CHAPTER 21

Mosses and Ferns



Rain forests do not occur in tropical areas only. Olympic National Park in Washington State is a temperate rain forest. Bathed by damp Pacific air currents, ferns and tiny mosses (inset) grow well.

Life began in the sea, and for millions of years living things remained in the sea. Yet, slowly, life emerged onto land. On empty ancient continents, new opportunities existed. But new challenges to survive and reproduce awaited as well.

The first land plants were the first multicellular organisms to meet these challenges. To these plants we owe a great debt: Had they not colonized the land, animals would not have been able to follow. In this chapter you will glimpse the struggle of early plants to survive on land—a struggle whose evidence is visible in the form of living plants that remain suspended in a life halfway between water and land.

CHAPTER OUTLINE

21–1 Plants Invade the Land
- The First Land Plants
- Demands of Life on Land

21–2 The Mosses, Liverworts, and Hornworts
- Physical Characteristics of Bryophytes
- Alternation of Generations in Mosses

21–3 The Ferns and the First Vascular Plants
- The First Vascular Plants
- Club Mosses and Horsetails
- Physical Characteristics of Ferns
- Alternation of Generations in Ferns

21–4 Where Mosses and Ferns Fit into the World

21–1 Plants Invade the Land

Section Objective

- Describe some of the adaptations plants need to survive on land.

Because the first multicellular organisms evolved in water, their entire lives were designed around an aquatic environment. All the processes that ensured survival—from photosynthesis to sexual reproduction—took place in water.

But over time, some organisms adapted to life in drier environments. In the following pages you will learn about some living plants and some extinct plants that represent stages in this process of adaptation. These plants illustrate steps in the evolution of structures to acquire, transport, and conserve water. They also demonstrate how land plants evolved reproductive cycles that enable them to survive in terrestrial environments, or land environments.

The First Land Plants

The fossil record does not provide much information about the very earliest stages of the evolution of land plants. Remember that it is the hard parts of organisms, such as shells and bones, that form the best fossils. Because the first land plants were soft-bodied, they have left few fossils. But we do have enough evidence about early plant life on land to say several things with certainty.



Figure 21–1 *Dating from the Carboniferous Period, this fossil fern looks very much like its still-growing relatives. As you can see, these plants have changed little over time.*



Figure 21–2 Ferns can grow in water as well as on land. This fern, Marsilia, *resembles a floating four-leaf clover.*

The adaptation of plants to life on land was a long, slow process. Algae that could live out of water at least part of the time evolved 500 to 600 million years ago. From these plant pioneers, at least two separate groups of algaelike land plants evolved between 450 and 500 million years ago.

One group developed into the phylum Bryophyta (bright-oh-FIGHT-uh), which includes mosses, liverworts, and hornworts. The other group evolved into the phylum Tracheophyta (tray-kee-oh-FIGHT-uh), which includes the ferns and the rest of the higher plants. Both the bryophytes and the tracheophytes faced the same set of problems in adapting to terrestrial environments, but each group evolved its own set of solutions.

Demands of Life on Land

The adaptations that enabled aquatic organisms to survive in dry environments were not simple. To understand how important these adaptations were, let us examine some of the requirements of life on land.

- All cells need a constant supply of water. For this reason, land plants must obtain water and deliver it to all of their cells, even those cells that grow above ground in dry air. Once plants provide water to their tissues, they must protect that water against loss by evaporation to the atmosphere.
- The parts of the plant that make food for the plant must be exposed to as much sunlight as possible. Aquatic plants that float on the surface of the water have no problem obtaining



Figure 21–3 Mosses grow well in the shade of trees, as this carpet of mosses on the floor of a pine forest illustrates. You can be certain that the ground beneath the pines remains relatively damp, for mosses grow best under damp conditions.

sunlight because there is little water above them to interfere with the absorption of the sun's energy. Land plants, however, need rigid supports to hold their leaves up to the sun in ways that expose the leaves to sunlight.

- Land plants take up water and nutrients in roots but make food in leaves. To supply all cells with the necessities of life, land plants must transport water and nutrients upward and the products of photosynthesis downward.
- Land plants must exchange water and carbon dioxide with the environment without losing too much water in the process.
- Fully terrestrial plants must be able to reproduce in environments that lack standing water in which the sperm can swim. In many terrestrial situations, the zygotes and young embryos of land plants are in danger of drying out.

The bryophytes have partially solved these problems. Bryophytes no longer need to be constantly submerged in water, but they do need to remain wet most of the time. The simplest tracheophytes—the ferns—have evolved further toward complete independence from water. But as you will see, ferns still have not solved all the problems posed by a terrestrial life.

21-1 SECTION REVIEW

1. What are two of the problems faced by plants that live on land?
2. What are the names of the two main phyla of land plants? Give examples of each.
3. Your friend finds a small plant growing in the desert. He identifies the plant as a moss. Explain why this plant is probably not a moss.

21-2 The Mosses, Liverworts, and Hornworts

Section Objectives

- Identify the characteristics of the three main groups of bryophytes.
- Describe some adaptations shown by bryophytes that enable them to survive on land.
- Identify patterns of reproduction in bryophytes.

The phylum Bryophyta includes the mosses, liverworts, and hornworts. **Bryophytes, like the algae from which they evolved, have life cycles that involve an alternation of generations between a haploid gametophyte and a diploid sporophyte. Also like the algae, bryophytes need water for reproduction to occur.** Thus bryophytes can thrive only in wet areas, or in areas where rainfall is plentiful at least part of the year. Bryophytes grow most abundantly in swamps, marshes, near streams, and in rain forests in tropical areas and along the western coast of the United States.





