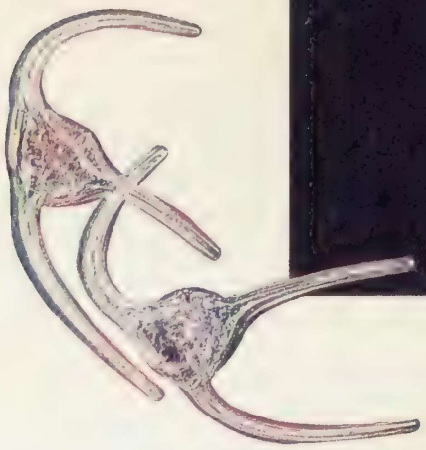
CHAPTER 18

Protists



*In some places, the ocean may glow with a ghostly blue light produced by thousands of protists. Appropriately, the scientific name of these glowing protists—*Noctiluca scintillans*—means "lights that sparkle at night." Closely related* Ceratium *protists (inset) get their name from a Greek word that means horn or antler.*

On a moonless night, a fishing boat motors toward a New England harbor. The dark water sparkles in its wake, glittering in a thousand places and leaving a ghostly glowing tail as it makes its way to port. Half a world away, the sun is high over a village in equatorial Africa. Although it is harvest time and many members of his family are in the fields working, a young man shudders in his bed, delirious from the burning fever of malaria. These two scenes, as different as they are, have one fundamental biological fact in common: The glowing ocean and the ravages of malaria are both produced by protists—organisms that belong to the kingdom Protista, the first kingdom of eukaryotic organisms.

CHAPTER OUTLINE

18–1 The Kingdom Protista
- Classification of Protists
- Evolution of Protists

18–2 Animallike Protists
- Ciliophora: Cilia-bearing Protists
- Zoomastigina: Animallike Protists with Flagella
- Sporozoa: Spore-producing Parasitic Protists
- Sarcodina: Protists with False Feet
- Summary of the Animallike Protists
- How Animallike Protists Fit into the World

18–3 Plantlike Protists
- Euglenophyta: Flagellates with Chloroplasts
- Pyrrophyta: Fire Protists
- Chrysophyta: Golden Protists
- The Slime Molds: Unusual Protists
- Summary of the Plantlike Protists
- How the Plantlike Protists Fit into the World

18–1 The Kingdom Protista

Section Objectives

- Describe the major characteristics of protists.
- Discuss the Endosymbiont Hypothesis.

The first kingdom of eukaryotic organisms (organisms whose cells contain nuclei and membrane-enclosed organelles) that we will consider is the kingdom **Protista**. The name is appropriate, for it is derived from a Greek word that means first. The term **protist** refers to any member of the kingdom Protista. **Protists are defined as being unicellular, or single-celled, eukaryotic organisms.** However, as you will discover later in this chapter, a few types of protists stretch the concept of unicellular. Many protists are solitary, which means that they live as individual cells. However, other protists are colonial, which means that they live in groups of individuals of the same species that are attached to one another.

As you learned in Chapter 16, the oldest fossils of monerans (single-celled organisms that lack a nucleus and membrane-enclosed organelles) are more than 3.5 billion years old. Compared with the kingdom Monera, the kingdom Protista is relatively young—the oldest fossils of protists are only about 1.5 billion years old. This indicates that the evolution of the first eukaryote may have taken nearly 2 billion years.

Classification of Protists

The kingdom Protista is an extremely diverse group that includes more than 115,000 species. In the past, many of these species were extremely difficult to classify because they had characteristics in common with more than one of the three kingdoms of multicellular organisms: Animalia (animals), Plantae (plants), and Fungi. The kingdom Protista was created



Figure 18–1 *This solitary protist zips through the water by means of swimming bristles formed of fused cilia (left). These colonial protists also have cilia. However, they lead a less active existence because they are attached to one another and to a base such as a stone or a water plant.*





Figure 18–2 *Protists often share characteristics with more than one multicellular kingdom. Some are photosynthetic like plants and can move like animals (bottom). Others are similar to fungi in life cycle and appearance but move like animals and have cells that are more like those of animals than those of fungi (top).*

primarily to solve the problem of classifying these difficult organisms and only partly because the protists may share an evolutionary ancestry. In fact, the American biologist Lynn Margulis wrote that the kingdom Protista "is defined by exclusion: its members are neither animals . . . , plants . . . , fungi . . . , nor prokaryotes."

Scientists do not agree on how organisms in the kingdom Protista should be classified. They do not even agree on which organisms should be considered protists! However, most would agree that there is much we can learn from protists. In this chapter we will examine the major kinds of protists and see what roles they play in the living world.

Evolution of Protists

Where did the first protists come from? Did prokaryotic cells gradually evolve nuclei? For many years, most biologists considered this a reasonable explanation. In recent years, however, biologist Lynn Margulis has revived an alternative explanation—one that many biologists now find persuasive. She suggests that the first protist cell was formed by a symbiosis among several prokaryotes. (Symbiosis literally means living together and is defined as the living together in close association of dissimilar organisms.)

Margulis noted that a number of organelles in eukaryotic cells are very similar in structure to prokaryotes. For example, mitochondria and chloroplasts closely resemble bacteria and blue-green bacteria, respectively. The flagella and cilia of many eukaryotic cells are similar to a group of bacteria known as the spirochetes. The similarities between organelles and prokaryotes, Margulis reasoned, are not merely coincidental—organelles are descended from symbiotic prokaryotes.

According to Margulis's **Endosymbiont Hypothesis**, these prokaryotes lived within another moneran as endosymbionts (symbiotic organisms that live within another organism, which is called the host organism). The endosymbionts and their

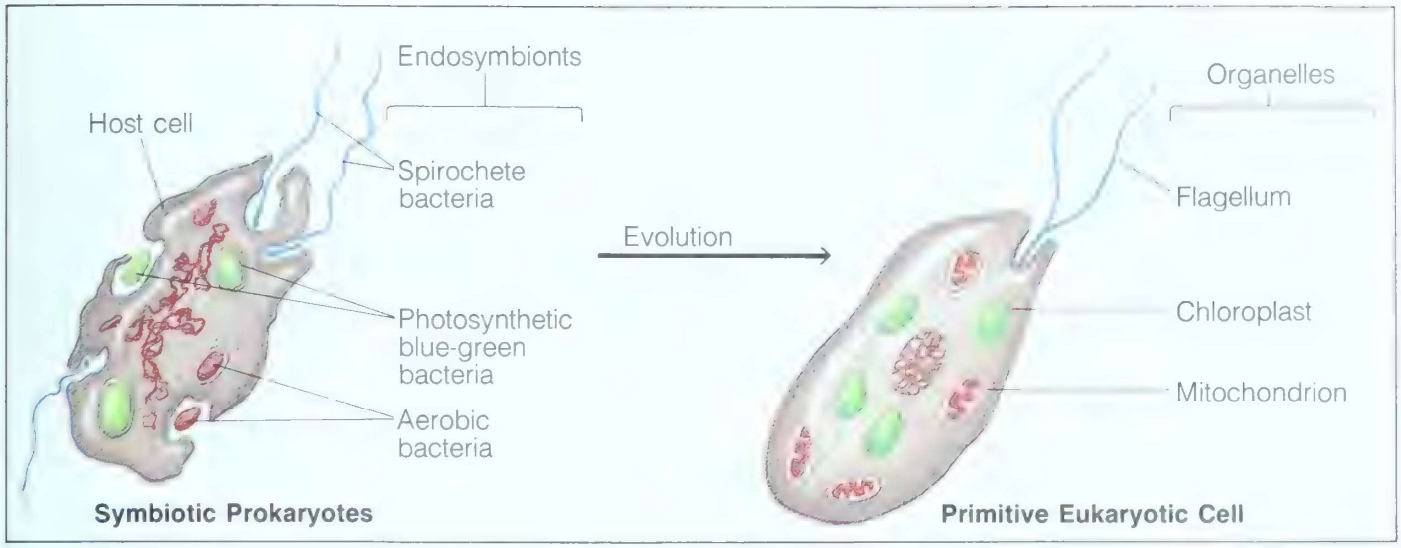


Figure 18–3 *According to the Endosymbiont Hypothesis, the organelles in eukaryotic cells evolved from symbiotic prokaryotes that lived inside a host cell.*

host cell formed an effective team—each member benefited from the relationship. But eventually the endosymbionts lost their independence, were unable to live without one another or outside the host cell, and gave rise to the organelles that we observe today in eukaryotic cells.

We will never be sure that Margulis's Endosymbiont Hypothesis is correct. But it does provide a model for how the first eukaryotic cell—the first protist—may have developed. Is there something in nature that supports this model? Are there cells alive today that suggest this is a reasonable idea?

The answer to each of these questions is yes. The protist *Cyanophora paradoxa* was first thought to be a kind of alga. However, it was soon learned that the "chloroplasts" within it were not chloroplasts at all. They were blue-green bacteria that could be removed from the cell in which they lived as endosymbionts. They could be grown outside the rest of the cell! The relationship between *Cyanophora paradoxa* and its blue-green bacteria may be similar to the relationships that produced the first protists. Thus when we examine a present-day eukaryotic cell, we may actually be dealing with the descendants of more than one organism!

18-1 SECTION REVIEW

1. What are protists? When did protists first appear on Earth?
2. What evidence has led scientists to believe that symbiosis played an important role in the evolution of protists?
3. How might the Endosymbiont Hypothesis explain the double membranes that surround organelles such as the nucleus, chloroplast, and mitochondrion?

Section Objectives

- Name and describe the four phyla of animallike protists.
- Discuss how animallike protists fit into the world.

18–2 Animallike Protists

At one time, many of the protists were called protozoa, which means first animals. Protozoa were classified separately from more plantlike protists. But biologists have found that the similarities between some animallike protists and the plantlike protists are so great that it no longer makes sense to place each in a separate kingdom. Four phyla within the kingdom Protista, however, are known as the animallike protists. These are the first protists that we shall examine.

Ciliophora: Cilia-bearing Protists

Members of the phylum **Ciliophora** (sihl-ee-AHF-uh-rah) are either solitary or colonial organisms. These organisms are often known as **ciliates** (SIHL-ee-ihts) because they have **cilia** (singular: cilium). (Ciliophora literally means cilia-bearing.) Cilia are short hairlike projections that produce movement. The internal structure of cilia consists of microtubulelike structures. The beating of cilia, like the pull of hundreds of oars in an ancient ship, propels the cell rapidly through water. Ciliates are found in both fresh and salt water—many may live in a lake or stream near your home.

