CHAPTER 20

Multicellular Algae



Sea otters, among the most appealing species of animals, make their home in the kelp forests off the coast of California. They wrap themselves in strands of algae to keep from floating away on the ocean waves.

Along the coasts of Washington, Oregon, and northern California, pine and redwood forests crown rocky cliffs that dive steeply into the pounding surf. Beneath the ocean waves, invisible to the casual observer, another type of forest thrives—a forest of giant greenish-brown kelp. Kelp are huge seaweeds that grow as long or longer than the tallest forest trees. Growing with amazing speed, kelp offer both home and food to a wide variety of fish, shellfish, and sea otters.

The kelp forest is but one scene from the little-known world of life beneath the sea, a world fed and sheltered by algae. What are algae? Where do they live? In this chapter we shall examine this extraordinary group of plants and explore the many ways in which algae are adapted to life on Earth.

CHAPTER OUTLINE

20–1 Characteristics of Algae
- Adaptations of Algae to Life Under Water
- Chlorophyll and Accessory Pigments

20–2 Groups of Algae
- Chlorophyta—The Green Algae
- Phaeophyta—The Brown Algae
- Rhodophyta—The Red Algae

20–3 Reproduction in Algae
- Reproduction as an Adaptation
- Reproduction in *Chlamydomonas*
- Reproduction in *Ulva*
- Reproduction in *Fucus*

20–4 Where Algae Fit into the World

20–1 Characteristics of Algae

Section Objectives

- Discuss the characteristics of algae.
- Describe the adaptations of algae to life in a water environment.

Algae are photosynthetic organisms that live in streams, ponds, lakes, swamps, and all the oceans of the world. Algae also live on damp tree trunks and rocks and in moist soil. The stringy green filaments you may have seen in a local pond are algae. So are the giant brown seaweeds that wash up on a beach after a storm. And if you keep tropical fish, you may have noticed algae covering the walls of the tank.

From these examples, you may already have determined one important characteristic of algae: Algae must live in or near a source of water. **Unlike land plants, most algae lack an internal system of tubes to move water and materials from one part of the plant to another.** The water in which algae live bathes their cells with carbon dioxide, oxygen, and nutrients, and carries away wastes produced by the cells.

Algae can be unicellular or multicellular and, therefore, vary considerably in size. Most algae are multicellular. Some species of multicellular algae, such as the giant kelp, can grow to more than 60 meters in length. Most unicellular algae are microscopic, resembling plantlike protists.



Figure 20–1 *Giant kelp are often washed up on shore when storms tear the plants loose from the holdfasts that anchor them to the bottom. These giant algae can be as long as a football field.*

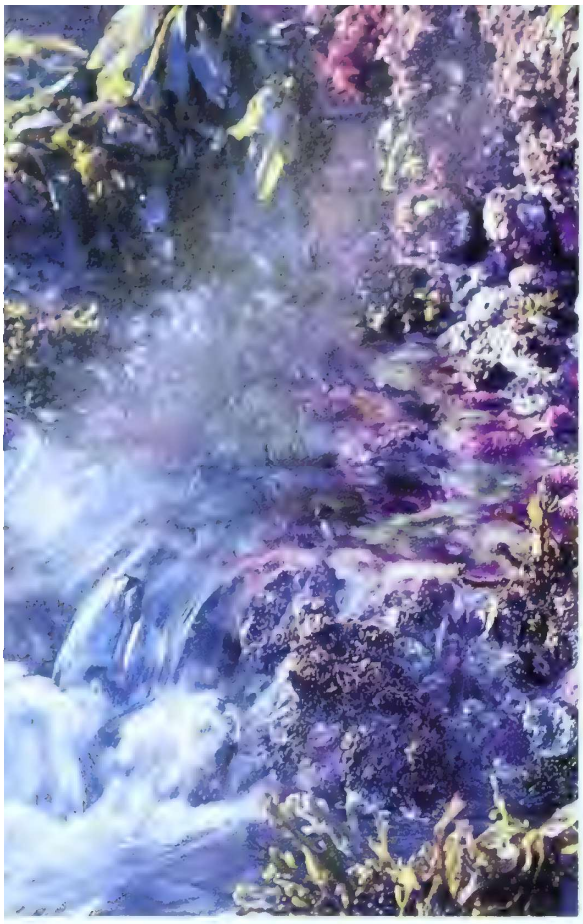


Figure 20–2 *Different kinds of algae, along with many kinds of small animals, live in tide pools. With each crashing wave, water brings food for the animals and plants. Wastes produced by the organisms are carried away as the ocean water seeps from the tide pool.*

The cells of all algae have a cell wall. Algae never develop the specialized root, stem, and leaf structures found in land plants. All algae contain chlorophyll *a*, one of several forms of chlorophyll. Some species of algae contain another form of chlorophyll in addition to chlorophyll *a*. Many species of algae have a complicated reproductive cycle in which stages of sexual reproduction alternate with stages of asexual reproduction.

There is some disagreement among scientists about the classification of algae. Because some species of algae are unicellular, some scientists place all algae in the kingdom Protista. But because many species of algae are multicellular, other scientists place all algae in the kingdom Plantae.

In this textbook we have chosen to use the following classification: The single-celled Chrysophytes (diatoms), Euglenophytes (euglenas), and Pyrrophytes (dinoflagellates) are placed in the kingdom Protista. (You read about these types of algae in Chapter 18.) But because of their chemistry and reproductive cycles, multicellular algae are placed in the kingdom Plantae. This chapter deals primarily with these multicellular species of algae. However, as you will notice in reading the chapter, certain single-celled algae have been included. These algae are more plantlike than protistlike and thus are grouped together with the multicellular algae they most resemble. You should also notice in reading this chapter that although some botanists call the major plant groups divisions, we call them phyla—as we do the major groups of all other organisms.

Adaptations of Algae to Life Under Water

Most algae live under water and show different adaptations from those of land plants. For example, underwater plants do not need protection from drying out. Thus many kinds of algae have very thin (often only two cells thick) leaflike structures that lack a waterproof covering. These thin structures can exchange oxygen, carbon dioxide, and nutrients directly with the water around them. As you already learned, algae have no specialized tissues to carry such materials throughout their body.

Because algae are supported by water, they do not need stemlike structures to keep them from falling over, such as land plants do. And, as you will soon learn, sexual reproduction can be more easily accomplished in water because reproductive cells can swim through water and the fragile young plants do not dry out.

Chlorophyll and Accessory Pigments

Life under water poses one major problem for plants: a lack of light for photosynthesis. As you will remember, light is necessary for the food-making process, and it is chlorophyll that traps the energy of sunlight. However, water absorbs much of

this energy as sunlight passes through it. In particular, seawater absorbs large amounts of energy corresponding to the red and violet wavelengths of sunlight. And it is exactly these two wavelengths that chlorophyll *a* uses best. Because seawater absorbs most of the red and violet wavelengths, light becomes much dimmer and bluer in color as the depth of water increases. The dim blue light that penetrates into deep water contains very little light energy that chlorophyll *a* can use.

