Chapter 19

Protists

What You'll Learn

- You will differentiate among the major groups of protists.
- You will recognize the ecological niches of protists.
- You will identify some human diseases and the protists responsible for them.

Why It's Important

Because protists are responsible for much of the oxygen in the atmosphere, and are the base for most food chains in aquatic environments, most other organisms depend on protists for their own existences.

Understanding the Photo

This pretzel slime mold is a multicellular protist that grows on logs and branches. Its appearance and growth are similar to those of a fungus.

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Section 19.1

The World of Protists

SECTION PREVIEW

Objectives

Identify the characteristics of Kingdom Protista.

Compare and contrast the four groups of protozoans.

Review Vocabulary

eukaryote: unicellular or multicellular organism whose cells contain membrane-bound organelles (p. 173)

New Vocabulary

protozoan
alga
pseudopodia
asexual reproduction
flagellate
ciliate
sporozoan
spore

How do you classify these things?

Using Prior Knowledge You have learned that the six kingdom classification system includes many obviously distinct kingdoms, such as animals, plants, and fungi. Although most of the organisms in these kingdoms are very different from each other, Kingdom Protista contains organisms that are often almost impossible to tell apart from animals, plants, or fungi. This kingdom includes an amazingly diverse group, many of which move like an animal, photosynthesize like a plant, or produce spores like a fungus.

Explain *Read Section 19.1 and decide how you would define a protist.*

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A protist in a water environment

What is a protist?

Kingdom Protista contains the most diverse organisms of all the kingdoms. Protists may be unicellular or multicellular, microscopic or very large, and heterotrophic or autotrophic. In fact, there is no such organism as a typical protist. When you look at different protists, you may wonder how they could be grouped together. The characteristic that all protists share is that, unlike bacteria, they are all eukaryotes, which means that most of their metabolic processes occur inside their membrane-bound organelles.

Although there are no typical protists, some resemble animals in the way they get food. The animal-like protists are called **protozoa** (proh tuh ZOH uh) (singular, protozoan). Unlike animals, though, all protozoans are unicellular. Other protists are plantlike autotrophs, using photosynthesis to make their food. Plantlike protists are called **algae** (AL jee) (singular, alga). Unlike plants, algae do not have organs such as roots, stems, and leaves. Still other protists are more like fungi because they decompose dead organisms. However, unlike fungi, funguslike protists are able to move at some point in their life and do not have chitin in their cell walls.

It might surprise you to learn how much protists affect other organisms. Some protists cause diseases, such as malaria and sleeping sickness, that result in millions of human deaths throughout the world every year.

Word Origin

protozoa from the Greek words *protos,* meaning "first," and *zoa,* meaning "animals"; Protozoa are animal-like protists.

James W. Evarts/Photo Researchers

Unicellular algae produce much of the oxygen in Earth's atmosphere and are the basis of aquatic food chains. Slime molds and water molds decompose a significant amount of organic material, making the nutrients available to living organisms. Protozoans, algae, and funguslike protists play important roles on Earth. Look at ***Figure 19.1*** to see some protists.

Reading Check **Describe** the characteristics of animal-like, plantlike, and funguslike protists.

Word Origin

pseudopodia from the Greek words *pseudo,* meaning "false," and *podos,* meaning "foot"; An amoeba uses pseudopodia to obtain food.

What is a protozoan?

If you sat by a pond, you might notice clumps of dead leaves at the water's edge. Under a microscope, a piece of those wet decaying leaves reveals a small world, probably inhabited by animal-like protists. Although a diverse group, all protozoans are unicellular heterotrophs that feed on other organisms or dead organic matter. They usually reproduce asexually, but some also reproduce sexually.

Diversity of Protozoans

Many protozoans are grouped according to the way they move. Some protozoans use cilia or flagella to move. Others move and feed by sending out cytoplasm-containing extensions of their plasma membranes. These extensions are called **pseudopodia** (sew duh POH dee uh). Other protozoans are grouped together because they are parasites. There are four main groups of protozoans: the amoebas (uh MEE buz), the flagellates, the ciliates, and the sporozoans (spor uh ZOH unz).

Amoebas: Shapeless protists

The phylum Rhizopoda includes hundreds of species of amoebas and amoebalike organisms. Amoebas have no cell wall and form pseudopodia to move and feed. As a pseudopod forms, the shape of the cell changes and the amoeba moves. Amoebas form pseudopodia around their food, as you can see in ***Figure 19.2.***

Although most amoebas live in salt water, there are freshwater ones that

Figure 19.1
Members of Kingdom Protista are animal-like, plantlike, and funguslike.

A Animal-like protists are unicellular heterotrophs that move in a variety of ways.

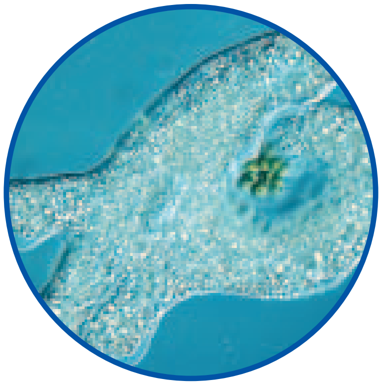
Color-enhanced LM
Magnification: 125×

B Plantlike protists are photosynthetic autotrophs and may be unicellular or multicellular like this one.

C During part of their life cycle, funguslike protists resemble some types of fungi.

CONTENTS

Figure 19.2
An amoeba feeds on small organisms such as bacteria.



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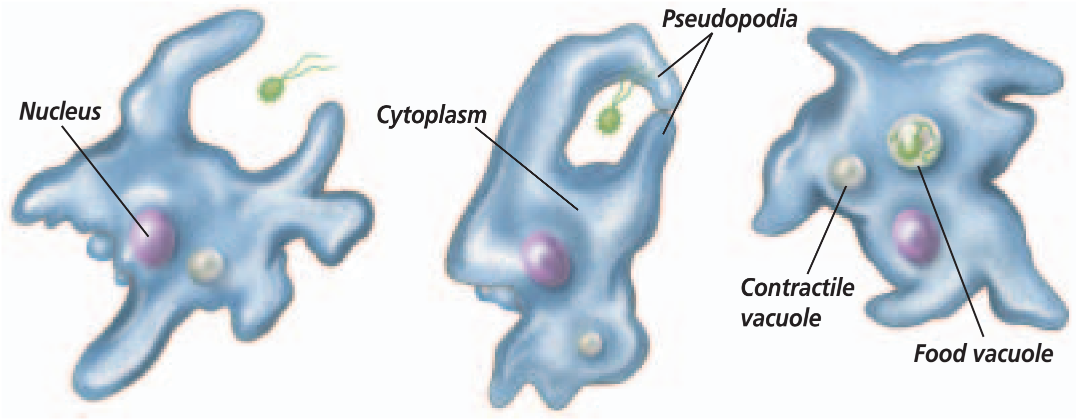

A As an amoeba approaches food, pseudopodia form and eventually surround the food.

B The food becomes enclosed in a food vacuole.

C Digestive enzymes break down the food, and the nutrients diffuse into the cytoplasm.

live in the ooze of ponds, in wet patches of moss, and even in moist soil. Because amoebas live in moist places, nutrients dissolved in the water around them can diffuse directly through their cell membranes. However, because freshwater amoebas live in hypotonic environments, they constantly take in water. Their contractile vacuoles collect and pump out excess water.

Two groupings of mostly marine amoebas, the foraminiferan (foh ram ih NIH fer in) and radiolarian shown in ***Figure 19.3***, have shells. Foraminiferans, which are abundant on the sea floor, have hard shells made of calcium carbonate. Fossil forms of these protists help geologists determine the ages of some rocks and sediments. Unlike foraminiferans, radiolarians have shells made of silica. Under a microscope, you can see the complexity of these shells. In addition, radiolarians are an important part of marine plankton—an assortment of microscopic organisms that float in the ocean's photic zone and form the base of marine food chains.

Most amoebas commonly reproduce by **asexual reproduction,** in which a single parent produces one or more identical offspring by dividing into two cells. When environmental conditions become unfavorable, some types of amoebas form cysts that can survive extreme conditions.

A

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B

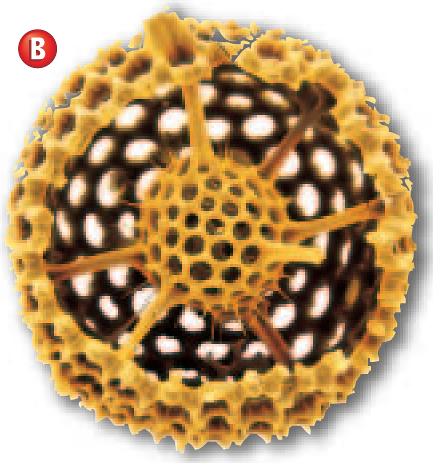

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Figure 19.3
Foraminiferans **(A)** and radiolarians **(B)** are amoebas that extend pseudopodia through tiny holes in their shells. Pseudopodia act like sticky nets that trap food. **Explain** ***What are pseudopodia composed of?***

(t)M. Abbey/Visuals Unlimited, (bl)Polaroid-Oldfield/Visuals Unlimited, (br)Juergen Berger, Max-Planck Institute/Science Photo Library/Photo Researchers

MiniLab 19.1

Observe and Infer

Observing Ciliate Motion The cilia on the surface of a paramecium move so that the cell normally swims through the water with one end directed forward. But when this end bumps into an obstacle, the paramecium responds by changing direction.

Observing a paramecium

Procedure

1. Observe a paramecium culture that has had boiled, crushed wheat seeds in it for several days.
2. Carefully place a drop of water containing wheat seed particles on a microscope slide. Gently add a coverslip.
3. Using low power, locate a paramecium near some wheat seed particles. **CAUTION:** ***Use caution when working with a microscope, glass slides, and coverslips.***
4. Watch the paramecium as it swims around among the particles. Record your observations of the organism's responses each time it contacts a particle.

Analysis

1. **Describe** What does a paramecium do when it encounters an obstacle?
2. **Observe** How long does the paramecium's response last?
3. **Describe** How does the shape of the paramecium change as it moves among the particles?

Flagellates: Protozoans with flagella

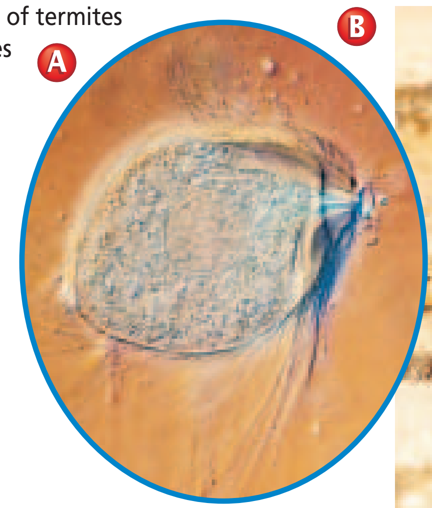
The phylum Zoomastigina consists of protists called **flagellates,** which have one or more flagella. Flagellated protists move by whipping their flagella from side to side.