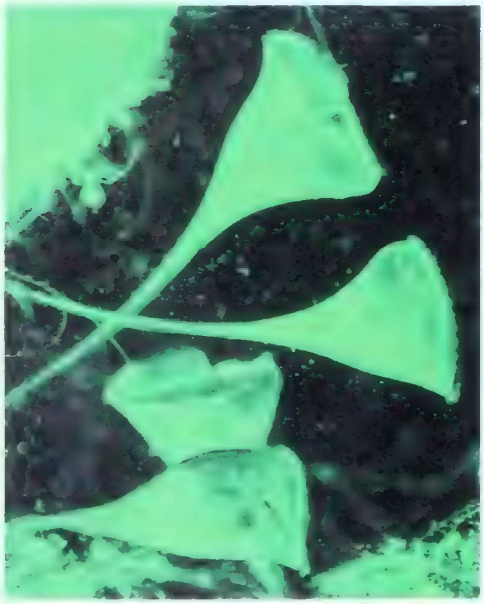
More than 7000 species of ciliates are known. Most ciliates are free-living, which means that they do not exist as parasites or symbionts. A well-studied example of the ciliates is found in the genus *Paramecium*.

A **paramecium** is a large organism (as unicellular organisms go)—as much as 350 micrometers in length. In the electron microscope, the cell membrane and cilia can be observed closely. A paramecium's cell membrane and associated underlying structures make up a complex living outer layer called the **pellicle** (PEHL-ih-kuhl). The pellicle is folded in a repeating pattern that gives the surface of the cell a quiltlike appearance. Embedded in the pellicle are a series of tiny flask-shaped structures known as **trichocysts** (TRIHK-oh-sihsts). Trichocysts are used for defense. When a paramecium is confronted by serious danger, the trichocysts discharge. The spiny projections produced in this way can injure a nearby cell as well as cover a paramecium with protective bristles.

Like almost all ciliates, a paramecium possesses two different kinds of nuclei. Each cell normally has a **macronucleus** and a smaller **micronucleus**. We will examine the roles that these two kinds of nuclei play when we consider the process of reproduction in ciliates.

A paramecium obtains food by using its cilia to force water into the **gullet**, an indentation in one side of the cell. Particles that include bits of food such as bacteria are trapped in the gullet and then forced into cavities called **food vacuoles** that form at the base of the gullet. The food vacuoles break off into the cytoplasm and eventually fuse with lysosomes, which are

Figure 18–4 *Ciliates include trumpet-shaped* Stentor *(top) and egg-shaped* Didinium *(bottom). As you can see,* Didinium *is a carnivore that feeds on other ciliates such as* Paramecium.





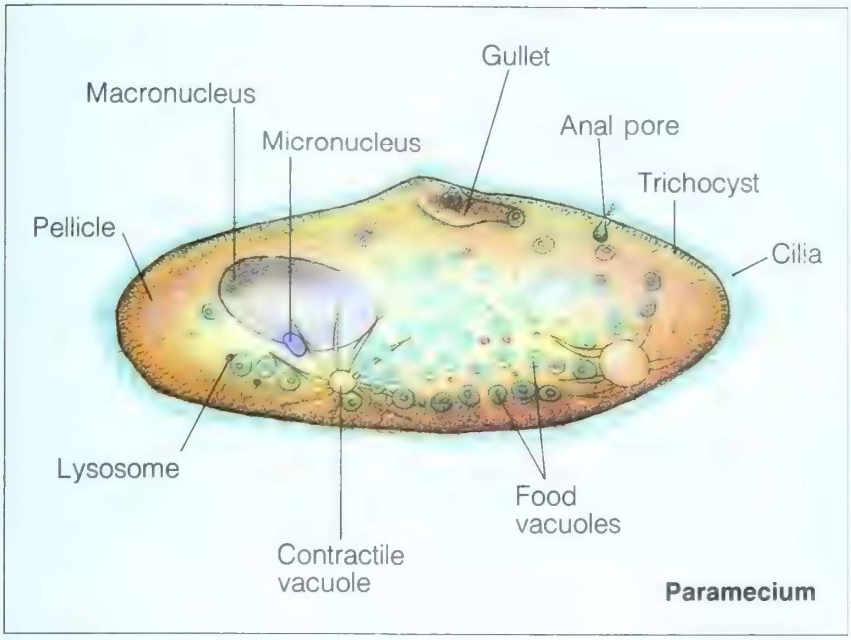


Figure 18–5 *The essential life functions of a paramecium are divided among many organelles (left), several of which can be seen in this live paramecium (right). The small green circles are food vacuoles that contain bits of algae.*



organelles that contain digestive enzymes. Thus the material in the food vacuoles is digested and the organism obtains the nourishment it requires. Waste materials are emptied into the environment when the food vacuole fuses with a region of the cell membrane called the **anal pore**.

Excess water (which moves into a cell in fresh water because of osmosis) is collected in other vacuoles. These vacuoles empty into canals that are arranged in a star-shaped pattern around structures known as **contractile vacuoles**. When a contractile vacuole is filled with water, it "contracts" quickly and pumps water out of the cell.

Under most conditions, a paramecium reproduces asexually by means of a form of mitotic cell division called binary fission. During this process, a single paramecium elongates, its gullet splits into two, and the cell divides in half crosswise. Binary fission results in two cells that are genetically identical.

Under certain circumstances, including starvation and temperature stress, paramecia will engage in a form of sexual reproduction known as conjugation. Refer to Figure 18–7 on page 386 as you read about the process of conjugation. In the first stages of conjugation, two paramecia attach themselves to each other. Their macronuclei disintegrate, and their diploid (2N) micronuclei undergo meiosis. When meiosis is complete, each paramecium contains 4 haploid (N) micronuclei. In the next stages of conjugation, 3 of the 4 micronuclei disintegrate. The 1 remaining micronucleus then divides to form 2 genetically identical haploid micronuclei. The paramecia exchange one set

Figure 18–6 *A paramecium can discharge its trichocysts to produce a shield of protective bristles.*



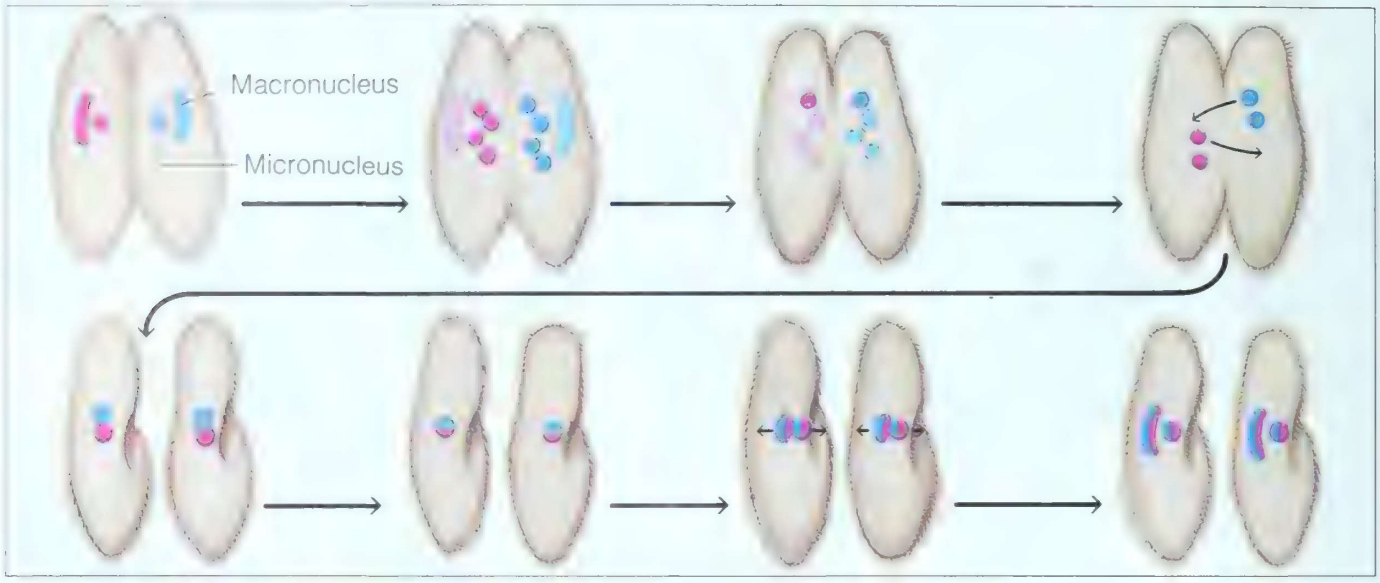


Figure 18–7 *In the process of conjugation, two paramecia join together and share genetic information. Conjugation produces new combinations of genes—combinations that may give paramecia a better chance of survival.*





Figure 18–8 *Paramecia usually reproduce asexually through binary fission (top). Under certain circumstances, paramecia will undergo a form of sexual reproduction called conjugation (bottom).*

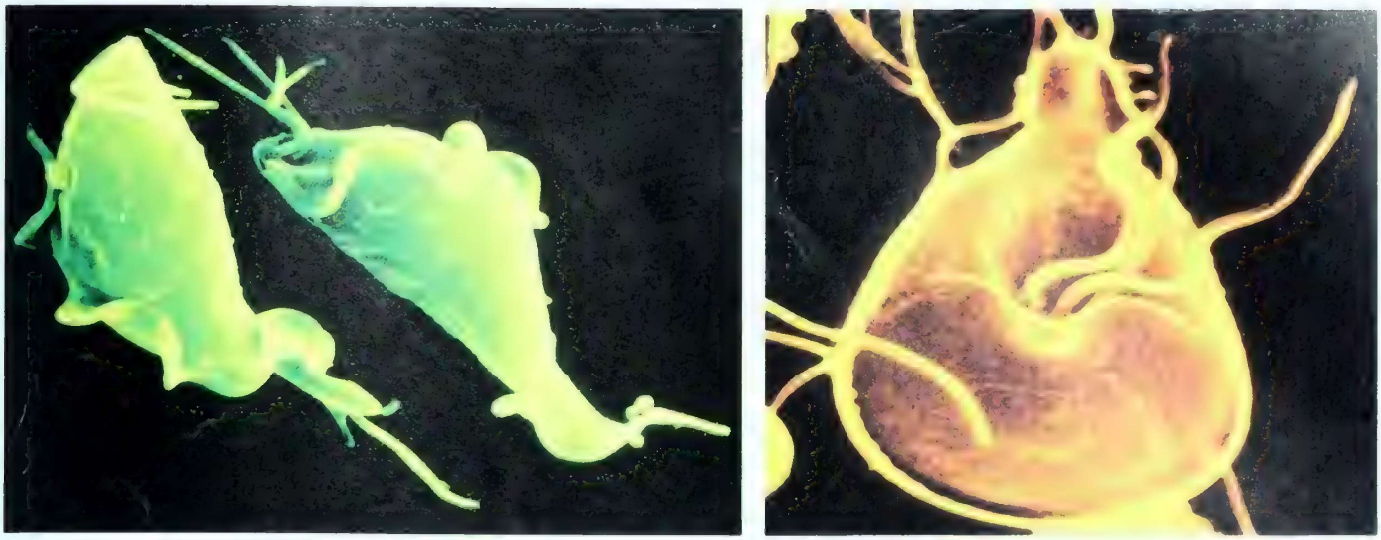
of micronuclei, so that each cell has 1 micronucleus obtained from the other cell and 1 micronucleus of its own. In the final stage of conjugation, the paramecia separate from each other. The 2 haploid micronuclei in each paramecium fuse to form a new diploid micronucleus. From the new micronucleus, a new macronucleus is formed. The two paramecia that participated in conjugation are now genetically identical.