Figure 21–4 *The tiny brown structures on the tip of these moss plants (left) are the sporophyte plants. When the spores are ripe, they are shed from the brown capsules like pepper from a shaker. Looking much like fallen leaves, these liverworts (right) have raised what appear like little green umbrellas. These structures produce gametes.*

Bryophytes vary in appearance. Some look like miniature evergreen trees; others, like the softest green carpet; still others, like leaves of a higher plant lying on the ground. Regardless of variations in appearance, almost all bryophytes are less than a few centimeters tall.

The moss plants you might observe on a walk through the woods are actually clumps of haploid moss gametophytes growing close together. Each moss plant has a thin upright shoot that looks like a stem with tiny leaves. Because the plant does not have tubes that conduct water and other substances, however, these are not true leaves and stems. From the base of the shoot grow a number of thin branches called **rhizoids** that penetrate into the ground and act like roots to securely anchor the plant.

The odd little plants called liverworts are bryophytes too. These plants are scarcer than mosses and need to live in places that remain wet constantly. Liverwort gametophytes look like flat green leaves growing along the ground. When these plants mature, the gametophytes produce structures that look like tiny green umbrellas. These "umbrellas" carry the structures that produce eggs and sperm.

The gametophytes of hornworts look very much like the gametophytes of liverworts. The hornwort sporophyte, however, differs from the liverwort sporophyte. Instead of looking like a tiny umbrella, the hornwort sporophyte looks like a tiny horn, which is why this plant received its common name.

Physical Characteristics of Bryophytes

Bryophytes are well-adapted to life in wet habitats, where they often grow much better than do the higher plants that you will learn about in the next chapter. But outside of wet habitats,

bryophytes do not usually grow well because they lack several critical adaptations to life in dry places.

Bryophytes lack the water-conducting tubes that are found in higher plants. In bryophytes, water passes from cell to cell by osmosis and by means of surface tension around the stems. These methods of transporting water work well over short distances only. This is one reason bryophytes never grow tall.

Bryophytes lack a protective surface covering to keep water from evaporating from their cells. Because their "leaves" are only one cell thick, the plants lose the water they contain very quickly if the surrounding air is dry.

Bryophytes lack true roots. True roots contain water-conducting tubes that enable a plant to absorb and transport water efficiently. Instead of roots, bryophytes have rhizoids that anchor them in the ground. Rhizoids, however, do not play a major role in the absorption and transport of water and minerals.

Bryophytes have sperm cells that must swim through water to fertilize the eggs. The sperm cells use their flagella to propel themselves. For this reason, bryophytes must live in areas that are wet for at least part of the year. Some bryophytes can survive dry periods, but to do so they must stop growing.

Alternation of Generations in Mosses

The life cycle of the moss *Mnium*, a typical bryophyte, is shown in Figure 21-6 on page 454. At the tips of the gametophytes are reproductive structures similar to those of several species of algae. One structure, the **antheridium** (an-ther-IHD-ee-uhm), produces tiny flagellated sperm cells. Another structure, the **archegonium** (ahr-kuh-GOH-nee-uhm), produces eggs. Unlike the reproductive structures of algae, the reproductive structures of mosses are designed to protect the gametes from drying out. Thus the eggs of mosses have a better chance of surviving during dry conditions.

Some species of mosses have both male and female reproductive organs on one gametophyte; other species have male and female reproductive structures on separate gametophytes. Mosses can reproduce sexually only when standing water is present. Sperm can swim to the archegonium only when the gametophytes are covered with rainwater or dew. When a sperm swims to an egg, syngamy (the fusing of gametes) occurs and a diploid zygote is produced.

When the zygote germinates, or begins to grow, it produces a diploid sporophyte. As it grows, the sporophyte is supplied with water and nutrients by the gametophyte. Moss sporophytes cannot live independent of the gametophyte from which they grow. This is one way in which bryophytes differ from all other land plants. The mature sporophyte is composed of a "foot" that remains stuck in the gametophyte—a long stalk—and a capsule that looks like a salt shaker. Inside the capsule,

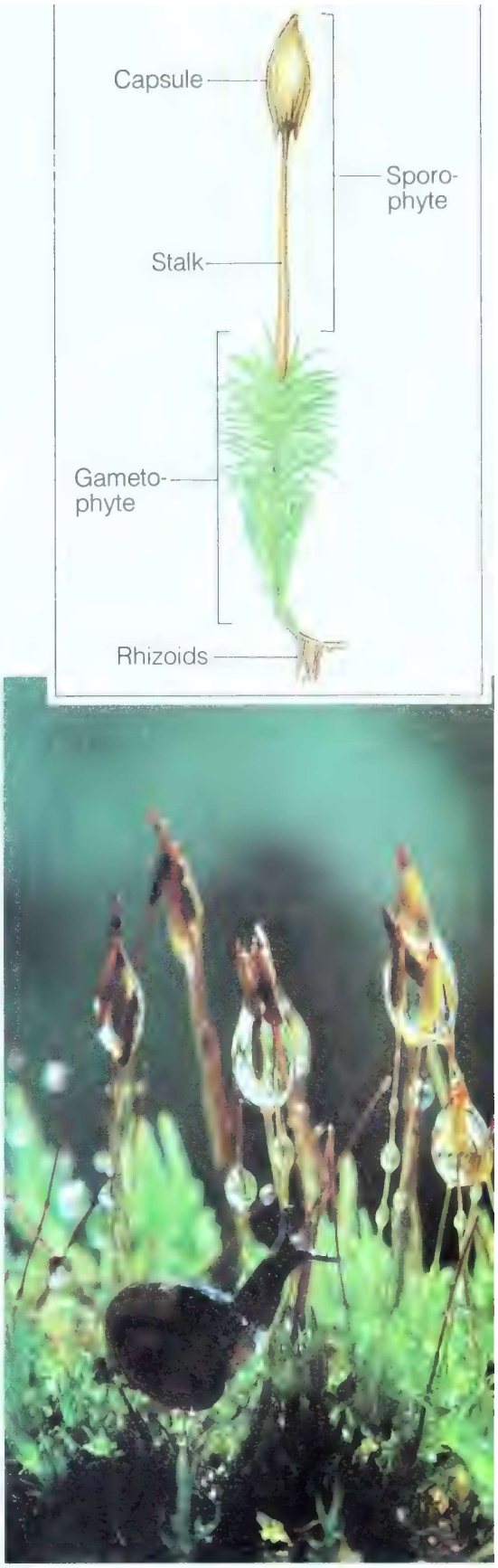


Figure 21–5 *This illustration (top) shows the parts of a typical moss plant. How many of these parts can you locate in the photograph?*

