LAB TOPIC 13

Protists

This lab topic gives you another opportunity to practice the scientific process introduced in Lab Topic 1. Before going to lab, review scientific investigation in Lab Topic 1 and carefully read Lab Topic 13. Be prepared to use this information to design an experiment with protists.

If possible in your laboratory situation, 1 week before this lab, instruct students to read the lab topic and meet with their investigative team to discuss possible independent investigations before coming to the lab. You may ask them to develop their preliminary question and hypothesis. Give students a list of available materials. Additional supplies and materials must be requested prior to lab.

Laboratory Objectives

After completing this lab topic, you should be able to:

1. Discuss the diversity of protists, and the current interest in their phylogenetic relationships.
2. Describe a current hypothesis for organizing clades of protists based on recent molecular evidence of relationships.
3. Identify and describe representative organisms in several major protistan clades.
4. Discuss the ecological role and economic importance of protists.
5. Describe the characteristics and representative organisms of the green algae and their relationship to land plants.
6. Design and perform an independent investigation of a protist.

For a 2-hour lab: Utilize two consecutive lab periods with the study of protists the first week and Exercise 13.5, the student-designed investigation, the second week. See Teaching Plan for additional suggestions.

MB In the Study Area of masteringbiology .com, see Student Media for suggested activities, investigations, and videos.

Introduction

Unicellular eukaryotic organisms originated over 2 billion years ago, and today they are found in every habitable region of Earth. The enormous diversity of organisms, their numerous adaptations, and their cellular complexity reflect the long evolutionary history of eukaryotes. For almost 30 years, scientists placed these diverse groups of unicellular organisms into the kingdom Protista. The Protista usually included all organisms not placed in the other eukaryotic kingdoms of Plants, Animals, and Fungi. This catchall kingdom included not only the unicellular eukaryotes, but also their multicellular relatives, like the giant kelps and seaweeds. However, scientists now agree that the designation kingdom Protista should be abandoned and these eukaryotic organisms should be placed in the domain Eukarya along with fungi, plants, and animals. (Recall from Lab Topic 12 that prokaryotes are placed in domains Bacteria or Archaea.) In this lab topic we will refer to this diverse group as *protists*, meaning a general term rather than a taxonomic category.

Most protists are unicellular, although there are colonial and multicellular species (see Lab Topic 2 for definitions of these terms). Historically protists were classified based on characteristics such as cellular structure, reproductive strategies, life cycles, and modes of nutrition. For example, one system of classification separated protists into **algae** and **protozoa.** Algae included autotrophic (photosynthetic) species that convert the sun's energy to organic compounds. The energy stored by autotrophs is called **primary production.** Protozoa was the designation for heterotrophic protists that obtain their food by absorbing large organic molecules or by **phagocytosis**—the uptake of large particles or whole organisms by the pinching inward of the cell membrane. Some protozoa, euglenoids for example, are **mixotrophic,** capable of photosynthesis and phagocytosis. However, these criteria were found to be unreliable when attempting to classifying protists based on their phylogeny, or evolutionary history. The emergence of molecular and biochemical research, particularly the ability to sequence genes and even whole genomes, has provided strong evidence for reconstructing phylogenetic relationships of protists.

Recently, scientists studying the genetics and biochemistry of protists have suggested that grouping protists into **clades** can be meaningful for indicating evolutionary relationships. A clade is a group of species, all of which are descended from one ancestral species, representing one phylogenetic group. One current hypothesis for classifying organisms in the domain Eukarya places protists, along with land plants, fungi, and animals, into four clades or "**supergroups.**" The first supergroup, **Excavata,** includes protists based on the structure of their mitochondria and their unique flagella. The second supergroup has been proposed recently and given the informal name of the **"SAR" clade.** The protists in this clade are grouped together based on DNA sequences in their genomes, and include **Stramenopiles, Alveolates,** and **Rhizarians.** The supergroup **Unikonta** includes the protistan clade Amoebozoans and another clade, the Opisthokonts (studied in other lab topics), and includes several groups of protists along with animals and fungi. Another supergroup, **Archaeplastida,** includes the protistan groups red algae and green algae, and also the land plants that will be studied in Lab Topics 14 and 15. Including land plants in this supergroup reflects the amount of evidence supporting the origin of land plants from the green algae.

As more information from a variety of sources becomes available, major groupings or clades will surely be modified. These investigations into the nature of eukaryotic diversity demonstrate the process of scientific inquiry. New technologies, new ideas, and novel experiments are used to test hypotheses, and the resulting evidence must be consistent with the existing body of knowledge and classification scheme. The results lead to modification of our hypotheses and further research. No matter how many groups or clades are proposed, remember that this is a reflection of the evolution of eukaryotes over the rich history of the Earth. It is not surprising that the diversity of life does not easily fit into our constructed categories.

In this lab topic, we will study diverse examples of protists. These protists represent some of the most common clades. As you investigate the diversity of protists and their evolutionary relationships in this exercise, ask questions about the nutritive mode of each. Note morphological characteristics of examples studied. Ask which characteristics are found in organisms in the same clade and those shared with organisms in other clades or groups.

Many of these characteristics are examples of evolutionary convergence. Ask questions about the ecology of the organisms. What means of locomotion do they possess, if any? What role do they play in an ecosystem? Do they have any economic value? Where do they live? (Protists live in a diversity of habitats, but most are aquatic. A great variety of protists may be found in **plankton,** the community of organisms found floating in the ocean or in bodies of fresh water.)

If you complete all of the lab topics in this laboratory manual, you will have studied examples of all the major groups of living organisms with the exception of those in domain Archaea. Bacteria are investigated in Lab Topic 12, and several additional protists are introduced in Lab Topic 2. Fungi are studied in Lab Topic 17, and you will investigate plant evolution and animal evolution in subsequent lab topics. *Table 13.1 is an overview of major clades and examples of each that will be investigated in this lab topic.*

At the end of this lab topic, you will be asked to design a simple experiment to further your investigation of the behavior, ecology, or physiology of one of the organisms studied. As you proceed through the exercises, ask questions about your observations and consider an experiment that you might design to answer one of your questions.

TABLE 13.1 Major Clades of Protists and Examples Studied in This Lab Topic

Supergroup	Clade	Lab study	Examples
Excavata (Exercise 13.1)	Euglenozoans	13.1A	Kinetoplastids—*Trypanosoma*
		13.1B	Euglenids—*Euglena* sp.
"SAR" (Exercise 13.2)	Stramenopiles	13.2A	Diatoms Brown algae Water mold—*Saprolegnia*
	Alveolates	13.2B	Ciliates—*Paramecia* Dinoflagellates Apicomplexan—*Plasmodium sp.*
	Rhizarians	13.2C	Foraminiferans Radiolarians
Unikonta (Exercise 13.3)	Amoebozoans	13.3A	Tubulinids—*Amoeba* sp.
		13.3B	Plasmodial slime molds—*Physarum* Cellular slime molds—*Dictyostelium*
Archaeplastida (Exercise 13.4)	Red algae	13.4A	Rhodophytes—*Porphyra*
	Green algae	13.4B	Chlorophytes—*Spirogyra, Ulva, Chlamydomonas,* Charophytes—*Chara*

EXERCISE 13.1
Supergroup Excavata

The supergroup **Excavata** includes *diplomonads*, *parabasalids*, and *euglenozoans*. These organisms are grouped in this supergroup based on the structure of their mitochondria and their unique flagella. Only examples of **euglenozoans** will be studied here.