Strictly speaking, conjugation is not reproduction. No new cells are produced—2 cells enter conjugation and 2 leave it. Nonetheless, it is still a sexual process. New combinations of genetic information are produced. Within a large population, the process of conjugation helps to create genetic diversity and ensures the ultimate survival of the species.

Zoomastigina: Animallike Protists with Flagella

The phylum **Zoomastigina** (zoh-oh-mas-tuh-GIGH-nuh) consists of animallike protists that move through the water by means of **flagella**. Flagella are long, whiplike projections that have an internal structure identical to that of cilia. The number of flagella varies from one zoomastiginan to the next, ranging from one to four or more. Because they have flagella, zoomastiginans are called **flagellates**. The term flagellate is also used for plantlike protists and unicellular algae that have flagella. Because of this, zoomastiginans are sometimes called zooflagellates, which means animal flagellates.

Zoomastiginans are generally able to absorb food through their cell membranes, which are not enclosed in shells or cell



walls. Some zoomastiginans have found special environments in which they are able to find enough food to absorb. Others live within the bodies of other organisms, taking advantage of the food that the larger organism provides.

Zoomastiginans can reproduce asexually by binary fission, although most also have a sexual life cycle as well. During sexual reproduction, gamete cells are produced by meiosis. Sometimes meiosis is triggered by a change in the food supply or in the amount of oxygen in the water. In some species, meiosis occurs only at certain times of the year. The gametes formed by meiosis fuse together, forming an organism with a new combination of genetic information.

Some zoomastiginans are found in lakes and ponds. Others exist as parasites or symbionts of other organisms. You will learn about the relationships of these zoomastiginans to other organisms shortly, when we consider how the animallike protists fit into the world.



Figure 18–9 *Many zoomastiginans are parasites.* Giardia *(top, right and bottom) attaches to the lining of the small intestine in humans, causing much irritation and digestive disturbance.* Trichomonas *(top, left) causes intestinal and venereal diseases in humans. It is also responsible for a number of diseases in livestock and poultry.*

Sporozoa: Spore-producing Parasitic Protists

The members of the phylum **Sporozoa** (spohr-oh-ZOH-uh) are nonmotile, which means that they do not move. All sporozoans are parasitic; that is, they live in a host organism and cause it harm. Sporozoans are parasites on a wide variety of other organisms, including worms, insects, fish, birds, and humans. Many sporozoans have complex life cycles that involve more than one host. Sporozoans reproduce by means of spores, which are cells or groups of cells enclosed in a protective membrane. Under the right conditions, spores are able to attach themselves to a host cell, penetrate it, and then live within it as parasites. A typical sporozoan is *Plasmodium*, which causes the human disease malaria.

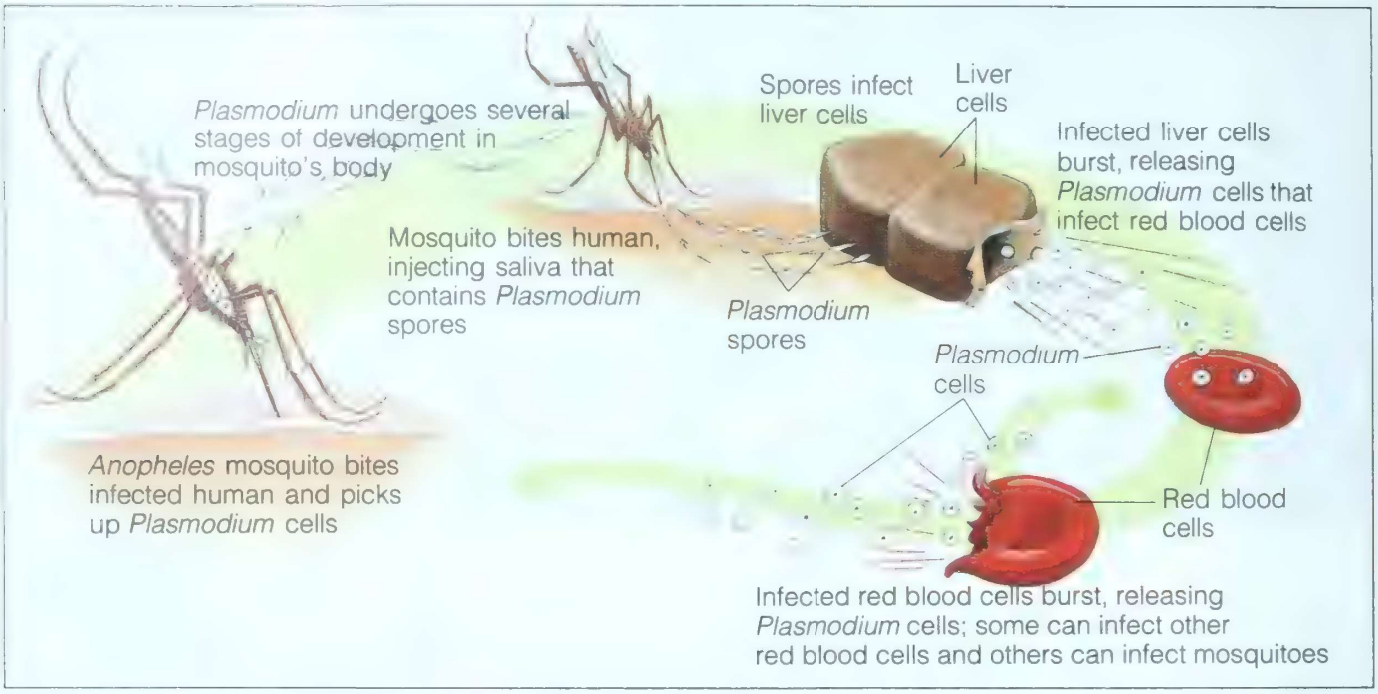


Figure 18–10 Plasmodium *causes the human disease malaria.*

Malaria is carried by the *Anopheles* (uh-NAHF-uh-leez) mosquito. When an infected mosquito bites a human, some of its saliva, which contains spores of the parasite, is injected into the bloodstream. Once inside the body, *Plasmodium* infects liver cells and then red blood cells. *Plasmodium* grows rapidly within the infected cells and eventually causes these cells to burst at intervals of 48 or 72 hours. When millions of parasite-filled red blood cells burst, they dump large amounts of toxins into the bloodstream. The toxins produce chills and fever—the symptoms of malaria.

The disease is transmitted back to the mosquito if a mosquito bites a human infected with malaria. The blood that the mosquito swallows contains *Plasmodium*. In the insect's digestive system, *Plasmodium* grows rapidly and penetrates the insect's entire body, including the salivary glands. After a time, the infected insect contains active *Plasmodium* spores in its saliva and is able to pass the infection on to another human. Malaria is a serious disease that weakens an infected individual and may lead to death. In areas of the world where *Anopheles* mosquitoes flourish, malaria is a serious problem. Every year, more than 250 million people suffer from malaria, and more than 2 million people die from it. Although drugs such as chloroquinine are effective against some forms of the disease, many strains of malaria-causing *Plasmodium* sporozoans are resistant to these drugs. To date, the most effective way to control malaria is to destroy breeding areas for *Anopheles* mosquitoes. This interrupts the life cycle of *Plasmodium* and thus prevents the spread of malaria.

Figure 18–11 *Malaria is transmitted to a human through the bite of an infected mosquito.*



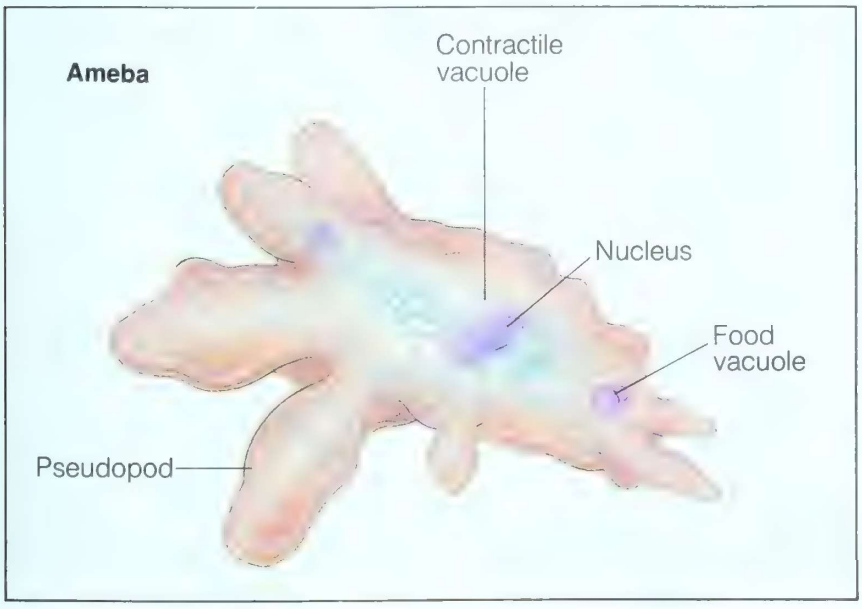
Sarcodina: Protists with False Feet

The phylum **Sarcodina** (sahr-kuh-DIGH-nuh) contains protists that use temporary projections of cytoplasm to move and feed. Such a projection is called a **pseudopod** (SOO-doh-pahd), which literally means false foot. Pseudopods are usually thought of as being rounded and broad. However, some sarcodines have thin, strandlike pseudopods and others have web-like pseudopods. The name Sarcodina comes from the word sarcode, which was coined in the nineteenth century to describe the homogeneous "jelly" from which these cells were thought to be composed.