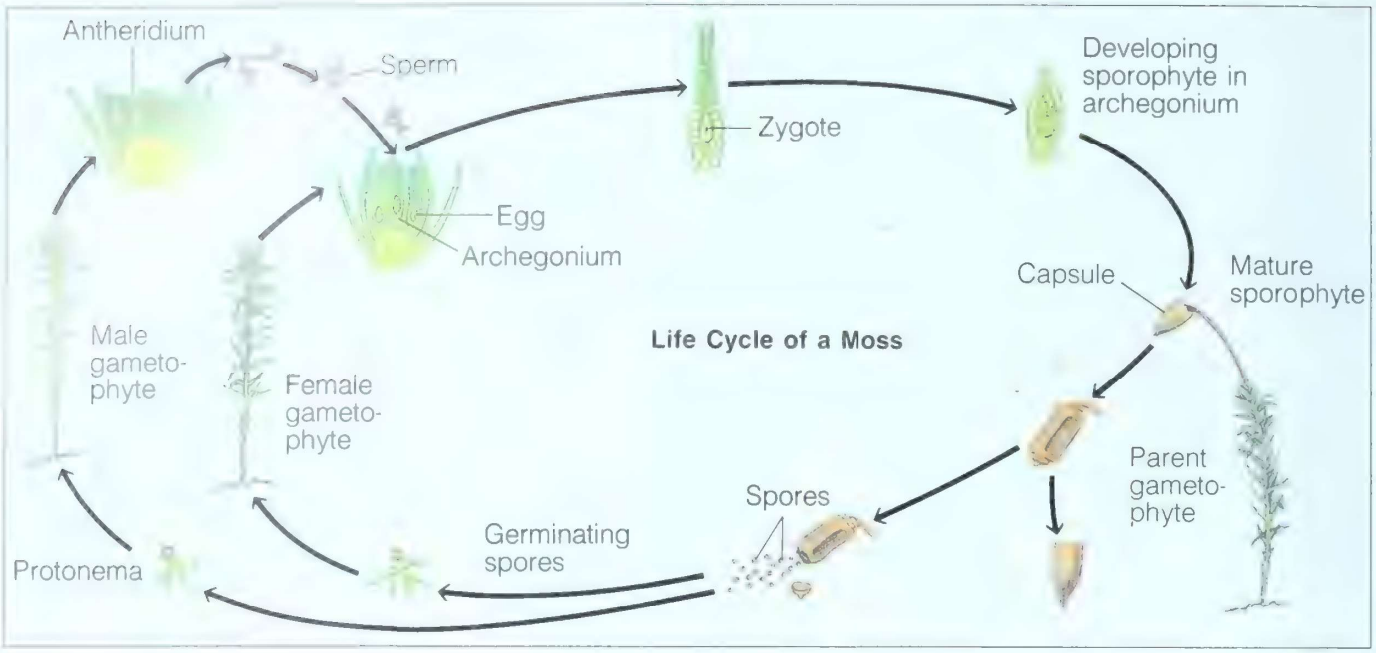


Figure 21–6 *Moss plants are usually short and grow close to the ground. These tiny plants need a supply of standing water in order for sperm to swim to and fertilize an egg.*

haploid spores are produced by meiosis. When the capsule ripens, special pores—and in some cases the whole top of the capsule—open. The spores are shaken out, to be carried off by wind and water.

If a spore lands in a moist place, it germinates and grows into a mass of tangled green filaments called a **protonema**. Moss protonemas look remarkably like filamentous green algae. (This resemblance is evidence that mosses evolved from either ancient green algae or from an ancestor common to both mosses and algae.) As the protonema grows, it forms rhizoids that grow into the ground and shoots that grow into the air. These shoots develop into the familiar moss gametophytes, and the cycle continues.

We can summarize the life cycle of mosses as follows:

1. The haploid gametophyte is the dominant, obvious stage. It is in fact the stage commonly thought of as a moss plant.
2. Standing water is needed for sperm to swim to and fertilize eggs.
3. The diploid sporophyte is small and can grow only with nourishment provided by the gametophyte.

21-2 SECTION REVIEW

1. List the characteristics of the three main groups of bryophytes.
2. What are two adaptations that enable bryophytes to survive on land?
3. What is an archegonium? An antheridium? Why are these structures important in the life cycle of a moss?

21–3 The Ferns and the First Vascular Plants

Section Objectives

- Recognize the importance of vascular tissue to land plants.
- Identify characteristics of club mosses and horsetails.
- Discuss ways in which ferns resemble other land plants.
- Describe alternation of generations in ferns.

Remember that although bryophytes live on land, they depend upon an abundant supply of water to survive. **The members of the phylum Tracheophyta are "true" land plants because they have evolved ways of freeing themselves from dependence on wet environments.**

Among the most important adaptations of tracheophytes are specialized tissues called **vascular tissues**. Vascular tissues transport water and the products of photosynthesis throughout the plant. There are two types of vascular tissue: **xylem** and **phloem**. Xylem tissue is associated with the movement of water from the roots to all parts of the plant. Phloem tissue is responsible for the transport of nutrients and the products of photosynthesis.

