CHAPTER 25

PROTISTS

The single-celled organisms shown here are protists from the genus *Stentor,* named after a Greek announcer who had a very loud voice. These trumpet-shaped cells are highly complex and adapted for capturing and consuming prey.

CHARACTERISTICS OF PROTISTS

SECTION 1

OBJECTIVES

- **Define** *protist.*
- **Describe** a hypothesis for the origin of eukaryotic cells.
- **Explain** how protists are classified.
- **Describe** the two major ways by which protists obtain energy.
- **List** three structures protists use for movement.
- **Describe** how protists reproduce.

VOCABULARY

protist
binary fission
multiple fission
conjugation

Protists are a diverse collection of eukaryotic organisms, such as protozoa, algae, slime molds, and water molds. Protists are sometimes described as animal-like, plantlike, or funguslike. However, these organisms lack the cellular differentiation found in animals, plants, and fungi.

A DIVERSE GROUP OF EUKARYOTES

Single-celled or simple multicellular eukaryotic organisms that generally do not fit in any other kingdom are called **protists.** Most protists are microscopic, but a few protists, such as some algae, are several meters in length. Protists are defined by exclusion—most protists are eukaryotic organisms that cannot be classified as fungi, plants, or animals. As a result, protists are the most diverse group of eukaryotes. Protists have varying body plans, types of movement, and means of obtaining food. Protists are made up of eukaryotic cells, each containing a nucleus and other organelles. Most living protists contain mitochondria. Some protists, such as *Euglena* shown in Figure 25-1, also contain chloroplasts.

The First Eukaryotes

Protists emerged early in the history of domain Eukarya. Some of the oldest eukaryotic cells were protists. Protists emerged as much as 2 billion years ago.

By analyzing genetic information in the nucleus, mitochondria, and chloroplasts of protists, scientists have found strong evidence that the first protists arose from prokaryotic cells. Nuclear genes in protists and in other eukaryotes resemble archaeal and bacterial genes. Additionally, the genetic information found in the mitochondria and chloroplasts of protists and other eukaryotes is similar to genetic information found in bacteria and cyanobacteria. Because of these genetic similarities, scientists hypothesize that protists and other eukaryotes arose from ancient prokaryotes that lived in *endosymbiosis*. In endosymbiosis, an organism lives inside a larger organism. Scientists think that mitochondria and chloroplasts arose from ancient prokaryotes that lived inside larger prokaryotes. Over time, the endosymbiotic prokaryotes became organelles within eukaryotic protists.

FIGURE 25-1
Most *Euglena* are unicellular, contain chloroplasts, move about, and sometimes consume other organisms. Because *Euglena* have both plantlike and animal-like characteristics, they cannot be classified in the plant or animal kingdoms. So, they are classified as protists.

CLASSIFICATION

Often, protists are classified by the characteristics that resemble those of fungi, plants, and animals. For example, the reproduction of some protists resembles the reproduction of fungi. Other protists capture light energy for photosynthesis, as plants do. Some protists move and consume other organisms, as animals do.

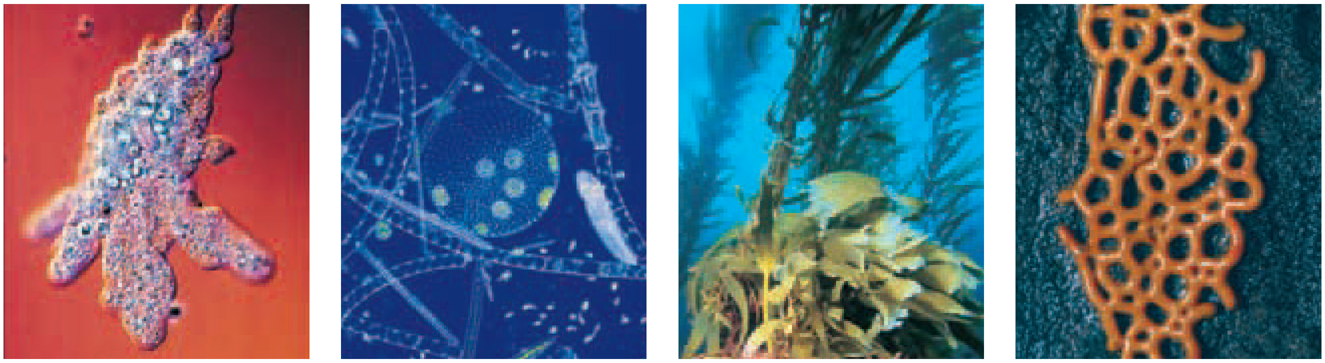
The great diversity among protist species makes them difficult to classify. Protists have traditionally been classified in kingdom Protista. Because of ongoing molecular analyses, many scientists now hypothesize that kingdom Protista should be divided into several kingdoms. Scientists are still revising the classification of protists.

CHARACTERISTICS

Table 25-1 summarizes the characteristics of several protist phyla. There are few general characteristics of protists, but they can be characterized by body plan, means of obtaining food, and motility.

TABLE 25-1 ***Characteristics of Various Protist Phyla***

Phylum	Common name	Body plan	Motility	Nutrition type	Representative genera
Protozoa	protozoa, sarcodines, mycetozoans	unicellular	pseudopodia	heterotrophic, some parasitic	*Amoeba, Entamoeba, Radiolaria*
Ciliophora	ciliates	unicellular	cilia	heterotrophic, some parasitic	*Paramecium, Balantidium, Stentor*
Sarcomastigophora	mastigophorans	unicellular	flagella	heterotrophic, some parasitic	*Trypanosoma, Leishmania*
Apicomplexa	apicomplexans	unicellular	none in adult	heterotrophic, parasitic	*Plasmodium, Toxoplasma*
Chlorophyta	green algae	unicellular, colonial, multicellular	some with flagella	autotrophic	*Spirogyra, Volvox, Chlamydomonas, Protococcus*
Bacillariophyta	diatoms	unicellular, colonial	mostly no flagella	autotrophic	*Cocconeis, Bacillaria*
Dinoflagellata	dinoflagellates	unicellular	flagella	autotrophic, some heterotrophic	*Noctiluca, Ceratium*
Euglenophyta	euglenoids	unicellular	flagella	autotrophic, some heterotrophic	*Euglena*
Dictyostelida	cellular slime molds	unicellular, multicellular	pseudopodia	heterotrophic	*Dictyostelium*
Oomycota	water molds	unicellular, multicellular	some with flagella	heterotrophic, some parasitic	*Phytophthora*



(a) (b) (c) (d)

FIGURE 25-2
Protists have a variety of body plans. (a) The single-celled *Amoeba proteus* constantly changes its body shape. (b) Cells from *Volvox,* a colonial protist, have coordinated activity. (c) Brown algae, such as this kelp (*Macrocystis pyrifera*), are multicellular giants among protists. (d) This pretzel slime mold (*Hemitrichia serpula*) reproduces similarly to fungi.

Unicellular and Multicellular

As shown in Figure 25-2, protists come in a wide variety of body plans. Most protists are unicellular, such as the amoeba shown in Figure 25-2a. Some protists, such as the *Volvox* in Figure 25-2b, form colonies in which several cells are joined into a larger body. Some of these colonies have a division of labor; certain cells specialize in reproduction, and other cells specialize in obtaining energy.

A few protists, such as the brown algae in Figure 25-2c and the pretzel slime mold in Figure 25-2d, form large multicellular bodies. Some brown algae may grow to more than 60 m in length. These marine giants have specialized regions for reproduction, photosynthesis, and attachment to the ocean floor. However, these regions lack the cellular differentiation found in true tissues and organs.

Nutrition

Protists obtain energy in a number of ways. Many protists are *autotrophs,* organisms that can make their own food molecules. These protists make food in much the same way that plants do. The protists absorb energy from sunlight with the aid of specialized light-absorbing pigments. Protists often utilize chlorophyll, as plants do, but they may use additional pigments. The protists use the captured light energy, water molecules, and carbon dioxide molecules to make carbohydrates.

Some protists are *heterotrophs,* organisms that must get their food by eating other organisms or their byproducts and remains. Some heterotrophic protists engulf smaller protists and digest them. Other heterotrophic protists obtain energy in the same way that fungi do. These protists secrete digestive enzymes into the environment. The enzymes break down cells or bits of food into small molecules that the protists can absorb and use.

Motility

Most protists are able to move at some time during their life cycles. Some protists move with the aid of long, whiplike structures called *flagella* (singular, *flagellum*). Other protists move with the aid of *cilia* (singular, *cilium*), which are shorter than flagella and often form rows. Finally, some protists, such as amoebas, move by temporarily extending structures called *pseudopodia* (singular, *pseudopodium*).