In adapting to the challenge of life with little light, various groups of algae have evolved different forms of chlorophyll. Each form of chlorophyll—chlorophyll *a*, chlorophyll *b*, chlorophyll *c*, and chlorophyll *d*— absorbs different wavelengths of light. As you have read, all algae contain chlorophyll *a*. Some species contain chlorophyll *a* in combination with *b*, *c*, or *d*. The result of this evolution of different forms of chlorophyll is that more of the energy of sunlight available to algae can be used.

Algae have also evolved compounds that absorb different wavelengths of light than chlorophyll absorbs. These light-absorbing compounds are called **accessory pigments.** Accessory pigments pass the energy they absorb on to the algae's photosynthetic machinery. For example, some accessory pigments make blue light more useful for photosynthesis. So, algae that contain these accessory pigments can live in deeper water than plants that contain only chlorophyll. Because accessory pigments also reflect different wavelengths of light than chlorophyll, they give algae a wide range of colors.



Figure 20–3 *The color of this beautiful plumelike red alga results from combinations of accessory pigments and chlorophyll. If you look closely, you can see tiny hooks on the alga. The alga uses the hooks to attach itself onto stationary algae, thus ensuring that it will remain in one place.*

20-1 SECTION REVIEW

1. What are two characteristics of algae?
2. In which kingdom are multicellular algae placed?
3. Why are some unicellular algae classified with multicellular algae?
4. How are algae adapted to life in water?

20–2 Groups of Algae

Section Objectives

- Identify the characteristics of three algae groups.
- Recognize differences between colonial and multicellular algae.

The colors provided by chlorophyll and accessory pigments, as well as the form in which food is stored, are characteristics used to classify algae into different groups. **There are three groups of multicellular algae: green algae, brown algae, and red algae.**

Green algae are members of phylum Chlorophyta (kluh-RAH-fuh-tuh). All green algae contain chlorophylls *a* and *b*. It is these chlorophylls that give the algae their green color. All green algae store food in the form of starch.

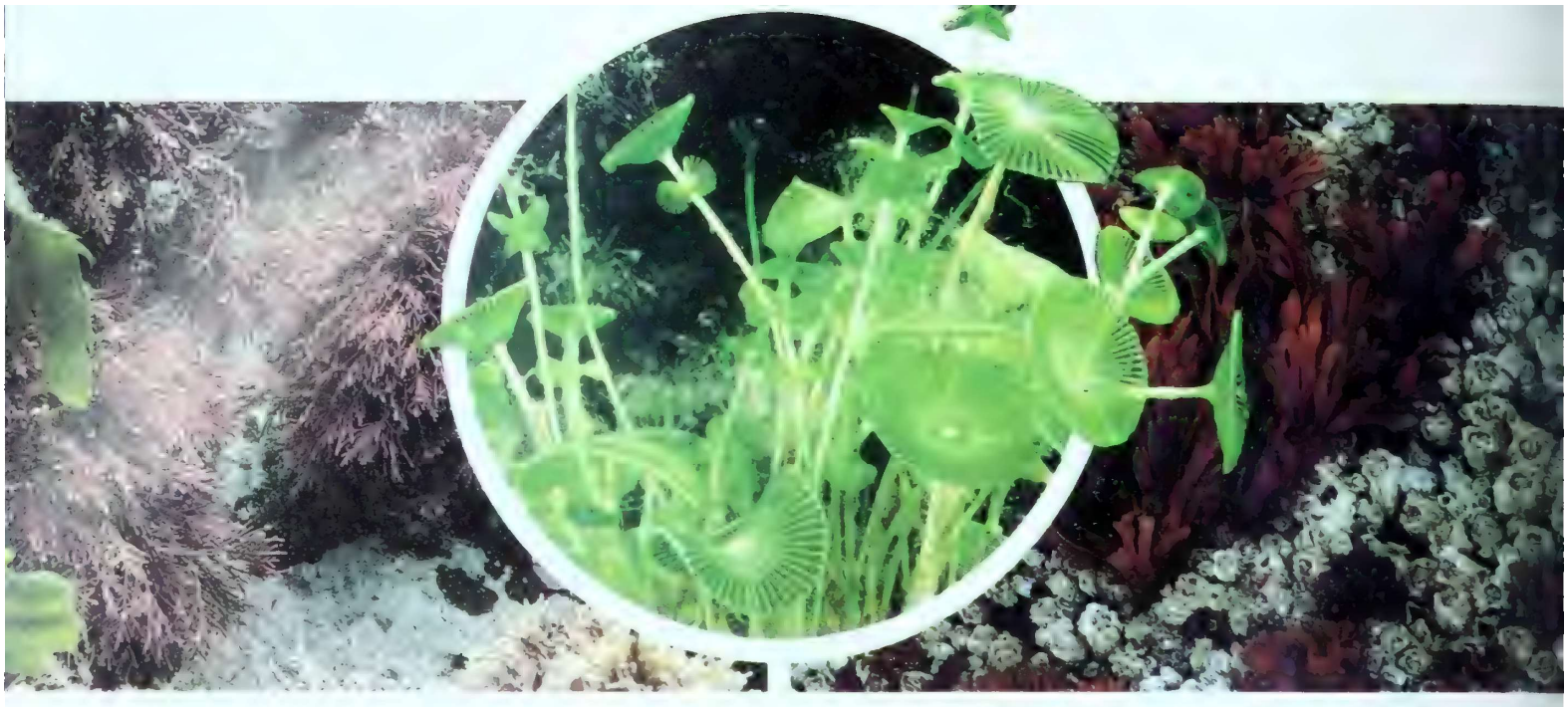
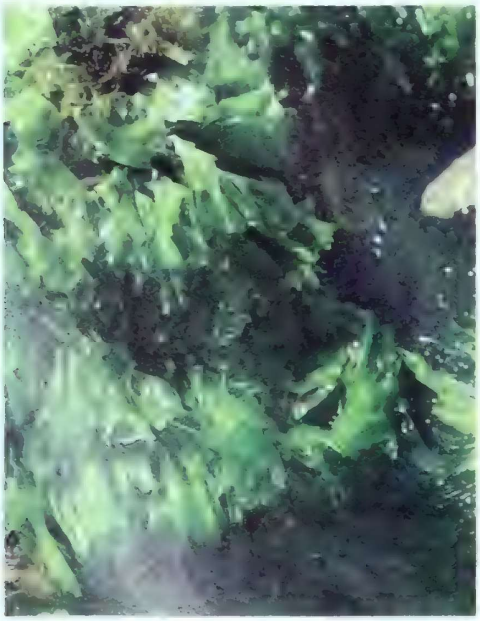


Figure 20–4 *As you can see, the colors of algae are quite varied. The red algae (left), brown algae (right), and green algae (center) illustrate how different combinations of pigments can result in dramatically different colors.*

Brown algae are members of phylum Phaeophyta (fee-AH-fuh-tuh). Brown algae contain chlorophylls *a* and *c*, as well as a brown accessory pigment called fucoxanthin (fyoo-koh-ZAN-thihn). The combination of fucoxanthin and chlorophyll *c* gives these plants their yellow-brown color. Brown algae store food in the form of special starches and oils.

