20.1 Origins of Plant Life

VOCABULARY

plant
cuticle
stomata
vascular system
lignin
pollen grain
seed

KEY CONCEPT **Plant life began in the water and became adapted to land.**

MAIN IDEAS

1. Land plants evolved from green algae.
2. Plants have adaptations that allow them to live on land.
3. Plants evolve with other organisms in their environment.

Connect to Your World

The flowering proteas shown on the previous page are not just plants with beautiful flowers. Various birds, rodents, and insects rely on protea nectar and pollen as food sources. Green protea beetles even live inside of protea flowers. Without plants, animal life as we know it would not exist on land.

MAIN IDEA

Land plants evolved from green algae.

All green algae share certain characteristics with plants. **Plants** are multicellular eukaryotes, most of which produce their own food through photosynthesis and have adapted to life on land. Like plants, green algae are photosynthetic eukaryotes. They have chlorophyll that captures energy from sunlight during photosynthesis. Chlorophyll is what makes these algae—and most of the plants that we are familiar with—green. Green algae and plants have the same types of chlorophyll. Another feature both green algae and plants share is that they use starch as a storage product. Most green algae also have cell walls that contain cellulose, a complex carbohydrate that is found in the cell walls of all plants.

Evidence from genetic analysis points to one ancient species of green algae that is the common ancestor of all plants. If it were alive today, this species would be classified as a member of the class Charophyceae, like the algae in **FIGURE 1.1.** Several other important plant characteristics likely originated in charophyceans.

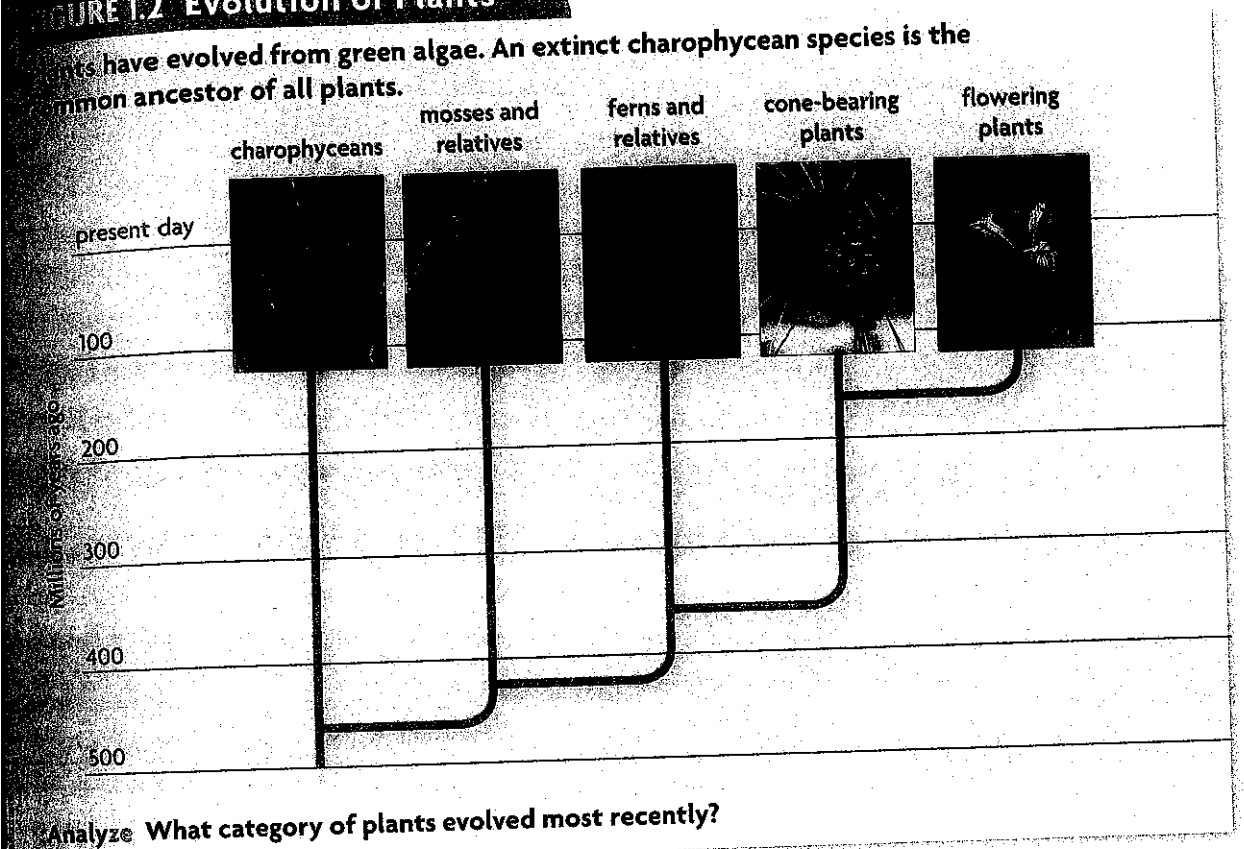
- A multicellular body, which led to the specialization of cells and tissues
- A method of cell division that produces cells with small channels in their walls, which allows cells to communicate with each other chemically
- Reproduction that involves sperm traveling to and fertilizing an egg cell