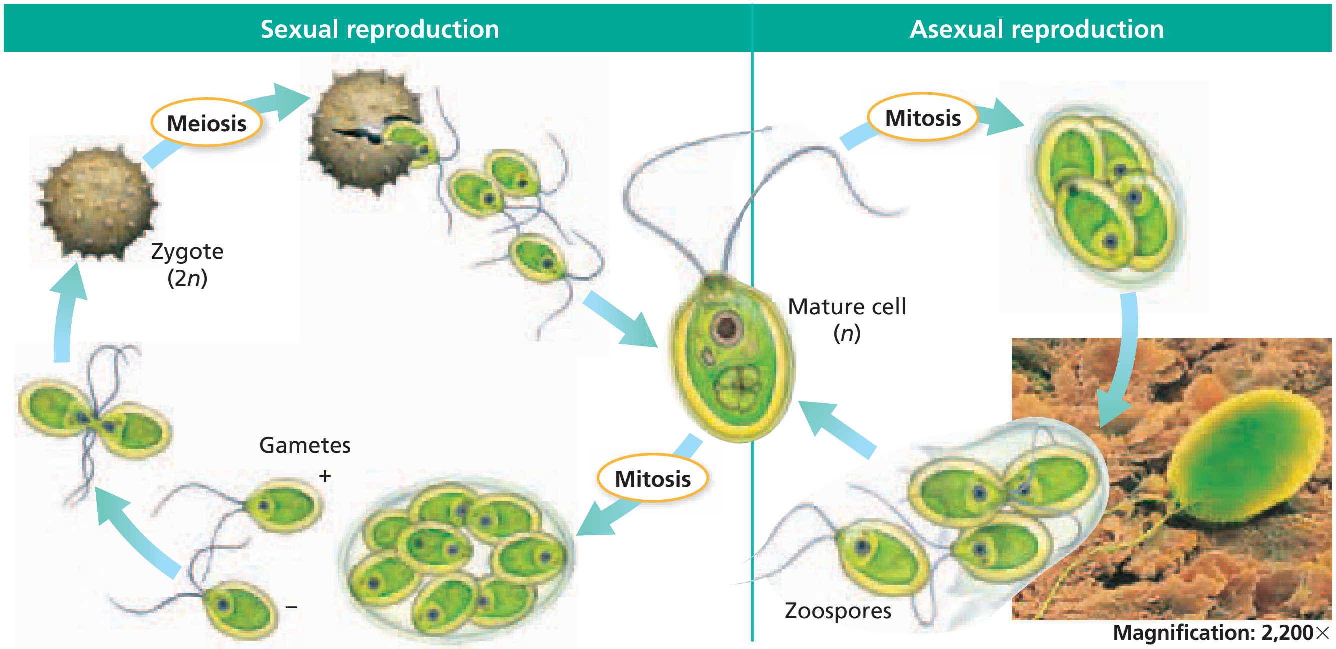


FIGURE 25-3

Algae of the genus *Chlamydomonas* are unicellular green algae that undergo both asexual and sexual reproduction. For many protist producers, the type of reproduction alternates by generation. For example, a parent may reproduce asexually, but its offspring may reproduce sexually. For other protists, sexual reproduction occurs only when environmental conditions are stressful.

REPRODUCTION

Many protists reproduce asexually. During **binary fission,** a single protist cell divides into two cells. Some protists reproduce by **multiple fission,** a form of cell division that produces more than two offspring. Both types of fission produce offspring that are genetically identical to the parent cell.

One way by which many protists reproduce sexually is conjugation. During **conjugation,** two individuals join and exchange genetic material stored in a small second nucleus. Then, the cells divide to produce four offspring. The offspring are genetically different from the parent cells. As shown in Figure 25-3, many protists can reproduce both asexually and sexually.

SECTION 1 REVIEW

1. What is the definition of *protist*?
2. What is a hypothesis for how eukaryotic cells arose?
3. How are protists often classified?
4. Describe unicellular and multicellular protists.
5. What are two ways by which protists obtain energy?
6. How do protists move?
7. Describe how some protists reproduce both asexually and sexually.

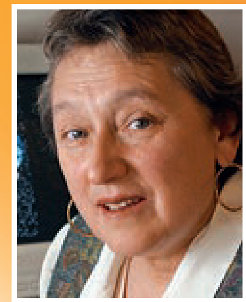
CRITICAL THINKING

8. **Applying Information** Why might scientists argue that protists should be classified in several kingdoms rather than in one kingdom?
9. **Relating Concepts** Compare binary fission and conjugation.
10. **Calculating Information** Make a bar graph comparing the volumes of the following: a protist (cone shaped, 500 μm long, 200 μm in diameter); a human white blood cell (sphere shaped, 10 μm in diameter); and a bacterial cell (cylinder shaped, 2 μm long, 0.8 μm in diameter).

Science in Action

How Did Eukaryotic Cells Evolve?

The idea that cellular organelles were originally separate organisms was first proposed in the early 1900s. The few scientists who later became aware of this hypothesis thought that it was preposterous. In the 1960s, Lynn Margulis thought that the idea should be reexamined. Her research led her to form a theory that shook the foundations of the biological community.



Lynn Margulis

HYPOTHESIS: Cellular Organelles Were the Result of Endosymbiosis

Endosymbiosis is a relationship in which one organism lives inside another. Lynn Margulis, an American biologist, thought that endosymbiosis led to the evolution of eukaryotic cells. Margulis proposed that mitochondria and chloroplasts, the cell's energy-producing organelles, were initially separate organisms that had become integral parts of larger cells.

Margulis hypothesized that the first cells with chloroplasts probably came about when a host organism ingested photosynthetic bacteria. A few of these bacteria were not digested. These unlikely partnerships provided something for everyone: The guest gave the host a source of food, while the host protected the guest. Margulis also surmised that mitochondria arose in a similar way.

METHODS: Use Electron Microscopy to Observe Organelles and Cells

Margulis took advantage of advances in electron microscopy and molecular biology to obtain evidence in support of her hypothesis. Working with her graduate research advisor, Hans Ris, Margulis used high-powered electron microscopy to carefully observe and compare mitochondria, chloroplasts, eukaryotic cells, and prokaryotic cells. In addition, she looked for the presence of DNA in the chloroplasts of *Euglena gracilis* by using radioactively labeled nucleotides.

RESULTS: Organelles Are Similar to Bacteria

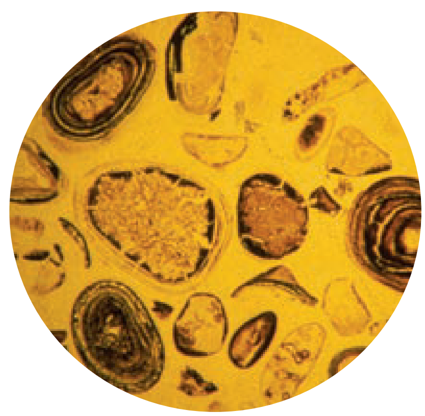
Margulis found that bacteria and organelles show many similarities. Like prokaryotes, mitochondria and chloroplasts have circular DNA. These organelles also have their own ribosomes, which are the same size as those found in prokaryotes but smaller than those found in the cytoplasm of eukaryotes. Both mitochondria and chloroplasts are found enclosed in membranes as though they were captured in a vacuole of a larger cell. Also, mitochondria and chloroplasts divide by fission, as bacteria do.

An endosymbiotic relationship was witnessed by Kwang Jeon at the University of Tennessee. One day, Jeon noticed that bacteria had infected his amoebas and that a few of the amoebas did not die. Their new partners replicated along with the hosts. Generations later, these amoebas are thriving; yet the formerly separate organisms are totally dependent upon one another. If the invader is removed from the host, both die.

CONCLUSION: Organelles Arose Through Endosymbiosis

Today, endosymbiosis is the accepted explanation for how eukaryotes arose. Additional support for Margulis's theory comes from examining modern organisms that contain intracellular symbiotic bacteria and photosynthetic protists. For example, sea slugs incorporate chloroplasts into some of their cells, which provides a source of energy for the sea slugs when other food is scarce.

Endosymbiosis led to the formation of eukaryotic cells. Multicellular eukaryotes, such as these fossil algae, arose around 2 billion years ago.



REVIEW

1. Restate the endosymbiosis hypothesis in your own words.
2. In what ways do prokaryotes resemble chloroplasts and mitochondria?
3. **Critical Thinking** Why must modern plants be the result of at least two separate endosymbiotic events?

SCILINKS.
www.scilinks.org
Topic: Endosymbiosis
Keyword: HM60506

SECTION 2

ANIMAL-LIKE PROTISTS

OBJECTIVES

- **Discuss** the key characteristics of Protozoa, Ciliophora, Sarcomastigophora, and Apicomplexa.
- **Describe** how protozoa use pseudopodia to move and to capture food.
- **Explain** how ciliates move and reproduce.
- **Describe** how mastigophorans move and capture food.
- **Describe** the role of apicomplexans in disease.

VOCABULARY

pseudopodium
amoeboid movement
test
cilium
pellicle
oral groove
mouth pore
gullet
anal pore
contractile vacuole
macronucleus
micronucleus
flagellum

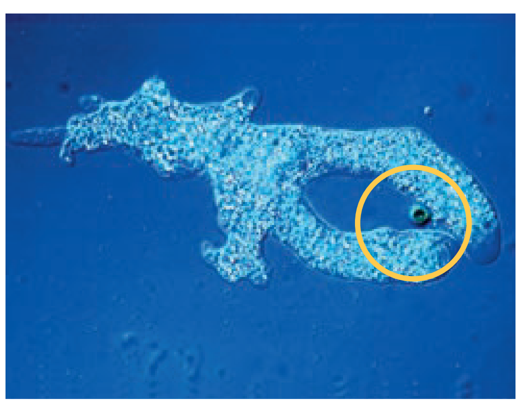
Protists aren't animals. However, four major groups of protists move and obtain food in animal-like ways. Having animal-like characteristics would seem to suggest that animal-like protists are closely related to animals in an evolutionary sense, but animal-like protists and animals are not closely related.

PHYLUM PROTOZOA

Most animal-like protists are heterotrophs that move about capturing and consuming prey. Animal-like protists are sometimes called *protozoa.* Protozoa are single-celled protists that can move independently without cilia or flagella. Biologists group more than 40,000 species of protozoa in the phylum Protozoa, which includes the subphyla Sarcodina (SAHR-kuh-DIE-nuh) and Mycetozoa (mie-SEET-uh-ZOH-uh). Of these species, about three-quarters are identified only by fossil remains. Figure 25-4 shows two examples of protozoans.

A key characteristic of most protozoa is the formation of pseudopodia (SOO-doh-POH-dee-uh). **Pseudopodia** are large, rounded cytoplasmic extensions that function both in movement and feeding. A pseudopodium forms when the cytoplasm flows forward to create a blunt, armlike extension. Simultaneously, other pseudopodia retract, and the cytoplasm flows in the direction of the new pseudopodium, causing the cell to move. This type of locomotion is called **amoeboid movement.** Amoeboid movement is a form of *cytoplasmic streaming,* the internal flowing of a cell's cytoplasm.

Protozoa actively prey on smaller cells, such as bacteria and smaller protists, and food particles. A sarcodine feeds by surrounding the food with pseudopodia and trapping the food in a vesicle. The sarcodine releases enzymes to digest the food trapped inside the vesicle. Figure 25-4a shows a sarcodine, an amoeba, using pseudopodia to capture food.


