



Section 1

Introduction to Protists

MAIN <Idea> Protists form a diverse group of organisms that are subdivided based on their method of obtaining nutrition.

Section 2

Protozoans— Animal-like Protists

MAIN <Idea> Protozoans are animal-like, heterotrophic protists.

Section 3

Algae—Plantlike Protists

MAIN <Idea> Algae are plantlike, autotrophic protists that are the producers for aquatic ecosystems.

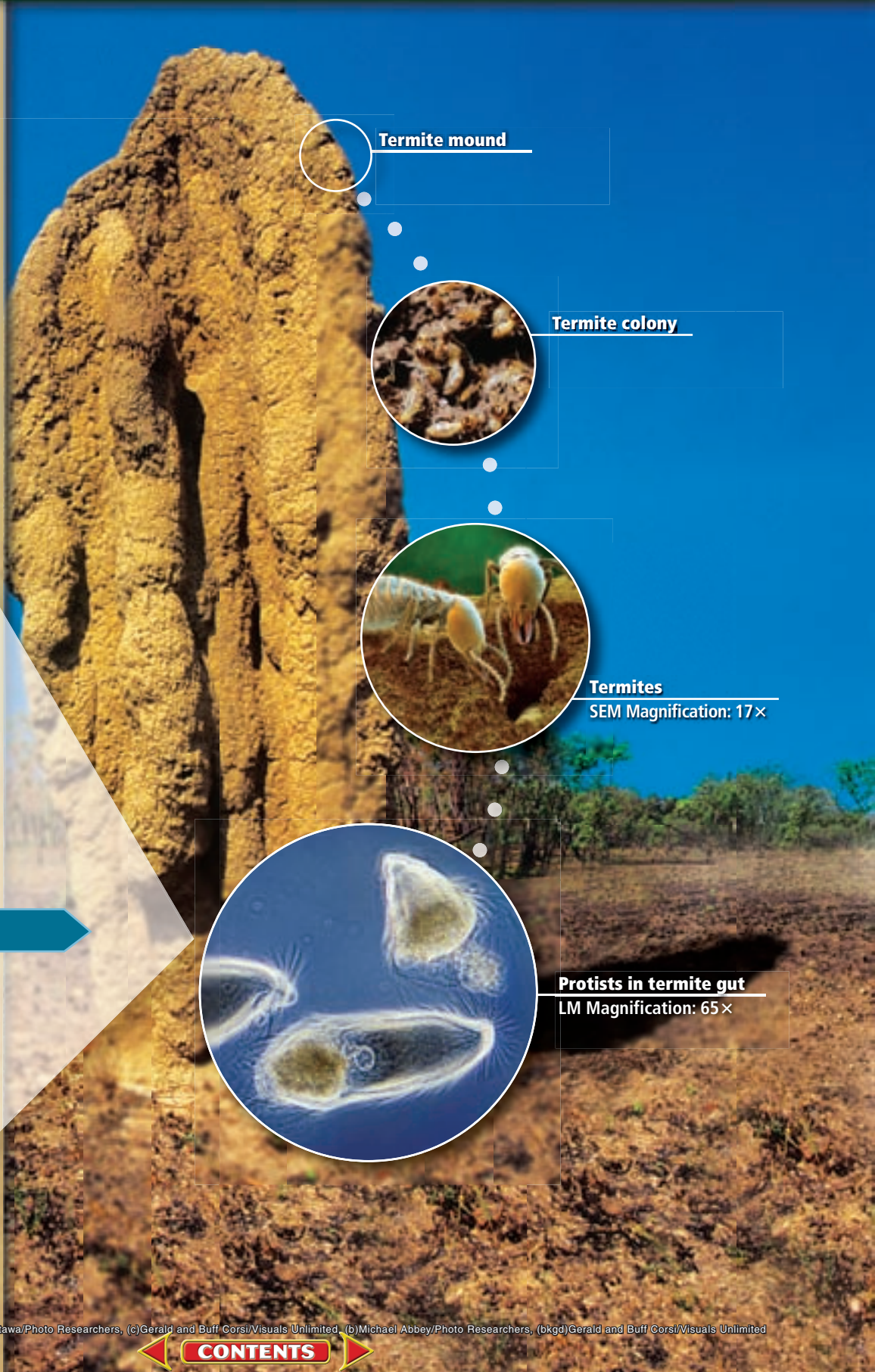
Section 4

Funguslike Protists

MAIN <Idea> Funguslike protists obtain their nutrition by absorbing nutrients from dead or decaying organisms.

BioFacts

- A protist that lives symbiotically in the gut of termites helps it digest cellulose found in wood.
- The amoeba *Amoeba proteus* is so small that it can survive in the film of water surrounding particles of soil.
- An estimated five million protists can live in one teaspoon of soil.



Termite mound



Termite colony



Termites
SEM Magnification: 17×



Protists in termite gut
LM Magnification: 65×

LAUNCH Lab

What is a protist?

The Kingdom Protista is similar to a drawer or closet in which you keep odds and ends that do not seem to fit any other place. The Kingdom Protista is composed of three groups of organisms that do not fit in any other kingdom. In this lab, you will observe the three groups of protists.

Procedure

1. Read and complete the lab safety form.
2. Construct a data table to record your observations.
3. Observe **different types of protists** with a **microscope**, noting their similarities and differences. Record your observations, notes, and illustrations in your data table.

Analysis

1. **Organize** the protists with similar characteristics into groups using the data that you collected.
2. **Infer** which of your groups are animal-like, plantlike, or funguslike.



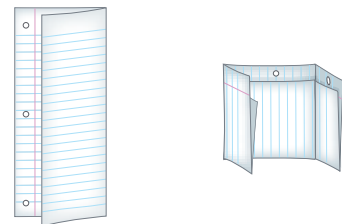
Visit biologygmh.com to:

- ▶ study the entire chapter online
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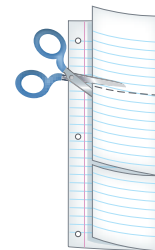
FOLDABLES™ Study Organizer

Classify Protists Make this Foldable to help you organize the characteristics of protists.

- ▶ **STEP 1** Fold a sheet of notebook paper in half vertically. Fold the sheet into thirds.



- ▶ **STEP 2** Cut along the creases of the top layer to form three tabs.



- ▶ **STEP 3** Label the edge with holes *Protists*. Label the top tab *Animal-like Protists*, the middle tab *Plantlike Protists*, and the bottom tab *Funguslike Protists*.



FOLDABLES Use this Foldable with **Section 19.1**. As you study the section, summarize the characteristics of each group under the appropriate tab.

Section 19.1

Objectives

- ▶ **Explain** how protists are classified.
- ▶ **Describe** how some protists with mitochondria might have evolved.
- ▶ **Describe** how some protists with chloroplasts might have evolved.
- ▶ **Explain** why the organization of Kingdom Protista might change.

Review Vocabulary

heterotroph: organism that cannot make its own food and must get its energy and nutrients from other organisms

New Vocabulary

protozoan
microsporidium

VOCABULARY

WORD ORIGIN

Protozoan

proto—prefix; from Greek; means *first*
-zoa from Greek, means *animals*.

Introduction to Protists

MAIN Idea Protists form a diverse group of organisms that are subdivided based on their method of obtaining nutrition.

Real-World Reading Link Hurricanes, such as Katrina in 2005, bring winds and water surges that leave destruction and devastation. Contaminated flood waters, damaged sewage systems, and crowded shelters provide breeding grounds for infectious bacteria, viruses, and microorganisms called protists.

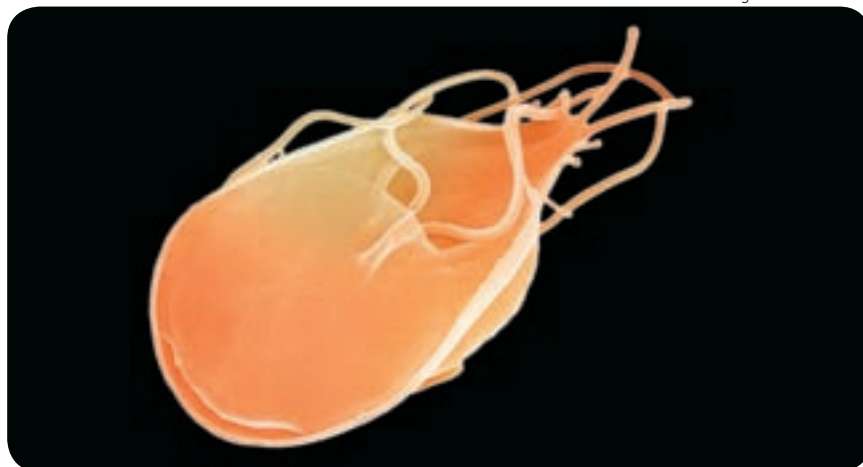
Protists

Protists are classified more easily by what they are not than by what they are. Protists are not animals, plants, or fungi because they do not have all of the characteristics necessary to place them in any of these kingdoms. The Kingdom Protista was created to include this diverse group of more than 200,000 organisms.

All protists share one important trait—they are eukaryotes. You learned in Chapter 7 that eukaryotic cells contain membrane-bound organelles. Like all eukaryotes, the DNA of protists is found within the membrane-bound nucleus. Although protists have a cellular structure similar to other eukaryotes, there are remarkable differences in their reproductive methods. Some reproduce asexually by mitosis while others exchange genetic material during meiosis.

Classifying protists Because they are such a diverse group of organisms, some scientists classify protists by their method of obtaining nutrition. Protists are divided into three groups using this method: animal-like protists, plantlike protists, and funguslike protists. The **protozoan** (proh tuh ZOH un) (plural, protozoa or protozoans), shown in **Figure 19.1**, is an example of an animal-like protist because it is a heterotroph—it ingests food. Additional examples of protists and a summary of characteristics are shown in **Table 19.1**.

Color-Enhanced SEM Magnification: 1000×



Giardia lamblia

■ **Figure 19.1** This animal-like protist is a parasite that might be found in the intestinal tract of a person who has consumed contaminated water.

Infer how this protist obtains its nutrients.



Animal-like protists The amoeba is an example of a unicellular, animal-like protist or protozoan. Protozoans are heterotrophs and usually ingest bacteria, algae, or other protozoans. The amoeba shown in **Table 19.1** is in the process of capturing and ingesting another unicellular protozoan—a paramecium.

Plantlike protists The giant kelp, shown in **Table 19.1**, is an example of a plantlike protist that makes its own food through photosynthesis. Plantlike protists commonly are referred to as algae (AL jee) (singular, alga). Some algae are microscopic. The unicellular algae *Micromonas* are about 10^{-6} m in diameter. Other forms of algae are multicellular and are quite large. The giant kelp, *Macrocystis pyrifera*, can grow up to 65 m long.

Funguslike protists The water mold in **Table 19.1** is an example of a funguslike protist that is absorbing nutrients from a dead salamander. Funguslike protists are similar to fungi because they absorb their nutrients from other organisms. These organisms are not classified as fungi because funguslike protists contain centrioles—small, cylindrical organelles that are involved in mitosis and usually are not found in the cells of fungi. Fungus and funguslike protists also differ in the composition of their cell walls.

 **Reading Check** Compare and contrast the three groups of protists.

VOCABULARY.....

WORD ORIGIN

Protist

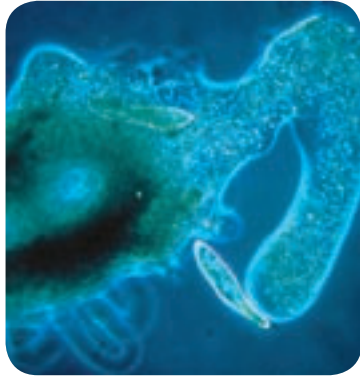


comes from the Greek word *protistos*, meaning *the very first*.....

FOLDABLES

Incorporate information from this section into your Foldable.



Interactive Table To explore more about protists, visit biologygmh.com.

Table 19.1		The Protists	
	Animal-like protists (Protozoans)	Plantlike protists (Algae)	Funguslike protists
Group	Ciliates, amoebas, apicomplexans, and zooflagellates	Euglenoids, diatoms, dinoflagellates, green algae, red algae, brown algae, yellow-green algae, and golden-brown algae	Slime molds, water molds, and downy mildews
Example	 Amoeba	 Giant kelp	 Water mold
Distinguishing Characteristics	<ul style="list-style-type: none"> • Considered animal-like because they consume other organisms for food • Some are parasites. 	<ul style="list-style-type: none"> • Considered plantlike because they make their own food through photosynthesis • Some consume other organisms or are parasites when light is unavailable for photosynthesis. 	<ul style="list-style-type: none"> • Considered funguslike because they feed on decaying organic matter and absorb nutrients through their cell walls • Some slime molds consume other organisms and a few slime molds are parasites.





■ **Figure 19.2** A protist, green algae, lives in the fur of this tree sloth, forming a symbiotic relationship.

Infer What type of symbiotic relationship do these organisms have?



Tree sloth

Green algae

(c)Michael & Patricia Fogden, M. I. Walker/Photo Researchers

LAUNCH Lab

Review Based on what you've read about protists, how would you now answer the analysis questions?

Habitats Protists typically are found in damp or aquatic environments such as decaying leaves, damp soil, ponds, streams, and oceans. Protists also live in symbiotic relationships. **Microsporidia** (MI kroh spo rih dee uh) are microscopic protozoans that cause disease in insects. Some species of microsporidia can be used as insecticides. New technology will allow these microsporidia to be used to control insects that destroy crops.

One beneficial protist lives in the hair of a sloth, shown in **Figure 19.2**. A sloth is a large, slow-moving mammal that lives in the uppermost branches of trees in tropical rain forests. The sloth spends most of its life hanging upside down. Green algae help the brown sloth blend into the leaves on the tree, providing camouflage for the sloth.