Today, charophyceans are common in freshwater habitats. Scientists hypothesize that the ancestral charophycean species may have grown in areas of shallow water that dried out from time to time. Natural selection likely favored individuals that could withstand longer dry periods. Eventually, the first true plant species evolved, as shown in **FIGURE 1.2.** True plants have multicellular embryos that remain attached to the female parent as they develop.

FIGURE 1.1 Multicellular green algae of the genus *Chara* can be found in many lakes and ponds. They are called charophyceans, and are thought to be the closest living relatives of the common ancestor of all plants.

URE 1.2 Evolution of Plants

nts have evolved from green algae. An extinct charophycean species is the mmon ancestor of all plants.



Analyze What category of plants evolved most recently?

The earliest plant fossils date to more than 450 million years ago. The first true plants probably grew on the edges of lakes and streams. Like modern-day mosses, they relied on droplets of water that brought sperm to eggs to produce the next generation of plants. They also had a fairly simple structure similar to that of moss, keeping low to the ground to retain moisture. Over time, the descendants of these plants were able to live in even drier areas.

Apply What evidence suggests that green algae are close relatives of land plants?

CONNECT TO

ALGAE

Recall from **Protists and Fungi** that algae are plantlike protists. Photosynthetic pigments give various types of algae their distinct colors.

MAIN IDEA

Plants have adaptations that allow them to live on land.

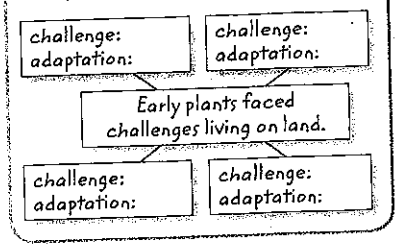
Life on land presents different challenges than does life in the water. Unlike land plants, algae are constantly surrounded by water, which is needed for photosynthesis. The buoyancy of water supports the weight of most algae. For algae, water provides a medium through which sperm and spores can travel, allowing for reproduction and dispersal. Finally, water prevents sperm, eggs, and developing offspring from drying out.

The challenges of living on drier land have acted as selective pressures for plant life on Earth. In turn, many land plants have evolved adaptations that allow them to retain moisture, transport water and other resources between plant parts, grow upright, and reproduce without free-standing water.

READING TOOLBOX

TAKING NOTES

Use a main idea web to take notes about the challenges of life on land and plants' adaptations to these challenges.



Retaining Moisture

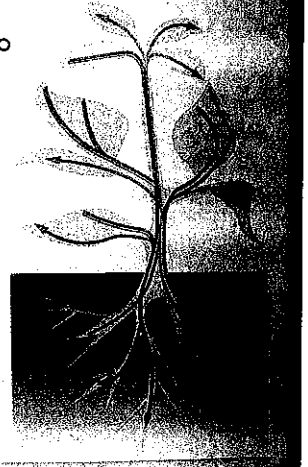
Plants will die if they dry out from exposure to air and sunlight. The surfaces of plants are covered with a cuticle. A **cuticle** is a waxy, waterproof layer that helps hold in moisture. As **FIGURE 1.3** shows, there are tiny holes in the cuticle called **stomata** (singular, *stoma*). Special cells allow stomata to close to prevent water loss, or to open to allow air to move in and out. Without stomata, the movement of air would be prevented by the cuticle.

