Exercise 25

Survey of Protists

The Algae

Learning Objectives

By the end of this exercise you should be able to:

1. Discuss the distinguishing features of different groups of algae.
2. Appreciate the economic importance of algae.
3. Outline the events of "alternation of generations" in green algae.

MULTI-MEDIA Please visit www.mhhe.com/vodopich10e to review multi-media resources tailored to this lab.

This exercise begins your study of **domain Eukarya.** Specifically, you'll begin studying the diverse phyla of protists. **Eukaryotes** are organisms composed of cells having membrane-bound nuclei. This domain is commonly divided into three well-defined kingdoms—Fungi, Animalia, Plantae—along with a group of organisms with diverse origins called protists. In a sense, **protists** include all eukaryotes that lack the distinguishing characteristics of fungi, animals, or plants. Protists live in moist habitats and include simple eukaryotes such as amoebas, as well as multicellular organisms such as the brown alga, kelp.

Fungi have cell walls and are heterotrophic. **Heterotrophic** organisms feed on organic matter produced by other organisms because they cannot make their required organic compounds from inorganic substances; that is, heterotrophs require organic nutrients produced by other organisms.

Animals are ingestive-feeding heterotrophs that lack cell walls and can respond rapidly to external stimuli. Animals are multicellular.

Plants are multicellular, **autotrophic** organisms, meaning that they can synthesize all required organic compounds from inorganic substances using external energy, usually sunlight.

Protists share two common characteristics: They are most abundant in moist habitats, and most of them are microscopic in size. But diversity of protists is immense (fig. 25.1). Despite shared features, modern phylogenetic analyses based on comparative analysis of DNA sequences and cellular features reveal that protists are not a well-defined, monophyletic group. Protists probably share common ancestry with fungi, plants, and animals. The diversity of protists clearly makes understanding their phylogeny and taxonomy a challenge. Currently, we classify protist phyla into several eukaryotic **supergroups** that each display distinctive features (table 25.1). Notice that one of these supergroups contains several phyla of protists sharing common ancestry with plants, while another supergroup links certain protists to the animal and fungal kingdoms.

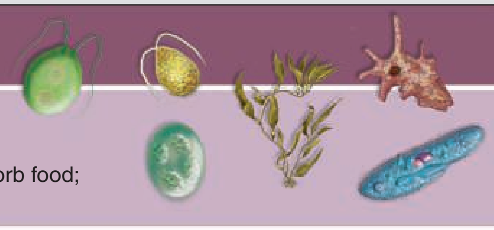
Protists may be conveniently grouped according to ecological roles as algae, protozoa, and funguslike protists. You will study algae in this exercise and protozoa and slime molds in the next exercise. The term **algae** (Latin for "seaweeds") applies to about 10 phyla of protists that are predominantly photosynthetic species. Despite the common feature of photosynthesis, algae do not form a monophyletic group descended from a single common ancestor. They are polyphyletic (i.e., they have more than one common ancestor), and the details of their phylogenies are still being discovered.

INTRODUCTION TO ALGAE

One way to determine the importance of something is to remove it and see what happens. If we did that with algae most people would be shocked by the result. Global oxygen production would immediately decline. A major food source, perhaps *the* major food source for the world's ecosystems, would be gone. Tens of thousands of irreplaceable algal species would be lost, along with their unique diversity of potentially useful chemicals, many with pharmaceutical value. The absence of algae would lead to rapid extinction of many hundreds of thousands of invertebrate animal species. Ecosystems would collapse. Fortunately we won't lose algae anytime soon; they have thrived for 1.5 billion years.

Algae are photosynthetic, eukaryotic organisms typically lacking multicellular sex organs. The major groups of algae are distinguished in part by their energy storage products, cell walls, and color, resulting from the type and abundance of colored **pigments** (substances that absorb light) in their plastids (table 25.2). Biologists often group algae by the colors of these pigments—for example, green algae, brown algae, and red algae.

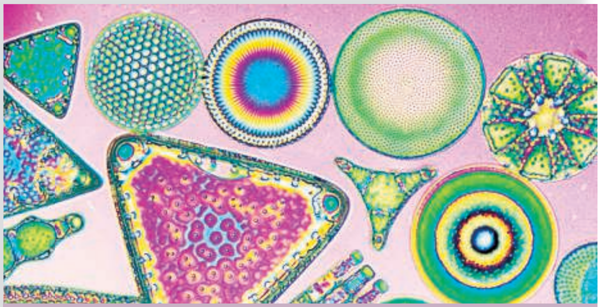
DOMAIN: Eukarya
Protists



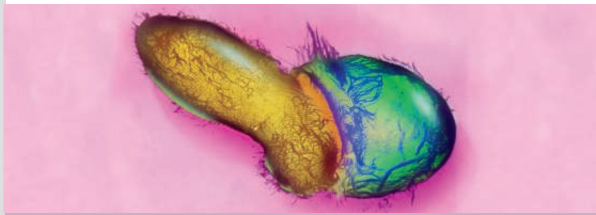
CHARACTERISTICS

Usually a complex single cell; photosynthesize, ingest, or absorb food; haploid life cycle

Supergroup	Members	Distinguishing Features
Archaeplastids	Green algae, red algae, land plants, charophytes	Plastids; unicellular, colonial, and multicellular
Chromalveolates	Stramenopiles: brown algae, diatoms, golden brown algae, water molds Alveolates: ciliates, apicomplexans, dinoflagellates	Most with plastids; unicellular and multicellular Alveoli support plasma membrane; unicellular
Excavates	Euglenids, kinetoplastids, parabasalids, diplomonads	Feeding groove; unique flagella; unicellular
Amoebozoans	Amoeboids, plasmodial and cellular slime molds	Pseudopods; unicellular
Rhizarians	Foraminiferans, radiolarians	Thin pseudopods; some with tests; unicellular
Opisthokonts	Choanoflagellates, animals, nucleariids, fungi	Some with flagella; unicellular and colonial



Assorted fossilized diatoms



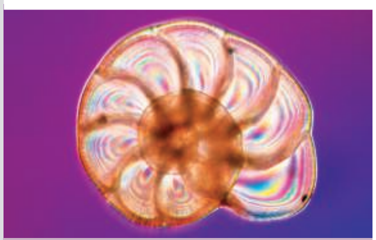
Onychodromus, a giant ciliate ingesting one of its own kind

Plasmodium, a slime mold

Blepharisma, a ciliate with visible vacuoles

Licmorpha, a stalked diatom

Acetabularia, a single-celled green alga (chlorophyte)

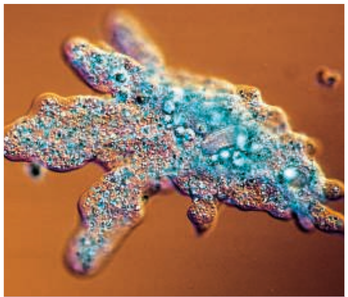


Nonionina, a foraminiferan

Ceratium, an armored dinoflagellate

Bossiella, a coralline red alga

Synura, a colony-forming golden brown alga



Amoeba proteus, a protozoan

Figure 25.1
Diversity of algal protists.