Lab Study A. Euglenozoans—Example: *Trypanosoma levisi*

Materials

compound microscope
prepared slides of *Trypanosoma levisi*

Introduction

Organisms in the clade Euglenozoa are grouped together based on the ultrastructure (structure that can be seen only with an electron microscope) of their **flagella** and their mitochondria. Included in this group are some heterotrophs, some autotrophs, and some parasitic species. The many diverse single-celled and colonial flagellates have been a particular challenge to taxonomists. Under the old two-kingdom system of classification, the heterotrophic flagellates were classified as animals, and the autotrophic flagellates (with chloroplasts) were classified as plants. However, euglenozoans include members of each type. The common flagellated, mixotrophic *Euglena* belongs in this clade.

The organism that you will investigate in this lab study, *Trypanosoma levisi*, is an example of a kinetoplastid. DNA within the mitochondria of these protists is organized into a mass called a *kinetoplast*. Organisms in the genus *Trypanosoma* are parasites that alternate between a vertebrate and an invertebrate host. *Trypanosoma levisi* lives in the blood of rats and is transmitted by fleas. Its flagellum originates near the posterior end but passes to the front end as a marginal thread of a long undulating membrane. Another organism in this same genus, *T. brucei*, causes African sleeping sickness in humans. Its invertebrate host is the tsetse fly.

Procedure

If time permits, you might repeat the exercise with termites in Lab Topic 2, even if you performed it previously, because there are several interesting flagellates present in the termite gut that students may not have observed the first time. Alternatively, you might isolate flagellates from one termite and have these on demonstration microscopes or use a microscopy projection system.

1. Obtain a prepared slide of *Trypanosoma levisi* (Figure 13.1) and observe it using low, intermediate, and high powers in the compound microscope.
2. Locate the organisms among the blood cells of the parasite's host.
3. Identify the **flagellum,** the **undulating membrane,** and the **nucleus** in several organisms.

Results

1. In the margin of your lab manual, draw several representative examples of *T. levisi* and several blood cells to show relative cell sizes.
2. Turn to Table 13.5 near the end of this lab topic and list the characteristics, ecological roles, and economic importance of *T. levisi*.

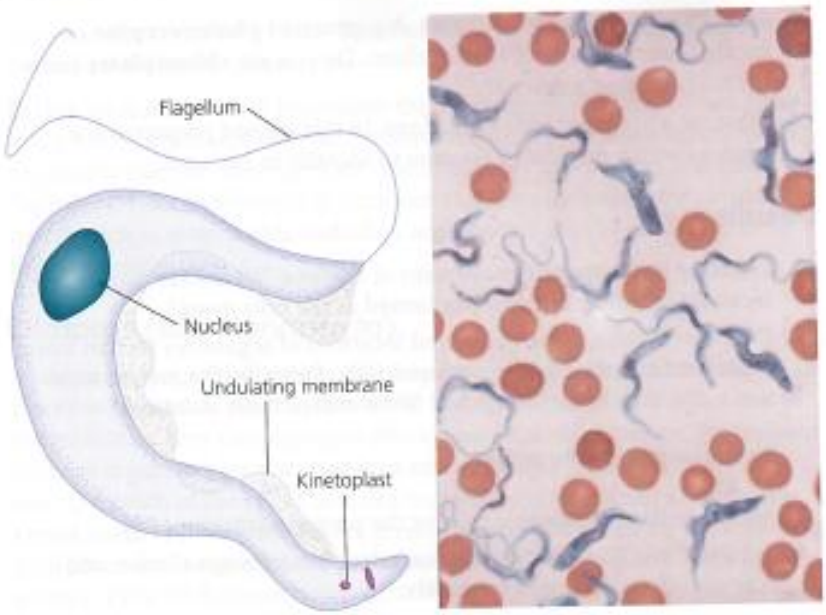


FIGURE 13.1
***Trypanosoma*, a euglenozoan.** (a) *Trypanosma* is a flagellated parasite that lives in the blood of its mammalian host. The flagellum originates near the posterior end, but passes along an undulating membrane to the anterior end. (b) The round cells in this photograph are red blood cells (erythrocytes) in the infected human. Trypanosomes are seen in the plasma surrounding the cells.

Lab Study B. Euglenozoans—Example: *Euglena*

Materials

compound microscope
microscope slides and coverslips
living cultures of *Euglena* sp.
prepared microscope slides of *Euglena* sp.
transfer pipettes
Protoslo, 10% methyl cellulose, or other quieting agent

Introduction

Euglena (Figure 13.2) is an example of a euglenid in the clade Euglenozoa. Most euglenids are unicellular and move using flagella. They may be *autotrophic*, containing chloroplasts and performing photosynthesis, but some may be *heterotrophic* or even *mixotrophic*, absorbing or engulfing nutrients from the environment. Experiments have shown that some species that are normally autotrophic, if grown in darkness, will lose their chloroplasts and become heterotrophic. Perhaps the most distinguishing characteristic of euglenids is the presence of a **pellicle,** made of strips of protein, lying just below the cell membrane. Species of *Euglena* are common in the surface scum of freshwater ponds and slowly moving waters. Some species are elongate and narrow, and others are more rounded. You may see examples of both shapes today in lab.

FIGURE 13.2
***Euglena* sp.** A photoreceptor is seen near the base of the flagellum in each cell. The nucleus appears as the clear area near the center of the cell.

Procedure

1. Place a drop of liquid from the living *Euglena* culture on a clean microscope slide. Add a coverslip and examine on low, intermediate, and high powers using phase contrast if possible. Observe the method and direction of locomotion. To slow cell movement, add a *small* drop of Protoslo or methyl cellulose to the edge of the coverslip and allow it to diffuse under the coverslip.
2. Note the shape of the cells and striations in the cell surface. Where is the **flagellum** located? Describe its movement—whiplash or spiraling? Does it *pull* or *push* the organism through the water?

3. Identify other cellular structures. A pigmented **photoreceptor** is located near the base of the flagellum. Do you see **chloroplasts** and a centrally located **nucleus?**
4. Observe a prepared slide of *Euglena*. In this stained preparation a nucleus with a **nucleolus** is easier to identify in each cell.

Results

1. Describe the shape and movement of *Euglena*. Where are flagella located and where are they positioned as the cells move?
2. Describe the shape, numbers, and locations of organelles seen in living organisms and then in the prepared slide. Describe the surface striations. Are they linear? Irregular? What makes these striations?

   the strips of protein in the pellicle

3. Speculate about a possible role for the photoreceptor.
4. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of euglenids.

EXERCISE 13.2
Supergroup "SAR"

Three clades are included in the SAR supergroup: Stramenopiles, Alveolates, and Rhizarians. These diverse protists were grouped together based on DNA sequence similarities. You will investigate examples of each of these groups in this exercise.

Lab Study A. Stramenopiles—Examples: Diatoms, Brown Algae, and Water Molds

Materials

compound microscope
stereoscopic microscope
slides and coverslips
living cultures of diatoms
transfer pipettes
prepared slides of diatomaceous earth (demonstration only)
demonstration materials of brown algae
agar plate cultures of *Saprolegnia*
prepared slides of *Saprolegnia*
dropper bottles of water
forceps

Introduction

The clade Stramenopila includes diatoms (phylum Bacillariophyta), golden algae (phylum Chrysophyta), brown algae (phylum Phaeophyta), and water molds (phylum Oomycetes). These organisms are grouped in this clade

based on the structure of their flagella (when present). The flagellum has many hairlike lateral projections.

In this lab study you will investigate three examples: diatoms, brown algae, and a water mold, *Saprolegnia*. Diatoms and brown algae are autotrophic organisms that play an important role in primary production in oceans. *Saprolegnia* is a heterotrophic organism that lives in freshwater environments such as quiet ponds and lakes, and is often found growing on dead fish in aquaria.

