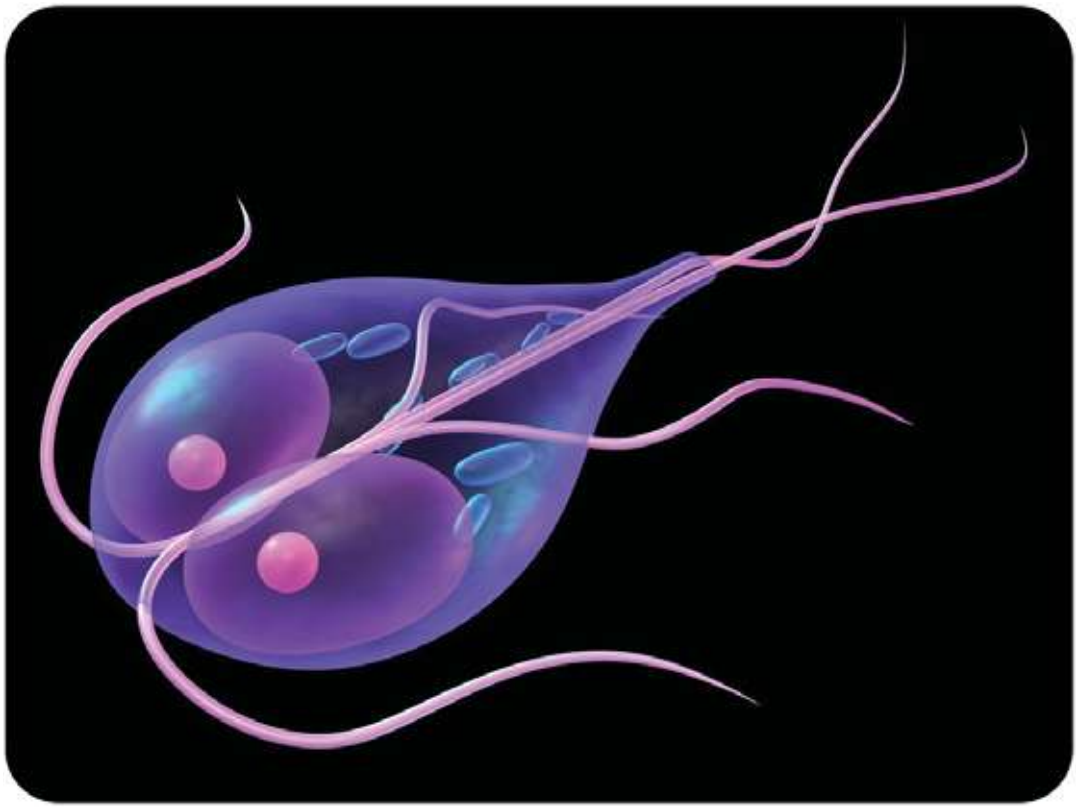
Chapter 14

Eukaryotes: Protists and Fungi



This organism consists of a single cell with several flagella. Is it a prokaryote, such as a bacterium? Actually, it's larger than a prokaryotic cell, and it also has a nucleus. Therefore, this organism belongs to the domain Eukarya, the domain that includes humans. This particular eukaryote is one of the smallest, simplest organisms in the domain, called a protist. It's scientific name is *Giardia lamblia.* As a human parasite, it can make us sick.

In this chapter, you'll read more about protists like *Giardia lamblia.* You'll discover that protists have a wide diversity of traits and ways of life. And only some of them make us sick.

14.1 Introduction to Protists

Lesson Objectives

- Describe the protist kingdom.
- Outline the evolution of protists.
- Identify protist characteristics.

Vocabulary

- cilia (singular, cilium)
- motility
- protist
- pseudopod

Introduction

Protists are the simplest eukaryotes. They are easiest to define by what they are not. Protists are not animals, plants, or fungi.

Kingdom Protista

The protist kingdom is sometimes called the "trash can" kingdom. It includes all eukaryotes that don't fit in one of the other three eukaryote kingdoms: Animalia, Plantae, or Fungi. There are thought to be between 60,000 and 200,000 protist species. Many have yet to be identified. The protist kingdom is very diverse, as shown in **Figure** 14.1.

Evolution of Protists

Scientists think that protists are the oldest eukaryotes. If so, they must have evolved from prokaryotic cells. How did this happen? The endosymbiotic theory provides the most widely-accepted explanation. That's because it is well supported by evidence.

The First Eukaryotic Cells

According to the endosymbiotic theory, the first eukaryotic cells evolved from a symbiotic relationship between two or more prokaryotic cells. Smaller prokaryotic cells were engulfed by (or invaded) larger prokaryotic cells. The small cells (now called endosymbionts) benefited from the relationship by getting a safe home and nutrients. The large cells (now called hosts) benefited by getting some of the organic molecules or energy released by the endosymbionts. Eventually, the endosymbionts evolved into organelles of the host cells. After that, neither could live without the other.

As shown in **Figure** 14.2, some of the endosymbionts were aerobic bacteria. They were specialized to break down chemicals and release energy. They evolved into the mitochondria of eukaryotic cells. Some of the small cells were cyanobacteria. They were specialized for photosynthesis. They evolved into the chloroplasts of eukaryotic cells.