Red algae are members of phylum Rhodophyta (roh-DAH-fuh-tuh). All red algae contain chlorophyll *a*. Some species of red algae also contain chlorophyll *d*. All red algae contain reddish accessory pigments called phycobilins (figh-koh-BIHL-ihnz). Phycobilins are very efficient at absorbing the energy of blue light and making it available for photosynthesis. Thus red algae can live deeper in the ocean than other kinds of algae. Depending on the amount of phycobilins they carry, red algae can be pink, red, purple, or even black. Red algae store food in the form of a special kind of starch.

Figure 20–5 *The green alga* Ulva *is called sea lettuce because the blades of this plant are flat and resemble salad greens.*



Chlorophyta—The Green Algae

Green algae are found primarily in moist areas on land and in fresh water. Some species of green algae live in the oceans. Green algae have evolved many forms in adapting to these widely different environments. Green algae may live as single cells. Some species of single-celled green algae form a **colony,** which is a group of cells that are joined together and show few specialized structures, or structures that perform a particular function. Other green algae are multicellular and have well-developed specialized structures. All species of green algae have reproductive cycles that include both sexual and asexual reproduction.

The multicellular green algae have cellulose in their cell walls, contain chlorophylls *a* and *b*, and store food in the form of starch, just like land plants. One stage in the life cycle of

mosses—small land plants you will learn about in the next chapter—looks remarkably like a tangled mass of green algae strands. All these characteristics lead scientists to believe that the ancestors of modern land plants looked a lot like certain species of living green algae. Unfortunately, algae rarely form fossils, so there is no single specific fossil that scientists can call an ancestor of both living algae and mosses. However, scientists believe that mosses and green algae shared such a common algaelike ancestor millions of years ago.

CHLAMYDOMONAS—A SINGLE-CELLED GREEN ALGAE *Chlamydomonas* (clam-uh-DAH-muh-nuhs), which is a single-celled green alga, grows in ponds, ditches, and wet soil. *Chlamydomonas* is a small egg-shaped cell with two flagella. A light-sensitive area called the eyespot cannot actually see but can sense whether the organism is in bright light or darkness.

Chlamydomonas has a large cup-shaped chloroplast. At the base of the chloroplast is a small pyrenoid (pigh-REE-noid), an organelle that synthesizes and stores starch. *Chlamydomonas* lacks the large vacuoles found in the cells of land plants. Instead it has two small contractile vacuoles. Unlike land plants, *Chlamydomonas* has a cell wall that does not contain cellulose.

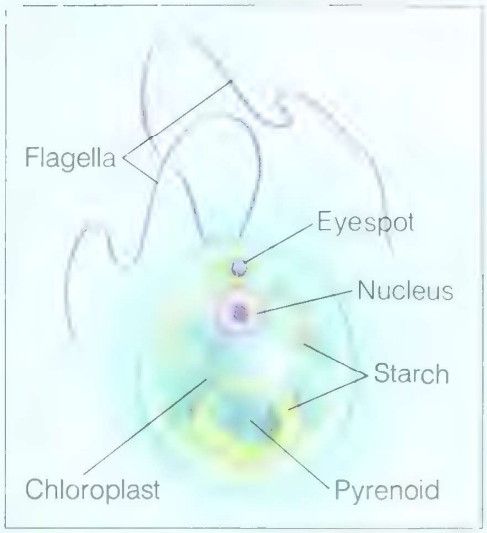
As you can see, *Chlamydomonas* has characteristics of both the algae grouped in the Protist kingdom and land plants. This combination of characteristics has led botanists to believe that *Chlamydomonas* is a good example of one step in the evolution of multicellular plants from unicellular protists.

COLONIAL GREEN ALGAE Several species of green algae provide an idea of how multicellular plants may have evolved. From single-celled species such as *Chlamydomonas*, species such as *Gonium* (GOH-nee-uhm) may have evolved. *Gonium* is a colonial alga composed of between 4 and 32 cells. In a colony, many identical cells live together although each cell still functions independently. The cells do not form specialized tissues. If the colony is broken apart, each cell can live and grow into a new colony.

Other species of green algae form larger colonies. The beautiful genus *Volvox* (VAHL-vahks) is one example. *Volvox* can form colonies consisting of as few as 500 or as many as 50,000 cells. Observation of *Volvox* provides two interesting details of the way this organism functions.

First, the cells in a *Volvox* colony are connected to one another by strands of cytoplasm. Thus the cells that make up this colony can communicate. Communication is necessary for the *Volvox* colony to swim: When the cells on one side of the colony "pull" with their flagella, the cells on the other side of the colony have to "push."

Second, although most cells in a *Volvox* colony are identical, a few cells are specialized for reproduction. These cells, which produce gametes, are the first step in the development



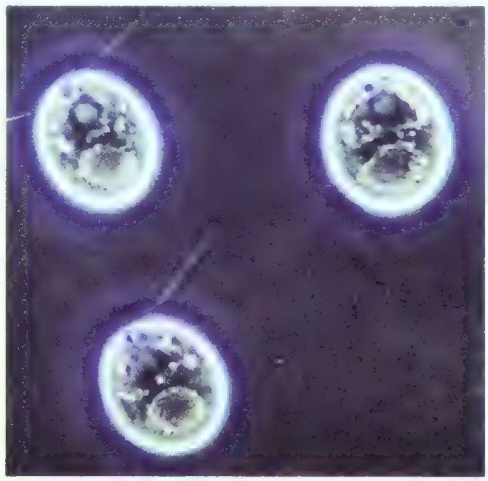


Figure 20–6 *The single-celled alga* Chlamydomonas *is a favorite subject of laboratory study. This alga is able to move about when it beats its two flagella back and forth in the water. It also has an eyespot that is sensitive to light.*