DATA ANALYSIS LAB 19.1

Based on Real Data*

Interpret Scientific Illustrations

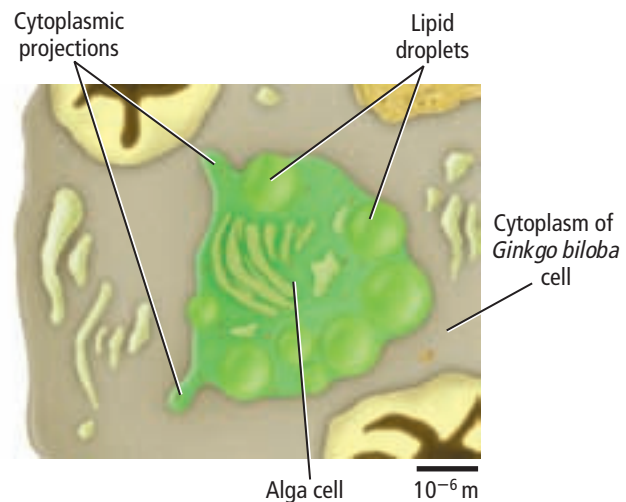
What is the relationship between green algae and *Ginkgo biloba* cells? In 2002, scientists in France reported the first confirmed symbiotic relationship between plantlike protists called green algae and a land plant's cells. The figure at the right represents an alga inside a cell from the *Ginkgo biloba* tree.

Think Critically

- Examine** the figure and estimate the size of the algal cell.
- Explain** why the term endophytic (en duh FIT ihk) is appropriate to describe these algae. The prefix *endo* means "within" and the suffix *-phyte* means "plant."

*Data obtained from: Tremoullaux-Guiller, et al. 2002. Discovery of an endophytic alga in *Ginkgo biloba*. *American Journal of Botany* 89(5): 727–733.

Data and Observations

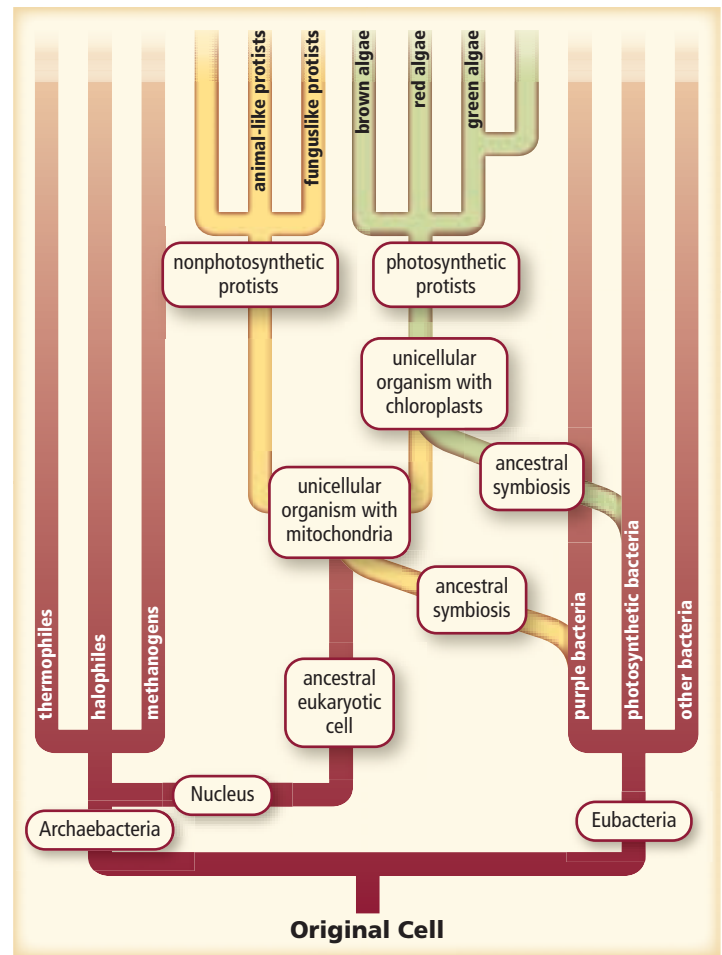


Origin of Protists

In Chapter 14, you read about the theory of endosymbiosis, which was proposed by Lynn Margulis. This theory suggests that eukaryotes, including protists, formed when a large prokaryote engulfed a smaller prokaryote. The two organisms lived symbiotically. Eventually, the organisms evolved into a single, more highly developed organism. Some scientists think that the mitochondria and chloroplasts found in some eukaryotes, including protists, were once individual organisms. Protists might have been the first eukaryotes to appear billions of years ago.

Grouping protists by how they obtain nutrition is a convenient method of classifying them. However, this method does not consider an organism's evolutionary history. Scientists are still trying to sort out the evolutionary relationships between protists and the other kingdoms. As scientists learn more information, the organization of Kingdom Protista most likely will change.

The diagram in **Figure 19.3** shows the current understanding of the evolutionary history of protists based on the theory of endosymbiosis. Notice in the diagram that all of the protists have a common ancestral eukaryotic cell. Examine the diagram and find where mitochondria entered into the evolutionary process. Mitochondria became part of protist cells early in the evolutionary process. Now, locate where chloroplasts entered cells. Follow the path of the arrow and you can see that algae are the only protists with chloroplasts and that undergo photosynthesis.



■ **Figure 19.3** This diagram shows how the theory of endosymbiosis explains the evolution of the protist kingdom.

Section 19.1 Assessment

Section Summary

- ▶ Protists include unicellular and multicellular eukaryotes.
- ▶ Protists are classified by their methods of obtaining food.
- ▶ The first protists might have formed through endosymbiosis.
- ▶ Protists might have been the first eukaryotic cells with chloroplasts and mitochondria, evolving billions of years ago.

Understand Main Ideas

1. **MAIN Idea** **Explain** why some scientists use nutrition to classify organisms in the Kingdom Protista.
2. **Sketch** a diagram that illustrates how the first protists might have formed from prokaryotes.
3. **Explain** why scientists have classified protists in one kingdom when they are such a diverse group.

Think Scientifically

4. **Apply Concepts** What if you discovered a new protist? What characteristics would help you decide the group in which it belongs?
5. **Compare and contrast** using nutrition methods and evolutionary relationships to classify protists.

Section 19.2

Objectives

- ▶ **Identify** the characteristics of protozoans.
- ▶ **Describe** the structures and organelles of protozoans.
- ▶ **Explain** the life cycles of protozoans.

Review Vocabulary

hypotonic: the concentration of dissolved substances is lower in the solution outside the cell than the concentration inside the cell

New Vocabulary

pellicle
trichocyst
contractile vacuole
pseudopod
test

Protozoans— Animal-like Protists

MAIN Idea Protozoans are animal-like, heterotrophic protists.

Real-World Reading Link Have you ever looked at pond water under a microscope? If you saw tiny organisms darting around, then you most likely have seen protozoans.

Ciliophora

One of the characteristics that biologists use to further classify protozoans into different phyla is their method of movement. Members of the phylum Ciliophora (sih lee AH fuh ruh), also known as ciliates (SIH lee ayts), are animal-like protists that have numerous short, hairlike projections. Recall from Chapter 7 that some single-celled organisms use cilia (singular, cilium) to propel themselves through water and to move food particles into the cell. Some ciliates have cilia covering their entire plasma membrane, while others have groups of cilia covering parts of their membrane, as shown in **Figure 19.4**. Note that the *Stentor*'s cilia are located on the anterior end; they help propel food into the cell. The ciliate *Trichodina pediculus* has two visible sets of cilia. The outer ring is used for movement and the inner ring is used for feeding.

There are more than 7000 species of ciliates. They are abundant in most aquatic environments—ocean waters, lakes, and rivers. They also are found in mud, and it is estimated that as many as 20 million ciliates can inhabit one square meter in some mud flats.

■ **Figure 19.4** *Stentor* and *Trichodina pediculus* are protozoans that have cilia.

LM Magnification: 125×



Stentor—use cilia for feeding

LM Magnification: 400×



Trichodina pediculus—use cilia for feeding and movement



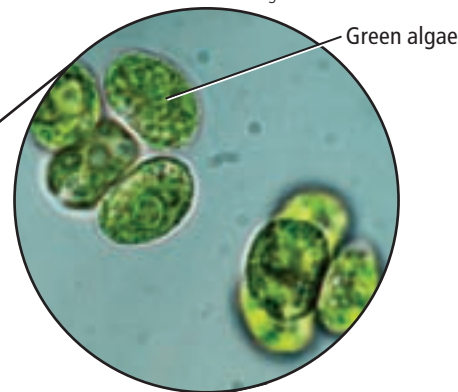
(i)Michael Abbey/Visuals Unlimited, (r) Sinclair Stammers/SPL/Photo Researchers

LM Magnification: 110×



Paramecium bursaria

LM Magnification: 2000×



■ **Figure 19.5** *Paramecium bursaria* provides a home for green algae that enter the paramecium during the feeding process, but the green algae are not digested.

Infer What type of symbiotic relationship does this represent?

Paramecia Some of the most commonly studied ciliates are found in the genus *Paramecium* (per uh MEE see um) (plural, paramecia). The paramecium in **Figure 19.5** lives symbiotically with green algae. The green algae undergoes photosynthesis, providing nutrients to the paramecium.

A paramecium is a unicellular protozoan. It is enclosed by a layer of membrane called a **pellicle**. Directly beneath the pellicle is a layer of cytoplasm called ectoplasm. Embedded in the ectoplasm are the **trichocysts** (TRIH kuh sihsts), which are elongated, cylindrical bodies that can discharge a spinelike structure. The function of trichocysts is not completely understood, but they might be used for defense, as a reaction to injury, as an anchoring device, or to capture prey.

Cilia Notice the cilia on the paramecium in **Figure 19.5**, which are used for movement and feeding. Cilia completely cover the organism—including the oral groove. Locate the oral groove on the paramecium in **Figure 19.6**. The cilia covering the wall of the oral groove are used to guide food, primarily bacteria, into the gullet. Once the food reaches the end of the gullet, it is enclosed in a food vacuole. Enzymes within the food vacuole break down the food into nutrients that can diffuse into the cytoplasm of the paramecium. Waste products from the paramecium are excreted through the anal pore.

Contractile vacuoles Because freshwater paramecia live in a hypotonic environment, water constantly enters the cell by osmosis. Recall from Chapter 7 that a hypotonic solution is one in which the concentration of dissolved substances is lower in the solution outside the cell than the concentration inside the cell. The **contractile vacuoles**, shown in **Figure 19.6**, collect the excess water from the cytoplasm and expel it from the cell. The expelled water might contain waste products, which is another way paramecia can excrete waste. Paramecia often have two or three contractile vacuoles that help to maintain homeostasis in the cell.

Reading Check Explain why the contractile vacuoles are necessary in hypotonic environments to maintain homeostasis.

CAREERS IN BIOLOGY

Microbiologist A microbiologist studies organisms that usually are seen only with a microscope. One area of study in which a microbiologist can specialize is the study of protists. For more information on biology careers, visit biologygms.com.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Expel

Science usage: to force out.

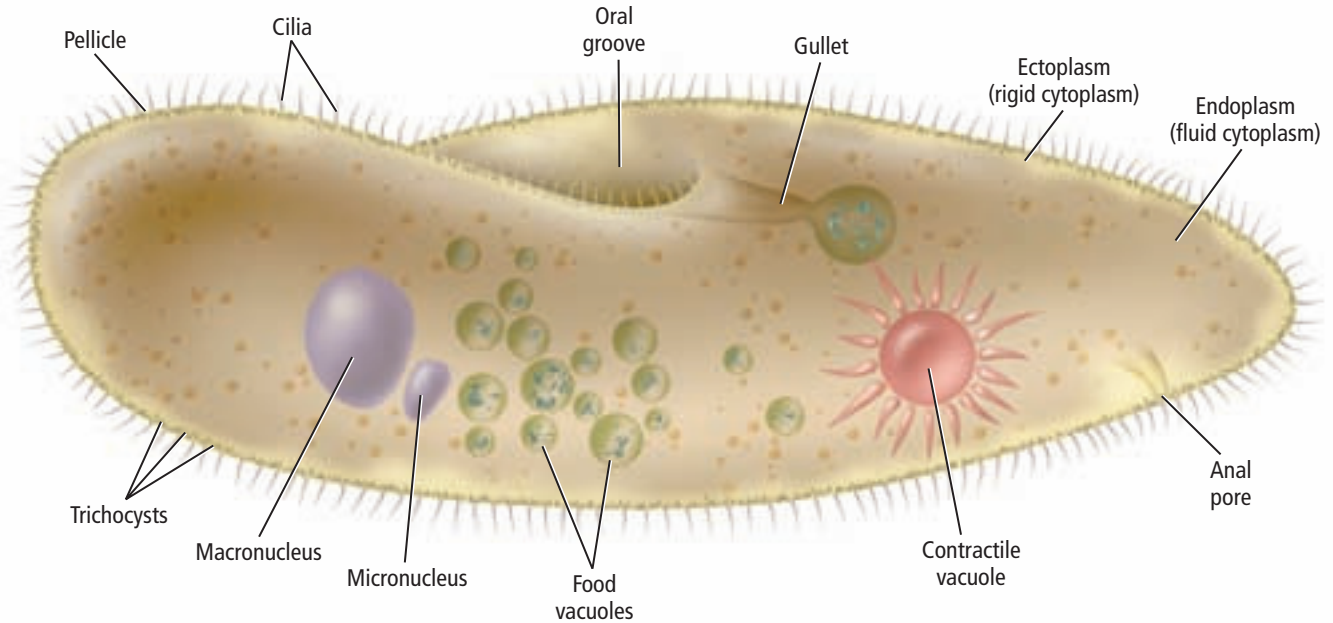
Contractile vacuoles expel water from cells.

Common usage: to force to leave.

