

# Plants

and the Colonization of Land



## The lives of modern plants and fungi are intertwined

- We depend on plants and indirectly, fungi for much of our food.

- Plants are often harmed by fungi.

- On the other hand, nearly all plants in the wild are aided by mycorrhizal fungi. **Mycorrhizae** are rootlike structures made of both fungi and plants. The fungi help plants obtain nutrients and water, and protect plant roots from parasites, in exchange for food the plants make by photosynthesis.

- Modern agricultural practices, such as killing parasitic fungi with fungicides, may disrupt mycorrhizal fungi, forcing the need for fertilizer.



**Plants and fungi evolved together as life moved onto land over 400 million years ago. This is supported by the earliest plant fossils having micorrhizae.**

## What is a plant?

- In the two-kingdom system, Linnaeus classified algae as plants. In the five-kingdom system, algae are protists.

- The definition of plants as multicellular, eukaryotic photosynthesizers also describes multicellular algae.

- Multicellular seaweeds, the most complex algae, are adapted for life in water, while plants are adapted for life on land. All the resources, including water, carbon dioxide, and minerals are in direct contact with their tissues, and waste products can be washed away. Water supports and suspends the body of alga. Holdfasts anchor the alga, and all other parts can be photosynthetic. Water provides a means of dispersal for gametes and offspring.

- Life on land imposes problems. Water and nutrients are concentrated in the ground, while carbon dioxide and light are most abundant above the ground. Air provides no support against the forces of gravity and will dry out reproductive cells.

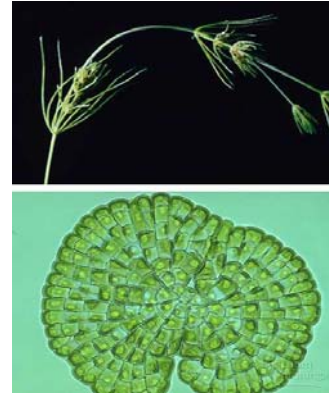
- Adaptations to terrestrial environment in plants include the following **(a)** Discrete organs: roots, stems, leaves, and gametangia specialized for anchorage and absorption, support, photosynthesis and reproduction, respectively. **(b)** Mycorrhizal fungi to increase the efficiency of absorption of their roots. **(c)** A vascular network to move food (phloem) and water (xylem) among the parts. **(d)** A cuticle on leaves and stems to help retain water. **(e)** Dependency on wind or animal carriers to disperse male gametes (contained in pollen) and offspring. **(f)** Offspring are kept moist by developing within the female gametangium.

### Plant probably evolved from green algae called charophytes

- Plants and green algae have a number of homologous features, such as identical photosynthetic pigments, food storage molecules, cell walls, and mechanisms of cell division.

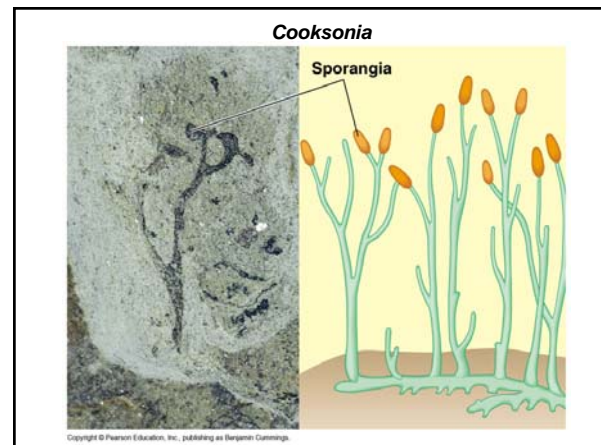
- Plants may have evolved from green algae about 500 mya. The ancestor is not known, but analysis of nucleic acid sequences, cell structure, and biochemistry indicate that a group of green algae, the charophytes are the probable ancestors of plants.

Charophyceans: *Chara* (top), *Coleochaete orbicularis* (bottom)



- Early plants thrived on moist shorelines where space was essentially limitless, sunlight was abundant, and where there may not have been any herbivorous animals.

- Among the earliest plant fossils is *Cooksonia*, which have been found in strata dated to 415 mya. This plant had branched, upright, photosynthetic stems and spore sacs (sporangia) but lacked leaves.