One important type of cell present in vascular tissue is the **tracheid**. Tracheid cells carry water from roots in the soil to leaves in the air. Thus they are the most important type of cells in xylem tissue. Tracheid cells have thick, strong cell walls that strengthen stems and help plants stand up against the pull of gravity. All plants in the phylum Tracheophyta have tracheids; in fact, the phylum is named after this type of cell.

The other kind of vascular tissue, phloem tissue, carries important nutrients and the products of photosynthesis from place to place within a plant. Both xylem and phloem tissue will be discussed in more detail in Chapters 22 and 23.

With the development of vascular tissue, tracheophytes have evolved true roots and true leaves. True roots have vascular tissues gathered in a central area of the root that is called the **vascular cylinder**. True leaves are photosynthetic organs



Figure 21–7 *Ferns are able to grow much taller than mosses because they have an internal system of water-conducting tubes. This tree fern is growing in a rain forest in New Caledonia. Although tree ferns were once widespread, today they are limited to the tropical areas on Earth.*

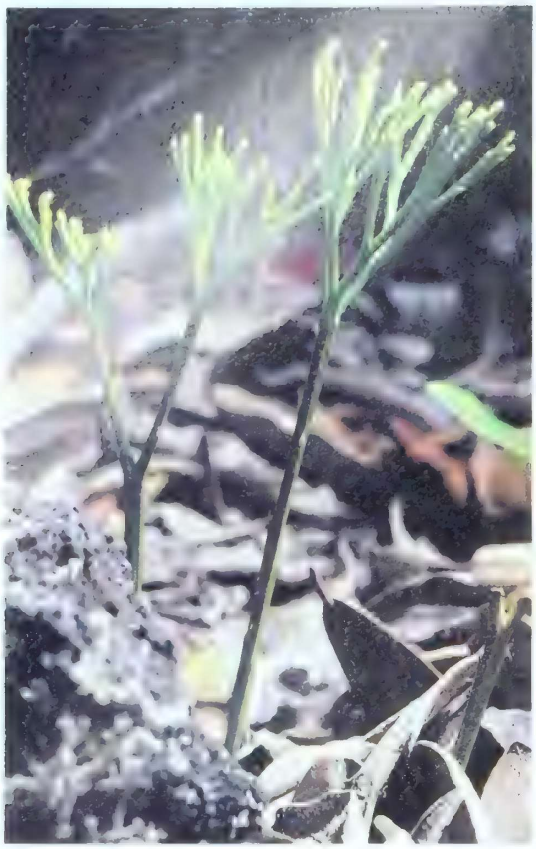


Figure 21–8 *The* Psilotum *plant is commonly called the whisk fern. Scientists believe that the first true land plants resembled this organism.*

that contain one or more bundles of vascular tissue gathered into **veins**. The leaves of tracheophytes usually have a waxy covering called a **cuticle** that helps prevent water loss by evaporation. These structures will also be discussed in more detail in Chapters 22 and 23. But it is important that you have an understanding of these terms as we begin a discussion of early vascular plants.

The First Vascular Plants

Fossils of psilophytes, the first vascular plants, were first found early in this century. These small creeping plants had primitive xylem and phloem tissues, but they lacked true roots and true leaves. Although most botanists think the psilophytes are extinct, some believe that two species of living plants (classified as ferns) are actually living psilophytes. At present, neither group of botanists can prove conclusively that they are correct. But both groups wonder why no psilophyte fossils more recent than the Devonian Period (400 million years ago) have been found.

Club Mosses and Horsetails

The club mosses (lycophytes) and horsetails (sphenophytes) alive today are the only living descendants of large and ancient groups of land plants. The first of these primitive tracheophytes appeared more than 400 million years ago. Over the next 100 to 200 million years, many more species evolved. Some ancient lycophytes and sphenophytes grew into huge trees—up to 40 meters tall. The Earth's very first forests were made up of vast numbers of these plants. At one point in the Earth's history, the entire area of what is now Pennsylvania was covered with a dense tropical jungle of these plants. It is the fossilized remains of these primitive tracheophytes that were transformed into Pennsylvania's huge beds of coal.

Over time, however, the climate of the Earth changed. (Pennsylvania does not have a tropical climate today!) For some reason, these primitive plants could not compete with new types of plants that evolved with the changing climate. Forests of lycophytes and sphenophytes were replaced by forests of entirely new plants. The few species of lycophytes and sphenophytes alive today are relatively small plants that live in moist woodlands and near stream beds and marshes.

Lycopodium (ligh-koh-POH-dee-uhm), the common club moss, looks like a miniature pine tree about 9 centimeters tall. Another common name for *Lycopodium* is "ground pine." *Lycopodium* has small scalelike leaves that cling to the stems.

The only living genus of sphenophytes is *Equisetum* (ehk-wih-SEET-uhm), a plant that grows about 1 meter tall. *Equisetum* is commonly called horsetail or scouring rush because its stems contain crystals of silica, which are quite abrasive. During Colonial times, horsetails were commonly used to scrape,



Figure 21–9 *This* Lycopodium *plant (left), which resembles a small evergreen tree, is better known by its common name ground pine. It is often used as a holiday decoration. Horsetails (right) incorporate silica, the main component of sand, in their stems. Silica gives the stems a rough texture, which is why these plants were once used as a scouring material for cleaning pots and pans.*

or scour, pots and pans. If you should some day set up camp near some *Equisetum*, you will know you can use this plant to clean your pots and pans. Like the lycophytes, horsetails have true leaves, stems, and roots. The leaves of horsetails are arranged in whorls at joints along the stems.