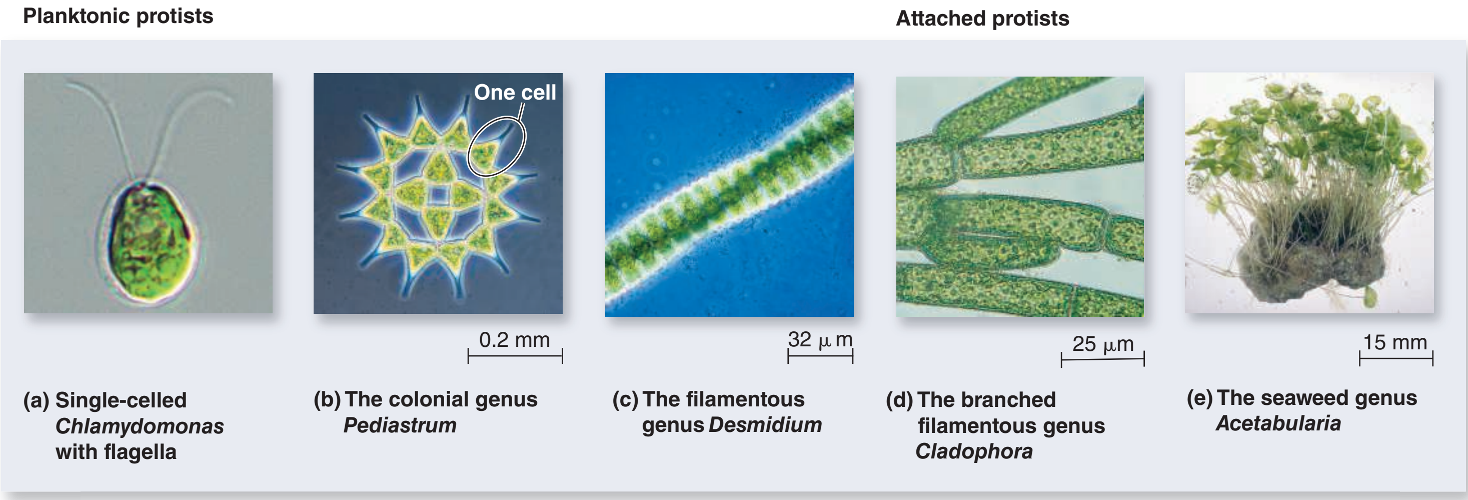


Figure 25.2

The diversity of algal body-types reflects their habitats. (*a*) The single-celled flagellate genus *Chlamydomonas* occurs in the phytoplankton of lakes. (*b*) The colonial genus *Pediastrum* consists of several cells arranged in a lacy star shape that helps to keep this alga afloat in water. (*c*) The filamentous genus *Desmidium* occurs as a twisted row of cells. (*d*) The branched filamentous genus *Cladophora* that grows attached to nearshore surfaces is large enough to see with the unaided eye. (*e*) The relatively large seaweed genus *Acetabularia* lives on rocks and coral rubble in shallow tropical oceans.

Algae are also distinguished by their cellular organization (fig. 25.2). **Unicellular** algal species occur as single, unattached cells that may or may not be motile. **Filamentous** algal species occur as chains of cells attached end to end. These filaments may be few to many cells long and may be unbranched or branched in various patterns. **Colonial** algae occur as groups of cells attached to each other in a nonfilamentous manner. For example, a colony may include several to many cells adhering to each other as a sphere, flat sheet, or other three-dimensional shape. Multicellular organization is not typical of protists but describes algae of more complex design than simple colonies. Multicellular species have cells of different types and functions and show significant interdependence.

GREEN ALGAE (PHYLUM CHLOROPHYTA)

Green algae are the most diverse and familiar algae in fresh water (fig. 25.3). However, a few genera live in salt water. Although their name (Chlorophyta) means "green chlorophyll plants" (*chloro* + *phyta*), algae are not classified as plants. Green algae may be ancestral to land plants and share many characteristics with land plants, such as

- Chlorophyll *a,* which occurs in algae and green plants
- Chlorophyll *b,* which occurs in land plants and in the green and euglenoid algae
- Starch as the carbohydrate storage material
- Cell walls made of cellulose

Let's examine a few representatives of green algae, a major phylum.

Unicellular Green Alga: *Chlamydomonas*

Chlamydomonas is a motile, unicellular alga found in soil, lakes, and ditches (fig. 25.3). It probably has the simplest structure and type of reproduction among green algae. The egg-shaped cells of *Chlamydomonas* contain a large chloroplast and a pyrenoid involved in the production and storage of starch.

Procedure 25.1

Observe *Chlamydomonas*

1. Observe a drop of water containing living *Chlamydomonas* and note the movement of the cells. If necessary, review in Exercise 3 the proper use of a compound microscope and the associated videos at the lab manual's website.

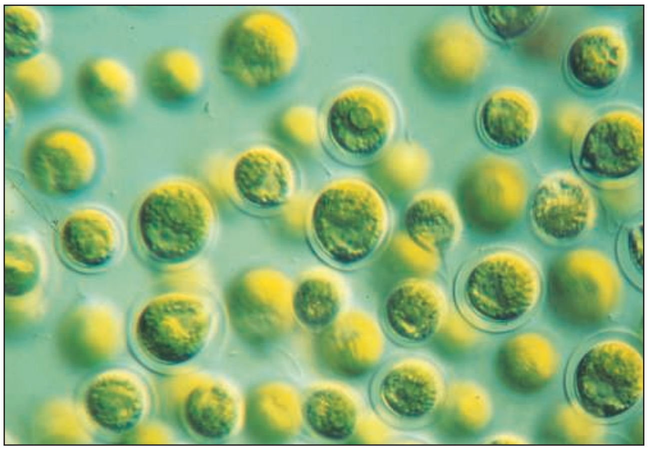


Figure 25.3

Chlamydomonas is a common alga that is rich in chlorophylls *a* and *b*. It is a single-celled green alga less than 100 µm long.