- Plants more complex than *Cooksonia* are known to have been abundant  $\approx$  400 mya. Like *Cooksonia*, they lacked leaves but they had more complex sporangia and were more firmly anchored to the soil.

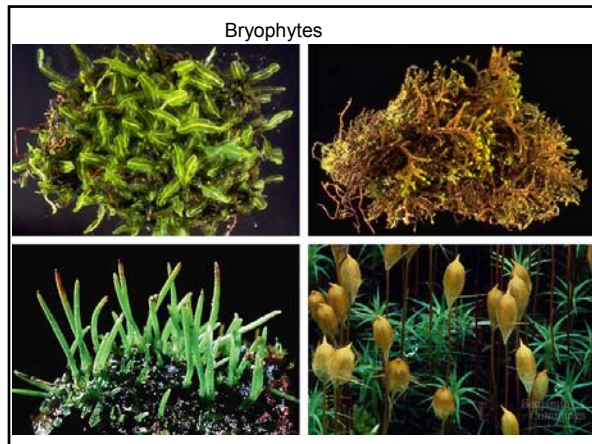
- A large number and diversity of plants with well-developed leaves and roots were present by 375 mya.

### Plant diversity provides clues to the evolutionary history of the plant kingdom

- Plant phylogeny shows branching of several plant lineages, reflecting major evolutionary steps.

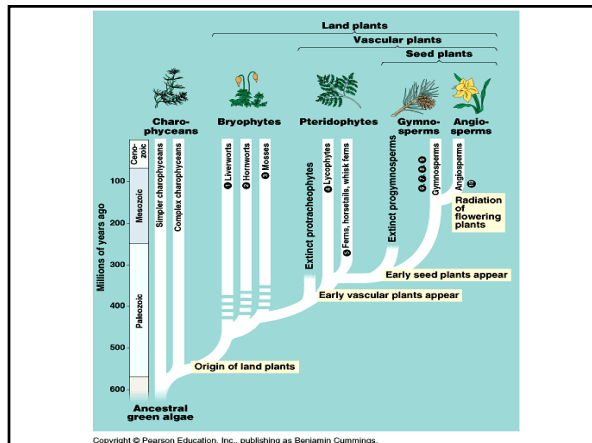
- Two lineages of plants arose, most likely from charophytes,  $\approx$  425 mya. One of these lineages gave rise to modern bryophytes. The other gave rise to vascular plants.

- Like other plants, bryophytes have a cuticle and embryos that develop within gametangia. However many bryophytes lack vascular tissue for water-conduction and internal support. Like their algal ancestors, bryophytes have flagellated sperm and depend on water for reproduction.



•Vascular plants have xylem and phloem, which transport water and nutrients and provide support. In addition, these plants have embryonic development within gametangia.

•About 350 mya, vascular plants split into two lineages. One of these lineages gave rise to seedless plants and the other gave rise to seed plants.



•Ferns are a modern example of seedless vascular plants. The leaves (fronds) develop from stems that grow along the ground. Ferns are found in shady temperate forests and are most diverse in the tropics.



•Seed plants make up  $\approx 90\%$  of all living plant species. Adaptations responsible for the success of this group include seeds, which provide the embryonic plant with a protective coating and a food supply. These plants also produce pollen, a vehicle that transfers nonflagellated sperm to the female parts of plants.

•The earliest seed plants to appear were the **gymnosperms** (naked seed). The name of these plants is based on their seeds not being contained within a fruit. Gymnosperms along with seedless plants, were dominant for over 200 million years. The largest living group of gymnosperms is the conifers.

Artist's conception of a Carboniferous forest based on fossil evidence



•Flowering plants (**angiosperms**) evolved from the seed plant line  $\approx 130\text{mya}$ . Flowers increase the efficiency of pollination and develop into fruits that protect the seeds and increase the efficiency of seed dispersal. The majority of modern plant species are angiosperms.