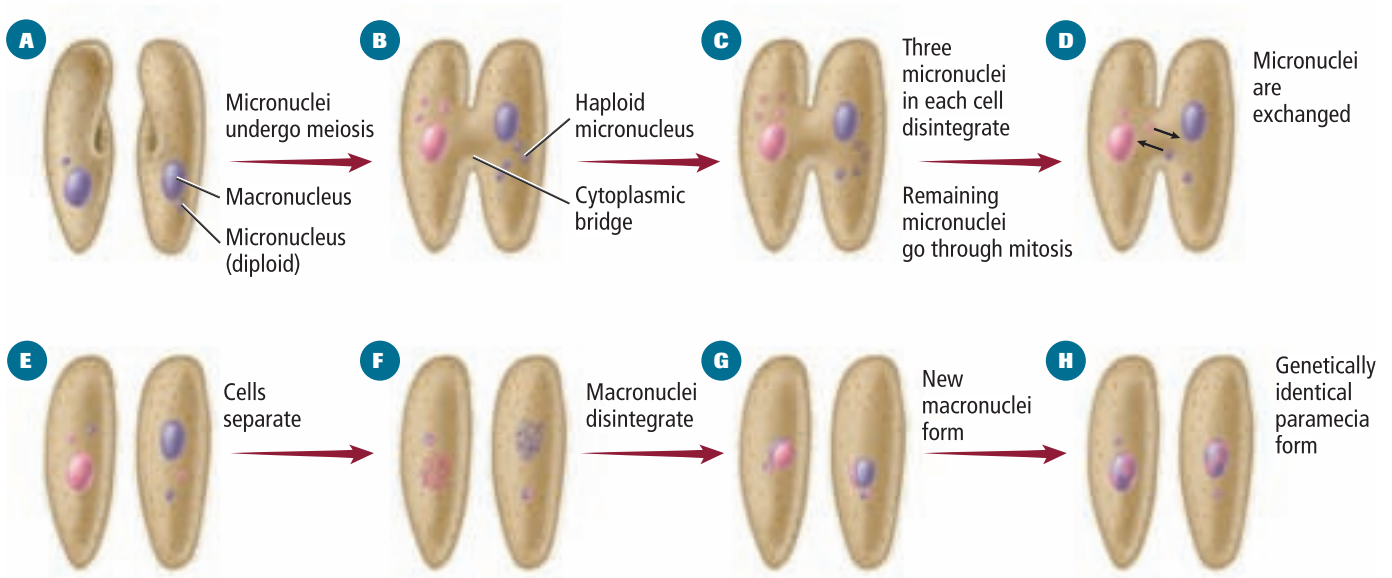
The principal will expel students for breaking school rules.

Figure 19.6

Paramecia are unicellular organisms with membrane-bound organelles. They undergo a process called conjugation in which a pair of paramecia will exchange genetic information as shown in the diagram at the bottom of the page. This is not considered sexual reproduction because new individuals are not formed.



Conjugation



Interactive Figure To see an animation of paramecia, visit biologygmh.com.



Reproduction in ciliates All known ciliates have two kinds of nuclei—the macronucleus and a smaller micronucleus. A cell might contain more than one of each of these nuclei. Both nuclei contain the genetic information for the cell. The macronuclei contain multiple copies of the cell’s genome, which controls the everyday functions of the cell such as feeding, waste elimination, and maintaining water balance within the cell. The micronucleus is used for reproduction.

Ciliates reproduce asexually by binary fission. During this process, the macronucleus elongates and splits rather than undergoing mitotic division. Most ciliates maintain genetic variation by undergoing conjugation—a sexual process in which genetic information is exchanged. Conjugation is considered a sexual process, but it is not considered sexual reproduction because new organisms are not formed.

The process of conjugation for *Paramecium caudatum* is typical of most ciliates and is illustrated in **Figure 19.6**. During conjugation, two paramecia form a cytoplasmic bridge and their diploid micronuclei undergo meiosis. After three of the newly formed haploid micronuclei dissolve, the remaining micronucleus undergoes mitosis. One micronucleus from each connected cell is exchanged, and the two paramecia separate. The macronucleus disintegrates in each paramecium, and the micronuclei combine and form a new, diploid macronucleus. Each cell now contains a macronucleus, micronuclei, and a new combination of genetic information.

Reading Check Explain the purpose of the cytoplasmic bridge, shown in **Figure 19.6**, during conjugation.

VOCABULARY

SCIENCE USAGE V. COMMON USAGE

Conjugation

Science usage: asexual reproduction in which there is an exchange of genetic information.

Paramecia reproduce in a process called conjugation.

Common usage: in grammar an arrangement of the correct form of a verb.

Victoria is practicing the conjugation of Spanish verbs.

DATA ANALYSIS LAB 19.2

Based on Real Data*

Recognize Cause and Effect

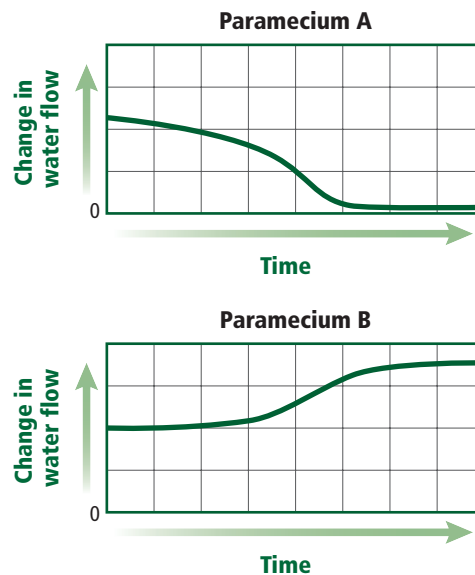
How does solution concentration affect the contractile vacuole? The contractile vacuole moves water from inside a paramecium back into its freshwater environment. Researchers have studied the effects of solution concentrations on paramecia.

Data and Observations

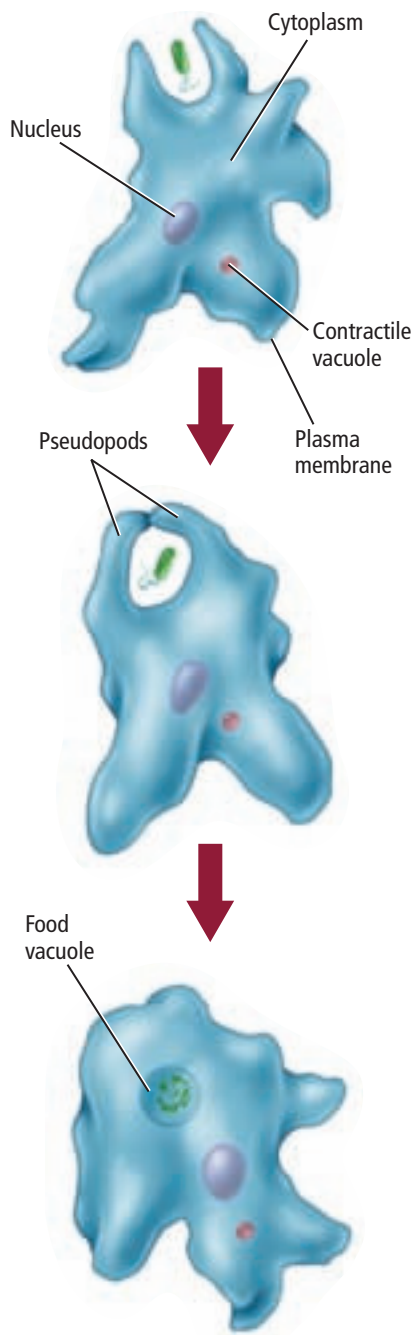
Paramecia were allowed to adapt to various solutions for 12 h. Then, they were placed into hypertonic and hypotonic solutions. The graphs show the change in rate of water flow out of the contractile vacuole over time.

Think Critically

- Analyze** What do the downward and upward slopes in the graphs indicate about the contractile vacuole?
- Infer** which paramecium was placed into a hypertonic solution. Explain.



*Data obtained from: Stock, et al. 2001. How external osmolarity affects the activity of the contractile vacuole complex, the cytosolic osmolarity and the water permeability of the plasma membrane in *Paramecium Multicronudeatum*. *The Journal of Experimental Biology* 204: 291–304.



■ **Figure 19.7** Chemical stimuli from smaller organisms can cause the amoeba to form pseudopods from their plasma membrane.

■ **Figure 19.8** Radiolarians have tests made of silica. Foraminiferans and radiolarians extend their pseudopods through openings in their tests.

Sarcodina

Members of the phylum Sarcodina (sar kuh DI nuh), also called sarcodines (SAR kuh dinez), are animal-like protists that use pseudopods for feeding and locomotion. A **pseudopod** (SEW duh pahd) is a temporary extension of cytoplasm and is shown in **Figure 19.7**. These extensions surround and envelop a smaller organism, forming a food vacuole. Digestive enzymes are secreted and break down the captured organism.

Some of the most commonly studied sarcodines are found in the genus *Amoeba*. Most amoebas are found in saltwater, although some freshwater species live in streams, in the muddy bottoms of ponds, and in damp patches of moss and leaves. Some amoebas are parasites that live inside an animal host.

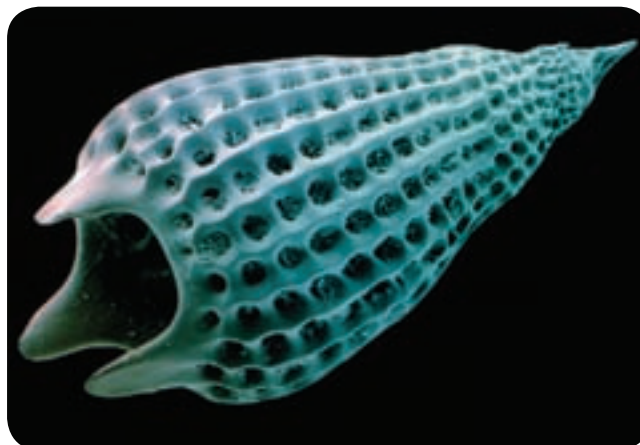
Amoeba structure The structure of an amoeba is simple, as shown in **Figure 19.7**. Amoebas are enveloped in an outer cell membrane and an inner thickened cytoplasm called ectoplasm. Inside the ectoplasm, the cytoplasm contains a nucleus, food vacuoles, and occasionally a contractile vacuole. Notice that an amoeba does not have an anal pore like the paramecium. Waste products and undigested food particles are excreted by diffusion through the outer membrane into the surrounding water. The oxygen needed for cellular processes also diffuses into the cell from the surrounding water.

Foraminiferans (fuh rah muh NIH fur unz) and radiolarians (ray dee oh LER ee unz) are types of amoebas that have tests. A **test** is a hard, porous covering similar to a shell, which surrounds the cell membrane. Most of these amoebas live in marine environments, although there are some freshwater species.

Connection to Earth Science Foraminiferans have tests made of calcium carbonate (CaCO_3), grains of sand, and other particles cemented together. Geologists use the fossilized remains of foraminiferans to determine the age of some rocks and sediments, and to identify possible sites for oil drilling. Radiolarians, another amoeba with tests shown in **Figure 19.8**, have tests made mostly of silica (SiO_2).

Amoeba reproduction Amoebas reproduce by asexual reproduction during which a parent cell divides into two identical offspring. During harsh environmental conditions, some amoebas become cysts that help them survive until environmental conditions improve and survival is more likely.

SEM Magnification: 190×



Andrew Syred/Photo Researchers

Apicomplexa

Animal-like protists that belong to the phylum Apicomplexa (ay puh KOM pleks uh) also are known as sporozoans (spo ruh ZOH unz). They are called sporozoans because they produce spores at some point in their life cycle. Spores are reproductive cells that form without fertilization and produce a new organism. Sporozoans lack contractile vacuoles and methods for locomotion. As in amoebas, respiration and excretion occur by diffusion through the plasma membrane.

All sporozoans are parasitic. Recall from Chapter 2 that parasites get their nutritional requirements from a host organism. Sporozoans infect vertebrates and invertebrates by living as internal parasites. Organelles at one end of the organism are specialized for penetrating host cells and tissues, allowing them to get their nutrients from their host.

The life cycle of sporozoans has both sexual and asexual stages. Often two or more hosts are required for an organism to complete a life cycle. The life cycle of *Plasmodium* is shown in **Figure 19.9**.

Sporozoans cause a variety of illnesses in humans, some of which are fatal. The sporozoans responsible for the greatest number of human deaths are found in the genus *Plasmodium*. These parasites cause malaria in humans and are transmitted to humans by female *Anopheles* mosquitoes. Malaria causes fever, chills, and other flu-like symptoms. Its greatest impact is in tropical and subtropical regions where factors such as high temperature, humidity, and rainfall favor the growth of mosquitoes and sporozoans, and preventative measures are too costly.