(a)

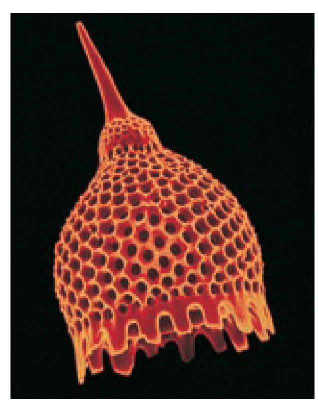

(b)

FIGURE 25-4
(a) Some sarcodines, such as amoebas, send out pseudopodia that engulf smaller organisms (indicated by the yellow circle). (b) Some mycetozoans, such as radiolarians, have distinctive glassy shells.

Protozoan Diversity

Sarcodines include hundreds of species that inhabit freshwater environments, marine environments, and soil. The cell membranes of some sarcodines, such as amoebas, are exposed directly to the environment. Other sarcodines are covered with a protective **test,** or shell. For example, *foraminifera* (fuh-RAM-uh-NIF-uhr-uh) are found primarily in oceans and are covered with intricate tests of calcium carbonate. The shells of ancient foraminifera accumulated at the ocean bottom where, after millions of years, they became limestone. The tests of a group of mycetozoans, the *radiolarians* (RAY-dee-oh-LER-ee-uhnz), contain silicon dioxide. Radiolarians often have radially arranged spines. Both foraminiferans and radiolarians have slender pseudopodia that extend through tiny openings in the test.

Although most amoebas live freely, some species live in human intestines and may cause disease. One such amoeba, *Entamoeba histolytica,* enters the body through contaminated food and water. It releases enzymes that attack the lining of the large intestine and cause ulcers. A sometimes fatal disease called *amebiasis* may result, causing acute abdominal pain.

SCILINKS.
www.scilinks.org
Topic: Protozoans
Keyword: HM61247

PHYLUM CILIOPHORA

The nearly 8,000 species that make up the phylum Ciliophora (SIL-ee-AHF-uh-ruh) share one key feature: they have cilia. **Cilia** are short, hairlike cytoplasmic projections that line the cell membrane. Cilia make it possible for these protists to move. Members of the genus *Paramecium,* shown in Figure 25-5, are among the most thoroughly studied ciliates. Paramecia are found in ponds and slow-moving streams that contain plants and decaying organic matter. A paramecium has cilia arranged in rows across its cell membrane. The cilia beat in waves, moving the cell through the water. Ciliates often feed on bacteria, algae, and other small organisms in their marine and freshwater habitats.

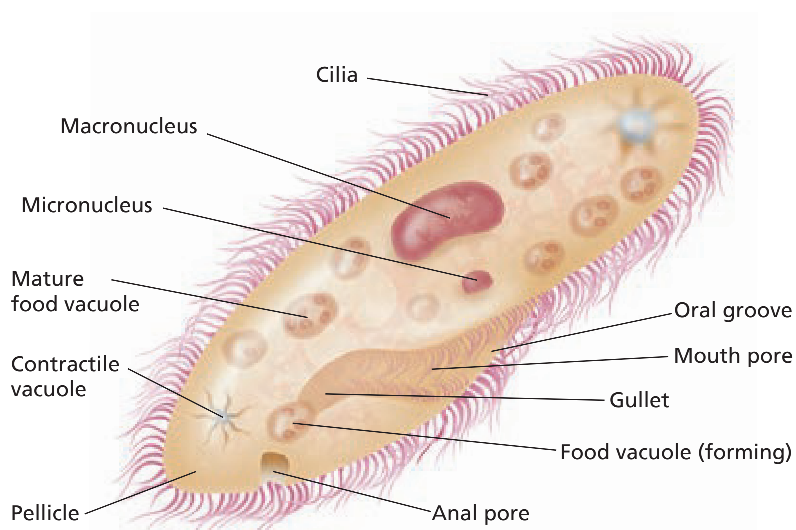


FIGURE 25-5

Like other ciliates, paramecia move by using hundreds of short projections called *cilia.* Paramecia have a large macronucleus, which controls many cell functions, and one or more micronuclei, which are involved in reproduction. The oral groove, mouth pore, and gullet collect food into vacuoles.

Characteristics

Ciliates have the most elaborate organelles of any protist. A clear, elastic layer of protein, called a **pellicle,** surrounds the cell membrane. The pellicle has a funnel-like depression called an **oral groove.** Cilia lining the oral groove create currents that sweep food down the groove to the **mouth pore.** The mouth pore opens into a **gullet,** which forms food vacuoles that move throughout the cytoplasm. Enzymes in the vacuoles digest food into small organic molecules that enter the cytoplasm. Undigested materials move to the **anal pore,** which contracts and expels them. Ciliates also have **contractile vacuoles,** saclike organelles that expand to collect excess water and contract to squeeze the water out of the cell.

Ciliates have two types of nuclei. The large **macronucleus** contains multiple copies of DNA that direct the cell's metabolism and development. The smaller **micronucleus** participates in the exchange of genetic material during conjugation.

Word Roots and Origins

macronucleus

from the Greek *makros,* meaning "long," and the Latin *nucleus,* meaning "nut" or "kernel"

Reproduction

Asexual reproduction in ciliates occurs by binary fission. In this process, the micronucleus divides by mitosis. The macronucleus, which has up to 500 times more DNA than the micronucleus, simply elongates and splits in half. One half goes to each new cell.

Sexual reproduction in ciliates involves conjugation. During conjugation, two cells join, and their macronuclei disintegrate. Each diploid micronucleus then undergoes meiosis, producing four haploid micronuclei. In each cell, all but one micronucleus disintegrates. The remaining micronucleus divides by mitosis, producing two identical haploid micronuclei. The two cells then exchange one micronucleus. The two micronuclei in each cell then fuse to form one diploid micronucleus. The two cells separate, and a macronucleus forms in each cell from products of mitotic divisions of the micronucleus. Although the cells exchange genetic material during conjugation, they produce no new cells. After conjugation, the two cells divide, forming four offspring.

FIGURE 25-6

Flagella are a key characteristic of mastigophorans, such as these trypanosomes (*Trypanosoma* sp.), shown with red blood cells. Trypanosome flagella are structurally similar to the tails of human sperm.

PHYLUM SARCOMASTIGOPHORA

The phylum Sarcomastigophora (SAR-koh-mas-ti-GAHF-uh-ruh) includes 1,500 species and the subphylum Mastigophora. Members of this phylum are characterized by one or more flagella. **Flagella** are long, whiplike structures that are made up of microtubules and used for movement. Flagella can be seen in Figure 25-6. The rapid motion of flagella moves the protist through water. Many mastigophorans are free-living species that inhabit lakes and ponds, where they feed on smaller organisms.

Some mastigophorans are parasites, including many in the genus *Trypanosoma.* Trypanosomes live in the blood of fish, amphibians, reptiles, birds, and mammals and are carried from host to host by bloodsucking insects. Two species of *Trypanosoma* cause sleeping sickness. The tsetse fly, which lives only in Africa, transmits these parasites. The disease is characterized by increasing fever, lethargy, mental deterioration, and coma.

PHYLUM APICOMPLEXA

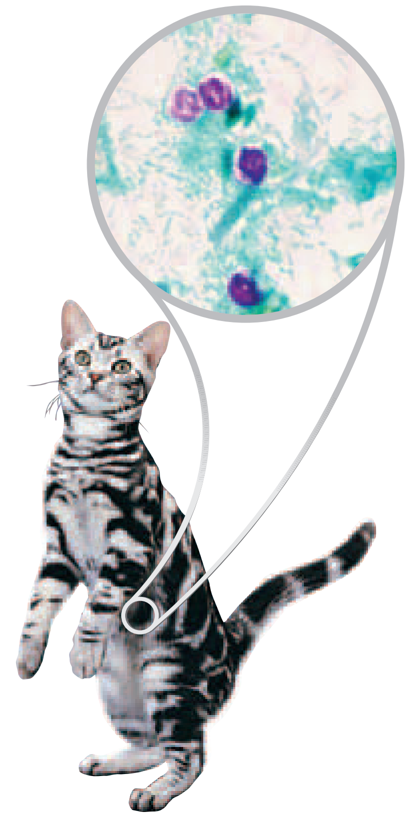
The phylum Apicomplexa (AY-PI-kuhm-PLEKS-uh) includes at least 4,000 species that have adult forms with no means of locomotion. Many apicomplexans were once known as *sporozoans* (SPOH-ruh-ZOH-uhnz). All apicomplexan species are animal parasites.

Apicomplexans have complex life cycles involving both asexual and sexual reproduction. The reproduction of apicomplexans often results in *sporozoites,* infectious cells that are protected by resistant coats. Apicomplexan sporozoites are characterized by an *apical complex,* or a group of organelles specialized for entering host cells and tissues. Because of their complex life cycles, many apicomplexans require two or more different hosts to complete their life cycle. For example, *Plasmodium,* the parasite that causes malaria, needs both mosquitoes and humans to complete its life cycle.

As apicomplexans inhabit a host's cells and tissues, the apicomplexans absorb nutrients and destroy host cells. Apicomplexans may have killed more people than any other group of pathogens on Earth. Each year, millions of people die as a result of *Plasmodium* infection. Another apicomplexan, *Toxoplasma gondii,* causes few symptoms in healthy adult humans but can be dangerous to developing fetuses and newborn babies. *Cryptosporidium,* which is shown in Figure 25-7, is often transmitted by contaminated drinking water or contact with the feces of infected animals.

FIGURE 25-7

Cryptosporidium (stained purple) is a genus of apicomplexans that cause diarrhea, abdominal pain, and vomiting. They sometimes spread to humans through the feces of infected animals, such as cats.



SECTION 2 REVIEW

1. Describe the key characteristics of each phylum of animal-like protists.
2. How are pseudopodia used for movement and the capture of food?
3. Describe reproduction in Ciliophora.
4. How do protozoa, ciliates, and mastigophorans move?
5. What is the role of apicomplexans in disease?
6. List five protists that cause disease, and briefly describe each disease.