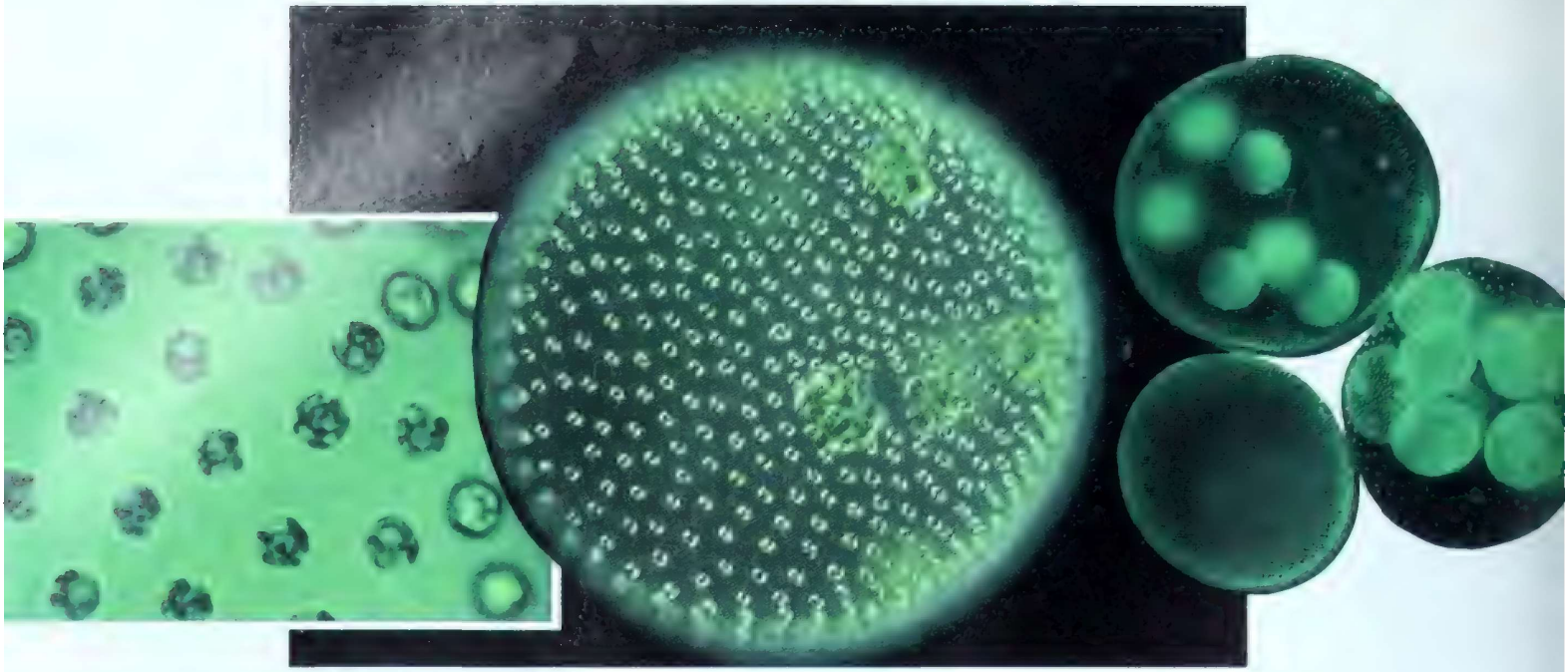
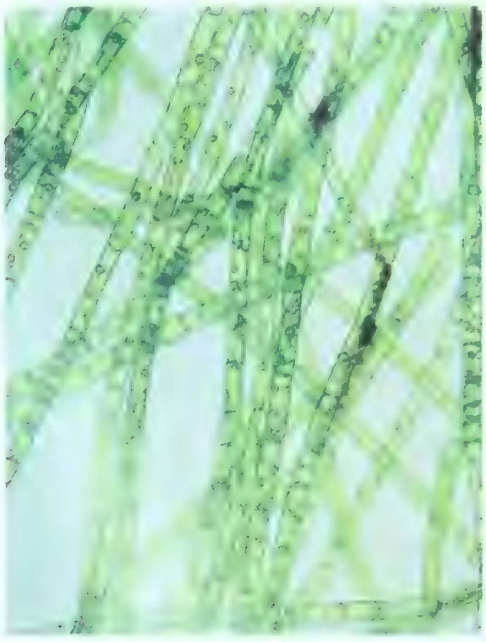


Figure 20–7 *Beautiful globes of the green alga* Volvox *can often be seen in bodies of fresh water (center). Each cell of this colonial alga is connected to other cells by strands of cytoplasm (left). New colonies often develop within a colony. Eventually the old colony ruptures, freeing the smaller colonies developing within (right).*

Figure 20–8 *Long strands of the green alga* Oedogonium *often grow in ponds. This alga can reproduce sexually by producing gametes. New algae can also form when pieces of the strands break off and develop into new plants.*



of specialized tissues that become more common in plants adapted to life on land. Because it shows some cell specialization, *Volvox* straddles the fence between colonial and multicellular life.

SPIROGYRA AND OEDOGONIUM—THREADLIKE GREEN ALGAE Many green algae form long threadlike colonies called **filaments,** the cells of which are shaped like soda cans stacked end on end. *Spirogyra* (spigh-roh-JIGH-ruh) and *Oedogonium* (ee-duh-GOH-nee-uhm) are two common examples of freshwater filamentous green algae. Filamentous algae can grow and reproduce asexually. For example, if the algae filaments are broken, the cells of each piece can continue to divide and grow. Many filamentous green algae can also reproduce sexually. *Oedogonium,* like *Volvox,* forms two different specialized reproductive cells, or gametes. Each *Oedogonium* filament is attached to the bottom of a lake or pond by another kind of specialized cell called a **holdfast cell.**

ULVA—A MULTICELLULAR GREEN ALGA *Ulva* (UHL-vuh), or "sea lettuce," is a bright-green multicellular marine alga that is commonly found along rocky seacoasts. Although *Ulva* plants are only two cells thick, they are tough enough to survive the pounding of waves on the shores where they live. A group of specialized cells at the base of the plant form holdfasts that attach *Ulva* to the rocks.

Phaeophyta—The Brown Algae

Brown algae are important marine plants that are found in cool shallow coastal waters of temperate or arctic areas. The brown algae have very complicated structures, although they are not as highly developed as land plants. Most of what are commonly called sea weeds are species of brown algae. The largest alga in the world is a form of giant kelp that can grow more than 60 meters long. Another brown alga called *Sargassum* (sahr-GAS-suhm) forms huge floating mats many kilometers long in an area of the Atlantic Ocean near Bermuda known as the Sargasso Sea. Bunches of *Sargassum* often drift on currents to beaches in the Caribbean and southern United States.

One common brown alga is *Fucus* (FYOO-kuhs), or rockweed, which lives along the rocky coast of the eastern United States. Each *Fucus* plant has a holdfast that glues the plant to the bottom. The body of the plant consists of flattened stemlike structures called stipes, leaflike structures called blades, and gas-filled swellings called bladders. Many species of brown algae have bladders, which keep the plants floating upright in the water.

Rhodophyta—The Red Algae

The *Rhodophyta* are another important group of marine algae that can be found in waters from the far north to the tropics. These algae can grow anywhere from the ocean's surface to depths of up to 170 meters. *Rhodophyta* can exist at such extreme depths because they have special pigments that enable them to trap whatever energy is contained in the small amount of light that penetrates there. Most species of red algae are multicellular, and all species have complicated life cycles.

One common red alga is *Chondrus crispus*, or Irish moss. It grows in tide pools and on rocky coastlines. Some red algae, known as the coralline algae, play an important role in the formation of coral reefs. In Japan, the red alga *Porphyra* (por-FIHR-uh) is grown on special marine farms. Dried *Porphyra*—called *nori* in Japanese—is used to wrap portions of rice to make sushi rolls.