One major family of Sarcodina is the **amebas**. Amebas are flexible, active cells without cell walls, flagella, cilia, and even a definite shape. Amebas move by means of thick pseudopods, which they extend out of the central mass of the cell. The cytoplasm of the cell streams into the pseudopod, and the rest of the cell follows. This motion is known as ameboid movement.

An ameba is capable of capturing and eating particles of food and even other cells. It does so by first surrounding its meal with streaming cytoplasm and then taking it inside the cell to form a food vacuole. Once inside the cell, the material is digested rapidly and the nutrients are passed along to the rest of the cell. Amebas reproduce by means of binary fission—one large ameba divides by mitosis to produce two smaller, but genetically identical, amebas.

Amebas are not the only members of the phylum Sarcodina. The phylum also includes three groups known as heliozoans, radiolarians, and foraminifers (for-uh-MIHN-ih-ferz). Most of these protists are beautiful organisms that produce external shells to help support their unusual shapes. Although some heliozoans and radiolarians do not have shells, many produce delicate shells of silica (SiO_2), a glasslike substance.



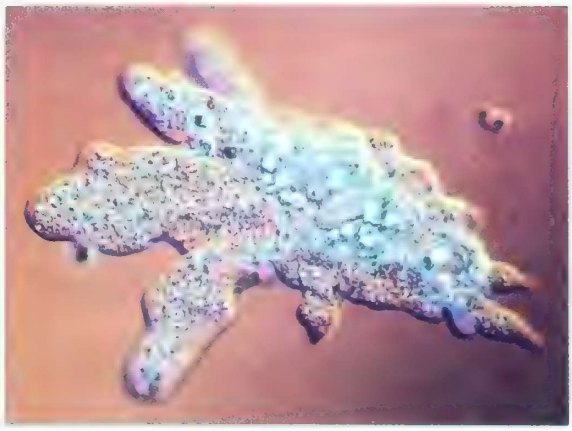


Figure 18–12 *Although a live ameba may at first appear to be a featureless blob (right), careful study reveals its internal structure is well-organized.*



Figure 18–13 *Radiolarians have delicate shells of silica.*

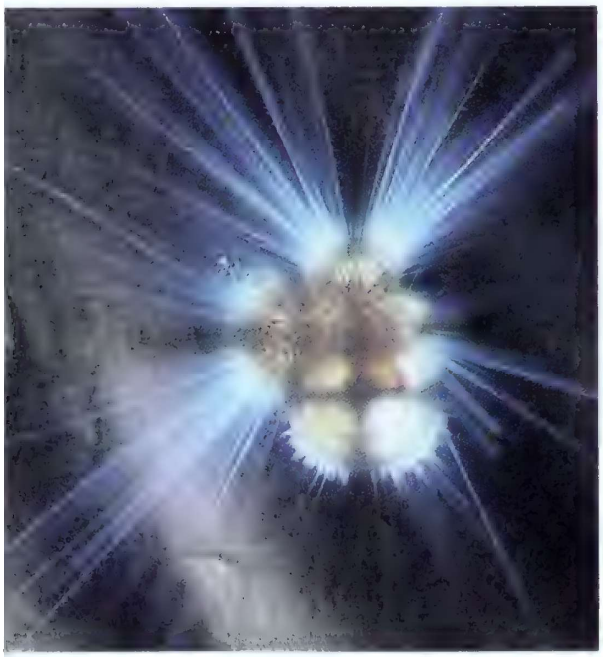
Foraminifers secrete shells of calcium carbonate ($CaCO_3$). These protists are abundant in the warmer regions of the oceans. As foraminifers die, the calcium carbonate from their shells accumulates on the ocean bottom. In some regions, thick deposits of foraminifer skeletons have formed on the ocean floor. The white chalk cliffs of Dover, England, are huge deposits of foraminifer skeletons that were raised above sea level by geological processes.

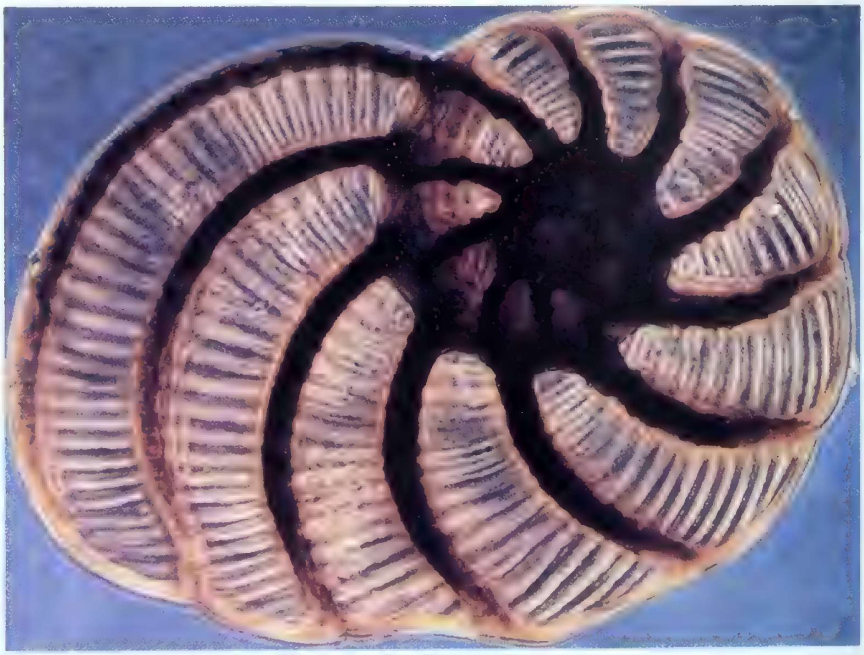
Most species of foraminifers are known not from living specimens but from fossils of their skeletons. Because they have continued to change and evolve over millions of years, the species of foraminifers found in sedimentary rocks are useful measures of the ages of such rocks. By examining foraminifer fossils from rock samples, geologists can determine the age of the samples. This makes it possible to date certain other fossils and also to predict where oil may be found. Because the richest oil deposits were formed at certain times in the Earth's history, foraminifer fossils are valuable clues to the presence of oil in rocks.

Summary of the Animallike Protists

- **Members of the phylum Ciliophora, such as *Paramecium*, are known as ciliates. Almost all ciliates use cilia for movement.**
- **Members of the phylum Zoomastigina are known as flagellates because they use flagella for movement.**
- **Members of the phylum Sporozoa, such as *Plasmodium*, reproduce by means of spores. Sporozoans are nonmotile and parasitic.**
- **The phylum Sarcodina includes amebas and foraminifers. Sarcodines use pseudopods for feeding and movement.**

Figure 18–14 *A live foraminifer, which resembles a clump of tinsel, captures food with its threadlike pseudopods (left). Foraminifers produce shells of calcium carbonate (right).*



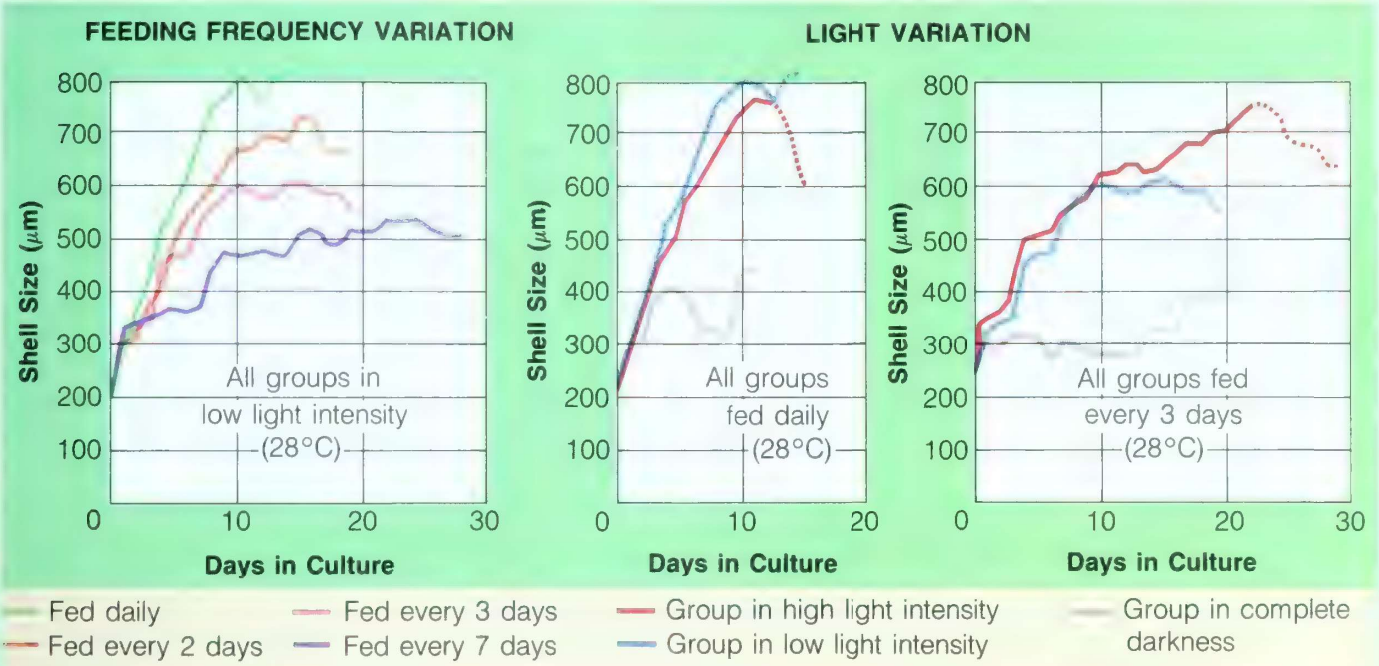


PROBLEM SOLVING IN BIOLOGY

INTERPRETING GRAPHIC DATA ABOUT A FORAMINIFER

Globigerinoides sacculifer is a foraminifer that lives near the surface of the ocean. The shell of *G. sacculifer* consists of several bubble-like chambers that are covered with long iridescent spines. Numerous perforations in the chambers of its shell permit *G. sacculifer* to extend many threadlike pseudopods among its spines. These pseudopods are used to capture microscopic animals and protists. In the laboratory, *G. sacculifer* is fed day-old brine shrimp.

