Protists and Fungi

BIG IDEA
Protists and fungi are highly diverse organisms that have both beneficial and detrimental impacts on human health and the environment.

19.1 Diversity of Protists

19.2 Animal-like Protists

19.3 Plantlike Protists

19.4 Funguslike Protists

19.5 Diversity of Fungi

19.6 Ecology of Fungi

Data Analysis
ANALYZING EXPERIMENTAL DESIGN

ONLINE BIOLOGY
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ONLINE Labs
- QuickLab  Investigating Motion in Protists
- Exploring Bioluminescence
- Video Lab  Protistan Response to Light
- Video Lab  Yeast and Fermentation
- Exploring Mushroom Anatomy
- Quantifying Mold Growth
- Algae in Products
- Investigating Meiosis in Sordaria fimicola
- Chemotaxis in Physarum
When these two protists meet, who is the prey?

Although they are both protists, the round *Didinium* hunts live paramecia almost exclusively. Paramecia are much longer than this predator, but that doesn’t stop *Didinium*. It captures, paralyzes, and reels in paramecia like fish on a line. It then eats its prey whole, expanding its own body just so that its meal will fit.

**USING LANGUAGE**

**General Statements**  A general statement summarizes the features of a group or describes an average feature of the members of the group. Some individuals in the group may not share all of the features. So, general statements may be true most of the time, but not always.

**YOUR TURN**

Use what you know about general statements to answer the following questions.

1. Write a general statement that summarizes the features of baseballs, basketballs, tennis balls, soccer balls, and footballs.

2. Brainstorm exceptions to the general statement “In general, dogs have four legs, fur, and a tail and can bark.”
Diversity of Protists

KEY CONCEPT  Kingdom Protista is the most diverse of all the kingdoms.

MAIN IDEAS
- Protists can be animal-like, plantlike, or funguslike.
- Protists are difficult to classify.

Connect to Your World

If you looked at a drop of water from a pond, a roadside puddle, or a bird bath, you might find specimens of both *Didinium* and *Paramecium*. Despite their unique appearances, they are single-celled. That is what makes single-celled protists so amazing—they can carry out all life functions within just one cell. As you will see, one cell can be quite complex.

MAIN IDEA

Protists can be animal-like, plantlike, or funguslike.

Large yellow globs of slime seemed to come out of nowhere. They were spreading across lawns and pulsing up telephone poles. Afraid that this was an alien invasion, residents of a Dallas neighborhood called police and firefighters. The firefighters turned their hoses on the blobs, but water only made the invaders grow.

Scientists came to the rescue. What the people in the Dallas neighborhood were seeing on this sunny day in 1973 wasn’t an alien life form, but a slime mold. Specifically, it was *Fuligo septica*, shown in FIGURE 1.1, a species commonly called dog-vomit slime mold because of its resemblance to—well, dog vomit.

Slime molds usually don’t grow large enough to scare a neighborhood, but they are unusual. Slime molds are one of several groups of living things classified in kingdom Protista, a very diverse kingdom that includes hundreds of phyla. Members of this kingdom are often simply called protists.

A protist is a eukaryote that is not an animal, a plant, or a fungus. Protists are generally grouped together because, although they share some features with animals, plants, and fungi, they also lack one or more traits that would place them in any of these three kingdoms. Protists may be single-celled or multicellular, microscopic or very large. They have different ways of moving around and responding to the environment. Some protists reproduce asexually, whereas others reproduce both asexually and sexually.
Protists can be divided informally into three broad categories based on how they get their food. Categorizing protists in this way does not reflect evolutionary relationships, but it is a convenient way to study their diversity.

- **Animal-like protists** Animal-like protists, such as the *Euplotes* in FIGURE 1.2, are heterotrophs—organisms that consume other organisms. However, all animal-like protists are single-celled, while all animals—no matter how simple—are multicellular.

- **Plantlike protists** Plantlike protists, such as the algae *Pediastrum* in FIGURE 1.2, make their own food by photosynthesis just as plants do. Although these protists may have chloroplasts, they do not have roots, stems, or leaves. And while all plants are multicellular, plantlike protists may be either single-celled, colonial, or multicellular.

- **Funguslike protists** Funguslike protists, such as slime molds, decompose dead organisms. Because of this trait, these protists were once classified in kingdom Fungi. However, funguslike protists can move during part of their life cycle, whereas fungi cannot. You will learn about fungi later in this chapter.

**Apply** What one characteristic do all protists share? TEKS 8C

**MAIN IDEA** TEKS 8B, 8C

**Protists are difficult to classify.**

You have learned that the three-domain system of classification divides prokaryotes into two domains, Archaea and Bacteria, and places all eukaryotes in one domain, Eukarya. There are four kingdoms within the domain Eukarya: Animalia, Fungi, Plantae, and Protista. The kingdom Protista includes many phyla. These phyla are very different from one another, and most are only distantly related. In fact, many protists are more closely related to members of other kingdoms than to other protists.

Kingdom Protista can be considered the junk-drawer of the kingdoms. It is a kingdom for all the eukaryotes that don’t seem to fit the animal, plant, or fungi definitions. Now that molecular biology techniques have revealed the genetic relationships between groups of organisms, many biologists think the protist kingdom will eventually be divided into several kingdoms within the domain Eukarya. If the genetic differences used to classify fungi, plants, and animals were used as a guide for classifying protists, we’d end up with more than 15 kingdoms of eukaryotes rather than the four we currently use. Until there is a widely accepted division of kingdom Protista into multiple kingdoms, the term *protist* remains useful when studying the group.
1. Name the three main groups within the kingdom Protista. What characteristics distinguish each group from the other two? **TEKS** 8B, 8C

2. Give two reasons why protists are difficult to classify. **TEKS** 8B, 8C

3. Infer What observable traits might green algae and plants share that support the molecular evidence that these two groups are closely related? **TEKS** 8C

4. Contrast At one time, scientists grouped all single-celled organisms together. What are the main differences between single-celled protists and bacteria or archaea? **TEKS** 8C

5. Organisms that get their food by ingesting it are called heterotrophs, while those that make their own food are called autotrophs. Categorize animal-like, plantlike, and funguslike protists using these two terms. **TEKS** 8B

You can see the genetic relationship of protists to each other and to other kingdoms in **FIGURE 1.3**. For example, a comparison of RNA sequences between plants and green algae indicates that green algae are more closely related to plants than to other algae. Protist classification is a very active area of research, and in the future may provide insight into areas of study such as preventing or treating protist-caused diseases.
Animal-like Protists

KEY CONCEPT Animal-like protists are single-celled heterotrophs that can move.

MAIN IDEAS
- Animal-like protists move in various ways.
- Some animal-like protists cause disease.

Connect to Your World
Think of all the ways that different animals move. Some walk on two legs, while others walk on four. Some spend most of their time flying, while others can only swim. Just like animals, animal-like protists use different ways to get around.

MAIN IDEA Animal-like protists move in various ways.

The animal-like protists represent the largest number of species in the kingdom Protista. In the early two-kingdom classification system, some protists were classified as animals because they had many animal-like traits. Like animals, they can move around, they consume other organisms, and their cells lack chloroplasts. The key difference between animal-like protists and animals is their body organization: all animal-like protists are unicellular, while animals are multicellular. The term protozoa is often used informally to describe the many phyla of animal-like protists. A few common protozoan groups are described below.

Protozoa with Flagella
The zooflagellates (zoh-uh-FLAJ-uh-lihts) are animal-like protists that have one or more flagella at some point in their life cycle. Recall that flagella are tail-like structures that help unicellular organisms swim. Although the flagella of zooflagellates (phylum Zoomastigophora) look like the flagella of prokaryotes, they are structurally very different. Prokaryotic flagella attach to the surface of the cell. In contrast, eukaryotic flagella, such as those of the zooflagellate shown in FIGURE 2.1, are extensions of the cytoplasm. They are made of bundles of small tubes called microtubules and are enclosed by the plasma membrane. Prokaryotic flagella are also much smaller than the flagella of protists. You can easily see protist flagella with the aid of a light microscope, but prokaryotic flagella are invisible at the same magnification.

