2.3 The Protists

The smallest eukaryotes and some of the largest belong to the Kingdom Protista. This kingdom is extremely diverse. Some of its members, such as amoebas and paramecia, are very small and mobile and show complex behaviours, while others, including giant "leafy" seaweeds, are stationary and look like plants (**Figure 1**). Most are aquatic, but some are terrestrial. In this section, you will explore the rich diversity of this kingdom and gain an appreciation for the role protists play in ecosystems.

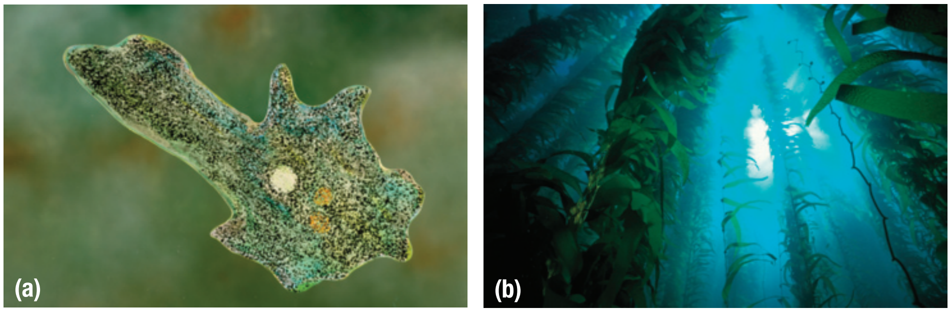

Figure 1 Protists range in size from (a) microscopic single-celled organisms to (b) giant multicellular species such as large green kelp.

Why Protists Are Important

Protists play key roles in aquatic ecosystems. Protists that perform photosynthesis, along with some prokaryotes, are the major producers in the world's oceans. Non-photosynthetic protists are important consumers, especially at the microscopic level, where they dominate the lowest levels of most aquatic food pyramids. Protists are abundant in moist terrestrial environments, including soil, but their ecological roles in these ecosystems are not understood as well.

Many protists are parasites—they live in, or on, other organisms. Most parasites do not harm their host organism, but some cause serious disease. Protists cause some important diseases in humans, in other animals, and in plants. On a global scale, the protist disease of greatest concern to humans is malaria, which causes more than one million deaths a year. Malaria is caused by several species of *Plasmodium*, a single-celled protist. Other serious human protist diseases are sleeping sickness and amoebic dysentery.

CAREER **LINK**

Adventure Tour Guide
Adventure tour guides need to know how to purify water to prevent diseases. For more information about careers in adventure tourism,

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A less serious disease that is of significant concern in Ontario is giardiasis, or "beaver fever." Giardiasis is caused by *Giardia lamblia*, the most common intestinal parasite of humans in North America (**Figure 2**). This parasite is very common in bodies of water, including ones that are formed by beaver dams. A host becomes infected with *Giardia* by drinking contaminated water. Infections can cause abdominal pain, diarrhea, and chronic inflammation of the gut.

Some protists are valuable to humans. If you like sushi, you have eaten nori, the seaweed used to wrap sushi rolls. Nori is the common name for several species of *Porphyra*, a multicellular protist (**Figure 3(a)**). Other products made from seaweed are agar (**Figure 3(b)**) and carrageenan, both used as food additives. Seaweed products are also common in toothpastes, cosmetics, and paints.

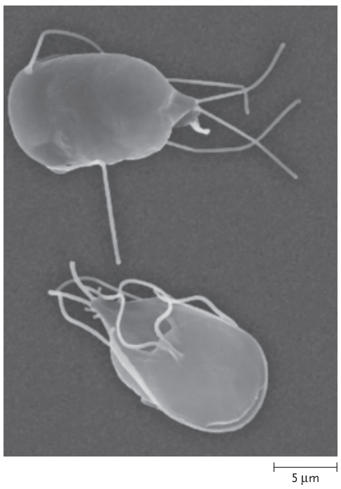

Figure 2 *Giardia lamblia* are unicellular protists that colonize and reproduce in the small intestines of some vertebrates.

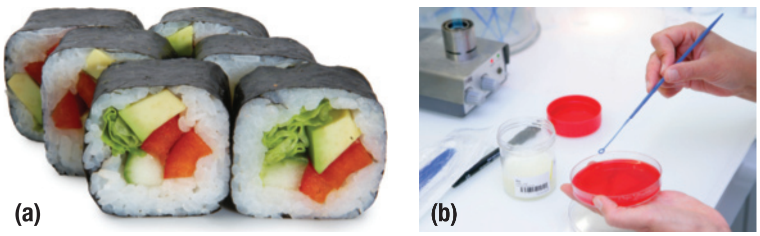

Figure 3 (a) Although *Prophyra* is sometimes green, such as the nori used to wrap sushi, it is classified as red algae. (b) Agar is a gelatinous substance derived from red algae. Microbiologists use agar as a culture medium for the growth of bacteria.

