21–3 Ecology of Fungi

Fungi have been around since life first moved onto land. In fact, the oldest known fossils of fungi, shown in **Figure 21–11**, were formed about 460 million years ago. At that time, the largest land plants were small organisms similar to mosses. Paleontologists think that fungi helped early plants to obtain nutrients from the ground. Their early appearance suggests that fungi may have been essential to plants' successful colonization of the land, one of the key events in the history of life.

Over time, fungi have become an important part of virtually all ecosystems, adapting to conditions in every corner of Earth. Because most fungi live their lives out of our sight, people often overlook them. But without fungi, the world would be a very different place.

All Fungi Are Heterotrophs

As heterotrophs, fungi cannot manufacture their own food. Instead, they must rely on other organisms for their energy. Unlike animals, fungi cannot move to capture food, but their mycelia can grow very rapidly into the tissues and cells of plants and other organisms. Many fungi are **saprobes,** organisms that obtain food from decaying organic matter. Others are parasites, which harm other organisms while living directly on or within them. Still other fungi are symbionts that live in close and mutually beneficial association with other species.

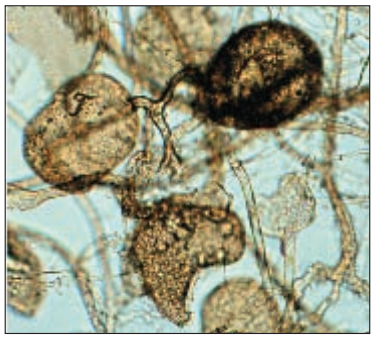
Although most fungi feed on decaying matter, a few feed by capturing live animals. *Pleurotus ostreatus* is a carnivorous fungus that lives on the sides of trees. As roundworms crawl into the fungus to feed, they are exposed to a fungal chemical that makes them become sluggish. As the worms slow to a stop, fungal hyphae penetrate their bodies, trapping them in place and then digesting them.

Guide for Reading

Key Concepts
- What is the main role of fungi in natural ecosystems?
- What problems do parasitic fungi cause?
- What kinds of symbiotic relationships do fungi form with other organisms?

Vocabulary
saprobe
lichen
mycorrhiza

Reading Strategy: Using Prior Knowledge
Before you read this section, write down all the different ways that you think fungi interact in the environment. As you read, add to or revise your list as necessary.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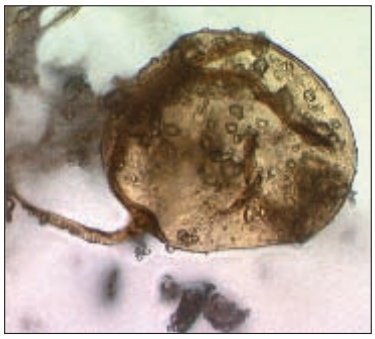
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Figure 21–11 These microscopic images show fossils of the earliest known fungi, zygomycetes that lived about 460 million years ago. An overview of fossilized hyphae with spores is shown on the left. The close-up of hyphae growing out of a spore is shown on the right. **Observing** *Can you identify structures similar to those of modern molds?*

SECTION RESOURCES

Print:
- ***Teaching Resources,*** Lesson Plan 21–3, Adapted Section Summary 21–3, Adapted Worksheets 21–3, Section Summary 21–3, Worksheets 21–3, Section Review 21–3
- ***Reading and Study Workbook A,*** Section 21–3
- ***Adapted Reading and Study Workbook B,*** Section 21–3
- ***Lab Worksheets,*** Chapter 21 Real-World Lab

Technology:
- ***iText,*** Section 21–3
- ***Transparencies Plus,*** Section 21–3

Section 21–3

1 FOCUS

Objectives
21.3.1 ***Explain*** what the ecological role of fungi is.
21.3.2 ***Describe*** problems that parasitic fungi cause.
21.3.3 ***Describe*** the kinds of mutualistic relationships that fungi form with other organisms.

Guide for Reading

Vocabulary Preview
Have students write the Vocabulary words, dividing each into its separate syllables as best they can. Remind students that each syllable usually has only one vowel sound. The correct syllabications are sap•robe, li•chen, my•cor•rhi•za.

Reading Strategy
Have students rewrite each of the section's blue headings in the form of a question and then find details within each subsection to answer their questions.