Table 25.1

Eukaryotic Supergroups and Examples of Included Kingdoms and Phyla*

Supergroup	Phyla	Unifying Characteristics
EXCAVATA	Jakobida	Unicellular flagellates, often with feeding groove; mitochondria highly modified in specialized parasites
EUGLENOZOA	Kinetoplastea Euglenida (euglenoids)	Unicellular flagellates; disk-shaped mitochondrial cristae; secondary plastids (when present) derived from endosymbiotic green algae
ARCHAEPLASTIDA	Glaucophyta Rhodophyta (red algae) Chlorophyta (green algae) KINGDOM PLANTAE	Primary plastids having only two envelope membranes
ALVEOLATA	Dinozoa (dinoflagellates) Ciliophora (ciliates) Apicomplexa (apicomplexans)	Peripheral membrane sacs (alveoli); some Dinozoa have secondary plastids derived from red algae, some have secondary plastids derived from green algae, and some have tertiary plastids derived from diatoms; some Apicomplexa have secondary plastids derived from red or green algae.
STRAMENOPILA	Bacillariophyta (diatoms) Phaeophyta (?) (brown algae)	Strawlike flagellar hairs; fucoxanthin accessory pigment common in autotrophic forms
RHIZARIA	Chlorarchniophyta Radiolaria Foraminifera	Thin, cytoplasmic projections; secondary plastids (when present) derived from endosymbiotic green algae
AMOEBOZOA	Dictyostelia (slime molds) Rhizopoda (?) (amoebas)	Amoeboid movement by pseudopodia
OPISTHOKONTA	Choanomonada (choanoflagellates) KINGDOM ANIMALIA KINGDOM FUNGI	Swimming cells possess a single posterior flagellum.

*Phyla of protists are not unified under a single kingdom but are scattered among supergroups above the kingdom level.

Table 25.2

The Common Pigments in Addition to Chlorophyll *a*, Storage Products, and Cell Wall Components Characteristic of Common Algal Phyla

Phylum	Predominant Organization	Pigment	Storage Product	Cell Wall
Chlorophyta	Unicellular, filamentous, colonial	Chlorophyll *b*	Starch	Mainly cellulose
Phaeophyta	Filamentous, multicellular	Chlorophyll *c*, fucoxanthin	Laminarin, mannitol, lipids	Cellulose, alginates
Rhodophyta	Multicellular	Chlorophyll *a*, phycobilins	Modified starch	Cellulose, agar, carrageenan
Bacillariophyta	Unicellular	Chlorophyll *c*, fucoxanthin	Chrysolaminarin, lipids	Silica
Dinozoa	Unicellular	Chlorophyll *c*	Starch, lipids	Pectin, cellulose plates
Euglenida	Unicellular	Chlorophyll *b*	Paramylon, lipids	None

2. If the movement is too fast, make a new preparation by placing one or two drops of methylcellulose on a slide and adding a drop of water containing *Chlamydomonas.*

3. Mix gently and add a coverslip.

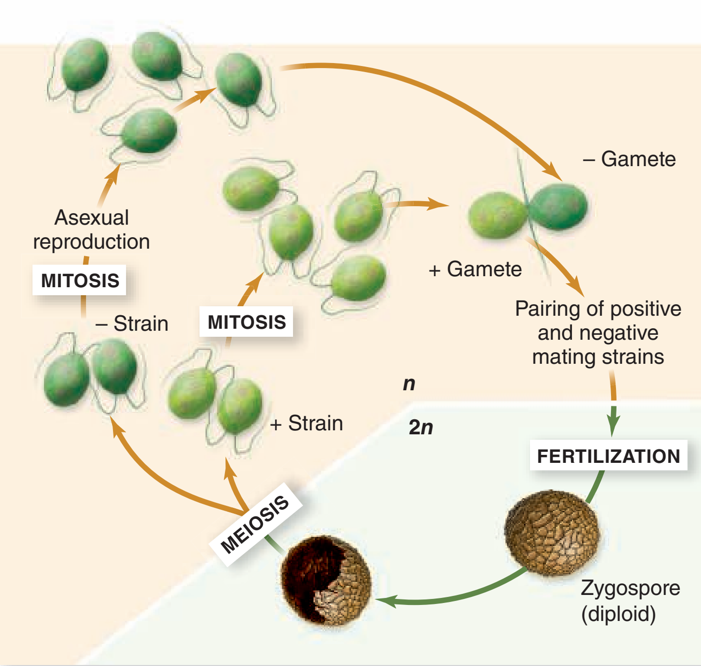
4. Note the **stigma,** which appears as a reddish, light-absorbing spot at the anterior end of the cell.

5. Examine prepared slides of *Chlamydomonas.*

Question 1

a. Is the movement of *Chlamydomonas* smooth or does it appear jerky?

b. Can you see both flagella? (You may need to reduce the light intensity to see flagella.)



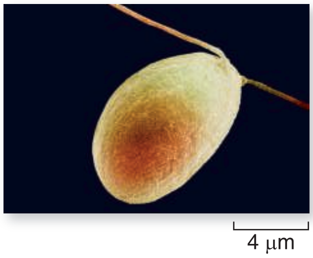


Figure 25.4

Chlamydomonas life cycle. Individual cells of *Chlamydomonas* (a microscopic, biflagellated alga) are haploid and divide asexually, producing copies of themselves. At times, such haploid cells act as gametes, fusing to produce a zygote. The zygote develops a thick, resistant wall, becoming a zygospore (as shown in the lower right-hand side of the diagram). Meiosis then produces four haploid individuals. Only + and − strains can mate with one another, although both may also divide asexually and reproduce themselves. © Richard Kessel and Gene Shih/Visuals Unlimited

c. How does methylcellulose affect the movement of *Chlamydomonas*?

d. How does the stigma help *Chlamydomonas* survive?

Asexual and Sexual Reproduction in *Chlamydomonas*

Chlamydomonas usually reproduces asexually via mitosis. Sexual reproduction in *Chlamydomonas* is a response to unfavorable environmental conditions. For sexual reproduction, vegetative cells of *Chlamydomonas* undergo mitosis to produce gametes. The gametes fuse to form a diploid **zygote,** the resting stage of the life cycle. In most species of *Chlamydomonas,* the gametes of two strains are **isogamous,** meaning they have an identical shape and appearance. For convenience, isogametes of *Chlamydomonas* are referred to as + or −. Gametes unite to form a diploid zygote. **Syngamy** is the pairing and fusion of morphologically similar haploid gametes to form a diploid zygote. Syngamy is similar to fertilization, but fertilization typically refers to fusion of unequal gametes such as egg and sperm cells. The zygote surrounds itself with a resistant surface and is called a **zygospore.** Under favorable conditions the zygote undergoes meiosis to produce haploid individuals called **spores.** Spores are reproductive cells capable of developing into an adult without fusing with another cell. Study the life cycle of *Chlamydomonas* shown in figure 25.4.

Procedure 25.2

Observe syngamy

1. Place drops of + and − gametes of *Chlamydomonas* provided by your instructor next to each other on a microscope slide, being careful not to mix the two drops. Do not add a coverslip.