Study these graphs, which show the results of experiments involving the growth of *G. sacculifer*'s shell under different conditions. Answer the questions that follow.



The shell of Globigernoides sacculifer *grows at different rates under different conditions. It stops growing when the protist dies or undergoes gamete formation. (In gamete formation, the body of the foraminifer divides into many tiny cells that leave through the pores of the shell.)*

1. What variables were tested in these experiments?
2. According to these graphs, what is the maximum shell size in *G. sacculifer*?
3. Explain why the data represented by the dotted lines are less significant than the data shown by the rest of the curve.
4. *G. sacculifer* has symbiotic dinoflagellates that live in its cytoplasm. How might this fact explain why the groups of foraminifers raised in complete darkness died or underwent premature gamete formation?
5. How does light intensity affect final shell size?
6. How does feeding frequency affect final shell size?
7. What is the dominant factor in shell growth in *G. sacculifer*? Explain your answer.



Figure 18–16 *Trypanosomes are parasites that live in the blood of vertebrates and cause a number of diseases, such as African sleeping sickness and Chagas disease.*

How Animallike Protists Fit into the World

The animallike protists are found throughout the world. They are some of the most common organisms in the oceans, and they are also abundant in fresh water, on land, and in the bodies of larger organisms.

HARMFUL RELATIONSHIPS Unfortunately for us and for other organisms, there are a great many parasitic protists. Parasitic protists affect plants, all types of animals (including humans), and even other protists. You have already read about one important protist parasite and pathogen (something that causes disease)—the genus of sporozoans called *Plasmodium*, which causes malaria.

Zoomastiginans, which belong to the genus *Trypanosoma*, are another example of pathogenic protists. Trypanosomes (trih-PAN-oh-sohmz) live in the blood of vertebrates such as humans and other mammals and cause a number of diseases. Although these diseases have different common names, any disease caused by trypanosomes is called trypanosomiasis, which means trypanosome infection. One form of trypanosomiasis that affects humans is commonly known as African sleeping sickness.

The trypanosomes that cause African sleeping sickness are passed from one person to another by an insect known as the tsetse (TSEET-see) fly. These trypanosomes destroy blood cells and infect other tissues in the body. The symptoms of infection include fever, chills, and skin rash. As the trypanosomes attack the nervous system, infected individuals become weak and lose consciousness, passing into a deep and often fatal sleep from which the disease gets its name.

Some trypanosome species infect domestic livestock. In areas infested with the tsetse fly, which include vast regions of central Africa, the raising of cattle is virtually impossible. The control of the tsetse fly and the protist pathogens that it spreads is a major goal of scientists in Africa and around the world. The only trypanosome native to the Western Hemisphere is *T. cruzi*, which causes Chagas disease. This disease can result in heart failure because the trypanosomes invade and weaken muscle, especially heart muscle. Some historians believe that Charles Darwin contracted this disease during his visit to South America and that it was this parasite that made him ill much of his life.

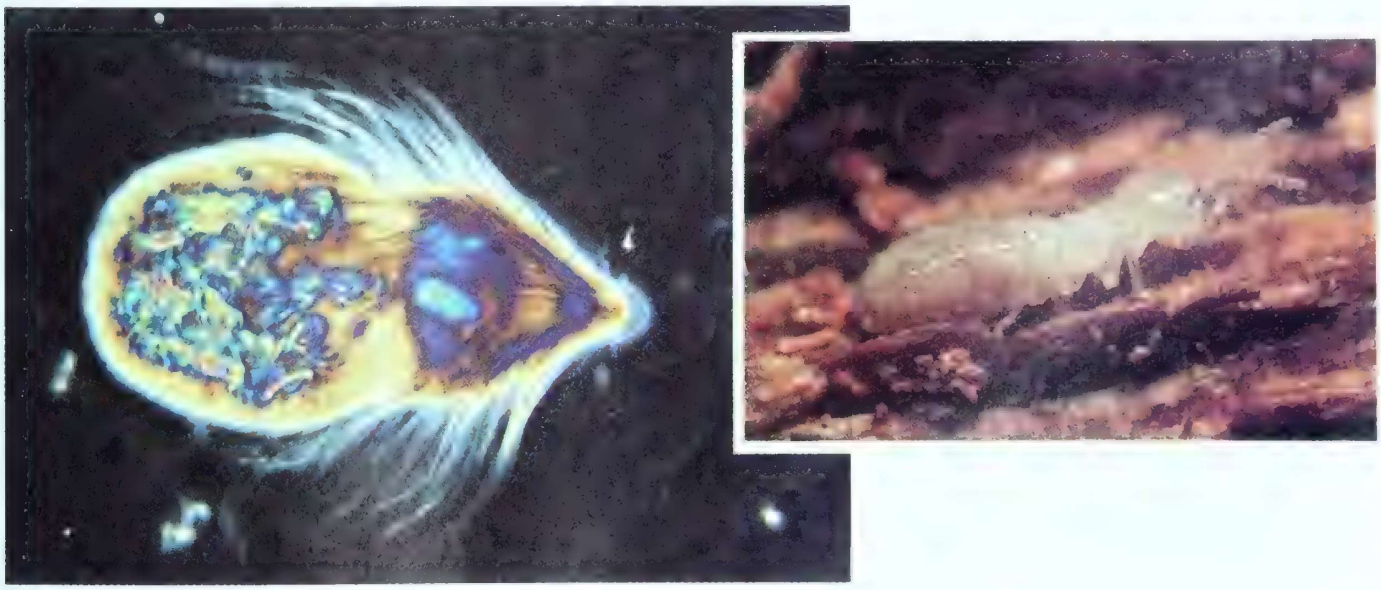
A third kind of pathogenic protist is similar in appearance to the harmless amebas that you may find in a nearby pond or examine under a microscope. In certain regions of the world, many people are infected with species of *Entamoeba*, which cause a disease known as amebic dysentery. The parasitic amebas that cause this disease live in the intestines, where they absorb food from the host. They also attack the wall of the

intestine itself, destroying parts of it in the process and causing severe bleeding. These amebas are passed out of the body in feces. In places where sanitation is poor, the amebas may then find their way into supplies of food and water. In some areas of the world, amebic dysentery is a major health problem, weakening the human population and contributing to the spread of other diseases.

HELPFUL RELATIONSHIPS Although many animallike protists are responsible for disease, there are many that are beneficial to other organisms. An interesting example of a beneficial protist is *Trichonympha*, a zoomastiginan that lives within the digestive systems of the termite and the wood roach. Termites eat wood, the major component of which is the carbohydrate cellulose. But termites do not have enzymes to break apart the chemical bonds that hold the simple sugars in cellulose together. Neither do we, incidentally, so it does us little good to munch on a woodchip. How, then, does a termite digest cellulose? It doesn't. *Trichonympha* does.

Young termites ingest some of the feces of an adult termite, thereby swallowing several thousand *Trichonympha*, which then take up residence in the termites' digestive system. Experiments have shown that insects deprived of these protists cannot live more than a few days. *Trichonympha* and other organisms living in the termites' gut manufacture cellulase, the enzyme that the termites need to break the chemical bonds in cellulose. Without these symbionts, termites and wood roaches would be no more able to digest wood than we are.

Figure 18–17 *Particles of wood appear as irregular grains inside the body of* Trichonympha, *a wood-digesting protist (left).* Trichonympha *lives in the digestive system of insects such as termites (right), making it possible for them to obtain nutrients from the wood they eat.*



The animallike protists play another major role in the living world. Enormous numbers of protists living in the seas are food for tiny multicellular animals that in turn serve as food for larger animals. A similar role is played by protists in freshwater lakes, streams, and ponds. Without such tiny organisms, the larger fish would have no food supply. The animallike protists thus perform an essential function for all other living things.

18-2 SECTION REVIEW

1. List the four phyla of animallike protists. Give an example of each.
2. Compare the forms of locomotion used by the four phyla of animallike protists.
3. Describe the process of conjugation. Is conjugation a form of reproduction? Explain your answer.
4. In what ways are animallike protists helpful to other living things?

Section Objectives

- Name and describe the five phyla of plantlike protists.
- Discuss how plantlike protists fit into the world.

18–3 Plantlike Protists

In addition to the four phyla of animallike protists, we recognize five phyla of plantlike protists. Like other protists, these organisms are unicellular and most of them are motile. We call them plantlike because most contain the pigment chlorophyll and carry out photosynthesis. Like zoomastiginans, many plantlike protists are called flagellates because they have flagella. These organisms are known as phytoflagellates, which means plant flagellates, to distinguish them from zoomastiginans (zooflagellates).

Three of the phyla of plantlike protists—Euglenophyta, Pyrrophyta, and Chrysophyta—are considered to be types of algae. These simple plantlike organisms, found in water or damp places, lack true roots, stems, and leaves. As a result, these three phyla are sometimes classified as plants. The unusual slime molds, which are placed in phyla Acrasiomycota and Myxomycota, are not photosynthetic and have many funguslike characteristics. They are sometimes known as funguslike protists, or are even classified as fungi.

Euglenophyta: Flagellates with Chloroplasts

The members of the phylum **Euglenophyta** (yoo-glee-nuh-FIGHT-uh) are closely related to zoomastiginans. In some classification schemes, euglenophytes and zoomastiginans are actually considered to be in the same phylum. The main reason

for grouping them together is that except for the fact that euglenophytes possess chloroplasts, the two phyla of protists closely resemble each other.

The most famous members of the phylum Euglenophyta belong to the genus from which the entire phylum takes its name: *Euglena.* As you can see in Figure 18–18, a **euglena** is a long cell that has a pouch that contains two flagella at its front end. The longer of these two flagella extends far out of the euglena's pouch and is used to propel the cell forward through the water. A euglena is an excellent swimmer and can move very quickly in this manner. However, when a euglena is forced against a surface—for example, when it is squeezed down on a glass laboratory slide—it is able to move in a different manner. The euglena changes shape rapidly and crawls along the surface by a process called euglenoid movement. Thus a euglena is able to move along in a distinctly animallike fashion.

A red eyespot at the front end of the cell (the end with the flagella) helps a euglena find the brightest areas of its immediate environment. Finding sunlight is important to a euglena because it is filled with between 10 and 20 oval chloroplasts. A euglena is a full-fledged phototrophic autotroph, or an organism that makes its own food from light and simple raw materials, and thus is able to carry out the light and dark reactions of photosynthesis.