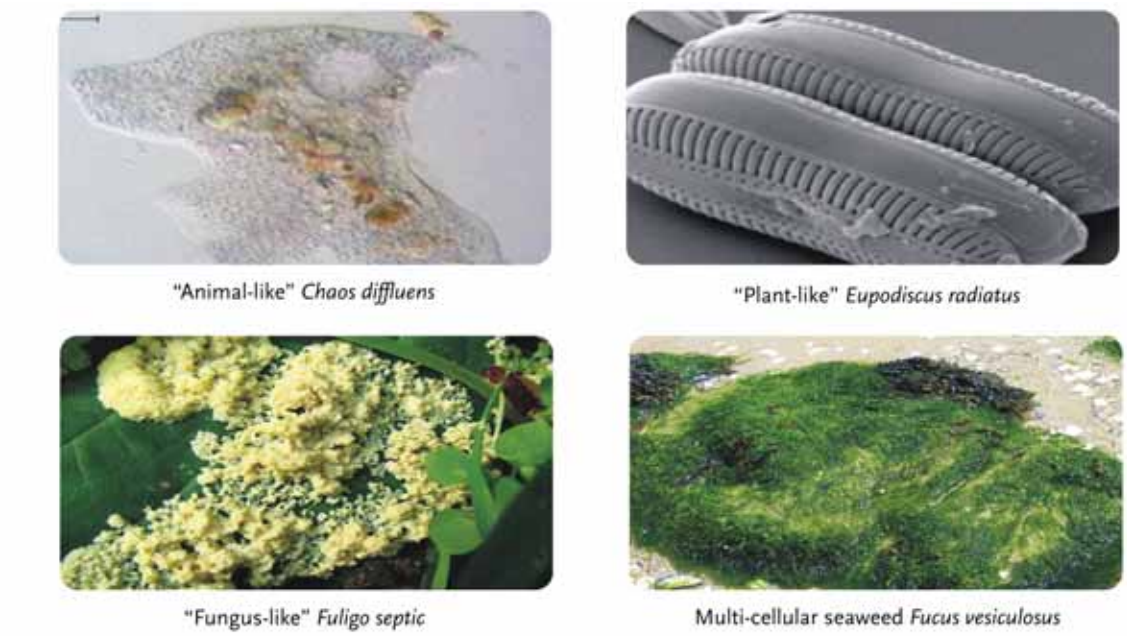


Figure 14.1: Protists range from single-celled amoebas to multicellular seaweed. Protists may be similar to animals, plants, or fungi.

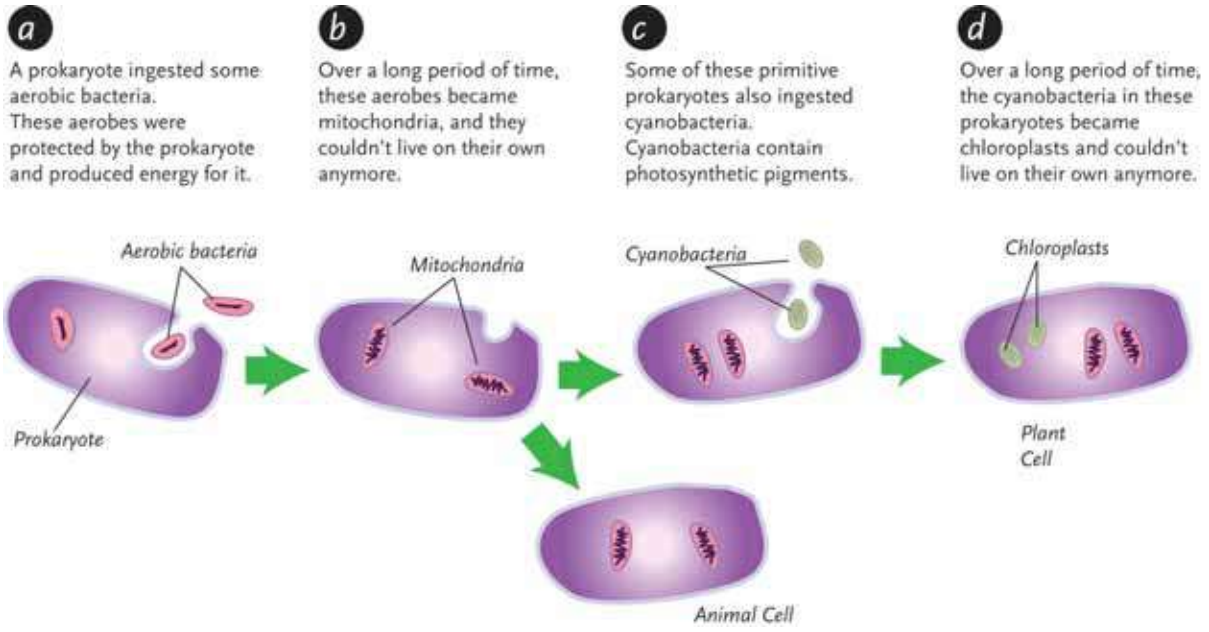


Figure 14.2: Endosymbiotic theory explains how eukaryotic cells arose.

Evidence for the Endosymbiotic Theory

Many pieces of evidence support the endosymbiotic theory. For example:

- Mitochondria and chloroplasts contain DNA that is different from the DNA found in the cell nucleus. Instead, it is similar to the circular DNA of bacteria.
- Mitochondria and chloroplasts are surrounded by their own plasma membranes, which are similar to bacterial membranes.
- New mitochondria and chloroplasts are produced through a process similar to binary fission. Bacteria also reproduce through binary fission.
- The internal structure and biochemistry of chloroplasts is very similar to that of cyanobacteria.

Characteristics of Protists

Like all other eukaryotes, protists have a nucleus containing their DNA. They also have other membrane-bound organelles, such as mitochondria. Most protists are single-celled. Some are multicellular. Because the protist kingdom is so diverse, their ways of getting food and reproducing vary widely.

Protist Habitats

Most protists are aquatic organisms. They need a moist environment to survive. They are found mainly in damp soil, marshes, puddles, lakes, and the ocean. Some protists are free-living organisms. Others are involved in symbiotic relationships. They live in or on other organisms, including humans.

Motility of Protists

Most protists have **motility**. This is the ability to move. Protists have three types of appendages for movement. As shown in **Figure** 14.3, they may have flagella, **cilia**, or pseudopods ("false feet"). There may be one or more whip-like flagella. Cilia are similar to flagella, except they are shorter and there are more of them. They may completely cover the surface of the protist cell. **Pseudopods** are temporary, foot-like extensions of the cytoplasm.

Protist Reproduction

Protists have complex life cycles. Many have both asexual and sexual reproduction. An example is a protist called *Spirogyra*, a type of algae, shown **Figure** 14.4. It usually exists as haploid cells that reproduce by binary fission. In a stressful environment, such as one that is very dry, *Spirogyra* may produce tough spores that can withstand harsh conditions. Spores are reproductive cells produced by protists (and other organisms). If two protist spores are close together, they can fuse to form a diploid zygote. This is a type of sexual reproduction. The zygote then undergoes meiosis, producing haploid cells that repeat the cycle.

Protist Nutrition

Protists get food in one of three ways. They may ingest, absorb, or make their own organic molecules.

- Ingestive protists ingest, or engulf, bacteria and other small particles. They extend their cell wall and cell membrane around the food item, forming a food vacuole. Then enzymes digest the food in the vacuole.