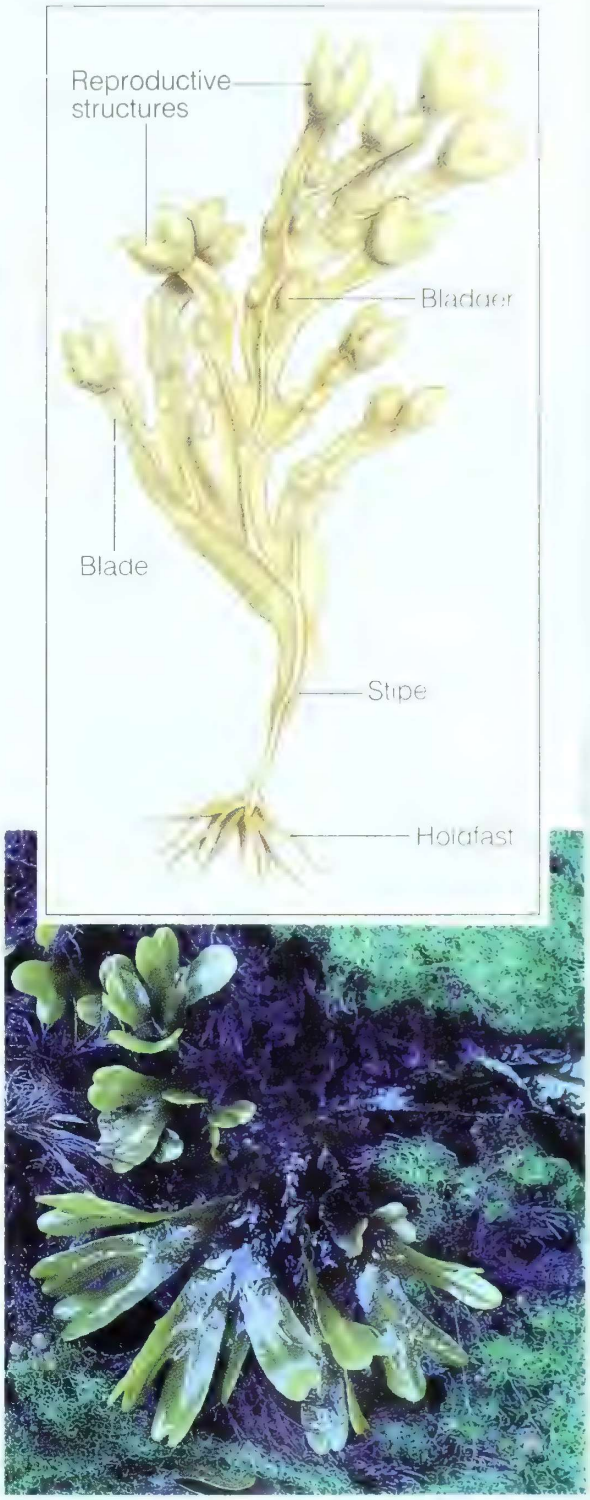


Figure 20–9 *Because the brown alga* Fucus *commonly grows attached to rocks along the shoreline, it is called rockweed.*

20–2 SECTION REVIEW

1. What important factors are used to group algae?
2. What is one important difference between *Chlamydomonas* and *Volvox*?
3. Red algae often live in deep water. What important adaptation do red algae show that enables them to do this?

Section Objectives

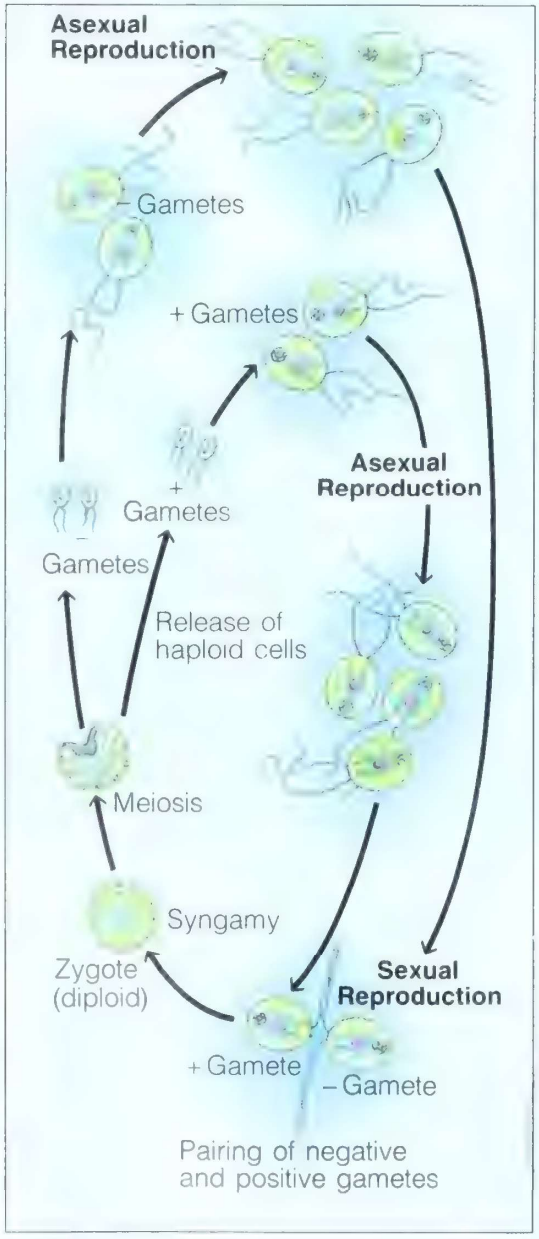
- Define alternation of generations.
- Discuss various ways groups of algae reproduce.

20–3 Reproduction in Algae

The life cycles of most algae include both a diploid and a haploid generation. Diploid cells have the normal number of chromosomes for a particular species, whereas haploid cells have half the normal number of chromosomes. The switching back and forth between the production of diploid and haploid cells is called **alternation of generations.** In addition to alternating generations, most species of algae also shift back and forth between sexual reproduction that involves the production of gametes and asexual reproduction that involves haploid cells called **zoospores** (ZOH-oh-sporz).

Complex life cycles that involve alternation of generations are characteristic of all members of the plant kingdom. These life cycles are much more complicated than the simple kinds of sexual reproduction that occur in familiar animals such as birds and mammals.

Figure 20–10 As you can see from this diagram of the life cycle of Chlamydomonas, *this green alga reproduces asexually by producing zoospores and sexually by producing zygospores.*



Reproduction in *Chlamydomonas*

The single-celled *Chlamydomonas* spends most of its life in the haploid stage. As long as its living conditions are suitable, this haploid cell reproduces asexually by mitosis. Each time the cell divides, it produces identical haploid zoospores. Smaller than the parent cell, the zoospores soon mature and are able to reproduce asexually. This sequence may be repeated over and over again.

If conditions become unfavorable, *Chlamydomonas* can switch to a stage that reproduces sexually. See Figure 20–10. The haploid cells continue to undergo mitosis, but instead of releasing zoospores, the cells release gametes. Different parent cells produce gametes of two different types, which we call (+) and (–). To our eyes, these gametes appear to be identical. The condition in which the gametes of an organism appear identical is called **isogamy** (igh-SAHG-uh-mee). *Iso* means equal; *gamy* refers to cells that are involved in sexual reproduction. So isogamy means identical reproductive cells.

