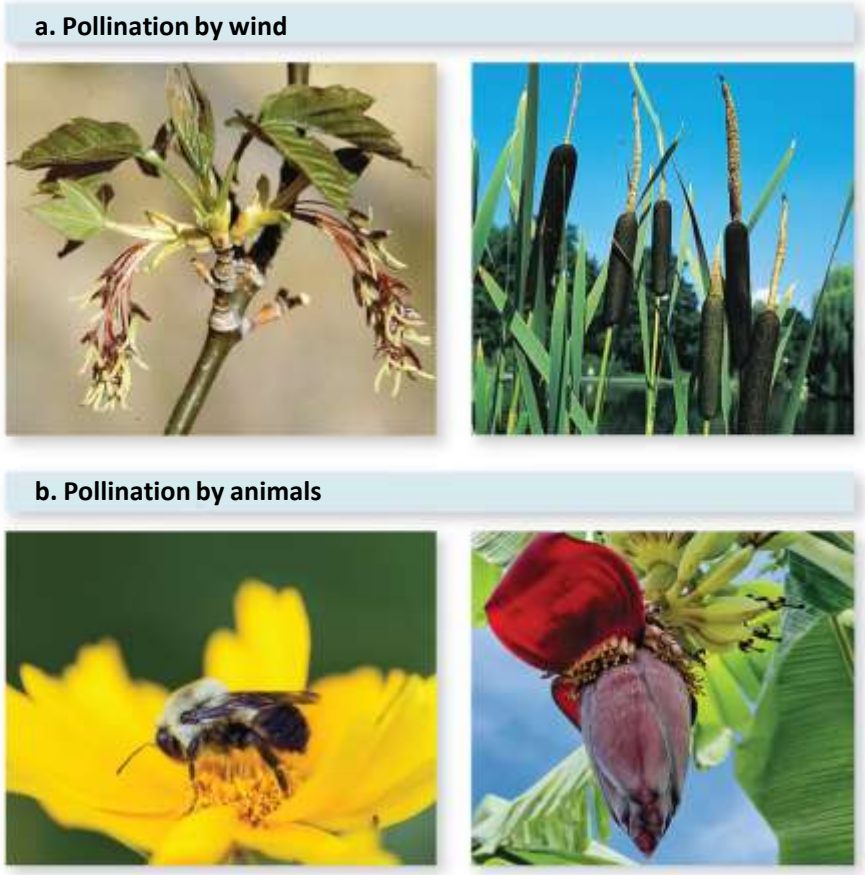
Seeds germinate into young sporophytes.



Section 19.5

Figure 19.15

Wind and animals assist angiosperm reproduction



(a, maple tree): ©Steven P. Lynch/McGraw-Hill Education; (a, cattails): ©Hans Reinhard/Okapia/Science Source; (b, chamomile): ©McGraw-Hill Education; (b, banana tree): ©Igor Prahin/Flickr Open/Getty Images RF

Pollen is transported great distances by wind.

Plants with attractive nectar, petals, or bright colors co-evolved with animals that pollinate them.

Figure 19.16

Clicker question #5

In the angiosperm life cycle, the seed is analogous to the ____ in the human life cycle.

A. male reproductive organs
B. female reproductive organs
C. uterus and fetus
D. sperm cell
E. egg cell

Clicker question #5, solution

In the angiosperm life cycle, the seed is analogous to the ____ in the human life cycle.

C. uterus and fetus

19.5 Mastering concepts

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In what ways are the life cycles of angiosperms similar to and different from those of conifers?

Summary: alternation of generations

The diploid sporophyte plant produces haploid spores that grow into gametophyte plants.

Haploid gametophytes produce gametes that unite at fertilization.