The Origins of Eukaryotes

Protists were the first eukaryotes—their cells have a nucleus and organelles bound by membranes. These internal membranes likely developed from the folded cell membrane of an ancestral prokaryotic cell (**Figure 4**). This folding would have increased the cell surface area, allowing the cell to better exchange materials with its environment. This ability is a necessary feature of large cells.

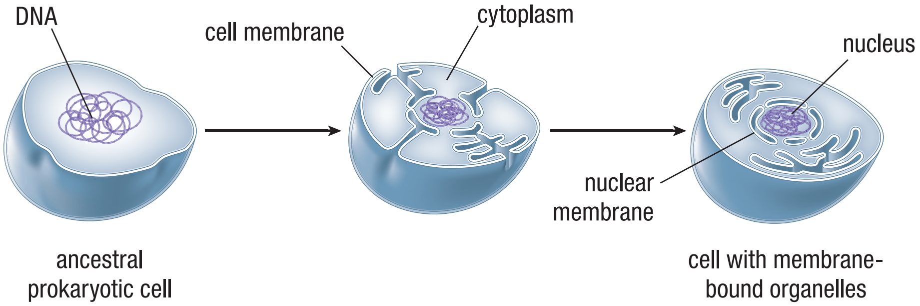

Figure 4 Internal organelles probably developed when the cell membrane of a prokaryotic ancestor—a bacterium or archaea—folded in on itself.

Two organelles have particularly interesting origins. Consider the following information:

- Present-day mitochondria and chloroplasts each have two membranes.
- Their inner membranes are similar to those of their ancestral prokaryote, while their outer membranes match the cell membranes of the eukaryote.
- Present-day mitochondria and chloroplasts have their own internal chromosomes.
- These chromosomes are very similar to prokaryote chromosomes and contain genetic information used by the organelles.
- Mitochondria and chloroplasts reproduce independently within eukaryotic cells by binary fission, just as prokaryotes do.

Based on the evidence summarized above, mitochondria and chloroplasts are thought to have originated by endosymbiosis. **Endosymbiosis** occurs when one type of cell lives within another type of cell. According to a widely accepted theory, mitochondria and chloroplasts were once prokaryotic organisms. These cells were engulfed by early anaerobic eukaryotic cells and incorporated into them (**Figure 5**).

endosymbiosis a relationship in which a single-celled organism lives within the cell(s) of another organism; recent findings suggest this may be very common

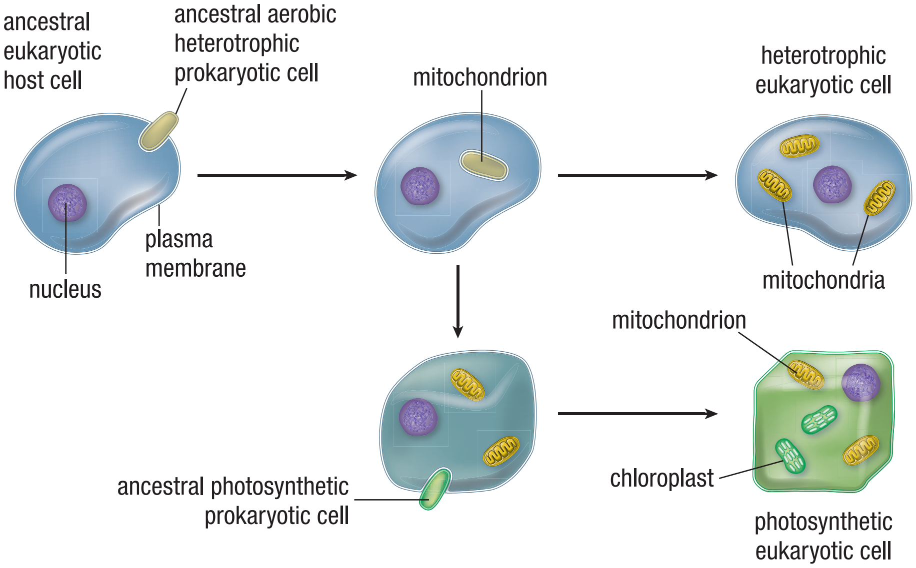

Figure 5 There is strong evidence that mitochondria and chloroplasts originated when aerobic and photosynthetic prokaryotes began living as symbiotic organisms within ancestral eukaryotic cells.