During sexual reproduction, the gametes gather in large groups. Then (+) and (–) gametes form pairs that soon move away from the group. The paired gametes join flagella and spin around in the water. Both members of the pair then shed their cell walls and fuse, forming a diploid zygote. The fusing of gametes is called **syngamy** (SIHNG-guh-mee).

The zygote sinks to the bottom of the pond or ditch and grows a thick protective wall. Within this protective wall *Chlamydomonas* can survive freezing or drying conditions that would ordinarily kill it. When conditions once again become favorable, the zygote begins to grow. It divides by meiosis to produce four flagellated haploid cells. These haploid cells can swim away, mature, and reproduce asexually.

Reproduction in *Ulva*

The life cycle of *Ulva* involves an alternation of generations in which both the diploid and the haploid stages are multicellular plants. See Figure 20–11. The diploid plant is called the **sporophyte,** or "spore producer," because it produces spores. The haploid plant is called the **gametophyte** (guh-MEET-uh-fight) because it produces gametes.

Ulva actually has two different types of gametophytes. Each type produces a different kind of gamete, one of which is larger than the other. The production of two different kinds of gametes is called **heterogamy.**

When the two different gametes fuse, the resulting diploid zygote does not enter a resting stage. Instead, it begins to grow into a multicellular diploid sporophyte. Specialized cells within the sporophyte reproduce asexually by undergoing meiosis and releasing haploid zoospores. These zoospores then divide by mitosis to grow into the two different types of multicellular gametophytes. The two different types of gametophytes produce their gametes and the cycle continues. The only tricky part of the *Ulva* life cycle, at least for humans, is that all three multicellular plants—the two gametophytes and the sporophyte—look exactly the same to the unaided eye!

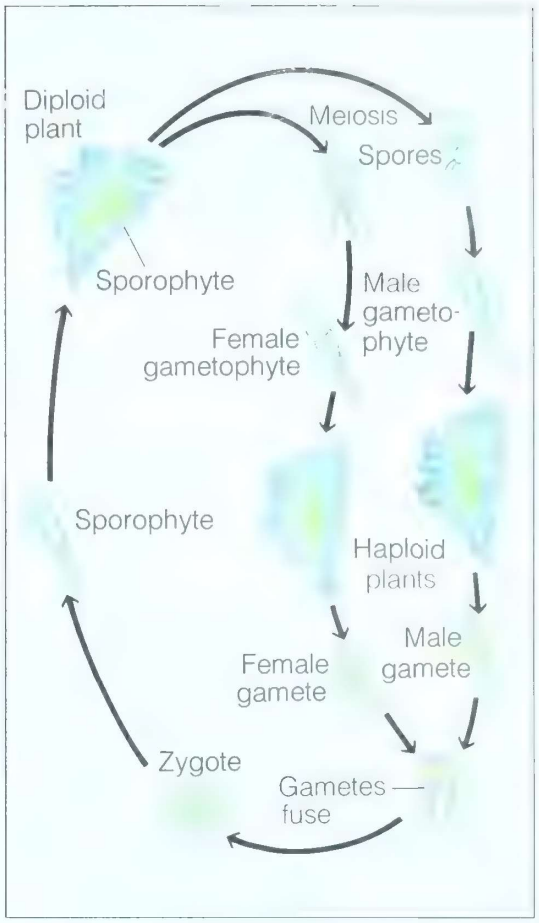


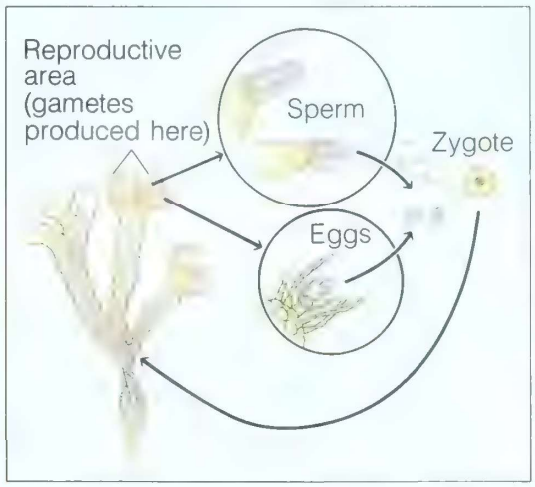
Figure 20–11 *Both generations of the green alga* Ulva *are multicellular plants.*

Reproduction in *Fucus*

The brown alga *Fucus* demonstrates both alternation of generations and heterogamy. Here, the two gametes are radically different from each another. The female gamete, or **egg,** is large and cannot swim. The male gamete, or **sperm,** is small, has a flagella, and can swim. Differences between male and female gametes develop further in plants adapted to land.

Fucus resembles land plants in that the multicellular haploid gametophyte is missing. The diploid sporophyte plant is the only multicellular part of the life cycle. There are two different types of specialized reproductive areas on the tips of the *Fucus* blades. One area produces eggs; the other area produces sperm. Both eggs and sperm are released into the water. If some of the sperm manage to swim to the drifting eggs, fertilization occurs and a zygote is formed. The zygote sinks, and with some luck, lands on a rock to which it will attach itself and grow by mitotic division into a new diploid sporophyte.

Figure 20–12 *Reproductive structures form on the tips of the blades of the brown alga* Fucus. *Most species of brown algae reproduce sexually.*



20-3 SECTION REVIEW

1. What is alternation of generations?
2. What is an advantage of asexual reproduction?
3. What is an advantage of sexual reproduction?
4. How is alternation of generations an effective way of ensuring that fit individuals survive?

Section Objectives

- Discuss the importance of algae to life on Earth.
- List several commercial applications of algae.

20–4 Where Algae Fit into the World

Single-celled algae, together with blue-green bacteria and some green flagellates, are food for most of the life in the oceans. Because they are such an important source of food, algae have been called the grasses of the seas. Algae also provide homes for many species of animals. The huge brown kelp forests along the coasts of the United States are home not only to sea otters but to many animal species.

Life as we know it would never have evolved without algae, for they produce much of Earth's free oxygen through photosynthesis. Scientists calculate that between 50 and 75 percent of all the photosynthesis that occurs on Earth is performed by algae. This fact alone makes algae one of the most important groups of organisms on the entire planet.

Over the years, people have learned to use algae—and the chemicals produced by algae—in many different ways. Many species of algae are rich in vitamin C and iron. Other chemicals in algae are used to treat stomach ulcers, lung ailments, high blood pressure, arthritis, and other health problems.

Algae are also used in the manufacture of many food products. Algae are used to make ice cream smooth and candy bars last longer. Algae are used in pickle relishes, salad dressings, chip dips, pancake syrups, egg nogs, and canned chow mein. In Japan and other parts of Asia, algae farms produce crops of red and brown algae that are eaten by millions of people. Algae are eaten as a vegetable and used as flavorings in soups, meat dishes, and candy. Toothpastes, adhesives, hand lotions, and finger paints all contain algae.