Some flagellates are parasites that cause diseases in animals, such as African sleeping sickness in humans. Other flagellates are helpful. For example, termites like those you see in ***Figure 19.4B*** survive on a diet of wood. Without the help of a certain species of flagellate that lives in the guts of termites, some termites could not survive on such a diet. In a mutualistic relationship, flagellates convert cellulose from wood into a carbohydrate that both they and their termite hosts can use.

Ciliates: Protozoans with cilia

The roughly 8000 members of the protist phylum Ciliophora, known as **ciliates,** use the cilia that cover their bodies to move. Use the *MiniLab* on this page to observe a typical ciliate's motion. Ciliates live in every kind of aquatic habitat—from ponds and streams to oceans and sulfur springs. What does a typical ciliate look like? To find out, look at ***Figure 19.5*** on the next page.

Figure 19.4
The flagellated protozoans **(A)** that live in the guts of termites **(B)** produce enzymes that digest wood, making nutrients available to their hosts.



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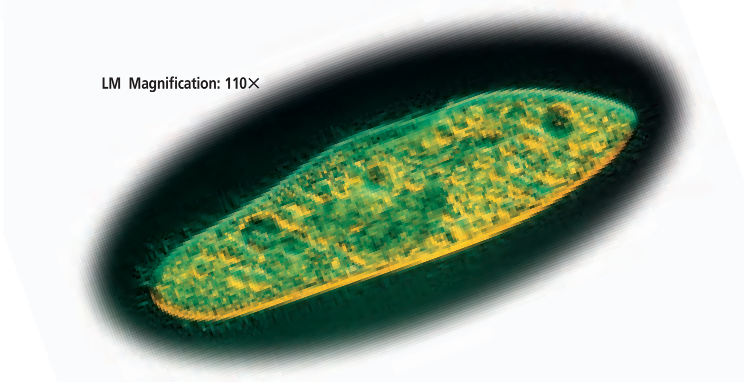
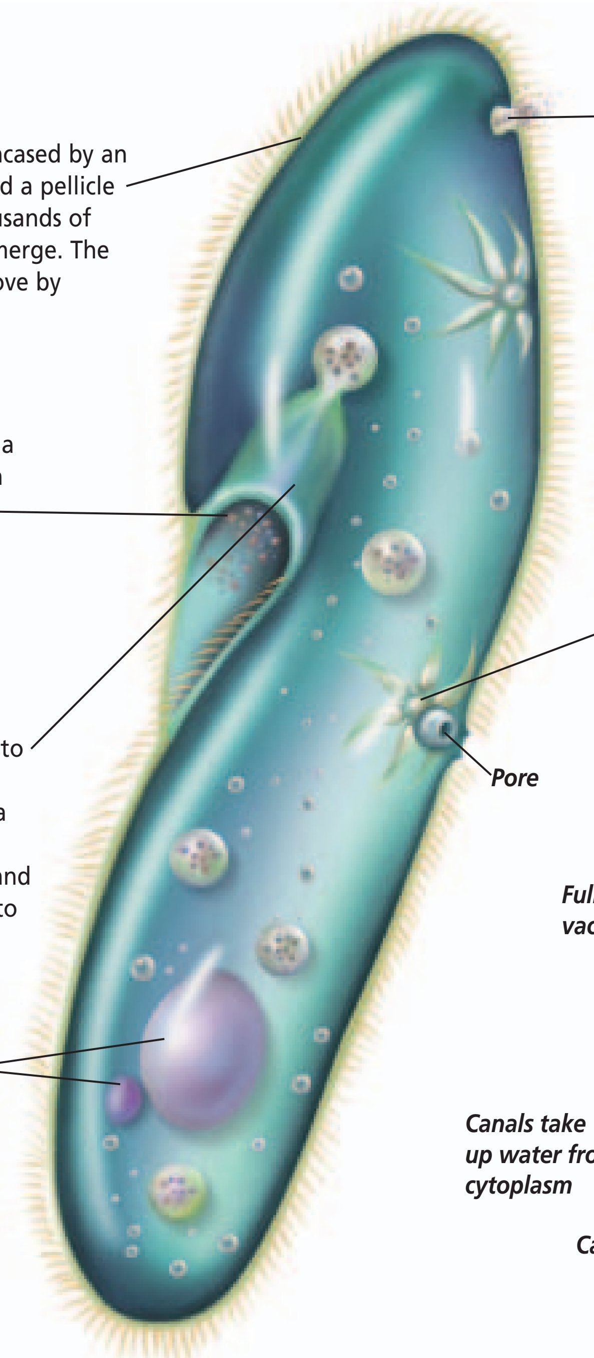
A Paramecium

Figure 19.5

Paramecia are unicellular organisms, but their cells are quite complex. Within a paramecium are many organelles and structures that are each adapted to carry out a distinct function. **Critical Thinking** ***How might the contractile vacuoles of a paramecium respond if the organism were placed in a dilute salt solution?***



Paramecium caudatum



A Cilia The cell is encased by an outer covering called a pellicle through which thousands of tiny, hairlike cilia emerge. The paramecium can move by beating its cilia.

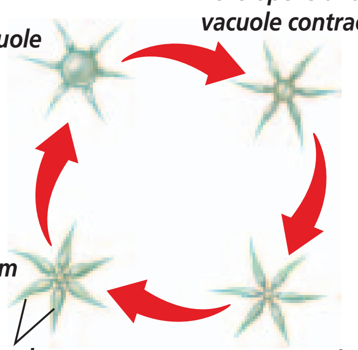
B Oral groove Paramecia feed primarily on bacteria that are swept into the gullet by cilia that line the oral groove.

C Gullet Food moves into the gullet, becoming enclosed at the end in a food vacuole. Enzymes break down the food, and the nutrients diffuse into the cytoplasm.

D Micronucleus and macronucleus The small micronucleus plays a major role in sexual reproduction. The large macronucleus controls the everyday functions of the cell.

E Anal pore Waste materials leave the cell through the anal pore.

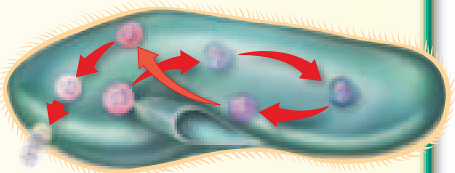
F Contractile vacuole Because a paramecium lives in a freshwater, hypotonic environment, water constantly enters its cell by osmosis. A pair of contractile vacuoles pump out the excess water.



M. Abbey/Visuals Unlimited

Problem-Solving Lab 19.1

Draw a Conclusion



How do digestive enzymes function in paramecia? Paramecia ingest food particles and enclose them in food vacuoles. Each food vacuole circulates in the cell as the food is digested by enzymes that enter the vacuole. Digested nutrients are absorbed into the cytoplasm.

Solve the Problem

1. Some digestive enzymes function best at high pH levels, while others function best at low (more acidic) pH levels.
2. Congo red is a pH indicator dye; it is red when the pH is above 5 and blue when the pH is below 3 (very acidic).
3. Yeast cells that contain Congo red can be produced by adding dye to the solution in which the cells are growing.
4. When paramecia feed on dyed yeast cells, the yeast is visible inside food vacuoles.
5. Examine the drawing above. The appearance of a yeast-filled food vacuole over time is indicated by the colored circles inside the paramecium. Each arrow indicates movement and the passing of time.

Thinking Critically

Observe and Infer What happens to the pH in the food vacuole over time? Explain what sequence of digestive enzymes might function in a paramecium.

Color-enhanced LM Magnification: 84×

Figure 19.6
A paramecium reproduces by dividing into two identical daughter cells.

Many structures found in ciliates' cells may work together to perform just one important life function. For example, a *paramecium* uses its cilia, oral groove, gullet, and food vacuoles in the process of digestion. Use the *Problem-Solving Lab* on this page to explore how a paramecium digests the food in a vacuole.

A paramecium usually reproduces asexually by dividing crosswise and separating into two daughter cells, as you can see in ***Figure 19.6***. Whenever their food supplies dwindle or their environmental conditions change, paramecia usually undergo a form of conjugation. In this complex process, two paramecia join and exchange genetic material. Then they separate, and each divides asexually, passing on its new genetic composition.

Sporozoans: Parasitic protozoans

Protists in the phylum Sporozoa are often called **sporozoans** because most produce spores. A **spore** is a reproductive cell that forms without fertilization and produces a new organism.

All sporozoans are parasites. They live as internal parasites in one or more hosts and have complex life cycles. Sporozoans are usually found in a part of a host that has a ready food supply, such as an animal's blood or intestines. *Plasmodium*, members of the sporozoan genus, are organisms that cause the disease malaria in humans and other mammals and in birds.

Sporozoans and malaria

Throughout the world today, more than 300 million people have malaria, a serious disease that usually occurs in places that have tropical climates. The *Plasmodium* that mosquitoes transmit to people cause human malaria. As you can see in ***Figure 19.7***, the

M. Abbey/Photo Researchers

malaria-causing *Plasmodium* live in both humans and mosquitoes.

Until World War II, the drug quinine was used to treat malaria. Today, a combination of the drugs chloroquine and primaquine are most often used to treat this disease because they cause few serious side effects in humans. But some species of *Plasmodium* have begun to resist these drugs. Therefore, new drugs are under development to treat malaria.