Transporting Resources

Taller plants often have more access to sunlight than do shorter plants, but growing tall presents another challenge. While plants must get sunlight and carbon dioxide from the air, they must also get water and nutrients from the soil. A structure for moving these resources to different parts of the plant evolved in the form of a vascular system. A **vascular system** is a collection of specialized tissues that bring water and mineral nutrients up from the roots and disperse sugars down from the leaves. A vascular system allows a plant to grow higher off the ground.

VISUAL VOCAB

A vascular system allows water, mineral nutrients, and sugars to be transported to various parts of a plant.



Growing Upright

Plant height is also limited by the ability of a plant to support its own weight. Plants need structure to support their weight and provide space for vascular tissues. This support comes from a material called **lignin** (LIHG-nihn), which hardens the cell walls of some vascular tissues. Lignin is also responsible for the strength of wood and provides stiffness to the stems of other plants. As a result, plants can retain their upright structure as they grow toward the sun.

Reproducing on Land

In all plants, eggs are fertilized within the tissue of the parent plant. There, the fertilized egg develops into an embryo, the earliest stage of growth and development for a plant. Some plants reproduce with the help of rainwater or dew, while others do not need free-standing water to reproduce. Pollen and seeds are adaptations that allow seed plants to reproduce completely free of water.

A **pollen grain** is a two-celled structure that contains a cell that will divide to form sperm. Pollen can be carried by wind or animals to female reproductive structures. A **seed** is a storage device for a plant embryo. A seed has a tough coat that protects the embryo from drying wind and sunlight. Once a seed encounters the right conditions, the embryo can develop into an adult plant.

Analyze **Discuss why the four challenges on this page do not apply to most algae.**

CONNECT TO

HUMAN BIOLOGY

A plant's vascular system is similar in function to a human's circulatory system. You will learn more about the human circulatory system in **Respiratory and Circulatory Systems**.

FIGURE 1 Adaptations of Land Plants

Land plants have evolved to adapt to the challenges of life on land.

POLLEN

Pollen can be carried by wind or animals. Each pollen grain contains one cell that will divide to form sperm.

Seeds protect and provide nutrients for developing embryos.

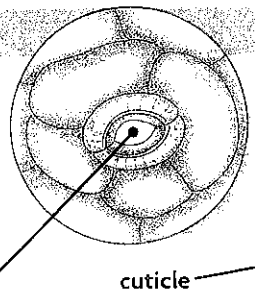
pollen

seeds

STOMATA

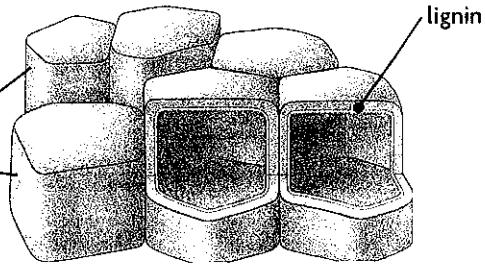
Stomata are small openings in the cuticle that allow for gas exchange between the plant and the atmosphere.

A cuticle is a waxy coating that protects plant leaves from drying out.



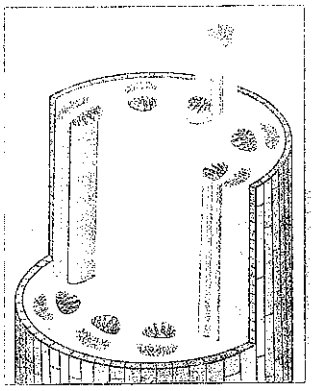
LIGNIN

Tough lignin is found in the cell walls of plant tissues that provide support and conduct fluids.



VASCULAR TISSUE

Vascular tissues form "pipelines" that carry resources up and down to different parts of the plant. A vascular system allows plants to grow higher off the ground.



CRITICAL VIEWING **Why is lignin especially important in the cell walls of vascular tissues?**

MAIN IDEA

Plants evolve with other organisms in their environment.