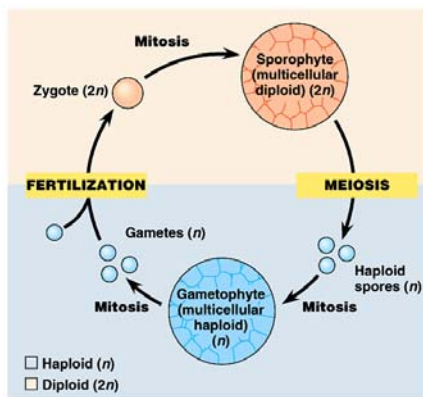


#### Haploid and diploid generations alternate in plant life cycles

•Plant life cycles alternate between multicellular, diploid ( $2n$ ), and haploid ( $1n$ ) adults, unlike animals that are diploid as adults and produce single-celled haploid gametes.

•**Sporophytes** grow from diploid zygotes and produce spores by meiosis.

•**Gametophytes** grow from haploid spores and produce gametes by mitosis.



•Alternation of generation provides two chances to produce large numbers of offspring, zygotes, and spores.

•Major changes from the algal life cycle that occur during the evolution of plants are the change in dominance from the gametophyte to the sporophyte, the change in dependency of sporophytes on gametophytes to the opposite dependency, and the loss of flagellated sperm.

#### Mosses have a dominant gametophyte

•The green growth we see consists mostly of gametophytes.

**Note:** Adult gametophytes consist of nonvascular stems and leaves and threadlike holdfasts. For water and minerals, they depend on rain or on water flowing along the stem from the ground surface.

•Gametophytes produce sperm and eggs in gametangia.

•Flagellated sperm require a film of water in which to swim from male gametangium to female gametangium.

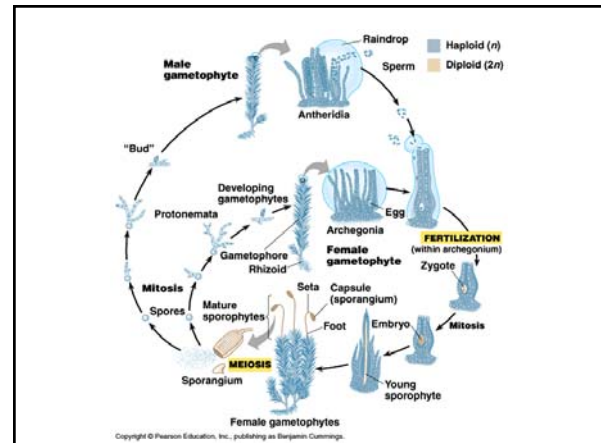
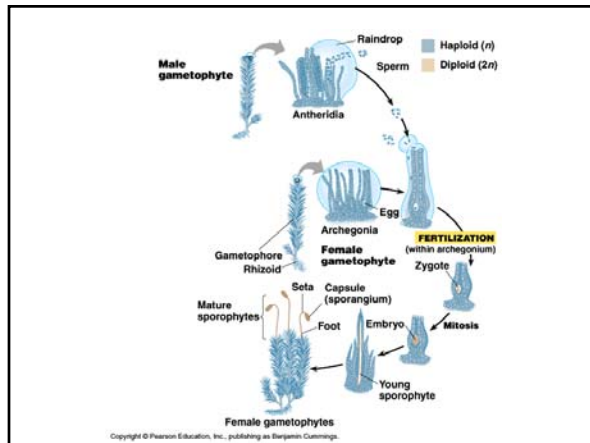
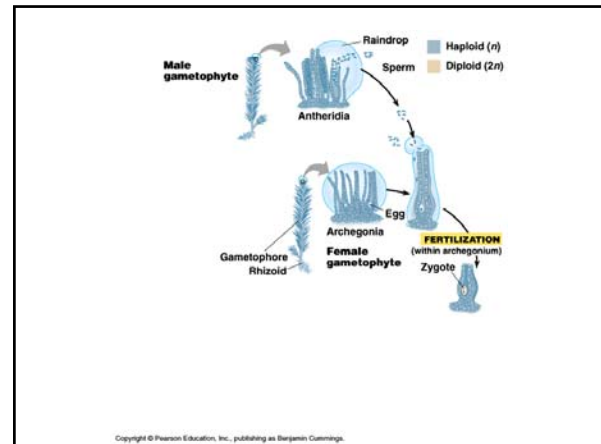
•The zygote remains in the female gametangium and develops into the sporophyte.