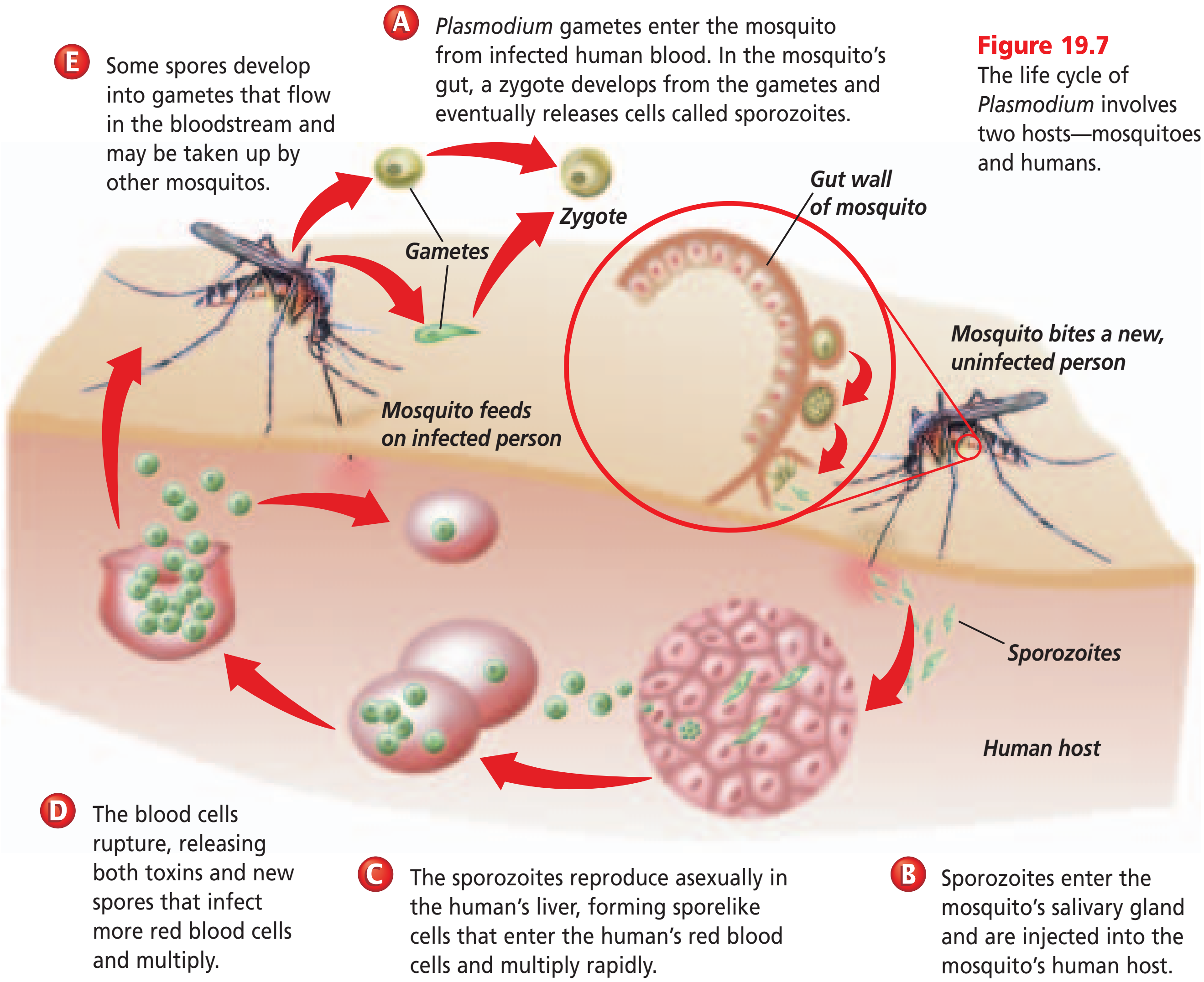


Figure 19.7
The life cycle of *Plasmodium* involves two hosts—mosquitoes and humans.

Section Assessment

Understanding Main Ideas

1. Describe the characteristics of the protist kingdom. Then compare the characteristics of the four major groups of protozoans. How is each group of protozoans animal-like?
2. How do amoebas obtain food?
3. Explain any differences that exist between ciliates and flagellates.
4. What makes a sporozoan different from other protozoan groups?

Thinking Critically

5. What role do contractile vacuoles play in helping freshwater protozoans maintain homeostasis?

Skill Review

6. **Sequence** Trace the life cycle of a Plasmodium that causes human malaria. Identify all forms of the sporozoan and the role each plays in the disease. For more help, refer to *Sequence* in the **Skill Handbook.**

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Section 19.2

Algae: Plantlike Protists

SECTION PREVIEW

Objectives

Compare and contrast the variety of plantlike protists.

Explain the process of alternation of generations in algae.

Review Vocabulary

photosynthesis: process by which autotrophs trap energy from sunlight with chlorophyll and convert carbon dioxide and water into simple sugars (p. 225)

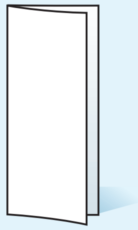
New Vocabulary

thallus
colony
fragmentation
alternation of generations
gametophyte
sporophyte

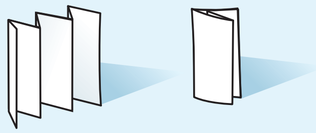
FOLDABLES Study Organizer

Protists Make the following Foldable to help identify and study the characteristics of each type of algae.

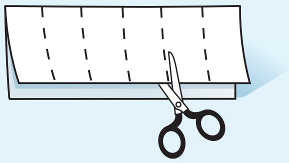
STEP 1 **Fold** a vertical sheet of paper from side to side. Make the back edge about 1.5 cm longer than the front edge.



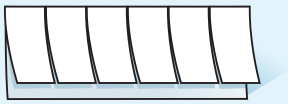
STEP 2 **Turn** lengthwise and **fold** into six sections.



STEP 3 **Unfold and cut** only the top layer along all five folds to make six tabs.



STEP 4 **Label** each tab as follows: *Euglenoids*, *Diatoms*, *Dinoflagellates*, *Red Algae*, *Brown Algae*, *Green Algae*. Label the edge as *Unicellular and Multicellular Algae*.



Read and Write As you read Section 19.2, list the characteristics of each type of algae under the appropriate tab. Use your foldable to take notes and as a study guide.

What are algae?

Photosynthesizing protists are called algae. All algae contain up to four kinds of chlorophyll as well as other photosynthetic pigments. These pigments produce a variety of colors in algae, including purple, rusty-red, olive-brown, yellow, and golden-brown, and are a way of classifying algae into groups.

Algae include both unicellular and multicellular organisms. The photosynthesizing unicellular protists, known as phytoplankton (fi toh PLANK tun), are so numerous that they are one of the major producers of nutrients and oxygen in aquatic ecosystems in the world. Through photosynthesis, algae produce much of the oxygen used on Earth. Although multicellular algae may look like plants because they are large and sometimes green, they have no roots, stems, or leaves. Use the *MiniLab* on the next page to observe algae.

Diversity of Algae

Algae are classified into six phyla. Three of these phyla—the euglenoids, diatoms, and dinoflagellates—include only unicellular species. However, in the other three phyla, which are the green, red, and brown algae, most species are multicellular.

Euglenoids: Autotrophs and heterotrophs

Hundreds of species of euglenoids (yoo GLEE noydz) make up the phylum Euglenophyta. Euglenoids are unicellular, aquatic protists that have both plant and animal characteristics. Unlike plant cells, they lack a cell wall made of cellulose. However, they do have a flexible pellicle made of protein that surrounds the cell membrane. Euglenoids are plantlike in that most have chlorophyll and photosynthesize. However, they are also animal-like because, when light is not available, they can ingest food in ways that might remind you of some protozoans. In other words, euglenoids can be heterotrophs. ***In Figure 19.8,*** you can see a typical euglenoid.

Euglenoids might also remind you of protozoans because they have one or more flagella to move.

MiniLab 19.2

Observe

Going on an Algae Hunt Pond water may be teeming with organisms. Some are macroscopic organisms, but the majority are microscopic. Some may be heterotrophs, and others autotrophs. How can you tell them apart?

Procedure

1. Copy the data table.

Data Table

Diagram	Motile/Nonmotile	Unicellular/Multicellular

2. Place a drop of pond water onto a glass slide and add a coverslip. **CAUTION:** ***Use caution when working with a microscope, glass slides, and coverslips.***
3. Observe the pond water under low magnification of your microscope, and look for algae that may be present. Algae from a pond will usually be green or yellow-green in color.
4. Diagram several different species of algae in your data table and indicate if each is motile or nonmotile. Indicate if the algae are unicellular or multicellular.

Analysis

1. **Analyze** What characteristic distinguished algae from any protozoans that may have been present?
2. **Describe** Explain how the characteristic in question 1 categorizes algae as autotrophs.
3. **Observe** Did you observe any relationship between movement and size? Explain your answer.

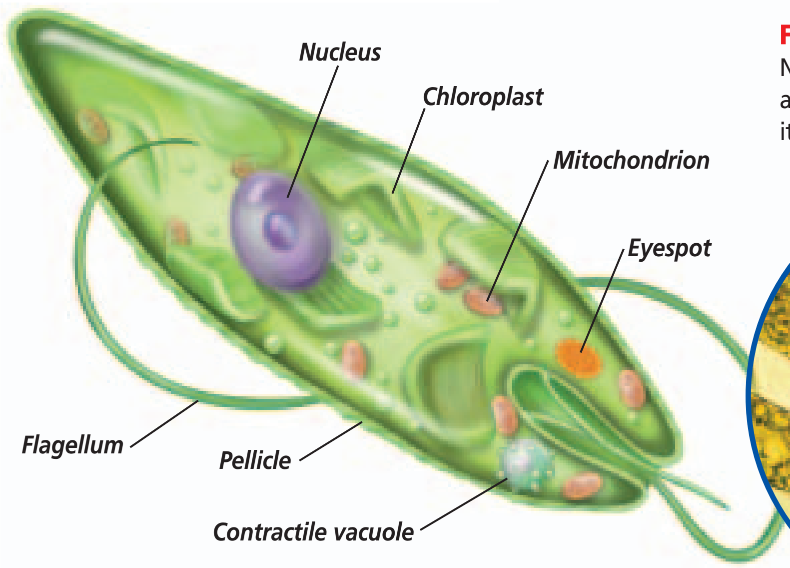
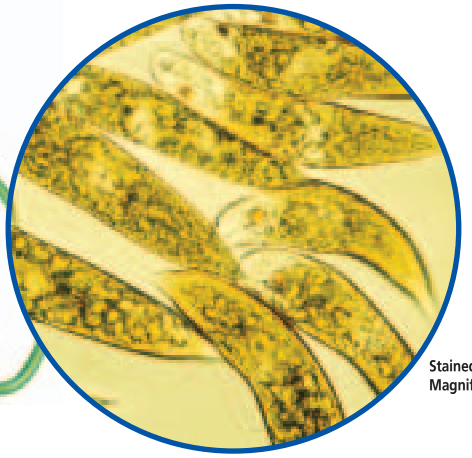


Figure 19.8
Notice the eyespot in this *Euglena gracilis.* It shades a light-sensitive receptor that helps *E. gracilis* orient itself toward light.



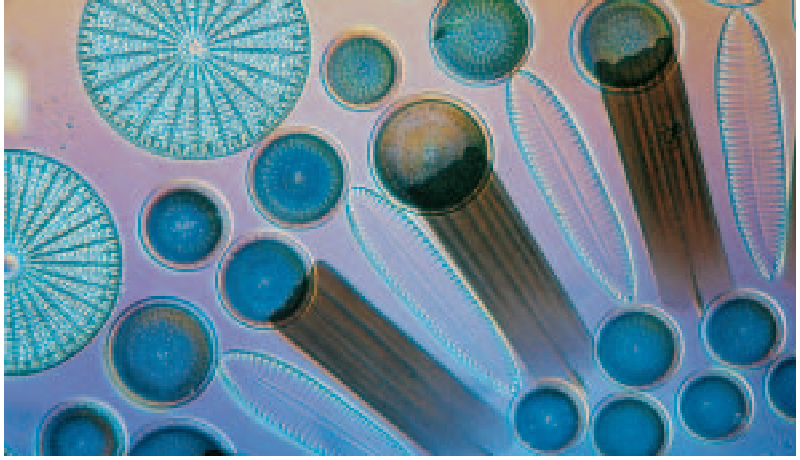


Figure 19.9
Diatom shells have many shapes.