Diatoms (Bacillariophyta)

Diatoms are important autotrophic organisms in plankton. In fact, they are the most important photosynthesizers in cold marine waters. They can be unicellular, or they can aggregate into chains or starlike groups. Protoplasts of these organisms are enclosed by a cell wall made of silica that persists after the death of the cell. These cell wall deposits are mined as **diatomaceous earth** and have numerous economic uses (for example, in swimming pool filters and as an abrasive in toothpaste and silver polish). Perhaps the greatest value of diatoms, however, is the carbohydrate and oxygen they produce that can be utilized by other organisms. Ecologists are concerned about the effects of acid rain and changing climatic conditions on populations of diatoms and their rate of primary productivity.

Diatom cells are either elongated, boat-shaped, bilaterally symmetrical **pennate** forms or radially symmetrical **centric** forms (Figure 13.3). The cell wall consists of two valves, one fitting inside the other, in the manner of the lid and bottom of a petri dish.

Procedure

1. Prepare a wet mount of diatoms from marine plankton samples or other living cultures.
2. Observe the organisms on low, intermediate, and high powers.

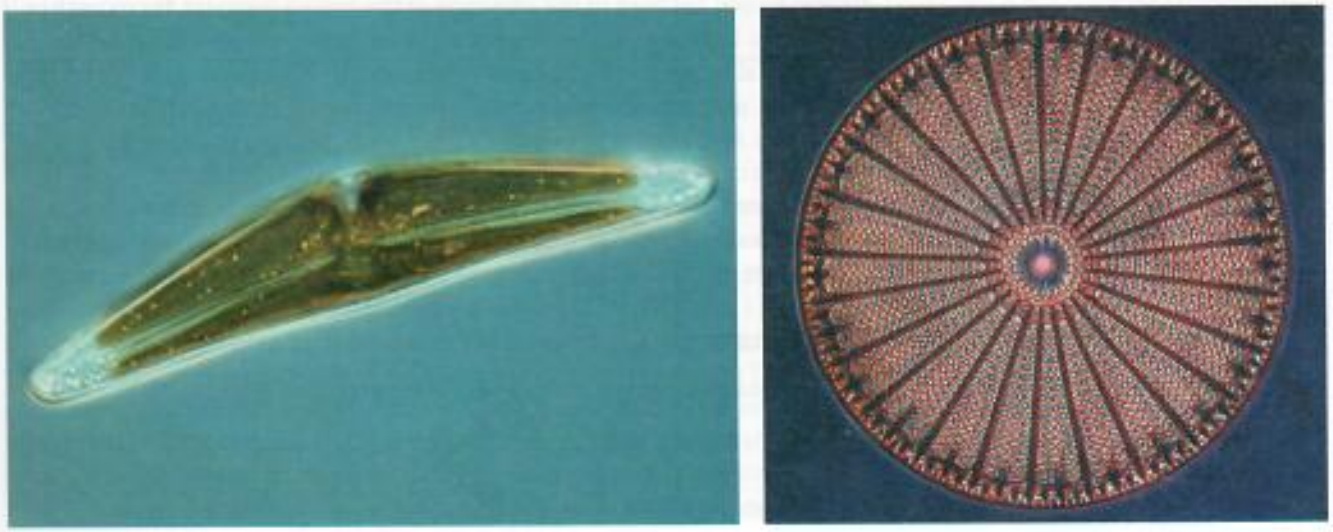


FIGURE 13.3
Diatoms are important autotrophs found in plankton. Many different species and forms exist. All have cell walls made of silica. (a) A bilaterally symmetrical pennate form. (b) A radially symmetrical centric form.

3. Describe the form of the diatoms in your sample. Are they centric, pennate, or both?
4. If you are studying living cells, you may be able to detect locomotion. The method of movement is uncertain, but it is thought that contractile fibers just inside the cell membrane produce waves of motion on the cytoplasmic surface that extends through a groove in the cell wall. What is the body form of motile diatoms?

Some pennate forms demonstrate locomotion.

5. Observe a single centric form on high power and note the intricate geometric pattern of the cell wall. Can you detect the two valves?
6. Look for chloroplasts in living forms.
7. Observe diatomaceous earth on demonstration and identify pennate and centric forms.

Results

1. Sketch several different shapes of diatoms in the margin of your lab manual.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of diatoms.

MB Student Media Videos—Ch. 28: Diatoms Moving: Various Diatoms

Brown Algae (Phaeophyta)

Some of the largest algae, the **kelps,** are brown algae. The Sargasso Sea is named after the large, free-floating brown algae *Sargassum*. These algae appear brown because of the presence of the brown pigment **fucoxanthin** in addition to chlorophyll *a*. Brown algae are perhaps best known for their commercial value. Have you ever wondered why commercial ice cream is smoother in texture than homemade ice cream? Extracts of **algin,** a polysaccharide in the cell wall of some brown algae, are used commercially as thickening or emulsifying agents in paint, toothpaste, ice cream, pudding, and in many other commercial food products. *Laminaria*, known as *kombu* in Japan, is added to soups, used to brew a beverage, and covered with icing as a dessert.

Procedure

We suggest that you have on demonstration some preserved specimen or herbarium mounts of *Fucus* or *Laminaria* and *Sargassum*.

Observe examples of brown algae on demonstration (Figure 13.4).

Results

1. In Table 13.2, list the names and distinguishing characteristics of each brown algal species on demonstration. Compare the examples with those illustrated in Figure 13.4.
2. Turn to Table 13.5 and list the key characteristics, ecological roles, and economic importance of brown algae.

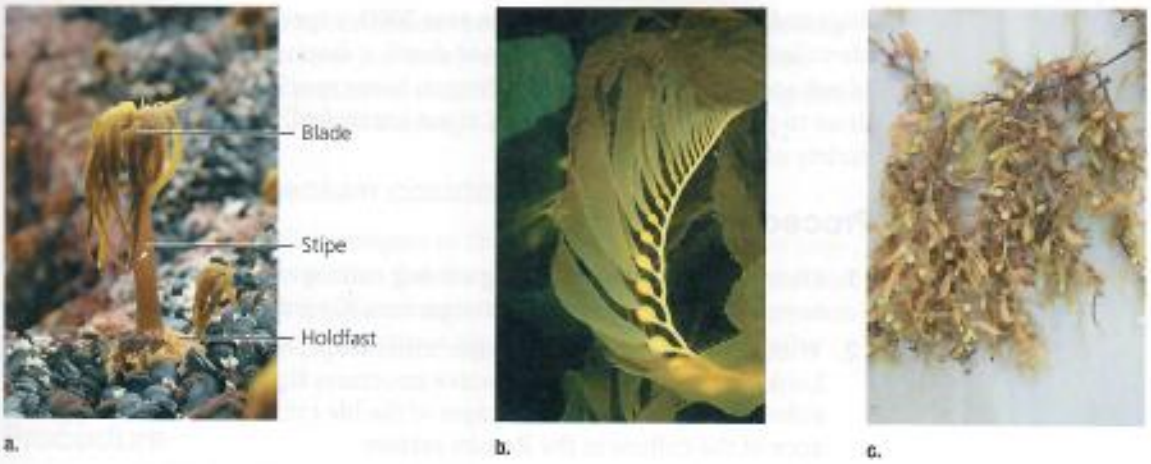


FIGURE 13.4
Examples of multicellular brown algae. The body of a brown alga consists of broad blades, a stemlike stipe, and a holdfast for attachment. These body parts are found in the kelps (a) sea palm (*Postelsia*) and (b) *Nereocystis*. Rounded air bladders for flotation are seen in (c) *Sargassum* and other species of brown algae.