More than 2000 species of zooflagellates exist. All free-living zooflagellates are heterotrophs. For example, some zooflagellates eat prokaryotes that feed on dissolved organic matter, thereby playing an important role in recycling nutrients through aquatic ecosystems. Other zooflagellates are pathogens, or disease-causing parasites of humans and other animals. Some zooflagellates live inside other organisms in mutualism—a relationship in which both organisms benefit.
Sometimes zooflagellates play a crucial role in another organism’s life. For example, termites cannot digest the wood they eat. Inside the gut of a termite is a complex community made of zooflagellates and bacteria that can digest wood. The termites get nutrition from the zooflagellate’s activity, and the zooflagellates get free meals and a place to live.

Protozoa with Pseudopods
Two groups of protozoa that can easily change shape as they move are the amoebas and the foraminifera.

Amoebas The amoebas (uh-MEE-buhz) are very flexible. Amoebas (phylum Rhizopoda) form pseudopods to move. A pseudopod (SOO-duh-PAHD), which means “false foot,” is a temporary extension of cytoplasm and plasma membrane that helps protozoa move and feed. To form a pseudopod, the cell cytoplasm flows outward, forming a bulge. This bulge spreads, anchors itself to the surface it is on, and pulls the rest of the cell toward it. Pseudopod formation uses energy. When the amoeba is not moving or feeding, it does not form pseudopods.

An amoeba’s method of getting food is shown in FIGURE 2.2. Ingestion takes place by the process of phagocytosis. Recall that phagocytosis is the engulfing of solid material by a cell. The amoeba surrounds the food with its pseudopod, and the outer membrane of the amoeba then forms a food vacuole, or sac. Digestive enzymes enter the food vacuole from the surrounding cytoplasm, and digestion takes place.

Amoebas live in fresh water, salt water, and soil. The majority of amoebas are free-living, but some species are parasites. Most amoebas are microscopic. However, Pelomyxa palustris is an amoeba that can grow as large as five millimeters in diameter—a huge size for a single-celled organism—and can be seen without a microscope.

Foraminifera Another group of protozoa with pseudopods are members of phylum Foraminifera (fuh-ram-uh-NIHF-uh-uh). Foraminifera, sometimes simply called forams, are named for their multi-chambered shell, shown in FIGURE 2.3. The Latin word foramen means “little hole.” Their shells are made of organic matter, sand, or other materials, depending on the species. Forams make up a large group of marine protozoa that, like amoeba, use pseudopods to move.

Protozoa with Cilia
This group’s name, Ciliates, comes from its most obvious feature—cilia. Cilia are short, hairlike structures that cover some or all of the cell surface and help the organism swim and capture food. Cilia are usually much shorter than flagella and found in much greater numbers. Some ciliates have many rows of cilia all over their surface, whereas other ciliates just have clusters of cilia.
About 8000 species of ciliates make up the phylum Ciliophora. Some ciliates are parasites that cause disease. However, most ciliates are free-living cells found in fresh water, such as the common pondwater protists in the genus Paramecium.

Structures of a paramecium are shown in Figure 2.4. Food is swept into the oral groove by the cilia, and is sent to the gullet. Eventually the food is digested in food vacuoles. Two organs that act like pumps, called contractile vacuoles, control the amount of water inside the cell. An unusual trait found in paramecia and other ciliates is the presence of two types of nuclei. Each cell has one large macronucleus, but there can be many small micronuclei. The macronucleus controls the cell’s structures and activities. The micronuclei contain all of the cell’s chromosomes. They function only during conjugation, a process of genetic exchange. Two paramecia unite at the oral grooves and exchange micronuclei. Some species of the genus Paramecium have up to 80 micronuclei. Because micronuclei can be exchanged during conjugation, having so many micronuclei allows for a huge amount of genetic variation in paramecia.

Summarize What functions do the two kinds of nuclei within Paramecium perform?

QuickLab Observing

Investigating Motion in Protists
In this investigation you will observe the movement of one or more of the following protists: Paramecium, Amoeba, or Euglena.

Problem What does a protist’s movement look like?
1. Make a wet mount slide of the protist. You may need to add a drop of methylcellulose solution to the wet mount so that you can slow down the organism enough to observe. Caution: Do not use a cover slip on the amoeba slide, as you will crush the organism.
2. Observe how the organism moves. Make a series of three drawings that depict the movement of the organism.
3. If time allows, repeat steps 1 and 2 with the other two protists.

Analyze and Conclude
1. Analyze Describe the movement of the protist(s) you observed.
2. Analyze What structures did the protist that you observed use to move?
3. Infer Based on the structures you observed, do you think the species of protist that you observed swims in the water or crawls in the bottom sediments? Explain.

Materials
• 4 eyedroppers
• 4 drops bottled spring water
• 3 microscope slides
• 2 cover slips
• culture of Paramecium
• 3 drops methylcellulose solution
• culture of Amoeba
• culture of Euglena
• microscope
Some animal-like protists cause disease.

Protists cause some of the world’s most well-known infectious diseases. The phylum Apicomplexa (a-pih-kuhm-PLEH-kuh) includes about 4000 species, all of which are parasites of animals. Many members of this phylum are known as sporozoans because they form sporozoites—infected cells that have tough outer coats. Malaria is an example of a disease caused by sporozoans. It is caused by infection with the protozoan Plasmodium, shown in Figure 2.5.

Malaria is passed to humans and other animals through the bite of the Anopheles mosquito. Symptoms of malaria include high fever and vomiting. In some cases, the parasite can severely affect kidney and liver function, leading to coma and even death. Although the disease was once on the decline, today more than 1 million people—mostly children in developing countries—die from malaria each year. Mosquitoes have developed resistance to the insecticides that once would kill them, and Plasmodium species have become resistant to antimalarial drugs.

Two other parasitic protists that cause disease are the zooflagellates Trypanosoma and Giardia. In Africa, several species of Trypanosoma cause the disease known as sleeping sickness in humans and other mammals. Trypanosomes are transmitted through the bite of the tsetse fly, and can cause coma and death. Giardia causes intestinal disease in humans. People can become infected with Giardia by drinking water contaminated with feces of infected animals. Campers and hikers must be careful of Giardia, as even streams or rivers that appear clean could be contaminated.

Compare How do the parasites Plasmodium and Giardia each infect humans?

Reviewing Main Ideas
1. Name and describe the three basic means of movement used by animal-like protists.
2. Describe how the parasite Plasmodium causes disease in humans.

Critical Thinking
3. Compare and Contrast In what ways are cilia and flagella similar? How are they different?
4. Infer Why do amoebas form pseudopods only when they need them?

Formative Assessment

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Connect to Analogous Structures
5. The flagella of eukaryotes and prokaryotes serve the same function, but they are structurally very different. What does this suggest about the evolution of flagella?
**Plantlike Protists**

**KEY CONCEPT** Algae are plantlike protists.

**Main Ideas**
- Plantlike protists can be single-celled or multicellular.
- Many plantlike protists can reproduce both sexually and asexually.

**Connect to Your World**
On your birthday, do you enjoy decorations on your cake, or do you prefer it topped with ice cream? Both cake decorations and ice cream are among the many products that commonly contain substances from seaweeds, types of plantlike protists.

**Main Idea**
Plantlike protists can be single-celled or multicellular.

Just as animal-like protists were once classified as animals, it is not surprising that many plantlike protists used to be classified as plants. Although many plantlike protists look like plants, they are different in many ways. Unlike plants, plantlike protists do not have roots, stems, leaves, specialized tissues, or the same reproductive structures that plants have. All plants are multicellular, while plantlike protists may be single-celled or multicellular.

Many single-celled plantlike protists are free-living aquatic organisms that, together with photosynthetic bacteria, are known as phytoplankton. Recall that phytoplankton form the base of aquatic food chains and provide about half of the oxygen in Earth's atmosphere. Several species of single-celled plantlike protists, such as Volvox, shown in FIGURE 3.1, live in colonies. Multicellular plantlike protists include the seaweeds or kelps. Some species eat other organisms, but most plantlike protists have chloroplasts and can produce their own food through photosynthesis. Photosynthetic plantlike protists are called algae.