•Meiosis occurs in the sporangium and produces spores.

•Spores are released and later develop into gametophytes by mitosis.



**Note:** Adult sporophytes lose their chlorophyll and become more dependent on the female gametophytes. The sporangia are adapted to dispersing spores by means of movable teeth around the sporangium opening, on wet/dry cycles.



### Ferns, like most plants, have a dominant sporophyte

- The fern fronds (leaves) we see are sporophytes.

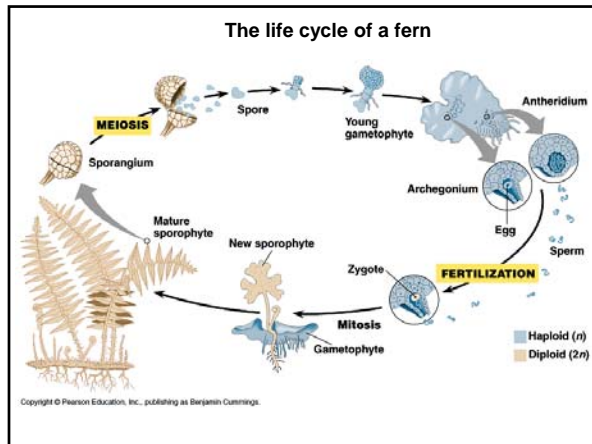
**Note:** Ferns have underground stems with small roots, and all parts are vascularized. The fronds are the principal organs of photosynthesis.

- Gametophytes produce flagellated sperm and eggs (like mosses).

- Like mosses, fern zygotes remain in the female gametangium and develop into adult sporophytes. Eventually the sporophytes take over.

- Sporangia in clusters on the frond's underside produce haploid spores by meiosis.

**NOTE:** Fern sporangia have a unique mechanism to release their spores. As the sporangia dry out, thick-walled cells along the "back" of the sporangium pull the thin-walled "front" cells into tension. In a fraction of a second, the front cells rupture, scattering the spores into the air.



- Spores are dispersed by wind and grow into small, heart-shaped gametophytes by mitosis.

- Today, about 95% of all plants have a dominant sporophyte generation.

#### Seedless plants formed vast “coal forests”

- During the carboniferous period ( $\approx 285\text{--}360\text{mya}$ ), vast forests grew in tropical, swampy, areas over what is now Eurasia and North America.
- The forests included dominant lycopods, horsetails (both seedless plants more primitive than ferns), and tree ferns.
- The compressed remains of these forests survive as deposits of coal and other fossil fuels.

- At the end of the Carboniferous period, the climate turned colder and drier, providing the conditions for further plant evolution. The evolution of pollen was key to the adaptation of seed plants to dry land.

- The most successful of early seed plants were the gymnosperms. They grew alongside seedless plants in Carboniferous swamps. Conifers survived the drying of these swamps and remain the dominant type of gymnosperm.

- Gymnosperms had a wide distribution for  $\approx 250$  million years. Conifers are the most successful of several groups of gymnosperms because they are adapted to harsh winter climates. They readily shed snow, their needles resist drying, and since they do not shed their leaves they are able to start photosynthesizing as soon as the growing season begins.

#### A pine tree is a sporophyte with tiny gametophytes in its cones

- Cones are a significant adaptation to land, protecting all reproductive structures: sporangia, microscopic gametophytes, and zygotes.

- Female cones are larger. Scales bear a pair of ovules (sporangia with a covering, or integument). Within the ovule, one of the four products of meiosis develop into a tiny, multicellular, “female” gametophyte.

- Male cones are smaller, and scales bear many sporangia that make spores by meiosis. Spores develop into tiny male gametophytes (pollen grains), each consisting of a few cells. Pollen grains house the cells that will develop into sperm.