CRITICAL THINKING

7. **Applying Information** How might controlling mosquito populations prevent the spread of malaria? Explain your answer.
8. **Making Inferences** Apicomplexans lack a means of locomotion. How does this relate to the fact that apicomplexans are parasites?
9. **Analyzing Information** A scientist found an animal-like protist that lacks cilia or flagella and does not form spores. To which phylum does the protist most likely belong? Explain.

SECTION 3

PLANTLIKE AND FUNGUSLIKE PROTISTS

OBJECTIVES

- **Describe** four main body forms of algae.
- **List** the common name for each of the seven phyla of plantlike protists.
- **Explain** how green algae and plants are similar.
- **Describe** four phyla of funguslike protists.
- **Compare** plasmodial slime molds, cellular slime molds, and water molds.

VOCABULARY

alga
gametangium
phytoplankton
thallus
accessory pigment
diatom
shell
bioluminescence
red tide
euglenoid
fruiting body
water mold
plasmodial slime mold
cellular slime mold

Algae are plantlike protists that vary in size from tiny unicellular organisms to multicellular giants that reach 60 m in length. Although many funguslike protists are called molds, *they do not fit in kingdom Fungi. Funguslike protists include slime molds and water molds.*

CHARACTERISTICS OF ALGAE

Many plantlike protists are known as algae. Unlike animal-like protists, which are heterotrophic, **algae** (singular, *alga*) are autotrophic protists. Algae have chloroplasts and produce their own carbohydrates by photosynthesis, as plants do. Older classification systems placed algae in kingdom Plantae. However, algae lack tissue differentiation and thus have no true roots, stems, or leaves. The reproductive structures of algae also differ from those of plants. Algae form gametes in single-celled gamete chambers called **gametangia** (GAM-uh-TAN-jee-uh). By contrast, plants form gametes in multicellular gametangia.

Despite their diversity, algae share several features. Algae have the photosynthetic pigment chlorophyll *a*. Most algae are aquatic and have flagella at some point in their life cycle. Algal cells often contain *pyrenoids* (pie-REE-NOYDZ), structures associated with algal chloroplasts that synthesize and store starch.

Algae have four basic body forms. *Unicellular algae* consist of a single cell. Most unicellular algae are free-living aquatic organisms and together are known as **phytoplankton.** Phytoplankton form the base of nearly all marine and freshwater food chains. *Colonial algae,* such as *Volvox,* consist of groups of individual cells acting in a coordinated manner. Some of the cells may become specialized, allowing for a division of labor. *Filamentous algae,* such as *Spirogyra,* are multicellular algae that are slender, rod shaped, and composed of cells joined end to end. Some filamentous algae have structures that anchor the organism to the ocean bottom. *Multicellular algae,* such as the kelp shown in Figure 25-8, are usually large and complex and often appear plantlike. Many large multicellular algae are also known as *seaweeds.* The plantlike body portion of a seaweed is called a **thallus** (THAL-uhs), and its cells are usually haploid.

FIGURE 25-8
Multicellular algae, such as kelp, often have air bladders, which help the algae float upright underwater or in mats on the ocean surface.

TABLE 25-2 ***Phyla of Plantlike Protists***

Phylum	Body form	Photosynthetic pigments	Form of food storage	Cell-wall composition
Chlorophyta (green algae)	unicellular, colonial, filamentous, multicellular	chlorophylls *a* and *b,* carotenoids	starch	polysaccharides, cellulose
Phaeophyta (brown algae)	multicellular	chlorophylls *a* and *c,* carotenoids, fucoxanthin	laminarin (a polysaccharide)	cellulose with alginic acid
Rhodophyta (red algae)	multicellular	chlorophyll *a,* phycobilins, carotenoids	starch	cellulose or pectin, many with calcium carbonate
Bacillariophyta (diatoms)	unicellular, colonial	chlorophylls *a* and *c,* carotenoids, fucoxanthin, some with none	laminarin, leucosin (an oil)	pectin, many with silicon dioxide
Dinoflagellata (dinoflagellates)	unicellular	chlorophylls *a* and *c,* carotenoids, xanthophyll, some with none	starch	cellulose
Chrysophyta (golden algae)	unicellular, colonial	chlorophylls *a* and *c,* carotenoids, fucoxanthin, xanthophyll, some with none	laminarin, leucosin	cellulose
Euglenophyta (euglenoids)	unicellular	chlorophylls *a* and *b,* carotenoids, many with none	paramylon (a starch)	no cell wall, protein-rich pellicle

PLANTLIKE PROTISTS

Plantlike protists are classified into seven phyla based on type of pigments, form of food storage, and cell-wall composition. The characteristics of the seven phyla are summarized in Table 25-2.

Phylum Chlorophyta (Green Algae)

The phylum Chlorophyta (klaw-RAHF-uh-tuh) contains more than 17,000 identified species of protists called *green algae*. Green algae have an amazing number of body forms, ranging from single cells and colonies to filamentous and multicellular forms.

Green algae share several characteristics with plants. Both green algae and plants have chlorophylls *a* and *b*. They both have carotenoids, which are **accessory pigments** that capture light energy and transfer it to chlorophyll *a*. Green algae and plants store food as starch and have cell walls made up of cellulose. The similarities between green algae and plants suggest that they may have had a common ancestor or that ancient green algae gave rise to land plants.

Most species of green algae are aquatic. Some species, such as the *Protococcus* shown in Figure 25-9, inhabit moist terrestrial environments, such as soil and tree trunks. Some green algae live as symbiotic partners with invertebrates, such as corals. Other green algae live with fungi as a part of organisms called *lichens.*

FIGURE 25-9

Many green algae, such as *Protococcus,* inhabit moist environments on land, such as the shady, often north-facing sides of tree trunks.

FIGURE 25-10
Giant kelp *(Macrocystis pyrifera)* forms kelp gardens along the Pacific coast and provides habitat for a rich variety of life, including crustaceans, fishes, sharks, and sea otters.

Word Roots and Origins

stipe

from the Latin *stipes,* meaning "log" or "trunk of a tree"

FIGURE 25-11
Red algae, such as this *Corallina* species, are smaller than most brown algae, but members of both phyla are often referred to as *seaweeds.*

Phylum Phaeophyta (Brown Algae)

The phylum Phaeophyta (fee-AHF-uh-tuh) contains approximately 1,500 species of multicellular organisms called *brown algae*. Brown algae contain chlorophylls *a* and *c* and fucoxanthin (FYOO-koh-ZAN-thin), an accessory pigment that gives the algae their characteristic brown color. Brown algae store food as laminarin, a carbohydrate whose glucose units are linked differently than those in starch.

Brown algae are mostly marine organisms, and they include plantlike seaweeds and kelps. They are most common along rocky coasts where ocean water is cool. A few species of brown algae, such as *Sargassum,* can be found far offshore, where they form dense, floating mats.

Some of the largest algae known are classified in the phylum Phaeophyta. The large brown alga shown in Figure 25-10 is *Macrocystis pyrifera,* a giant kelp that thrives in intertidal zones and reaches 60 m in length. The thallus is anchored to the ocean bottom by a rootlike *holdfast*. The stemlike portion of the alga is called the *stipe*. And the leaflike region, modified to capture sunlight for photosynthesis, is the *blade*.

Phylum Rhodophyta (Red Algae)

The 4,000 species in the phylum Rhodophyta (roh-DAHF-uh-tuh) are known as *red algae.* Red algae contain chlorophyll *a* and accessory pigments called *phycobilins*. Phycobilins play an important role in absorbing light for photosynthesis. These pigments can absorb the wavelengths of light that penetrate deep into the water. As a result, phycobilins allow red algae to live at depths where algae lacking these pigments cannot survive. Some species of red algae have been found at depths of nearly 270 m, which is about three times deeper than organisms from any other algal phyla have been found.

A few species of red algae live in fresh water or on land, but most red algae are marine seaweeds. Despite their common name, not all red algae are reddish in appearance. The depth at which red algae live determines the amount of phycobilins they have. The *Corallina* alga shown in Figure 25-11 displays typical red algae pigmentation and body shape.

Phylum Bacillariophyta (Diatoms)

The phylum Bacillariophyta (BAS-uh-ler-ee-AHF-uh-tuh) contains as many as 100,000 species of unicellular protists called **diatoms.** Diatoms have cell walls, or **shells,** consisting of two pieces that fit together like a box and lid. Each half is called a *valve,* and the shells contain silicon dioxide. There are two basic types of diatoms. *Centric diatoms* have circular or triangular shells and are most abundant in marine environments. *Pennate diatoms* have rectangular shells and are most abundant in freshwater environments. Diatoms are an abundant component of phytoplankton and important producers in freshwater and marine food webs. In addition, diatoms release atmospheric oxygen.

Phylum Dinoflagellata (Dinoflagellates)

More than 2,000 species of organisms called *dinoflagellates* make up the phylum Dinoflagellata (DIE-noh-FLAJ-uh-LAH-tuh). Dinoflagellates, such as those shown in Figure 25-12, are small, usually unicellular organisms bearing two flagella of unequal length. The flagella are oriented perpendicular to each other. Dinoflagellates have cell walls made of cellulose plates that look like armor when seen under a microscope.

Most dinoflagellates are photosynthetic autotrophs, but a few species are colorless and heterotrophic. Photosynthetic dinoflagellates usually have a yellowish green to brown color due to large amounts of carotenoids, as well as chlorophylls *a* and *c*.

Some species of dinoflagellates, such as those in genus *Noctiluca,* can produce **bioluminescence,** the production of light by means of a chemical reaction in an organism. Other species produce toxins and red pigments. When the populations of these species explode, they turn the water brownish red, resulting in a phenomenon known as **red tide.** Red tides are fairly common in the Gulf of Mexico. Red tide toxins can kill large numbers of fish. When shellfish, such as oysters, feed on red tide dinoflagellates, they also consume the toxins, which are dangerous to humans who eat the shellfish.