**From Single-Celled to Multicellular**
In the distant past, single-celled organisms combined to become multicellular. It is likely that multicellular algae arose from colonies of algae such as Volvox. Members of the order Volvocales include three kinds of forms: single-celled forms, multicellular forms with every cell acting independently, and multicellular forms in which the cells are specialized. In the evolution from single-celled to multicellular algae, some individual cells in colonies were probably very efficient at certain tasks, such as digesting food or producing gametes. These cells and their offspring would have become more specialized over time, and eventually may have become dependent on each other. Over many generations, colonies could have led to multicellular forms.
Diversity of Plantlike Protists

Plantlike protists are found in most habitats on Earth. Most are aquatic organisms that live in freshwater and marine ecosystems. Some species live in deserts, while others live in the tundra. Despite their great diversity, plantlike protists have certain features in common, such as the chlorophyll they use for photosynthesis. Also, most plantlike protists have flagella at some point in their life cycle. Although their classification will likely change, for now many biologists group the plantlike protists into several phyla based on their photosynthetic pigments and cell wall structure.

Euglenoids  The euglenoids (phylum Euglenophyta) are a large group of single-celled organisms that swim with the aid of one or two flagella. Although most of these species are found in fresh water, some live in ocean environments. Members of this group are both animal-like and plantlike. Like animals, these protists can move around easily. Euglenoids have a pellicle, a flexible coatlike covering on their cell surface. The pellicle allows the cell to change shape. In some species, the pellicle helps the organism to creep across solid surfaces using a type of movement that resembles the inching movement of worms. Although some colorless species of euglenoids eat other organisms, most make their own food through photosynthesis.

Plantlike photosynthetic euglenoids are green, such as the euglena shown in Figure 3.2. Their bright green color comes from two different chlorophyll pigments, called chlorophyll $a$ and $b$. Chlorophyll $a$ is found in all photosynthesizing organisms. Chlorophyll $b$ is found only in green algae and plants.

Dinoflagellates  The dinoflagellates (phylum Dinoflagellata) are single-celled. About 90 percent of dinoflagellates are marine plankton. Recall that plankton are often microscopic organisms that live suspended in the water. Some dinoflagellates are freshwater species, and a few species have even been found in snow. About half of all marine dinoflagellates photosynthesize.

Dinoflagellates have two flagella. One flagellum extends from the rear of the cell and propels it forward. The other is a ribbonlike strand that circles the cell in a groove along its body. This flagellum allows the cell to turn over and change direction. The combination of the two flagella cause this protist to turn in a spiral as it moves forward. Some species also have a covering of stiff plates that form a protective armor.

Some dinoflagellates, such as *Noctiluca*, are bioluminescent; that is, they can produce light through internal chemical reactions. The name *Noctiluca* means “night-light.” If you have ever visited the ocean at night, you may have seen these tiny, blue glowing organisms along the surface of the water. They give off light when they are disturbed. The light may act as an alarm to help them avoid being eaten.
Certain other photosynthetic dinoflagellates help build coral reefs through their symbiotic partnership with corals. These dinoflagellates live in the inner tissues of the corals. In return for shelter from the corals, the dinoflagellates provide the corals with nutrients in tropical waters that are usually nutrient-poor.

Some species of dinoflagellates produce toxins. A large population of these dinoflagellates can create what is known as a red tide, due to the reddish color produced by a high density of these species. Red tides, shown in Figure 3.3, occur when changes in ocean currents bring up nutrients from far below the ocean surface. The higher nutrient levels produce a rapid increase, or bloom, in the dinoflagellate population. A toxic bloom in the waters can kill large numbers of fish. The toxins can also build up in the tissues of shellfish, which then can be dangerous to humans who eat the contaminated seafood.

**Diatoms** Most diatoms (phylum Bacillariophyta) are easy to recognize when viewed through a microscope. These tiny single-celled algae are covered with delicately patterned glasslike shells. The shells of diatoms serve almost as an external skeleton, helping the cell to hold a rigid shape. Diatom shells, such as those shown in Figure 3.4, are made of silica, the same brittle substance that is used to make glass. The silica shell is divided into two parts that overlap each other, like the lid of a box.

Like other autotrophs, all diatoms release oxygen into the environment. In fact, diatoms could be considered the world champions of photosynthesis. They play a critical role in the uptake of carbon dioxide on Earth and produce about half of the oxygen we breathe. Diatoms may be freshwater or marine. Many species are phytoplankton. Others live clinging to rocks, plants, soil, and even animals—diatoms have been found growing on crustaceans, turtles, and even whales. Because of their glassy, mineralized shells, diatoms have been well preserved in the fossil record. Some fossil rocks consist almost entirely of diatoms. These diatom skeletons have many industrial uses, such as an ingredient in scrubbing products, because of their rough texture.
Green algae  The green algae (phylum Chlorophyta) may be found in water or on land, although most species are aquatic. Recall that algae are not considered plants because they do not have roots, stems, or leaves. Like plants, however, green algae are multicellular and contain the photosynthetic pigments chlorophyll a and chlorophyll b. Both plants and green algae also have accessory pigments called carotenoids. Accessory pigments capture light energy and transfer it to chlorophyll during photosynthesis. Both plants and green algae also have cell walls made of cellulose and store food within their cells as starch. These similarities suggest that green algae share an early ancestor with land plants.

Brown algae  The brown algae (phylum Phaeophyta) include the giant kelp, shown in FIGURE 3.5, that form thick underwater forests. Brown algae are multicellular and can grow to be extremely large. Some giant kelp can grow up to 100 meters high (about 330 ft). Most brown algae live in marine environments. Brown algae are photosynthetic but have a different form of chlorophyll—chlorophyll c—than do plants or green algae. Brown algae share this trait with the diatoms. This observation has led some biologists to propose classifying brown algae and diatoms together in their own kingdom.

Red algae  Most red algae are found in the ocean, though a few live in freshwater habitats. Red algae (phylum Rhodophyta) use chlorophyll a for photosynthesis, but they get their color from the pigment phycoerythrin. Red algae can grow at deeper depths than other algae because the red pigments allow red algae to absorb the blue light that reaches deepest into the ocean. Some species secrete calcium carbonate, forming thick crusts that look like corals and provide habitats for tiny invertebrates. Red algae provide many products for the food industry. Carrageenan and agar, thickening agents used in products such as ice cream, come from red algae. In Japan, red algae is dried to make nori, a seaweed wrap used for sushi.

Compare and Contrast  What are the similarities and differences between green, brown, and red algae?

MAIN IDEA
Many plantlike protists can reproduce both sexually and asexually.

Most protists can undergo both sexual and asexual reproduction. All algae can reproduce asexually. Multicellular algae can fragment; each piece is capable of forming a new body. When a single-celled alga, such as the green alga Chlamydomonas shown in FIGURE 3.6, reproduces asexually, its life cycle is a bit more complex. The dominant phase of the life cycle for this species is haploid. Before reproducing asexually, the haploid parent alga absorbs its flagella and then divides by mitosis. This division may occur two or more times, producing up to eight cells. The daughter cells develop flagella and cell walls. These daughter cells, called zoospores, leave the parent cell, disperse, and grow. The zoospores then grow into mature haploid cells.
Sexual reproduction occurs in algae as well. Some species alternate generations so that the offspring from sexual reproduction reproduce asexually, and the next generation then reproduces sexually. In other species, asexual reproduction occurs for several generations until conditions change. For the single-celled Chlamydomonas, sexual reproduction is triggered by stress such as lack of moisture or food. As shown in Figure 3.7, it begins with cells dividing by mitosis to produce one of two types of gametes. Because the gametes look identical in most species of Chlamydomonas, they are usually identified as different mating types, labeled + and –. When the gametes come together, they join and form a diploid zygote. The zygote may develop into a zygospore by making a thick wall that can protect it during unfavorable conditions. When favorable conditions return, meiosis occurs, producing four haploid cells.