2 INSTRUCT

All Fungi Are Heterotrophs

Build Science Skills
Formulating Hypotheses Point out the statement on page 537 that fungi may have been essential to plants' successful colonization of the land. Also review the definitions of the three kinds of fungi: saprobes, parasites, and mutualists. Then, ask each student to write a hypothesis about how fungi helped in plants' colonization of the land. Their hypotheses should be in the form of a brief statement. Tell students that they will learn whether their hypotheses are correct later in the section. L2 L3

Answer to . . .

Figure 21–11 *Modern molds have hyphae and spores, just as the fossil fungi had.*

Fungi as Decomposers

Make Connections

Earth Science To help students understand how fungi aid in soil formation, explain that soil is a combination of mineral and organic matter, water, and air. Soil forms through the weathering, or breaking down, of rock at the surface of the earth. Although rock and mineral fragments form the major part of soil, it also contains a significant amount of organic matter, called humus. Display a pile of sand and a mound of potting soil, and have students examine and compare both materials. Then, ask: **Which of these materials will best support plant life, and why?** *(Students should know that the potting soil will best support plant life. Some may know that it does so because it contains humus.)* Explain that geologists don't classify a material as soil unless it contains humus. The humus is the result of decomposers, including bacteria and fungi. L1 L2

Fungi as Parasites

Build Science Skills

Posing Questions Divide the class into small groups, and ask each group to brainstorm for a list of questions about parasitic fungi. Typical questions might include: How do parasitic fungi harm plants? Are any human diseases caused by parasitic fungi serious or fatal? How can human diseases caused by parasitic fungi be prevented? Are pets susceptible to fungal diseases? Once groups have made their lists, discuss as a class which questions would be most productive to investigate. Then, encourage interested students to find the answers to some of the questions. L2

▲ **Figure 21–12** **Many fungi are decomposers that recycle nutrients by breaking down the bodies of other organisms.** The mycelia of these mushrooms have released enzymes that are breaking down the wood tissues of the decaying tree stump.

Fungi as Decomposers

Fungi play an essential role in maintaining equilibrium in nearly every ecosystem, where they recycle nutrients by breaking down the bodies and wastes of other organisms. Like the fungi in **Figure 21–12**, many fungi feed by releasing digestive enzymes that break down leaves, fruit, and other organic material into simple molecules. These molecules then diffuse into the fungus. The mycelia of fungi produce digestive enzymes that speed the breakdown of wastes and dead organisms. In so doing, they promote the recycling of nutrients and essential chemicals, helping to maintain ecosystem equilibrium.

Imagine a world without decomposers. Without decay, the energy-rich compounds that organisms accumulate during their lifetimes would be lost forever. Many organisms, especially plants, remove important trace elements and nutrients from the soil. If these materials were not returned, the soil would quickly be depleted, and Earth would become lifeless and barren.

Fungi as Parasites

As useful as many fungi are, others can infect both animals and plants, disrupting their internal equilibrium and causing disease. **Parasitic fungi cause serious plant and animal diseases. A few cause diseases in humans.**

Plant Diseases Fungi cause diseases such as corn smut, which destroys the corn kernels, as shown in **Figure 21–13.** Mildews, which infect a wide variety of fruits, are also fungi. Fungal diseases are responsible for the loss of approximately 15 percent of the crops grown in temperate regions of the world. In tropical areas, where high humidity favors fungal growth, the loss of crops is sometimes as high as 50 percent. Fungi are in direct competition with humans for food. Unfortunately for us, sometimes fungi win that competition.

One fungal disease—wheat rust—affects one of the most important crops grown in North America. Rusts are caused by a type of basidiomycete that needs two different plants to complete its life cycle. Spores produced by rust in barberry plants are carried by the wind into wheat fields. There, the spores germinate and infect wheat plants. The patches of rust produce a second type of spore that infects other wheat plants, allowing the disease to spread through the field like wildfire.

Later in the growing season, a new variety of spore is produced by the rust. These tough black spores easily survive through the winter. In spring, they go through a sexual phase and produce spores that infect barberry plants. Once on the barberry leaves, the rust produces the spores that infect wheat plants, and the cycle continues. Fortunately, once agricultural scientists understood the life cycle of the rust, they were able to slow its spread by destroying barberry plants.