They use their flagella to move toward light or food. In the *BioLab* at the end of this chapter, you can learn more about how a euglenoid responds to light.

Diatoms: The golden algae

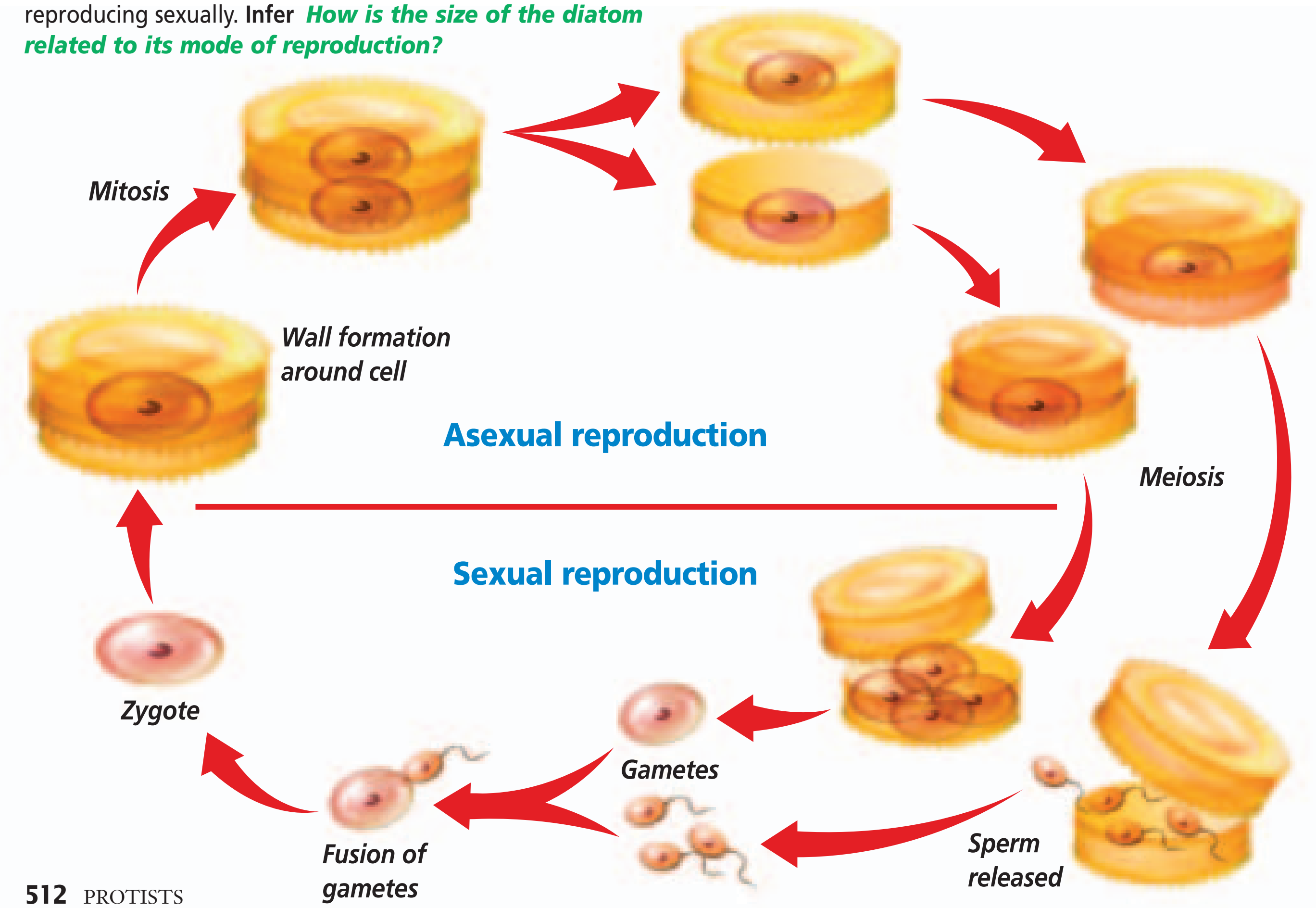
Diatoms (DI uh tahmz), members of the phylum Bacillariophyta, are unicellular photosynthetic organisms with shells composed of silica. They make up a large component of the phytoplankton population in both marine and freshwater ecosystems.

The delicate shells of diatoms, like those you see in ***Figure 19.9***, might remind you of boxes with lids. Each species has its own unique shape, decorated with grooves and pores.

Diatoms contain chlorophyll as well as other pigments called carotenoids (ke RUH tuhn oydz) that usually give them a golden-yellow color. The food that diatoms make is stored as oils rather than starch. These oils give fishes that feed on diatoms an oily taste. They also give diatoms buoyancy so that they float near the surface where light is available.

When diatoms reproduce asexually, the two halves of the box separate; each half then produces a new half to fit inside itself. This means that half of each generation's offspring are smaller than the parent cells. When diatoms

Figure 19.10
Diatoms reproduce asexually for several generations before reproducing sexually. **Infer** ***How is the size of the diatom related to its mode of reproduction?***



A

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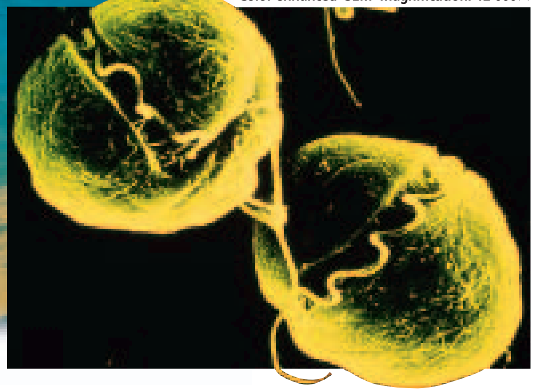


B

Figure 19.11
Red tides, such as the one shown here **(A),** are often caused by dinoflagellates such as this one called *Gonyaulax* **(B).**

are about one-quarter of their original size, they reproduce sexually by producing gametes that fuse to form zygotes. The zygote develops into a full-sized diatom, which will divide asexually for a while. You can see both the asexual and sexual reproductive processes of diatoms in ***Figure 19.10.***

When diatoms die, their shells sink to the ocean floor. The deposits of diatom shells—some of which are millions of years old—are dredged or mined, processed, and used as abrasives in tooth and metal polishes, or added to paint to give the sparkle that makes pavement lines more visible at night.

Dinoflagellates: The spinning algae

Dinoflagellates (di nuh FLA juh layts), members of the phylum Dinoflagellata, have cell walls that are composed of thick cellulose plates. They come in a great variety of shapes and styles—some even resemble helmets, and others look like suits of armor.

Dinoflagellates contain chlorophyll, carotenoids, and red pigments. They have two flagella located in grooves at right angles to each other. The cell spins slowly as the flagella beat. A few species of dinoflagellates live in freshwater, but most are marine and, like diatoms, are a major component of phytoplankton. Many species live symbiotically with jellyfishes, mollusks, and corals. Some free-living species are bioluminescent, which means that they emit light.

Several species of dinoflagellates produce toxins. One toxin-producing dinoflagellate, *Pfiesteria piscicida*, that some North Carolina researchers discovered in 1988, has caused a number of fish kills in the coastal waters from Delaware to North Carolina.

Another toxic species, *Gonyaulax catanella*, produces an extremely strong nerve toxin that can be lethal. In the summer, these organisms may become so numerous that the ocean takes on a reddish color as you can see in ***Figure 19.11.*** This population explosion is called a red tide. In some red tides, there can be as many as 40 to 60 million dinoflagellates per liter of seawater.

The toxins produced during a red tide may make humans ill. During red tides, the harvesting of shellfish is usually banned because shellfish feed on the toxic algae and the toxins concentrate in their tissues. People who eat such shellfish risk being poisoned. You can learn more about the causes and effects of red tides in the *Problem-Solving Lab* on the next page.

Problem-Solving Lab 19.2

Recognize Cause and Effect

Why is the number of red tides increasing? Scientists have been aware of red tide poisoning of birds, fishes, and mammals such as whales and humans for years. Could the rise in red tide poisoning be related to human activities?

A sperm whale's carcass

Solve the Problem

The following events are associated with the appearance of red tides.

1. The dinoflagellate toxin that causes illness and sometimes death in humans accumulates in the body tissues of shellfish, such as clams and oysters.
2. Within five weeks, 14 humpback whales died on beaches in Massachusetts. The whales' stomachs contained mackerel with high levels of dinoflagellate toxin.
3. Between 1976 and 1986, the human population of Hong Kong increased sixfold, and its harbor had an eightfold increase in red tides. Human waste water was commonly emptied into the harbor.
4. Studies show that red tides are increasing worldwide.
5. An algal bloom occurs when algae, using sunlight and abundant nutrients, increase rapidly in number to hundreds of thousands of cells per milliliter of water.

Thinking Critically

1. **Think Critically** Which statement above provides evidence that supports each of the following ideas? Explain each answer.
   a. Dinoflagellate poisons flow through the food chain.
   b. Dinoflagellates are autotrophs.
   c. There is a correlation between human activities and algae growth.
2. **Think Critically** Based on the evidence presented above, can you conclude that human activity is responsible for the increase in red tides? Why or why not?

Red algae

Red algae, members of the phylum Rhodophyta, are mostly multicellular marine seaweeds. The body of a seaweed, as well as that of some plants and other organisms, is called a **thallus** and lacks roots, stems, or leaves. Red algae use structures called holdfasts to attach to rocks. They grow in tropical waters or along rocky coasts in cold water. You can see a red alga in ***Figure 19.12.***

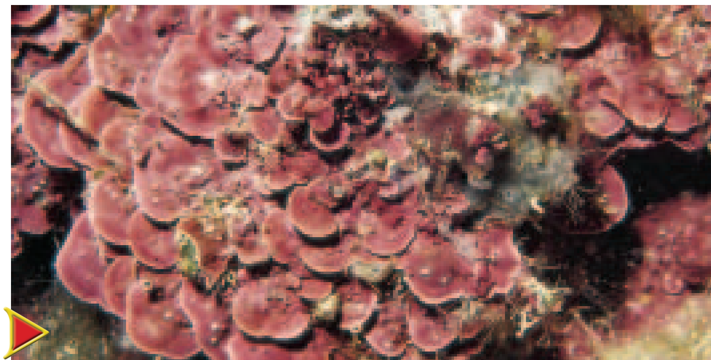
In addition to chlorophyll, red algae also contain photosynthetic pigments called phycobilins. These pigments absorb green, violet, and blue light—the only part of the light spectrum that penetrates water below depths of 100 m. Therefore, the red algae can live in deep water where most other seaweeds cannot thrive.