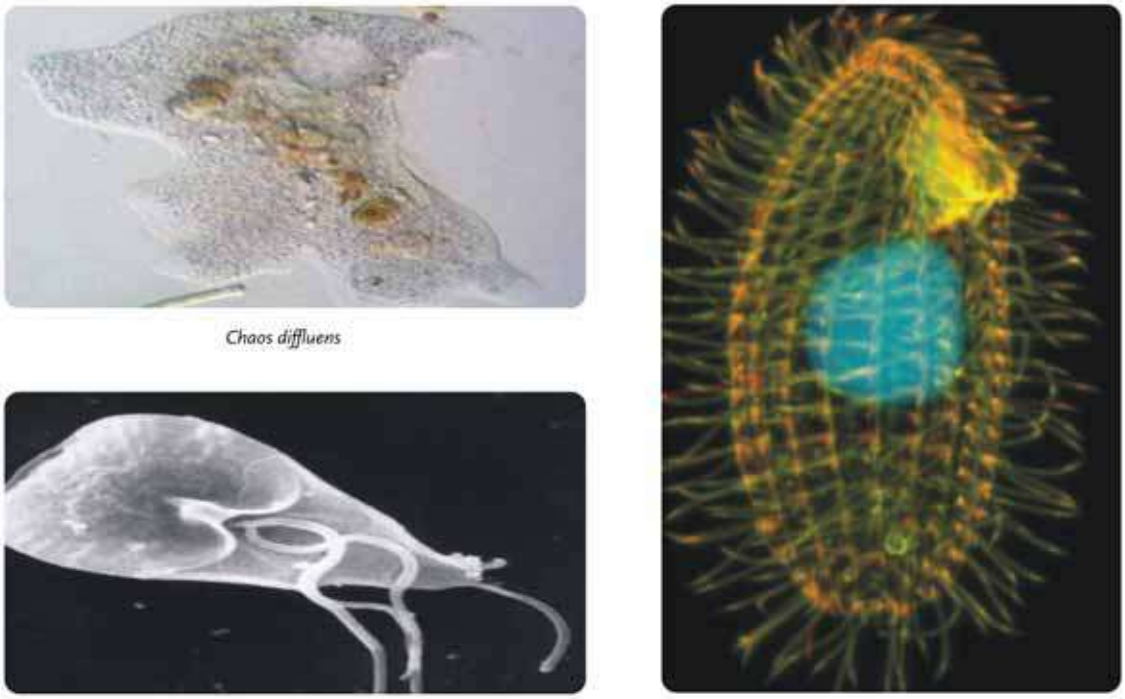


Figure 14.3: Protists use flagella, cilia, or pseudopods to move.

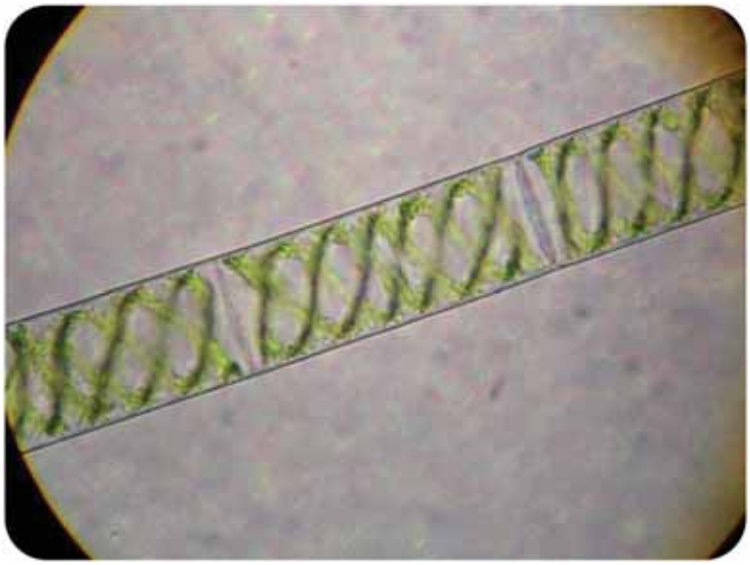


Figure 14.4: Spirogyra is a genus of algae with a complex life cycle. Each organism consists of rectangular cells connected end-to-end in long filaments.

- Absorptive protists absorb food molecules across their cell membranes. This occurs by diffusion. These protists are important decomposers.
- Photosynthetic protists use light energy to make food. They are major producers in aquatic ecosystems.

Lesson Summary

- Kingdom Protista includes all eukaryotes that are not animals, plants, or fungi. It is a very diverse kingdom. It consists of both single-celled and multicellular organisms.
- Scientists think that protists are the oldest eukaryotes. They most likely evolved from prokaryotic cells, as explained by the endosymbiotic theory. This theory is well-supported by evidence.
- Protists have nuclear membranes around their DNA. They also have other membrane-bound organelles. Many live in aquatic habitats, and most are motile, or able to move. Protists have complex life cycles that may include both sexual and asexual reproduction. They get food through ingestion, absorption, or photosynthesis.

Lesson Review Questions

Recall

1. What are protists?
2. How did the first eukaryotic cells evolve, according to endosymbiotic theory?
3. Identify three structures that protists use to move.
4. Describe three ways that protists get food.

Apply Concepts

5. A mystery organism consists of one cell. It could be a protist or a prokaryote. What single fact about the mystery cell would allow you to determine which type of organism it is? Explain your answer.

Think Critically

6. Identify one piece of evidence for endosymbiotic theory. Explain how this evidence supports the theory.
7. Compare and contrast asexual and sexual reproduction in protists.

Points to Consider

Protists are traditionally classified as animal-like, plant-like, or fungi-like. You will read more about each of these types of protists in the next lesson.

- Based on what you already know about animals, plants, and fungi (such as mushrooms), how might the three types of protists differ?
- Why do you think these protists are not classified with the organisms they resemble? For example, why aren't animal-like protists classified as animals? What sets protists apart from other eukaryotes?

14.2 Types of Protists

Lesson Objectives

- Describe animal-like protists.
- Give an overview of plant-like protists.
- Identify types of fungus-like protists.

Vocabulary

- algae (singular, alga)
- amoeboid
- ciliate
- flagellate
- kelp
- protozoa (singular, protozoan)
- slime mold
- sporozoa (singular, sporozoan)
- water mold

Introduction

Protists are often classified based on how similar they are to other eukaryotes—animals, plants, and fungi. This lesson describes protists that resemble each of these other eukaryote kingdoms.

Animal-Like Protists: Protozoa

Animal-like protists are commonly called **protozoa** (singular, protozoan). Most protozoa consist of a single cell. They are animal-like because they are heterotrophs, and are capable of moving. Although protozoa are not animals, they are thought to be the ancestors of animals.