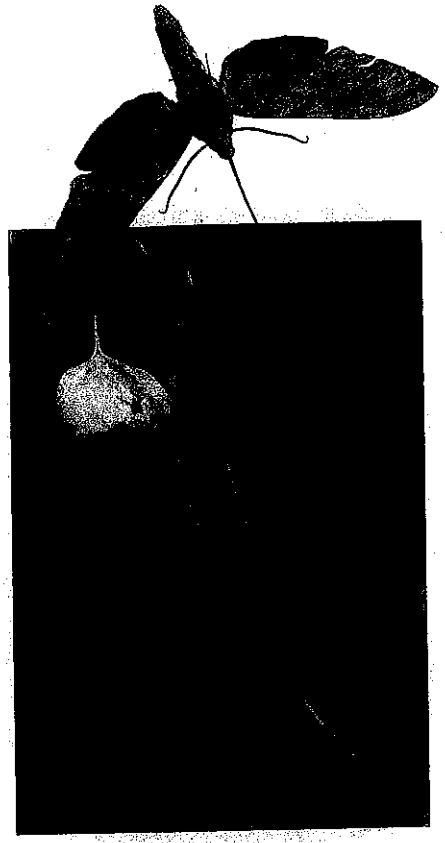


FIGURE 1.4 The hawk moth has a tongue that measures between 30 and 35 cm (12–14 in.). It is the pollinator of a night-blooming orchid whose nectar is produced 30 cm down inside the flower.

Plants have coevolved with other terrestrial organisms for millions of years. Some of these relationships are cooperative, while others have evolved between plant species and the animal species that eat them.

Mutualisms

A mutualism is an interaction between two species in which both species benefit. Some mutualisms exist between plant roots and certain types of fungi and bacteria. Roots provide a habitat for these fungi and bacteria, while the fungi and bacteria help the plant get mineral nutrients from the soil.

Many flowering plants depend on specific animal species for pollination or seed dispersal. In turn, these animals are fed by the plant's pollen, nectar, or fruit. For example, in Madagascar, Darwin noticed a variety of orchids with long, tubular flower parts. He predicted that a nocturnal moth with a tongue 10 to 12 inches long must be the pollinator. That very moth, shown in **FIGURE 1.4**, was discovered 40 years after Darwin's prediction.

Plant-Herbivore Interactions

Plants have a variety of adaptations that discourage animals from eating them. The spines on a cactus and the thorns on a rose stem are examples. Other plants produce defensive chemicals that act as pesticides against plant-eating predators. Natural selection favors herbivores that can overcome the effects of defensive plant adaptations. In turn, natural selection favors plants that produce even sharper spines or thorns or even more toxic chemicals.

Some insects use defensive chemicals produced by plants to their advantage. The larvae of monarch butterflies, for example, feed exclusively on milkweed species. Milkweed plants produce a chemical that makes monarch larvae, adults, and even eggs taste bad to potential predators. In this way, the butterfly has a type of chemical protection as a result of eating milkweed leaves during its development.

Synthesize **Describe how defensive chemicals in plant leaves may have evolved.**

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PREMIUM CONTENT

20.1 Formative Assessment

REVIEWING MAIN IDEAS

1. What characteristics do land **plants** share with green algae?
2. What adaptations allow plants to thrive on dry land?
3. Describe two ways in which plants evolve with other organisms.

CRITICAL THINKING

4. **Synthesize** Describe how a **cuticle** could have evolved through natural selection.
5. **Evaluate** For plants, what are the advantages and disadvantages of growing tall?

CONNECT TO

CLASSIFICATION

6. Some scientists think that certain species of green algae should be in the kingdom Plantae. What reasons might these scientists use to defend their position?

CHAPTER 20 Summary

KEY CONCEPTS

20.1 Origins of Plant Life

Plant life began in the water and became adapted to land. The common ancestor of plants is an ancient species of green algae. Green algae called charophyceans are the closest living relatives to this common ancestor. Over time, the first true plant species evolved as they adapted to life on land. Land plants have evolved mechanisms to retain moisture, transport resources, grow upright, and reproduce on land. They have also coevolved with other organisms that inhabit dry land.

20.2 Classification of Plants

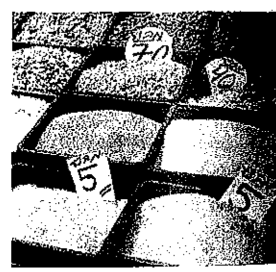
Plants can be classified into nine phyla. Mosses and their relatives make up three phyla of seedless nonvascular plants. These plants rely on water for reproduction and must grow low to the ground to absorb water and nutrients. Club mosses and ferns make up two phyla of seedless vascular plants. Vascular tissue allows these plants to grow higher above the ground. Seed plants, which include three phyla of cone-bearing plants and one phylum of flowering plants, do not rely on water for reproduction. Sperm of seed plants are produced by pollen grains. Seeds nourish and protect the embryos of these plants.