Brown algae

About 1500 species of multicellular brown algae make up the phylum Phaeophyta. Almost all of these species live in salt water along rocky coasts in cool areas of the world. Brown algae contain chlorophyll as well as a yellowish-brown carotenoid called fucoxanthin, which gives them their brown color. Many species of brown algae have air bladders that keep their bodies floating near the surface, where light is available.

The largest and most complex of brown algae are kelp. In kelp, the thallus is divided into the holdfast,

Figure 19.12
This Coralline alga is only one of about 4000 species of red algae. Some species are popular foods in Japan and other countries.



(t)Joyce Photo/Photo Researchers, (b)R. DeGoursey/Visuals Unlimited stipe, and blade. The holdfasts anchor kelp to rocks or the sea bottom. Some giant kelp may grow up to 60 meters long. In some parts of the world, such as off the California coast, giant kelps form dense, underwater forests. These kelp forests are rich ecosystems and provide a wide variety of marine organisms with their habitats.

Green algae

Green algae make up the phylum Chlorophyta. The green algae are the most diverse algae, with more than 7000 species. The major pigment in green algae is chlorophyll, but some species also have yellow pigments that give them a yellow-green color. Most species of green algae live in freshwater, but some live in the oceans, in moist soil, on tree trunks, in snow, and even in the fur of sloths—large, slow-moving mammals that live in the tropical rain forest canopy.

Green algae can be unicellular, colonial, or multicellular in organization. As you can see in ***Figure 19.13***, *Chlamydomonas* is a unicellular and flagellated green alga. *Spirogyra* is a multicellular species that forms slender filaments. *Volvox* is a green alga that can form a **colony,** a group of cells that lives together in close association.

A *Volvox* colony is composed of hundreds, or thousands, of flagellated cells arranged in a single layer forming a hollow, ball-shaped structure. The cells are connected by strands of cytoplasm, and the flagella of individual cells face outward. The flagella can beat in a coordinated fashion, spinning the colony through the water. Small balls of daughter colonies form inside the large sphere. The wall of the large colony will eventually break open and release the daughter colonies.

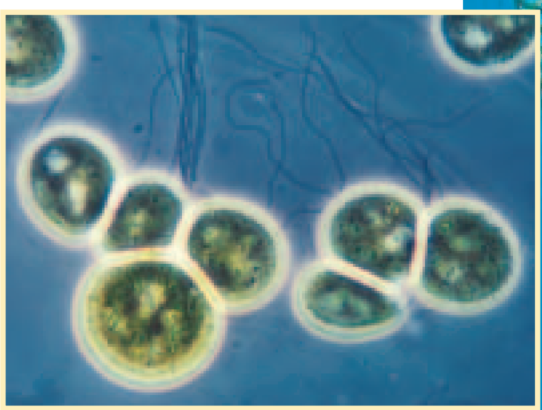
Green algae can reproduce both asexually and sexually. For example, *Spirogyra* can reproduce asexually through fragmentation. During **fragmentation,** an individual breaks up into pieces and each piece grows into a new individual.

Physical Science Connection

Interaction of light and water When light waves interact with matter, some waves are reflected, some are absorbed, and some might pass through. Water absorbs red light more than 150 times more strongly than blue light. As a result, below about 10 m depth in the ocean, almost all wavelengths in the red part of the visible spectrum have been absorbed.

Figure 19.13
Chlamydomonas is a unicellular species of green algae **(A),** while *Spirogyra* is a multicellular form **(B).** The wall of a *Volvox* colony contains hundreds of cells **(C).** The smaller balls inside the sphere are daughter colonies.

A



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B

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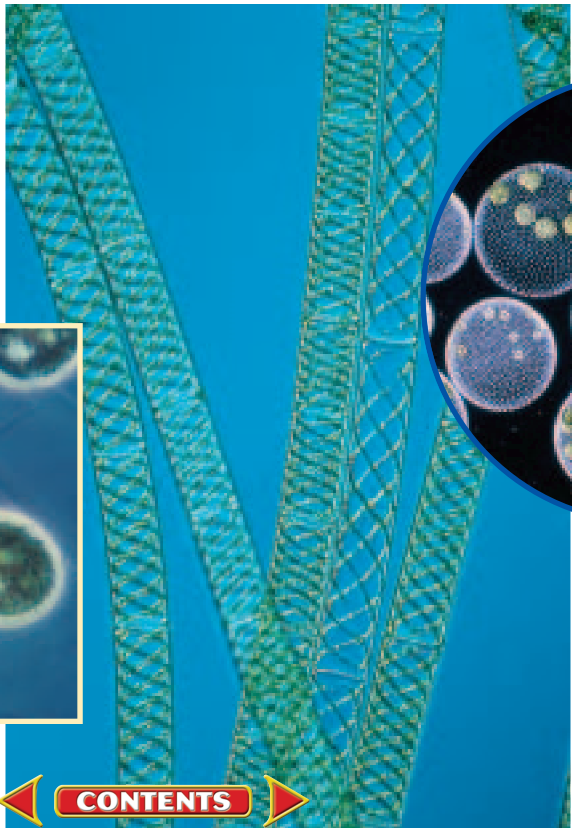
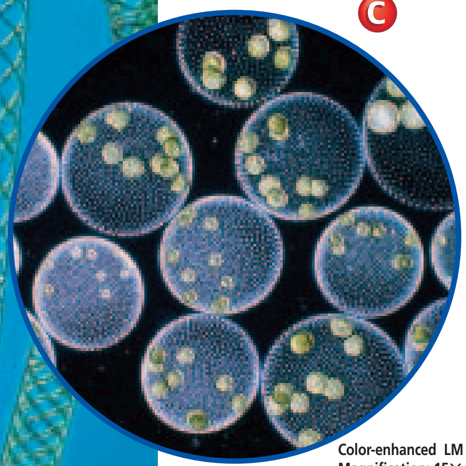


C



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(l)Dale Sarver/Animals Animals, (c)Nuridsany et Perennou/Photo Researchers, (r)M.I. Walker/Photo Researchers

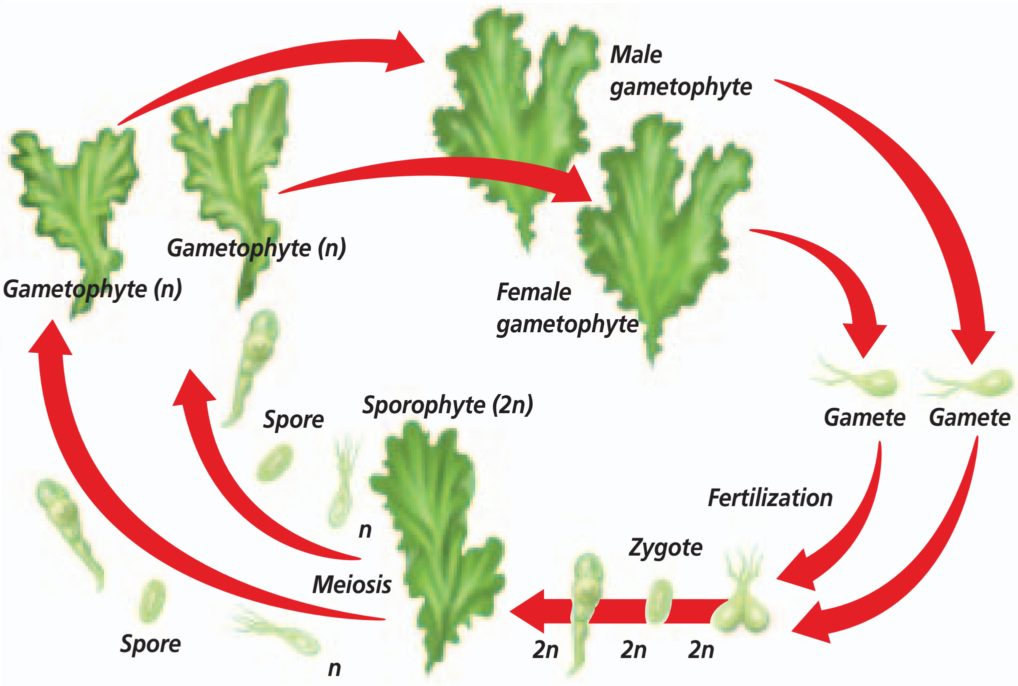

Figure 19.14
In the life cycle of the sea lettuce *(Ulva),* the generations alternate between haploid (gametophyte) and diploid (sporophyte). Both fungi and plants also alternate generations.

Green algae, and some other types of algae, have a complex life cycle. This life cycle consists of individuals that alternate between producing spores and producing gametes.

Alternation of Generations

The life cycles of some of the algae and all plants have a pattern called **alternation of generations.** An organism that has this pattern alternates between existing as a haploid and a diploid organism, creating two different generations.

The haploid form of the organism is called the **gametophyte** because it produces gametes. The gametes fuse to form a zygote from which the diploid form of the organism, which is called the **sporophyte,** develops. Certain cells in the sporophyte undergo meiosis. Eventually, these cells become haploid spores that can develop into a new gametophyte. Look at ***Figure 19.14*** to see the life cycle of *Ulva*, a multicellular green alga.

Reading Check **List and describe** the different types of algae.

Section Assessment

Understanding Main Ideas

1. In what ways are algae important to all living things on Earth?
2. Give examples that show why the green algae are considered to be the most diverse of the six phyla of algae.
3. In what ways do the sporophyte and gametophyte generations of an alga such as *Ulva* differ from each other?
4. Why are phycobilins an important pigment in red algae?

Thinking Critically

5. Use a table to list the reasons why euglenoids should be classified as protozoans and also as algae.

Skill Review

6. **Make and Use Tables** Construct a table listing the different phyla of algae. Indicate whether they have one or more cells, their color, and give an example of each. For more help, refer to *Make and Use Tables* in the **Skill Handbook.**

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Section 19.3

Slime Molds, Water Molds, and Downy Mildews

SECTION PREVIEW

Objectives

Contrast the cellular differences and life cycles of the two types of slime molds.

Discuss the economic importance of the downy mildews and water molds.

Review Vocabulary

heterotroph: organisms that cannot make their own food and must feed on other organisms for energy and nutrients (p. 47)

New Vocabulary

plasmodium

Why aren't they fungi?

Finding the Main Idea Until recently, many of the funguslike protists were classified as fungi. Slime molds, water molds, and downy mildews can often look and act like fungi, and many cause diseases in plants the way fungi do.

Describe *As you read the section, write a description or draw your perception of how the funguslike protists appear physically and how they live. Compare and contrast these descriptions with how you would describe fungi.*

A plasmodial slime

What are funguslike protists?