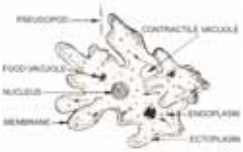
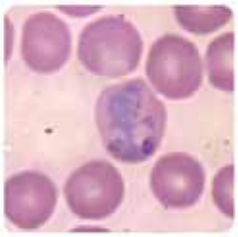
Ecology of Protozoa

Protozoa generally feed by engulfing and digesting other organisms. As consumers, they have various roles in food chains and webs. Some are predators. They prey upon other single-celled organisms, such as bacteria. In fact, protozoa predators keep many bacterial populations in check. Other protozoa are herbivores. They graze on algae. Still others are decomposers. They consume dead organic matter. There are also parasitic protozoa that live in or on living hosts. For example, the protozoan that causes malaria lives inside a human host. For their part, protozoa are important food sources for many larger organisms, including insects and worms.

Classification of Protozoa

Protozoa can be classified on the basis of how they move. As shown in **Table** 14.1, protozoa move in three different ways. Only sporozoa cannot move. Note that this classification is based only on differences in movement. It does not represent phylogenetic relationships.

Table 14.1: **Classification of Protozoa Based on Movement**

Type of Protozoa	How It Moves	Example (Genus)
Amoeboid	pseudopods	*Amoeba* 
Ciliate	cilia	*Paramecium* 
Flagellate	flagella	*Giardia* 
Sporozoan	does not move (as adult)	*Plasmodium* 

Plant-Like Protists: Algae

Plant-like protists are called **algae** (singular, alga). They are a large and diverse group. Some algae, diatoms, are single-celled. Others, such as seaweed, are multicellular (see **Figure** 14.5).

Why are algae considered plant-like? The main reason is that they contain chloroplasts and produce food through photosynthesis. However, they lack many other structures of true plants. For example, algae do not have roots, stems, or leaves. Some algae also differ from plants in being motile. They may move with pseudopods or flagella. Although not plants themselves, algae were probably the ancestors of plants.

Figure 14.5: Diatoms are single-celled algae. Other forms of algae are multicellular.

Ecology of Algae

Algae play significant roles as producers in aquatic ecosystems. Microscopic forms live suspended in the water column. They are the main component of phytoplankton. As such, they contribute to the food base of most marine ecosystems.

Multicellular seaweeds called **kelp** may grow as large as trees. They are the food base of ecosystems called kelp forests (see **Figure** 14.6). Kelp forests are found throughout the ocean in temperate and arctic climates. They are highly productive ecosystems.

Figure 14.6: Kelp Forest. This kelp forest supports a large community of many other types of organisms.

Classification of Algae

Types of algae include red and green algae, euglenids, and dinoflagellates (see **Table** 14.2 for examples). Scientists think that red and green algae evolved from endosymbiotic relationships with cyanobacteria. Their chloroplasts have two membranes because the cell membranes of the cyanobacteria became additional plasma membranes of the chloroplasts. Scientists think that euglenids and dinoflagellates evolved later, from endosymbiotic relationships with green and red algae. This is why their chloroplasts have three membranes. Differences in the types of chlorophyll in the four types of algae also support the hypothesized evolutionary relationships.

Table 14.2: **Types of Algae**

Type of Algae	Origin of Chloroplast	Type of Chloroplast
Red algae 	cyanobacteria	two membranes, chlorophyll like the majority of cyanobacteria
Green algae 	cyanobacteria	two membranes, chlorophyll like a minority of cyanobacteria
Euglenids 	green algae	three membranes, chlorophyll like green algae
Dinoflagellates 	red algae	three membranes, chlorophyll like red algae

Reproduction of Algae

Algae have varied life cycles. Two examples are shown in **Figure** 14.7. Both cycles include phases of asexual reproduction (haploid, n) and sexual reproduction (diploid, $2n$). Why go to so much trouble to reproduce? Asexual reproduction is fast, but it doesn't create new genetic variation. Sexual reproduction is more complicated and risky, but it creates new gene combinations. Each strategy may work better under different conditions. Rapid population growth is adaptive when conditions are favorable. Genetic variation helps ensure that some organisms will survive if the environment changes.

KQED: Algae Power

QUEST explores the potential of algae-–once considered nothing more than pond scum–-to become the fuel of the future. Entrepreneurs from throughout California are working to create the next generation of biofuels from algae. But will you ever be able to run your car off it? See `http://www.kqed.org/quest/television/algae-power` for additional information.

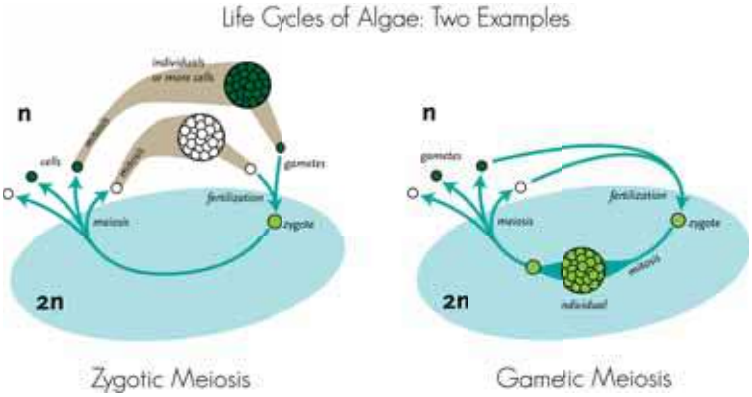


Figure 14.7: Life Cycles of Algae: Two Examples - Zygotic meiosis and Gametic meiosis. In life cycle A (left), diploid (2n) zygotes undergo meiosis and produce haploid (n) gametes. The gametes undergo mitosis and produce many additional copies of themselves. How is life cycle B (right) different from life cycle A?

Figure 14.8: (Watch Youtube Video)
http://www.ck12.org/flexbook/embed/view/1215

Fungus-Like Protists: Molds

Fungus-like protists are molds. They are absorptive feeders on decaying organic matter. They resemble fungi, and they reproduce with spores as fungi do. However, in other ways, they are quite different from fungi and more like other protists. For example, they have cell walls made of cellulose, whereas fungi have cell walls made of chitin. Like other protists, they have complicated life cycles with both asexual and sexual reproduction. They are motile cells during some stages of their life cycle. Two major types of fungus-like protists are slime molds and water molds.

