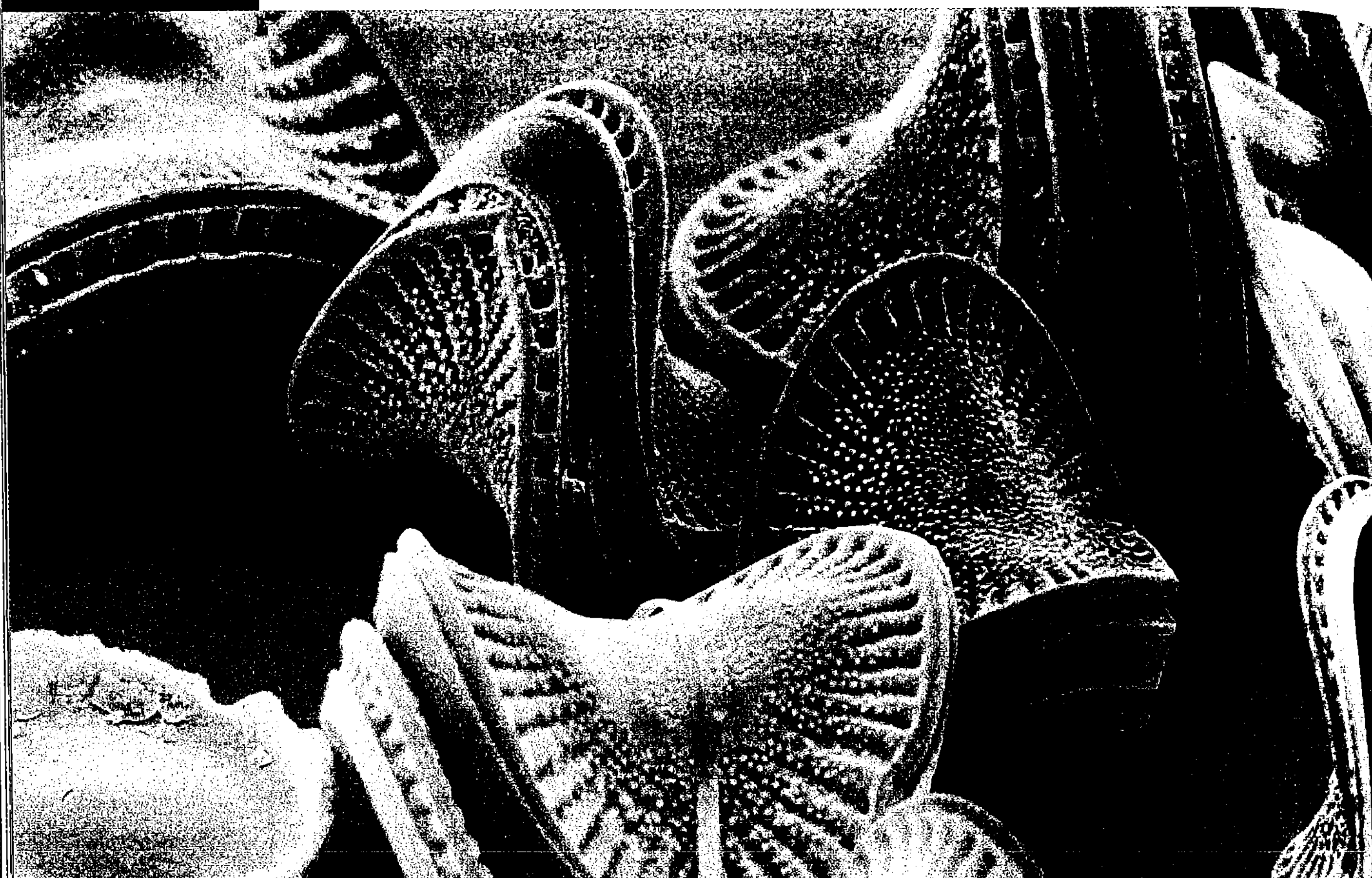
Chapter 18

Protists



Characterized by their beautifully patterned shells of silica (a glasslike substance), diatoms are among the most important components of marine and freshwater plankton. Magnification 250X.