When sunlight is not available, a euglena can also live as a heterotroph, or an organism that eats food made by other organisms. If dissolved nutrients are available in the water, a euglena can absorb them and get along in darkness with no ill effects. In nature this gives euglenas the ability to live as saprophytes, or organisms that absorb the nutrients available in decayed organic material.

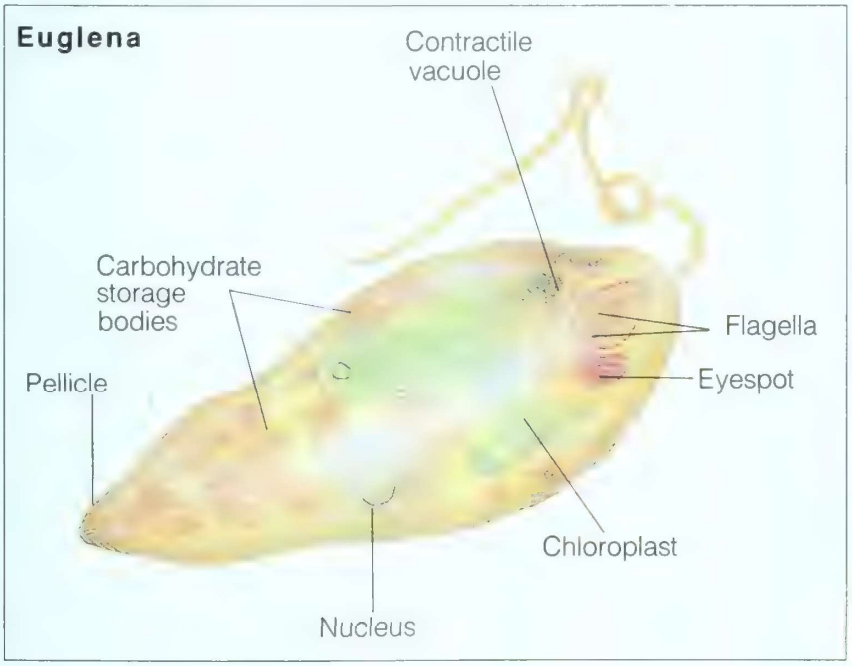




Figure 18–18 *A euglena's organelles include a large prominent nucleus, whiplike flagella, green chloroplasts, and grainy yellow food-storage structures.*

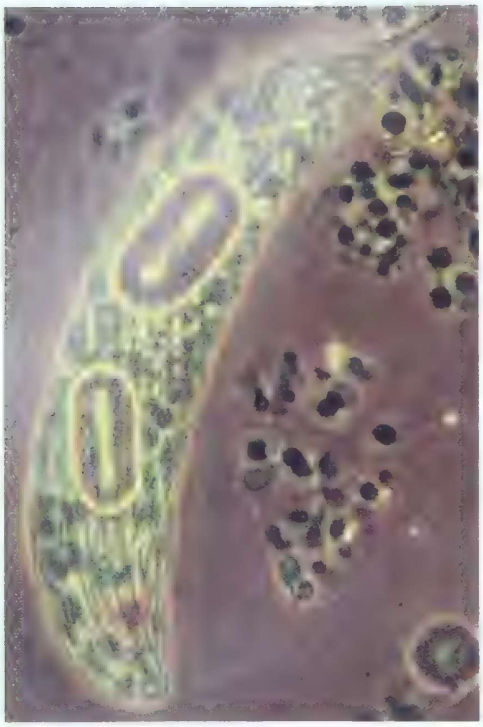


Figure 18–19 *A euglena is a photosynthetic protist that swims by means of flagella. The ridges that spiral around the body of the euglena are part of its pellicle.*

The pellicle (the cell membrane and associated structures) of *Euglena* is of special interest to many biologists because of its unusual structure. The pellicle consists of a series of ribbon-like ridges that spiral around the surface of the organism. See Figure 18–19. Underneath each ridge is a small sac and a set of microtubules. The microtubules and the sacs probably are important in maintaining the shape of the cell when it is swimming and in generating the force for euglenoid movement.

A euglena reproduces asexually by binary fission. In this process, a single euglena divides in two, beginning at the end with the flagella and finally separating at the base. Just prior to cell division, the cell doubles the number of ridges in its pellicle by producing tiny new ridges between the old ones. Because of their adaptability—there are few organisms able to exist as both autotrophs and heterotrophs—euglenas are able to live in many different places and are quite common.

Pyrrophyta: Fire Protists

The members of phylum **Pyrrophyta** (pigh-roh-FIGHT-uh) are a group of organisms known as the **dinoflagellates**. Most dinoflagellates are photosynthetic, although a few have lost their chloroplasts and exist as heterotrophs. The cells usually swim by means of two flagella. In most dinoflagellates, one flagellum wraps around the organism like a belt, whereas the other trails behind like a tail. Many dinoflagellates are surrounded by thick plates that give them a strange armored appearance. Dinoflagellates reproduce asexually by binary fission.

The dinoflagellates have two interesting properties that set them apart from most other protists and, indeed, most other organisms. First, a great many dinoflagellate species are luminescent. When agitated by sudden movement in the water, they give off light. Many areas of the ocean are so filled with dinoflagellates that the movement of an oar or the wake of a boat will cause the dark water to shimmer with a ghostly blue light. This is a remarkable sight, and one that gives the phylum its name (Pyrrophyta means fire plants).

The second interesting property of dinoflagellates has to do with their genetic material. Like other organisms, dinoflagellates store genetic information in the form of DNA. In the case of all other eukaryotic cells, however, that DNA is tightly bound with special proteins known as histones. Dinoflagellates do not have histones. In fact, they are the only eukaryotes that do not. The reason for this difference, as well as an explanation of how the roles of the histone proteins are carried out without them in dinoflagellates, remains a mystery.

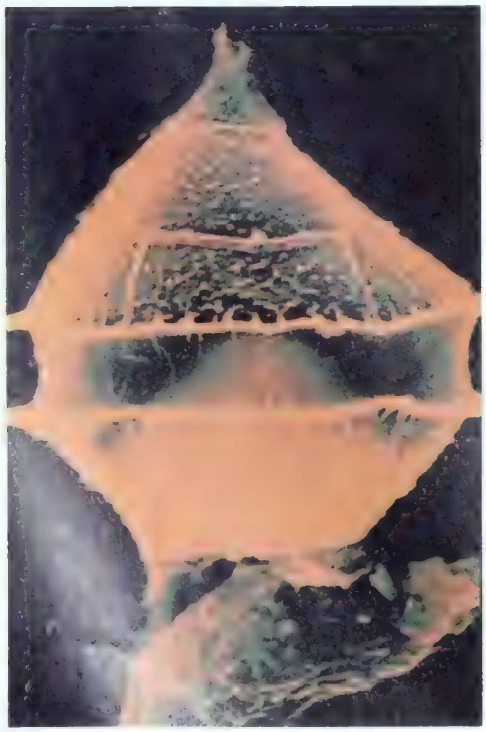


Figure 18–20 *Dinoflagellates are plantlike protists. They often have thick protective shells that give them bizarre shapes.*

The Line Between Plant and Animal

Because of its mix of autotroph and heterotroph, *Euglena* is often said to straddle the division between plant and animal. Today, scientists who classify organisms generally solve the plant or animal problem by placing *Euglena* in a separate phylum among the Protista. However, it is worth noting just how indefinite the line between plant and animal can be at the level of a single cell.

An important member of the phylum Zoomastigina is *Astasia*. The resemblance between *Astasia* and *Euglena* is striking. The shapes of the cells are similar, the manner in which they move is similar, even the organization of their cell membranes is similar. In many older systems of classification, one was classified as an animal (*Astasia*) and one as a plant (*Euglena*). The only clear-cut difference between them is that *Euglena* possesses chloroplasts. Should the presence of chloroplasts be enough to place an organism in a separate kingdom?

Most scientists have concluded that it is not enough. A simple experiment gives some of the reasons why. Usually *Euglena* is grown at a temperature of about 25°C—the temperature of a slightly warm room. If *Euglena* is grown in the laboratory at a higher than normal temperature (for example, at about 37°C), something remarkable happens. *Euglena* loses its chloroplasts! After several generations of growth at the elevated temperature, the green *Euglena* cells will have become colorless—their chloroplasts will have vanished. The colorless *Euglena* cells, which can only be distinguished from *Astasia* cells by an expert, never regain their chloroplasts.

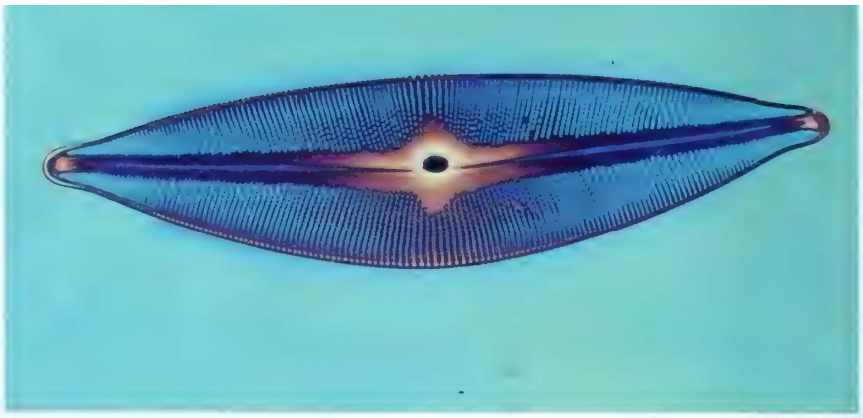
We now understand the reason for this phenomenon. The enzymes that replicate chloroplast DNA do not function at the elevated temperature, whereas those that replicate nuclear DNA do. Hence the cell can keep on dividing, but the chloroplasts do not. As the cells grow, the average of 16 chloroplasts per cell is quickly reduced to 8, then 4, then 2, then finally none!

Regardless of the cause, scientists quickly realized that the presence or absence of chloroplasts could not serve as a basis for placing organisms in two different kingdoms—not when chloroplasts can be so easily lost! Instead, there is now an interesting debate among scientists regarding the relationship between *Euglena* and the colorless flagellates of the phylum Zoomastigina. Are zoomastiginans descended from *Euglena*-like organisms that lost their chloroplasts? Or are the euglenophytes actually zoomastiginans that acquired chloroplasts? An interesting question.