Slime Molds

Slime molds are fungus-like protists commonly found on rotting logs and compost. They move very slowly in search of decaying matter to eat. When food is scarce, individual cells swarm together to form a blob-like mass, like the "dog vomit" slime mold in **Figure** 14.9. The mass glides along on its own secretions, engulfing decaying organic matter as it moves over it.

Figure 14.9: "Dog Vomit" Slime Mold. This slime mold looks like its name.

There are two types of slime molds when it comes to how they swarm: acellular and cellular.

- When acellular slime molds swarm, they fuse together to form a single cell with many nuclei.
- When cellular slime molds swarm, they remain as distinct cells.

Cellular slime molds are used as model organisms in molecular biology and genetics. They may be the key to how multicellular organisms evolved. Can you explain why?

Water Molds

Water molds are commonly found in moist soil and surface water. Many are plant pathogens that destroy crops. They infect plants such as grapes, lettuce, corn, and potatoes. Some water molds are parasites of fish and other aquatic organisms, such as the mold in **Figure** 14.10.

Figure 14.10: Water mold is growing on this fly larva.

Lesson Summary

- Animal-like protists are called protozoa. Most consist of a single cell. Like animals, they are heterotrophic and capable of moving. Examples of protozoa include amoebas and paramecia.
- Plant-like protists are called algae. They include single-celled diatoms and multicellular seaweed. Like plants, they contain chlorophyll and make food by photosynthesis. Types of algae include red and green algae, euglenids, and dinoflagellates.
- Fungus-like protists are molds. They are absorptive feeders, found on decaying organic matter. They resemble fungi and reproduce with spores as fungi do. Examples of fungus-like protists include slime molds and water molds.

Lesson Review Questions

Recall

1. How are protozoa similar to animals?
2. What roles do protozoa play in food chains and webs?
3. State pros and cons of asexual and sexual reproduction in algae.
4. How are fungus-like protists similar to fungi? What is one way they are different?

Apply Concepts

5. Assume that a new species of organism has been discovered and it's your job to classify it. The organism consists of a single cell with a nucleus. It has cilia and obtains food by consuming other single-celled organisms. Name a genus that the new species could possibly be placed in. Explain your answer.

Think Critically

6. Compare and contrast algae and plants.

7. Explain why dinoflagellates and euglenids have chloroplasts with three membranes instead of two.

8. Why might cellular slime molds—but not acellular slime molds—be the key to how multicellular organisms evolved?

Points to Consider

In this lesson you read about slime molds and water molds. These aren't the only kinds of molds. In fact, you are probably more familiar with molds that are classified as fungi. The next lesson introduces the fungi.

- How do you think fungi might be different from fungi-like protists? (*Hint:* Fungi are also eukaryotes, but they belong to a different kingdom than protists.)
- What types of molds might be fungi rather than protists?

14.3 Introduction to Fungi

Lesson Objectives

- Identify what fungi are.
- Describe habitats of fungi.
- Outline the structure of fungi.
- Describe fungi reproduction.
- Summarize the evolution of fungi.
- Give an overview of fungi classification.

Vocabulary

- budding
- chitin
- fungi (singular, fungus)
- hyphae (singular, hypha)
- mycelium
- zygospore

Introduction

Do you see the organisms growing on the bread in **Figure** 14.11? They belong to the Kingdom Fungi. Molds growing on foods are some of the most common fungi in our everyday lives. These organisms may seem useless, gross, and costly. But fungi play very important roles in almost every terrestrial ecosystem on Earth.

Figure 14.11: The mold growing on this bread is a common fungus.

What Are Fungi?

Fungi (singular, fungus) are a kingdom in the domain Eukarya. The fungi kingdom may contain more than a million species, but fewer than 100,000 have been identified. As shown in **Figure** 14.12, fungi include mushrooms and yeasts in addition to molds.

Figure 14.12: Several examples of fungi are pictured here.

Most fungi are multicellular, but some exist as single cells. Fungi spend most of their life cycle in the haploid state. They form diploid cells only during sexual reproduction. Like the cells of protists and

plants, the cells of fungi have cell walls. But fungi are unique in having cell walls made of chitin instead of cellulose. **Chitin** is a tough carbohydrate that also makes up the exoskeleton (outer skeleton) of insects and related organisms.

Habitats of Fungi

You probably already know where some species of fungi live. No doubt, you've seen them growing on rotting logs and moist soil. In fact, most fungi live on dead matter or soil. However, some fungi are aquatic. Others live in or on other organisms in symbiotic relationships.

Structure of Fungi

Except for yeasts, which grow as single cells, most fungi grow as thread-like filaments, like those shown in **Figure** 14.13. The filaments are called **hyphae** (singular, hypha). Each hypha consists of one or more cells surrounded by a tubular cell wall. A mass of hyphae make up the body of a fungus, which is called a **mycelium** (plural, mycelia).

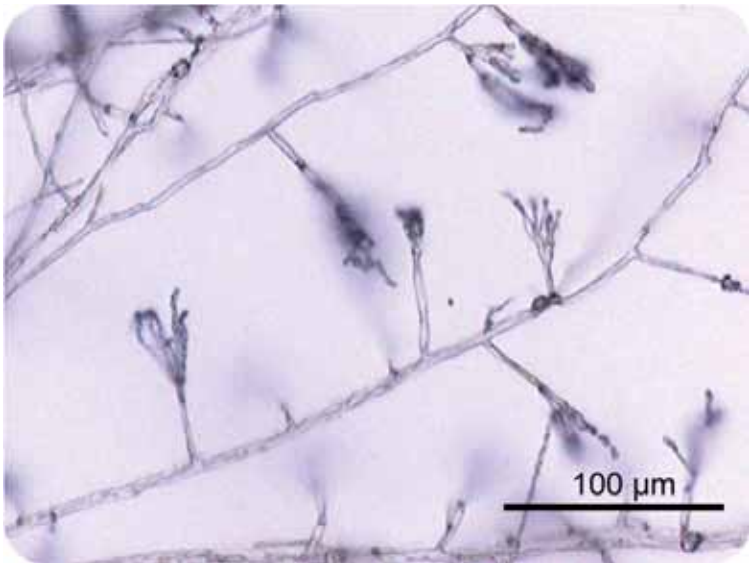


Figure 14.13: These branches are hyphae, or filaments, of a mold called Penicillium.

A mycelium may range in size from microscopic to very large. In fact, one of the largest living organisms on Earth is the mycelium of a single fungus. A small part of a similar fungus is pictured in **Figure** 14.14. The giant fungus covers 8.9 square kilometers (3.4 square miles) in an Oregon forest. That's about the size of a small city. The fungus didn't grow that large over night. It's estimated to be 2,400 years old—and it's still growing!