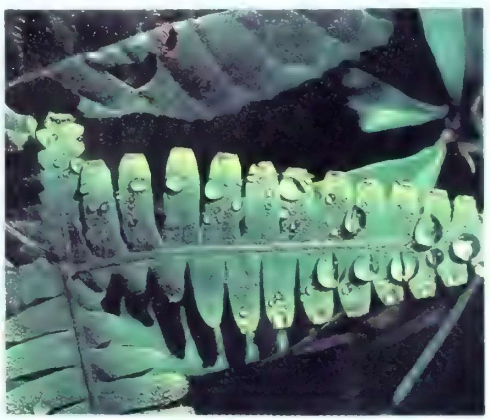
Physical Characteristics of Ferns

Ferns probably evolved about 400 million years ago, at about the same time as the lycophytes and sphenophytes. Ferns were an important part of the lycophyte forests that covered the ancient Earth. Ferns, however, have been more successful at competing with other plants that have appeared during the Earth's long history. Today more than 11,000 species of ferns are still alive!

In many respects, ferns are well-developed tracheophytes. They have true vascular tissues, strong roots, creeping or underground stems called **rhizomes**, and large leaves called **fronds**. Ferns that commonly grow in the United States range in height from a few centimeters to about one meter.

Ferns are most abundant in wet, or at least seasonally wet, habitats around the world. Ferns grow throughout the United States, but they grow best in the rain forests of the Pacific Northwest, and in wet tropical areas. In tropical forests, some species of ferns grow as large as small trees.

Figure 21–10 *The leaves of ferns are covered by a waxy coating that prevents water loss. The waxy coating also causes drops of water to bead up on the leaf surface, much like wax on a car causes water to form beads.*

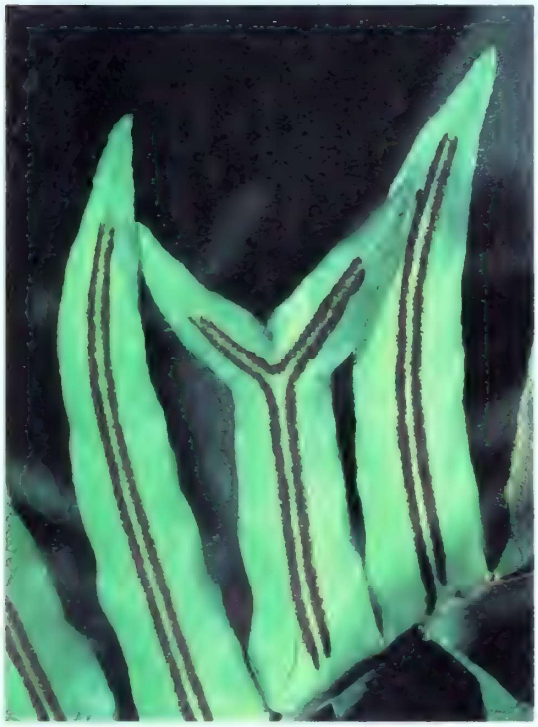


Alternation of Generations in Ferns

Like the life cycles of all other plants, those of ferns involve alternation of generations. The plants that are recognizable as ferns are the diploid sporophytes. Because of their well-developed vascular tissues, these sporophytes can grow in drier places than can bryophyte sporophytes. But sexual reproduction in ferns still depends upon the presence of standing water for sperm to swim to eggs.

Fern sporophytes produce haploid spores on the underside of their fronds. Spores are produced in tiny containers called **sporangia**. Sporangia do not occur individually but are grouped into large clusters called **sori** (singular: sorus).

Figure 21–11 Clusters of sporangia form on the underside of fern leaves. As you can see, sporangia can form many varied, beautiful patterns.