2. While you observe the drops through low power of the microscope, mix the two drops of isogametes.

3. Switch to high magnification and note the clumping gametes. Try to locate cells that have paired.

Question 2

a. Under what environmental conditions would a zygote not undergo meiosis immediately?

b. Are spores of *Chlamydomonas* haploid or diploid?

c. Which portions of the life cycle of *Chlamydomonas* are haploid?

d. Which are diploid?

Filamentous Green Algae: *Spirogyra* and *Cladophora*

Two of the most common genera of filamentous green algae are *Spirogyra* and *Cladophora. Spirogyra* grows in running streams of cool fresh water and secretes mucilage that makes it feel slippery. *Cladophora* is also common in streams and has a much coarser appearance and texture.

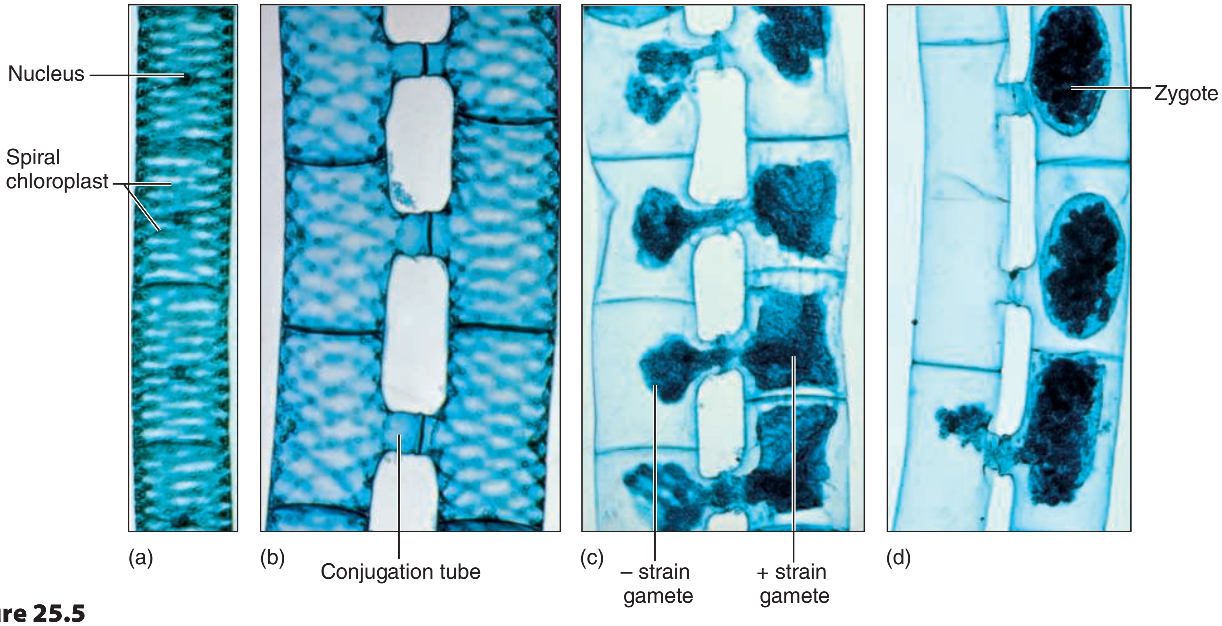


Figure 25.5

Spirogyra (watersilk). (*a*) Ribbonlike chloroplasts are spirally arranged in a vegetative filament. (*b*) Conjugation tubes have formed from papillae that grow out of opposing cells in adjacent filaments. (*c*) The + strain gametes (right) are condensed protoplasts. (*d*) Fusion of gametes in some of the cells has produced zygotes. The zygotes then undergo meiosis to produce haploid cells that can each divide to produce a filament (400×).

Figure 25.6

The green alga *Cladophora* forms branched filaments consisting of multinucleate cells (100×).

Spirogyra reproduces sexually by a process called **conjugation.** During conjugation, filaments of opposite mating types lie side by side and form projections that grow toward each other. These projections touch and the separating wall dissolves, thus forming a **conjugation tube** (fig. 25.5). The cellular contents of the − strain then migrate through the conjugation tube and fuse with that of the non-motile + strain. The cellular contents of these two strains function as nonflagellated isogametes. The zygote resulting from the fusion of gametes develops a thick, resistant cell wall and is termed a zygospore. The zygospore is released when the filament disintegrates, at which time the zygospore undergoes meiosis to form haploid cells that become new filaments.

Procedure 25.3

Examine *Spirogyra* and *Cladophora*

1. Obtain and examine a living culture of *Spirogyra.*
2. Prepare a wet mount with a small amount of living *Spirogyra.* Examine it with low and then high magnification. Notice the arrangement of the chloroplasts and whether filaments are branched.
3. Examine a prepared slide of *Spirogyra.*
4. In the following space, sketch a filament of *Spirogyra* and note the arrangement of its chloroplasts.
5. Examine a prepared slide of filaments of *Spirogyra* undergoing conjugation. Locate the conjugation tubes, gametes, and zygotes.
6. Prepare and examine a wet mount of living *Cladophora* (fig 25.6). Then examine a prepared slide of *Cladophora.*

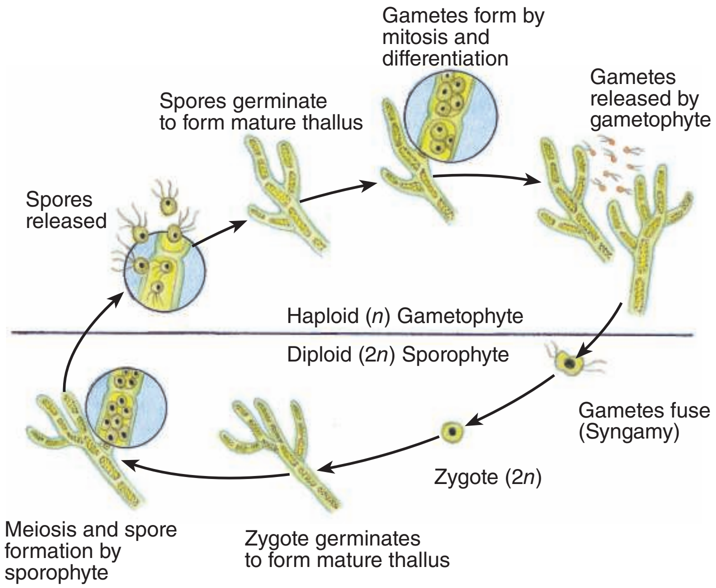


Figure 25.7

Alternation of generations in *Cladophora.* During alternation of generations, the haploid (n) gametophytes alternate with diploid ($2n$) sporophytes. Gametophytes produce haploid gametes that fuse to form a diploid zygote, the first cell of the sporophyte generation. The zygote germinates and undergoes meiosis to form haploid spores, the first cells of the gametophyte generation. The gametophyte then uses mitosis to produce gametes, thereby completing the life cycle.