Reproduction of Fungi

The majority of fungi can reproduce both asexually and sexually. This allows them to adjust to conditions in the environment. They can spread quickly through asexual reproduction when conditions are stable. They can increase their genetic variation through sexual reproduction when conditions are changing and variation may help them survive.

Figure 14.14: The fungus shown here has been dubbed the "humongous fungus" because it covers such a large area.

Asexual Reproduction

Almost all fungi reproduce asexually by producing spores. A fungi spore is a haploid cell produced by mitosis from a haploid parent cell. It is genetically identical to the parent cell. Fungi spores can develop into new haploid individuals without being fertilized.

Spores may be dispersed by moving water, wind, or other organisms. Some fungi even have "cannons" that "shoot" the spores far from the parent organism. This helps to ensure that the offspring will not have to compete with the parents for space or other resources. You are probably familiar with puffballs, like the one in **Figure** 14.15. They release a cloud of spores when knocked or stepped on. Wherever the spores happen to land, they do not germinate until conditions are favorable for growth. Then they develop into new hyphae.

Yeasts do not produce spores. Instead, they reproduce asexually by budding. **Budding** is the pinching off of an offspring from the parent cell. The offspring cell is genetically identical to the parent. Budding in yeast is pictured in **Figure** 14.16.

Sexual Reproduction

Sexual reproduction also occurs in virtually all fungi. This involves mating between two haploid hyphae. During mating, two haploid parent cells fuse, forming a diploid spore called a **zygospore**. The zygospore is genetically different from the parents. After the zygospore germinates, it can undergo meiosis, forming haploid cells that develop into new hyphae.

Evolution of Fungi

DNA evidence suggests that almost all fungi have a single common ancestor. The earliest fungi may have evolved about 600 million years ago or even earlier. They were probably aquatic organisms with a flagellum. Fungi first colonized the land at least 460 million years ago, around the same time as plants. Fossils of terrestrial fungi date back almost 400 million years (see **Figure** 14.17). Starting about 250 million years ago, the fossil record shows fungi were abundant in many places. They may have been the dominant life forms on Earth at that time.

Figure 14.15: Puffballs release spores when disturbed.

Figure 14.16: Yeast reproduce asexually by budding.

Figure 14.17: This rock contains fossilized fungi. The fungi lived 396 million years ago in what is now Scotland. They were preserved when they were covered with lava from a volcano. The lava cooled and hardened into rock.

Classification of Fungi

For a long time, scientists considered fungi to be members of the plant kingdom because they have obvious similarities with plants. Both fungi and plants are immobile, have cell walls, and grow in soil. Some fungi, such as lichens, even look like plants (see **Figure** 14.18).

Figure 14.18: Moss (Plant) and Lichen Growing on Tree Bark. Both fungi and moss are growing on this tree. Can you tell them apart?

The Kingdom Fungi

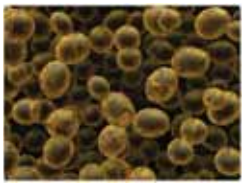
Today, fungi are no longer classified as plants. We now know that they have unique physical, chemical, and genetic traits that set them apart from plants (and other eukaryotes). For example, the cell walls of

fungi are made of chitin, not cellulose. Also, fungi absorb nutrients from other organisms, whereas plants make their own food. These are just a few of the reasons fungi are now placed in their own kingdom.

Fungal Phyla

Classification of fungi below the level of the kingdom is controversial. There is no single, widely-accepted system of fungal classification. Most classifications include several phyla (the next major taxon below the kingdom). Three of the most common phyla are compared in **Table** 14.3.

Table 14.3: **Three Common Phyla of Fungi**

Phylum	Description	Example
Zygomycota	mainly terrestrial, live in soil and compost and on foods such as bread	black bread mold 
Basidiomycota	have many different shapes, considerable variation exists even within species	button mushrooms 
Ascomycota	found in all terrestrial ecosystems world-wide, even in Antarctica, often involved in symbiotic relationships	baker's yeast 

Lesson Summary

- Fungi are a kingdom in the domain Eukarya that includes molds, mushrooms, and yeasts. Most fungi are multicellular. They are unique in having cell walls made of chitin.
- Most fungi live on dead matter or soil. Some live in aquatic habitats. Many are involved in symbiotic relationships.
- Most fungi grow as thread-like filaments called hyphae. A mass of hyphae make up the body of a fungus, called a mycelium.
- The majority of fungi can reproduce both asexually and sexually. This allows them to adjust to conditions in the environment. Yeast reproduce asexually by budding. Other fungi reproduce asexually by producing spores. Sexual reproduction occurs when spores from two parents fuse and form a zygospore.
- Almost all fungi have a single common ancestor. The earliest fungi may have evolved about 600 million years ago. Fungi colonized land at least 460 million years ago. By 250 million years ago, they may have been the dominant life forms on Earth.
- Fungi used to be classified as plants. Now, they are known to have unique traits that set them apart

from plants. For example, their cell walls contain chitin, not cellulose, and fungi absorb food rather than make their own. Below the level of the kingdom, fungi classification is controversial.

Lesson Review Questions

Recall

1. What are fungi?
2. List several habitats where fungi live.
3. Describe the general structure of multicellular fungi.
4. Identify ways that fungi spores may be dispersed.
5. Summarize the evolution of fungi.
6. State why fungi were once classified as plants.

Apply Concepts

7. Create a diagram to show the life cycle of a multicellular fungus.

Think Critically

8. Explain the significance of the chitin cell wall of fungi.
9. Compare and contrast a fungi spore and zygospore.

Points to Consider

In this lesson, you read that fungi differ from plants in major ways. For example, unlike plants, fungi do not make their own food by photosynthesis.

- How do you think fungi obtain food? What organisms might they consume?
- What roles do you think fungi might play in food chains and webs?

14.4 Ecology of Fungi

Lesson Objectives

- Describe the role of fungi as decomposers.
- Identify symbiotic relationships of fungi.
- List human uses of fungi.

Vocabulary

- lichen
- mycorrhiza

Introduction

Fungi lack chlorophyll, so they cannot make food by photosynthesis as plants can. Instead, they are heterotrophs, like animals. But they don't have a mouth or teeth. So how do fungi "eat"? They get their nutrition by absorbing organic compounds from other organisms. The other organisms may be dead or alive, depending on the fungus.