Chapter Inquiry Classifying

1. Examine photographs of various protists. As a group, brainstorm to make a list of the similarities and differences that exist among these protists.
2. From that list, design a tentative classification system for protists. What are the important features of this system?

Connect to the Main Ideas

Of the six kingdoms of life, scientists debate the grouping of organisms in Protista the most. Because its organisms are so diverse, some scientist want to split the kingdom into three. But what similarities do all protists have? Why is the kingdom still a useful grouping?

Chapter Preview

Main Ideas

In this chapter, you will describe the major characteristics of protists and discuss the Endosymbiont Hypothesis, which explains the evolution of protists from prokaryotes. You will also examine the features of animallike protists and plantlike protists and their relationships with other organisms.

Reading Strategy

Outlining Information As you read this chapter, organize your notes according to Linnaeus's system of classification. Give characteristics at the kingdom and phylum levels. Draw and name a representative of each phylum.

Journal Activity

Biology and Your World When did you first become aware of the existence of organisms so tiny that they could not be seen with the unaided eye? In your journal, describe your thoughts and feelings after making this discovery.

18–1 The Kingdom Protista

Guide For Reading

- What are the major characteristics of protists?
- What is the Endosymbiont Hypothesis?

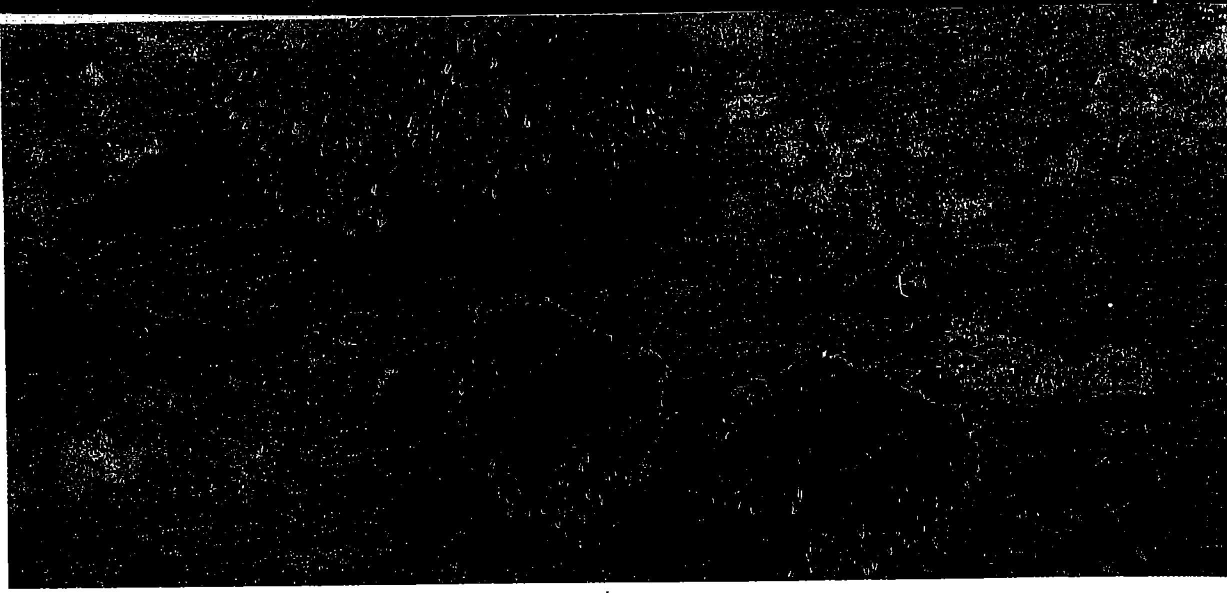
The first kingdom of eukaryotic organisms (organisms whose cells contain nuclei and membrane-enclosed organelles) that we will consider is the kingdom **Protista**. The name is appropriate, for it is derived from a Greek word that means first. The term **protist** refers to any member of the kingdom 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 bacteria (single-celled organisms that lack a nucleus and membrane-enclosed organelles) are more than 3.5 billion years old. Compared with bacteria, 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 (right). 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.