Certain groups of protists, the slime molds, the water molds, and the downy mildews, consist of organisms with some funguslike features. Recall that fungi are heterotrophic organisms that decompose organic materials to obtain energy. Like fungi, the funguslike protists decompose organic materials.

There are three phyla of funguslike protists. Two of these phyla consist of slime molds. Slime molds have characteristics of both protozoans and fungi and are classified by the way they reproduce. Water molds and downy mildews make up the third phylum of funguslike protists. Although funguslike protists are not an everyday part of human lives, some disease-causing species damage vital crops.

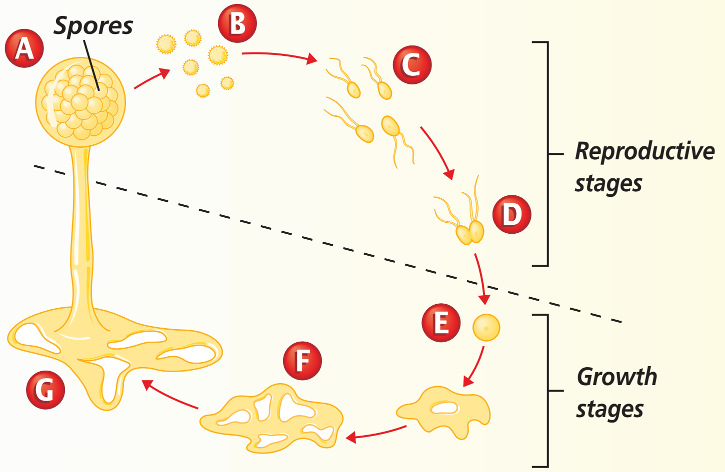
Slime Molds

Many slime molds are beautifully colored, ranging from brilliant yellow or orange to rich blue, violet, and jet black. They live in cool, moist, shady places where they grow on damp, organic matter, such as rotting leaves or decaying tree stumps and logs.

Problem-Solving Lab 19.3

Predict

What changes occur during a slime mold's life cycle? Plasmodial slime molds undergo a number of different stages during their life cycle. The most visible stage is the plasmodial stage, where the organism looks like a slimy mass of material. The plasmodium changes into a reproductive stage that is microscopic and, therefore, less visible.



Solve the Problem

Examine the life cycle of a plasmodial slime mold. The structures below the dashed line are diploid in chromosome number. Based on the diagram and your understanding of mitosis and meiosis, answer the questions below.

Thinking Critically

1. **Explain** What cell process, mitosis or meiosis, takes place between F and G? Explain why. Between A and B? Explain why.
2. **Explain** What letter best shows fertilization occurring? Motile spores? An embryo? Explain why in each case.
3. **Observe** During which stage does the slime mold feed? Explain.

There are two major types of slime molds—plasmodial slime molds and cellular slime molds. The plasmodial slime molds belong to the phylum Myxomycota, and the cellular slime molds make up another grouping, the phylum Acrasiomycota.

Slime molds are animal-like during much of their life cycle, moving about and engulfing food in a way similar to that of amoebas. However, like fungi, slime molds make spores to reproduce. Use the *Problem-Solving Lab* on this page to learn more about the life cycle of a slime mold.

Plasmodial slime molds

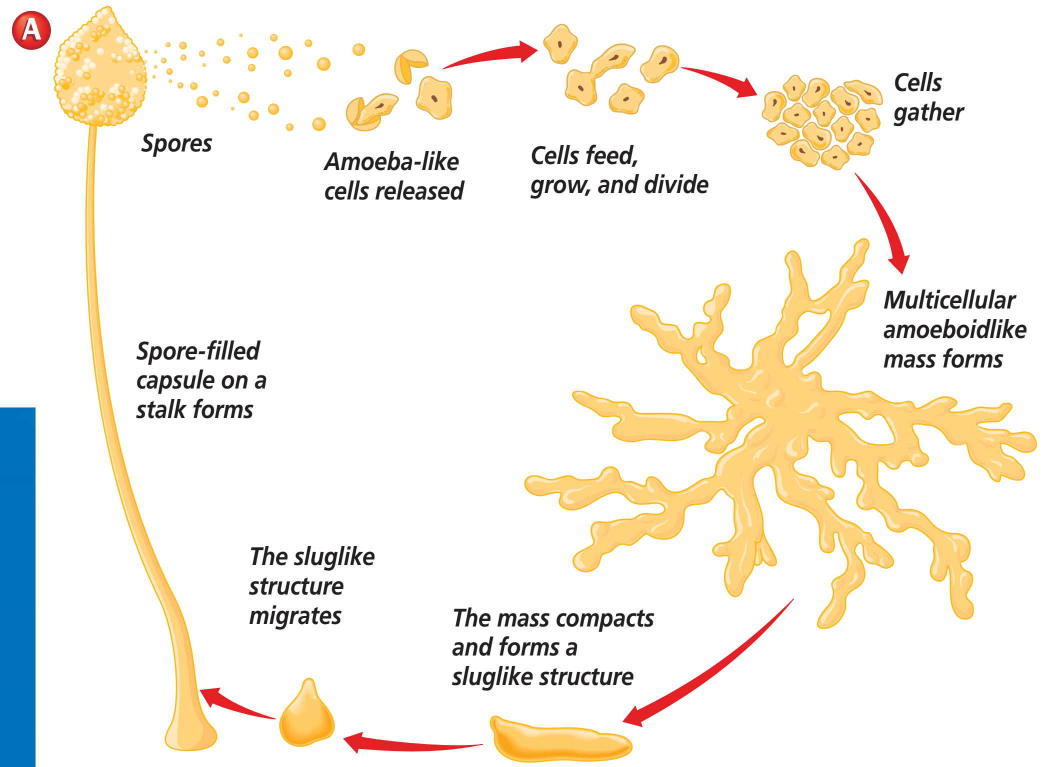
Plasmodial slime molds get their name from the fact that they form a **plasmodium** (plaz MOH dee um), a mass of cytoplasm that contains many diploid nuclei but no cell walls or membranes. This slimy, multinucleate mass, like the one you see in ***Figure 19.15***, is the feeding stage of the organism. The plasmodium creeps like an amoeba over the surfaces of decaying logs or leaves. Some quicker plasmodiums move at the rate of about 2.5 centimeters per hour, engulfing microscopic organisms and digesting them in food vacuoles. At that rate, a plasmodium would cross your textbook page in eight hours.

A plasmodium may reach more than a meter in diameter and contain thousands of nuclei. However, when moisture and food become

Figure 19.15
The moving, feeding form of a plasmodial slime mold is a multinucleate blob of cytoplasm. **Infer** ***How does a plasmodial slime mold acquire food?***

Patrick W. Grace/Photo Researchers

Figure 19.16
The reproductive cycle of a cellular slime mold is complex **(A).** Single cells clump and form a structure that resembles a small garden slug **(B).** Eventually, the clump forms a stalked reproductive structure that produces spores **(C).**



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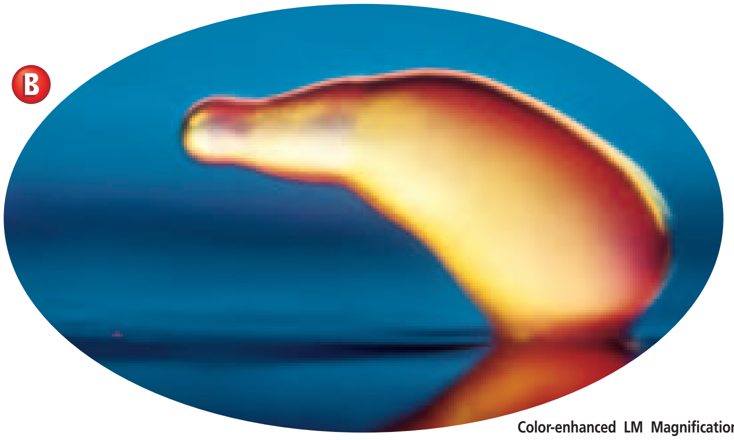

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scarce in its surroundings, a plasmodium transforms itself into many separate, stalked, spore-producing structures. Meiosis takes place within these structures and produces haploid spores, which the wind disperses. A spore germinates into either a flagellated or an amoeboid cell, or a gamete, that can fuse with another cell to form a zygote. The diploid zygote grows into a new plasmodium.

Cellular slime molds

Unlike plasmodial slime molds, cellular slime molds spend part of their life cycle as an independent amoeboid cell that feeds, grows, and divides by cell division, as shown in ***Figure 19.16.*** When food becomes scarce, these independent cells join with hundreds or thousands of others to reproduce. Such an aggregation of amoeboid cells resembles a plasmodium. However, this mass of cells is multicellular—made up of many individual amoeboid cells, each with a distinct cell membrane. Cellular slime molds are haploid during their entire life cycle.

Reading Check **Compare and contrast** the two types of slime molds.

Word Origin

plasmodium from the Greek word *plassein,* meaning "mold," and the Latin word *odium,* meaning "hateful"; One form of a slime mold is a plasmodium.

Water Molds and Downy Mildews

Water molds and downy mildews are both members of the phylum Oomycota. Most members of this large and diverse group of funguslike protists live in water or moist places. As shown in ***Figure 19.17***, some feed on dead organisms and others are plant parasites.

Most water molds appear as fuzzy, white growths on decaying matter. They resemble some fungi because they grow as a mass of threads over a food source, digest it, and then absorb the nutrients. But at some point in their life cycle, water molds produce flagellated reproductive cells—something that fungi never do. This is why water molds are classified as protists rather than fungi.

One economically important member of the phylum Oomycota is a downy mildew that causes disease in many plants. A downy mildew called *Phytophthora infestans* affected the lives of the people of Ireland by destroying their major food crop of potatoes. The famine that followed caused a mass immigration to America.

Origin of Protists

How are the many different kinds of protists related to each other and to fungi, plants, and animals? You can see the relationships of protists to each other in ***Figure 19.18.***

Although taxonomists are now comparing the RNA and DNA of these groups, there is little conclusive evidence to indicate whether ancient protists were the evolutionary ancestors of fungi, plants, and animals or whether protists emerged as evolutionary lines that were separate. Because of evidence from comparative RNA sequences in modern green algae and plants, many biologists agree that ancient green algae were probably ancestral to modern plants.