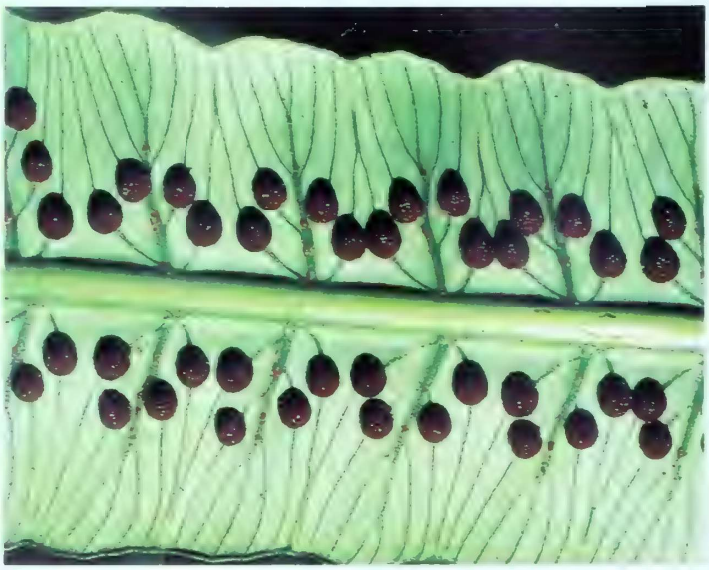


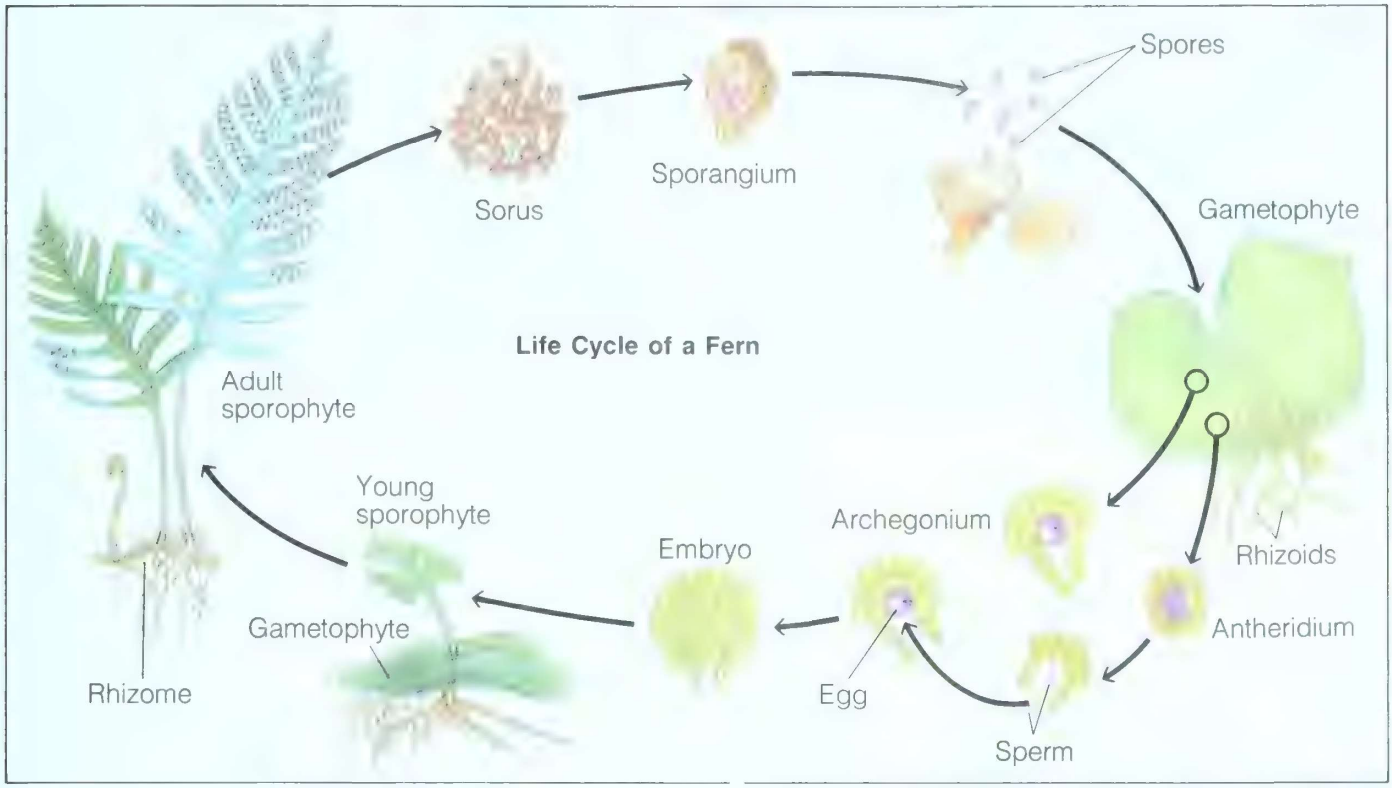
When spores are ripe, they are released from the sporangia and may be carried by wind and water over long distances. If environmental conditions are right for the spores to germinate, they develop into haploid gametophytes. The gametophyte first grows a set of rootlike rhizoids. Then it flattens out into a thin heart-shaped green structure called a **prothallium** (proh-THAL-ee-uhm). Antheridia and archegonia, which produce gametes, are found on the underside of the prothallium. If there is a moist woods near your home where you have seen ferns growing, take a close look at the ground near the base of the plants. See if you can spot the tiny prothallia among the mature plants.

When the antheridia are mature, sperm are released. Fertilization can take place when the ground and the prothallia are covered with a thin film of water. As in bryophytes, fern sperm have to swim to the archegonia to fertilize the eggs.

The diploid zygote produced by fertilization immediately begins to grow into a new sporophyte plant. The developing sporophyte quickly puts out its first fronds and then its creeping stems, or rhizomes. As the sporophyte grows, the gametophyte withers away. Fern sporophytes often live for many years. In some species, the fronds produced in the spring die in







the fall, but the rhizomes live through the winter and sprout again the following spring.

We can summarize the life cycle of ferns as follows:

1. Ferns employ alternation of generations, but in ferns the diploid sporophyte is the dominant, obvious stage. The gametophyte is tiny and lives for only a short time.
2. The sporophyte is a well-developed land plant with true vascular tissues. The gametophyte lacks vascular tissues, is very tiny and delicate, and can grow only in moist areas.
3. Sexual reproduction in ferns still requires water because sperm from the antheridia must swim to the archegonia to fertilize eggs.

It should be obvious to you that ferns still need abundant water to reproduce sexually. In the next chapter you will see how the evolution of the seed has freed the higher tracheophytes from this dependence on water.

21–1 SECTION REVIEW

1. What is vascular tissue?
2. What adaptations do ferns show that help them survive on land?
3. What generation in ferns is most obvious? What substance is needed by ferns to reproduce sexually?
4. Even though ferns survive under many of the same environmental conditions as mosses, ferns are able to grow much larger than mosses. Why is this so?



Figure 21–12 *In the life cycle of a typical fern, the heart-shaped gametophyte plant (bottom) is small and requires dampness for the sperm it produces to fertilize an egg. The young sporophyte grows from the gametophyte plant. In ferns, the sporophyte plant is large and obvious.*

Section Objectives

- Describe ways in which certain characteristics of mosses make these plants useful to people.
- List ways in which ferns are used by people.

21–4 Where Mosses and Ferns Fit into the World

Mosses and ferns are well-adapted to certain types of environments. Mosses are quite common in areas that remain damp for much of the year. Ferns, which can thrive with only little light, are often found living in the shadows of forest trees, where direct sunlight hardly penetrates the forest's leafy umbrella. But wherever conditions are right, mosses and ferns grow abundantly.

Both mosses and ferns are important plants to gardeners. Several kinds of mosses are grown in gardens for decorative purposes. For example, mosses are often used to carpet the ground in Japanese-style gardens.