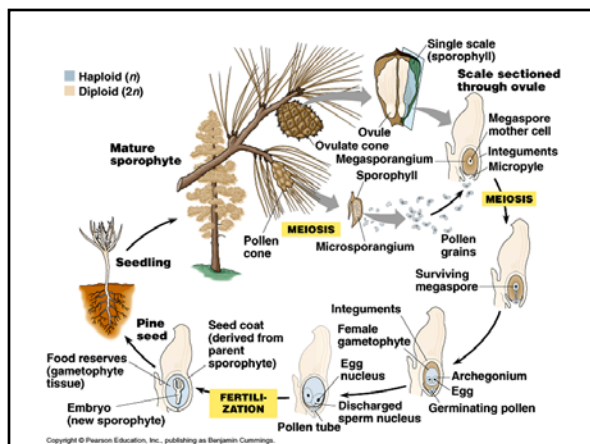
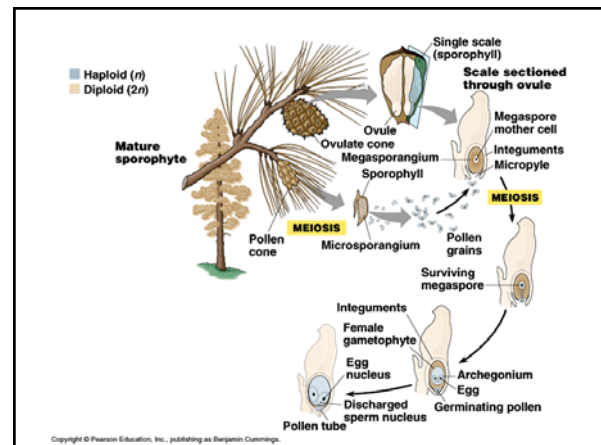
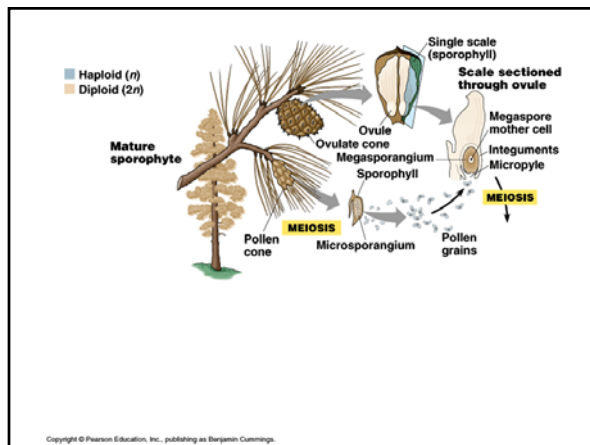
•Pollen is dispersed by wind. Pollination occurs when a pollen grain lands near an ovule and grows into it.

•Meiosis occurs in the ovule where a haploid spore cell begins to develop into the female gametophyte. Months later, a few of the female gametophyte's cells inside the ovule function as eggs. The pollen tube delivers a male gametophyte's nucleus (functioning as a nonflagellated sperm) to fertilize an egg.

•The zygote develops into the embryonic sporophyte, and the remaining ovule develops into the other parts of the seed (the integument becomes the seed coat, and the female gametophyte becomes a food supply).

•Seed dispersal by wind or animal.

•Under favorable conditions, the seed germinates and the embryo grows into a tree.



### Angiosperms dominate most landscapes

•Although coniferous forests dominate northern areas, flowering plants dominate most other land areas. About 80% of plant species are angiosperms.

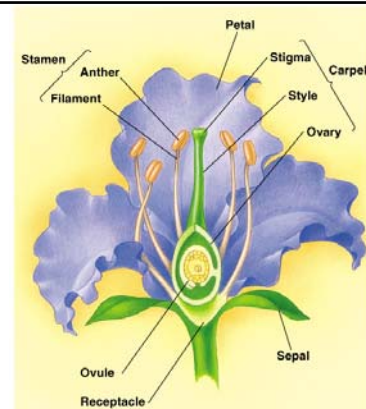
•Angiosperms supply nearly all our food and much of our natural fibers.

•Several adaptations account for the success of the angiosperms: flat, efficiently photosynthetic leaves; vascular tissue with thicker, stronger cell walls; and flowers and fruits.

### The flower is the centerpiece of angiosperm reproduction

•Flowers expose an angiosperm's sexual parts and are the sites of pollination and fertilization.