VOCABULARY

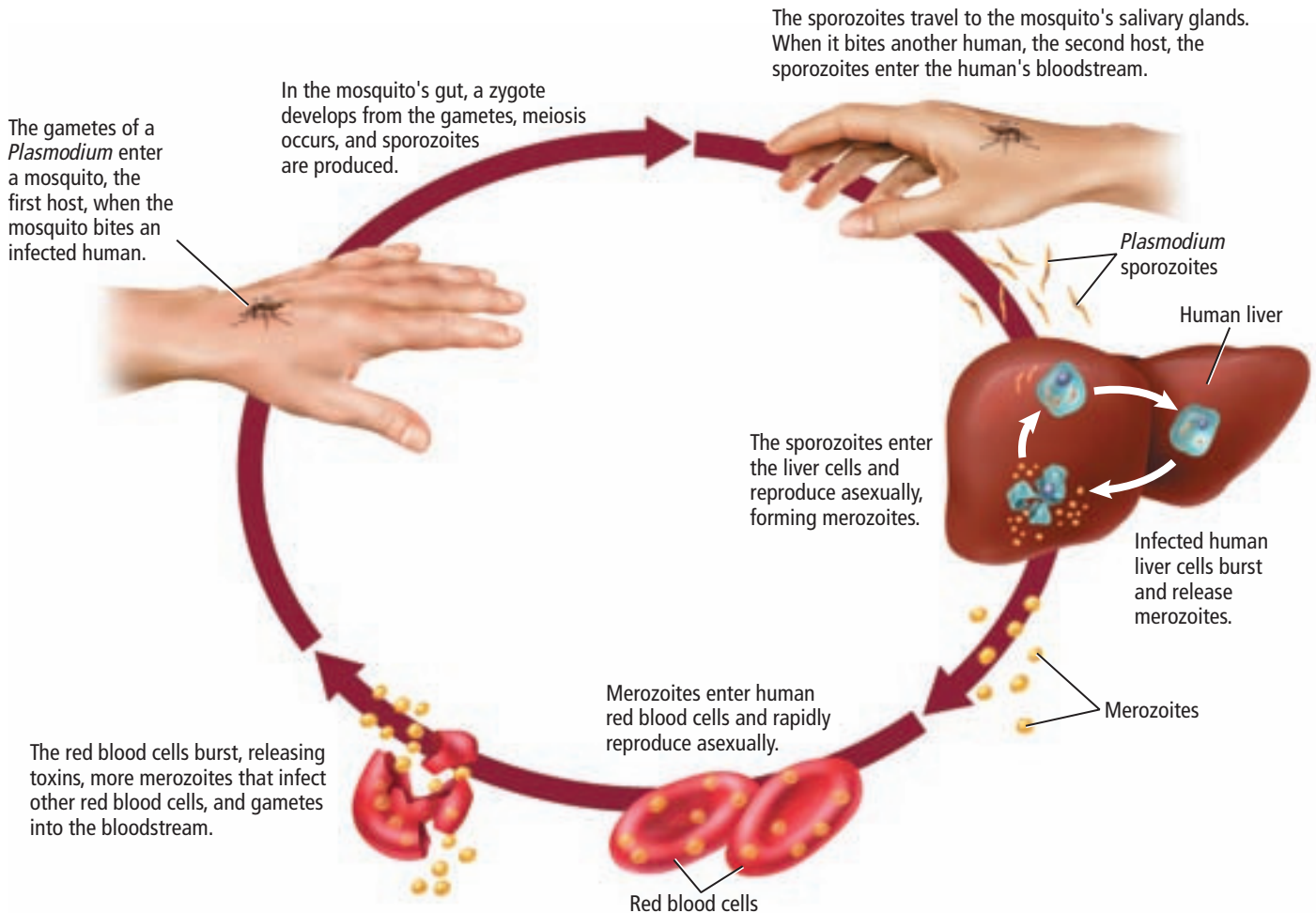
WORD ORIGIN

Apicomplexa

apicalis from Latin; meaning uppermost point or tip

complexus from Latin; meaning comprised of multiple objects

■ **Figure 19.9** Malaria is caused by a sporozoan transmitted by a mosquito.
Identify What are the two hosts that are required for this sporozoan to be successful?





Reduviid bug



Tsetse fly

■ **Figure 19.10** The insects that carry protozoans from person to person are controlled by insecticides.

Zoomastigina

Protozoans in the phylum Zoomastigina (zoh oh mast tuh JI nuh) are called zooflagellates. Zooflagellates (zoh oh FLA juh layts) are animal-like protozoans that use flagella for movement. Recall from Chapter 7 that flagella are long whiplike projections that protrude from the cell and are used for movement. Some zooflagellates are free living, but many are parasites inside other organisms.

At least three species of zooflagellates from the genus *Trypanosoma* (TRY pan uh zohm uh) cause infectious diseases in humans that often are fatal because of limited treatment options. One species found in Central and South America causes Chagas disease, sometimes called American sleeping sickness. The second species causes East African sleeping sickness. The third species causes West African sleeping sickness.

American sleeping sickness The zooflagellates that cause Chagas' disease are similar to the sporozoans that cause malaria because they have two hosts in their life cycle and insects spread the diseases through the human population. The reduviid bug (rih DEW vee id) bug, shown in **Figure 19.10**, serves as one host for the protist in Central and South America. The parasitic zooflagellates reproduce in the gut of this insect. The reduviid bug gets its nutrients by sucking blood from a human host. During the feeding process, the zooflagellates pass out of the reduviid body through its feces. The zooflagellates enter the human body through the wound site or mucus membranes. Once the zooflagellate enters the body, it multiplies in the bloodstream and can damage the heart, liver, and spleen.

African sleeping sickness The life cycles of the zooflagellates that cause both African sleeping sicknesses are similar to the one that causes American sleeping sickness. The insect host is the tsetse (SEET see) fly, shown in **Figure 19.10**. The blood-sucking tsetse fly becomes infected when it feeds on an infected human or other mammal. The zooflagellate reproduces in the gut of the fly and then migrates to its salivary glands. When the fly bites the human, the zooflagellate is transferred to the human host. The zooflagellates reproduce in the human host and cause fever, inflammation of the lymph nodes, and damage to the nervous system.

(t) Charles Melton/Visuals Unlimited, (b) Anthony Bamister/Getty Images

Section 19.2 Assessment

Section Summary

- ▶ Protozoans are single-celled protists that feed on other organisms to obtain nutrients.
- ▶ Protozoans live in a variety of aquatic environments.
- ▶ Protozoans reproduce in a variety of ways, including sexually and asexually.
- ▶ Protozoans have specialized methods for movement, feeding, and maintaining homeostasis.

Understand Main Ideas

1. **MAIN Idea** Compare the methods of feeding, locomotion, and reproduction of three groups of protozoa.
2. **Explain** the function of three organelles found in protozoans.
3. **Diagram** and explain the life cycle of a member of the genus *Plasmodium*.
4. **Explain** why paramecium conjugation is not considered reproduction.

Think Scientifically

5. **WRITING in Biology** Create an informational brochure about zooflagellates for people living in South America.
6. **MATH in Biology** There are approximately 50,000 species of protozoa, of which about 7000 are ciliates. What percentage of protozoans are ciliates?

Section 19.3

Objectives

- **Describe** the characteristics of several phyla of algae.
- **Identify** secondary photosynthetic pigments that are characteristic of some algae.
- **Explain** how diatoms differ from most other types of algae.

Review Vocabulary

chloroplasts: chlorophyll-containing organelles found in the cells of green plants and some protists that capture light energy and convert it to chemical energy

New Vocabulary

bioluminescent
colony
alternation of generations

Algae—Plantlike Protists

MAIN Idea Algae are plantlike, autotrophic protists that are the producers for aquatic ecosystems.

Real-World Reading Link Have you ever looked at a group of people and wondered what they had in common? You might discover that they all like the same type of music or they like the same type of sports. Most plantlike protists have something in common—they make their own food.

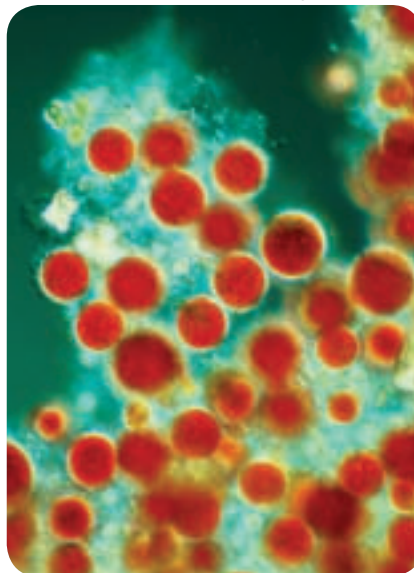
Characteristics of Algae

The group of protists called algae (singular, alga) is considered plantlike because the members contain photosynthetic pigments. Recall from Chapter 8 that photosynthetic pigments enable organisms to produce their own food using energy from the Sun in a process called photosynthesis. Algae differ from plants because they do not have roots, leaves, or other structures typical of plants.

The light-absorbing pigments of algae are found in chloroplasts. In many algae, the primary pigment is chlorophyll—the same pigment that gives plants their characteristic green color. Many algae also have secondary pigments that allow them to absorb light energy in deep water. As water depth increases, much of the sunlight's energy is absorbed by the water. These secondary pigments allow algae to absorb light energy from wavelengths that are not absorbed by water. Because these secondary pigments reflect light at different wavelengths, algae are found in a variety of colors, as shown in **Figure 19.11**.

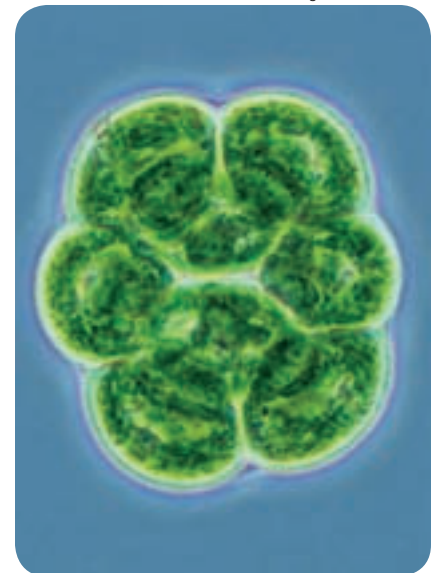
Reading Check Explain the function of chloroplasts and photosynthetic pigments in algae.

LM Magnification: 160×



Red algae

LM Magnification: 250×

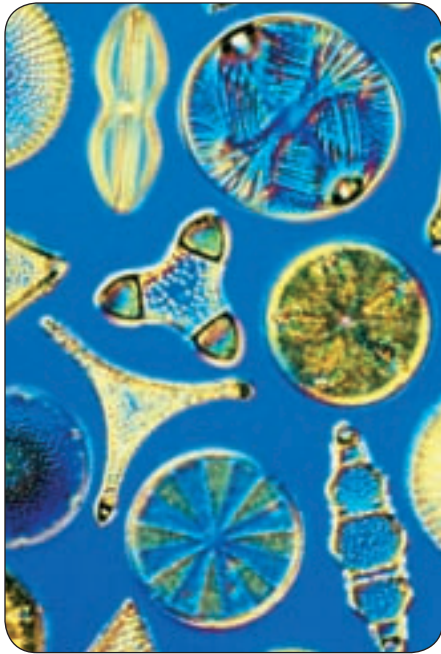


Green algae

■ **Figure 19.11** Algae vary in color because they contain different light-absorbing pigments.



LM Magnification: 30×



■ **Figure 19.12** The various species of diatoms have different shapes and sizes.

CAREERS IN BIOLOGY

Algologist A biologist who specializes in the study of algae is an algologist. Algologists might work at fish hatcheries or conduct marine research. For more information on biology careers, visit biologygmh.com.

Diversity of Algae

Algae have more differences than their color. For example, many algae exist as single cells, whereas others are huge multicellular organisms reaching 65 m in length. Some unicellular algae are referred to as phytoplankton—meaning “plant plankton.” Phytoplankton is vital in aquatic ecosystems because it provides the base of the food web in these environments. As a by-product of photosynthesis, they also produce much of the oxygen found in Earth’s atmosphere.

The great diversity of algae makes them a challenge to classify. Algologists usually use three criteria to classify algae: the type of chlorophyll and secondary pigments, the method of food storage, and the composition of the cell wall.

Diatoms The unicellular algae, shown in **Figure 19.12**, are members of the phylum Bacillariophyta (BAH sih LAYR ee oh FI tuh). These intricately shaped organisms are called diatoms. Look at **Figure 19.13** and notice that the diatom consists of two unequal halves—one fits neatly inside the other, forming a small box with a lid.

Connection to Physics

Diatoms are photosynthetic autotrophs. They produce food by photosynthesis using chlorophyll and secondary pigments called carotenoids, which give diatoms their golden-yellow color. Diatoms store their food as oil instead of as a carbohydrate. The oil not only makes diatoms a nutritious food source for many marine animals, but it also provides buoyancy. Oil is less dense than water, so diatoms float closer to the surface of the water, where they can absorb energy from the Sun for photosynthesis.

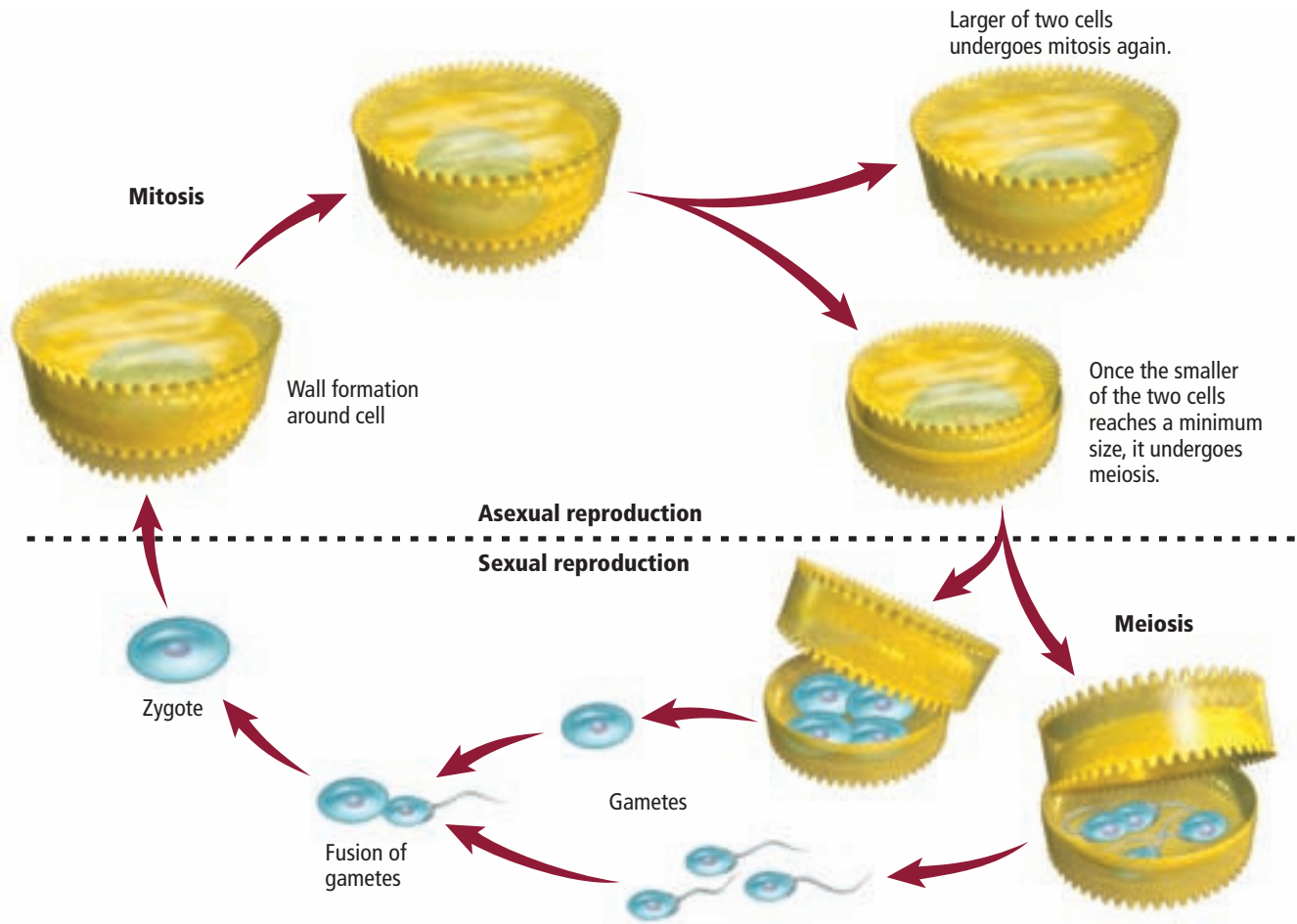
Diatoms reproduce both sexually and asexually, as illustrated in **Figure 19.14**. Asexual reproduction occurs when the two separated halves each create a new half that can fit inside the old one. This process produces increasingly smaller diatoms. When a diatom is about one-quarter of the original size, sexual reproduction is triggered and gametes are produced. The gametes fuse to form a zygote that develops into a full-sized diatom. The reproduction cycle then repeats.