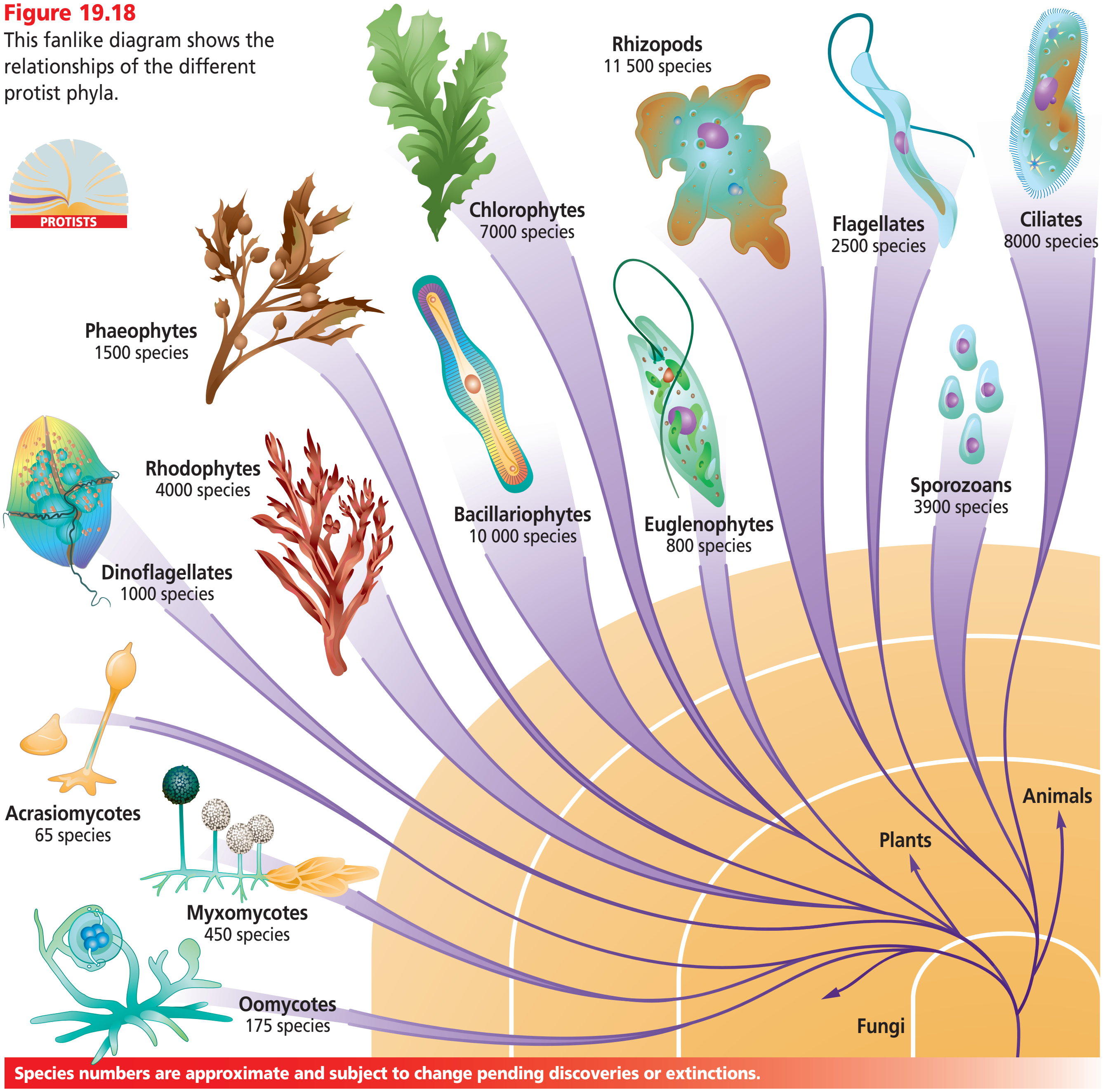
Figure 19.17
Water molds and downy mildews live in moist places and cause both plant and animal diseases.

A The downy mildew *Phytophthora infestans* is killing this potato plant.

B The water mold growing on this insect is decomposing the insect's tissues and absorbing the nutrients.

(l)Holt Studios International/Nigel Cattlin/Photo Researchers, (r)James W. Richardson/Visuals Unlimited

Figure 19.18
This fanlike diagram shows the relationships of the different protist phyla.



Section Assessment

Understanding Main Ideas

1. Describe the protozoan and funguslike characteristics of slime molds.
2. Why might some biologists refer to plasmodial slime molds as acellular slime molds? (Hint: Look in the **Skill Handbook** for the origins of scientific terms.)
3. How could a water mold eventually kill a fish?
4. How does a plasmodial slime mold differ from a cellular slime mold?

Thinking Critically

5. In what kinds of environments would you expect to find slime molds? Explain your answer.

Skill Review

6. **Observe and Infer** If you know that a plasmodium consists of many nuclei within a single cell, what can you infer about the process that formed the plasmodium? For more help, refer to *Observe and Infer* in the **Skill Handbook.**

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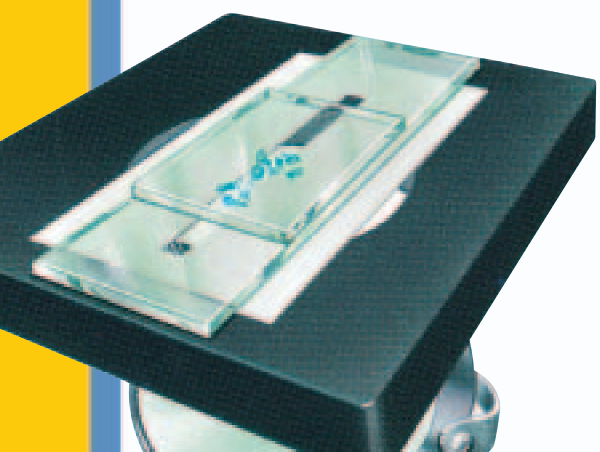
DESIGN YOUR OWN

BioLab

How do *Paramecium* and *Euglena* respond to light?

Before You Begin

Members of the genus *Paramecium* are ciliated protozoans—unicellular, heterotrophic protists that move around in search of small food particles. *Euglena* are unicellular algae—autotrophic protists that usually contain numerous chloroplasts. In this *BioLab,* you'll investigate how these two protists respond to light in their environment.



PREPARATION

Problem

Do both *Paramecium* and *Euglena* respond to light, and do they respond in different ways? Decide on one type of protist activity that would constitute a response to light.

Hypotheses

Decide on one hypothesis that you will test. Your hypothesis might be that *Paramecium* will not respond to light and *Euglena* will respond, or that *Paramecium* will move away from light and *Euglena* will move toward light.

Objectives

In this BioLab, you will:

- **Prepare** slides of *Paramecium* and *Euglena* cultures and observe swimming patterns in the two organisms.
- **Compare** how these two different protists respond to light.

Possible Materials

Euglena culture
Paramecium culture
microscope
microscope slides
dropper
methyl cellulose
coverslips
metric ruler
index cards
scissors
toothpicks

Safety Precautions

CAUTION: ***Always wear goggles in the lab. Use caution when working with a microscope, glass slides, and coverslips. Wash your hands with soap and water immediately after working with protists and chemicals.***

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook.**

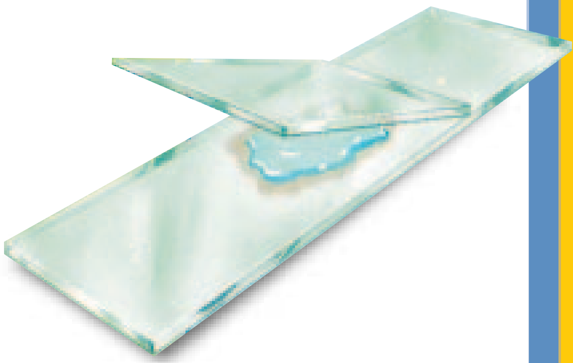
PLAN THE EXPERIMENT

1. Decide on an experimental procedure that you can use to test your hypothesis.
2. Record your procedure, step-by-step, and list the materials you will be using.
3. Design a data table in which to record your observations and results.

Check the Plan

Discuss all the following points with other group members to determine your final procedure.

1. What variables will you have to measure? What will be your control?
2. What will be the shape of the light-controlled area(s) on your microscope slide?
3. Decide who will prepare materials, make observations, and record data.
4. ***Make sure your teacher has approved your experimental plan before you proceed further.***
5. To mount drops of *Paramecium* culture and *Euglena* culture on microscope slides, use a toothpick to place a small ring of methyl cellulose on a clean microscope slide. Place a drop of *Paramecium* or *Euglena* culture within this ring. Place a coverslip over the ring and culture. The thick consistency of methyl cellulose should slow down the organisms for easy observation.
6. Make preliminary observations of swimming *Paramecium* and *Euglena.* Then think again about the observation times that you have planned. Maybe you will decide to allow more or less time between your observations.
7. Carry out your experiment.
8. **CLEANUP AND DISPOSAL** Work with your teacher to make wise choices concerning disposal of materials.



ANALYZE AND CONCLUDE

1. **Compare and Contrast** Compare and contrast all the responses of the *Paramecium* and *Euglena* to both light and darkness. What explanations can you suggest for their behavior?
2. **Make Inferences** Can you use your results to suggest what sort of responses to light and darkness you might observe using other heterotrophic or autotrophic protists?
3. **ERROR ANALYSIS** Did your data support your hypothesis? Why or why not?

Apply Your Skill

Project You may want to extend this experiment by varying the shapes or relative sizes of light and dark areas or by varying the brightness or color of the light. In each case, make hypotheses before you begin. Keep your data in a notebook, and draw up a table of your results at the end of your investigations.

Web Links To find out more about protists, visit bdol.glencoe.com/protists

BIO TECHNOLOGY

The Diversity of Diatoms

What do most swimming pool filters, fine porcelain, metal polishes, and some insecticides have in common? All contain the remains of millions of single-celled algae known as diatoms. In addition to their many industrial uses, diatoms can be used to solve crimes and may someday aid in fighting cancer.

Diatoms are unicellular algae enclosed in hard, perforated shells made of silica. Each half of a diatom's shell resembles the top or bottom of a miniature circular box. When diatoms die, their shells fall to the bottom of the water body in which they lived. Over time, the shells undergo physical changes to become diatomite—a very porous, highly absorbent, powdery rock with many uses.

Some industrial uses for diatoms As a result of the structure and composition of diatoms' shells, diatomite is extremely absorbent and essentially chemically inert. Thus, diatomite is a common component in many industrial absorbents used to clean up chemical spills. Diatomite is also a critical ingredient in some types of pet litter and potting soils and can also be added to fertilizers and pesticides to prevent caking.

Another important use of diatomite is as an insecticide. When added to stored grains, the razor-sharp diatom shells in diatomite can pierce the cuticles of insects that may be in the silo, causing them to dehydrate and die. Diatomite is nontoxic to most other animals, and thus does not have to be removed before the grain is used.

Diatomite can also be cut into blocks and bricks and used for thermal and acoustic insulation. It can be ground up to produce filters that are used in swimming pools and in the processing of some beverages. Ground diatomite is also used as filler in many kinds of paints, plastics, cements, pesticides, and pharmaceuticals, and is a major component of most fine porcelain and many mild abrasives.