Apply Explain how sudden population increases, or “blooms,” of algae may occur.
Analyzing Experimental Design

Scientists repeating another person’s experiment must be able to follow the procedures exactly and obtain the same results in order for the experiment to be valid. Valid experiments must have

- a testable hypothesis
- a control group and an experimental group
- defined independent and dependent variables
- all other conditions held constant
- repeated trials

**Model**

A student performed an experiment to determine whether a certain species of coral larvae prefer to settle on live red algae or dead red algae. She placed live red algae and dead algae in a tank held at 28°C (82°F). In a second tank held at 26°C (79°F), she placed a piece of lettuce as a control because it had a texture similar to the algae. After 24 hours, she counted the number of larvae that settled on each type of algae. The following flaws exist in this experiment:

- A controlled variable—temperature—was not held constant.
- The lettuce control was separated from the algae choices.
- There were no repeated trials.

A valid experimental design would have all of the choices in a single aquarium, which makes it easier to maintain constants, and allows accurate observation of which surface types the larvae prefer. At least three aquariums should be used with the same setup so that the results could be compared.

**Practice Identify Experimental Design Flaws**

A student wanted to determine what concentration—low, medium, or high—of a chemical released from brown algae prevented coral larvae from settling and growing on the algae. Each concentration level of the chemical from one brown alga was added to the water of each tank. Tank size, water temperature, and algae species were held constant. A different number and species of larvae were dropped into each tank. After three days, the percent of settled larvae for each concentration of inhibiting chemical was found.

1. **Evaluate** What are the design flaws in this experiment? How would you change the experiment to make the results more valid?

2. **Analyze** The student concluded that at all levels the inhibiting chemical affected the rate of settlement of marine larvae. Is this an accurate conclusion based on the data collected? Explain.

**TABLE 1. RESULTS OF INHIBITING CHEMICAL ON LARVAL SETTLEMENT**

<table>
<thead>
<tr>
<th>Inhibiting Chemical Concentration</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of Larvae Settled</td>
<td>85%</td>
<td>40%</td>
<td>1%</td>
</tr>
</tbody>
</table>
Funguslike Protists

**KEY CONCEPT**
Funguslike protists decompose organic matter.

**MAIN IDEAS**
- Slime molds and water molds are funguslike protists.

**VOCABULARY**
- slime mold
- water mold

**Connect to Your World**
Perhaps you have seen a funguslike protist and didn’t recognize it, like the Dallas residents you read about at the start of this chapter. Most funguslike protists don’t grow large enough to scare people. In fact, some you can barely see.

**MAIN IDEA**
Slime molds and water molds are funguslike protists.

As decomposers, funguslike protists play an important role in ecosystems by recycling nutrients such as carbon and nitrogen back into the soil. For a long time, funguslike protists were classified as fungi because they are all decomposers and have similar reproductive structures and cycles. However, funguslike protists can move during part of their life cycle, while fungi cannot.

**Slime Molds**

**Slime molds** are eukaryotic organisms that have both funguslike and animal-like traits. They can be divided into two phyla: plasmodial slime molds (phylum Myxomycota) and cellular slime molds (phylum Acrasiomycota).

**Plasmodial slime molds** For most of their life, plasmodial slime molds live as a single mass of cytoplasm that actually is a large single cell with many nuclei, called a plasmodium. They can grow as large as a meter or more in diameter. A plasmodium, shown in **FIGURE 4.1**, moves like a giant amoeba, creeping over the ground as it absorbs bacteria and nutrients from decaying matter. *Fuligo septica*, the dog-vomit slime mold, is typical of this group.

**FIGURE 4.1** A plasmodial slime mold (left) in the plasmodium stage resembles a giant amoeba. A cellular slime mold (right) forms a stalk in the spore-producing stage. (colored SEMs; plasmodial slime mold magnification 80×; cellular slime mold magnification 100×)
Plasmodial slime molds are common on the underside of logs and on dead leaves. When food or moisture is in short supply, the plasmodial slime mold stops growing and develops nonmoving reproductive structures that produce spores. Such a structure is a resistant, resting form of the slime mold. When the spores are released, they are often able to move on their own. They may creep like an amoeba, or, if water is present, they can develop up to four flagella per cell. Eventually, the spores swarm together and form a new plasmodium.

**Cellular slime molds** The cellular slime molds are common in soil. Each spore released by a cellular slime mold becomes a single amoeba-like cell. However, when food is scarce, individual cells can release chemical signals that cause the cells to swarm together. They form a sluglike body that moves as though it were one organism. This form of a cellular slime mold is called a pseudoplasmadium, meaning “fake plasmodium,” because each cell is independent—the membranes of each cell do not fuse. These slime molds are of interest to biologists who study how cells can communicate with each other.

**Water Molds**

**Water molds** are funguslike protists (phylum Oomycota) that are made up of branching strands of cells. They are common in freshwater habitats. Like slime molds, many water molds are decomposers. However, some water molds are parasites of plants or fish. For example, if you keep an aquarium, you may have seen a water mold that infects fish. The mold appears first as a cottony coating on the skin and gills but later causes deep wounds.

Perhaps the best known water mold is the downy mildew *Phytophthora infestans*, shown in **FIGURE 4.2**, which causes a disease called potato blight. An outbreak of this disease in Ireland from 1845 to 1849 destroyed almost all of the country’s potato crops. As a result, more than 1 million people died of starvation in what became known as the Great Potato Famine.

**Infer** Many protists have two modes of reproduction. How does having two modes of reproduction affect when and how they reproduce?

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**FIGURE 4.2** The water mold *Phytophthora infestans* causes disease, including potato blight in many plants. This disease was the cause of a seven-year famine in Ireland in the 1800s. (colored SEM; magnification 100×)
Diversity of Fungi

**KEY CONCEPT** Fungi are heterotrophs that absorb their food.

**MAIN IDEAS**
- Fungi are adapted to absorb their food from the environment.
- Fungi come in many shapes and sizes.
- Fungi reproduce sexually and asexually.

**Connect to Your World**

What is the largest living thing in the world? The blue whale? A giant redwood tree? Although they are big, both species are tiny compared with a fungus growing in Oregon—a single honey mushroom, *Armillaria ostoyae*. Most of it is underground, but this mushroom could cover more than 1500 football fields. It is thought to be at least 2400 years old. As amazing as it sounds, there are other fungi throughout the world nearly as large.

**MAIN IDEA**

Fungi are adapted to absorb their food from the environment.

Despite how little most people know about fungi, they are all around us—in soil, water, and even in the air. Many forms live in and on plants and animals. Scientists have named about 70,000 species but estimate there may be a total of 1.5 million fungi species in the world.

**Comparing Fungi and Plants**

Members of the kingdom Fungi fall into one of three groups—the single-celled yeasts, the molds, and the true fungi. For many years, biologists classified fungi as plants. But there are a few traits that separate these two kingdoms.
- Plants contain chlorophyll and photosynthesize. Fungi do not have chlorophyll and get food by absorbing it from their environment.
- Plants have true roots, leaves, and stems, but fungi do not.
- Plant cell walls are made of the polysaccharide cellulose. Fungal cell walls are made of chitin (KYT-uhn), a tough polysaccharide that is also found in the shells of insects and their close relatives.

**Anatomy of Fungi**

With the exception of the yeasts, fungi are multicellular organisms. The bodies of multicellular fungi are made of long strands called hyphae (HY-fee). Hyphae (singular, *hypha*) are shown in **FIGURE 5.1**. Depending on the species, each hypha may consist of a chain of cells or may contain one large, long cell with many nuclei. In both cases, cytoplasm can flow freely throughout the hyphae, and each hypha is surrounded by a plasma membrane and a cell wall of chitin.
Hyphae often group together in long tangled masses to form a mycelium. A **mycelium** (my-SEE-lee-uhm) is an underground network of hyphae. Under certain conditions, such as a moist environment, a mycelium (plural, **mycelia**) can grow quickly to cover a large area. Mycelia may produce fruiting bodies. A **fruiting body** is a reproductive structure of a fungus that grows above ground. Mushrooms are one type of fruiting body.

Fungi absorb their food from their environment. The food can be from a wide variety of food sources—including tree bark, bread, cheese, and even flesh. As fungi grow, hyphae extend into the food source and release enzymes. These enzymes break down their food so that it can be absorbed across their cell walls. Fungi can take in large amounts of nutrients due to their mycelia, which in turn allows mycelia to grow very quickly.