TABLE 13.2 Representative Brown Algae

Name	Body Form (single-celled, filamentous, colonial, leaflike; broad or linear blades)	Characteristics (pigments, reproductive structures, structures for attachment and flotation)

Water Mold *Saprolegnia* (Oomycetes)

Saprolegnia sp. (Figure 13.5) is an example of a water mold, an Oomycete. Water molds were formerly considered to be fungi because the body of these organisms consists of fungus-like hyphae organized into mycelia. (You will learn more about hyphae and mycelia in Lab Topic 17 Fungi.) However, there are key differences between water molds and fungi. For example, cell walls in water molds are made of cellulose, not chitin as in fungi. The most convincing evidence separating water molds from fungi are the molecular and genetic differences. *Saprolegnia* is common in aquaria and quiet ponds, where it may be found growing on dying or dead animals such as insects, fish, and even amphibians. This mode of growth reflects the **saprophytic** nutrition (deriving nutrients by absorption from decaying matter) of most water molds. Other species in this group are **parasites,** living on and harming other organisms (a host). One destructive species of water mold causes *potato late blight*, the plant disease responsible for the Irish potato famine of the mid-1800s, when a million people in Ireland died and a million more

FIGURE 13.5
Saprolegnia. A saprophytic water mold on a decaying goldfish.

migrated to other countries. In the year 2000, a species of water mold was identified as the cause of *sudden oak death*, a disease killing a wide range of oak species in California and Oregon. Some species of water molds continue to plague farmers today and, if not controlled, can be devastating to a variety of crops.

Procedure

1. Obtain a petri dish containing a living culture of *Saprolegnia* and return to your lab bench to study the organism. Keep the dish closed.
2. With the aid of your stereoscopic microscope, examine the culture. Look for hyphae and reproductive structures that may contain spores in either the asexual or sexual stages of the life cycle. Describe the appearance of the culture in the Results section.
3. If directed by your instructor, add a drop of water to a microscope slide and use forceps to remove a portion of the culture and add to the water drop. Add a coverslip. Observe the slide using a compound microscope, first on low and then intermediate and high powers. Describe the appearance of filaments and any reproductive structures. Are reproductive cells present? Make sketches in the Results section.
4. Observe a prepared slide of *Saprolegnia*. Large round reproductive structures may be visible.

Results

1. From your observations, describe the vegetative (nonreproductive) body of *Saprolegnia*. Do you see filaments (hyphae)?
2. Sketch and describe any reproductive structures observed. Did they appear to contain spore-like structures?
3. In Table 13.5, list the characteristics, ecological role, and economic importance of *Saprolegnia*.

Lab Study B. Alveolates—Examples: Paramecia, Dinoflagellates, and *Plasmodium* sp.

Materials

compound microscope
slides and coverslips
cultures of living *Paramecium caudata*
Protoslo or other quieting agent
solution of yeast stained with Congo red
cultures of *Paramecium caudata* that have been fed yeast stained with Congo red (optional)
dropper bottle of 1% acetic acid
transfer pipettes
living cultures or prepared slides of dinoflagellates
microscope slides of *Plasmodium* sp. life cycle
wall charts diagramming the life cycle of *Plasmodium* sp.

Introduction

Alveolates are single-celled organisms; some are heterotrophic, others autotrophic, and still others are parasitic. The common characteristic of all

alveolates is the presence of membrane-bound saclike structures (**alveoli**) packed into a continuous layer just inside and supporting the cell membrane. New groupings of protistans into clades place ciliates, dinoflagellates, and apicomplexans (e.g., *Plasmodium* sp.) in the Alveolates.

A Ciliate—*Paramecium caudatum*

The first example you will investigate in this lab study is *Paramecium caudatum*, a heterotrophic organism that moves about using cilia (short projections from the cell surface). Cilia are generally shorter and more numerous than flagella. Internally both structures are similar in their microtubular arrangement.

Procedure

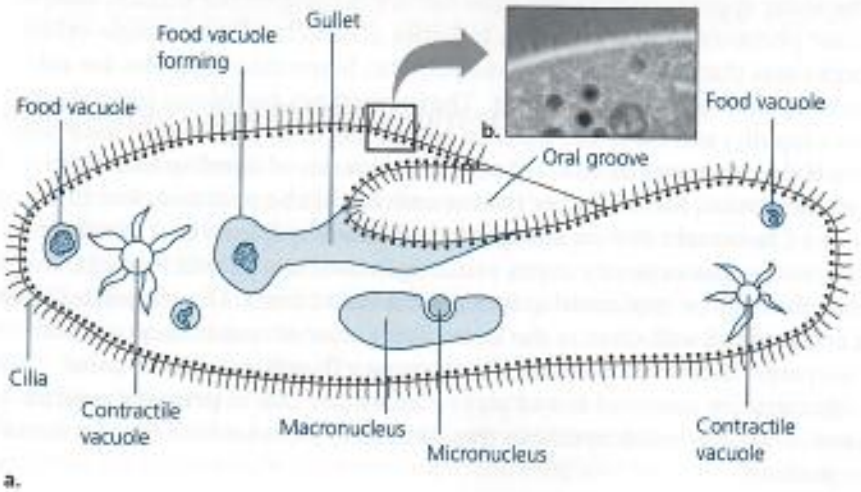
1. Using the compound microscope, examine a living paramecium (Figure 13.6). Place a drop of water from the bottom of the culture on a clean microscope slide. Add a *small* drop of Protoslo or some other quieting solution to the water drop, then add the coverslip.
2. Observe paramecia on the compound microscope using low, then intermediate powers.
3. Describe the movement of a single paramecium. Does movement appear to be directional or is it random? Does the organism reverse direction only when it encounters an object, or does it appear to reverse direction even with no obstruction?
4. Locate a large, slowly moving organism, switch to high power, and identify the following organelles:

   Oral groove: depression in the side of the cell that runs obliquely back to the mouth that opens into a **gullet.**

   Food vacuole: forms at the end of the gullet. Food vacuoles may appear as dark vesicles throughout the cell.

   Macronucleus: large, grayish body in the center of the cell. The macronucleus has many copies of the genome and controls most cellular activities, including asexual reproduction.

   Micronucleus: often difficult to see in living organisms, this small round body may be lying close to the macronucleus. Micronuclei are



a.

FIGURE 13.6
Paramecium. (a) Complete the drawing of a paramecium, labeling organelles and structures. (b) An enlarged view of cilia and the region of alveoli just under the cell membrane.

involved in sexual reproduction. Many species of paramecia have more than one micronucleus.

Contractile vacuole: used for water balance, two of these form, one at each end of the cell. Each contractile vacuole is made up of a ring of radiating tubules and a central spherical vacuole. Your organism may be under osmotic stress because of the Protoslo, and the contractile vacuoles may be filling and collapsing as they expel water from the cell.

You may choose to have students make slides of paramecia that you have fed yeast stained with Congo red 1 to 2 hours before lab.

5. Observe feeding in a paramecium. Add a drop of yeast stained with Congo red to the edge of the coverslip and watch as it diffuses around the paramecium. Study the movement of food particles from the oral groove to the gullet to the formation of a food vacuole that will subsequently move through the cell as the food is digested in the vacuole. You may be able to observe the discharge of undigested food from the food vacuole at a specific site on the cell surface.

Students may need to make a fresh paramecium slide for this activity.

6. Observe the discharge of **trichocysts,** structures that lie just under the outer surface of the paramecium. When irritated by a chemical or attacked by a predator, the paramecium discharges these long thin threads that may serve as a defense mechanism, as an anchoring device, or to capture prey. Make a new slide of paramecia. Add a drop of 1% acetic acid to the edge of the coverslip and carefully watch a paramecium. Describe the appearance of trichocysts in this species.