Fungi as Decomposers

Most fungi get organic compounds from dead organisms. They are decomposers called saprotrophs. A saprotroph feeds on any remaining organic matter after other decomposers do their work. Fungi use enzymes to digest organic remains and then absorb the resulting organic compounds. As decomposers, fungi are vital for the health of ecosystems. They break down nonliving organic matter and release the nutrients into the soil. Plants can then use the nutrients and pass them on to herbivores and other consumers.

Bacteria are also major decomposers, but they can grow and feed only on the exposed surfaces of organic matter. In contrast, fungi can use their hyphae to penetrate deep into organic matter. Fungi are also the only decomposers that can break down tough plant substances, including lignin (in wood) and cellulose (in plant cell walls). They have special enzymes to do this work. The enzymes are released by the tips of the hyphae. Because of these abilities, fungi are the primary decomposers in forests (see **Figure** 14.19).

Figure 14.19: Forest Decomposers. These forest mushrooms may look fragile, but they do a powerful job. They decompose dead wood and other tough plant material.

Symbiotic Relationships of Fungi

Not all fungi feed on dead organisms. Many are involved in symbiotic relationships, including parasitism and mutualism.

Fungi as Parasites

In a parasitic relationship, the parasite benefits while the host is harmed. Parasitic fungi live in or on other organisms and get their nutrients from them. Fungi have special structures for penetrating a host. They also produce enzymes that break down the host's tissues.

Parasitic fungi often cause illness and may eventually kill their host. They are the major cause of disease in agricultural plants. Fungi also parasitize animals, such as the insect pictured in **Figure** 14.20. Fungi even parasitize humans. Did you ever have athelete's foot? If so, you were the host of a parasitic fungus. You can read more about fungi and human disease in the last lesson of this chapter.

Figure 14.20: Parasitic Fungus and Insect Host. The white parasitic fungus named Cordyceps is shown here growing on its host—a dark brown moth.

Mutualism in Fungi

Fungi have several mutualistic relationships with other organisms. In mutualism, both organisms benefit from the relationship. Two common mutualistic relationships involving fungi are mycorrhiza and lichen.

- A **mycorrhiza** is a mutualistic relationship between a fungus and a plant. The fungus grows in or on the plant roots. The fungus benefits from the easy access to food made by the plant. The plant benefits because the fungus puts out mycelia that help absorb water and nutrients. Scientists think that a symbiotic relationship such as this may have allowed plants to first colonize the land.
- A **lichen** is a mutualistic relationship between a fungus and a photosynthetic organism. The other organism is usually a cyanobacterium or green alga. The fungus grows around the bacterial or algal cells. The fungus benefits from the constant supply of food produced by the photosynthesizer. The photosynthesizer benefits from the water and nutrients absorbed by the fungus. **Figure** 14.21 shows lichen growing on a rock.

Some fungi have mutualistic relationships with insects. For example:

- Leafcutter ants grow fungi on beds of leaves in their nests. The fungi get a protected place to live. The ants feed the fungi to their larvae.
- Ambrosia beetles bore holes in tree bark and "plant" fungal spores in the holes. The holes in the bark give the fungi an ideal place to grow. The beetles harvest fungi from their "garden."

Figure 14.21: Lichen Growing on Rock. Unlike plants, lichen can grow on bare rocks because they don't have roots. That's why lichens are often pioneer species in primary ecological succession. How do lichen get water and nutrients without roots?

Human Uses of Fungi

Whenever you eat pizza, you eat fungi, even if you don't like your pizza with mushrooms. That's because pizza dough contains yeast. Do you know other foods that are made with fungi?

Fungi for Food

Humans have collected and grown mushrooms for food for thousands of years. **Figure** 14.22 shows some of the many types of mushrooms that people eat. Yeasts are used in bread baking and brewing alcoholic beverages. Other fungi are used in fermenting a wide variety of foods, including soy sauce, tempeh, and cheeses. Blue cheese has its distinctive appearance and flavor because of the fungus growing though it (see **Figure** 14.23).

Figure 14.22: These are just a few of the many species of edible mushrooms consumed by humans.

Figure 14.23: Blue Cheese. The dark blue strands running through this cheese are a fungus. In fact, this cheese is moldy! The fungus is Penicillium roqueforti, a type of mold.

Fungi for Pest Control

Harmless fungi can be used to control pathogenic bacteria and insect pasts on crops. Fungi compete with bacteria for nutrients and space, and they parasitize insects that eat plants. Fungi reduce the need for pesticides and other toxic chemicals.

Other Uses of Fungi

Fungi are useful for many other reasons.

- They are a major source of citric acid (vitamin C).
- They produce antibiotics such as penicillin, which has saved countless lives.
- They can be genetically engineered to produce insulin and other human hormones.
- They are model research organisms. To see how one lab is using yeast in cancer research, watch the video at this link: http://college.usc.edu/news/stories/727/yeast-unleashed/.

Lesson Summary

- Most fungi are decomposers called saprotrophs. They feed on decaying organic matter and return nutrients to the soil for plants to use. Fungi are the only decomposers that can break down wood and the cellulose in plant cell walls, so they are the primary decomposers in forests.
- Many fungi are involved in symbiotic relationships. Some are parasites. They are specialized to penetrate a host and break down the host's tissues. Parasitic fungi often cause illness and may eventually kill their host. Two common mutualistic relationships involving fungi are mycorrhiza

(fungi and plant roots) and lichen (fungi and either cyanobacteria or green algae). Some fungi also have mutualistic relationships with insects.
- Humans use fungi for many purposes, including as food or in the preparation of food. Humans also use fungi for pest control. In addition, fungi can be used to produce citric acid, antibiotics, and human hormones. Fungi are model research organisms as well.

Lesson Review Questions

Recall

1. How do fungi obtain organic compounds from dead organisms?
2. Why are fungi the primary decomposers in forests?
3. How significant are fungi as plant parasites?
4. Describe an example of a mutualistic relationship between fungi and insects.
5. List several ways that humans use fungi.

Apply Concepts

6. Assume that you notice a fungus growing on a plant. What possible relationships might exist between the fungus and the plant? What type of evidence might help you identify which is the correct relationship?

Think Critically

7. Compare and contrast mycorrhiza and lichen.
8. Explain how fungi might have allowed early plants to colonize the land.

Points to Consider

You read in this lesson that many fungi are parasites, and they make their hosts sick. An example in humans is athlete's foot.

- Do you know any other human diseases caused by fungi?
- Besides parasitism, how else might fungi make people sick?