7. In the following space, draw a few cells of *Cladophora* showing their general shape and the filament's branching pattern.

Question 3

a. Are filaments of *Spirogyra* branched?

b. What is the arrangement of chloroplasts of *Spirogyra?*

c. Can you see any conjugation tubes? If you can't, examine the prepared slides that show these structures.

d. How do you think *Spirogyra* reproduces asexually?

Question 4

a. How is *Cladophora* morphologically similar to *Spirogyra*? How is it different?

b. What is the shape of its chloroplasts?

Mature *Cladophora* exists in diploid and haploid forms. The diploid stage of the life cycle produces spores and is called the **sporophyte.** The haploid stage of the life cycle produces gametes and is called the **gametophyte.** This phenomenon of alternating haploid and diploid stages of a life cycle is called **alternation of generations.** Alternation of generations is a reproductive cycle in which the haploid gametophyte produces gametes that fuse to form a zygote that germinates to produce a diploid sporophyte. Within the sporophyte, meiosis produces spores that germinate into gametophytes, thus completing the cycle (fig. 25.7). Alternation of generations occurs in many green algae, including *Cladophora,* and in all land plants.

You should become familiar with the concept of alternation of generations because it occurs frequently in the plant kingdom and we will refer to it repeatedly in this and future exercises. Refer to your textbook or instructor for more information.

Colonial Green Alga: *Volvox*

Volvox consists of many *Chlamydomonas*-like cells bound in a common spherical matrix (fig. 25.8). Each cell in the sphere has two flagella extending outward from the surface of the colony. Synchronized beating of the flagella spins the colony through the water like a globe on its axis. *Volvox* is one of the most structurally advanced colonial forms of algae, so much so that some biologists consider *Volvox* to be multicellular. Some of the cells of a *Volvox* colony are functionally differentiated; a few specialized cells can produce new colonies, and eggs and sperm are formed by different cells in the colony.

Volvox reproduces by **oogamy.** Motile sperm swim to and fuse with the large nonmotile eggs to form a diploid zygote. The zygote enlarges and develops into a thick-walled zygospore released when the parent colony disintegrates. The zygospore then undergoes meiosis to produce haploid cells that subsequently undergo mitosis and become a new colony. During asexual reproduction, some cells of *Volvox* divide, bulge inward, and produce new colonies called **daughter colonies** that initially are held within the parent colony.

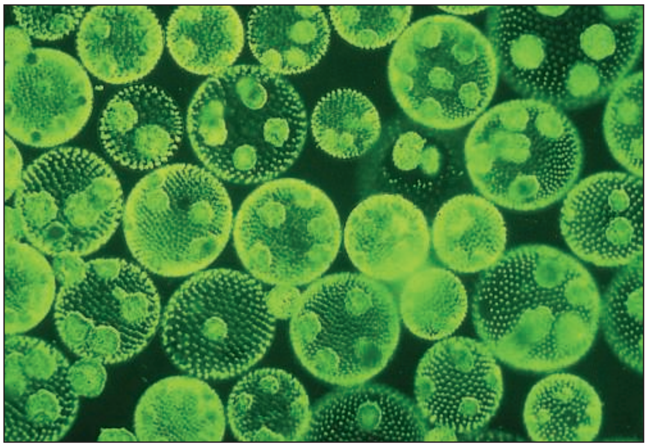


Figure 25.8

Colonies of *Volvox.* Many parent colonies contain asexually produced daughter colonies (400×).

Procedure 25.4

Observe *Volvox*

1. Examine a prepared slide of *Volvox.*
2. Obtain a living culture of *Volvox.* Place a drop of living *Volvox* on a depression slide.
3. Under low magnification, observe the large, hollow, spherical colonies for a few minutes to appreciate their elegance and beauty.
4. Search for flagella on the surface.
5. Complement your observations of this alga by re-examining prepared slides of *Volvox.*

Question 5

a. What is oogamy?

b. What are the tiny spheres inside the larger sphere of *Volvox*?

c. How do you suppose they get out?

d. How do you think the number of cells in a young *Volvox* colony compares to the number in a mature colony?

BROWN ALGAE (PHYLUM PHAEOPHYTA)

Phaeophytes are primarily marine algae that are structurally complex; there are no unicellular or colonial brown algae. Brown algae usually grow in cool water and obtain their name from the presence of a brown pigment called **fucoxanthin.** Brown algae range in size from microscopic forms to kelps over 50 m long. Thalli of some phaeophytes are similar to those of land plants. Review table 25.2 for the characteristics of brown algae.

Among the larger brown algae is *Macrocystis,* a kelp reaching 100 m in length (fig. 25.9). The flat blades of this kelp float on the surface of the water, while the base is anchored far below the surface. Another ecologically important brown alga is sargasso weed (*Sargassum;* fig. 25.10), which forms huge floating masses that dominate the vast Sargasso Sea in the Atlantic Ocean northeast of the Caribbean. These mats are microhabitats for a variety of highly adapted and cryptically colored animals.

Fucus

Fucus is another common genus of brown algae (fig. 25.11). *Fucus* (rockweed) typically attaches to rocks in the intertidal zone via a specialized structure called a holdfast. The outer surface of *Fucus* is covered by a gelatinous sheath. Tips of *Fucus* branches, called **conceptacles,** may be swollen and contain reproductive structures called **oogonia** (female) and **antheridia** (male), as shown in figure 25.11. Oogonia are multicellular sex organs that produce eggs. Antheridia are multicellular sex organs that produce sperm. Most protists do not have multicellular reproductive organs.

The life cycle of *Fucus* is similar to the common life cycle of animals. The mature thallus is diploid, and cells within reproductive structures undergo meiosis to produce gametes, thereby skipping the multicellular haploid stage common to many protists, plants, and fungi.

Procedure 25.5

Examine *Fucus*

1. Refer to figure 25.11 as you examine *Fucus* in the lab. Use your dissecting microscope to examine a cross section of the flattened, dichotomously branched thallus of *Fucus.*
2. Notice the presence of swollen areas on the thallus of *Fucus.*
3. Work in a group to dissect one of these structures.
4. Examine prepared slides of antheridia and oogonia of *Fucus.* Sketch what you see.

Figure 25.9

Brown alga. The giant kelp, *Macrocystis pyrifera,* grows in relatively shallow water along coasts throughout the world and provides food and shelter for many different kinds of organisms.

Figure 25.10

Sargassum, a floating brown alga from which the Sargasso Sea got its name. *Sargassum* also lives in other oceans.