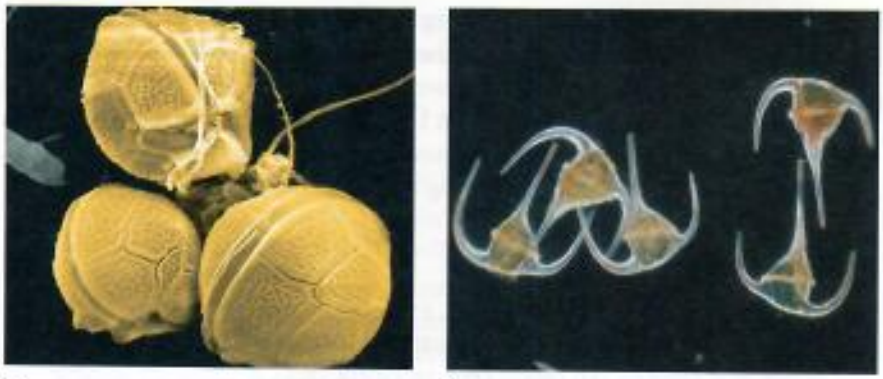
Results

1. Complete the drawing of a paramecium (Figure 13.6), labeling all the organelles and structures shown in bold in the text.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of paramecia.

Student Media Videos—Ch. 28: *Paramecium* Vacuole: *Paramecium* Cilia

Dinoflagellates

Swirl your hand through tropical ocean waters at night and you may notice a burst of tiny lights. Visit a warm, stagnant inlet and you might notice that the water appears reddish and dead fish are floating on the surface. Both of these phenomena may be due to activities of dinoflagellates—single-celled organisms that are generally photosynthetic. Some dinoflagellates are able to bioluminesce, or produce light. They sometimes can *bloom* (reproduce very rapidly) and cause the water to appear red from pigments in their bodies. If the organisms in this "red tide" are a species of dinoflagellate that releases toxins, fish and other marine animals can be poisoned. Red tides in the Chesapeake Bay are thought to be caused by *Pfiesteria*, a dinoflagellate that produces deadly toxins resulting in invertebrate and fish kills, and that also may be implicated in human illness and death. Dinoflagellates have a cellulose cell wall often in the form of an armor of numerous plates with two perpendicular grooves, each containing a flagellum. Most of these organisms are autotrophic and play an important role in **primary production** in oceans—photosynthesis that ultimately provides food for all marine organisms.



a. b.

FIGURE 13.7
Dinoflagellates. (a) In this SEM the cellulose plates of the cell wall are visible. Note also the two perpendicular grooves, each containing a flagellum. (b) Note the elongated spines of the cell wall plates in this species.

Dinoflagellates have traditionally been considered algae, but they are now thought to share a common ancestor with ciliates, as evidenced by the presence of alveoli.

Procedure

1. Obtain a prepared slide or make a wet mount of dinoflagellates (Figure 13.7).
2. Focus the slide on low power and attempt to locate the cells. You may have to switch to intermediate power to see them.
3. Switch to high power.
4. Identify the perpendicular **grooves** and the **cellulose plates** making up the cell wall. Are the plates in your species elongated into spines? **Flagella** may be visible in living specimens.

If you are using living dinoflagellates, have students add a drop of Protoslo or other quieting agent such as 10% methyl cellulose to their preparations.

Results

1. Draw several examples of cell shapes in the margin of your lab manual. Note differences between the species on your slide and those in Figure 13.7.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of dinoflagellates.

MB Student Media Video—Ch. 28: Dinoflagellate

Apicomplexan—*Plasmodium* sp.

Other protists included in the clade Alveolates are apicomplexans, named from the complex of organelles in the apex of the cell. Most apicomplexans are parasitic, they have no means of locomotion, and their reproductive structures are called spores. Included in this group are organisms in the genus *Plasmodium*. This protist has played an important role in human health worldwide. At least five species in this genus can infect humans, causing the devastating disease malaria. These organisms have a complex life cycle that alternates between female *Anopheles* mosquitos and humans. When an infected mosquito bites a person, the parasite is injected into the human, first entering the bloodstream, then passing to the liver, and then moving back

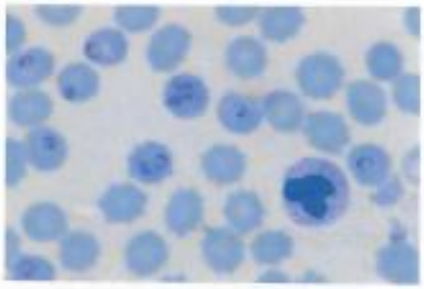


FIGURE 13.8
***Plasmodium* sp.** This parasite is seen in red blood cells in this photomicrograph of a human blood smear.

to the bloodstream, ultimately infecting the red blood cells. Sexual stages in the life cycle are transmitted back to the mosquito when it bites the infected human, continuing the life cycle. You will observe a prepared slide of *Plasmodium* sp. in the blood of the human host. Depending on the stage of the life cycle on your slide, the parasites may be seen among the red blood cells or within the red blood cells, appearing as a ring-like structure.

Procedure

1. Using the compound microscope, examine a prepared slide of *Plasmodium* sp. (Figure 13.8). Begin with the lowest power on your microscope and identify red blood cells (erythrocytes).
2. Increase the magnification, focusing and scanning the slide with each magnification increase. Examine carefully, looking first outside the red blood cells, and then look for cells with darker granules inside.
3. Consult diagrams of the *Plasmodium* life cycle posted in your lab room or in your text to help identify the stage observed on your slide.

Results

1. In the margin of your lab manual, sketch a view of your slide showing several red blood cells and parasites.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of *Plasmodium* sp.

Lab Study C. Rhizarians—Examples: Foraminiferans and Radiolarians

Materials

compound microscope
prepared slides of foraminiferans
prepared slides of radiolarian skeletons (demonstration only)

Introduction

Rhizarians include foraminiferans, radiolarians, and cercozoans, closely related groups composed of ameboid, heterotrophic organisms with **threadlike pseudopodia** or cellular extensions used in feeding and, in some species, locomotion. You will study examples of foraminiferans and radiolarians.

Foraminiferans

Foraminiferans, commonly called **forams,** are another example of organisms that move and feed using pseudopodia. Forams are marine planktonic (freely floating) or benthic (bottom-dwelling) organisms that secrete a calcium carbonate shell-like *test* (a hard outer covering) made up of chambers. In many species, the test consists of chambers secreted in a spiral pattern, and the organism resembles a microscopic snail. Although most forams are microscopic, some species, called *living sands*, may grow to the size of several centimeters, an astounding size for a single-celled protist. Threadlike pseudopodia extend through special pores in the calcium carbonate test.

The test can persist after the organism dies, becoming part of marine sand. Remains of tests can form vast limestone deposits.

Procedure

1. Obtain a prepared slide of representative forams (Figure 13.9).
2. Observe the organisms first on the lowest power of the compound microscope and then on intermediate and high powers.
3. Note the arrangement and attempt to count the number of chambers in the test. In most species, the number of chambers indicates the relative age of the organism, with older organisms having more chambers. Which are more abundant on your slide, older or younger organisms?

   Chambers can be arranged in a single row, in multiple rows, or wound into a spiral. Protozoologists determine the foram species based on the appearance of the test. Are different species present?

Results

1. Sketch several different forams in the margin of your lab manual. Note differences in the organisms on your slide and those depicted in Figure 13.9.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of forams.

Radiolarians

The **radiolarians** studied here are common in marine plankton. They secrete skeletons of silicon dioxide that can, as with the forams, collect in vast deposits on the ocean floor. Their threadlike pseudopodia, called **axopodia,** extend outward through pores in the skeleton in all directions from the central spherical cell body.

Procedure

1. Observe slides of radiolarians on demonstration (Figure 13.10).
2. Observe the size and shape of the skeletons and compare your observations with Figure 13.10.

Results

1. Sketch several different radiolarians skeletons in the margin of your lab manual, noting any differences between the organisms on demonstration and those in the figure.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of radiolarians.