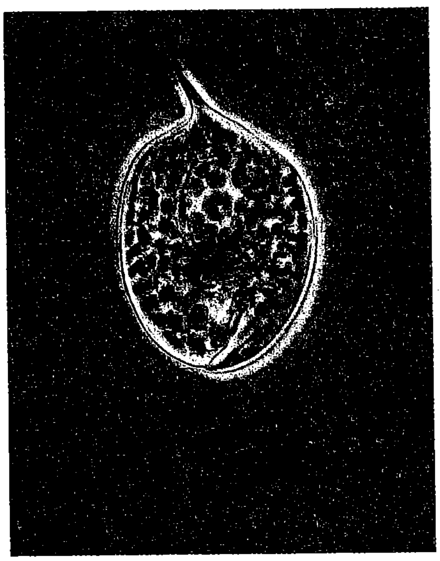


Figure 18–2 *Protists often share characteristics with more than one multicellular kingdom. Some are photosynthetic like plants and can move like animals (bottom). Others are similar to fungi in life cycle and appearance but move like animals and have cells that are more like those of animals than those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

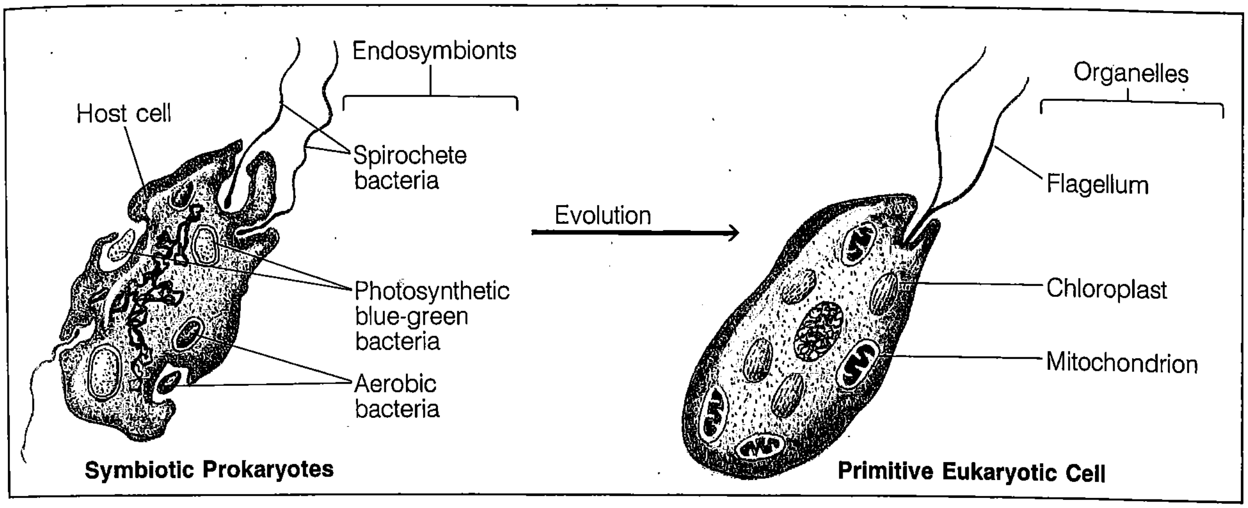


***Figure 18–3** According to the Endosymbiont Hypothesis, the organelles in eukaryotic cells evolved from symbiotic prokaryotes that lived inside a host cell.*

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!