CHECKPOINT *What are two examples of plant diseases caused by fungi?*

UNIVERSAL ACCESS

Less Proficient Readers

Help students understand the importance of recycling nutrients by having them recall what they learned about organic molecules in Chapter 2. Elicit from volunteers that there are four groups of compounds in living things—carbohydrates, lipids, proteins, and nuclei acids. Remind students that carbohydrates and lipids are energy-rich compounds that decomposers help recycle, and those compounds would be lost to living things without decomposers. L1

Advanced Learners

Encourage interested students to further investigate the problem of wheat rust. Explain that the fungus that causes the disease is *Puccinia graminis*, which is often known as black stem rust of wheat. Ask students to prepare a presentation about wheat rust, including an illustration of the organism's life cycle. Students will discover that the wheat-rust problem persists despite development of rust-resistant strains of wheat. L3



Figure 21–13 Parasitic fungi cause serious diseases in plants and animals. Corn smut (left) grows on a corn plant, harming it. The fungus releases millions of spores that survive in the soil during the winter and begin their life cycle again in the spring. Wheat rust (center) is a basidiomycete that infects both wheat and barberry plants. Athlete's foot (right) infects the outer layers of human skin.

Human Diseases Fungal parasites can also infect humans. One deuteromycete can infect the areas between the toes, causing the infection known as athlete's foot. The fungus forms a mycelium directly within the outer layers of the skin. This produces a red, inflamed sore from which the spores can easily spread from person to person. When the same fungus infects other areas, such as the skin of the scalp, it produces a red scaling sore known as ringworm, which is not a worm at all.

The microorganism *Candida albicans,* a yeast, can disrupt the equilibrium within the human body, causing fungal disease. *Candida,* which grows in moist regions of the body, is usually kept in check by competition from bacteria that grow in the body and by the body's immune system. This normal balance can be upset by many factors, including the use of antibiotics, which kill bacteria, or by damage to the immune system. When this happens, *Candida* may produce thrush, a painful mouth infection. Yeast infections of the female reproductive tract usually are due to overgrowth of *Candida*.

Other Animal Diseases As problematic as human fungal diseases can be, few fungal diseases are as deadly as the infection by one fungus from the genus *Cordyceps.* This fungus infects grasshoppers in rain forests in Costa Rica. Microscopic spores become lodged in the grasshopper, where they germinate and produce enzymes that slowly penetrate the insect's tough external skeleton. The spores multiply in the insect's body, digesting all its cells and tissues until the insect dies. To complete the process of digestion, hyphae develop, cloaking the decaying exoskeleton in a web of fungal material. Reproductive structures, which will produce more spores that will spread the infection, then emerge from the grasshopper's remains, as shown in **Figure 21–14.**

▲ **Figure 21–14** This grasshopper is the victim of *Cordyceps,* a fungus. Once the fungus's tiny spore enters the insect's body, it multiplies rapidly and digests body tissues. The structures growing out of the grasshopper's body are the fungus's fruiting bodies. **Comparing and Contrasting** ***Some pathogens rely on their host to spread them to other potential hosts. How does this fungus spread?***

Use Visuals

Figure 21–13 After students have examined the photos and read the caption, ask: **What is a parasite?** *(An organism that lives within or on another organism and harms that organism by feeding on it)* Have students recall that parasitism is one of the three symbiotic relationships they learned about in Chapter 4. Point out that parasites generally weaken but do not kill their hosts. Ask: **What hosts are shown in this figure?** *(Corn, wheat, and human)* **Does athlete's foot kill the host?** *(No)* Explain that corn smut and wheat rust also don't kill their hosts, though they do enough damage to their hosts that the plants become worthless to the farmer who grows them. L2

Make Connections

Health Science After students have read about the fungal parasite that causes athlete's foot, ask: **In what kind of location are you most likely to "catch" this disease?** *(Many students will know that athlete's foot is spread in locker rooms.)* Point out that the disease is spread from person to person by spores. Ask: **What is it about locker rooms that enhances the spread of these fungal spores?** *(Locker rooms are warm and damp and people walk around barefoot, especially from the shower to lockers. Spores in a sore on one person's foot can easily spread to other people's feet.)* L1 L2

BIO INSIGHTS

FACTS AND FIGURES

The fungus among us

Fungal infections in humans are called mycoses. Fungi that cause superficial skin, or cutaneous, infections are known as dermatophytes. These pathogens are generally classified as deuteromycetes, and they include members of the fungi genera *Trichophyton, Epidermophyton,* and *Microsporum.* The medical names of cutaneous mycoses look like genus and species names, but they really identify the infected part of the body. For example, the common "athlete's foot" is known as tinea pedis. *Tinea* means "worm," and *pedis* means "foot." Other cutaneous mycoses are tinea capitis (ringworm of the scalp), tinea cruris (ringworm of the groin, or "jock itch"), and tinea unguium (ringworm of the nails). Usually, these cutaneous infections occur when there are cuts and other breaks in the skin that become infected with fungal spores.