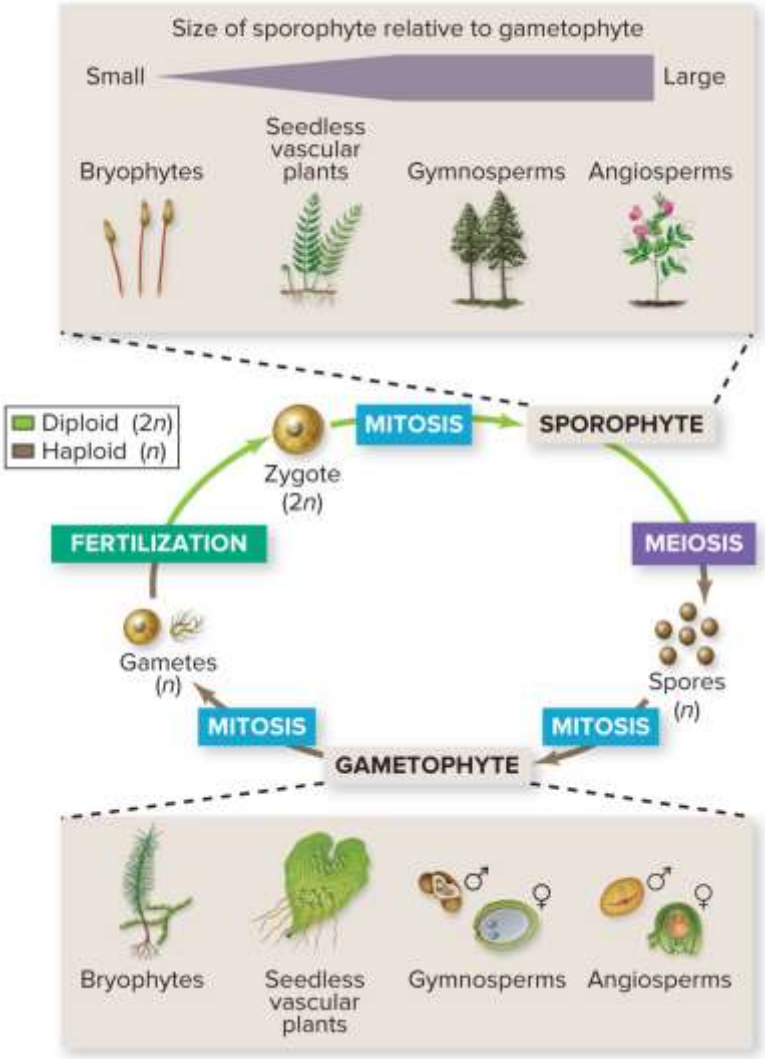


Figure 19.19

Investigating life:
Genetic messages from ancient ecosystems

Frozen soils preserve DNA from organisms that lived long ago.

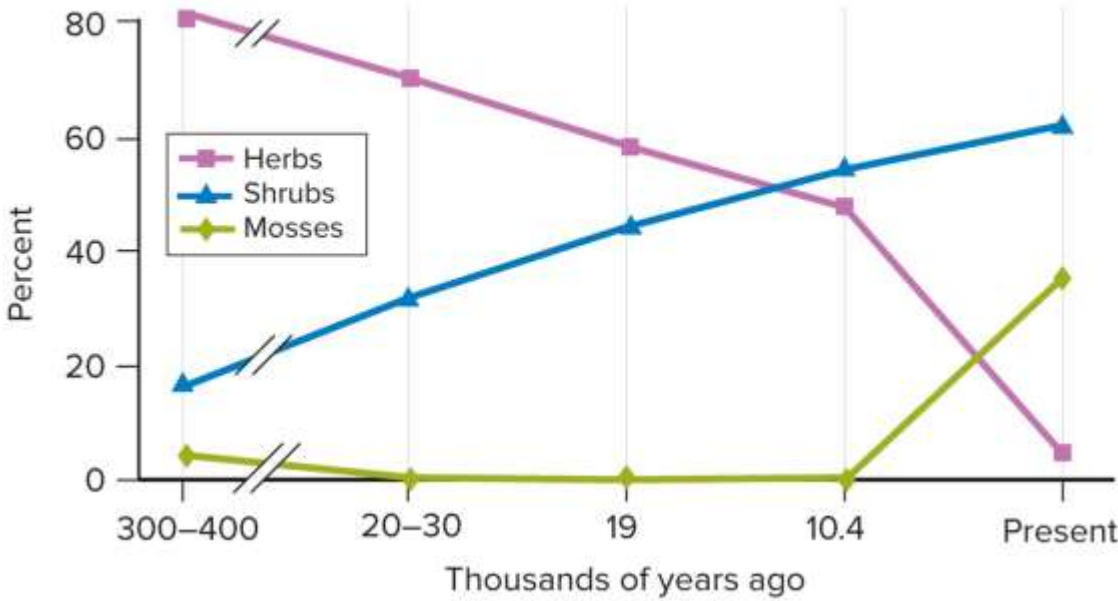
Researchers drill through the permafrost to collect DNA that will help them learn about ancient ecosystems.

Courtesy of K. Schaefer

Investigating life:

Data reveals changing plant communities

Chloroplast DNA isolated from sediment samples shows that herbs predominated in Siberia from 400,000 years ago until about 10,000 years ago, when mosses and shrubs overtook them.



Section 19.6

Figure 19.18