Scientists believe that mitochondria were once aerobic prokaryotes, related to modern proteobacteria. Inside the eukaryotic cells, these prokaryotes benefited from a rich food supply, while the eukaryotes benefited from the excess energy released by the aerobic prokaryotes.

Chloroplasts were likely once photosynthetic prokaryotes, related to modern cyanobacteria. Inside the early eukaryotes, these prokaryotes benefited from the carbon dioxide produced as waste by the eukaryote, which they used in photosynthesis. The eukaryotes benefited from the excess food made by the prokaryotes.

Over millions of years, these endosymbiotic prokaryotes have become permanent residents of their eukaryotic host cells and have lost their ability to live independently. They are passed on to new daughter cells when the eukaryotic cells undergo mitosis.

Recent observations suggest that endosymbiosis is much more widespread than previously suspected. Many eukaryotic organisms, including protists, plants, and animals, have prokaryotes living within some of their cells. These prokaryotes may be beneficial to the eukaryote, or they may be parasites. As you will learn in the next unit, endosymbiosis can give rise to very unusual organisms.

Classification and Phylogeny

Protists are by far the most diverse kingdom of eukaryotes—there are more than 200 000 known species. The Kingdom Protista is a traditional taxonomic group that has been used as a matter of convenience. The Animal, Plant, Fungi, Eubacteria, and Archaea Kingdoms are all based on evolutionary kinship, but the Protist Kingdom is not. Instead, this kingdom has traditionally been a "catch-all" for any species that did not fit into the other major kingdoms of life. **Figure 6** is a phylogenetic tree of the Domain Eukaryotes. Animals, Plants, and Fungi are the only branches on this evolutionary tree that are not classified as protists.

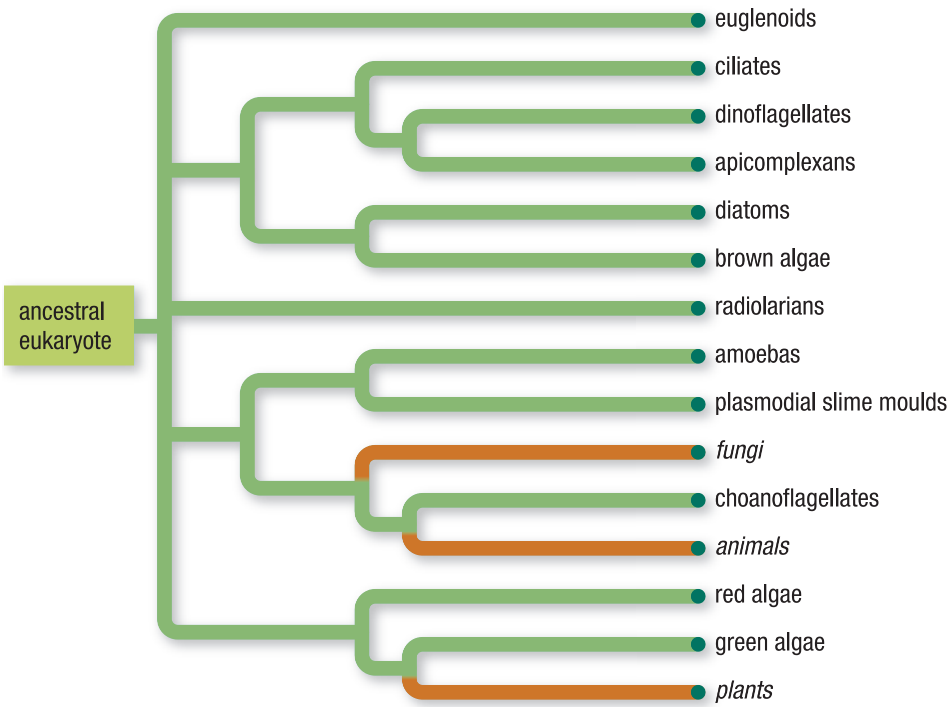

Figure 6 A phylogenetic tree of the Domain Eukaryotes. Fungi, animals, and plants are the only groups that are not included in the Protist Kingdom. The major protist groups are often only distantly related to each other. For example, amoeba are more closely related to elephants than to paramecia or kelp!

Research in the area of protist classification is very active, and more meaningful classifications will likely soon replace this single kingdom.

Investigation 2.3.1

Observing Protists (page 69)
Now that you have read about protists, you can complete Investigation 2.3.1.

In this observational study you will observe, classify, and make biological drawings of protists.

Characteristics

There is no "typical" protist. The only characteristic that all protists share is that they are not animals, plants, or fungi. In all other ways, protists vary greatly. Most are unicellular, while others are multicellular. Protists exhibit a wide variety of cell features, different ways of moving (if they move at all), different ways of getting nutrients and energy, and very different methods of reproducing.