Euglena *(top) and* Astasia *(bottom) are virtually identical—except that one has chloroplasts.*





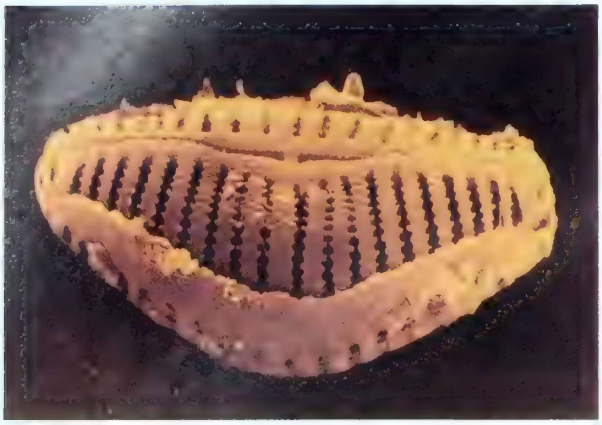


Figure 18–21 *Diatom cells are enclosed within delicate and ornate two-part shells of silica. These glassy shells are quite beautiful.*

Chrysophyta: Golden Protists

There are three general kinds of organisms found within the phylum **Chrysophyta** (krihs-uh-FIGHT-uh): yellow-green algae, golden-brown algae, and diatoms. The name of the phylum, which means golden plants, refers to the one or two gold-green chloroplasts found in the cells of most species of chrysophytes.

The cell walls of chrysophytes contain the carbohydrate pectin rather than cellulose, and they generally store food in the form of oil rather than starch. Chrysophytes are extremely diverse. They reproduce asexually and sexually. Most are solitary, but some form threadlike colonies. Some have flagella and others do not. And some live within cell walls of glass! All but about 2000 of the species in this phylum belong to the **diatoms**.

The diatoms are cells that produce intricate cell walls rich in silicon (Si)—the main ingredient in glass. These walls are shaped like the two sides of a petri dish or flat pillbox, with one side fitting snugly into the other. They are etched with fine lines and designs that seem to be carved into the glasslike brilliance of both sides. Even a modest sampling of the range of diatom species will serve to establish that they are among the most beautiful organisms on Earth. Diatoms are photosynthetic and are among the most abundant species in the oceans.

The Slime Molds: Unusual Protists

Slime molds are found near rich sources of food such as rotting wood, piles of compost, and even thick wet lawns. The slime molds are organisms that are extremely difficult to classify. At one stage of their life cycle they appear as amebalike cells. At other stages they produce moldlike masses that give rise to spores. As a result, slime molds have been classified as amebas and as fungi. They are now placed in two phyla within the kingdom Protista.

ACRASIOMYCOTA: CELLULAR SLIME MOLDS Cellular slime molds belong to the phylum **Acrasiomycota** (uh-kras-ee-oh-migh-KOH-tuh). Cellular slime molds begin their life cycle as individual cells that look very much like amebas. In fact, cellular slime molds spend most of their lives as free-living cells not

easily distinguishable from soil amebas. These ameboid, or amebalike, cells reproduce very rapidly. When the food supply is exhausted, groups of ameboid cells gather together to produce a large mass of cells that begins to function as a single organism. This unusual behavior forces scientists to stretch the definition of protists. Protists are defined as being unicellular —but here is a group of protists acting like a primitive multicellular organism!

These solid masses of cells may migrate for several centimeters. They then form a reproductive structure called a fruiting body that produces spores by mitosis. These spores give rise to ameboid cells that repeat the cycle.

Cellular slime molds are an interesting system for biologists who study how cells communicate. The formation of an intricate structure such as the fruiting body from what was previously a mass of independent cells is a most intriguing process. It has kept biologists busy for decades, and its secrets are still not fully understood.

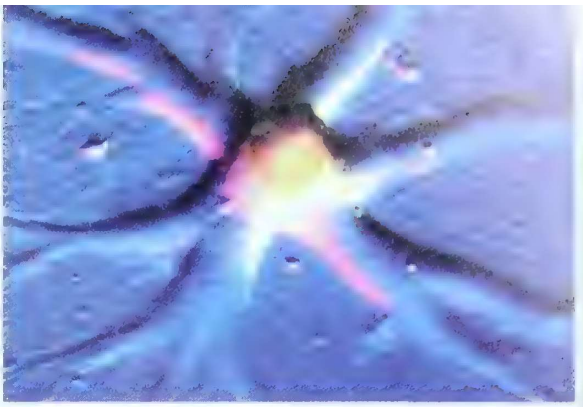
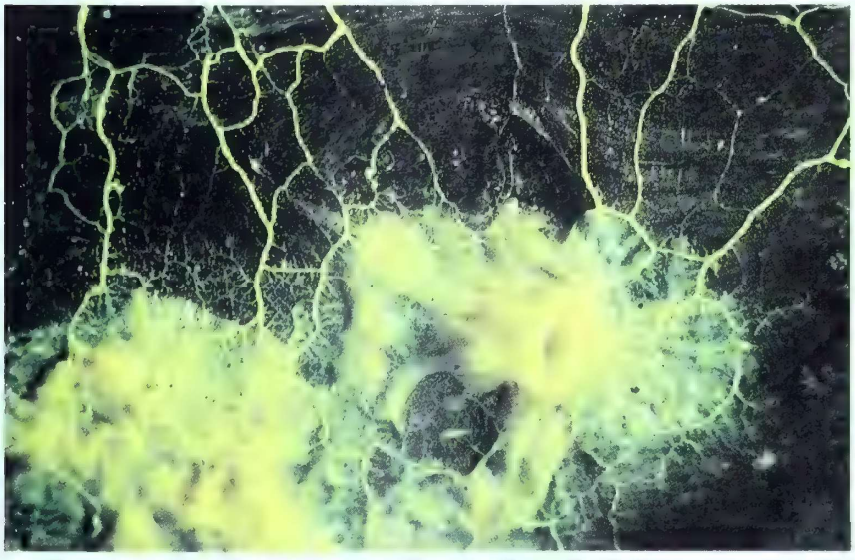


Figure 18–22 *When the food supply runs out, cellular slime mold cells come together. The collection of cells that results from this process looks and acts much like a simple multicellular organism.*

MYXOMYCOTA: ACELLULAR SLIME MOLDS Acellular slime molds belong to the phylum **Myxomycota** (mihks-uh-migh-KOH-tuh). Like a cellular slime mold, an acellular slime mold begins its life cycle as an amebalike cell. However, acellular slime molds produce structures known as **plasmodia** (singular: plasmodium) that contain thousands of nuclei enclosed in a single cell membrane. In contrast to the cellular slime molds, the large plasmodium of an acellular slime mold is a single multinucleate cell. A plasmodium may grow as large as several centimeters in diameter.

Eventually small structures known as fruiting bodies spring up from the plasmodium. The fruiting bodies produce haploid spores by meiosis. These spores scatter to the ground where they germinate into flagellated cells. These flagellated cells fuse to produce diploid ameboid cells that repeat the cycle.

Figure 18–23 *At one point in its life cycle, an acellular slime mold forms a structure called a plasmodium, which contains many nuclei and creeps about like a giant ameba (left). Later, reproductive structures called fruiting bodies are produced by the plasmodium (right).*





Summary of the Plantlike Protists

- **Members of the phylum Euglenophyta are very similar to zoomastiginans. Euglenophytes, such as *Euglena*, are photosynthetic flagellates.**
- **Members of the phylum Pyrrophyta are called dinoflagellates. Most dinoflagellates are photosynthetic, and some are luminescent.**
- **The phylum Chrysophyta is a diverse group of protists that have gold-colored chloroplasts. Most of the species of chrysophytes are diatoms, photosynthetic protists that lack flagella and live in beautiful glasslike "boxes."**
- **Slime molds are unusual organisms that are difficult to classify. Cellular slime molds belong to the phylum Acrasiomycota. Acellular slime molds belong to the phylum Myxomycota.**



Figure 18–24 *Red tide (top) is produced by blooms of the dinoflagellate* Gonyaulax *(bottom).* Gonyaulax *contains a toxin that can become concentrated in the tissues of shellfish such as clams and oysters, making them unfit to eat. This toxin can also kill fish and other marine animals.*

How the Plantlike Protists Fit into the World

Like the animallike protists, plantlike protists are found throughout the world in bodies of fresh water, in the ocean, and on land. Unlike animallike protists, most plantlike protists are autotrophs rather than heterotrophs. Although plantlike protists can be harmful to other organisms, few plantlike protists are truly parasitic.

HARMFUL RELATIONSHIPS In lakes and ponds, euglenophytes are among the most common organisms. In areas into which large amounts of sewage are discharged, euglenophytes may thrive. Because they are able to absorb organic material directly and use it for food, they grow rapidly in such regions and their presence may actually turn the water of a lake or slow-moving stream a murky green. They play a vital role in helping to recycle sewage and other waste materials. But when the amount of waste dumped into a body of water is excessive, the euglenophytes and other green organisms may grow into enormous masses of cells known as **blooms**. While not harmful in themselves, these blooms quickly run out of nutrients and the cells begin to die in great numbers, compounding the problem of disposing of waste matter.

Great blooms of the dinoflagellate *Gonyaulax polyhedron* have occurred in recent years on the east coast of the United States, although scientists are not sure of the reasons. This species contains a toxin that can cause paralysis and even death if ingested in large amounts. Fortunately for all but the most allergic people, it simply is not possible to swallow enough of the "red tide" of *Gonyaulax* while swimming to be affected by the toxin. Thus the blooms of dinoflagellates are not harmful to most swimmers. However, shellfish such as clams

and oysters filter enormous amounts of sea water in order to trap organisms like *Gonyaulax* for food and thus become filled with the toxin. Eating shellfish from areas infected with red tide can cause serious illness. In addition, the toxin can kill fish and weaken or even kill dolphins.

HELPFUL RELATIONSHIPS The plantlike protists form some spectacular symbiotic relationships with other organisms. Many types of coral contain intercellular dinoflagellates. These dinoflagellates allow the tiny animals that form the coral to use the products of photosynthesis, allowing coral to grow in areas where nutrients are few. In turn, the dinoflagellates can use many of the waste products of the coral organisms before they are diluted by diffusion through sea water.

Other dinoflagellates make their homes with other organisms. In the giant clam *Tridacna gigas*, a special tissue called the mantle contains large numbers of symbiotic photosynthetic protists. These dinoflagellates are held in a position from which they are able to gather as much sunlight as possible and increase the nutrient benefit to the organism.