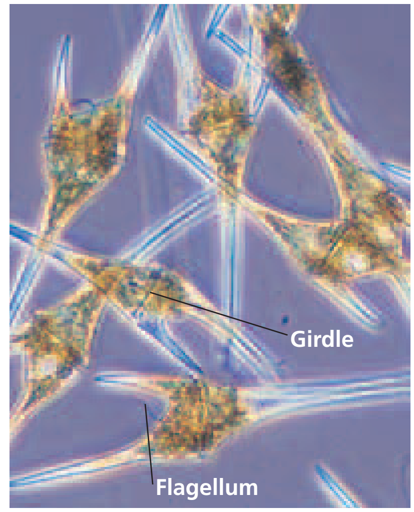


FIGURE 25-12

Flagella spin dinoflagellates, such as these members of genus *Ceratium,* through the water like tops. Only one of the two flagella is clearly visible in this picture. The second flagellum lies in the girdle at the middle of the organism. (450×)

Phylum Chrysophyta (Golden Algae)

The phylum Chrysophyta (kruh-SAHF-uh-tuh) contains about 1,000 species of *golden algae*. Most golden algae live in fresh water, but a few species are found in marine environments. Golden algae cells form highly resistant cysts that enable them to survive beneath the frozen surfaces of lakes during winter and dry lake beds during summer. Two flagella of unequal length are located at one end of each cell.

Most golden algae appear yellow or brown because of the presence of carotenoids. Golden algae also have chlorophylls *a* and *c* and store much of their surplus energy as oil. Golden algae likely played a role in the formation of petroleum deposits.

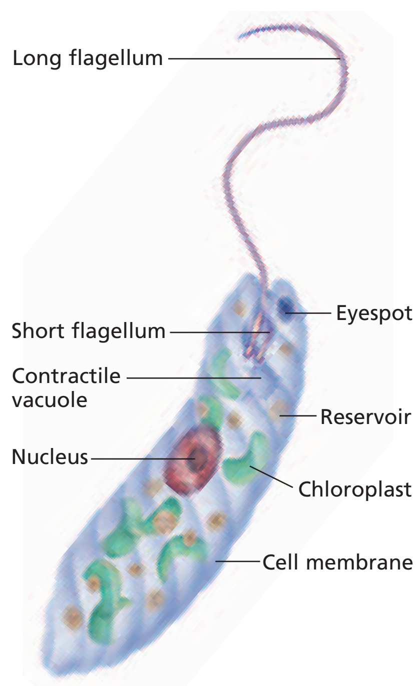
Phylum Euglenophyta (Euglenoids)

The phylum Euglenophyta (YOO-gluh-NAHF-uh-tuh) contains about 1,000 species of flagellated unicellular algae called **euglenoids.** Euglenoids are both plantlike and animal-like. Many are autotrophic, like plants, but they lack a cell wall and are highly motile, like animals. Euglenoids contain chlorophylls *a* and *b* and carotenoids. Most euglenoids live in fresh water, but a few occupy moist environments, such as soil or the digestive tracts of certain animals.

Euglena, shown in Figure 25-13, are abundant in fresh water, especially water polluted by excess nutrients. *Euglena* lack a cell wall, so they are flexible and can change their shape. *Euglena* have an elastic, transparent pellicle made of protein just beneath their cell membrane. Eyespots help *Euglena* sense their environment. Euglena also have a contractile vacuole that expels excess water. Although usually photosynthetic, *Euglena* raised in the dark do not form chloroplasts and become heterotrophs.

FIGURE 25-13

Members of the genus *Euglena* contain chloroplasts like a plant but move around like an animal. *Euglena* are common in ponds. They are propelled by a long flagellum. An eyespot guides them toward light.



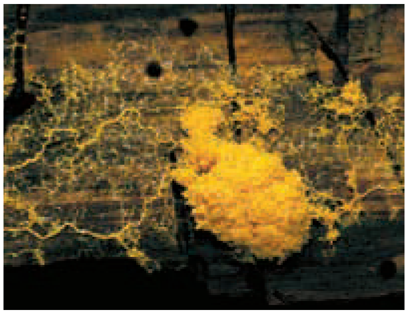


FIGURE 25-14
Slime molds often grow on decomposing organic matter, such as rotting logs. Slime molds consume small organisms and organic matter.

FUNGUSLIKE PROTISTS

Biologists recognize two groups of funguslike protists: slime molds and water molds. Slime molds are typically found on moist, decaying matter. They appear as glistening white, yellow, or red masses of slime, as shown in Figure 25-14. Slime molds have life cycles in which they spend part of their lives in a mobile, amoeba-like feeding form, consuming organic matter and bacteria much as protozoa do. However, these protists have a stationary reproductive stage in which they produce a funguslike, spore-bearing structure called a **fruiting body,** shown in Figure 25-15. A **water mold** is a funguslike protist composed of branching filaments of cells. Water molds are found mainly in bodies of fresh water but sometimes live in soil or as parasites.

Phylum Myxomycota (Plasmodial Slime Molds)

The phylum Myxomycota (MIKS-oh-mie-KOH-tuh) includes about 700 species of **plasmodial slime molds.** During the feeding stage of its life cycle, a plasmodial slime mold is a mass of cytoplasm, called a *plasmodium,* that may be as large as several square meters. Each plasmodium is multinucleate, containing many diploid nuclei that are not separated by cell walls. As the plasmodium creeps along the forest floor by cytoplasmic streaming, it consumes decaying leaves and other debris by phagocytosis.

When food or water is scarce, the plasmodium begins to reproduce. It forms stalked fruiting bodies in which haploid spores are produced by meiosis. Spores are resistant to harsh conditions. Under favorable conditions, spores crack open and give rise to haploid reproductive cells. Two such cells fuse, and their nuclei combine to form a diploid nucleus. Repeated mitotic divisions follow, but the cells do not undergo cytokinesis. The lack of cytokinesis results in the multinucleated plasmodium.

Phylum Dictyostelida (Cellular Slime Mold)

The phylum Dictyostelida (dik-TEE-oh-STEL-uh-duh) includes about 65 species of cellular slime molds. **Cellular slime molds** live as individual haploid cells that move about like amoebas. Each cell moves as an independent organism, creeping over the ground or swimming in fresh water and ingesting food.

When food or water becomes scarce, the cells release a chemical that attracts nearby cells, causing them to gather by the thousands into a dense structure called a *pseudoplasmodium*. A pseudoplasmodium is a coordinated colony of individual cells that resembles a slug and leaves a slimy trail as it crawls. Although the cells move as one unit, each cell retains its membrane and identity. Eventually, the pseudoplasmodium settles and forms fruiting bodies in which haploid spores develop. When a fruiting body breaks open, the spores are dispersed. Each spore may grow into an individual amoeboid cell, thus completing the life cycle.

FIGURE 25-15
Both plasmodial slime molds and cellular slime molds produce fruiting bodies that resemble those of fungi.

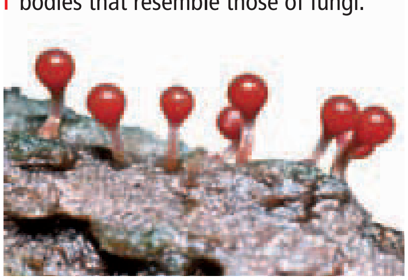


FIGURE 25-16
Some parasitic water molds attack aquatic organisms, such as fish, forming long filaments that eventually harm the fish.

Phylum Oomycota (Water Molds)

The phylum Oomycota (OH-mie-KOH-tuh) includes a number of organisms that are parasitic. For example, some oomycotes affect fish, as shown in Figure 25-16. Oomycotes reproduce asexually and sexually. During asexual reproduction, they produce flagellated zoospores. Zoospores germinate into threadlike cells. Some zoospores form a *zoosporangium,* which produces new zoospores. During sexual reproduction, water mold cells develop egg-containing and sperm-containing structures. Fertilization tubes grow between the two types of structures, enabling sperm to fertilize eggs, which forms diploid zygotes. A zygote grows into a new mass of filaments, which can again reproduce asexually or sexually.

Phylum Chytridiomycota (Water Molds)

Members of phylum Chytridiomycota (kie-TRID-ee-oh-mie-KOH-tuh), or the *chytrids* (KIE-tridz), are primarily aquatic protists characterized by gametes and zoospores with a single, posterior flagellum. Most chytrids are unicellular and parasitic.

Chytrids share many characteristics with fungi. They have similar means of obtaining nutrients, cell walls made of the same type of material, filamentous bodies, and similar enzymes and biochemical pathways. Because of these similarities, many biologists classify chytrids as fungi. Other biologists hypothesize that chytrids are a link between protists and fungi.

Quick Lab

Comparing Funguslike Protists

Materials paper and pencil

Procedure Create a chart that compares the phyla of funguslike protists. Include descriptions of cellular structure, locomotion, and means of reproduction.

Analysis Which funguslike protists are haploid? Which are diploid? Which funguslike protists reproduce sexually? Which reproduce asexually?

SECTION 3 REVIEW

1. What are four body forms of algae?
2. List seven phyla of plantlike protists.
3. Why do biologists theorize that ancient green algae gave rise to plants?
4. How are brown algae different from green and red algae?
5. What are the main characteristics of slime molds and water molds?
6. Compare plasmodial slime molds and cellular slime molds.

CRITICAL THINKING

7. **Applying Information** *Pseudo* means "false." Why do biologists call the migrating structure of a cellular slime mold a *pseudoplasmodium*?
8. **Identifying Relationships** Assume that chytrids are a link between protists and fungi, and draw a phylogenetic tree reflecting this information.
9. **Applying Information** An organism contains chlorophylls *a* and *c* and carotenoids, and it is unicellular. To which phylum does it belong? Explain your answer.

SECTION 4

OBJECTIVES

- **State** four environmental roles of protists.
- **Describe** algal blooms and red tides and their impact.
- **State** an important role for protists in research.
- **List** a use of protists as food and three uses of protist byproducts.
- **Describe** four protist-caused diseases.