EXERCISE 13.3
Supergroup Unikonta

The supergroup Unikonta includes many diverse organisms with their phylogenetic relationships supported by molecular systematics. Fungi and animals are included in this supergroup and will be studied in subsequent

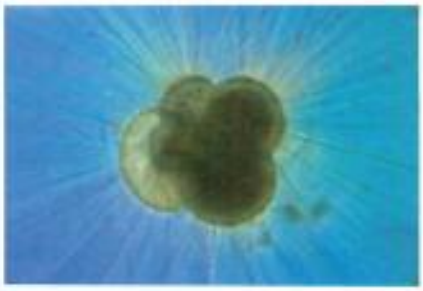


FIGURE 13.9
Forams. These heterotrophic organisms move using threadlike pseudopodia. Their shell-like tests are made of calcium carbonate.

The best way to teach this lab is to have living organisms available. If you are fortunate enough to live near the ocean, you will easily find radiolarians in plankton and forams in plankton and in benthic samples. You may also find radiolarians in plankton from freshwater ponds. The study of plankton tows and bottom samples will be much more exciting than the study of prepared slides, although the slides ensure that students see all organisms. If plankton is available, we suggest that you begin with prepared slides, then have students study the plankton. Add a few drops of formaldehyde to plankton samples if you must keep them longer than a couple of hours.

If samples of Indiana limestone are available, foram fossils can be seen with a stereoscopic microscope.

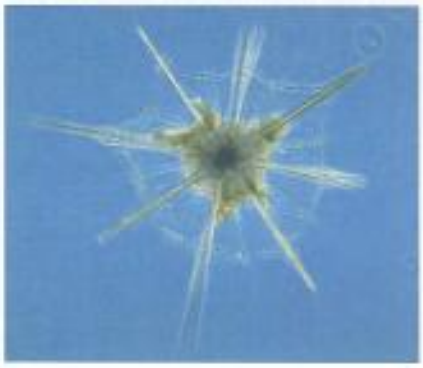


FIGURE 13.10
Radiolarians. These organisms are supported by a skeleton of silicon dioxide. They use threadlike pseudopodia to obtain food.

lab topics. Examples studied in this exercise are protists in the clade Amebozoans. These organisms have pseudopodia as do foraminifera and radiolarians, but the structure is different. Rather than threadlike pseudopodia, amebozoans' pseudopodia are *lobe-shaped*. Based on their ameboid characteristics, their phagocytic mode of obtaining nutrition, and molecular systematics, both amoeba and slime molds are included in the clade **Amoebozoa.**

Lab Study A. Amoebozoan Tubulinids—Example: *Amoeba*

Materials

cultures of *Amoeba proteus* (if amoeba were not studied in Lab Topic 2)
compound microscope
slides and coverslips
stereoscopic microscope

FIGURE 13.11
Amoeba proteus. These organisms use lobed-shaped pseudopodia to move and ingest food.

Amoeba

In Lab Topic 2, you studied *Amoeba proteus*, a protozoan species of organisms that move using lobed-shaped pseudopodia (Figures 2.6 and 13.11). Amoeba have no fixed body shape and they are naked; that is, they do not have a shell. Different species may be found in a variety of habitats, including freshwater and marine habitats. Recall that pseudopodia are cellular extensions. As the pseudopod extends, endoplasm flows into the extension. By extending several pseudopodia in sequence and flowing into first one and then the next, the amoeba proceeds along in an irregular, slow fashion. Pseudopodia are also used to capture and ingest food. When a suitable food particle such as a bacterium, another protist, or a piece of detritus (fragmented remains of dead organisms) contacts an amoeba, a pseudopod will flow completely around the particle and take it into the cell by phagocytosis.

If you did not observe *Amoeba proteus* or some other naked amoeba in Lab Topic 2, use the following procedure to observe these organisms.

Procedure

1. Obtain a drop of water containing living *Amoeba* (Figure 13.11) from the class culture.
2. To transfer a specimen to your slide, follow these procedures:
   a. Use the dissecting microscope to focus on the bottom of the dish. The amoeba will appear as a whitish, irregularly shaped organism attached to the bottom.
   b. Transfer a drop with several amoebas to your microscope slide.
   c. Cover your preparation with a clean coverslip.
3. Observe the amoeba using your compound microscope.
   a. Scan the slide at low power to locate an amoeba. Center the specimen in your field of view; then switch to higher powers.
   b. The following structures may be seen in the amoeba: **endoplasm** is the granular cytoplasm containing the cell organelles. **Contractile vacuoles** are clear, spherical vesicles of varying sizes that gradually

enlarge as they fill with excess water. These vacuoles serve an excretory function for the amoeba. **Food vacuoles** are small, dark, irregularly shaped vesicles within the endoplasm. They contain undigested food particles. You may observe movement by **pseudopodia** and perhaps **phagocytosis.**

An amoeba video is available at http://www.microscopy.fsu.edu/moviegallery/pondscum/protozoa/amoeba/

MB Student Media Videos—Ch. 28: Amoeba; Amoeba Pseudopodia

Lab Study B. Amoebozoan Slime Molds—Examples: *Physarum* and *Dictyostelium*

Materials

stereoscopic microscope
Physarum growing on agar plates
Dictyostelium growing on agar plates

Introduction

William Crowder, in a classic *National Geographic* article (April 1926) describes his search for strange creatures in a swamp on the north shore of Long Island. This is his description of his findings: "Behold! Seldom ever before had such a gorgeous sight startled my unexpectant gaze. Spreading out over the bark [of a dead tree] was a rich red coverlet . . .consisting of thousands of small, closely crowded, funguslike growths. . . . A colony of these tiny organisms extended in an irregular patch . . . covering an area nearly a yard in length and slightly less in breadth. . . . Each unit, although actually less than a quarter of an inch in height, resembled . . . a small mushroom, though more marvelous than any I have ever seen."

The creatures described by Crowder are heterotrophic organisms called **slime molds.** They have been called plants, fungi, animals, fungus animals, protozoa, Protoctista, Protista, Mycetozoa, and probably many more names. Classifying slime molds as fungi (as in previous classification schemes) causes difficulties because whereas slime molds are phagocytic like protozoa, fungi are never phagocytic but obtain their nutrition by absorption. Characteristics other than feeding mode, including cellular ultrastructure, cell wall chemistry, and other molecular characteristics, indicate that slime molds fit better with the ameboid protists than with the fungi. These studies suggest that slime molds descended from unicellular amoeba-like organisms.

There are two types of slime molds, plasmodial slime molds and cellular slime molds. In this lab study, you will observe the plasmodial slime mold *Physarum* and the cellular slime mold *Dictyostelium.* In a plasmodial slime mold the vegetative stage is called a **plasmodium,** and it consists of a multinucleate mass of protoplasm totally devoid of cell walls. This mass feeds on bacteria as it creeps along the surface of moist logs or dead leaves. When conditions are right, it is converted into one or more reproductive structures, called **fruiting bodies,** that produce spores.

FIGURE 13.12

Plasmodial slime mold. Slime molds are protists that share some characteristics with both protozoa and fungi. The vegetative stage of a plasmodial slime mold includes an amoeboid phase consisting of a multinucleate mass known as a plasmodium.

You can expand your *Physarum* cultures by transferring pieces of the stock culture to sterile petri dishes of 1% water agar. Add a few flakes of oatmeal. Then students can use these for their independent investigations.

Physarum—A Plasmodial Slime Mold

Procedure

1. Obtain a petri dish containing *Physarum* and return to your lab bench to study the organism. Keep the dish closed.
2. With the aid of your stereoscopic microscope, examine the plasmodium (Figure 13.12). Describe characteristics such as color, size, and shape. Look for a system of branching veins. Do you see any movement? Speculate about the source of the movement. Is the movement unidirectional or bidirectional—that is, flows first in one direction and then in the other? Your instructor may have placed oat flakes or another food source on the agar. How does the appearance of the plasmodium change as it contacts a food source?