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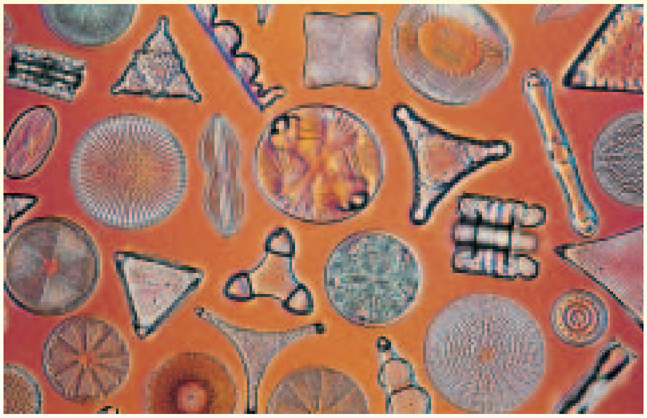


Diatoms

Diatoms and forensics In addition to their many industrial uses, diatoms may be used in forensics. Forensic biology is a science that uses biological evidence in court to support or disprove guilt. Diatoms can be collected from the shoes or clothing of persons involved or suspected in a crime in order to identify the criminal(s) and/or the scene of the crime. Diatoms can also pinpoint the time of year during which a crime occurred.

Diatoms—Possible cancer drugs In nature, certain species of diatoms produce substances that kill the developing embryos of copepods and sea urchins. In the lab, these same substances have been shown to prevent some human cancer cells from dividing. Such studies suggest that a drug made from certain types of diatoms might be able to slow down or even prevent the abnormal reproduction of some kinds of cancer cells.

Applying Biotechnology

Draw Conclusions Suppose that police find a dead body at the edge of a pond in early May. Examination of the body showed drowning as the cause of death. The time of death was estimated to have been about two weeks prior to the discovery of the body. Very few diatoms were found in the water that filled the person's lungs. Did this person drown in the pond? Explain.

To find out more about diatoms, visit bdol.glencoe.com/biotechnology

Study Guide

Section 19.1

The World of Protists

Key Concepts

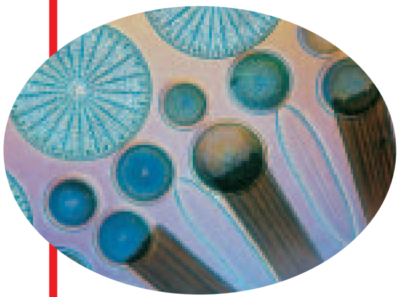
- Kingdom Protista is a diverse group of living things that contains animal-like, plantlike, and funguslike organisms.
- Some protists are heterotrophs, some are autotrophs, and some get their nutrients by decomposing organic matter.
- Amoebas move by extending pseudopodia. The flagellates use one or more flagella to move. The beating of cilia produces cilliate movement. Sporozoans live as parasites and produce spores.

Vocabulary

alga (p. 503)
asexual reproduction (p. 505)
ciliate (p. 506)
flagellate (p. 506)
protozoan (p. 503)
pseudopodia (p. 504)
spore (p. 508)
sporozoan (p. 508)

Section 19.2

Algae: Plantlike Protists



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Key Concepts

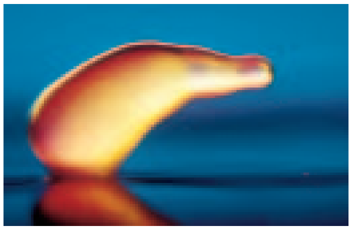
- Algae are unicellular and multicellular photosynthetic autotrophs. Unicellular species include the euglenoids, diatoms, dinoflagellates, and some green algae. Multicellular species include red, brown, and green algae.
- Green, red, and brown algae, often called seaweeds, have complex life cycles that alternate between haploid and diploid generations.

Vocabulary

alternation of generations (p. 516)
colony (p. 515)
fragmentation (p. 515)
gametophyte (p. 516)
sporophyte (p. 516)
thallus (p. 514)

Section 19.3

Slime Molds, Water Molds, and Downy Mildews



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Key Concepts

- Slime molds, water molds, and downy mildews are funguslike protists that decompose organic material to obtain nutrients.
- Plasmodial and cellular slime molds change in appearance and behavior before producing reproductive structures.

Vocabulary

plasmodium (p. 518)

FOLDABLES Study Organizer

To help you review protists, use the Organizational Study Fold on page 510.

Chapter 19 Assessment

Vocabulary Review

Review the Chapter 19 vocabulary words listed in the Study Guide on page 525. Match the words with the definitions below.

1. cytoplasm-containing extensions of protozoan plasma membranes

2. haploid form of an alga that produces gametes

3. mass of cytoplasm that contains many diploid nuclei but no separating cell walls or membranes

4. diploid form of an alga that contains cells that undergo meiosis

5. a group of cells that lives together in close association

Understanding Key Concepts

6. Which organisms may cause red tides?
A. dinoflagellates
B. euglenoids
C. green algae
D. red algae

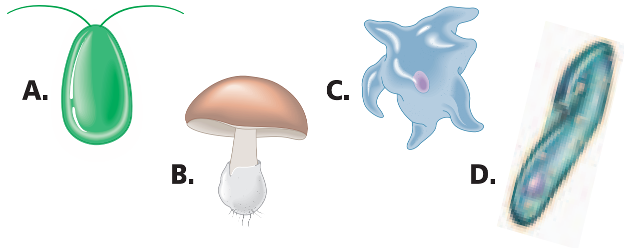
7. Which organelle in protists is able to eliminate excess water?
A. anal pore
B. mouth
C. contractile vacuole
D. gullet

8. Producers in aquatic food chains include ________.
A. algae
B. protozoans
C. slime molds
D. amoebas

9. Protists are classified on the basis of their ________.
A. nutrition
B. method of locomotion
C. reproductive abilities
D. size

10. Euglenoids are unique algae because of their ________.
A. flagella
B. cilia
C. silica walls
D. heterotrophic nature

11. Which of the following is not a protist?



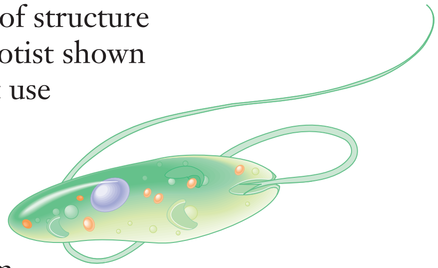
12. The algae that can survive in the deepest water are the ________.
A. brown algae
B. red algae
C. diatoms
D. green algae

13. The largest and most complex of brown algae are the ________.
A. kelp
B. *Chlamydomonas*
C. sea lettuce
D. *Spirogyra*

14. Which of the following are protected by armored plates?
A. kelp
B. fire algae
C. dinoflagellates
D. diatoms

15. Unlike bacteria, all protists are ________.
A. prokaryotes
B. eukaryotes
C. nonliving
D. both prokaryotic and eukaryotic

16. What type of structure does the protist shown to the right use to move?



A. cilium
B. gullet
C. pellicle
D. flagellum

Constructed Response

17. Infer In which ecosystem would a plasmodial slime mold transform itself into spore-producing structures more frequently: a rainy forest in the Pacific Northwest or a dry, oak forest in the Midwest? Explain.

18. Infer Give three examples of organelles that help protists maintain homeostasis.

19. Explain To fight malaria, wetlands were often drained. How did this cut down on malaria cases?

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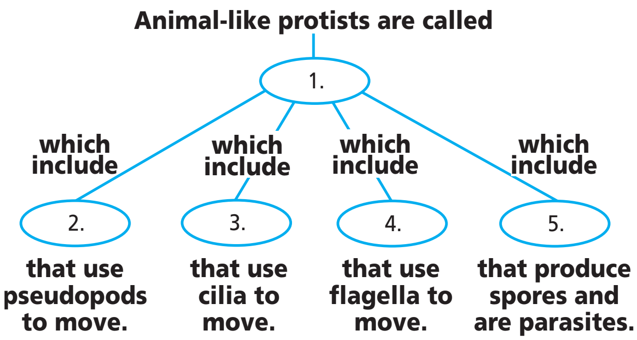
CONTENTS

Chapter 19 Assessment

Thinking Critically

20. Concept Map Complete the concept map with the terms: amoebas, sporozoans, flagellates, protozoans, ciliates.



21. REAL WORLD BIOCHALLENGE More than two million people worldwide die from malaria infections transmitted by just four species of the sporozoan *Plasmodium*. Recent attempts to decrease deaths caused by malaria are yielding promising new methods of prevention. Visit **bdol.glencoe.com** to discover the potential of this research. What are the hosts of the malaria parasite? Discuss with your classmates how the number of people who die from malaria could be reduced.

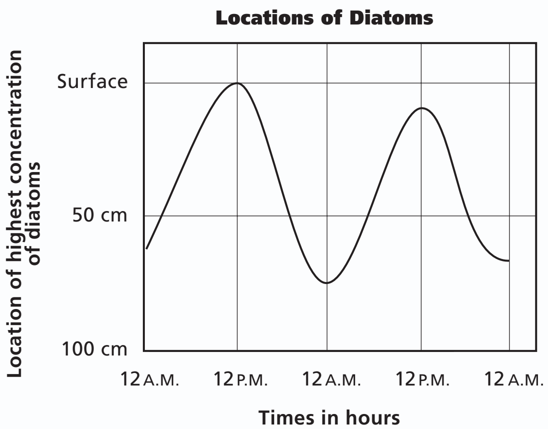
Standardized Test Practice

All questions aligned and verified by The Princeton Review

Part 1 Multiple Choice

Use the graph to answer questions 22 and 23.

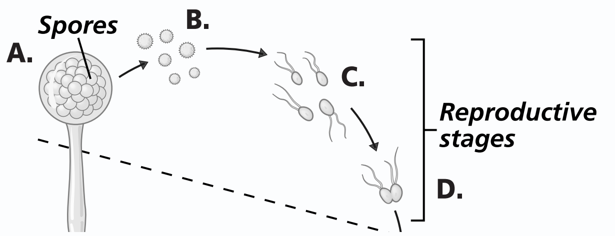
A group of high school students studied unicellular algae in the middle of a pond. For two days they measured the number of cells in the water at various depths. They produced the following graph based on their data.



22. At what time were the highest concentrations of diatoms at the surface?
A. midnight **C.** 3 A.M.
B. noon **D.** 6 P.M.

23. At what time were the highest concentrations of diatoms about a meter below the surface?
A. midnight **C.** 3 A.M.
B. noon **D.** 6 P.M.

Study the diagram and answer questions 24 and 25.



24. Which of the following represents fertilization?
A. A **C.** C
B. B **D.** D

25. Cells in stage C have ________ chromosomes.
A. n **C.** a diploid number of
B. $2n$ **D.** no

Part 2 Constructed Response/Grid In

Record your answer on your answer document.

26. Open Ended Describe how protozoa eliminate excess water from their internal environments.

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