Answers to . . .

CHECKPOINT *Corn smut, wheat rust*

Figure 21–14 *The spores of* Cordyceps *are spread by fruiting bodies that grow out of the grasshopper's body.*

Symbiotic Relationships

Make Connections

Earth Science Explain that lichens are able to break down rocks through both mechanical and chemical weathering. Mechanical weathering includes processes that break rock into smaller pieces. Chemical weathering actually changes the chemical makeup of rocks. The fungus part of a lichen sends its hyphae into cracks in a rock, eventually wedging the rock apart. This is mechanical weathering. More important, the fungus produces acids that seep into rock and break it apart. This is chemical weathering. In addition to these weathering processes, lichens that grow on bare rock trap soil particles. As soil builds up, plants are able to grow. Thus, lichens are often the most important part of the so-called pioneer community on bare rock. L2

Use Visuals

Figure 21–16 Call students' attention to the lichen's layers. Then, ask: **Which of the organisms in this mutualistic association provides a protective upper layer?** *(The fungus)* **How would you describe the photosynthetic component of a lichen?** *(The algal or cyanobacterial cells are scattered among strands of fungal hyphae in the second layer of the lichen.)* **What attaches the lichen to a rock or tree?** *(Small projections)* Explain that these lichen anchors are fungal hyphae called rhizines. L1 L2

Build Science Skills

Observing Provide students with photos of different species of lichens. Explain that lichens are found on trees and rocks, as well as on the sides of buildings, gravestones, and other rocklike structures. Encourage students to find one or two examples of lichens near their homes. For each example, they should make a drawing and write a description. L2 L3

Figure 21–15 Lichens grow in one of three forms. Crustose lichens (top) are flat; foliose lichens (middle) resemble leaves; and fruticose lichens (bottom) grow upright. **Inferring** *How do lichens assist in soil formation?*

Symbiotic Relationships

Fungi often grow in close association with members of other species in symbiotic relationships. Although fungi are parasites in many of these relationships, that is not always the case. **Some fungi form symbiotic relationships in which both partners benefit. Two such mutualistic associations, lichens and mycorrhizae, are essential to many ecosystems.** Lichens are shown in **Figure 21–15.**

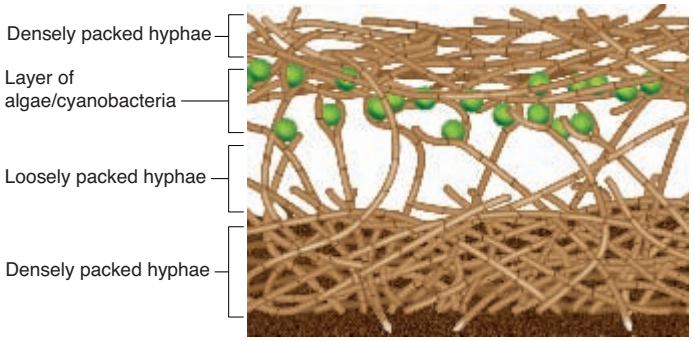
Lichens

Lichens (LY-kunz) are not single organisms. Rather, they are symbiotic associations between a fungus and a photosynthetic organism. The fungi in lichens are usually ascomycetes, although a few are basidiomycetes. The photosynthetic organism is either a green alga or a cyanobacterium, or both. **Figure 21–16** shows the structure of a lichen.

Lichens are extremely resistant to drought and cold. Therefore, they can grow in places where few other organisms can survive—on dry, bare rock in deserts and on the tops of mountains. Lichens are able to survive in these harsh environments because of the relationship between the two partner organisms. The algae or cyanobacteria carry out photosynthesis, providing the fungus with a source of energy. The fungus, in turn, provides the algae or bacteria with water and minerals that it collects and protects the delicate green cells from intense sunlight.

Lichens are often the first organisms to enter barren environments, gradually breaking down the rocks on which they grow. In this way, lichens help in the early stages of soil formation. Lichens are also remarkably sensitive to air pollution, and they are among the first organisms to be affected when air quality deteriorates.

CHECKPOINT *What two groups of organisms grow together in lichens?*



▲ **Figure 21–16** **Lichens are a mutualistic relationship between a fungus and an alga or a cyanobacterium, or both.** The protective upper surface of a lichen is composed of fungal hyphae. Below this is the layer of cyanobacteria or algae with loosely woven hyphae. The third layer consists of loosely packed hyphae. The bottom layer is a protective surface covered by small projections that attach the lichen to a rock or tree.