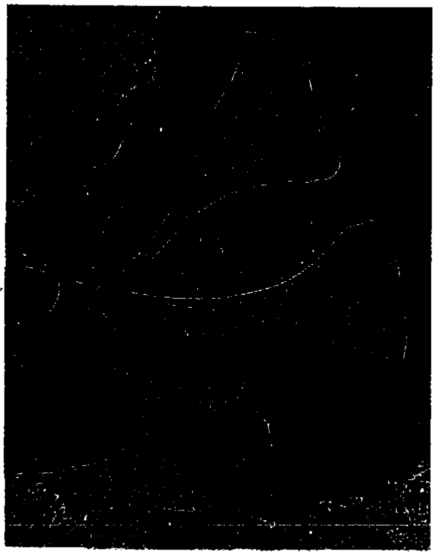
18–1 SECTION REVIEW

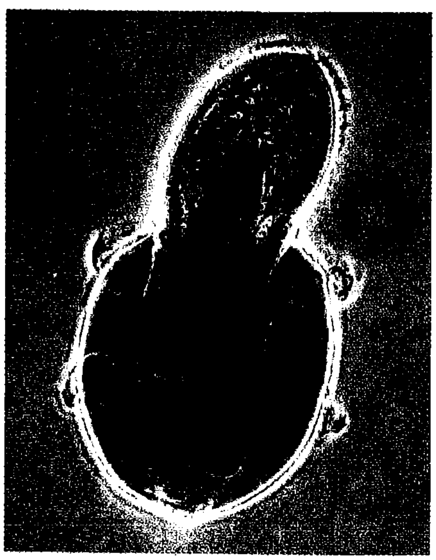
1. What are protists? When did protists first appear on Earth?
2. What evidence has led scientists to believe that symbiosis played an important role in the evolution of protists?
3. **Critical Thinking—Applying Concepts** How might the Endosymbiont Hypothesis explain the double membranes that surround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

Guide For Reading

- What are the major characteristics of the four phyla of animallike protists?
- How do animallike protists fit into the world?

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.





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

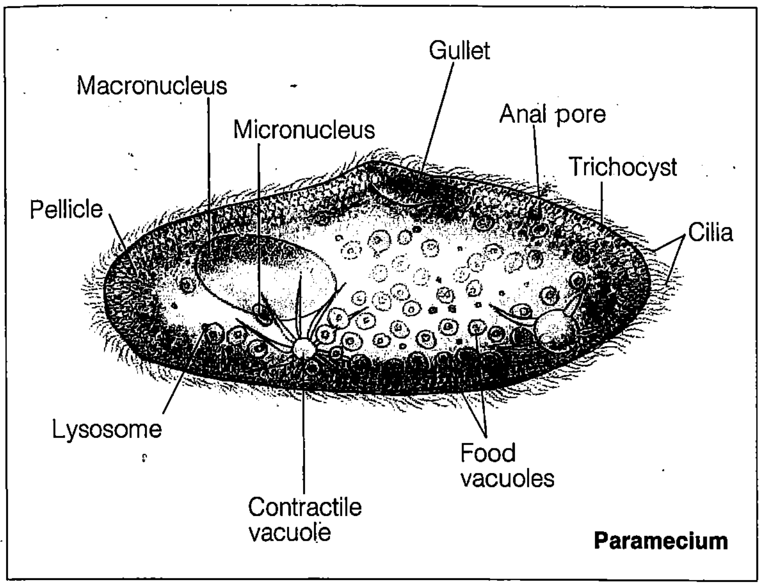
Members of the phylum **Ciliophora** (sihl-ee-AHF-uh-rah) are either solitary or colonial organisms. These organisms are often known as **ciliates** (SIHL-ee-ihts) because they have **cilia** (singular: cilium). (Ciliophora literally means cilia-bearing.) Cilia are short hairlike projections that produce 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



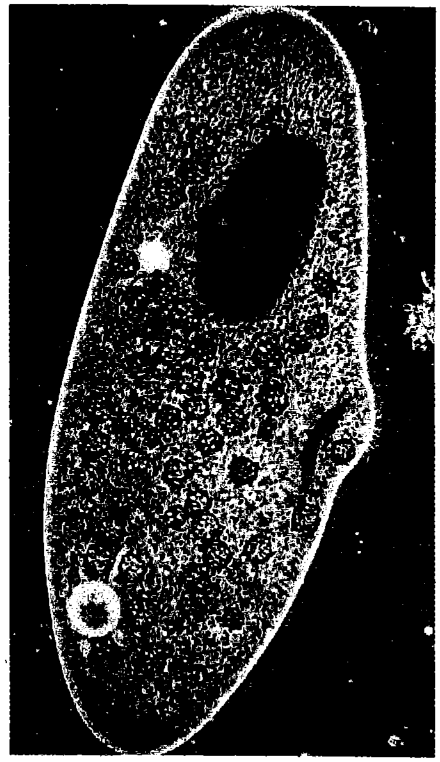


__Figure 18–5__ The essential life functions of a paramecium are divided among many organelles (left), several of which can be seen in this live paramecium (right). The small green circles are food vacuoles that contain bits of algae.