The hard silica walls of the diatom last long after the diatom has died. The silica walls accumulate on the ocean floor to form sediment known as diatomaceous earth. This sediment is collected and used as an abrasive and a filtering agent. The gritty texture of many tooth polishes and metal polishes is due to the presence of diatom shells.



Color-Enhanced SEM Magnification: 13000×

■ **Figure 19.13** Diatoms are found in both marine and freshwater environments. A unique feature of the diatom is its cell wall made of silica.



■ **Figure 19.14** Diatoms reproduce asexually for several generations before undergoing sexual reproduction.

Dinoflagellates Plantlike protists that are members of the phylum Pyrrophyta (puh RAH fuh tuh) are called dinoflagellates (di nuh FLA juh layts). Most members of the phylum are unicellular and have two flagella at right angles to one another. As these flagella beat, a spinning motion is created, so dinoflagellates spin as they move through the water. Some members in this group have cell walls made of thick cellulose plates that resemble helmets or suits of armor. Other members of this group are **bioluminescent**, which means they emit light. Although there are a few freshwater dinoflagellates, most are found in saltwater. Like diatoms, photosynthetic dinoflagellates are a major component of phytoplankton.

Dinoflagellates vary in how they get their nutritional requirements. Some dinoflagellates are photosynthetic autotrophs, and other species are heterotrophs. The heterotrophic dinoflagellates can be carnivorous, parasitic, or mutualistic. Mutualistic dinoflagellates have relationships with organisms such as jellyfishes, mollusks, and coral.

Algal blooms When food is plentiful and environmental conditions are favorable, dinoflagellates reproduce in great numbers. These population explosions are called blooms. Algal blooms can be harmful when they deplete the nutrients in the water. When the food supply diminishes, the dinoflagellates die in large numbers. As the dead algae decompose, the oxygen supply in the water is depleted, suffocating fish and other marine organisms. Additional fish suffocate when their gills become clogged with the dinoflagellates.

VOCABULARY

WORD ORIGIN

Pyrrophyta

pyro- prefix; from Greek; meaning *fire*
-phyton from Greek word *phyton*, meaning *plant*.



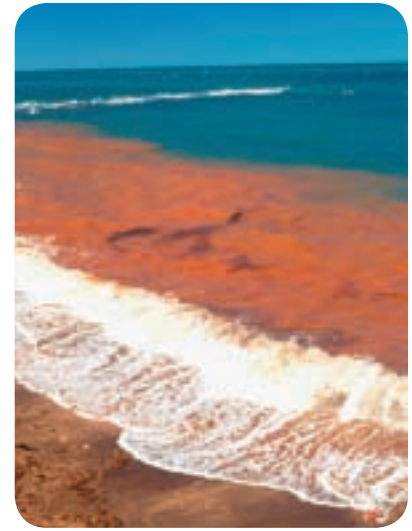


■ **Figure 19.15** The microscopic organism *Gonyaulax catanella* is one species of dinoflagellates that causes red tides. During red tides, many marine organisms die and shellfish can be too toxic for humans to eat.

Color-Enhanced SEM Magnification: 12000×



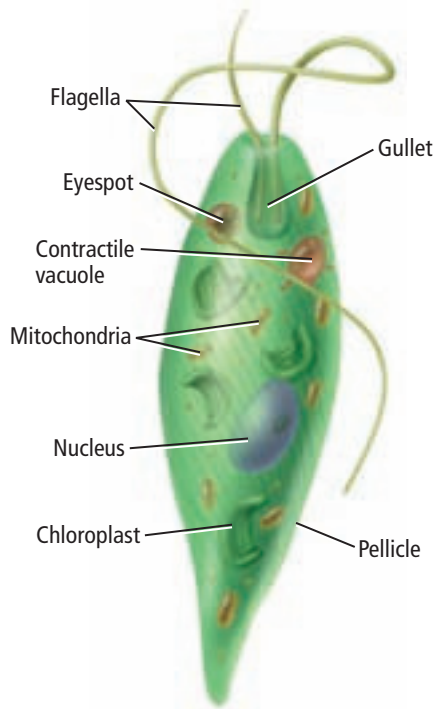
Gonyaulax catanella



Red tide

(l)Dr. David M. Phillips/Visuals Unlimited, (r)Bill Bachman/Photo Researchers

■ **Figure 19.16** *Euglena gracilis* are unicellular, plantlike algae that have characteristics of both plants and animals.



Red tides Some dinoflagellates have red photosynthetic pigments, and when they bloom, the ocean is tinged red, as shown in **Figure 19.15**. These blooms are called red tides. Red tides can be a serious threat to humans because some species of dinoflagellates produce a potentially lethal nerve toxin. The toxins affect people primarily when people eat shellfish. Shellfish that feed by filtering particles ingest the toxic dinoflagellates from the water. The toxins become concentrated in tissues of the shellfish. People and other organisms can become seriously ill or die from consuming these toxic shellfish.

Red tides must be closely monitored. One method scientists use to track red tides is reviewing satellite images. However, floating robots are being developed that can constantly measure the concentration of red tide algae. If the concentration becomes too high, scientists can issue a warning to stop shellfish harvesting.

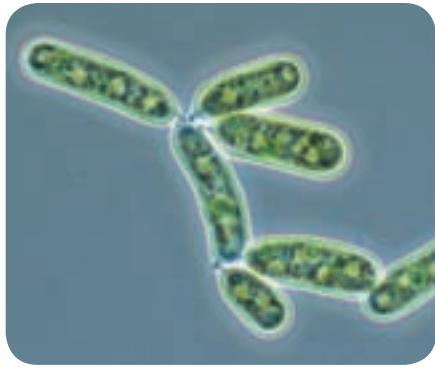
Euglenoids Members of the phylum Euglenophyta are unicellular, plantlike protists called euglenoids (yoo GLEE noydz). Most euglenoids are found in shallow freshwater, although some live in saltwater. Euglenoids are challenging to classify because they have characteristics of both plants and animals. Most euglenoids contain chloroplasts and photosynthesize, which is characteristic of plants, yet they lack a cell wall. Euglenoids also can be heterotrophs. When light is not available for photosynthesis, some can absorb dissolved nutrients from their environment. Others can ingest other organisms such as smaller euglenoids, which is a characteristic of animals. There even are a few species of euglenoids that are animal parasites.

The structure of a typical euglenoid is shown in **Figure 19.16**. Notice that instead of a cell wall, a flexible, tough outer membrane, called a pellicle, surrounds the cell membrane, which is similar to a paramecium. The pellicle allows euglenoids to crawl through mud when the water level is too low to swim. Note the flagella that are used to propel the euglenoid toward food or light. The eyespot is a light-sensitive receptor that helps orient the euglenoid toward light for photosynthesis. The contractile vacuole serves the same purpose in the euglenoid as it does in paramecia. It expels excess water from the cell to maintain homeostasis inside the cell.



(c)Michael Abbey/Visuals Unlimited, (r)Wim Van Egmond/Visuals Unlimited

LM Magnification: 250×




Yellow-green algae

LM Magnification: 40×



Golden-brown algae

Chrysophytes Yellow-green algae and golden-brown algae are in the phylum Chrysophyta (KRIS oh fyt uh) and are called chrysophytes (KRIS oh fytz). Like diatoms, these algae have yellow and brown carotenoids that give them their golden brown color. The algae in **Figure 19.17** are two examples of organisms from this phylum. Most members of this phylum are unicellular, but some species form colonies. A **colony** is a group of cells that join together to form a close association. The cells of chrysophytes usually contain two flagella attached at one end of the cell. All chrysophytes are photosynthetic, but some species also can absorb dissolved organic compounds through their cell walls or ingest food particles and prokaryotes. They reproduce both asexually and sexually, although sexual reproduction is rare. Chrysophytes are components of both freshwater and marine plankton.

 **Reading Check** Identify the substance that gives chrysophytes their golden-brown color.

Brown algae Brown algae are members of the phylum Phaeophyta (FAY oh FI tuh) and are some of the largest multicellular plantlike algae. These algae get their brown color from a secondary carotenoid pigment called fucoxanthin (fyew ko ZAN thun). Most of the 1500 species of brown algae live along rocky coasts in cool areas of the world. Look back at **Table 19.1** to see kelp, an example of a brown alga. The body of a kelp is called the thallus, as shown in **Figure 19.18**. The blades are the flattened portions, the stipe is the stalklike part, the holdfast is the rootlike structure, and the bladder is the bulging portion of the alga. The bladder is filled with air and keeps the alga floating near the surface of the water where light is available for photosynthesis.

Green algae The diverse group of algae from the phylum Chlorophyta (kloh RAH fy tuh) contains more than 7000 species. Green algae have several characteristics in common with plants. Green algae and plants both contain chlorophyll as a primary photosynthetic pigment, which gives both groups a green color. Both green algae and plant cells have cell walls, and both groups store their food as carbohydrates. These shared characteristics lead some scientists to think there is an evolutionary link between these two kingdoms. You will learn more about the plant kingdom in Chapter 21.

Most species of green algae are found in freshwater, but about ten percent are marine species. Green algae also are found on damp ground, tree trunks, and in snow. Green algae even are found in the fur of some animals, such as the sloth shown in **Figure 19.2**.

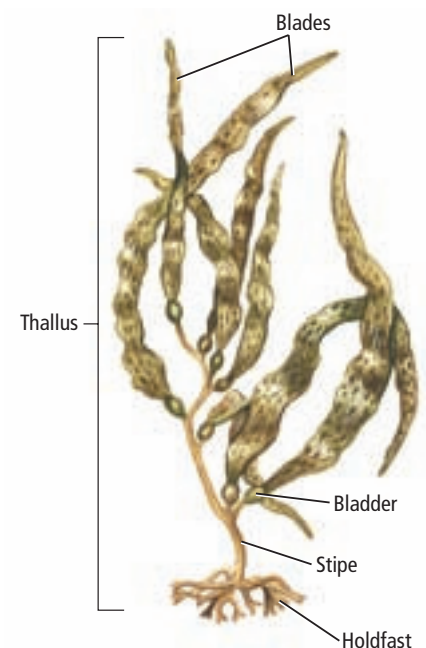
■ **Figure 19.17** Chrysophytes, like yellow-green and golden-brown algae, have carotenoids—secondary pigments used in photosynthesis.

Study Tip

Shared Reading Have a partner read two paragraphs aloud. Then, you summarize the key ideas in the paragraphs. Then, you read aloud and have your partner summarize the key ideas in your paragraphs.

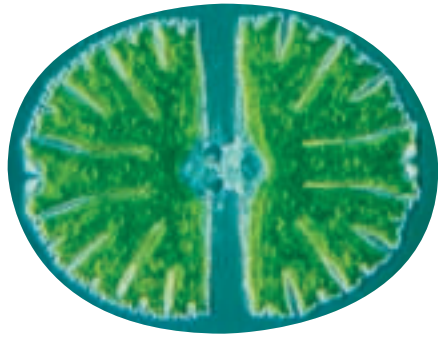
■ **Figure 19.18** Underwater kelp forests provide a habitat for many marine organisms, as well as provide algin—an additive used in many products.

Explain What is the function of the bladder in kelp?





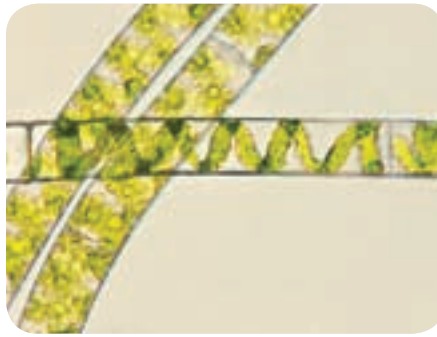
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Desmids

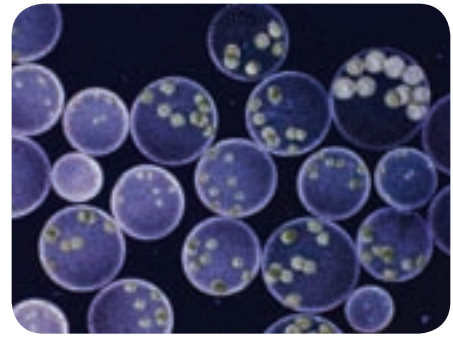
■ **Figure 19.19** *Desmids* are unicellular green algae that have elaborate cell walls. The green alga *Spirogyra* is named for its spiraling chloroplasts. Many cells that make up the *Volvox* colony have daughter colonies within the larger colony.