TEACHER TO TEACHER

A day before discussing lichens in class, I show students a sample of tree bark with a lichen growing on it. Each student is asked to describe what he or she sees and make a few notes about the physical appearance of the lichen. (It is typically gray and lifeless in appearance.) After each student has had a chance to observe the bark, I spray the lichen with water, place the bark in a large plastic bag, and put it under a plant light. In a day or two, the lichen will develop a green color. I use this to emphasize that a photosynthetic organism is part of the lichen.

—Debbie Richards
Biology Teacher
Bryan High School
Bryan, TX

Problem Solving

Repotting Orchids

You are working in a greenhouse that has just begun to grow orchids. The plants arrive in small pots from a nursery. When they outgrow the pots, your supervisor asks you to place them in larger pots with fresh soil, just as you have done with other plants. However, every time you follow the greenhouse procedure for repotting, which includes carefully washing off the "old" soil and placing the roots into a sterilized soil mix, the plants soon wither and die.

Defining the Problem In your own words, what is the problem the greenhouse faces?

Organizing Information What problems could sterile, microbe-free soil present to a plant? Are there microorganisms in soil that might be essential to orchids? Might the loss of such organisms cause problems for the plants? What kinds of problems?

Creating a Solution Describe an experiment that you could use to find out if the use of sterile soil is causing the problems with repotting. Be sure to devise controls that might determine whether the mechanical stress of repotting, rather than the soil mixture, is causing the problems.

Presenting Your Plan Make a poster showing the steps and procedures in your proposed experiment, and explain it to the class.

Mycorrhizae Fungi also form mutualistic relationships with plants. Almost half of the tissues of trees are hidden beneath the ground in masses of tangled roots. These roots are woven into a partnership with an even larger web of fungal mycelia. These associations of plant roots and fungi are **mycorrhizae** (my-koh-RY-zee; singular: mycorrhiza).

Scientists have known about this partnership for years, but recent research shows that it is more common and more important than was previously thought. Researchers now estimate that 80 percent of all plant species form mycorrhizae with fungi.

How do plants and fungi benefit from each other? The tiny hyphae of the fungi aid plants in absorbing water and minerals. They do this by producing a network that covers the roots of the plants and increases the effective surface area of the root system. This allows the roots to absorb more water and minerals from the soil. In addition, the fungi release enzymes that free nutrients in the soil. The plants, in turn, provide the fungi with the products of photosynthesis.

The presence of mycorrhizae is essential for the growth of many plants. The seeds of some plants, such as orchids, cannot germinate in the absence of mycorrhizal fungi. Many trees are unable to survive without fungal symbionts. Mycorrhizal associations have even been cited as an adaptation that was critical in the evolution of land plants from more-aquatic ancestors.

Problem Solving

Explain that the problem described is a common one experienced by greenhouse workers. Although many plants can be repotted into fresh, sterile soil, those that depend on mycorrhizae cannot. The fungi that form mycorrhizae with orchids are zygomycetes that live in soil. L2 L3

Defining the Problem Students' definitions of the problem will differ, though all should mention that repotting plants in a sterilized soil mix causes the plants to die.

Organizing Information Students should suggest that sterilized soil would not contain the fungi for the mycorrhizal relationships with orchids that the plants need to absorb necessary minerals.

Creating a Solution A typical experiment might retain some of the old soil attached to the roots when repotting a plant. To determine whether mechanical stress is part of the problem, students might suggest adding fungicide to soil instead of replacing it.

Presenting Your Plan Students' plans should show the steps necessary to carry out the proposed experiment. Each plan should designate a control, a variable, and a means to collect the data needed to evaluate the results.

Use Community Resources

Invite a manager of a local greenhouse to speak to the class about repotting plants and whether and why sterilized soil is ever used. Have students write questions ahead of time both about mycorrhizal associations and about fungal diseases that affect greenhouse plants. L2

BIO INSIGHTS — FACTS AND FIGURES

Fungus roots

The term *mycorrhizae* means "fungus roots," and the name aptly describes the association that develops between plant roots and fungi. The hyphae of some fungi form a sheath around the root, and hyphae also penetrate a short way into the root, growing between the root cells. These are called ectomycorrhizae. Other fungi have hyphae that penetrate root cells, through which materials are exchanged. These are called endomycorrhizae. Many plants have difficulty absorbing such elements as phosphorus from the soil, and the hyphae provide these elements to the plant. In return, the plant provides the fungus with sugars and amino acids. About half of all basidiomycetes that form mushrooms live in mycorrhizae with trees such as oaks and pines. The mushrooms that pop up at the base of these trees are evidence of the "fungus roots" underground.