VOCABULARY

algal bloom
chemotaxis
alginate
carrageenan
agar
diatomaceous earth
malaria
sporozoite
merozoite
gametocyte
giardiasis
cryptosporidiosis
trichomoniasis

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PROTISTS AND HUMANS

A casual glance out the window usually will not include a sighting of protists, except perhaps for some green algae growing on a tree trunk or some slime collected at a pond's edge. Protists have a profound impact on human lives through their modification of the environment, their use in research and industry, and the harm they may cause to human health.

PROTISTS IN THE ENVIRONMENT

Protists are seldom apparent to the naked eye, but they play important roles in the environment. They produce large amounts of oxygen, form the foundation of food webs, recycle materials, and play a role in several symbiotic relationships.

Along with plants and photosynthetic bacteria, protists produce large quantities of atmospheric oxygen. Nearly every organism on Earth relies on this oxygen for *cellular respiration,* the process in which oxygen is used to obtain energy from organic molecules.

Photosynthetic protists are also critical components of marine and freshwater food webs. Photosynthetic protists produce carbohydrates. Larger protists and other aquatic organisms feed on these carbon-rich protists. For example, diatoms support large schools of anchovy, which sea lions eat before they, themselves, become the prey of orcas.

Protists play an important role in the carbon cycle. Photosynthetic protists use carbon dioxide and water from the environment to make carbohydrates, which are taken up by other living things or used by the protists for cellular processes. When protists use the carbohydrates, they release carbon dioxide and water back into the environment. Some protists, such as slime molds, are decomposers that aid in the cycling of other nutrients as well.

Protists form several important symbiotic relationships. For example, protists living in symbiosis with corals give the corals both their color and much of their carbon supply. Symbiosis between algae and fungi forms lichens. When lichens grow on newly exposed rocks, their secretions break down the rock. This process creates new soil that can support the growth of plants. Finally, protists found in the guts of some animals help the animals digest cellulose. For example, *Trichonympha* is one of the protists that help termites digest cellulose.

Ecology of Protists

Temperature and the availability of light and nutrients influence the growth of algal populations. Algae grow in the *photic zone,* the portion of a body of water through which light penetrates. Nitrate and phosphate availability usually limits algal growth rates. In the open ocean, the availability of iron ions may limit algal growth.

High water temperatures and nutrient concentrations can cause **algal blooms,** a vast increase in the concentration of diatoms and other photosynthetic protists. Algal blooms often occur during spring in bays and estuaries and frequently harm these environments. During an algal bloom, large numbers of dying protists sink to the bottom, where they decompose. Bacterial decomposers use up oxygen, which fish, crustaceans, and other sea life need to survive. Dropping oxygen levels can cause these larger species to die off.

Dinoflagellate blooms cause red tides, shown in Figure 25-17. Toxins produced by dinoflagellate blooms concentrate as they move up the food chain. These toxins can sicken or kill humans and other organisms that consume clams, oysters, or krill that have fed on the red tide dinoflagellates.

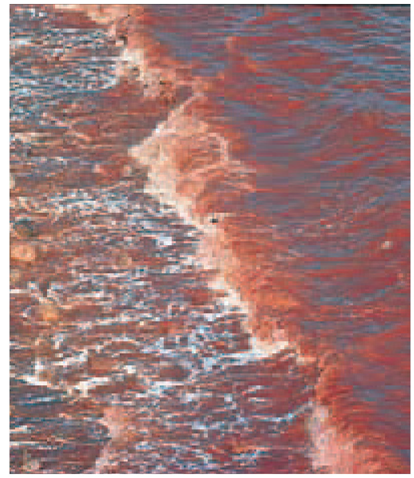


FIGURE 25-17

Because red tides produce dangerous toxins, people in some areas are often advised not to eat shellfish during the summer months, the time when red tides are most likely to happen.

PROTISTS IN RESEARCH

Research on protists has helped biologists understand a number of fundamental cellular functions, such as cell movement. For example, individual cells of the cellular slime mold *Dictyostelium discoidum* move toward a source of AMP, a precursor to the energy-storage molecule ATP. These cells crawl using amoeboid movement, shown in Figure 25-18.

Researchers are interested in learning how *Dictyostelium* cells can recognize AMP and crawl toward it, a process called **chemotaxis.** The researchers think that human leukocytes, or white blood cells, also perform chemotaxis as they crawl toward sites of infection. Biologists studying chemotaxis in human leukocytes have found the same proteins and cell movement seen in *Dictyostelium* cells. This discovery has improved the understanding of how leukocytes protect against disease. Some scientists believe this knowledge may help improve the treatment of diseases, such as cancers.

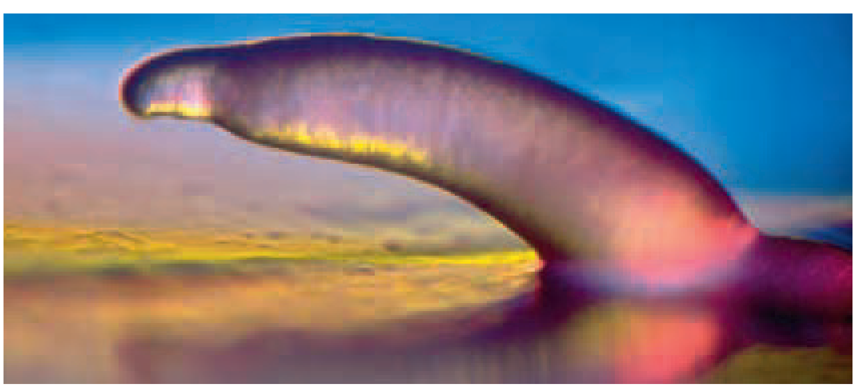


FIGURE 25-18

Dictyostelium uses amoeboid movement to reach a source of AMP. Understanding how *Dictyostelium* cells move improves the understanding of how human leukocytes move.

Eco Connection

Protist Biocontrol

Scientists from the United States Department of Agriculture are conducting field studies with the protist *Edhazardia aedis* to test its effectiveness as a control agent for disease-carrying mosquitoes. The chemical DDT was used previously, but it was banned in the 1970s after it was discovered to be harmful to bird populations. *E. aedis,* which was discovered in Argentina, infects mosquito larvae in the water and kills them. Scientists think that this protist will prevent disease while causing no environmental damage.

PROTISTS IN INDUSTRY

Humans make daily use of protists and their byproducts. Humans eat protists directly and use them as food additives, as fertilizers, and in cosmetics and medicines.

Protists as Food

For thousands of years, humans have been collecting seaweeds for food. People in Japan began cultivating seaweeds for food nearly 300 years ago. Today, about 10 percent of the Japanese diet is seaweeds. Among the most popular of these seaweeds is *nori,* a red alga from the genus *Porphyra*. Nori is used in soups, salads, and sushi, shown in Figure 25-19. More than half a million tons of nori are harvested each year. *Porphyra* has also been used for hundreds of years by people in Great Britain and is known there as *laverbread*. *Kombu,* made from kelps of the genus *Laminaria,* is another staple in Asian diets. More than 10 million tons of these kelps are harvested annually.

Protist Byproducts

The cell walls of most brown algae, especially large kelps, contain alginic acid. Alginic acid is a source of a commercially important polysaccharide called **alginate.** Alginate is used in cosmetics and various drugs and as a stabilizer in ice cream and salad dressings. Alginate is also used in textiles, water-soluble medical dressings for burns, and inks.

Certain species of red algae have cell walls that are coated with a sticky substance called **carrageenan** (KAR-uh-GEEN-uhn). Carrageenan is a polysaccharide that is used to control the texture of many commercial and food products. It is used in the production of cosmetics, gelatin capsules, and some types of cheese.

FIGURE 25-19

Sushi, a traditional food in Asian countries, has become more popular in the United States. The seaweeds used in sushi are high in protein, vitamins, and minerals.

Agar is another polysaccharide that comes from the cell walls of red algae. Agar is commonly used in scientific research. It is the gel-forming base used for culturing microbes, such as bacteria. Agar is also widely used by the food industry in canned foods and bakery items.

Diatoms are quite abundant in aquatic ecosystems. As diatoms die, their shells sink and accumulate in large numbers at the bottom of lakes and oceans, forming a layer of material called **diatomaceous** (DIE-uh-tuh-MAY-shuhs) **earth.** This slightly abrasive material is a component of many commercial products, such as detergents, paint removers, and toothpaste. Diatomaceous earth is also used in filters, and some people use it as a natural insecticide.

PROTISTS AND HEALTH

Many protists are parasites. Table 25-3 summarizes the effects of three protist parasites.

Malaria

Apicomplexans from the genus *Plasmodium* cause **malaria,** which is characterized by severe chills, headache, fever, and fatigue. Each year, nearly 3 million people die from malaria. The four species of *Plasmodium* that infect humans all have life cycles involving an *Anopheles* mosquito. When an infected *Anopheles* mosquito bites a person, *Plasmodium* cells called **sporozoites** enter the bloodstream and infect the liver. New cells called **merozoites** emerge from the liver and infect red blood cells. At regular intervals, merozoites burst from red blood cells and release toxins, causing malarial symptoms. Without treatment, merozoites may remain in the liver for years, causing recurrent disease.

Some merozoites in the blood develop into the sexual forms of the parasite, **gametocytes.** When an *Anopheles* mosquito bites an infected person, the mosquito ingests these gametocytes. The gametocytes form gametes, which combine to form zygotes that develop into more sporozoites. When the insect bites another person, the life cycle begins again. Figure 25-20 shows the life cycle of *Plasmodium*.