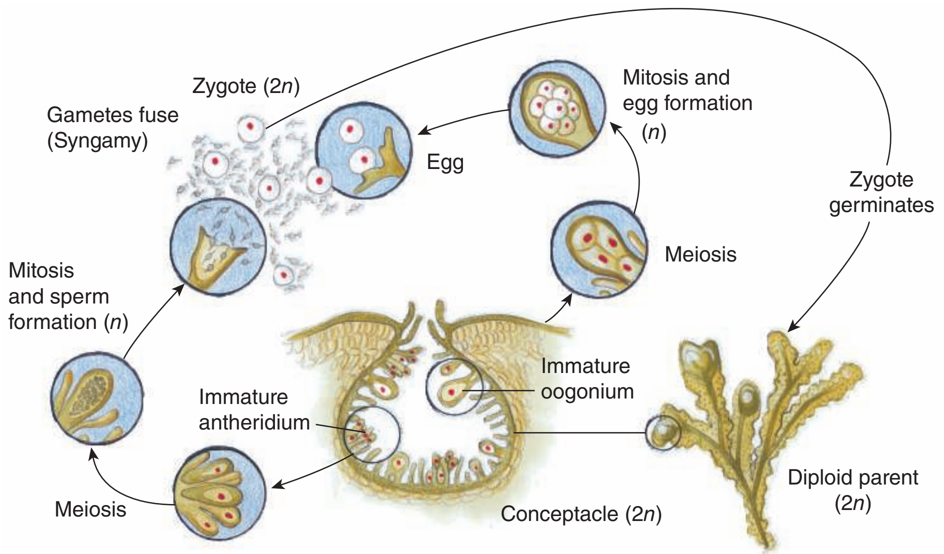


Figure 25.11

Sexual reproduction in a monoecious species of *Fucus.* Some species of *Fucus* have separate male thalli and female thalli containing conceptacles with only antheridia, and only oogonia, respectively.

Question 6

a. How does the structure of *Fucus* differ from the green algae that you examined earlier in this exercise?

b. Are all portions of the thallus photosynthetic? How can you tell?

c. Considering where *Fucus* lives, what do you think is the function of its gelatinous sheath?

d. Are the swollen structures solid masses or are they hollow?

Question 7

a. Are the gametes of *Fucus* isogamous or oogamous?

b. How does the structure of tissue surrounding the reproductive structures compare with that of green algae?

Economic Importance of Phaeophyta

In the Orient, some brown algae are used as food. One of these algae is *Laminaria,* a kelp marketed as "kombu." Brown algae are also important sources of **alginic acid,** a hydrophilic substance (i.e., it absorbs large quantities of water). Alginic acid is used as an emulsifier (an additive used to stabilize processed food and other products) in dripless paint, ice cream, pudding mixes, and cosmetics.

Procedure 25.6

Examine some commercial products of brown algae

1. Taste a small piece of kelp packaged as a food product. How would you describe its taste and texture?
2. Observe the products on display and, in the case of foods, read their contents labels.

RED ALGAE (PHYLUM RHODOPHYTA)

Red algae obtain their color from the presence of red **phycobilins** in their plastids. Red algae typically live in warm marine waters. The thallus of a red alga can be attached or free-floating, filamentous, or fleshy (fig. 25.12).

Procedure 25.7

Examine *Polysiphonia, Porphyra,* and commercial products of red algae

1. Obtain prepared slides of *Polysiphonia* and *Porphyra* and any living cultures that are available in lab.
2. Examine a prepared slide of *Polysiphonia.* Notice the thickness of the filaments compared with that of filamentous green algae.
3. Examine living *Polysiphonia.* This genus is highly branched and filamentous. As with other red algae, their life cycles can be quite complex. Gametophytes of these organisms are dioecious (i.e., they are either male or female).
4. Examine some prepared slides and living *Porphyra* if available. Compare the structure of *Polysiphonia* with that of *Porphyra.* "Blades" of *Porphyra* consist of two layers of cells separated by colloidal material.
5. Study the display of carrageenan, agar, and other products derived from red algae.
6. Pick up and feel a piece of agar, noting its texture. Agar is a gelatinous polysaccharide from red algae used as a solidifying agent in culture media for microbiology labs (fig. 25.13*b*). A 1% suspension of hot agar remains liquid until it cools to about body temperature.

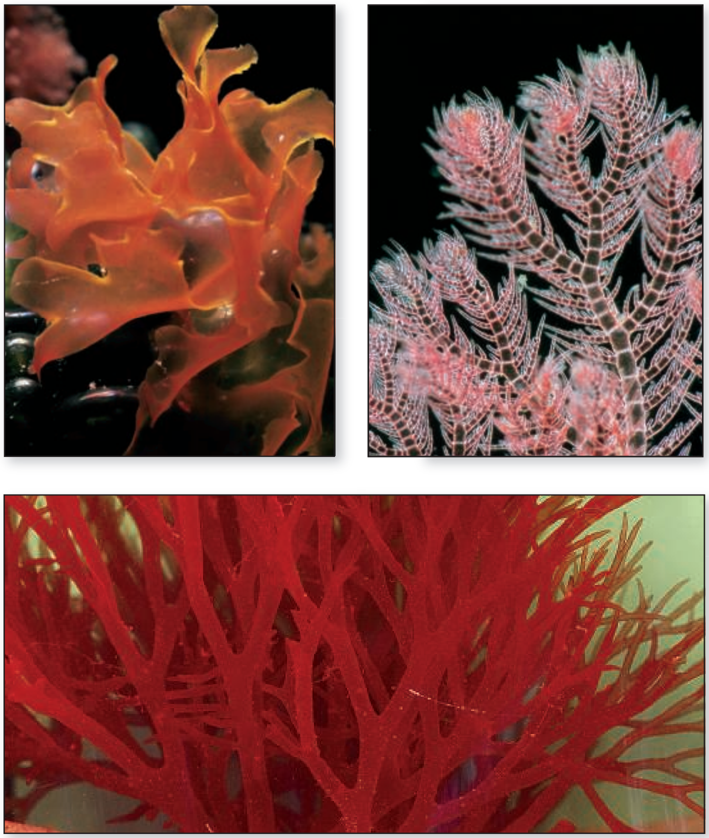
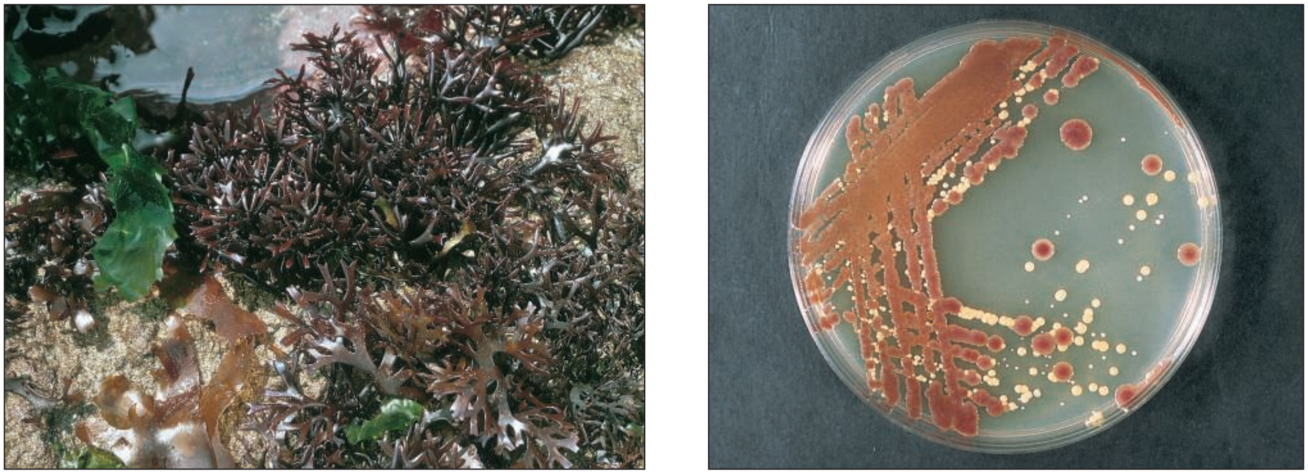