**Contrast** How is the way that fungi get their food different from that of any other group of organisms? [TEKS] 8C

**M A I N I D E A** [TEKS] 8B, 8C, 11A, 12A

**Fungi come in many shapes and sizes.**

The kingdom Fungi is diverse, and it is commonly divided into four main groups—primitive fungi (phylum Chytridiomycota), sac fungi (phylum Ascomycota), bread molds (phylum Zygomycota), and club fungi (phylum Basidiomycota).

**Primitive Fungi**

The primitive fungi, or chytrids, are the smallest and simplest group of fungi. They are mostly aquatic, and their spores have flagella, which help propel them through the water. They are the only fungi with flagellated spores. Some primitive fungi are decomposers, while others are parasites of protists, plants, or animals. One explanation for the global decrease of amphibians such as frogs is that a parasitic type of chytrid fungi is attacking them.

**Sac Fungi**

Yeasts, certain molds such as *Penicillium*, and morels and truffles—which many people consider delicious to eat—are all sac fungi. The sac fungi are a diverse group, but they have one key trait in common. They all form a sac, called an ascus, that contains spores for reproduction. Some examples of sac fungi are shown in **FIGURE 5.2**

The yeast that makes bread rise is *Saccharomyces cerevisiae*. This yeast is also an important model organism used in molecular biology. As a eukaryote, it has many of the same genes as humans. Because it is single-celled, it is easy to work with in a laboratory.

If you’ve ever let an orange grow moldy, you’ve seen *Penicillium chrysogenum*. This mold is usually a deep green color and appears fuzzy. *Penicillium* is also the source for the antibiotic penicillin. In contrast, one dangerous sac fungus is *Aspergillus flavus*, a mold that makes a poison called aflatoxin that can contaminate cereals, nuts, and milk.
Bread Molds
The bread molds range from the molds you see on spoiled foods to fungi used to ferment certain foods such as soy sauce. Most members of this phylum get food by decomposing dead or decaying matter. At least one group of symbiotic fungi belongs to this group. Mycorrhizae (my-kuh-RY-zuh) are mutualistic partnerships between fungi and the roots of certain plants. Mycorrhizae help these plants to fix nitrogen—that is, they take inorganic nitrogen from the soil and convert it to nitrates and ammonia, which the plants use.

Club Fungi
The club fungi get their name because their fruiting bodies are club-shaped. This phylum includes mushrooms, puffballs, and bracket, or shelf, fungi. It also includes the rusts and smuts, which are two types of fungi that cause diseases in plants. Puffballs, shown in FIGURE 5.3, form dry-looking structures that release their spores when someone or something strikes the mature fruiting body. Bracket fungi are a common sight in forests, where they grow outward from tree trunks, forming a little shelf.

Identify What two organisms share a mutualistic partnership in the formation of mycorrhizae? TEKS 12A

MAIN IDEA TEKS 8B, 8C, 11A
Fungi reproduce sexually and asexually.

Most fungi reproduce both sexually and asexually through a wide variety of strategies.

Reproduction in Single-Celled Fungi
Yeasts are single-celled fungi. They reproduce asexually, either through simple fission or through a process called budding, shown in FIGURE 5.4. Fission is identical to mitosis—the cell’s DNA is copied and the nucleus and cytoplasm divide, making two identical daughter cells. During budding, the parent cell forms a small bud of cytoplasm that also contains a copy of the nucleus. When these buds reach a certain size, they detach and form a cell.

Some yeasts undergo sexual reproduction. A diploid yeast cell undergoes meiosis, producing four haploid nuclei. However, the parent cell’s cytoplasm does not divide. Recall that a yeast is a type of sac fungi. Instead of the cytoplasm dividing, it produces the characteristic saclike structure of this phylum called an ascus. The haploid nuclei it contains are actually a type of spore. The ascus undergoes budding, releasing each of the haploid spores. Some spores may then reproduce more haploid spores through budding. Others may fuse with other haploid spores to form diploid yeast cells.

FIGURE 5.3 Puffballs release a cloud of spores when the fruiting body matures and bursts.

FIGURE 5.4 Yeast can reproduce by budding, the pinching of small cells off the parent cell. (colored SEM; magnification 6000×)
Reproduction in Multicellular Fungi

The multicellular fungi have complex reproductive cycles. Examples of life cycles for two phyla of fungi are shown in FIGURE 5.6.

Club fungi  Basidiomycota are named for their club-shaped structures called basidia, where spores are produced during sexual reproduction. Basidia are found on the undersides of mushrooms. They form within the leaflike gills that you can easily see. In club fungi, unlike the other phyla, spores are most often formed by sexual reproduction.

- Nuclei within the basidia fuse to form diploid zygotes.
- The zygotes undergo meiosis to form haploid spores.
- The spores drop from the gills and are carried away by wind or by contact with animals.
- If the spores land in a favorable environment, they grow and form haploid hyphae.
- Some cells of the haploid mycelium may fuse with the cells of another haploid mycelium, producing a diploid mycelium underground.
- An environmental cue, such as rain or change in temperature, can trigger the formation of aboveground fruiting bodies such as mushrooms.

Bread molds  Members of Zygomycota are also known as zygote fungi because of the structures they form during sexual reproduction. Bread molds reproduce sexually when the food supply is low but can also reproduce asexually when there is plenty of food. They reproduce asexually by producing spores in sporangia, spore-forming structures at the tips of their hyphae. The term sporangium is used to describe similar reproductive structures of a variety of organisms, including some fungi, mosses, algae, and ferns.

- As in the club fungi, sexual reproduction in zygote fungi involves hyphae that look alike but are different mating types.
- The two types of hyphae fuse their nuclei to produce a diploid zygospore that can tolerate long periods of extreme conditions.
- When the conditions become favorable, a sporangium grows and produces haploid spores.
- The spores are released and can grow into new hyphae.
- The new hyphae in turn may reproduce asexually, by forming haploid spores in sporangia. Or they may reproduce sexually, by fusing hyphae to produce more zygospores.

**CONNECT TO**

**ASEXUAL REPRODUCTION**

Recall from the chapter Cell Growth and Division that asexual reproduction is the creation of offspring from a single parent that does not involve the joining of gametes. The offspring are genetically identical to each other and to the parent.
Reproduction in fungi can occur in several ways. Although most club fungi reproduce sexually, bread molds can reproduce both sexually and asexually.

**LIFE CYCLE OF CLUB FUNGI**

A fruiting body, or mushroom, develops aboveground.

**GROWTH UNDERGROUND**

A mycelium (2n) grows underground.

Spores grow into hyphae of opposite mating types underground.

**LIFE CYCLE OF BREAD MOLDS**

A zygote produces a sporangium (1n).

The sporangium bursts and releases spores (1n).

Some hyphae grow above ground and produce sporangia (1n).

**CRITICAL VIEWING**

How are the life cycles of club fungi and bread molds similar?

How are they different? TEKS 8C
Sac fungi  Members of Ascomycota are called the sac fungi due to the saclike case, or ascus (plural, asci), that forms during sexual reproduction. These reproductive structures are shown in FIGURE 5.7. Most asci are found within the fungi’s cup-shaped fruiting body. As in club fungi and bread molds, sexual reproduction in multicellular sac fungi involves the joining of two mycelia that are different mating types. The joined hyphae grow into the aboveground fruiting body. An ascus, or sac, develops at the tip of each hypha within the fruiting body. Inside the ascus, haploid spores form. When mature, the cup-shaped fruiting body collapses, and releases the spores.

Like the bread molds, sac fungi usually reproduce asexually when conditions are favorable and reproduce sexually when conditions are harsh. They produce different types of spores during asexual reproduction than they do during sexual reproduction. Spores produced during asexual reproduction are called conidia, which means “dust,” because they travel easily through air.

Release of Spores
Fungi release their spores at the tips of their hyphae, high above their food source. This strategy allows the small spores to be carried in air currents to a new location. Some species of fungi go even further and use unusual strategies in releasing their spores. For example, members of the fungal genus Cordyceps grow on insects. In some species, the fungi penetrate the insect’s brain, causing the insect to climb high into a tree or other vegetation. Eventually, the insect stops climbing and remains fixed in place. The fungus then releases its spores from this greater height.