Modern industry has even more uses for algae. Chemicals from algae are used to make plastics, waxes, transistors, deodorants, paints, lubricants, and even artificial wood. Algae products are found in poultry feed, cake batters, pie fillers, bakery jellies, and doughnut glazes. Algae even have an important use in scientific laboratories. The compound agar-agar, derived from certain seaweeds, thickens the nutrient mixtures scientists use to grow bacteria and other microorganisms. As you can see, our lives would be very different without algae.

Figure 20–13 *Although polar bears are carnivores, they will eat algae. People eat algae, too. Algae are often used to thicken frozen dairy desserts—much to the delight of these two youngsters.*





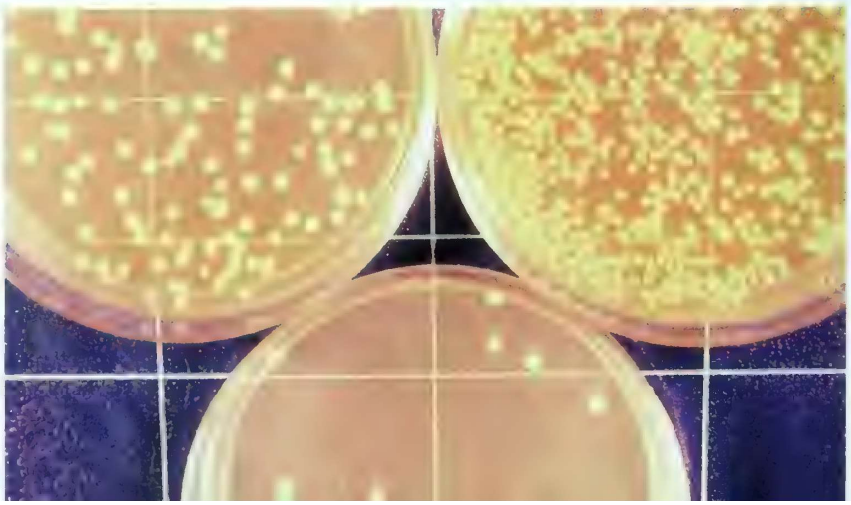


Figure 20–14 *One important product of algae is agar, a substance used to thicken growth media. Colonies of bacteria are growing on agar in the petri dishes shown here.*

SCIENCE, TECHNOLOGY, AND SOCIETY **APPLICATION**

Algae: A Natural Sewage Treatment Plant

Researchers are studying ways to use algae to clean sewage produced by cities and towns. Sewage, or waste water, contains the liquid and solid wastes each of us produces every day. Since there is no way to avoid producing sewage, we must learn to dispose of it without harming the environment. Untreated sewage released into streams and ponds has several unpleasant consequences. One is that algae in the streams and ponds begin to grow rapidly. Algae may grow so rapidly, in fact, that they cover the surface of the water. This increased growth is called an algal bloom. An algal bloom may harm other forms of life that live in the water.

Why does sewage cause algal blooms? Human wastes—like the wastes of all animals—contain substances that plants use as nutrients for growth. As algae grow, they remove these nutrients from sewage. In other words, sewage acts as fertilizer for algae.

Some researchers think they have found a way to put this characteristic of algae to use in treating sewage. Their plan works as follows: First the sewage is diluted. Then the sewage is trickled through large tanks of algae. As the algae grow, they remove nutrients contained in the sewage. Eventually, treated water can be released carefully into the environment. Because it contains a smaller concentration of harmful wastes, this water does not threaten the environment as much as untreated sewage does. If researchers can grow the right kinds of algae, not only will they be able to treat sewage, but they may also be able to produce plants for use in industry.



As they grow, algae take in chemicals and other substances from water. Various species of algae are being used in pilot programs to design new methods of treating sewage.

20-4 SECTION REVIEW

1. How have algae changed the atmosphere on Earth?
2. How would life on Earth be different if all algae suddenly became extinct?
3. What two foods contain algae products?
4. How have algae contributed to our understanding of human disease?

LABORATORY INVESTIGATION

STUDYING FILAMENTOUS GREEN ALGAE

PROBLEM

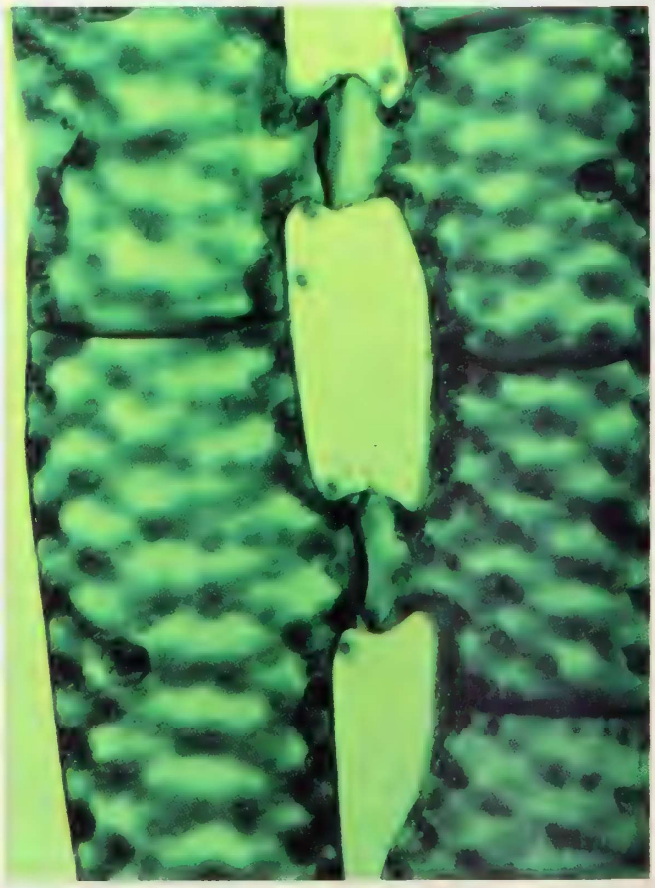
What are the characteristics of *Spirogyra?*

MATERIALS *(per group)*

microscope
prepared slide of *Spirogyra*

PROCEDURE

1. Using a microscope, examine a prepared slide of *Spirogyra* under the low-power objective. Notice the general shape of *Spirogyra.* On a separate sheet of paper, draw a diagram of a filament of *Spirogyra.* Indicate the appearance of individual cells. Note the arrangement of the chloroplasts.
2. Move your slide until you locate two parallel filaments that are attached to each other by small "bridges," or tubes. This attachment is a form of sexual reproduction called conjugation. Switch to the medium-power objective and focus. Draw the portion of the filaments that shows the conjugation tubes. If possible, locate a portion of the filaments where material is passing from one cell to another through the tubes. Draw these cells.
3. Switch to the high-power objective. Use the fine adjustment to focus on a nucleus in one of the cells. Draw a diagram of a single cell and its nucleus. Label the nucleus.
4. Leaving the high-power objective in place, move the slide to focus on a portion of a chloroplast. Draw a diagram of a chloroplast.