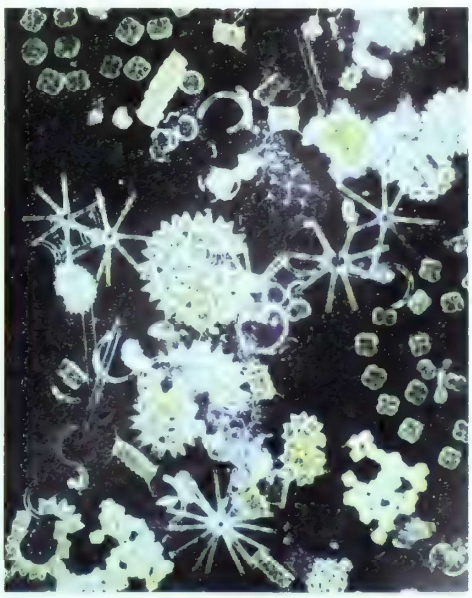
Plantlike protists play a major ecological role: They make up a considerable part of the **phytoplankton**. The term phytoplankton is applied to any small photosynthetic organism found in great numbers near the surface of the ocean. Thus it can apply to any photosynthetic organism, regardless of kingdom or phylum.

The importance of the phytoplankton for other forms of life cannot be underestimated. More than 70 percent of the photosynthesis that occurs on Earth goes on near the surface of the oceans. The result of this photosynthesis is that the rest of the organisms on our planet are provided with enormous amounts of oxygen and food. The phytoplankton provide a direct source of nourishment for organisms as diverse as shrimp and whales. And even land animals such as humans obtain nourishment indirectly from the phytoplankton. When you eat a tuna fish sandwich, you are eating fish that fed on smaller fish that fed on still smaller animals that fed on phytoplankton!



Figure 18–25 *Symbiotic photosynthetic protists live inside the tissues of animals such as sea anemones (top) and giant clams (bottom).*

Figure 18–26 *Phytoplankton provide enormous amounts of food and oxygen for other organisms on Earth.*



18–3 SECTION REVIEW

1. List the five phyla of plantlike protists. Give an example of an organism in each phylum.
2. What are slime molds? Why is it appropriate for the slime molds to be considered protists?
3. Why is red tide particularly damaging to the shellfish industry?
4. "Life on Earth depends on plantlike protists." Defend or refute this statement.

LABORATORY INVESTIGATION

EXAMINING PROTISTS

PROBLEM

What characteristics of protists can be observed with a microscope?

MATERIALS *(per group)*

pond water	cotton
coverslips	microscope
microscope slides	protist identification guide
medicine dropper	

PROCEDURE

1. Using the medicine dropper, put a drop of pond water in the center of a clean glass microscope slide.
2. Pull apart a small piece of cotton and put a few threads in the drop of pond water. **Note:** *Only a few threads are necessary.*
3. Cover the drop of pond water with a coverslip. With your microscope set on low power, look for signs of life in the water.
4. When you find microorganisms, switch to medium power and focus with the fine adjustment. Observe what happens when one of the microorganisms bumps into the thread.
5. Try to get a microorganism in the center of the field of view. Switch to high power and focus with the fine adjustment. **Note:** *Use only the fine adjustment to focus when using the high-power objective. When using the high-power objective, do not focus downward (do not bring the objective closer to the slide) while looking through the microscope.*
6. Draw the protist on a separate sheet of paper. Next to your drawing, write down your observations of the protist's appearance and behavior. Note its shape and color and the organelles that are visible. Try to determine how it moves—a "fluttery" edge on the protist, for example, is a sure sign of cilia.
7. Repeat steps 5 and 6 with as many different protists as you can find.
8. Using a protist identification guide, try to identify the protists in your drawings.



OBSERVATIONS

1. What types of movement did you observe in the protists?
2. What organelles did you observe in the protists?
3. Describe what protists do when they bump into an obstacle such as a thread.
4. What characteristics did the protists have in common?
5. How were the protists different from one another?

ANALYSIS AND CONCLUSIONS

1. What important characteristics of protists are difficult or impossible to observe with a light microscope?
2. Why was the cotton put into the drop of pond water? Predict what you might have observed if there were no cotton in the pond water.
3. Was it easy to identify the protists you observed? Explain.
4. Suggest what might be done to make it easier to observe and identify protists.

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

18–1 The Kingdom Protista

- Protists, or members of the kingdom Protista, are unicellular eukaryotic organisms.
- The Endosymbiont Hypothesis states that the first eukaryotic cell was formed by a symbiosis among several prokaryotes.

18–2 Animallike Protists

- Ciliates possess cilia.
- Zoomastiginans possess flagella.
- Sporozoans are nonmotile parasitic protists.
- Sarcodines use pseudopods for locomotion and feeding.
- Some animallike protists are symbionts of other organisms. A few species are pathogens. Animallike protists are a source of food for small organisms that in turn are food for larger organisms.

18–3 Plantlike Protists

- Euglenophytes are photosynthetic flagellates that are similar in form to zoomastiginans.
- Pyrrophytes are also known as dinoflagellates. Some dinoflagellates are luminescent.
- Most of the species in the phylum Chrysophyta are diatoms.
- Slime molds are also known as funguslike protists. Unlike most plantlike protists, slime molds are not photosynthetic.
- Cellular slime molds form a mass of cells that function like a single organism at one point in their life cycle.
- Acellular slime molds form plasmodia at one point in their life cycle.
- Photosynthetic plantlike protists form an important part of the phytoplankton, which supplies much of the earth's oxygen.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meanings. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

18–1 The Kingdom Protista
Protista
protist
Endosymbiont Hypothesis

18–2 Animallike Protists
Ciliophora
ciliate
cilium
paramecium
pellicle
trichocyst
macronucleus
micronucleus
gullet
food vacuole
anal pore
contractile vacuole
Zoomastigina
flagellum
flagellate
Sporozoa
Sarcodina
pseudopod
ameba

18–3 Plantlike Protists
Euglenophyta
euglena
Pyrrophyta
dinoflagellate
Chrysophyta
diatom
slime mold
Acrasiomycota
Myxomycota
plasmodium
bloom
phytoplankton

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. All protists are
   a. solitary. c. motile.
   b. colonial. d. eukaryotic.
2. Which organism causes malaria?
   a. *Paramecium* c. *Plasmodium*
   b. *Trypanosoma* d. *Euglena*
3. Short hairlike projections that produce movement in certain protists are
   a. cilia. c. flagella.
   b. pseudopods. d. microtubules.
4. Diatoms belong to the phylum
   a. Ciliophora. c. Pyrrophyta.
   b. Chrysophyta. d. Myxomycota.
5. Which of the following organisms are not placed in the phylum Sarcodina?
   a. amebas c. heliozoans
   b. radiolarians d. flagellates
6. A euglena moves by means of
   a. pseudopods. c. spores.
   b. cilia. d. flagella.
7. Which organism is not associated with a disease in humans?
   a. *Trichonympha* c. *Trypanosoma*
   b. *Entamoeba* d. *Plasmodium*
8. A paramecium excretes excess water through the
   a. gullet. c. contractile vacuole.
   b. trichocysts. d. micronucleus.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. Red tides are caused by dinoflagellates.
2. Cellular slime molds produce plasmodia.
3. Animallike protists make up a considerable part of the phytoplankton.
4. During conjugation, paramecia exchange macronuclei.
5. Sporozoans use pseudopods to move.
6. In some protists, the cell membrane and associated structures make up the flagellum.
7. A paramecium uses flask-shaped structures called contractile vacuoles for defense.
8. Some species in the phylum Pyrrophyta are luminescent.

Word Relationships

A. *In each of the following sets of terms, three of the terms are related. One term does not belong. Determine the characteristic common to three of the terms and then identify the term that does not belong.*

1. dinoflagellate, diatom, ameba, euglena
2. macronucleus, micronucleus, flagella, cilia
3. red tide, malaria, African sleeping sickness, amebic dysentery
4. sporozoan, foraminifer, radiolarian, heliozoan

B. *Replace the underlined definition with the correct vocabulary word.*

5. Flexible, active cells without cell walls, flagella, cilia, and even a definite shape engulf prey by using pseudopods.
6. Slime molds are heterotrophic organisms that feed on dead or decaying organic material.
7. The oldest fossils of members of the kingdom that consists of unicellular eukaryotic organisms are about 1.5 billion years old.
8. Diatoms, chrysophytes, and euglenophytes are an important part of the small photosynthetic organisms that are found in great numbers near the surface of the ocean.

CONCEPT MASTERY

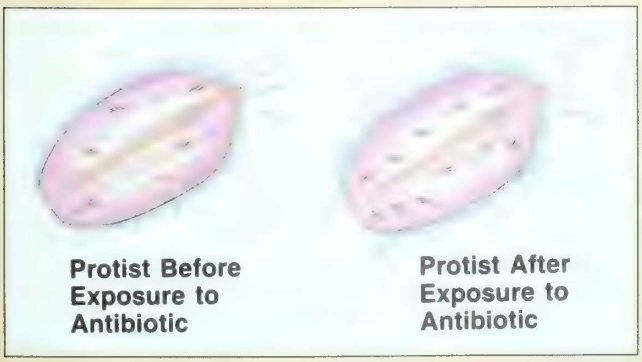
Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. What is the significance of the Endosymbiont Hypothesis?
2. Are the categories animallike, plantlike, or funguslike useful in classifying protists? Explain your answer.
3. Why are diatom shells often used in toothpaste and reflective paint?
4. Explain why protists are difficult to classify.
5. Make a table that contains the following information about each protist phylum: Name of Phylum; Animallike or Plantlike; Representative Members; Means of Locomotion; Relationships with Other Organisms.

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Developing a hypothesis** A scientist observes that termites that are fed a certain antibiotic die of starvation after a few days. The scientist also notices that certain protists that live inside the termite's gut are affected by the antibiotic in a peculiar way: Although the protists continue to thrive, they lose a certain kind of structure in their cytoplasm. Develop a hypothesis to explain these observations.



Protist Before Exposure to Antibiotic

Protist After Exposure to Antibiotic

2. **Relating cause and effect** How might water pollution result in a red tide?
3. **Making predictions** Growing "holes" in the Earth's ozone layer may increase the amount of radiation that reaches the surface of the ocean. If this radiation were to affect the growth of phytoplankton, what long-term consequences might this have on the Earth's atmosphere?
4. **Using the writing process** Imagine that you could shrink down to microscopic size and fit inside a paramecium. Describe the adventures you and the paramecium have in a small pond one summer day.