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

Quick Lab

To reinforce the **Main Idea** of protist characteristics, perform the Quick Lab activity called Observing Food Ingestion in a Paramecium on p. 1092.

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

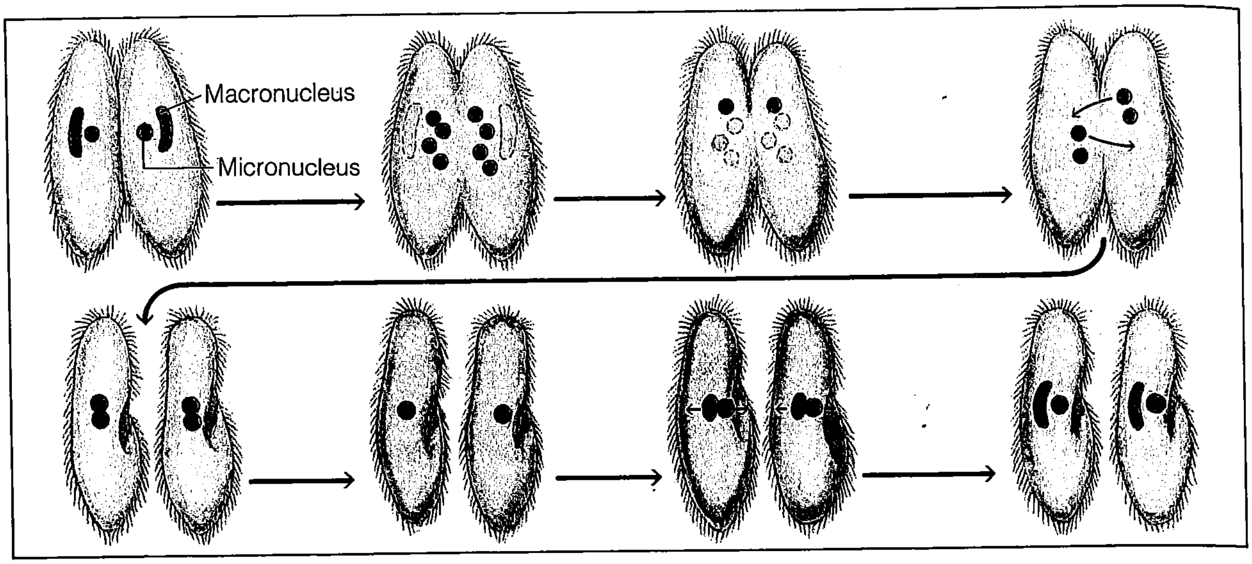
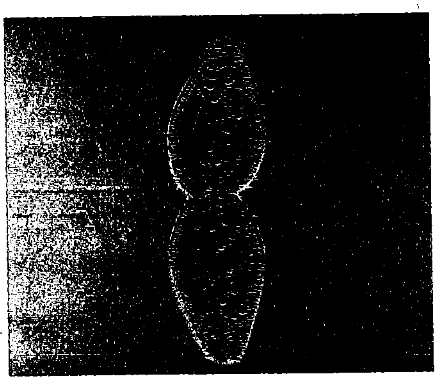


Figure 18–7 *In the process of conjugation, two paramecia join together and share genetic information. Conjugation produces new combinations of genes—combinations that may give paramecia a better chance of survival.*



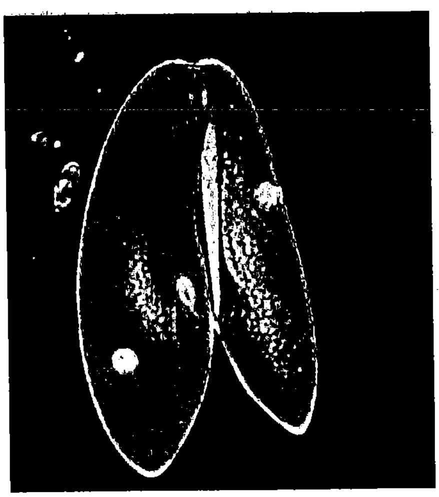


Figure 18–8 *Paramecia usually reproduce asexually through binary fission (top). Under certain circumstances, paramecia will undergo a form of sexual reproduction called conjugation (bottom).*