OBSERVATIONS

1. Are there different kinds of cells in *Spirogyra?*
2. What is the shape of *Spirogyra?*
3. Based on your observations, describe what happens during conjugation in *Spirogyra?*
4. How is the nucleus held in place?
5. What is the shape of the chloroplasts?

ANALYSIS AND CONCLUSIONS

1. Are *Spirogyra* multicellular or colonial algae? Explain your answer.
2. What is the function of the conjugation tubes?
3. How are *Spirogyra* adapted to life in water? Would these plants survive on land? Explain your answer.

STUDENT STUDY GUIDE

SUMMARIZING THE CONCEPTS

The key concepts in each section of this chapter are listed below to help you review the chapter content. Make sure you understand each concept and its relationship to other concepts and to the theme of this chapter.

20–1 Characteristics of Algae

- Algae must live in or near a source of water.
- Algae vary in size, shape, and color. Some species of algae are unicellular, other species form colonies, and still other species are multicellular.
- Algae show many different adaptations to life in water. Unlike land plants, most algae lack a system of internal tubes to move water and nutrients from one part of the plant to another. Since algae live in water, they do not need protection from drying out or stemlike structures to keep them upright.
- Algae contain accessory pigments in addition to different forms of chlorophyll. These pigments give algae their color. Scientists group algae on the basis of the chlorophylls and pigments they contain, as well as the form in which they store food.

20–2 Groups of Algae

- There are three groups of multicellular algae: green algae, red algae, and brown algae. Each group receives its color from combinations of special pigments and chlorophyll.
- The three different groups of algae store the food they make as special starches and/or oils.

20–3 Reproduction in Algae

- Algae have complex life cycles that involve alternation of generations.
- Many algae produce special cells during reproduction that enable the algae to survive harsh environmental conditions. These cells can resume growth when environmental conditions improve.

20–4 Where Algae Fit into the World

- Algae produce much of the Earth's free oxygen during photosynthesis. Without this oxygen, life on Earth as we know it would never have evolved.
- Algae provide food for animals and people. Algae are also used in the manufacture of many foods and industrial products.

REVIEWING KEY TERMS

Vocabulary terms are important to your understanding of biology. The key terms listed below are those you should be especially familiar with. Review these terms and their meanings. Then use each term in a complete sentence. If you are not sure of a term's meaning, return to the appropriate section and review its definition.

20–1 Characteristics of Algae

accessory pigment

20–2 Groups of Algae

colony
filament
holdfast cell

20–3 Reproduction in Algae

alternation of generations
zoospore
isogamy
syngamy
sporophyte
gametophyte
heterogamy
egg
sperm

CHAPTER REVIEW

CONTENT REVIEW

Multiple Choice

Choose the letter of the answer that best completes each statement.

1. Unlike most plants, algae lack
   a. chloroplasts.
   b. accessory pigments.
   c. a nucleus.
   d. an internal system of tubes.
2. Which of the following algae are able to live in deep ocean water?
   a. red algae
   b. green algae
   c. *Volvox*
   d. *Spirogyra*
3. Algae take in nutrients through their
   a. holdfast.
   b. stipe.
   c. blade.
   d. cell membrane.
4. Some single-celled algae are included in the kingdom
   a. Monera.
   b. Protista.
   c. Animalia.
   d. Fungi.
5. Red algae have a special pigment that enables them to absorb energy from
   a. red light.
   b. yellow light.
   c. violet light.
   d. blue light.
6. Green algae live in each of the following environments except
   a. dry land.
   b. a pond.
   c. moist areas on land.
   d. a lake.
7. Filaments of some forms of green algae are attached to the bottom of a lake or pond by a (an)
   a. stipe.
   b. holdfast cell.
   c. air bladder.
   d. egg.
8. The largest algae in the world are the
   a. red algae.
   b. filamentous algae.
   c. green algae.
   d. brown algae.

True or False

Determine whether each statement is true or false. If it is true, write "true." If it is false, change the underlined word or words to make the statement true.

1. Alternation of generations is a characteristic of all plants.
2. Chlorophyll can make blue light more useful for photosynthesis.
3. Fucus are single-celled green algae.
4. Kelp are the largest algae in the world and can grow longer than 60 meters.
5. Filamentous algae can reproduce sexually when they break apart.
6. A colony is a group of cells that are joined together and that show few specialized structures.
7. Special light-absorbing pigments found in some kinds of algae are called gametes.
8. Most algae get necessary gases and nutrients from the air.

Word Relationships

In each of the following sets of terms, three of the terms are related. One term does not belong. Determine the characteristic common to three of the terms and then identify the term that does not belong.

1. eggs, sperm, spores, stipes
2. red, brown, green, yellow
3. *Chlamydomonas, Volvox, Spirogyra, Fucus*
4. ponds, lakes, rivers, oceans

CONCEPT MASTERY

Use your understanding of the concepts developed in the chapter to answer each of the following in a brief paragraph.

1. Explain the importance of algae to life.
2. Describe two characteristics that help scientists classify algae.
3. How are some kinds of red algae adapted to life in deep ocean water?
4. What is the main difference between a colony and a multicellular organism?
5. What is alternation of generations?
6. Why do some scientists place all algae in the kingdom Protista?
7. How are algae different from land plants?
8. Accessory pigments do more than provide color for algae. What important function do accessory pigments perform?

CRITICAL AND CREATIVE THINKING

Discuss each of the following in a brief paragraph.

1. **Applying concepts** How does having a method of both asexual reproduction and sexual reproduction contribute to an organism's survival?
2. **Making predictions** Suppose all species of algae on Earth died out. What effects would this have on other organisms?
3. **Relating cause and effect** Suppose you were able to design a new species of algae that could live in deep water. What important characteristics would you include? Why?
4. **Applying technology** You have been chosen to work on a new space probe that will carry humans deep into space. A friend suggests that it would be important to have a population of algae on this trip. How could these algae help human space travelers on a long voyage in space?
5. **Analyzing concepts** You know that all life comes from life. Your friend observes that a pond in the area has dried up and appears to lack life. Later, this pond fills with water again. Algae begin to grow. Your friend is puzzled. How could you explain the growth of algae in this pond?
6. **Relating concepts** Some scientists think that a form of algae was an ancestor of certain land plants. What are some changes that would have to occur in order to make algae able to survive on land?
7. **Using the writing process** The huge kelp forests along the west coast of the United States are home to the sea otter. There are relatively few of these animals alive in the wild. The otters are fond of eating abalone and other shellfish. Because of their eating preferences, they often come into conflict with local people who earn a living by capturing and selling the shellfish. These local people want to eradicate the kelp. They feel that the sea otters will move away if the kelp is destroyed. You are the lawyer hired by the government to protect the kelp and the otters. The local newspaper wants you to write an article detailing your position. Here is your chance to influence people. Write an article for the paper. Save the otters!