Many protists have very complex cells (**Figure 7**). For example, heterotrophic paramecia have both macronuclei and micronuclei. Both types of nuclei contain DNA, but they play different roles in using and processing genetic information. Some protists have many copies of their chromosomes and very large amounts of DNA. Paramecia also have specialized vacuoles that contract to eliminate excess water, a gullet (similar to a mouth) for taking in food, hair-like cilia for moving, and trichocysts that release long fibres used for defence. In contrast, photosynthetic *Euglena* contain chloroplasts for performing photosynthesis. They have an eye spot for detecting light, a stiff but flexible supporting layer called a pellicle, and a large flagellum for moving.

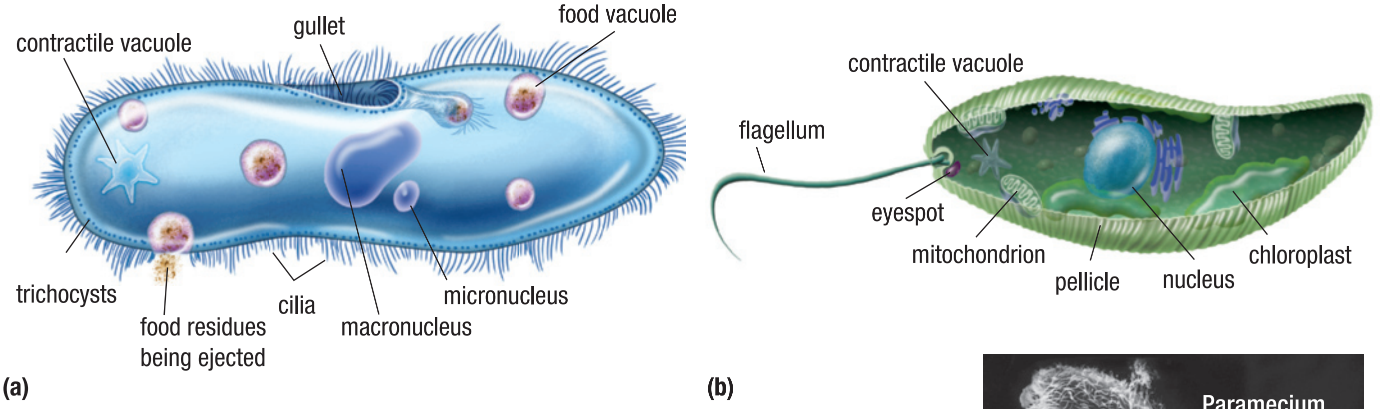

Figure 7 (a) *Paramecium*, a ciliate, and (b) *Euglena*, a euglenoid, are complex unicellular organisms.

Table 1 lists some characteristics of seven representative groups of protists.

Table 1 Characteristics of Representative Protists

Group	Energy source	Key features
euglenoids	autotrophs, photosynthetic	• They are unicellular. • They usually have two flagella for moving. • Their outer surface covering consists of stiff proteins.
ciliates	heterotrophs	• They are unicellular. • They have very complex internal structures. • They have many cilia and no cell walls (**Figure 8**).
apicomplexa	heterotrophs	• They are unicellular. • They have no cell wall. • All are parasites of animals.
diatoms	autotrophs, photosynthetic	• They are unicellular (**Figure 9**). • They move by gliding. • They are covered by glass-like silica shells.
amoebas	heterotrophs	• Some have hard outer skeletons. • They move by extensions of the cytoplasm called pseudopods.
slime moulds	heterotrophs	• Their life cycles have unicellular stages and multicellular stages. • They move with flagella or pseudopods.
red algae	autotrophs, photosynthetic	• Almost all are multicellular. • They have no cilia or flagella. • Their cell walls are made of cellulose.

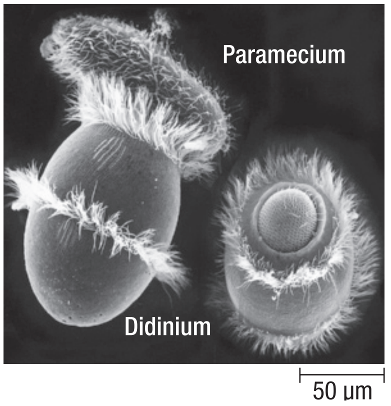

Figure 8 The ciliate *Didinium* is a voracious predator of another ciliate, *Paramecium*.