LM Magnification: 300×



Spirogyra

LM Magnification: 15×



Volvox

There are a variety of growth patterns exhibited by green algae. The unicellular algae *Desmids*, shown in **Figure 19.19**, are characterized by their symmetrically divided cells. Notice how the cells have two identical sides that are connected by a bridge. Another growth pattern is found in *Spirogyra*, shown in **Figure 19.19**. *Spirogyra* is a multicellular green algae characterized by its long, thin filaments. The name *Spirogyra* comes from the spiral pattern of the chloroplasts. *Volvox*, shown in **Figure 19.19**, is an example of an alga that has a colonial growth pattern.

The single cells of the *Volvox* colony are held together by a gelatinlike secretion called cytoplasmic strands. Each cell has flagella that beat in unison to move the colony. *Volvox* colonies might include hundreds or even thousands of cells that form a hollow ball. Smaller colonies, called daughter colonies, form balls inside the larger colony. When the daughter cells have matured, they digest the parental cell and become free-swimming.



Reading Check Identify the growth patterns for the algae above.

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MiniLab 19.1

Investigate Photosynthesis in Algae

How much sunlight does green algae need to undergo photosynthesis? Algae contain photosynthetic pigments that allow them to produce food by using energy from the Sun. Observe green algae to determine whether the amount of light affects photosynthesis.

Procedure: 

1. Read and complete the lab safety form.
2. Obtain samples of **green algae** from your teacher. Place the sample of each type of algae in different locations in the classroom. Be sure one location is completely dark.
3. Hypothesize what will happen to the algae in each location.
4. Check each specimen every other day for a week. Record your observations.

Analysis

1. **Describe** the evidence you used to determine whether photosynthesis was occurring.
2. **Conclude** Was your hypothesis supported? Explain.
3. **Identify** What organelles would you expect to see if you looked at each type of algae under a microscope?



Coralline

Red Algae Most red algae in phylum Rhodophyta (roh dah FI duh) are multicellular. Look at **Figure 19.20** to see how red algae got their name. These organisms contain red photosynthetic pigments called phycobilins that give them a red color. These pigments enable the red algae to absorb green, violet, and blue light that can penetrate water to a depth of 100 m or more. This allows red algae to live and photosynthesize in deeper water than other algae.

Some red algae also contribute to the formation of coral reefs. The cell walls of the red algae *Coralline* contain calcium carbonate. The calcium carbonate binds together the bodies of other organisms called stony coral to form coral reefs. You will learn more about the formation of coral reefs in Chapter 27.

Uses for Algae

Algae are used as a source of food for animals and people worldwide. In coastal areas of North America and Europe, algae are fed to farm animals as a food supplement. Algae are found in many dishes and processed foods, as described in **Table 19.2**. Algae are nutritious because of their high protein content and because they contain minerals, trace elements, and vitamins. Some of the substances found in algae also are used to stabilize or improve the texture of processed foods.

■ **Figure 19.20** The red photosynthetic pigments allow the red algae to live in deep water and still use sunlight to photosynthesize.

Explain How do the red photosynthetic pigments make this possible?

VOCABULARY

ACADEMIC VOCABULARY

Supplement:

something that completes or makes an addition.

Vitamins are taken to supplement one's diet.

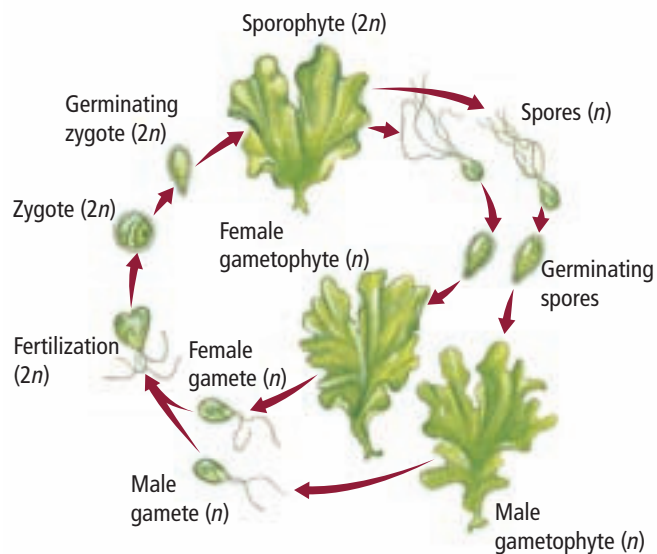


Interactive Table To explore more about the uses for algae, visit biologygmh.com.

Table 19.2

Some Uses for Algae

Type of Algae	Uses
Red algae	A species of red alga, <i>Porphyra</i> , is called nori, which is dried, pressed into sheets, and used in soups, sauces, sushi, and condiments. Some species of red algae provide agar and carrageenan, which are used in the preparation of scientific gels and cultures. Agar also is used in pie fillings and to preserve canned meat and fish. Carrageenan is used to thicken and stabilize puddings, syrups, and shampoos.
Brown algae	Brown algae are used to stabilize products, such as syrups, ice creams, and paints. The genus <i>Laminaria</i> is harvested and eaten with meat or fish and in soups.
Green algae	Species from the genera <i>Monostroma</i> and <i>Ulva</i> , also called sea lettuce, are eaten in salads, soups, relishes, and in meat or fish dishes.
Diatoms	Diatoms are used as a filtering material for processes such as the production of beverages, chemicals, industrial oils, cooking oils, sugars, water supplies, and the separation of wastes. They also are used as abrasives.



■ **Figure 19.21** The life cycle of many algae, including the sea lettuce *Ulva* shown here, includes an alternation between a diploid and haploid generation. Alternation of generations also is found in members of both the plant and fungi kingdoms.

Life Cycle of Algae

The life cycles of many algae are complex. Algae can alternate between spore-producing forms and gamete-producing forms. They can reproduce sexually as well as asexually. Green algae also reproduce asexually through fragmentation—a process in which a multicellular individual breaks into separate pieces and each grows into an individual organism.

Alternation of generations The life cycles of many algae exhibit a pattern called alternation of generations, illustrated in **Figure 19.21** for the sea lettuce *Ulva*. **Alternation of generations** is a life cycle of algae that takes two generations—one that reproduces sexually and one that reproduces asexually—to complete a life cycle. Organisms alternate between a diploid ($2n$) form and a haploid (n) form in which each is considered a generation.

Haploid and diploid generations The haploid form of the organism is called the gametophyte generation because it produces gametes. This generation is represented by the red arrows in the diagram. Gametes from two different organisms combine to form a zygote with two complete sets of chromosomes. The diploid form of the organism is represented by blue arrows in the diagram. The zygote develops into the sporophyte ($2n$). In the sporophyte, some cells divide by meiosis and become haploid spores (n). Spores are reproductive cells that develop into gametophytes. The new gametophytes continue the cycle as shown in **Figure 19.21**.

Section 19.3 Assessment

Section Summary

- ▶ Plantlike protists produce their own food through photosynthesis.
- ▶ Algae are important producers of oxygen and food for aquatic ecosystems.
- ▶ Euglenoids, diatoms, and dinoflagellates are unicellular algae.
- ▶ Red, brown, and green algae have multicellular forms.
- ▶ The life cycles of algae include an alternation of generations.

Understand Main Ideas

1. **MAIN Idea** **Explain** why algae are considered the primary producers for aquatic and marine ecosystems.
2. **Describe** the major characteristics of the three groups of algae.
3. **Explain** why you would expect to find more evidence of diatoms than green algae in a sample of ocean floor sediment.
4. **Apply** what you know about photosynthesis to explain why most algae live at or near the surface of the water.

Think Scientifically

5. **Design an experiment** to determine the optimum color of light to grow green algae.
6. **Summarize** the role of secondary photosynthetic pigments in algae.
7. **WRITING in Biology** Write a brief public service announcement explaining the dangers of eating shellfish during a red tide.

Section 19.4

Objectives

- Describe the characteristics of cellular and acellular slime molds.
- Compare the life cycle of cellular and acellular slime molds.
- Explain how water molds obtain their nutrition.

Review Vocabulary

cellulose: a glucose polymer that forms the cell walls of plants and some funguslike protists

New Vocabulary

plasmodium
acrasin

Funguslike Protists

MAIN Idea Funguslike protists obtain their nutrition by absorbing nutrients from dead or decaying organisms.

Real-World Reading Link Have you ever heard the saying, “don’t judge a book by its cover”? The same could be said of funguslike protists. Although at first glance they look like fungi, when they are examined more closely, many traits are revealed that are not true of fungi.

Slime Molds

As you can imagine, funguslike protists are protists that have some characteristics of fungi. Fungi and slime molds use spores to reproduce. Slime molds, like fungi, feed on decaying organic matter and absorb nutrients through their cell walls. However, fungi and slime mold differ in the composition of their cell walls. Fungi cell walls are composed of a substance called chitin (KI tun). Chitin is a complex carbohydrate that is found in the cell walls of fungi, and in the external skeletons of insects, crabs, and centipedes. The cell walls of funguslike protists do not contain chitin as a true fungus does. The cell walls of these protists contain cellulose or celluloselike compounds.

Slime molds are found in a variety of colors, ranging from yellows and oranges to blue, black, and red as shown in **Figure 19.22**. They usually are found in damp, shady places where decaying organic matter is located, such as on a pile of decaying leaves or on rotting logs. Slime molds are divided into two groups—acellular slime molds and cellular slime molds.

■ **Figure 19.22** Slime molds have a variety of colors and shapes, but they all have funguslike characteristics.

Infer Where might these slime molds be obtaining their nutrition?

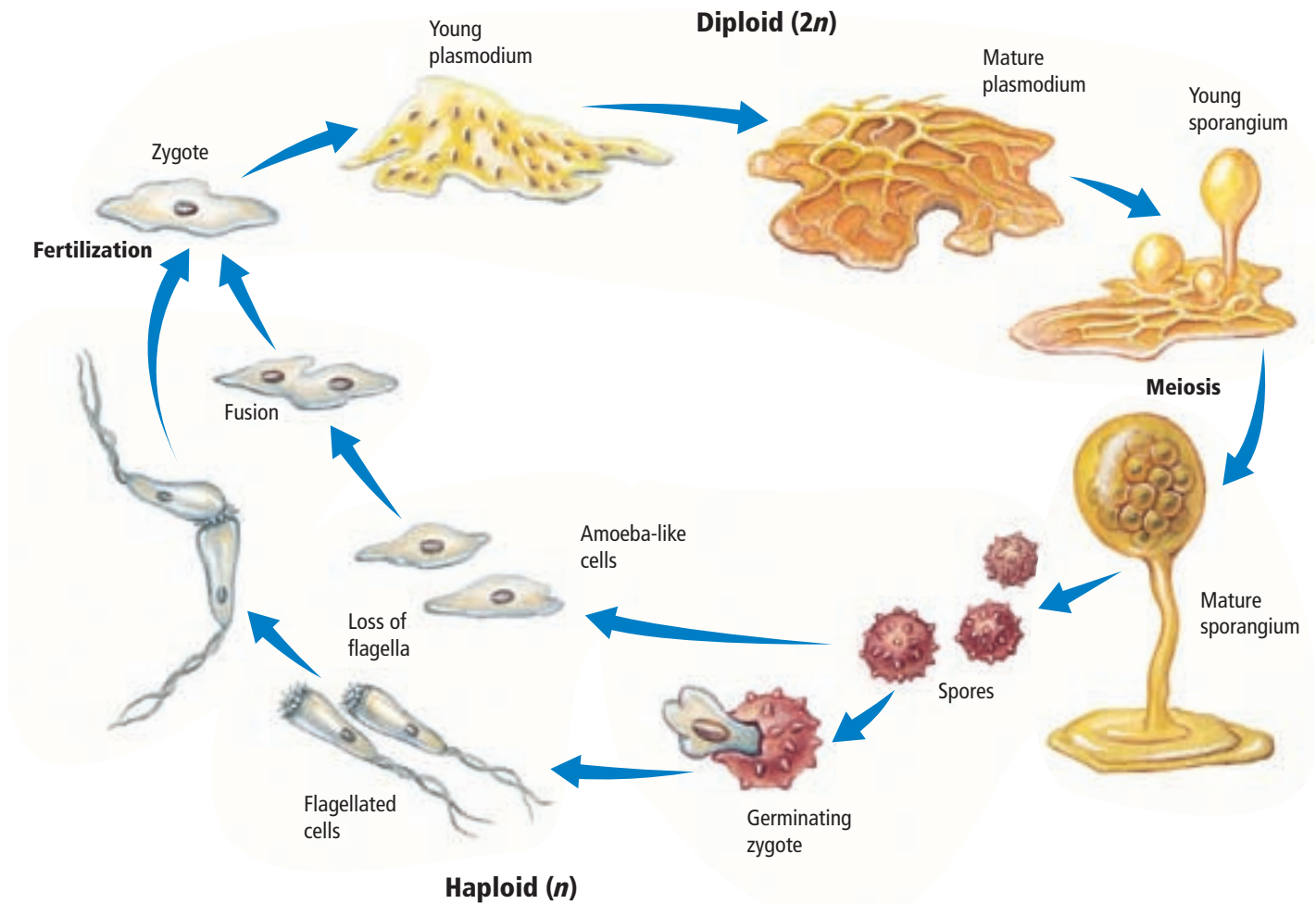
Reading Check Compare and contrast fungi and slime molds.



Myxamoebae slime mold



Red raspberry slime mold



■ **Figure 19.23** Acellular slime mold goes through haploid and diploid phases during its life cycle.

Acellular slime molds Funguslike protists called acellular slime molds are found in the phylum Myxomycota (mihk soh mi COH tuh). They are acellular because they go through a phase in their life cycle in which the nucleus divides but no internal cell walls form, resulting in a mass of cytoplasm with multiple nuclei.

Follow the life cycle of a typical acellular slime mold shown in **Figure 19.23**. Acellular slime molds begin life as spores, usually when conditions are harsh—such as during a drought. In the presence of water, the spore produces a small mass of cytoplasm, or an amoeboid cell, or a cell with a flagella. The cell is propelled by the flagella until it comes in contact with a favorable surface. Then, the flagella permanently retract and the cell produces pseudopods that allow it to move like an amoeba. Both the flagellated cell and the amoeba-like cell are gametes and are haploid (n).