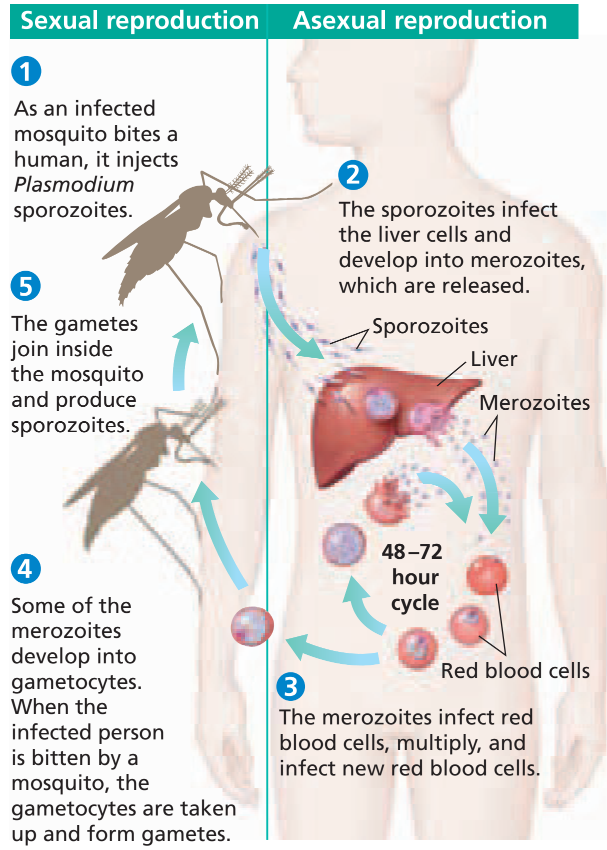


FIGURE 25-20
The life cycle of the malaria-causing *Plasmodium* requires two hosts.

TABLE 25-3 *Examples of Disease-Causing Protists*

Disease	Pathogen (Phylum)	Symptoms	Spread by	Precautions
Amebiasis	*Entamoeba histolytica* (Protozoa)	severe diarrhea, fever, and gastrointestinal tract hemorrhage	contaminated water or food	*E. histolytica* is common in developing countries. Drink bottled, boiled, or filter-purified water. Peel fresh fruit, and avoid unpasteurized dairy products.
Sleeping sickness	*Trypanosoma* sp. (Sarcomastigophora)	swollen lymph nodes, severe headaches, fever, fatigue, and coma	tsetse flies	Tsetse flies are found only in Africa. Wear protective clothing, such as long pants and long-sleeved shirts. Use insect repellent, and avoid open vehicles and bushes.
Leishmaniasis	*Leishmania donovani* (Sarcomastigophora)	skin sores, swollen glands, fever, and swollen spleen and liver	sand flies	Sand flies are found mostly in tropical and subtropical regions. Stay indoors during the day, when sand flies are most active. Wear protective clothing, and use insect repellents.

FIGURE 25-21

Giardia lamblia is a mastigophoran. The *Giardia* shown in this picture are shown in their natural habitat—the human intestine.

Giardiasis

Giardia lamblia, shown in Figure 25-21, causes an illness called **giardiasis** (JEE-ahr-DIE-uh-sis). Giardiasis is characterized by severe diarrhea and intestinal cramps. Cattle, beavers, and several other animals carry the parasite and contaminate water with their feces. Hikers and other people who are likely to drink this contaminated water are susceptible to giardiasis. Thousands of cases occur annually in the United States. The disease usually is not fatal, and drugs aid recovery. Drinking bottled, boiled, or filtered water prevents giardiasis.

Cryptosporidiosis

Cryptosporidiosis (KRIP-toh-spawr-I-dee-OH-sis) is characterized by diarrhea and is most often caused by *Cryptosporidium parvum,* an apicomplexan that lives on the surface of cells lining the small intestine. A stage called the *oocyst* (OH-sist) can pass in feces from infected animals to humans. An outer shell protects the parasite outside the body, allowing it to survive for long periods and making it resistant to chlorine disinfectants. Cryptosporidiosis is usually not fatal, but it can be dangerous for people with immune disorders. Washing hands thoroughly after coming in contact with feces and avoiding untreated water can prevent cryptosporidiosis.

Trichomoniasis

The mastigophoran *Trichomonas vaginalis* is responsible for **trichomoniasis** (TRIK-oh-moh-NIE-uh-sis), a sexually transmitted disease. The parasite does not survive well outside the body, so it is mainly spread by sexual contact. Trichomoniasis is one of the most common sexually transmitted diseases.

Many people do not have symptoms when infected with trichomoniasis. However, women are more likely to have symptoms of trichomoniasis than men are. Symptoms include discolored discharge, genital itching, and the urge to urinate. Abstinence from sexual intercourse prevents trichomoniasis.

SECTION 4 REVIEW

1. Outline three environmental roles of protist producers.
2. What are three examples of protist symbioses?
3. Why do researchers use slime molds to study chemotaxis?
4. How are protists used for food?
5. Identify three protist byproducts and how people use them.
6. Describe four protist-caused diseases, and name the organisms that cause the diseases.

CRITICAL THINKING

7. **Applying Information** What basic precautions can decrease exposure to protist diseases?
8. **Making Predictions** Some scientists hypothesize that global warming will increase mosquito populations. Predict what might happen to rates of malaria as a result.
9. **Calculating Information** If 500 million people contract malaria annually and 6.5 billion people live on Earth, what fraction of the human population becomes infected with malaria annually?

CHAPTER HIGHLIGHTS

SECTION 1 Characteristics of Protists

- Protists are unicellular or simple multicellular eukaryotic organisms that are not plants, fungi, or animals. Protists are classified by the characteristics that make them funguslike, plantlike, or animal-like.
- Evidence suggests that the first protists arose from endosymbiotic prokaryotes.
- Many protists are autotrophs. Other protists are heterotrophs. Protists use flagella, cilia, or pseudopodia for locomotion.
- Protists reproduce either asexually, sexually, or both. They reproduce asexually by binary fission or multiple fission. They often reproduce sexually by conjugation.

Vocabulary

protist (p. 501)
binary fission (p. 504)
multiple fission (p. 504)
conjugation (p. 504)

SECTION 2 Animal-like Protists

- Animal-like protists include the phyla Protozoa, Ciliophora, Sarcomastigophora, and Apicomplexa. For locomotion, protozoa use pseudopodia, ciliates use cilia, and sarcomastigophorans use flagella.
- Ciliates reproduce asexually by binary fission and sexually by conjugation.
- Apicomplexans lack locomotion, so they are parasites.

Vocabulary

pseudopodium (p. 506)
amoeboid movement (p. 506)
test (p. 507)
cilium (p. 507)
pellicle (p. 508)
oral groove (p. 508)
mouth pore (p. 508)
gullet (p. 508)
anal pore (p. 508)
contractile vacuole (p. 508)
macronucleus (p. 508)
micronucleus (p. 508)
flagellum (p. 508)

SECTION 3 Plantlike and Funguslike Protists

- Algae can be unicellular, colonial, filamentous, or multicellular. Seven phyla of plantlike protists are Chlorophyta, Phaeophyta, Rhodophyta, Bacillariophyta, Dinoflagellata, Chrysophyta, and Euglenophyta.
- Green algae and plants have the same pigments, store food as starch, and have cell walls made of cellulose.
- Slime molds are found on decaying matter and spend part of their lives as mobile feeding forms and the other part as stationary reproductive forms.
- Plasmodial slime molds are multinucleate, and cellular slime molds live as individual haploid cells. Water molds are composed of branching filaments.

Vocabulary

alga (p. 510)
gametangium (p. 510)
phytoplankton (p. 510)
thallus (p. 510)
accessory pigment (p. 511)
diatom (p. 512)
shell (p. 512)
bioluminescence (p. 513)
red tide (p. 513)
euglenoid (p. 513)
fruiting body (p. 514)
water mold (p. 514)
plasmodial slime mold (p. 514)
cellular slime mold (p. 514)

SECTION 4 Protists and Humans

- Protists produce large amounts of oxygen, form the foundation of food webs, recycle materials, and play a role in several symbiotic relationships.
- Algal blooms can lead to the depletion of oxygen in water. Red tides produce harmful toxins.
- Protists can help scientists understand the movement of leukocytes, provide food, and provide important byproducts, such as alginate, carrageenan, and agar.
- Parasitic protists cause malaria, giardiasis, cryptosporidiosis, and trichomoniasis in humans.

Vocabulary

algal bloom (p. 517)
chemotaxis (p. 517)
alginate (p. 518)
carrageenan (p. 518)
agar (p. 518)
diatomaceous earth (p. 518)
malaria (p. 519)
sporozoite (p. 519)
merozoite (p. 519)
gametocyte (p. 519)
giardiasis (p. 520)
cryptosporidiosis (p. 520)
trichomoniasis (p. 520)

CHAPTER REVIEW

USING VOCABULARY

1. Choose the term that does not belong in the following group, and explain why it does not belong: *binary fission, macronucleus, multiple fission,* and *conjugation*.
2. For each pair of terms, explain the relationship between the terms.
   a. *pseudopodia* and *amoeboid movement*
   b. *macronucleus* and *micronucleus*
   c. *algae* and *thallus*
   d. *sporozoites* and *merozoites*
3. Use each of the following terms in a separate sentence: *algal bloom, red tide, fruiting body,* and *pellicle*.
4. **Word Roots and Origins** The word *diatom* comes from the Greek word *diatomos,* which means "cut in half." Using this information, explain how *diatom* is an appropriate term for the organisms it describes.

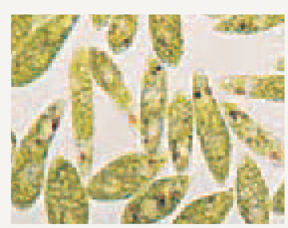
UNDERSTANDING KEY CONCEPTS

5. **Define** *protist*.
6. **Describe** a hypothesis for the origin of eukaryotic cells.
7. **State** the way in which protists are generally classified.
8. **Compare** two ways by which protists obtain food and three ways by which they move.
9. **List** three ways by which protists reproduce.
10. **Differentiate** between Protozoa, Ciliophora, Sarcomastigophora, and Apicomplexa.
11. **Explain** how protozoa use pseudopodia to move and capture food.
12. **Relate** how ciliates reproduce.
13. **Compare** movement in sarcodines, ciliates, and mastigophorans.
14. **Identify** the relationship between apicomplexans and disease.
15. **List** four body forms of algae.
16. **State** the common name for each of the seven phyla of plantlike protists.
17. **Compare** green algae and plants.
18. **Summarize** the main characteristics of the four phyla of funguslike protists.
19. **Describe** plasmodial slime molds and cellular slime molds.
20. **Describe** four roles of protists in the environment.
21. **Describe** algal blooms and red tides.
22. **Name** an important role for protists in research.
23. **List** four uses of protists and protist byproducts.
24. **Summarize** the characteristics of four protist-caused diseases.
25. **CONCEPT MAPPING** Use the following terms to create a concept map that describes the characteristics of animal-like protists: *Protozoa, amoeboid movement, pseudopodia, Ciliophora, flagella, Sarcomastigophora, cilia, cytoplasmic streaming, test, pellicle, parasites,* and *Apicomplexa*.