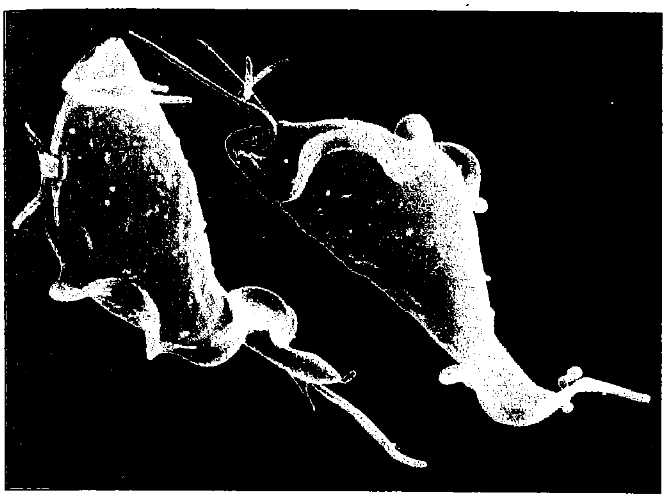
of micronuclei, so that each cell has 1 micronucleus obtained from the other cell and 1 micronucleus of its own. In the final stage of conjugation, the paramecia separate from each other. The 2 haploid micronuclei in each paramecium fuse to form a new diploid micronucleus. From the new micronucleus,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

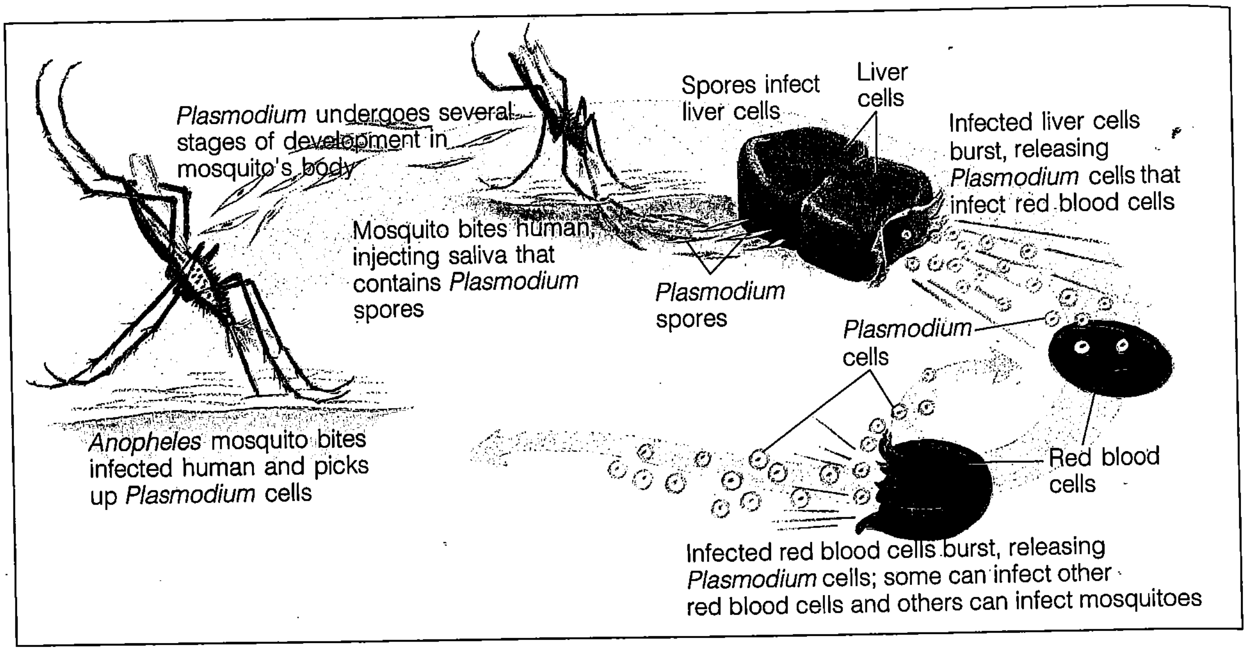
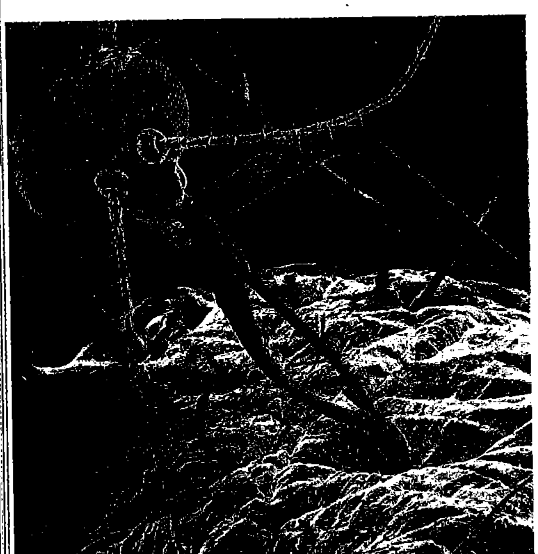