   The plasmodia do not have a definite size or shape. *Physarum* plasmodia are often yellow. A network of veins is visible, and protoplasmic streaming may be seen in the veins. The streaming can be very rapid in one direction for a minute or so, then it slows, stops, and flows in the opposite direction. The plasmodium pools around the oat flakes.

3. Examine the entire culture for evidence of forming or mature fruiting bodies. Are the fruiting bodies stalked or are they sessile, that is, without a stalk? If a stalk is present, describe it.

   Physarum cinereum has sessile fruiting bodies; *P. polycephalum* has gyrose, stalked fruiting bodies.

Results

1. Sketch the plasmodium and fruiting bodies in the margin of your lab manual. Label structures where appropriate.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of slime molds.

MB Student Media Videos—Ch. 28: Plasmodial Slime Mold Streaming; Plasmodial Slime Mold

Dictyostelium—A Cellular Slime Mold

Like the plasmodial slime molds, the natural habitat of cellular slime molds is the forest floor, living on bacteria on decaying logs or dead leaves. Unlike plasmodial slime molds in which the feeding stage is a *multinucleate* plasmodium, cellular slime molds consist of *individual ameboid cells* that function independently under optimum conditions. However, when food is scarce, individual cells will begin to migrate toward a central cell, probably directed by a chemical secretion. Cells continue to aggregate, forming a "pseudoplasmodium"—an aggregation that migrates as a unit until a suitable food supply is located. Once this is found, the aggregation dramatically develops into a fruiting body that produces asexual spores. When these spores are released from the fruiting body they develop into individual ameboid cells. Watch amazing videos of this process at http://youtube/vjRPla0BONA and www.youtube.com/watch?v=V51t5cC4yAU.

Procedure

1. Obtain an agar plate containing *Dictyostelium* (Figure 13.13) and return to your lab bench to examine the organism. Keep the dish closed.
2. With the aid of your stereoscopic microscope, examine the aggregation of cells. Describe characteristics of the aggregate such as color, size, and shape.
3. Examine the entire culture for evidence of migrating cells—trails through the mass of cells that may be pathways.
4. Look for evidence of forming or mature fruiting bodies. Describe the color, size, and shape of these. Where are they located in the aggregate? Do the fruiting bodies have a stalk or are they sessile? If a stalk is present, describe it.

FIGURE 13.13
Cellular slime mold *Dictyostelium*. The feeding stage is a multinucleate plasmodium consisting of individual ameboid cells.

Results

1. Sketch an aggregate and any fruiting bodies in the margin of your lab manual. Label structures observed.
2. Turn to Table 13.5 and list the characteristics, ecological roles, and economic importance of cellular slime molds.

EXERCISE 13.4
Supergroup Archaeplastida

Supergroup Archaeplastida includes the protistan groups red algae and green algae, and land plants. In this exercise you will investigate examples of red algae and two groups of green algae, chlorophytes and charophytes.

Lab Study A: Red Algae (Rhodophyta)

Materials

examples of red algae on demonstration

Introduction

The simplest red algae are single celled, but most species have a macroscopic, multicellular body form. The red algae, unlike all the other algae, do not have flagella at any stage in their life cycle. Some scientists suggest that the red algae represent a monophyletic (having a single origin) group and should be placed in their own kingdom. Red algae are autotrophic, containing chlorophyll *a* and the accessory pigments **phycocyanin** and **phycoerythrin** that often mask the chlorophyll, making the algae appear red. These pigments absorb green and blue wavelengths of light that penetrate deep into ocean waters. Many red algae also appear green or black or even blue, depending on the depth at which they are growing. Because of this, color is not always a good characteristic to use when determining the classification of algae. Recall that in Lab Topic 12 you grew bacteria and fungi on plates of agar. This substance, **agar,** is a polysaccharide extracted from the cell wall of red algae. Another extract of red algae cell

We suggest that you have on demonstration preserved specimen or herbarium mounts of *Agardhiella*, coralline algae, *Polysiphonia*, or *Porphyra*. We do not require that students memorize names of the demonstration materials, or even characteristics of the examples, because many of the latter are variable and the most consistent distinguishing characteristics are related to microscopic and biochemical features and details of life cycles. The value of this activity is that students appreciate the diversity within and among the groups and the difficulty faced by those attempting to classify organisms. The structure of the algae may give evidence of the ecology and distribution of groups.

walls, **carrageenan,** is used to give the texture of thickness and richness to foods such as dairy drinks and soups. In Asia and elsewhere, the red algae *Porphyra* (known as *nori*) are used as seaweed wrappers for sushi. The cultivation and production of *Porphyra* constitute a billion-dollar industry.

Procedure

Observe the examples of red algae that are on demonstration (Figure 13.14).

Results

1. In Table 13.3, list the names and distinguishing characteristics of the red algae on demonstration. Compare the demonstration examples with those illustrated in Figure 13.14.
2. Turn to Table 13.5 and list the key characteristics, ecological roles, and economic importance of red algae.

a.

b.

c.

FIGURE 13.14
Examples of multicellular red algae (phylum Rhodophyta). (a) Some red algae have deposits of carbonates of calcium and magnesium in their cell walls and are important components of coral reefs. (b) Most red algae have delicate, finely dissected blades. (c) *Porphyra* (or *nori*) is used to make sushi.

TABLE 13.3 Representative Red Algae

Name	Body Form (single-celled, filamentous, colonial, leaflike)	Characteristics (reproductive structures, structures for attachment or flotation, pigments)

Lab Study B. Green Algae (Chlorophyta and Charophyta)—The Protist–Plant Connection

Materials

compound microscope
microscope slides and coverslips
transfer pipettes
living cultures and prepared slides of *Chlamydomonas* sp.
cultures or prepared slides of *Spirogyra* sp.
living or preserved *Ulva lactuca*
living or preserved *Chara* sp.

Introduction

The green algae are photosynthetic organisms divided into two main groups, chlorophytes and charophytes. These groups include the largest numbers of algal species and perhaps the most important from both ecological and evolutionary perspectives. You can find examples of unicellular, motile and nonmotile, colonial, filamentous, and multicellular species that inhabit both freshwater and marine environments. All green algae share some characteristics with land plants (for example, the storage of the starch amylase and the presence of chlorophylls *a* and *b*), but it is the charophytes that are considered to be most closely related to land plants because of several unique similarities. The method of cell wall formation during cell division, the organization of proteins that synthesize cellulose, and the structure of sperm, when present, are all similarities in charophytes and land plants. Results of recent work in nuclear and chloroplast DNA sequencing confirm the close relationship between charophytes and land plants, and have led some scientists to propose that charophytes be included in the Plant kingdom.

Green algae play an important ecological role as primary producers, providing food for animals in aquatic ecosystems; and organisms in one genus, *Ulva*, commonly called sea lettuce, are eaten by humans in salads and cooked in soups. Because of the rapid reproductive rate of some green algae, particularly those in the genus *Chlorella*, some scientists have proposed the use of these green algae for biofuels and for human and livestock food. *Chlorella* has been shown to be a good source of proteins, fats, and carbohydrates, and small chlorella "farms" have been established in various countries. The discovery of a "*Chlorella* growth factor" that is reported to stimulate growth and wound repair in animals has led to the formation of a multibillion-dollar segment of the health food industry.

In this lab study you will view several body forms of green algae: single-celled, filamentous, colonial, and multicellular. Finally, you will observe the multicellular, branched green algae *Chara* (the stonewort), believed to be most similar to the green algae that gave rise to land plants over 475 million years ago.