•Flowers are short stems with the following modified leaves: **sepals**, to protect flower buds; **petals**, to attract animal pollinators; **stamens**, the male parts (holding the anthers in which pollen develops); and **carpels**, the female parts (consisting of sticky stigma to trap pollen, and the ovary, which bears ovules and later develop into fruit).



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

### The angiosperm plant is a sporophyte with gametophytes in its flowers

•Flowers protect all microscopic reproductive structures: sporangia, male and female gametophytes, and zygotes.

•Meiosis in the anthers lead to haploid spores that undergo mitosis and develop into the male gametophytes (pollen grains).

•Meiosis in the ovules leads to haploid spores that undergo mitosis and develop into the female gametophytes, each which produces an egg, inside the ovules.

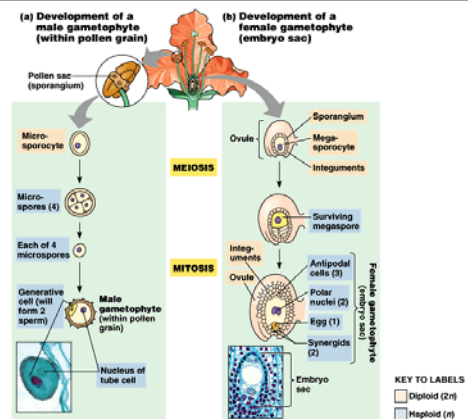
•Pollen is dispersed by either wind or insects. Pollination occurs when a pollen grain lands on the stigma.

•The pollen grows into the ovary and delivers one nucleus (again functioning as a nonflagellated sperm) to the egg nucleus in the ovule. Fertilization usually occurs within 12 hours after pollination.

•Following fertilization, the zygote develops into the embryonic sporophyte in the seed, and the ovary develops into the fruit.

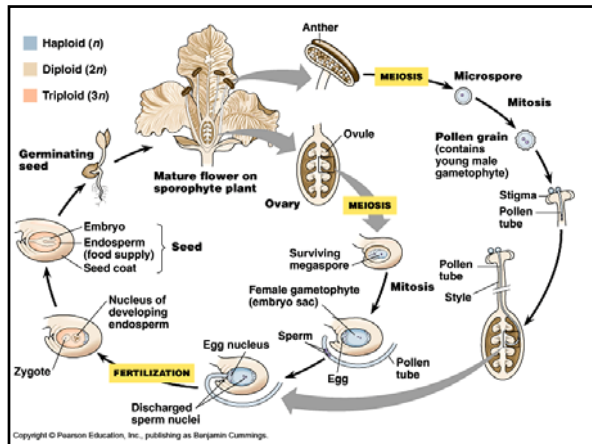
•Seed dispersal is also by wind or animal and is aided by enveloping fruit.

•Under favorable conditions, the seed germinates and the embryo develops into a mature sporophyte.



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





### The structure of a fruit reflects its function in seed dispersal

- Fruits develop from ovaries and ripen quickly, within one growing season.
- Some fruits are adapted for wind dispersal of seeds.
- Others are adapted to hitch a ride on animals.
- Fleshy, edible fruits are attractive to animals as food. Seeds of these fruits usually pass unharmed through the animal's digestive tract and are deposited, with fertilizer, far from the parent plant.

Table 30.1 Classification of Fleshy Fruits

Type of Fruit	Floral Origin	Example
Simple	Single ovary of one flower	Cherry
Aggregate	Many ovaries of one flower	Raspberry
Multiple	Many ovaries of many clustered flowers	Pineapple

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

### Interactions with animals have profoundly influenced angiosperm evolution

- Most flowering plants depend on insects, birds, or mammals for pollination and seed dispersal.
- Most land animals depend on flowering plants for food.
- Pollen and nectar provide food for pollinators. Bees are one of the most highly coevolved groups of pollinators.

•Flowers that are pollinated by birds are usually pink or red.

•Flowers that are pollinated at night by bats or moths are usually large and light-colored.

•These mutual dependencies have been favored by natural selection.

Flower-pollinator relationships: Scottish broom flower and honeybee (left), hummingbird (top right), baobab tree and bat (bottom right)