Spores of fungi are everywhere, and have even been found in the air more than 150 kilometers (93 mi) above the surface of Earth. The great number of spores in the air at any given time is the reason that the growth of mold on our leftover food cannot be avoided, even if the food is refrigerated. Fungal spores are also a source of allergies for many people worldwide.

Hypothesize  How might producing spores benefit an organism?

FIGURE 5.7  A cross-section of the cup-shaped fruiting body of a sac fungus shows spores encased in an ascus. (magnification 400×)

19.5  Formative Assessment

**REVIEWING  MAIN IDEAS**

1. Describe how fungi use hyphae to obtain their food.
2. Describe a typical fruiting body of sac fungi, bread mold, and club fungi.  **TEKS** 8B
3. Sporangia are formed during the life cycle of a typical bread mold. At what stage are they formed?

**CRITICAL THINKING**

4. Summarize  Draw a flowchart showing the sequence of steps in the reproduction of yeast, a single-celled fungus.
5. Infer  The mycelium of a fungus grows underground. In what ways might this be helpful for the fungus?  **TEKS** 11C

**CONNECT TO  ECOLOGY**

6. Some scientists support using fungi such as Cordyceps instead of pesticides to control insect pests in agriculture. What might be some pros and cons of such a plan?  **TEKS** 11C
The Other KINGDOM

Sickening Protists  Learn how to diagnose and treat three patients with diseases caused by protists.

Comparing Protists  Run an experiment on different samples of protists to determine which of them are autotrophs and which are heterotrophs.

Protist and Fungus Life Cycles  Build the life cycles of a slime mold, a cup fungus, and brown algae.
Ecology of Fungi

**KEY CONCEPT** Fungi recycle nutrients in the environment.

**MAIN IDEAS**
- Fungi may be decomposers, pathogens, or mutualists.
- Fungi are studied for many purposes.

**Connect to Your World**

Fungi just might be the most overlooked and unappreciated organisms on Earth. Fungi grow on shower curtains, spoil food, and cause illnesses in humans. But humans also eat some fungi and use them to make things that range from bread to antibiotics. Perhaps most importantly, these unusual organisms play a major role in every ecosystem on Earth.

**MAIN IDEA**

Fungi may be decomposers, pathogens, or mutualists.

Some fungi act as decomposers in the environment. Others act as either pathogens or mutualists to other organisms—including humans.

**Fungi as Decomposers**

Fungi and bacteria are the main decomposers in any ecosystem. Fungi, such as those shown in **FIGURE 6.1**, decompose dead and decaying organic matter such as leaves, twigs, logs, and animals. They return nutrients such as carbon, nitrogen, and minerals back into the soil. Because of the large surface area of their mycelia, fungi are well adapted for absorbing their food and can recycle nutrients quickly. This constant cycling of nutrients helps enrich soil with organic compounds. The nutrients can then be taken up by other organisms.

Plants and animals could not survive without the activity of decomposers. The ability of fungi to break down tough plant materials such as lignin and cellulose is especially important in woodland ecosystems. Fungi are the main decomposers of these hard parts of plants, which cannot be used by animals without being first broken down by decomposers.

The decomposing activity of fungi is not always helpful to humans, however. Fungi can damage fruit trees, and they can also cause damage inside wooden houses and boats. Molds and other fungi inside a house can weaken its walls, and their spores can cause respiratory illness. Homeowners should check for and remove molds that are established in their homes.
**Fungi as Pathogens**
Like bacteria, some fungi can be pathogenic, or disease-causing. A few pathogenic fungi always cause disease. These fungi are called obligate pathogens—the term *obligate* means necessary or obliged. Other fungi are normally harmless, coexisting with other organisms in a delicate ecological balance. However, changes in environmental circumstances can upset this balance and lead to disease. Organisms that normally don't cause a problem until there is a change in the host's homeostasis are called opportunistic pathogens. A change in the host's body provides them an opportunity to grow unchecked and cause infection.

**Fungi and humans** The overuse and incorrect use of antibiotics is one example of how humans allow pathogens an opportunity to cause infection. Antibiotics can destroy certain beneficial bacteria in the human digestive system, allowing other organisms such as fungi to thrive. Typically harmless fungi also cause disease when the immune system is not functioning at its best. For instance, all healthy humans have populations of the yeast *Candida* that occupy certain parts of the body, such as the skin and mouth. If a human's immune system is damaged, populations may grow and cause disease.

Some fungal pathogens, such as those that cause ringworm and athlete's foot, have fairly mild effects. But several fungi cause severe diseases, such as some lung illnesses, that are hard to cure and can even cause death. Fungal infections are hard to treat because fungi are eukaryotes, and so their cellular structure is very similar to ours. It is difficult to develop medicine that will harm fungal cells but not damage human cells.

**Fungi and plants** Fungal diseases also affect plants, and they can be especially devastating in agriculture and horticulture. Dutch elm disease is caused by a fungus that is transmitted by elm bark beetles, shown in **FIGURE 6.2**. In the United States, the first cases of Dutch elm disease were reported in Ohio in 1930. Today, the disease has destroyed more than half of the elms in the northern United States. Fungi also destroy a large portion of the world's fruit crops. A disease of peaches called peach scab is caused by a fungus and results in millions of dollars in losses to growers each year. Gray mold is a disease of produce such as strawberries. This fungus can grow even in refrigerated fruit and is a major cause of fruit spoilage during shipment and storage.

Fungal diseases in agriculture are often treated with chemical sprays called fungicides. Today, however, crops that are genetically engineered to resist fungi are becoming more common. Fungal diseases in animals, including those in humans, are usually treated with antifungal medications. These treatments usually come from fungi themselves, which produce them as a defense against other fungi. Like bacteria and protists, however, fungi can develop resistance to treatments if they are overused. These products should be used carefully.

**FIGURE 6.2** A fungus is responsible for Dutch elm disease. Adult elm bark beetles tunnel into the bark of elms to lay their eggs. If the trees are diseased, fungus spores stick to the adults as they visit new trees.
Fungi as Mutualists

Mutualism is a symbiotic relationship in which both organisms benefit. Fungi form mutualistic relationships with several types of organisms.

Lichens  A lichen (LY-kuhn) is a mutualistic relationship between a fungus and algae or photosynthetic bacteria. Only certain fungi, algae, or cyanobacteria can combine to form a lichen body. The body itself consists mainly of fungal hyphae that surround and grow into the algal cells, as shown in FIGURE 6.3. The algal part of the lichen carries out photosynthesis, making sugars that feed both the alga and the fungus. Lichens (phylum Mycomycota) can grow on almost any solid surface, from tree trunks to soil to rocks. They are common in cool, dry environments. They can also withstand severe temperatures. This characteristic of lichens allows them to live in habitats such as tundra, where fungi could not survive alone.

Lichens play several roles in the environment and in the lives of humans. For example, they are extremely important during primary succession, because they can live on bare rock. Many species of lichens are sensitive to air pollution and can be used as indicators of air quality. Lichens are also important in nutrient cycling, because they function as both a decomposer and a producer. Lichens produce hundreds of unique chemicals, including pigments used as dyes in traditional cultures and compounds that have antibiotic properties.

Mycorrhizae  Mutualistic associations between plant roots and soil fungi are called mycorrhizae. More than 80 percent of the world’s plants have mycorrhizae on their roots. Mycorrhizae form when the hyphae of a fungus colonize the roots of a nearby plant. The huge surface area of the fungal mycelium is much larger than the root surface area of the plants, so the mycelium can absorb soil nutrients and water faster than the plant’s roots could alone. In return, the fungus benefits because it gets sugars and other nutrients from the plant. Mycorrhizae can boost plant growth and reduce the need for fertilizers, which can cause soil and water pollution. Mycorrhizae also produce chemicals with antibiotic properties that help fight harmful bacteria.
**Fungal gardens and insects** Some insects also live as partners in a mutualistic symbiosis with fungi. The leafcutter ants of Central and South America, shown in FIGURE 6.4, don’t just use fungi—they actually grow them. These ants cut tiny pieces of leaf from plants with their jaws. They carry these leaf pieces back to an underground nest area, where they build a garden of leaf pieces. Next, the ants add pieces of the fungus. The fungus breaks down the leaf pieces and absorbs nutrients from them. The ants in turn feed on the fungal mycelium.