Mosses are frequently added to garden soil. Dried sphagnum moss absorbs many times its own weight in water and thus acts as a sort of natural sponge. Over time sphagnum moss decomposes into peat moss. Gardeners add peat moss to the soil because it improves the soil's ability to retain water. In addition, peat moss has a low pH, so when added to the soil it increases the soil's acidity. Some plants, such as azaleas, will grow well only if planted in acid soil. Sphagnum peat moss is also used to add organic material to sandy soil.

SCIENCE, TECHNOLOGY, AND SOCIETY **APPLICATION**

Ferns as Fertilizer

Rice farmers in Southeast Asia have learned to make good use of the floating water fern *Azolla*. In nature, *Azolla* does not grow alone but rather in association with *Anabaena*, a blue-green bacteria. Colonies of *Anabaena* live within tiny cavities in the flat *Azolla* fronds, where they grow much more rapidly than they do when they live in water.

Like several other Monerans, Anabaena can take nitrogen out of the air and "fix" it into a form that other plants can use. Rice farmers plant the fern and its accompanying bacteria along with rice in their paddies. The nitrogen that the blue-green bacteria fix makes the use of expensive chemical fertilizers unnecessary. In fact, the nitrogen fixed by *Azolla* can increase the rice paddy yield by 150 percent. *Azolla* is so important to the people of Southeast Asia that a temple in Vietnam has been dedicated to this useful plant.



The water fern Azolla *is often grown in rice paddies. This plant is able to convert nitrogen in the air into fertilizer that can be used by rice plants.*

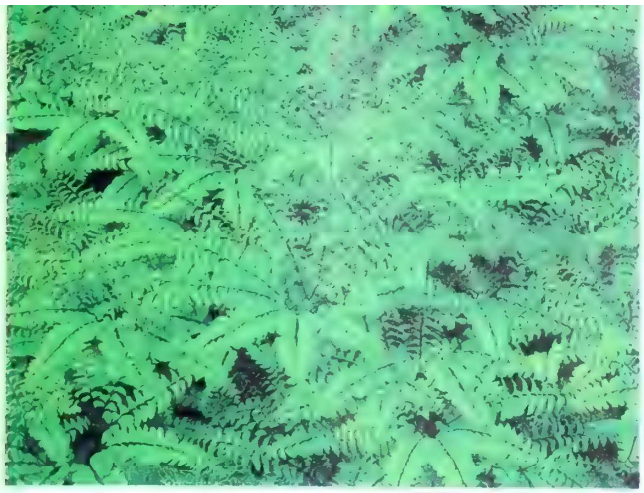




Figure 21–13 *Maidenhair ferns are one of the more beautiful ferns (left). The leaves are produced on thin stems that quiver in even the most gentle breeze. Maidenhair ferns are frequently grown in gardens or as a houseplant. Mosses often carpet the floor of Japanese gardens (right). Although moss plants appear quite similar to one another at first glance, different species vary in color and shape.*

Many different varieties of ferns are planted and cultivated by gardeners for their ornamental value. Although they do not produce flowers, fern fronds can be quite beautiful.

At one time, mosses were ground up and used by Native Americans to treat burns and bruises. Aside from its many uses in gardening, sphagnum moss is also used to add flavor to Scotch whisky. The moss is burned by brewers. The smoke produced by the burning moss gives Scotch whisky its characteristic "smoky" flavor.

Certain species of moss form peat. Peat forms after mosses die and are subjected to enormous pressure for long periods of time. Peat is actually a kind of coal that is cut from the ground and burned as a fuel.

A few types of ferns are eaten by humans. In the early spring, fern fronds emerge from the ground. When they are just beginning to grow, the fronds look very much like the top part of a violin. For this reason, the fern fronds are called fiddleheads. If picked when they are young and cooked when they are fresh, fiddlehead greens are considered a delicacy. Unless you are certain which ferns are edible, it is best to purchase fiddleheads in a supermarket or at a vegetable stand.



Figure 21–14 *These unfurling fern fronds resemble the top of a violin and are thus called fiddleheads. At this stage they are quite tender and can be eaten. However, you should not eat wild plants.*

21–4 SECTION REVIEW

1. In what kinds of areas would you expect to find mosses growing in nature?
2. What characteristics of mosses make them useful?
3. What are two ways in which ferns are used by people?

LABORATORY INVESTIGATION

COMPARING MOSSES AND FERNS

PROBLEM

Are ferns better adapted to live on land than mosses?

MATERIALS *(per group)*

2 microscope slides	metric ruler
2 coverslips	scissors
medicine dropper	fern plant
microscope	moss plant

PROCEDURE

1. Examine a fern frond carefully. Notice whether the top surface of the frond is shiny or dull. Notice whether the bottom surface of the frond is shiny or dull. Draw a diagram of the frond on a separate piece of paper.
2. Bend the fern frond gently back and forth. Notice whether the frond bends easily.
3. Use a ruler to measure the length and width of the frond. Record your observations.
4. Remove a few moss plants from the clump of moss provided by your teacher. Bend one plant gently back and forth. Notice whether the moss bends easily.
5. Use a ruler to measure the length and width of a moss plant.



6. Cut a small piece (about 5 mm long) from the tip of one of the leaflets of the fern frond. Place it face down on a clean microscope slide. Use the medicine dropper to place a drop of water on top of the piece of fern. Cover the fern with a coverslip.
7. Examine the fern leaflet under the low-power objective of your microscope. Focus on the midline of the leaflet. Notice whether there are veins in the leaflet. Draw a diagram of what you observe.
8. Remove a single moss plant from the clump of moss. Place the plant in the center of another clean microscope slide. Use a medicine dropper to place a drop of water on top of the moss plant. Cover the moss with a coverslip.
9. Examine the moss "leaflet" under the low-power objective of your microscope. Draw a diagram of what you observe.