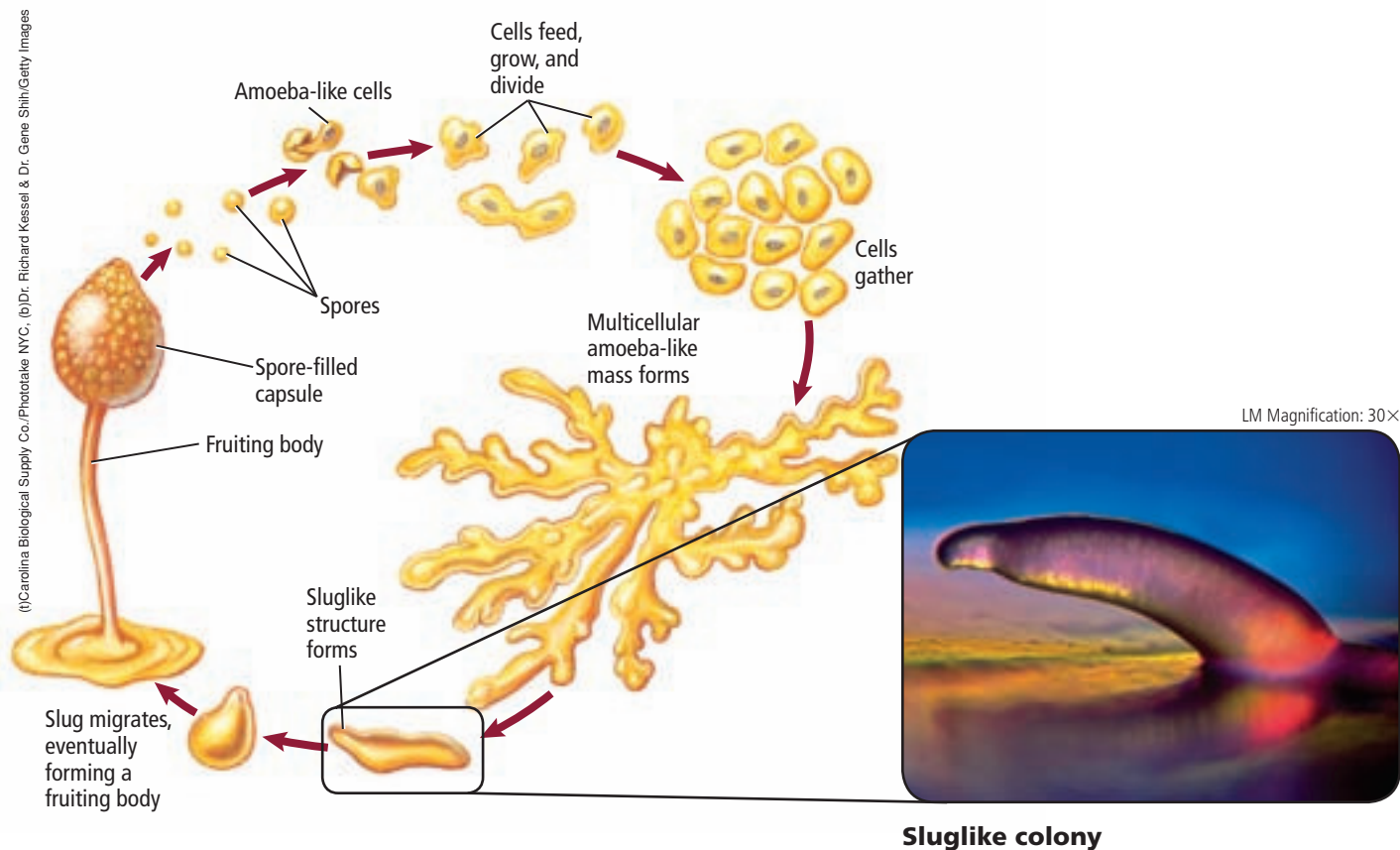
When two gametes unite, the next phase of the life cycle begins. The fertilized cells undergo repeated divisions of the nuclei, forming a plasmodium. A **plasmodium** (plaz MOH dee um) is a mobile mass of cytoplasm that contains many diploid nuclei but no separate cells. This is the feeding stage of the organism. It creeps over the surface of decaying leaves or wood like an amoeba and can grow as large as 30 cm in diameter. When food or moisture becomes limited, the slime mold develops spore-producing structures. Spores are produced through meiosis and dispersed by the wind. Once the spores are in the presence of water, the cycle repeats.

VOCABULARY

ACADEMIC VOCABULARY

Phase: a particular state in a regular cycle of changes.

The phases of the moon are based on the positions of Earth, the Sun, and the moon.



■ **Figure 19.24** Cellular slime molds reproduce both sexually and asexually. Amoeba-like cells congregate during asexual reproduction, shown above, to form a sluglike colony, which functions like a single organism.
Explain why the sluglike stage is considered a colony.

Cellular slime molds Cellular slime molds are found in the phylum Acrasiomycota (uh kray see oh my COH tuh). These funguslike protists creep over rich, moist soil and engulf bacteria. Unlike acellular slime molds, they spend most of their life cycle as single amoeba-like cells and they have no flagella.

The life cycle of cellular slime molds is shown in **Figure 19.24**. When food is plentiful, the single amoeba-like cells reproduce rapidly by sexual reproduction. During sexual reproduction, two haploid amoebas unite and form a zygote. The zygote develops into a giant cell and undergoes meiosis followed by several divisions by mitosis. Eventually, the giant cell ruptures, releasing new haploid amoebas.

When food is scarce, the single amoeba-like cells reproduce asexually. The starving amoeba-like cells give off a chemical called **acrasin** (uh KRA sun). The amoeba-like cells begin to congregate in response to the chemical signal, forming a sluglike colony that begins to function like a single organism. The colony migrates for a while, eventually forming a fruiting body, like the one shown in **Figure 19.25**. The fruiting body produces spores. Once the spores are fully developed, they are released. The spores germinate, forming amoeba-like cells, and the cycle repeats.

Reading Check Infer why the stages in the life cycle of cellular slime molds contribute to their long-term survival.

■ **Figure 19.25** Cellular slime molds produce fruiting bodies that contain spores during part of their life cycle.





■ **Figure 19.26** This water mold is absorbing nutrients found in this dead insect.

Explain *What funguslike characteristic do water molds have?*



Water mold

Water Molds and Downy Mildew

There are more than 500 species of water molds and downy mildews in the phylum Oomycota (oo oh my COH tuh). Most members of this group of funguslike protists live in water or damp places. Some absorb their nutrients from the surrounding water or soil, while others obtain their nutrients from other organisms, as shown in **Figure 19.26**.

Originally, water molds were considered fungi because of their method of obtaining nutrients. Like fungi, water molds envelope their food source with a mass of threads; they break down the tissue, and absorb the nutrients through their cell walls. Although this is characteristic of fungi, water molds differ from fungi in the composition of their cell walls and they produce flagellated reproductive cells. Recall that the cell walls of funguslike protists are composed of cellulose and celluloselike compounds.

 **Reading Check** Compare and contrast water molds and fungi.

Mini Lab 19.2

Investigate Slime Molds

What is a slime mold? In a kingdom of interesting creatures, slime molds perhaps are the most interesting. Observe different types of slime molds and observe the unusual nature of their bodies.

Procedure     

1. Read and complete the lab safety form.
2. Obtain slides of different specimens of slime molds. Examine the slides under a microscope.
3. Create a data table to record your information. Sketch and describe each specimen.

Analysis

1. **Compare and contrast** the specimens.
2. **Identify** specimens that have similar characteristics. Explain why the specimens are similar.
3. **Think Critically** How would you classify each specimen that you examined? Explain.



(l)Astria & Hanns-Freider Michter/Photo Researchers, (r)David Munns/Photo Researchers



Infected potato



Healthy potato

■ **Figure 19.27** Compare the infected potato on the left with the normal one on the right. *Phytophthora infestans* will destroy the harvested potato in a matter of weeks.

Connection to History

One member of phylum Oomycota has had a far-reaching impact. The downy mildew *Phytophthora infestans* (FI toh fah thor uh • in FEST unz) infects potato plants and destroys the potato, as shown in **Figure 19.27**. This organism devastated the potato crop of Ireland in the 19th century. Because the potato was their primary food source, about one million people died of starvation or famine-related diseases in Ireland. Ironically, during this time many other agricultural products were produced in Ireland. The Irish peasants could not afford to purchase the agricultural products, so the products were exported to Britain. The British government did provide some assistance to the peasants, but it was too little to prevent the widespread famine. During this time, a large number of people emigrated from Ireland to the United States to escape the terrible famine.

Section 19.4 Assessment

Section Summary

- The cell walls of funguslike protists do not contain chitin.
- Slime molds, water molds, and downy mildew grow in aquatic or damp places.
- Acellular slime molds form a plasmodium that contains many nuclei but no separate cells.
- Cellular slime molds form colonies of cells to reproduce.
- Water molds envelop their food source with a mass of threads.

Understand Main Ideas

1. **MAIN Idea** **Explain** how funguslike protists obtain their nutrition.
2. **Explain** the life cycle of a cellular slime mold.
3. **Describe** how amoeba-like cells move.
4. **Contrast** cellular and acellular slime molds.
5. **Classify** an organism that has cell walls made of cellulose and absorbs its nutrients from dead organisms.

Think Scientifically

6. **Design an experiment** to determine the moisture requirements of an acellular slime mold.
7. **Recommend** a procedure a garden shop owner should follow in order to prevent slime molds from growing on his or her wooden benches.
8. **WRITING in Biology** Write a short newspaper article about the Irish Potato Famine.

In the Field

Career: Nanotechnologist

Diatoms: Living Silicon Chips

Diatoms have recently gained the attention of nanotechnologists—scientists who engineer devices on the atomic level. Diatoms build intricate shells with incredible precision and regularity. Nanotechnologists think these organisms could be used to build useful structures from silicon on the atomic level.

Nature's nanotechnologists Humans still have a lot to learn from diatoms about constructing materials on the nanoscale. Currently, nanotechnologists etch features on to silicon and other materials to produce components. The process is costly, time-consuming, and generates chemical waste.



Silicon dioxide shell in a hand

Living silicon chips Diatoms have been described as living silicon chips because they construct their shells atom by atom. Silicon derived from sea water is processed into intricate microstructures to form a rigid silica shell, such as the one shown in the photo. Each diatom species forms a unique and potentially useful shell structure.

To create nanomaterials from diatoms, scientists prepare feeding solutions containing silicon and other elements they wish to test. The diatoms take these elements in and use them to build shells. When diatoms replace silicon atoms in their shell with elements like magnesium or titanium, a structurally intact unit with a desired shape and chemical makeup is produced. Scientists are working to use diatom shell patterns, many of which cannot currently be duplicated by nanotechnologists, as templates to build components with desired specifications.

Future Applications Diatoms might prove to be an important tool in the evolving science of nanotechnology with potential applications in biomedicine, telecommunications, and energy storage and production.

Color-Enhanced SEM Magnification: 390×



Color-Enhanced SEM Magnification: 390×



Diatoms

WRITING in Biology

Newspaper Article The worldwide need for nanotechnology workers could reach two million by the year 2015. Visit biologygmh.com to find more information about the field of nanotechnology. Write a want ad for a specific career in nanotechnology.

BIOLAB

Design Your Own

INVESTIGATE: HOW DO PROTOZOA BEHAVE?

Background: Animals respond and react to the world around them. One such type of reaction is known as *taxis*, in which an animal orients itself toward (positive) or away (negative) from a stimulus. Some of the things animals respond to are: light (phototaxis), temperature (thermotaxis), chemicals (chemotaxis), and gravity (gravitaxis).

Question: *How do simple unicellular, animal-like protozoa respond to stimuli?*

Materials

cultures of live protozoa
compound microscope
glass slides and coverslips
materials needed to produce stimuli

Safety Precautions



WARNING: Use care when handling slides. Dispose of any broken glass in a container provided by your teacher.

LM Magnification: 390×



Plan and Perform the Experiment

1. Read and complete the lab safety form.
2. Design an experiment to answer the question to the left. Reword the original question to include the taxis you plan to investigate.
3. Make sure your teacher approves your plan before you proceed.
4. Collect the materials and supplies needed and begin conducting your experiment.
5. Dispose of your protozoan cultures as instructed by your teacher.

Analyze and Conclude

1. **Observe and Infer** Some protozoa often are described as animal-like. What animal-like characteristics did you observe?
2. **State the Problem** What stimuli were you trying to test with your experimental design?
3. **Hypothesize** What was your hypothesis for the question to be solved?
4. **Summarize** What data did you collect during the experiment?
5. **Analyze and Conclude** Did your data support your hypothesis? What is your conclusion?
6. **Error Analysis** Compare your data and conclusions with other students in your class. Explain the differences in data.

WRITING in Biology

Report In this lab, you tested the response of an organism to a stimuli. To find out more about how scientists test an organism's response to a stimulus, visit Biolabs at biologygmh.com. Write a short report critiquing your methods. Include ways in which you can improve your techniques.



FOLDABLES **Hypothesize** Is it possible to describe the typical protist? Hypothesize why the organisms in the Kingdom Protista are more diverse than the organisms in any of the other kingdoms.

Vocabulary

Key Concepts

Section 19.1 Introduction to Protists

- microsporidium (p. 544)
- protozoan (p. 542)

MAIN ◀ **Idea** Protists form a diverse group of organisms that are subdivided based on their method of obtaining nutrition.

- Protists include unicellular and multicellular eukaryotes.
- Protists are classified by their methods of obtaining food.
- The first protists might have formed through endosymbiosis.
- Protists might have been the first eukaryotic cells with chloroplasts and mitochondria, evolving billions of years ago.

Section 19.2 Protozoans—Animal-like Protists

- contractile vacuole (p. 547)
- pellicle (p. 547)
- pseudopod (p. 550)
- test (p. 550)
- trichocyst (p. 547)

MAIN ◀ **Idea** Protozoans are animal-like, heterotrophic protists.