**Summarize** Describe three ways that fungi are important to the environment.

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**MAIN IDEA  TEKS 11C**

**Fungi are studied for many purposes.**

Many species of fungi are edible, such as the mushrooms we eat on pizza and the yeast we use to bake bread. In addition, fungi make citric acid, which is used in soft drinks and some candy. Fungi are also useful in the health care industry. Since the discovery of antibiotics in the 1900s, scientists have been researching how pathogens interact with their natural environments. This knowledge is then applied to develop useful medicines. For example, in their natural habitats fungi and bacteria compete for similar resources, such as space and nutrients. This is true whether they live on a forest floor or in a human digestive tract. Over time, fungi have evolved natural defenses against bacteria.

Studies of yeast have produced equally valuable insights. These tiny single-celled organisms are among the most important model systems used in molecular biology. Most yeasts have many of the same genes and proteins found in plants and animals. Insights gained from studies of a yeast’s genome can often be applied to multicellular organisms. Yeast are small, grow quickly, and are easy to culture, or raise, in the laboratory.

**Summarize** What are three ways that fungi benefit humans?  TEKS 11C

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**19.6 Formative Assessment**

**REVIEWING  MAIN IDEAS**

1. How do fungi contribute to the balance of an ecosystem?  TEKS 11C
2. What are three reasons lichens are useful to humans?  TEKS 11C

**CRITICAL THINKING**

3. **Compare** Draw a Venn diagram comparing lichens and mycorrhizae. Include terms such as **roots, photosynthesis,** and **mutualism.**
4. **Analyze** Some antifungal medications can damage the patient’s own tissues. Why doesn’t this problem occur with antibiotics?

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**CONNECT TO**

**ANTIBIOTICS**
Recall from the chapter **Viruses and Prokaryotes** that an antibiotic is a chemical that kills or slows the growth of bacteria.

**SELF-CHECK Online**

GO ONLINE

**CONNECT TO**

**NATURAL SELECTION**

5. A peach farmer is faced every year with an outbreak of peach scab, a fungal disease of peaches. Every year he sprays his crop carefully with fungicides, but each time these seem less effective than the year before. Why might this be?  TEKS 11C, 12A
Summary

KEY CONCEPTS

19.1 Diversity of Protists

Kingdom Protista is the most diverse of all the kingdoms. It includes organisms that are animal-like, plantlike, and funguslike. Protists may be single-celled or multicellular, and may be microscopic or very large. Protist classification is likely to change in the future, as some protists are more closely related to members of other kingdoms than they are to other protists.

19.2 Animal-like Protists

Animal-like protists are single-celled heterotrophs that can move. Commonly known as protozoa, animal-like protists have various structures that help them move, such as flagella, pseudopods, or cilia. Some animal-like protists can cause diseases such as malaria and sleeping sickness.

19.3 Plantlike Protists

Algae are plantlike protists. Unlike animal-like protists, which are all single-celled, plantlike protists can be either single-celled or multicellular. Most plantlike protists can make their own food through photosynthesis. Plantlike protists are not classified as plants because they do not have roots, stems, leaves, or the specialized tissues and reproductive structures that plants have. However, like many plants, most plantlike protists can reproduce both sexually and asexually.

19.4 Funguslike Protists

Funguslike protists decompose organic matter. These protists have an important role in recycling nutrients through ecosystems. Unlike fungi, funguslike protists can move during part of their life cycle. Funguslike protists include slime molds and water molds.

19.5 Diversity of Fungi

Fungi are heterotrophs that absorb their food. Their bodies are made of long strands, called hyphae, which grow underground in a tangled mass called a mycelium. The parts of fungi that humans normally recognize, such as mushrooms, are actually only the reproductive structures of the fungi, called fruiting bodies.

19.6 Ecology of Fungi

Fungi recycle nutrients in the environment. Some fungi cause illness in humans, such as those that cause athlete’s foot and ringworm. Other fungi, such as those that cause Dutch elm disease, cause illness to plants or other organisms. Some fungi share a mutualistic relationship with organisms such as algae to form lichens, or plant roots, which form mycorrhizae. Humans use fungi for foods, medicine, and as model organisms in scientific research.

Supporting Main Ideas

Use a supporting main ideas diagram to summarize how the three groups of protists get their food.

- Protists get their food in several ways
  - animal-like protists
  - plantlike protists
  - funguslike protists

Concept Map

Use a concept map like the one below to summarize what you know about the roles of fungi in the environment.

- Fungi
  - act as decomposers
    - by breaking down organic matter
  - by helping plants grow
  - by aiding in decomposition

BIG IDEA

Protists and fungi are highly diverse organisms that have both beneficial and detrimental impacts on human health and the environment.
CHAPTER 19 Review

CHAPTER VOCABULARY

19.1 protist
19.2 protozoa
19.3 algae
19.4 slime mold
19.5 chitin
19.6 lichen

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Reviewing Vocabulary

Compare and Contrast
Describe one similarity and one difference between the two terms in each of the following pairs.

1. pseudopod, cilia
2. slime mold, water mold
3. mycorrhizae, lichen
4. protozoa, algae
5. fruiting body, sporangia
6. hyphae, mycelium

Reviewing MAIN IDEAS

12. Give one characteristic of each type of protist that explains why it is animal-like, plantlike, or funguslike. TEKS 8B, 8C
13. Explain why the phyla of the kingdom Protista might be regrouped into several kingdoms and what would likely be the basis for this reclassification. TEKS 8B, 8C
14. What are three types of structures that help some protists move? 15. When does an amoeba form a pseudopod?
16. Name two animal-like protists that cause disease and briefly describe the diseases they cause. TEKS 11G, 12A
17. Are protists classified on the basis of being single-celled or multicellular? Give an example to support your answer. TEKS 8B, 8C
18. How do multicellular algae reproduce asexually?
19. Slime molds have animal-like traits. What might be one reason they are classified with water molds as funguslike protists? TEKS 8B, 8C
20. Explain how hyphae help a fungus absorb food.
21. The phyla Ascomycota and Basidiomycota are both in the kingdom Fungi. What structures are the basis for placing organisms in one or the other of these phyla? TEKS 8B, 8C
22. Describe sexual reproduction in yeast, or single-celled fungi.
23. How can the hyphae of bread molds be involved in both asexual and sexual reproduction?
24. Why are yeasts useful to scientific research? TEKS 11C
25. How is the decomposing activity of fungi both beneficial and harmful? TEKS 11C

Greek and Latin Word Origins

7. The term hyphae comes from the Greek word huphe, which means “web.” Explain how this meaning relates to hyphae.

8. The term mycorrhizae comes from the Greek words mukes, which means “fungus,” and rhiza, which means “root.” Explain how these meanings relate to mycorrhizae.

Labeling Diagrams

In your notebook, write the vocabulary term that matches each numbered item below.

9.

10.

11.
Critical Thinking

26. **Analyze** What characteristics of protists prevent them from being classified as animals, plants, or fungi? **TEKS 8B, 8C**

27. **Analyze** Amoebas have pseudopods, zooflagellates have flagella, and ciliates have cilia to help them move. Would you expect to find each of these types of protists on land or water? Explain your answer. **TEKS 8B, 8C**

28. **Classify** A new plantlike protist has been discovered. It has the following characteristics: two flagella, found in a marine environment, body covering made of cellulose. What phylum would it likely be placed in? **TEKS 8B, 8C**

29. **Describe** The prefix pseudo- means “false” or “fake.” Why is the term pseudoplasmodium used to describe one form of a cellular slime mold? **TEKS 8B, 8C**

30. **Predict** A grape crop is infected with a fungus. There is a fungicide that targets only this kind of fungus and kills it. But a broad-spectrum fungicide that kills many kinds of fungi is cheaper, and the farmer decides to use it instead. Explain why the farmer’s crops may actually become less healthy. **TEKS 11C**

Interpreting Visuals

Use the diagram below to answer the next two questions.