If you completed Lab Topic 2 Microscopes and Cells, you may remember observing aggregates of single-celled algae, *Protococcus*, and the spherical green algae *Volvox*. Your instructor may ask you to review your notes and drawings from Lab Topic 2. In this lab study you will observe the single-celled green algae *Chlamydomonas*, the filamentous alga *Spirogyra*, and the multicellular algae *Ulva* (chlorophyte) and *Chara* (charophyte) (Figures 13.15 and 13.16).

Chlamydomonas—A Unicellular Chlorophyte

Chlamydomonas in the group Chlorophyta is a unicellular green algae that swims with two flagella (Figure 13.15a). There are many species in this genus that are distributed in moist soil, ponds, and other freshwater habitats, and in marine environments.

Procedure

1. Place a drop of liquid from the *Chlamydomonas* class culture on a clean microscope slide and add a coverslip.
2. Observe the organisms using the compound microscope on low, intermediate, and high powers using phase contrast if possible.
3. Describe the shape of individual cells and the swimming pattern. Look for the two flagella. Where are they attached to the cell? Do they appear to pull or push the cell through the water?
4. Identify organelles in the cytoplasm. The clear **nucleus** may be visible with phase contrast. Each cell has a large cup-shaped **chloroplast** containing a proteinaceous body surrounded by starch granules called a **pyrenoid.** A pigmented **photoreceptor** may be visible inside the chloroplast.
5. Examine a prepared slide of *Chlamydomonas*, and identify the **flagella, chloroplast, pyrenoid,** and **nucleus** in each cell if possible.

Spirogyra—A Filamentous Chlorophyte; *Ulva*—A Multicellular Chlorophyte

Procedure

1. Using your compound microscope, observe living materials or prepared slides of the filamentous alga *Spirogyra* (Figure 13.15b). This organism is common in small, freshwater ponds. The most obvious structure in the cells of the filament is a long chloroplast. Can you determine how the alga got its name? Describe the appearance of the chloroplast.

   Can you see a nucleus in each cell of the filament?

a.

b.

c.

FIGURE 13.15

Examples of chlorophytes. (a) *Chlamydomonas*, a unicellular chlorophyte. (b) A filamentous green alga, *Spirogyra*. (c) Some green algae are multicellular, as in *Ulva*, sea lettuce.

2. Observe the living or preserved specimen of *Ulva* sp., commonly called sea lettuce (Figure 13.15c). This multicellular alga is commonly found on rocks or docks in marine and brackish water and is used as food in some cultures.
   a. Describe the appearance and body form of *Ulva*.

      The body is a bright-green, very thin, broad and flat blade.

   b. Are structures present that would serve to attach *Ulva* to its substrate (dock or rock)? If so, describe them.

      A small multicellular holdfast that attaches the blade to the substrate may be present.

   c. Compare your specimen of *Ulva* with that shown in the figure.

Chara—A Multicellular Charophyte

Living *Chara* may be available from local lakes.

Procedure

1. Examine the living or preserved specimen of the multicellular green alga *Chara* (Figure 13.16). This alga grows in muddy or sandy bottoms of clear lakes or ponds. Its body form is so complex that it is often mistaken for a plant, but careful study of its structure and reproduction confirms its classification as a green alga.
2. Note the cylindrical branches attached to nodes. Compare your specimen to Figure 13.16. Sketch the appearance of your specimen in the margin of your lab manual.

Results

1. In Table 13.4, list the names and distinguishing characteristics of each green algal species studied. Compare these examples with those illustrated in Figures 13.15 and 13.16.
2. Turn to Table 13.5 and list the key characteristics, ecological roles, and economic importance of green algae.

FIGURE 13.16
***Chara* is a multicellular charophyte.** Algae in this group are believed to be similar to the green algae that gave rise to land plants.

TABLE 13.4 Representative Green Algae

Name	Body Form (single-celled, filamentous, colonial, leaflike)	Characteristics (pigments, specialized structures, flagella, structures for attachment)
Chlamydomonas		
Spirogyra		
Ulva		
Chara		

Discussion

1. Describe the mechanism for feeding in amoeboid, flagellated, and ciliated protozoans.

   Amoeboid protozoa feed by phagocytosis. Flagellated protozoa may simply take up organic carbon or nitrogen compounds by simple diffusion or active transport, or some species use phagocytosis in special regions of the cell. Ciliated protozoa often have an elaborate oral groove and cell "mouth" through which food passes by phagocytosis. Cilia move the food down the groove to the mouth region.

2. How do you think amoeboid organisms with skeletons, such as the radiolarians, move food to their cell bodies?

   The pseudopodia that protrude through skeletal pores engulf the food by phagocytosis. Food vacuoles can be detected moving along the long, slender pseudopodia.

3. Compare the appearance and rate of locomotion in amoeboid, flagellated, and ciliated organisms observed in this exercise.

   Amoeboid movement, as in *Amoeba proteus*, is slow and irregular, with many pseudopodia being extended in sequence. Flagellates (example, *Euglena*) move rapidly by beating or undulating the flagella, often giving the appearance of irregular movement. Ciliates (example, *Paramecium*) move rapidly with a gliding motion, the body rotating as it swims.

4. Describe mechanisms for defense in the organisms studied.

   Mechanisms for defense include the trichocysts that may play a defensive role in ciliates. In some cases, protozoa retreat when threatened. Some (forams, radiolarians) secrete protective shells.

5. Single-celled protists use several strategies to protect or maintain the shape of their cells. This is illustrated in *Euglena*, diatoms, *Paramecium*, and dinoflagellates. How is cell shape maintained in these organisms?

   - Euglena has a pellicle, made of strips of protein, inside the cell membrane.
   - Diatoms have a cell wall made of silica outside the cell membrane.
   - The cell shape of Paramecium is impacted by alveoli packed into a continuous layer just inside the cell membrane.
   - Dinoflagellates have a cellulose cell wall outside the cell membrane, often in the form of an armor of plates.

6. What is one characteristic that you could observe under the microscope to distinguish diatoms and dinoflagellates?

two grooves with flagella for dinoflagellates; etched cell walls for diatoms

7. Slime molds were once placed in the kingdom Fungi. What characteristics suggest that these organisms are protistan?

phagocytic mode of nutrition, cellular ultrastructure

8. What important ecological role is shared by the macroscopic algae (green, red, and brown)?

primary production

9. Based on your observations in the laboratory, what two characteristics might you use to distinguish brown and red algae?

pigmentation and body form

10. What characteristics of green algae have led scientists to conclude that this group includes the ancestors of land plants, most likely the charophytes?

Shared characteristics include storage of amylase and the presence of chlorophylls *a* and *b*. Plants share with the charophytes similarities in cell wall formation during cell division, as well as similarities in cellulose synthesis. Molecular evidence from ribosomal and transfer RNA gene studies support this conclusion.

EXERCISE 13.5

Designing and Performing an Open-Inquiry Investigation

Many students race through the activities in this lab topic and have ample time to design an interesting investigation. This may not be true for your students. The independent investigation could take place in a subsequent lab, or this section can be omitted entirely. Alternatively, consider having students design an investigation and prepare a proposal as part of the writing program.

Materials

protozoa and algae cultures
cultures of slime molds *Physarum, Didymium, Dictyostelium*
cultures of *Saprolegnia*
sterile agar plates
sterile agar with oat flakes
sterile agar with sugar
sterile agar with albumin
sterile agar with pH 6, 7, or 8
pH solutions, pH 6, 7, or 8
aluminum foil
small lamps
aquarium mold retardants from pet store
culture media for *Paramecium*
ice
Chrysanthemum and *Yucca* plants
commercial chemicals that may control water mold