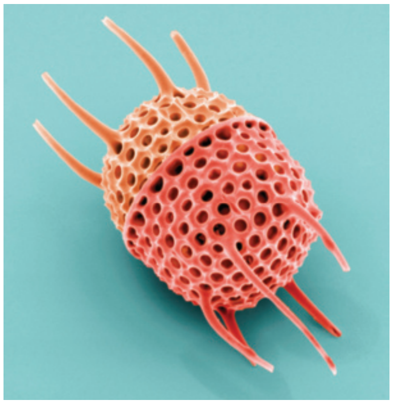

Figure 9 Diatoms are important producers in marine ecosystems.

Interactions in Ecosystems

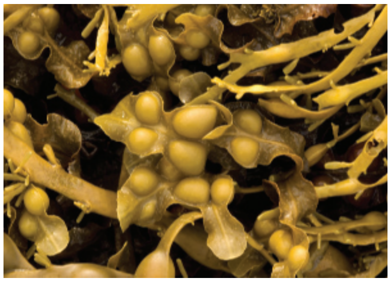

Figure 10 Gas "bladders" allow algae to float to the surface for more light.

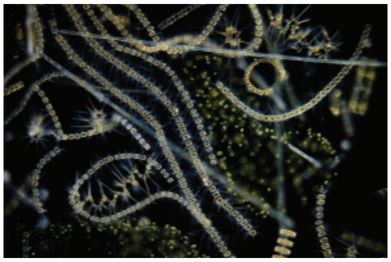

Figure 11 Phytoplankton are microscopic algae that live in marine environments. They are key to marine ecosystems, and produce about half of Earth's oxygen. The world's population of phytoplankton is thought to be declining by 1 % each year, probably because of warming ocean temperatures.

Protists play key roles in ecosystems as producers or consumers. For example, the large green, red, and brown algae called seaweeds have gas-filled bladders that help them float toward the light (**Figure 10**). This allows them to produce energy through photosynthesis. Photosynthetic protists are the primary producers in aquatic food webs. The large kelps, belonging to the brown algae group, can grow up to a half metre a day and reach a length of 80 m!

Climate change is affecting many protists, including algae (**Figure 11**). In aquatic ecosystems the temperatures of oceans and lakes are rising. The water is also becoming more acidic, which may interfere with some protists' ability to produce their outer protective shells. Without their protective shells, they may not survive. The loss of these protists may severely damage food webs that rely on the photosynthetic protists as the primary producers. Warmer water temperatures may also allow the population sizes of some species to increase, which can also interfere with natural food webs in unpredictable ways.

Some protists live as symbiotic organisms in the bodies of animals. Corals are a diverse group of animals responsible for building coral reefs. For food, corals rely on symbiotic photosynthetic protists called zooxanthellae that live within their bodies. Corals are not well understood, but we know that if the corals are stressed by pollution or unusually warm water temperatures, the zooxanthellae lose their green chlorophyll pigment and cannot perform photosynthesis. The coral then take on a bleached white appearance and will die if the condition persists.

Other symbiotic protists are parasites. *Plasmodium*, the parasitic protist that causes malaria, is an example of this. Malaria is spread from person to person by the bite of mosquitoes of the genus *Anopheles*. Since these mosquitoes cannot survive winter in cold climates, malaria is generally found only in tropical and subtropical climate zones. Climate change is already causing warmer temperatures in areas that were too cold for these mosquitoes to survive. As a result, cases of malaria may be found in new areas.

Life Cycles

Single-celled protists reproduce asexually and sexually. Asexual reproduction involves simple binary fission—the cell divides into two genetically identical daughter cells. When a paramecium undergoes binary fission, the macronucleus is elongated and then divides (**Figure 12(a)**). The micronuclei and other organelles are divided approximately equally between the two daughter cells.

Sexual reproduction of many unicellular protists involves conjugation—cells align and exchange genetic material. In a paramecium, conjugation involves the exchange of special micronuclei (**Figure 12(b)**).

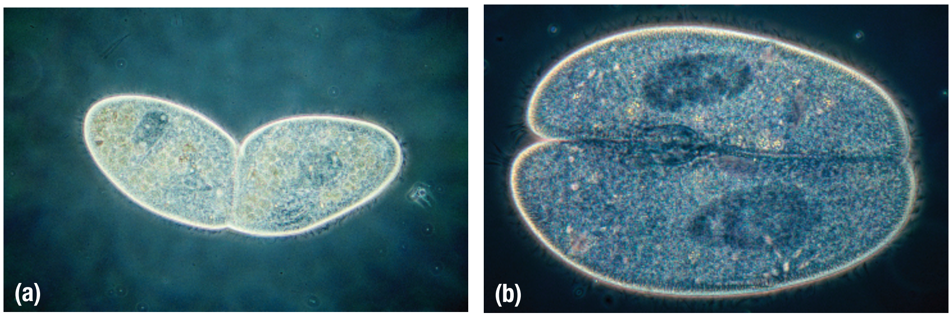

Figure 12 Paramecia reproduce (a) asexually by binary fission and (b) sexually by conjugation.