20.3 Diversity of Flowering Plants

The largest phylum in the plant kingdom is the flowering plants. Flowers and fruit are two adaptations that have allowed flowering plants to become the dominant plant group on Earth today. Flowers often allow for more efficient pollination by animals, while fruit can aid in seed dispersal. Botanists classify flowering plants into two groups based on the number of cotyledons inside the seed. Flowering plants can also be categorized based on stem type and lifespan.

20.4 Plants in Human Culture

Humans rely on plants in many ways. Plants are essential to human existence. All of the food that we eat comes either directly or indirectly from plant life. Agriculture provides stable food supplies for most people today. Many agricultural products are important economic resources on a global scale. Plants also provide us with clothing, paper, textiles, lumber, and medicines.

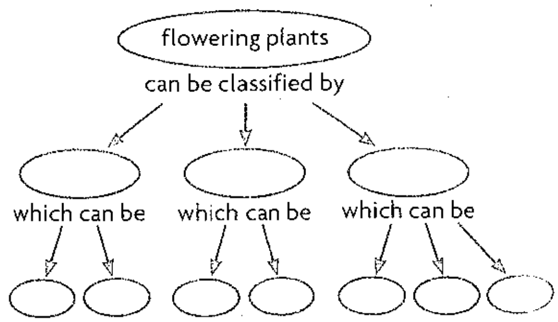


READING TOOLBOX SYNTHESIZE YOUR NOTES

Three-Column Chart Use a three-column chart to take notes about the nine divisions of plants. Use the columns to write the scientific names of each division, the common names, and details about the plants.

Scientific Name	Common Name	Details

Concept Map Use a concept map to review how flowering plants can be classified.



20 Review

CHAPTER VOCABULARY

20.1 plant
cuticle
stomata
vascular system
lignin
pollen grain
seed

20.2 pollination
gymnosperm
angiosperm
cone
flower
fruit

20.3 cotyledon
monocot
dicot
wood

20.4 botany
ethnobotany
pharmacology
alkaloid

Reviewing Vocabulary

Vocabulary Connections

For each group of words below, write a sentence or two to clearly explain how the terms are connected. For example, for the terms *cuticle* and *stomata*, you could write "Together, the cuticle and stomata prevent water loss while allowing for gas exchange."

1. lignin, wood
2. pollen grain, pollination
3. gymnosperm, seed, cone
4. angiosperm, seed, flower, fruit
5. cotyledon, monocot, dicot
6. pharmacology, alkaloid

READING TOOLBOX GREEK AND LATIN WORD ORIGINS

7. *Cuticula* is the Latin word for "skin." How does this meaning relate to the definition of *cuticle*?
8. In Greek, the word *stoma* means "mouth." How does this meaning relate to its botanical meaning?
9. In Latin, the word *pollen* means "dust" or "fine flour." How does this meaning relate to its botanical meaning?
10. *Conus* is a Latin word that means "wedge" or "peak." How does this meaning relate to the definition of *cone*?
11. *Frui* is a Latin verb meaning "to enjoy." How does this meaning relate to the role that various fruits play in human culture?
12. The prefix *mono-* means "one" in Latin, while the prefix *di-* means "two." How do these meanings relate to the words *monocot* and *dicot*?

Reviewing MAIN IDEAS

13. Summarize the evidence supporting the statement that modern plants evolved from an ancient species of green algae.
14. Discuss four major challenges that early plants faced while adapting to life on dry land.
15. The 30-centimeter tongue of the hawk moth is long enough to reach the nectar—and reproductive organs—of the night-blooming orchid. What can be concluded about the evolution of plants from these types of relationships? Explain.
16. Describe the structural features that limit the height of mosses and their relatives.
17. Explain why most seedless vascular plants live in moist environments.
18. What is the main difference between the seeds of cone-bearing plants and the seeds of flowering plants?
19. Summarize two of the adaptations of flowering plants that allow them to flourish in today's world.
20. Describe the system that botanists use to classify flowering plants into two main groups.
21. Compare and contrast annual, biennial, and perennial lifespans.
22. What role does agriculture play in the stability and survival of modern human populations?
23. How can plants play a role in developing modern medicines, even if they are not used as ingredients?