Figure 25.12
Red algae come in many forms and sizes.

DIATOMS (PHYLUM BACILLARIOPHYTA)

Diatoms are unicellular algae containing chlorophylls *a* and *c* and xanthophyll pigments that give them their golden-brown color. Although diatoms are tiny, their great numbers, rapid rates of reproduction, and photosynthetic capacity make them vitally important as a primary link in the food chain of the oceans.

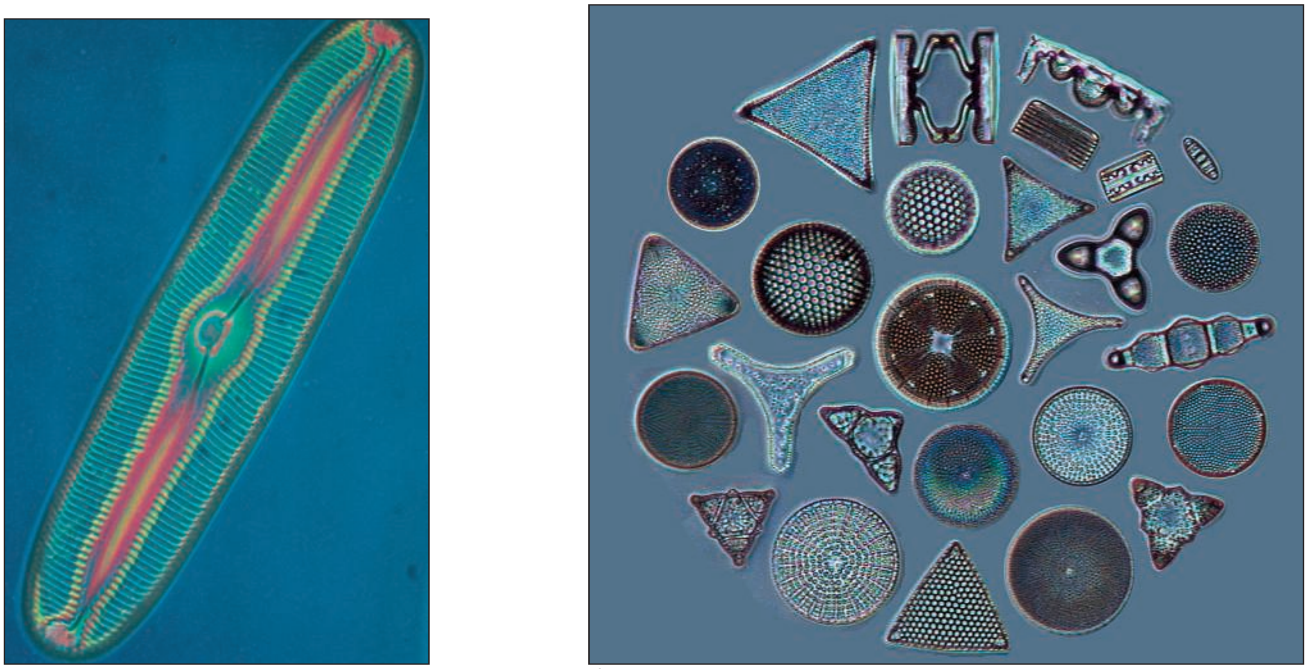
Diatoms have a hard cell wall made of silicon dioxide (glass) (fig. 25.14). These walls are arranged in overlapping halves, much like the halves of a petri dish. The glass walls of diatoms persist long after the remainder of the cell disintegrates (fig. 25.15) and may accumulate in layers of **diatomaceous earth** several hundred meters deep. This depth indicates how many diatoms have existed through the ages.



(a) (b)

Figure 25.13

A red alga and a common extract, agar. (*a*) Irish moss (*Chondrus crispus*) is a red alga that is commercially important as a source of carrageenan. Carrageenan is used as a stabilizer in paints and cosmetics, as well as in foods such as salad dressings and dairy products. (*b*) Microbiologists grow a variety of organisms on media solidified with agar (shown here), extracted from seaweeds such as *Gracilaria.* The bacteria shown here and the fungus shown in figure 27.10 are growing on agar. Agar is also used to make drug capsules, cosmetics, and gelatin desserts.



(a) (b)

Figure 25.14

Diatoms (phylum Bacillariophyta). (*a*) A pennate (bilaterally symmetrical) diatom. (*b*) Several different kinds of diatoms, including some centrate (round) species (600×).

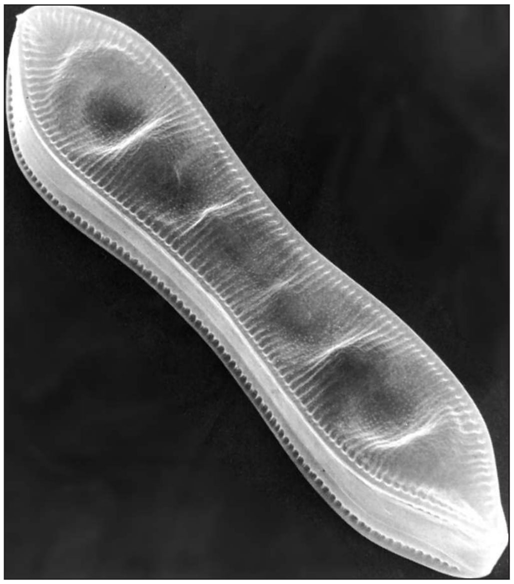


Figure 25.15
A diatom showing its ornate, silicon cell wall (600×).