Multicellular protists have more complex life cycles. Sexual reproduction in multicellular protists may involve the formation of sex cells—male sperm cells and female eggs. These sex cells contain only half the usual number of chromosomes; they are **haploid**. When a sperm cell fuses with an egg, the resulting cell is called a **zygote**. Most zygotes have two copies of every chromosome—one copy from the sperm and one copy from the egg. This makes the zygote **diploid**.

haploid a cell containing half the usual complement of chromosomes (*n*)

zygote a cell produced by the fusion of two gametes

diploid a cell containing two copies of each chromosome (2*n*)

The life cycle of brown algae is quite different, because it alternates between a diploid stage and a haploid stage (**Figure 13**).

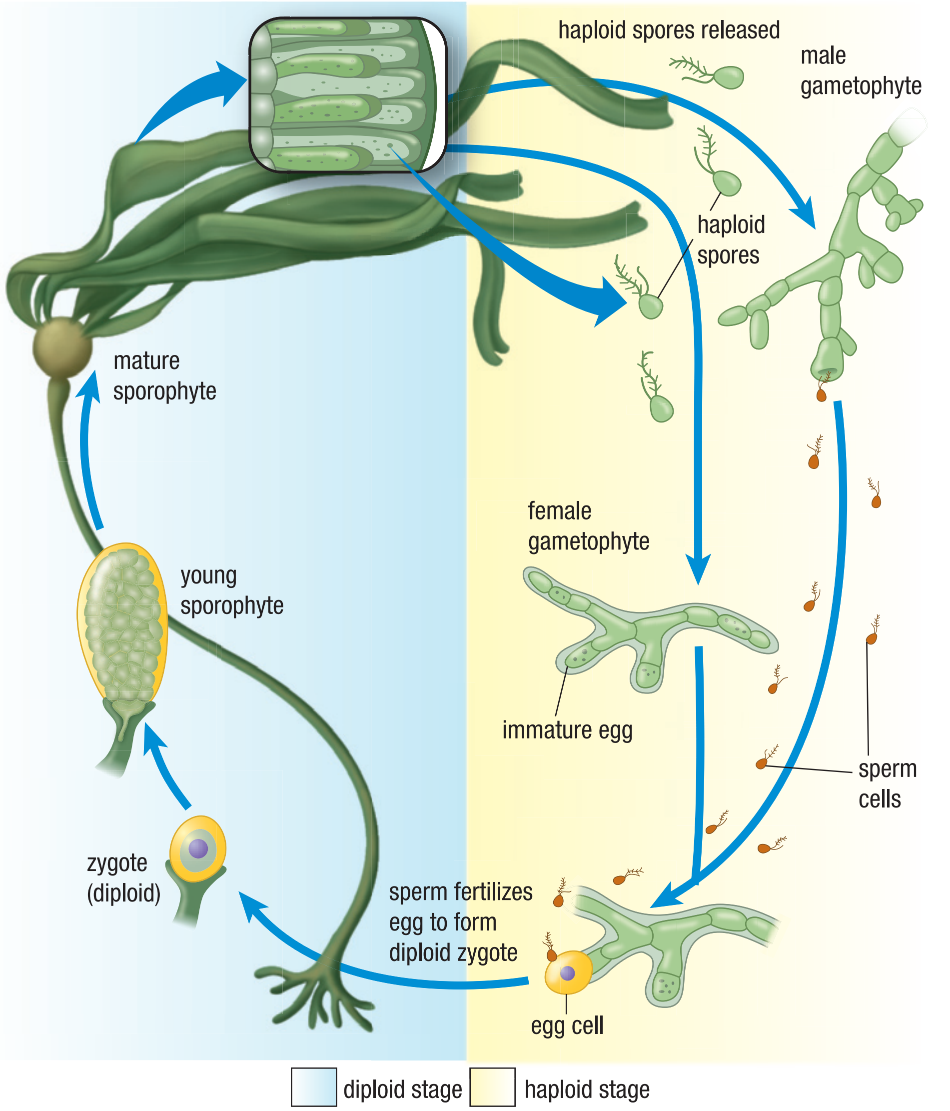

Figure 13 Brown algae have a life cycle that alternates between a diploid stage and a haploid stage.

The large brown alga is a diploid **sporophyte** that produces and releases single-celled haploid **spores**. These spores then find and attach to a surface and begin dividing and growing into multicellular haploid **gametophytes**. These gametophytes eventually produce haploid sperm and eggs. When an egg is fertilized by a sperm, it becomes a diploid zygote that grows into a multicellular sporophyte. This type of life cycle, with both diploid sporophyte and haploid gametophyte stages, is called an **alternation of generations**.