OBSERVATIONS

1. What are the dimensions of the fern frond? Of the moss plant? Which plant grows larger?
2. Which surface of the fern frond is shinier?
3. Which is firmer, the fern frond or the moss plant?
4. Which plant has veins in its leaves?

ANALYSIS AND CONCLUSIONS

1. Why is the fern able to grow larger than the moss?
2. How can you explain the firmness of the fern frond?
3. What do you think makes the surface of the fern frond shiny? How is this an adaptation to life on land?
4. Which of the plants shows adaptations that make it better able to survive on land? Explain.

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

21–1 Plants Invade the Land

- At least two separate groups of algaelike land plants evolved between 450 and 500 million years ago. One group developed into the Bryophyta; the other group developed into the Tracheophyta.
- Land plants have certain adaptations that enable them to live in a dry environment. These adaptations prevent water loss from the plant; expose the plant to the sunlight; take up water and nutrients from the soil; and move water and nutrients, along with the products of photosynthesis, throughout the plant. Special adaptations have evolved to permit plants to reproduce in land environments.

21–2 The Mosses, Liverworts, and Hornworts

- Like the algaelike organisms from which they evolved, mosses, liverworts, and hornworts have a complex life cycle that involves an alternation of generations between a haploid gametophyte and a diploid sporophyte.
- Bryophytes lack the water-conducting tubes that are found in higher plants. Without these tubes, bryophytes can never grow tall.

21–3 The Ferns and the First Vascular Plants

- The ferns were among the first land plants to develop vascular tissue: xylem and phloem. Vascular tissue is a system of tubes that move water and other materials throughout the plant. A well-developed vascular system enables ferns to grow tall. Some ferns may even grow as tall as a small tree.
- Ferns have true roots, stems, and leaves. They also have a thick waxy covering called a cuticle. The cuticle helps prevent water loss from the cells.

21–4 Where Mosses and Ferns Fit into the World

- Because mosses and ferns are well-adapted to life in certain environments, they are grown in many gardens.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meanings. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

21–2 The Mosses, Liverworts, and Hornworts

rhizoid
antheridium
archegonium
protonema

21–3 The Ferns and the First Vascular Plants

vascular tissue
xylem
phloem
tracheid
vascular cylinder
vein
cuticle
rhizome
frond
sporangium
sorus
prothallium

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. All of the following plants are bryophytes except
   a. ferns. c. liverworts.
   b. mosses. d. hornworts.
2. Fern leaves are called
   a. sori. c. rhizomes.
   b. fronds. d. spores.
3. The most obvious stage of a moss is the
   a. sporophyte. c. protonema.
   b. parent. d. gametophyte.
4. Mosses are used for all of the following except
   a. food. c. soil additive.
   b. garden plants. d. fuel.
5. Mosses do not grow in
   a. swamps. c. deserts.
   b. marshes. d. rain forests.
6. Each of the following can be found on a fern sporophyte except a
   a. sorus. c. prothallium.
   b. frond. d. rhizome.
7. The moss sporophyte lives
   a. a solitary life.
   b. attached to the gametophyte.
   c. attached to a spore.
   d. attached to a leaf.
8. The waxy covering on the leaves of a tracheophyte is called the
   a. cuticle. c. xylem.
   b. sori. d. phloem.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. Mosses are tracheophytes.
2. Moss sporophytes are the most obvious stage of the moss life cycle.
3. Fern gametophytes are small heart-shaped structures.
4. Fern leaves are called sori.
5. Sexual reproduction in ferns depends on the presence of water.
6. Xylem tissue conducts water in a plant stem.
7. There are many fossils of early land plants.
8. In mosses, the archegonium produces sperm.

Word Relationships

A. *In each of the following sets of terms, three of the terms are related. One term does not belong. Determine the characteristic common to three of the terms and then identify the term that does not belong.*

1. sori, sporangium, spore, sperm
2. xylem, phloem, tracheids, cuticle
3. sperm, egg, zygote, spore
4. antheridium, archegonium, gametophyte, sporophyte
5. rhizoid, frond, rhizome, vascular cylinder

B. *Write the vocabulary word whose meaning is opposite that of the following words.*

6. archegonium 7. gametophyte 8. gametes

CONCEPT MASTERY

Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. Why is water needed for reproduction to occur in mosses?
2. Describe the appearance of the moss sporophyte.
3. Briefly describe sexual reproduction in a fern.
4. What are two uses of mosses and ferns?
5. Mosses must live in areas that remain damp for much of the time. Ferns can live in drier environments. What adaptations do ferns show that enable them to survive in areas that would not support moss plants?
6. Briefly summarize the life cycle of a typical moss plant.

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Applying concepts** Moss plants are small. Ferns can grow as tall as a small tree. Explain why this is so.
2. **Relating concepts** Suppose you wanted to grow a garden of mosses in your backyard. What kinds of conditions would you have to provide to make these plants grow well?
3. **Applying concepts** What stage in a fern's life cycle would require more water to survive? Why?
4. **Identifying patterns** This photograph shows the structure of a tracheophyte. What structure is it? To what kind of plant does this structure belong? Is this a part of a sporophyte or a gametophyte plant?
5. **Making predictions** A friend of yours lives in a desert area of New Mexico. She wants to grow a garden of mosses. Is this a good idea? What will probably happen to her garden?
6. **Using the writing process** Imagine that you are a moss plant living in the Olympic Forest in Washington State. Every day, moist fogs roll in from the Pacific Ocean. One day the prevailing winds that blow from the west abruptly change direction. Now the winds blow from the east. Write a brief autobiography that describes your life before the winds changed direction, explaining the transformation that would occur in you and your forest home as a result.