14.5 Protists, Fungi, and Human Disease

Lesson Objectives

- Explain how protists cause human disease.
- Identify three ways fungi can make humans sick.

Vocabulary

- athlete's foot

- candidasis
- giardiasis
- malaria
- ringworm

Introduction

Protists and fungi may seem defenseless, but they can be deadly. Both are important causes of disease and death in other living things—including humans.

Protists and Human Disease

Most protist diseases in humans are caused by animal-like protists, or protozoa. Protozoa make us sick when they become human parasites. Three examples of parasitic protozoa are described below.

Trypanosoma Protozoa

Members of the genus *Trypanosoma* are flagellate protozoa that cause sleeping sickness, which is common in Africa. They also cause Chagas disease, which is common in South America. The parasites are spread by insect vectors. The vector for Chagas disease is shown in **Figure** 14.24. *Trypanosoma* parasites enter a person's blood when the vector bites. Then they spread to other tissues and organs. The diseases may be fatal without medical treatment.

Figure 14.24: Vector for Chagas Disease. In Chagas disease, the Trypanosoma parasite is spread by an insect commonly called the "kissing bug." A bite from this bug could be the kiss of death.

The discovery of Chagas disease is unique in the history of medicine. That's because a single researcher—a Brazilian physician named Carlos Chagas—single-handedly identified and explained the new infectious disease. In the early 1900s, Chagas did careful lab and field studies. He determined the pathogen, vector, host, symptoms, and mode of transmission of the disease that is now named for him.

Giardia Protozoa

Giardia are flagellate protozoa that cause **giardiasis**. The parasites enter the body through food or water that has been contaminated by feces of infected people or animals. The protozoa attach to the lining of the host's small intestine, where they prevent the host from fully absorbing nutrients. They may also cause diarrhea, abdominal pain, and fever. A picture of a *Giardia* protozoan opens this chapter.

Plasmodium Protozoa

Plasmodium protozoa cause **malaria**. The parasites are spread by a mosquito vector. Parasites enter a host's blood through the bite of an infected mosquito. The parasites infect the host's red blood cells, causing symptoms such as fever, joint pain, anemia, and fatigue.

Malaria is common in tropical and subtropical climates throughout the world (see **Figure** 14.25). In fact, malaria is one of the most common infectious diseases on the planet. Malaria is also a very serious disease. It kills several million people each year, most of them children.

Figure 14.25: Worldwide Distribution of Malaria. This map shows where malaria is found. The area is determined by the mosquito vector. The mosquito can live year-round only in the red-shaded areas.

Fungi and Human Disease

Fungi cause human illness in three different ways: poisonings, parasitic infections, and allergic reactions.

Fungal Poisoning

Many fungi protect themselves from parasites and predators by producing toxic chemicals. If people eat toxic fungi, they may experience digestive problems, hallucinations, organ failure, and even death. Most cases of mushroom poisoning are due to mistaken identity. That's because many toxic mushrooms look very similar to safe, edible mushrooms. An example is shown in **Figure** 14.26. Y

Fungal Parasites

Some fungi cause disease when they become human parasites. Two examples are fungi in the genera *Candida* and *Trichophyton.*

- *Candida* are yeast that cause **candidiasis**, commonly called a "yeast infection." The yeast can infect the mouth or the vagina (in females). If yeast enter the blood, they cause a potentially life threatening

Figure 14.26: Poisonous or Edible? The destroying angel mushroom on the left causes liver and kidney failure. The puffball mushroom on the right is tasty and harmless. Do you think you could tell these two species of mushrooms apart?

illness. However, this is rare, except in people with a depressed immune system.

- *Trichophyton* are fungi that cause **ringworm**. This is a skin infection characterized by a ring-shaped rash. The rash may occur on the arms, legs, head, neck, or trunk. The same fungi cause **athlete's foot** when they infect the skin between the toes. Athlete's foot is the second most common skin disease in the U.S.

Figure 14.27 shows signs of these two infections.

Figure 14.27: Ringworm produces a ring-shaped rash, but it isn't caused by a worm. It's caused by the same fungus that causes athlete's foot.

Fungal Allergies

Mold allergies are very common. They are caused by airborne mold spores. When the spores enter the respiratory tract, the immune system responds to them as though they were harmful microbes. Symptoms may include sneezing, coughing, and difficulty breathing. The symptoms are likely to be more severe in people with asthma or other respiratory diseases. Long-term exposure to mold spores may also weaken the immune system.

Molds grow indoors as well as out. Indoors, they grow in showers, basements, and other damp places. Homes damaged in floods and hurricanes may have mold growing just about everywhere (see **Figure** 14.28). Indoor mold may cause more health problems than outdoor mold because of the closed, confined space. Most people also spend more time indoors than out.

Figure 14.28: The mold growing on the walls and ceiling of this storm-damaged home may be harmful to human health.

Lesson Summary

- Most protist diseases in humans are caused by protozoa. Protozoa make humans sick when they become human parasites. *Trypanosoma* protozoa cause Chagas disease and sleeping sickness. *Giardia* protozoa cause giardiasis, and *Plasmodium* protozoa cause malaria.
- Fungi cause three different types of human illness: poisonings, parasitic infections, and allergies. Many poisonous mushrooms are eaten by mistake because they look like edible mushrooms. Parasitic yeasts cause candidiasis, ringworm, and athlete's foot. Mold allergies are very common.

Lesson Review Questions

Recall

1. Describe how the protozoa that cause Chagas disease are spread to human hosts.
2. State why malaria is commonly found only in tropical and subtropical regions of the world.
3. How does mold cause allergies?
4. State why indoor mold may cause more health problems than outdoor mold.

Apply Concepts

5. Terri lost her water bottle while hiking in Canada. It was a hot day, so she drank water from a stream to stay hydrated. A few days later, Terri became ill with abdominal pain, fever, and diarrhea. Her doctor

thinks she has a protozoan infection. Which type of protozoa do you think is most likely responsible for Terri's illness? How do you think Terri became infected?

Think Critically

6. Explain why you should never eat mushrooms you find in the woods unless you know for certain which type of mushrooms they are.

7. Compare and contrast ringworm and athlete's foot.

Points to Consider

In this chapter you learned about two kingdoms of Eukarya, the protists and fungi. In the next chapter, you'll learn about another kingdom of Eukarya, the plants.

- Plants are a very diverse kingdom. How many different kinds of plants can you think of?
- What traits do you think might distinguish plants from other eukaryotes? What do you already know about plants that might help you answer this question?

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