It should be emphasized that in species that exhibit an alternation of generations, both asexual and sexual reproduction are needed to complete a full life cycle. This is in contrast to many other species that reproduce both asexually and sexually.

Consider the example of hydra that can reproduce asexually by forming buds. These buds grow into adult hydras that resemble the original parent organism. Hydra can also reproduce sexually, with a fertilized egg growing into an adult that also resembles the original adult. In this way, asexual and sexual reproduction represent two *different* ways of completing a life cycle.

sporophyte a diploid organism that produces haploid spores in an alternation of generations life cycle

spore a haploid reproductive structure; usually a single cell; capable of growing into a new individual

gametophyte a haploid organism that produces haploid sex cells in an alternation of generations life cycle

alternation of generations a life cycle in which diploid individuals produce spores that create haploid individuals; the haploid individuals reproduce sexually, producing sporophyte individuals and completing the cycle

Brown algae are producers, capable of living independently and making their own food. At the other extreme are parasitic organisms that are completely dependent on other organisms. **Figure 14** illustrates a simplified diagram of the life cycle of *Plasmodium*, the protist that causes malaria.

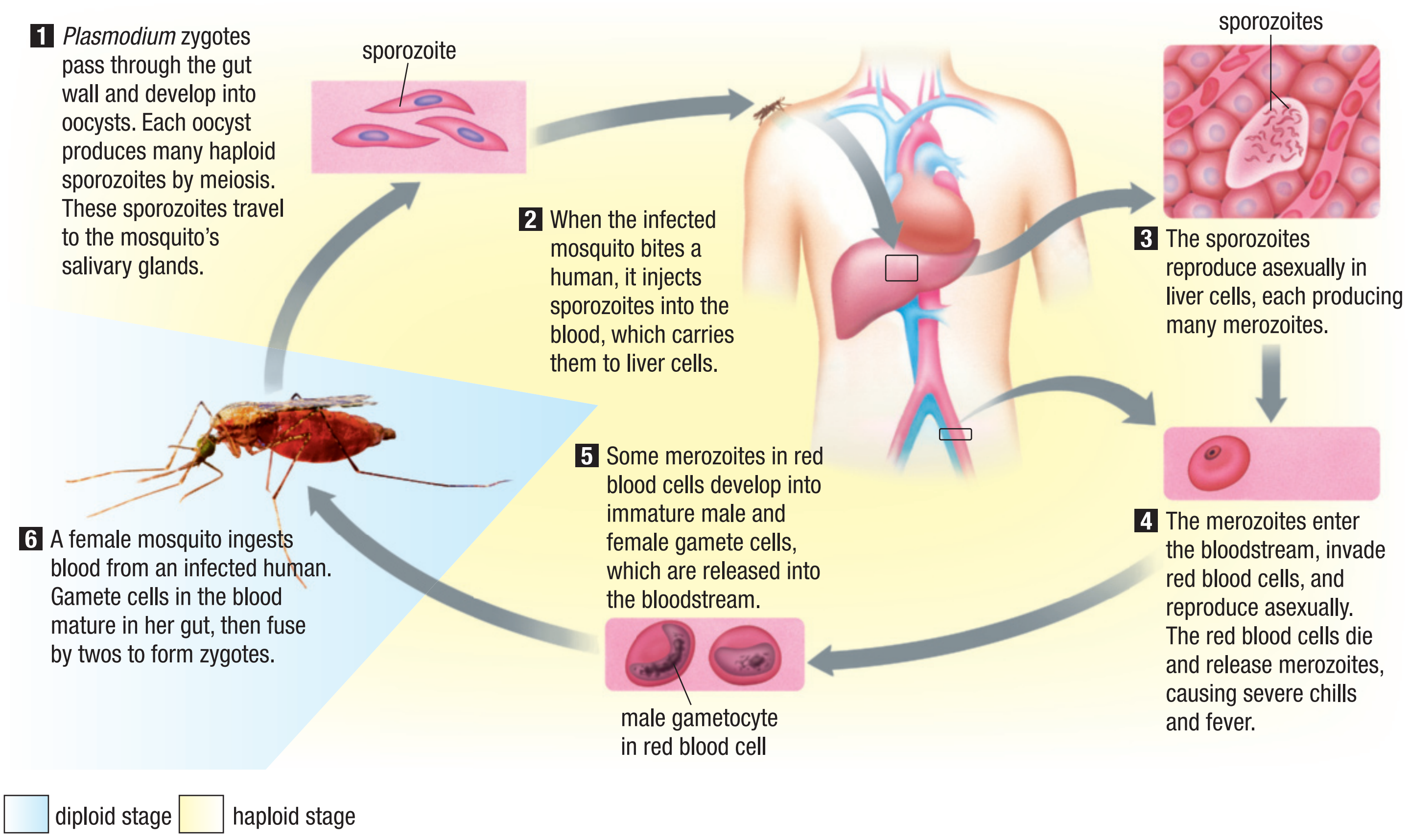

Figure 14 The life cycle of *Plasmodium*

Research This

Protistology

Skills: Researching, Analyzing, Evaluating, Communicating — SKILLS HANDBOOK **A2.1, A5.1**