Procedure 25.8

Examine prepared slides of diatoms, living diatoms, and diatomaceous earth

1. Examine a prepared slide of diatoms. Sketch some of the cells here. Some cells are long and thin, whereas others are disklike.
2. Prepare a wet-mount slide from a culture of living diatoms. Compare the shapes of the cells with those on the prepared slide.
3. Mount a small amount of diatomaceous earth in water on a microscope slide. Examine the diatomaceous earth with your microscope. Note the variety of shells, some broken and others intact. A mass of these shells is clean, insoluble, and porous.

Question 8

a. Can you see any pores in the walls of diatoms?

b. Are any of the diatoms moving?

c. If diatoms lack flagella, how do you explain their motility?

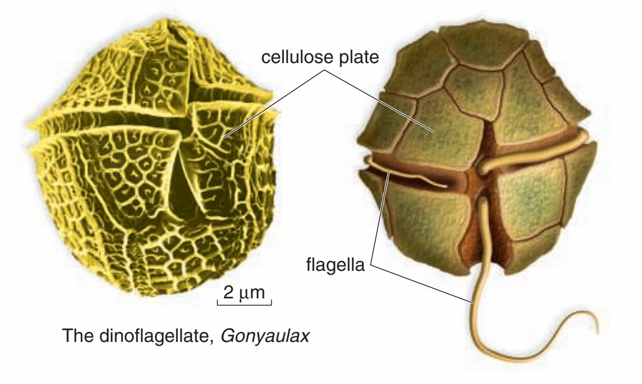


Figure 25.16
Dinoflagellate *Gonyaulax*. Most dinoflagellates have rigid cellulose plates and pair of flagella in perpendicular grooves.

d. How would diatomaceous earth compare to sand as a material for swimming pool filters? Which would be better and why?

DINOFLAGELLATES (PHYLUM DINOZOA)

Members of this phylum, like those of Bacillariophyta, are all unicellular. Dinoflagellates are characterized by the bizarre appearance of their cellulose plates and by the presence of two flagella located in perpendicular grooves (fig. 25.16). Blooms of a red-pigmented dinoflagellate called *Ptychodiscus brevis* produce a "red tide." Toxin production and oxygen depletion by these blooms of algae can kill massive numbers of fish. Dinoflagellates are important primary producers in oceans (second only to diatoms) and include many autotrophic and heterotrophic forms. Some dinoflagellates are bioluminescent, others live symbiotically with corals, and some are heterotrophic.

Procedure 25.9

Examine dinoflagellates

1. Examine a prepared slide of *Peridinium* or *Ceratium.* Look for longitudinal and transverse flagella and flagellar grooves.
2. Prepare a wet-mount slide from a living culture of dinoflagellates. Dinoflagellates are quite small, so be patient while searching for organisms.

Question 9

How do the shapes of dinoflagellates compare with other unicellular algae that you have observed in this exercise?

EUGLENOIDS (PHYLUM EUGLENIDA)

This small phylum includes mostly freshwater unicellular algae. Although plastids of euglenoids contain chlorophylls *a* and *b* (like the green algae), euglenoids are distinctive because they lack a cell wall, and instead have a pellicle made largely of protein. The protein makes the cell more flexible. Euglenoids are motile and have two flagella (fig. 25.17).

Procedure 25.10

Observe *Euglena*

1. Observe living and prepared slides of *Euglena* available in the lab while referring to figure 25.17.
2. You may want to add a drop of methylcellulose in your preparation to slow the *Euglena.*
3. Note the colored **eyespot** near the base of the flagella.
4. Observe the movement and changing shapes of the organisms.

Chloroplasts of *Euglena* may contain a single pyrenoid, which appears as a clear, circular area within the plastid. *Euglena* is best known for its ability to be autotrophic, heterotrophic, and saprophytic. Its specific mode of nutrition is determined by current environmental conditions. This phenomenon illustrates why it is often impossible to distinguish plant from animal at the cellular level and why classification of protists seems so unwieldy. Our classification schemes for these and other organisms will improve as we learn more about them.

Question 10
What is the function of the eyespot of *Euglena?*

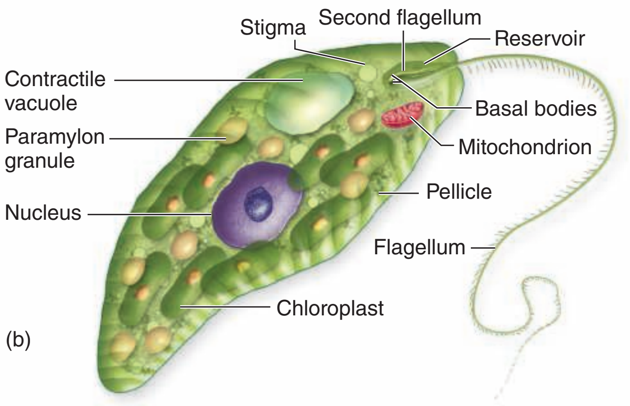


Figure 25.17
Euglenoids. (*a*) Micrograph of individuals of the genus *Euglena* (Euglenida) (400×). (*b*) Diagram of *Euglena.* Paramylon granules are areas where food reserves are stored.

INVESTIGATION

The Responses of Algae to Changing Environmental Stimuli

Observation: You learned in Exercise 23 how algae are affected by environmental changes involving nutrients, pollutants, and temperature changes. As a result, algal growth can be used to monitor environmental changes (e.g., eutrophication).

Question: How can algae be used to monitor environmental conditions?

a. Establish a working lab group and obtain Investigation Worksheet 25 from your instructor.
b. Discuss with your group well-defined questions relevant to the preceding observation and question. Choose and record your group's best question for investigation.
c. Translate your question into a testable hypothesis and record it.
d. Outline on Worksheet 25 your experimental design and supplies needed to test your hypothesis. Ask your instructor to review your proposed investigation.
e. Conduct your procedures, record your data, answer your question, and make relevant comments.
f. Discuss with your instructor any revisions to your questions, hypotheses, or procedures. Repeat your work as needed.

Questions for Further Thought and Study

1. What are examples of unicellular, filamentous, and colonial green algae?

2. How are green algae different from cyanobacteria?

3. What is meant by "alternation of generations"?

4. What is meant by the term "kelp"?

5. Are the stem, holdfast, and blade of brown algae the same as stems, roots, and leaves of land plants? Why or why not?

6. Brown algae contain chlorophyll. Why, then, do they appear brown and not green?

7. What are the main differences and similarities among the major groups of algae? How are these groups related to each other evolutionarily?

8. Describe three ways that algae affect your life.

9. Why are green algae considered to be ancestral to plants?

DOING BIOLOGY YOURSELF

Would you expect environmental conditions to influence syngamy? Design two experiments to investigate the effects of two environmental conditions on the frequency of syngamy. How would you measure syngamy? Its frequency?

WRITING TO LEARN BIOLOGY

Describe the plant-like and animal-like characteristics of *Euglena*. Which characteristics conclusively define a plant? Which ones define an animal?