- Protozoans are single-celled protists that feed on other organisms to obtain nutrients.
- Protozoans live in a variety of aquatic environments.
- Protozoans reproduce in a variety of ways, including sexually and asexually.
- Protozoans have specialized methods for movement, feeding, and maintaining homeostasis.

Section 19.3 Algae—Plantlike Protists

- alternation of generations (p. 560)
- bioluminescent (p. 555)
- colony (p. 557)

MAIN ◀ **Idea** Algae are plantlike, autotrophic protists that are the producers for aquatic ecosystems.

- Plantlike protists produce their own food through photosynthesis.
- Algae are important producers of oxygen and food for aquatic ecosystems.
- Euglenoids, diatoms, and dinoflagellates are unicellular algae.
- Red, brown, and green algae have multicellular forms.
- The life cycles of algae include an alternation of generations.

Section 19.4 Funguslike Protists

- acrasin (p. 563)
- plasmodium (p. 562)

MAIN ◀ **Idea** Funguslike protists obtain their nutrition by absorbing nutrients from dead or decaying organisms.

- The cell walls of funguslike protists do not contain chitin.
- Slime molds, water molds, and downy mildew grow in aquatic or damp places.
- Acellular slime molds form a plasmodium that contains many nuclei but no separate cells.
- Cellular slime molds form colonies of cells to reproduce.
- Water molds envelop their food source with a mass of threads.

Section 19.1

Vocabulary Review

Answer the following questions with complete sentences.

1. What is another name for animal-like protists?
2. What are microscopic protozoans that are found in the gut of insects?

Understand Key Concepts

3. Which process is most likely the way in which the first protists formed?

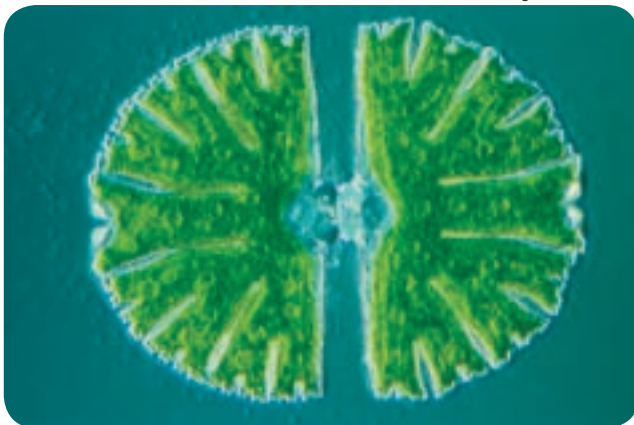
A. aerobic respiration	C. endosymbiosis
B. decomposition	D. photosynthesis
4. Which method below is used to divide protists into three groups?

A. method of getting food
B. method of movement
C. type of reproduction
D. type of respiration
5. Which is least likely to be a suitable environment for protists?

A. decaying leaves	C. damp soil
B. the ocean	D. dry sand

Use the photo below to answer questions 6 and 7.

LM Magnification: 125×



6. To which group does the protist belong?

A. algae	C. funguslike
B. animal-like	D. protozoan
7. Which term best describes this protist?

A. acellular	C. multicellular
B. eukaryotic	D. prokaryotic

Constructed Response

8. **Open Ended** Describe three locations near your home or school where you might be able to find protists.
9. **CAREERS IN BIOLOGY** If you were a taxonomist given the task of organizing protists into groups, would you use the same method described in this book? Explain your answer.

Think Critically

10. **Predict** changes in protist populations if an area had an above-average amount of rainfall.

Section 19.2

Vocabulary Review

Define each of the structures below and provide an example of an organism where it could be found.

11. pseudopod
12. contractile vacuole
13. test

Understand Key Concepts

Use the diagram below to answer question 14.



14. Which structure does this organism use for movement?

A. cilia
B. contractile vacuole
C. flagella
D. pseudopodia
15. What does the paramecium's contractile vacuole help regulate inside the cell?

A. amount of food	C. movement
B. amount of water	D. reproduction
16. Which are most likely to form fossils?

A. apicomplexans	C. foraminifera
B. flagellates	D. paramecia

Constructed Response

- 17. **Open Ended** Explain why termites might die if their symbiotic flagellates died.
- 18. **Short Answer** Describe the process of conjugation in paramecia.

Think Critically

- 19. **Apply Concepts** Recommend several options a village might consider to slow down the spread of malaria.
- 20. **Research Information** Research other diseases that are caused by protozoans. Use a map and plot locations where the diseases occur.

Section 19.3

Vocabulary Review

Match each definition below with the correct vocabulary term from the Study Guide page.

- 21. a life cycle of algae that requires two generations
- 22. a group of cells living together in close association
- 23. gives off light

Understand Key Concepts

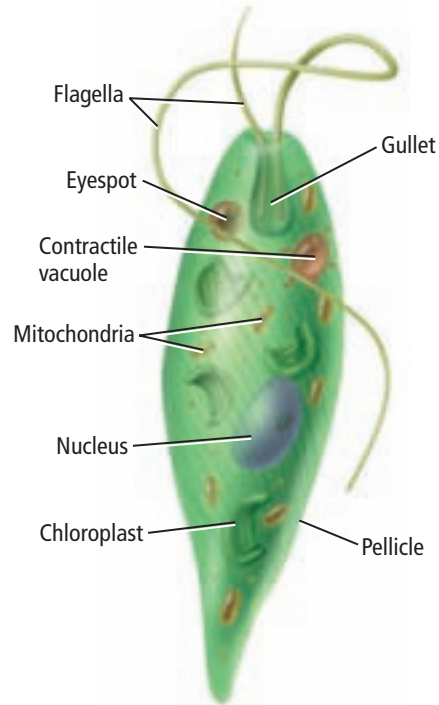
Use the photo below to answer question 24.



- 24. Which term best describes how this organism stores its excess food?
 - A. cellulose
 - B. oil
 - C. protein
 - D. carbohydrate
- 25. Which are used in the human food supply?
 - A. dinoflagellates
 - B. euglenoids
 - C. protozoans
 - D. red algae

- 26. Which organism has silica walls?
 - A. brown alga
 - B. diatom
 - C. dinoflagellate
 - D. euglenoid

Use the illustration below to answer questions 27 and 28.



- 27. What is the name of the structure used by the organism above for movement?
 - A. cilia
 - B. contractile vacuole
 - C. flagella
 - D. pseudopod
- 28. Which structure is used to sense light?
 - A. chloroplast
 - B. eyespot
 - C. nucleus
 - D. pellicle

Constructed Response

- 29. **Open Ended** Why are there more fossils of diatoms, foraminiferans, and radiolarians than of other algae?
- 30. **Short Answer** Explain why diatoms must reproduce sexually occasionally.
- 31. **Short Answer** Explain the relationship between the sporophyte and gametophyte in alternation of generations.

Think Critically

- 32. **Analyze** the difference between freshwater algae and marine algae.

- 33. Recognize Cause and Effect** Explain the effects of a marine parasite that kills all phytoplankton.

Section 19.4

Vocabulary Review

Replace the underlined words with the correct vocabulary term from the Study Guide page.

- 34.** A motile organism that consists of many diploid nuclei but no separate cells is a protoplasm.
- 35.** Starving amoeboid cells give off a chemical called arsenic.

Understand Key Concepts

- 36.** Acellular slime molds have many nuclei, but what structure do they not have?
- chromosomes
 - spores
 - separate cells
 - cilia
- 37.** Which is present in the life cycle of water molds in a flagellated form?
- nuclei
 - plasmidia
 - pseudopods
 - reproductive cells

Constructed Response

- 38. Short Answer** Compare and contrast a water mold and a cellular slime mold.
- 39. Open Ended** Describe some environmental conditions that might lead to the production of spores by an acellular slime mold.

Think Critically

- 40. Analyze and Conclude** During the multinucleated plasmodial stage, could acellular slime molds be classified as multicellular organisms? Explain your reasoning.

Additional Assessment

- 41. WRITING in Biology** Choose one protist and help it “evolve” by determining a new organelle or structure that is going to develop. How will this new condition affect the protist? Will this change increase or decrease the chance of survival?



Document-Based Questions

The text below describes a new detection method for finding microscopic organisms in water sources.

The protozoans *Giardia lamblia* and *Cryptosporidium parvum* are major causes of waterborne intestinal diseases throughout the world. A very sensitive detection method was developed using the DNA amplification procedure—polymerase chain reaction. This procedure can detect the presence of incredibly small amounts of these pathogens—as little as a single cell in two liters of water.

Data obtained from: Guy, et al. 2003. Real-time PCR for quantification of *Giardia* and *Cryptosporidium* in environmental water samples and sewage. *Applications of Environmental Biology* 2003 69(9): 5178-5185.

- 42.** Explain how this detection method might be used by municipal water departments.
- 43.** Analyze the significance of this research for global human health concerns especially in remote regions of the world.
- 44.** Predict how this detection method might be used to monitor the level of organisms that cause red tides.

Cumulative Review

- 45.** Point out how meiosis provides genetic variety. (Chapter 10)
- 46.** Sketch a branching diagram that explains evolution of hominoids from genus *Proconsul* to genus *Homo*. (Chapter 16)
- 47.** Pick the traits you would use to make a key for classifying the kingdoms. Describe why you chose the characteristics on the list. (Chapter 17)

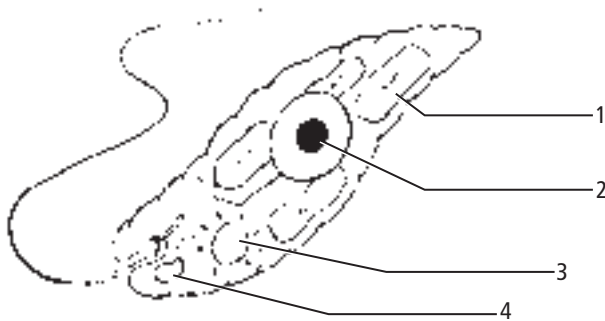
Standardized Test Practice

Cumulative

Multiple Choice

1. Which environment would likely have chemosynthetic autotrophic eubacteria?
- A. coral reef
 - B. deep-ocean volcanic vent
 - C. lake in the mountains
 - D. soil near a spring

Use the diagram below to answer questions 2 and 3.



2. Which number represents the eyespot of the *Euglena*?
- A. 1
 - B. 2
 - C. 3
 - D. 4
3. Which number represents an organelle that captures energy for the cell from sunlight?
- A. 1
 - B. 2
 - C. 3
 - D. 4
4. Which do the two bats *Craseonycteris thonglongyai* and *Noctilio leporinus* have in common?
- A. division
 - B. genus
 - C. phylum
 - D. species

5. Suppose you are investigating bone characteristics of two birds to determine how closely they are related in terms of phylogeny. Which type of evidence are you using?
- A. biochemical characters
 - B. cellular characters
 - C. chromosomal characters
 - D. morphological characters

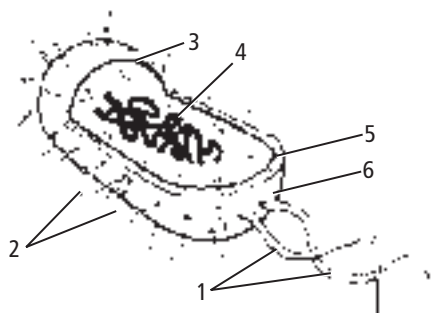
Use the diagram below to answer question 6.



6. Members of the phylum Sarcodina use this structure for locomotion and which other activity?
- A. conjugation
 - B. feeding
 - C. protection
 - D. reproduction
7. How do prions harm their host?
- A. by activating synthesis of viral RNA
 - B. by causing normal proteins to mutate
 - C. by deactivating part of the host's DNA
 - D. by disrupting the way cells reproduce
8. Which could be a derived, rather than ancestral, character in one group of vertebrates?
- A. nervous system
 - B. organized systems of tissues
 - C. role of ATP in mitochondria
 - D. wings used for flight

Short Answer

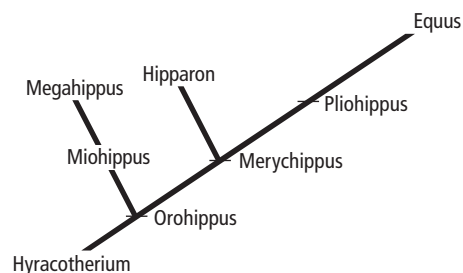
Use the diagram below to answer questions 9 and 10.



- Name the parts of this bacterium and classify each part according to its function.
- From the diagram, deduce how the structure of a typical bacterium enables it to survive in a harsh environment that frequently changes.
- Imagine that you have been asked to do an experiment in which you boil different leaves and flower petals in different solutions to extract the pigments. State what safety equipment would be appropriate for your experiments and give reasoning for your choices.
- Organisms in Kingdom Fungi and Kingdom Plantae used to be classified in the same kingdom. State a reason to classify them in different kingdoms.
- Write a hypothesis about how the life cycle of a retrovirus, such as HIV, might be disrupted to slow or stop the reproduction of the virus.

Extended Response

Use the illustration below to answer question 14.



- The figure above shows the evolution of horses, including the modern-day horse, *Equus*. Does this diagram support the idea of gradualism or of punctuated equilibrium? Explain your answer.

Essay Question

One challenge people face is the presence of antibiotic-resistant bacteria. Antibiotics are used to treat many diseases. Generally, they improve the quality of life of people. However, the widespread use and misuse of antibiotics has created antibiotic-resistant bacteria. This means that some diseases caused by bacteria no longer can be cured with the same antibiotics. Doctors must use new and stronger antibiotics to cure the disease. This gives bacteria an opportunity to develop a resistance to the new antibiotics. Unfortunately, antibiotic resistance in bacteria is spreading faster than new antibiotics are being developed.

Using the information in the paragraph above, answer the following question in essay format.

- Evaluate how the characteristics of bacteria contribute to the rapid development of antibiotic-resistant bacteria.

NEED EXTRA HELP?

If You Missed Question . . .	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Review Section . . .	18.1	19.3	19.3	17.1	17.2	19.2	18.2	17.2	18.1	18.1	1.3	17.3	18.2	15.3	18.1