Answers to . . .

CHECKPOINT *A lichen is a symbiotic association between a fungus and an alga or a cyanobacterium.*

Figure 21–15 *They gradually break down the rocks on which they grow.*

21–3 (continued)

Use Visuals

Figure 21–17 Ask students: **In the bottom photograph, what did the seedlings on the left, grown without mycorrhizae, have less of in comparison with the seedlings on the right?** *(They had less water and nutrients, which fungal symbionts aid plants in absorbing in mycorrhizae.)* **If the plants on the right benefited from a mycorrhizal association, how did the fungi in that association benefit?** *(The fungi were provided with the products of photosynthesis by the plants.)* L2

3 ASSESS

Evaluate Understanding

Call on students at random to compare and contrast the relationship between the fungus that causes corn smut and a corn plant and the relationship between a mycorrhizal fungus and a Douglas fir. Students should contrast a parasitic relationship with a symbiotic relationship.

Reteach

Have students make a chart listing the beneficial roles and the harmful roles of fungi in the environment.

Focus on the BIG Idea

Both bacteria and fungi are decomposers that feed by releasing digestive enzymes that break down organic matter into simple molecules. Thus, they share the characteristics of digesting food outside their bodies and of recycling nutrients and essential chemicals, which are released into the soil and taken up by the roots of plants.

iText

If your class subscribes to the iText, use it to review the Key Concepts in Section 21–3.

Answer to . . .

Figure 21–17 *Mutualism*

Figure 21–17 Plants and fungi often form associations called mycorrhizae (top photograph). The fungi in the mycorrhizae allow the host plant to absorb more water and nutrients. In the bottom photograph, the lemon seedlings on the left were grown without mycorrhizae. Those on the right, of the same age, were grown with mycorrhizae. **Applying Concepts** ***What type of symbiotic relationship is illustrated by mycorrhizae?***

Mycorrhizal relationships are often very specialized. For example, the Douglas fir forests of the Pacific Northwest are dependent on the presence of a particular species of white truffle. In Europe, black truffles are found growing with oak and beech trees. The fly agaric grows mostly with birch and pine trees. **Figure 21–17** shows how mycorrhizae affect the growth of young lemon trees.

Why is this networking relationship so important? The partnership between plant and fungus does not end with a single plant. The roots of each plant are plugged into mycorrhizal networks that connect many plants. What's more astounding is that these networks appear to connect plants of different species.

A recent experiment showed that carbon atoms from one tree often end up in another nearby tree. In an experiment using carbon isotopes to track the movement of carbon, ecologist Suzanne Simard found that mycorrhizal fungi transferred carbon from paper birch trees growing in the sun to Douglas fir trees growing in the shade. As a result, the sun-starved fir trees thrived, basically by being "fed" carbon from the birches.

Simard's findings suggest that plants are far from being isolated individuals, as was previously thought. Instead, plants—and their associated fungi—may be evolving as part of an ecological partnership.

21–3 Section Assessment

1. **Key Concept** What is the major role of fungi in an ecosystem?
2. **Key Concept** Explain the roles of fungi in causing disease in humans and in other living things.
3. **Key Concept** Describe two mutualistic relationships that fungi form with other organisms.
4. Describe the life cycle of wheat rust.
5. **Critical Thinking Applying Concepts** What might happen to a garden if it were sprayed with a long-acting fungicide?
6. **Critical Thinking Applying Concepts** Summarize the role of fungi in disrupting the equilibrium in an ecosystem. Give one specific example.

Focus on the BIG Idea

Structure and Function
Both bacteria and fungi are decomposers. What characteristics do these two groups share that allow them to function in this ecological role? Use the information in Chapter 19 to help answer this question.

21–3 Section Assessment

1. To recycle nutrient material by breaking down organic matter
2. Parasitic fungi cause serious plant and animal diseases, including those in humans.
3. A lichen is a symbiotic association between a fungus and an alga or a cyanobacterium. Mycorrhizae are mutualistic relationships between plant roots and fungi.
4. Spores produced by the rust in barberry plants are carried by wind into wheat fields, where they infect wheat plants and produce a second type of spore that infects other wheat plants. Another type of spore survives through the winter and produces yet another spore that infects barberry plants.
5. The garden plants would not flourish, because the mycorrhizae between plants and fungi benefit both plants and fungi.
6. Answers will vary. Most students will focus on plant or animal diseases caused by fungi.