The diversity of protists is truly remarkable. They vary dramatically in size and shape, in their ecological roles, and in their significance to humans. In this activity you will research and explore some of this protist variety.

1. Search for and view online video clips of protists moving and feeding using (i) flagella, (ii) cilia, and (iii) pseudopodia (extensions of their cytoplasm; singular: pseudopod). Describe how these structures allow protists to move and feed.
2. Investigate the life cycle of *Plasmodium vivax*. Describe how this parasite makes use of mosquitoes, liver cells, and blood cells to complete its life cycle.
3. Potato blight is an important plant disease that causes billions of dollars in crop losses every year. It was also the main cause of the famous Irish Potato Famine. Do research and answer the following questions:

A. Which protist is responsible for this disease? How does the protist affect potato plants? K/U T/I

B. Genetic engineers have recently inserted a gene from another plant into potatoes to create potatoes that are resistant to the disease. What plant did scientists take this gene from? T/I

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CAREER LINK

Protistologists

Scientists who specialize in research on protists are called protistologists. To find out more about becoming a protistologist,

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2.3 Summary

- Protists are extremely diverse eukaryotic species that are mostly unicellular. Most are aquatic.
- Protists are important producers and consumers in many ecosystems.
- Some protists are responsible for serious human diseases, including malaria.
- Eukaryote nuclei are thought to have evolved by the folding in of the cell membrane. This was followed by the acquisition of mitochondria and chloroplasts through the process of endosymbiosis.
- The Protist Kingdom includes all the eukaryotes that are not fungi, plants, or animals.
- Protists vary dramatically in cellular structure, metabolism (energy sources), how they move, and life cycles.
- Warming temperatures and increased water acidity can harm some protists and threaten major aquatic food webs.
- Some protist life cycles include an alternation of generations with both sporophyte and gametophyte individuals.

UNIT TASK **BOOKMARK**

As you work on the Unit Task, consider how your chosen group of organisms and the other organisms it interacts with are affected by climate change.

2.3 Questions

1. Choose and describe four examples of different protists that highlight the diversity within this kingdom. K/U
2. Some protists are more closely related to animals, plants, or fungi than they are to each other. What does this suggest about the classification criteria used for members in this kingdom? K/U A
3. Give an example of a protist that is
   (a) a parasite of humans
   (b) very large and photosynthetic
   (c) a unicellular species with two flagella and photosynthetic
   (d) covered in cilia
   (e) surrounded by a silica shell K/U A
4. Explain how a warming climate might lead to the spread of malaria. K/U A
5. How does an increase in acidity harm some protists with shells? K/U
6. Distinguish between each of these terms:
   (a) haploid and diploid
   (b) zygote and spore
   (c) gametophyte and sporophyte K/U
7. Create labelled sketches in your notebook to illustrate
   (a) the formation of the nucleus in ancient eukaryotic cells
   (b) the evolution of mitochondria and chloroplasts by the process of endosymbiosis K/U C
8. Slime moulds are among the most unusual protists. Use the Internet and other sources to learn more about slime moulds. T/I
   (a) Describe and compare plasmodial slime moulds and cellular slime moulds.
   (b) What roles do slime moulds play in ecosystems?
   (c) Watch online video clips of slime mould motion. Describe what you see.
9. African sleeping sickness is a serious parasitic disease caused by the protist *Trypanosoma brucei* (**Figure 15**). Use the Internet and other sources to find out more about this disease.
   (a) Where in the world is it most prevalent?
   (b) How is it spread?
   (c) What are the symptoms?
   (d) Can the disease by effectively treated? T/I

Figure 15 *Trypanosoma brucei* causes sleeping sickness.

10. Some protists are considered colonial organisms. Research the criteria that biologists use to distinguish between colonial and multicellular organisms. Summarize your findings. T/I
11. Use the Internet and other sources to research some uses of protist products. T/I
    (a) What properties of agar and carrageenan make them valuable?
    (b) List five or more uses for agar and carrageenan.
    (c) What is diatomaceous earth?
    (d) List five or more uses for diatomaceous earth.

GO TO NELSON SCIENCE