31. **Analyze** What does this diagram suggest about the relationship between fungi and animals, as compared with fungi and plants? **TEKS 8B, 8C**

32. **Interpret** Are green algae more closely related to red algae or plants? Explain your answer. **TEKS 8B, 8C**

Analyzing Data  Analyze Experimental Design

Use the text and the data below to answer the next two questions. The following experiment was conducted by two students to determine if adding yeast to a decomposing fruit would speed up the rate of decomposition.

Two 3-cm² pieces of banana were cut. Each was placed in a different plastic bag and the bags were sealed. Each student took one of the banana pieces home.

- Student A placed her banana piece on a bookshelf.
- Student B put some dry yeast on his banana and resealed the bag. He also put his banana piece on a bookshelf.

Both students looked at the banana pieces every day for the next four days and recorded their observations.

**PERCENT DECOMPOSITION**

<table>
<thead>
<tr>
<th>Organism</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student A’s banana</td>
<td>1%</td>
<td>5%</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td>Student B’s banana</td>
<td>0%</td>
<td>4%</td>
<td>7%</td>
<td>10%</td>
</tr>
</tbody>
</table>

33. **Experimental Design** What is the main design flaw in this experiment? **TEKS 8B, 8C**

34. **Analyze** Does the experimental design clearly support the question that the students were trying to answer? Explain. **TEKS 8B, 8C**

Making Connections

35. **Write an Argument** Write an imaginary argument between two euglenoids in which one wants to be placed with animals and the other wants to be placed with plants. Include the decision of the referee who explains why they can be neither plants nor animals. **TEKS 8B, 8C**

36. **Evaluate** Look again at the picture of Didinium eating the Paramecium on the chapter opener. What might be one advantage and disadvantage of having a specialist feeding strategy? a generalist feeding strategy? Explain your answer.
Record your answers on a separate piece of paper.

**MULTIPLE CHOICE**

**TEKS 2C, 6H, 8C**

1. When scientists first observed protists with chlorophyll, they thought the protists were actually single-celled plants. By using more recent molecular techniques, scientists have determined that these organisms are genetically different from plants. This is an example of —
   A. how scientific theories can change with the development of new technologies
   B. why scientific theories should not be influenced by new scientific evidence
   C. why all scientific investigations should involve genetic analysis
   D. why protists should be classified as plants

2. The grouping of kingdoms into prokaryotes and eukaryotes is shown in the Venn diagram above. One cellular characteristic that could be placed in the area that overlaps both groups is —
   A. nucleus
   B. organelles
   C. chloroplasts
   D. cell membrane

3. Diatoms carry out a large portion of the photosynthesis that occurs on Earth. In which biogeochemical cycle do diatoms probably have the greatest effect?
   A. phosphorus cycle
   B. nitrogen cycle
   C. carbon cycle
   D. water cycle

**TEKS 8C, 12A**

4. Most fungi are decomposers. How do their life processes affect other organisms in the community?
   A. Fungi keep other populations under control by preying on weak organisms.
   B. Fungi make stored nutrients available to other organisms.
   C. Fungi compete with plants for soil nutrients.
   D. Fungi compete with plants and animals for space.

**THINK THROUGH THE QUESTION**

If you are having a hard time answering this question in terms of fungi, try to consider it based on the role of decomposers in general.

**TEKS 2G**

5. A researcher discovers a new type of organism. Only some structures, labeled above, can be seen clearly. Based on this information, the researcher is able to conclude that the organism —
   A. is a protist that lives in colonies
   B. is a multicellular protist
   C. can capture energy from the sun
   D. will not prey upon other organisms

6. Yeast is a single-celled fungus that can reproduce both asexually and sexually. How is sexual reproduction in a yeast cell different from sexual reproduction in animals?
   A. In a yeast cell, the DNA is not copied.
   B. The yeast cell does not undergo meiosis.
   C. During meiosis, a yeast cell produces only two haploid nuclei.
   D. During meiosis in a yeast cell, the cytoplasm does not divide.
Pandemics—Is the Next One on the Way?

Imagine that a new virus emerges and people have no immunity. There is no vaccine. If this were to happen, there could be mandatory travel restrictions, quarantines, and social distancing—including staying out of all crowded places. In the United States alone, such an outbreak could kill up to 2 million people. But how can such a virus emerge, and how can we prepare for it?
Pandemics

When a new virus emerges, it infects organisms that have not developed immunity, or resistance, to the virus. If a new virus infects humans, it may spread easily from person to person before a vaccine can be produced. A disease outbreak that affects large areas of the world and has a high fatality rate is called a pandemic. The disease is spread very quickly through infection—for example, by sneezing or coughing—to a great number of people.

The 1918 flu pandemic was the most devastating pandemic recorded in world history. This virus infected nearly one-fifth of the world’s population, killing about 50 million people worldwide. It spread mainly along global trade routes and with the movement of soldiers during World War I.

If a new and deadly disease emerges today, a pandemic could rapidly result. A carrier could travel around the world in 24 hours. Several million people travel internationally by plane every year, easily reaching their destinations before they show any symptoms of carrying a disease.

The “Perfect” Virus

Not every virus is well suited to cause massive human casualties. For many viruses, humans represent a dead-end infection because they cannot be passed from human to human. For other viruses, victims die too quickly for the virus to reproduce. Quarantines can contain this type of virus relatively easily.

What characteristics would make an emerging virus likely to cause a pandemic? The virus would need to be adapted to humans as hosts and easily spread through casual contact. Victims would also have to survive infection long enough without symptoms to go about their daily business and infect other people. Finally, the most deadly virus would mutate rapidly, foiling the attempts of scientists to develop a vaccine or a drug that targets it.

Dissecting a Virus

Scientists have long debated how the genetic material of influenza A viruses, RNA, is likely arranged. In 2005 virologist Yoshihiro Kawaoka and his team of researchers at the University of Wisconsin unraveled the mystery using a technique called electron tomography.

Electron tomography is a way to construct a three-dimensional image from a series of electron microscope images taken at different angles. By making slices along flu virus particles that cut them into “top” and “bottom” halves, researchers found that all influenza A viruses have a total of eight RNA strands. As shown at the right, seven strands form a circle just inside the edge of the virus particle, surrounding an eighth strand in the center.

Based on this similarity in structure, the researchers concluded that all influenza A viruses must share a specific mechanism for packaging their genetic material. This knowledge may make it possible to engineer viruses that can be used to mass produce vaccines to defend against these viruses, which are responsible for regular seasonal outbreaks as well as the avian flu.

Read More at HMDScience.com
Diseases That Jump to New Species

A zoonosis is a disease that can jump between species. A virus that evolves the ability to jump from a nonhuman animal species to humans will spread very quickly in the human body, which has not yet developed defenses. If this virus exchanges genetic material with another human virus, the virus may become capable of spreading from person to person.

The swine flu pandemic was caused by the H1N1 virus that originated in pigs. In 2009, it was estimated that 22 million people were infected with the H1N1 virus! World health officials urged individuals to get vaccinated and educated people on its symptoms. A year later, the swine flu was officially contained.

Avian Flu H5N1

Perhaps the most familiar zoonosis is the avian flu virus. Sometimes called the bird flu, this virus normally infects wild birds such as ducks and geese as well as domestic birds such as chickens. Migrating birds can carry it to other continents.

Researchers have been tracking a form of avian flu called H5N1. Like other flu viruses, H5N1 mutates rapidly. Random mutations may or may not help the virus adapt to new host species. However, viruses can mutate in a faster, less random way. If an animal becomes infected with viruses from two different species at the same time, the viruses can exchange genetic information. If this happens, the avian flu can jump the species barrier, becoming a flu virus that can be transmitted from one human to another.

Unanswered Questions

Despite the danger that a new virus represents, no one knows how the virus may mutate or whether it will cause a pandemic. Some of the most important questions include the following:

- How can vaccines be developed quickly enough to stop a disease that can spread in hours or days?
- Can a broad-spectrum antiviral drug be developed that could target more than one flu virus?
- What specific molecular factors allow a virus to jump from one species to another?