CRITICAL THINKING

26. **Relating Concepts** Health officials advise that people should not eat shellfish from certain areas during the summer months. Explain the reason for this warning.
27. **Analyzing Data** Scientists are trying to develop a vaccine against malaria. Because malaria has several life stages, scientists must decide which life stage should be the target of the vaccine. Some scientists are trying to develop a vaccine against gametocytes as a way of controlling malaria. If they are successful in developing this vaccine, how will it help people living in areas where malaria regularly occurs? Explain your answer.
28. **Making Comparisons** How is the movement of *Dictyostelium* toward AMP similar to the movement of leukocytes? How is it different? Based on this information, is *Dictyostelium* a good model for leukocytes? Justify your answer.
29. **Interpreting Graphics** A scientist found two different euglenoids. The scientist concluded that specimen a is exclusively heterotrophic but specimen b is not. Examine the images of the specimens below, and determine if the scientist is correct in his or her conclusions.


(a)


(b)

Standardized Test Preparation

DIRECTIONS: Choose the letter of the answer choice that best answers the question.

1. Most scientists believe that protists evolved from which of the following?
   A. fungi
   B. plants
   C. euglenoids
   D. prokaryotes
2. Protist habitats are often characterized by the presence of which of the following?
   F. soil
   G. algae
   H. blood
   J. moisture
3. Flagella are characteristic of members of which phylum?
   A. Protozoa
   B. Ciliophora
   C. Apicomplexa
   D. Sarcomastigophora

INTERPRETING GRAPHICS: The table below shows cases of amebiasis and malaria in the United States between 1986 and 1994. Use the table to answer the questions that follow.

Protist-Caused Diseases in the United States, 1986–1994

	Number of cases	
Year	**Amebiasis**	**Malaria**
1986	3,532	1,123
1988	2,860	1,099
1990	3,328	1,292
1992	2,942	1,087
1994	2,983	1,229

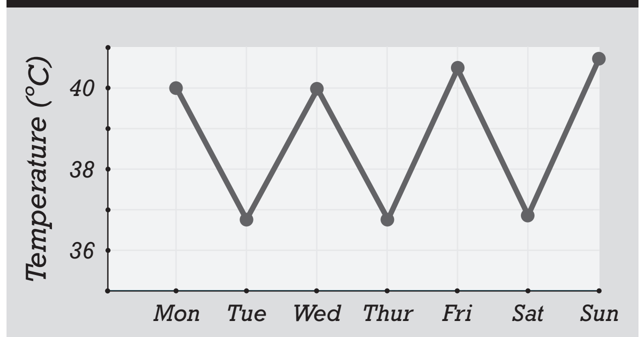
4. How many people had malaria in 1992?
   F. 1,087
   G. 1,229
   H. 1,292
   J. 2,942
5. How did the number of cases of amebiasis change between 1986 and 1994?
   A. The number of cases increased.
   B. The number of cases decreased.
   C. The number of cases stayed the same.
   D. The number of cases increased, then decreased.

DIRECTIONS: Complete the following analogy.

6. Bacillariophyta : autotrophs :: Apicomplexa :
   F. cilia
   G. flagella
   H. parasites
   J. plasmodium

INTERPRETING GRAPHICS: The graph below shows the cycle of fever in a malaria patient. Use the graph to answer the question that follows.

Cycle of Fever in a Malaria Patient



7. In this patient, how often does the cycle of fever repeat?
   A. every 12 h
   B. every 24 h
   C. every 48 h
   D. every 96 h

SHORT RESPONSE

Anopheles mosquitoes require water to breed.

What would happen to malaria cases during a dry season and during a wet season?

EXTENDED RESPONSE

A scientist wants to examine the effect of fertilizer on algal blooms. In the laboratory, the scientist adds increasing amounts of fertilizer to three samples of pond water and adds no fertilizer to a fourth sample of pond water.

Part A Which samples will show increased algal growth? Explain your answer.

Part B How can the scientist apply his or her laboratory results to a natural ecosystem? Compare the scientist's experiment to a natural ecosystem, such as a pond.

Test TIP For a question involving experimental data, determine the constants, variables, and control **before** answering the question.

EXPLORATION LAB

Classifying Green Algae

OBJECTIVES

- Observe live specimens of green algae.
- Compare unicellular, colonial, filamentous, and multicellular green algae.
- Classify genera of colonial green algae.

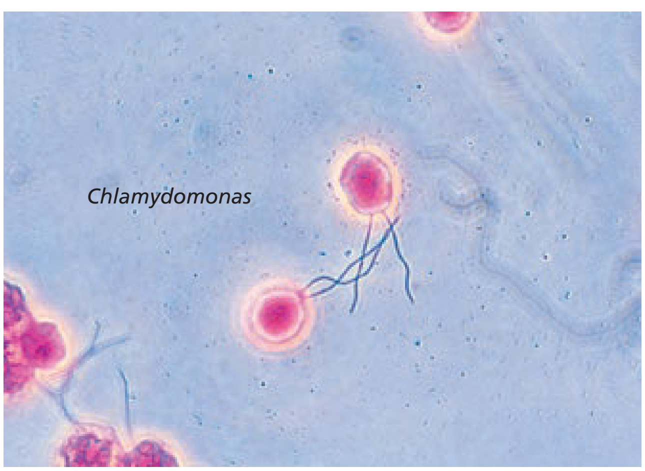
MATERIALS

- safety goggles
- lab apron
- protective gloves
- culture of *Chlamydomonas*
- mixed colonial green algae culture (*Eudorina, Gonium, Pandorina, Volvox,* and *Hydrodictyon*)
- culture of *Spirogyra*
- 3 depression slides
- 3 coverslips
- 3 medicine droppers
- compound light microscope

SAFETY

Background

1. Distinguish between the terms *protozoa* and *algae.*
2. Green algae are either unicellular, colonial, filamentous, or multicellular.
3. Explain why green plants are thought to have evolved from green algae.
4. List characteristics of green algae. Include ways that algae differ from plants.
5. How do green algae differ from other algae?



PART A Observing Unicellular Green Algae

1. Make a table similar to the one below in your lab report. Allow substantial space in your data table for labeled sketches of the different kinds of green algae you will view in this investigation. Use your data table to record your observations of each kind of green algae that you view.
2. CAUTION **Slides break easily. Use caution when handling them.** Put on safety goggles, a lab apron, and protective gloves. Prepare a wet mount of the *Chlamydomonas* culture by placing a drop of the culture on a microscope slide with a medicine dropper and placing a coverslip on top of the specimen.

OBSERVATIONS OF GREEN ALGAE

Genus	Sketch of organism	**Type of green algae** (unicellular, colonial, filamentous, or multicellular)

3. Examine the slide of *Chlamydomonas,* first under low power and then under high power.
4. In your lab report, make a sketch of *Chlamydomonas.* Label the cell wall, flagella, nucleus, and chloroplasts if they are visible.

PART B Observing and Identifying Colonial Green Algae

5. CAUTION **Slides break easily. Use caution when handling them.** Prepare a wet mount of the colonial green algae culture using a clean medicine dropper, a clean microscope slide, and a clean coverslip.
6. Examine the slide of mixed colonial green algae under low power, switching to the high-power setting as needed for clarity. Some of the organisms on your slide should resemble the photograph of *Volvox* above. How many different kinds of colonial green algae can you find?
7. In your data table, draw each type of colonial green algae you observe. How are these algae different in appearance from *Chlamydomonas*?
8. Use the dichotomous key, above right, to identify each type of colonial green algae. Choose an alga, and start at 1. Decide which choice best describes the alga. If the alga is not identified, go to the next number and make the next decision. Continue until you identify the alga. Then, label your drawing of the alga.

PART C Observing Filamentous Green Algae

9. CAUTION **Slides break easily. Use caution when handling them.** Prepare a wet mount of the *Spirogyra* culture using a clean medicine dropper, a clean microscope slide, and a clean coverslip.

DICHOTOMOUS KEY FOR COLONIAL GREEN ALGAE

1a	single cells	***Chlamydomonas***
1b	colony of cells	go to 2
2a	flattened or netlike colony	go to 3
2b	round colony	go to 4
3a	netlike colony	***Hydrodictyon***
3b	flattened colony	***Gonium***
4a	more than 100 cells in colony	***Volvox***
4b	fewer than 100 cells in colony	go to 5
5a	cells close together	***Pandorina***
5b	cells apart from each other	***Eudorina***

10. Examine *Spirogyra* under low power. Switch to the high-power setting if you need more magnification to see the specimen clearly. How does *Spirogyra* differ in appearance from the other kinds of algae you have observed in this investigation?
11. In your data table, make a sketch of *Spirogyra.* Label the filaments and the individual cells in your drawing. Also, label the spiral-shaped chloroplasts if they are visible.
12. Clean up your lab materials, and wash your hands before leaving the lab.

Analysis and Conclusions

1. What characteristics did all of the algae you viewed have in common?
2. Describe examples of specialization in the different kinds of algae you viewed. In which types of algae do some cells depend on others?
3. What differences did you observe between small and large colonies of algae?
4. Which specializations in algae are characteristic of green plants?

Further Inquiry

How might you search for evidence of evolutionary relationships among algae and between algae and green plants?