Figure 18–10 Plasmodium *causes the human disease malaria.*

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



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.

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 weblike 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.

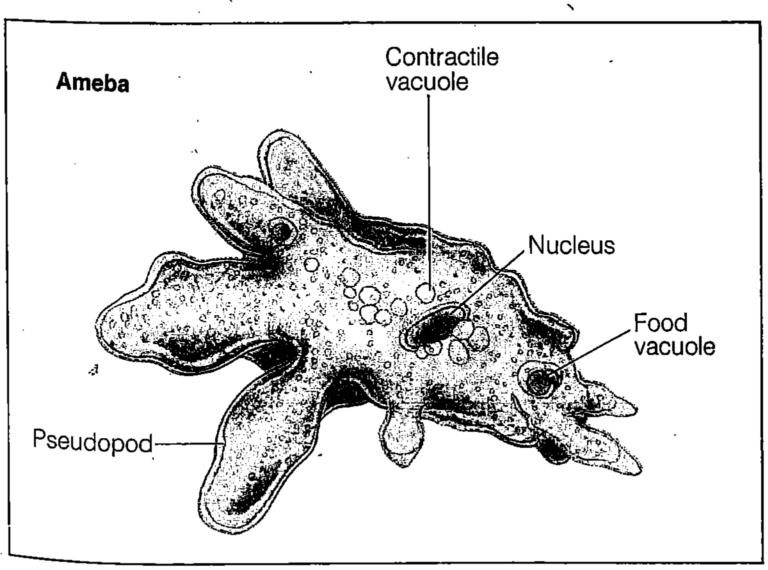


Figure 18–12 *Although a live ameba may at first appear to be a featureless blob (right), careful study reveals its internal structure is well-organized.*

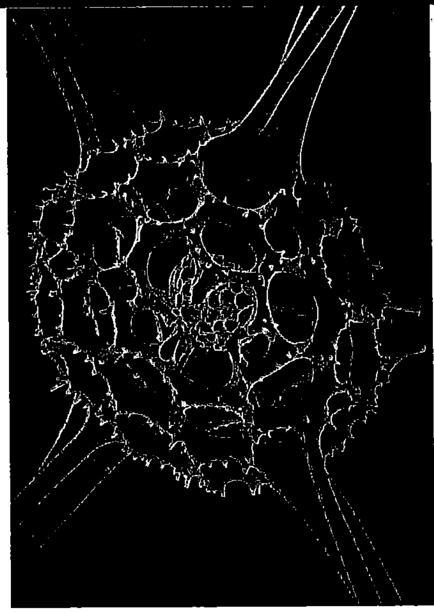


Figure 18–13 Radiolarians have delicate shells of silica.

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).