Section 20–4

1 FOCUS

Objectives

20.4.1 ***Describe*** the major phyla of multicellular algae.
20.4.2 ***Explain*** how multicellular algae reproduce.
20.4.3 ***Identify*** some human uses of algae.

Guide for Reading

Vocabulary Preview

Pronounce each of the Vocabulary words out loud, and ask students to pronounce the terms back in unison.

Reading Strategy

Explain that an outline should include several levels of entries, with each of the entries providing support for the level above. To make an outline of this section, students should use the blue headings as their first level of entries. The green headings, such as those under Green Algae, should form the second level of entries. Third and fourth levels should include supporting details, concepts, and examples.

2 INSTRUCT

Red Algae

Make Connections

Physics Some students may not know that the color of an object depends on which colors of the visible spectrum of light are absorbed and which are reflected. Point to a pair of blue pants and ask students: **Are these pants blue because they absorb blue light or reflect blue light?** *(The pants are blue because they reflect blue light.)* Point out that the pants not only reflect blue light but also absorb the other colors in the visible light spectrum. Explain that the different pigments in the different kinds of algae absorb some colors and reflect others. The pigments in red algae, for example, reflect red light and absorb other colors. L1 L2

20–4 Plantlike Protists: Red, Brown, and Green Algae

Guide for Reading

Key Concepts
- What are the distinguishing features of the major phyla of multicellular algae?
- How do multicellular algae reproduce?

Vocabulary
phycobilin
filament
alternation of generations
gametophyte
spore
sporophyte

Reading Strategy: Outlining Before you read, use the blue and the green headings to make an outline about multicellular algae. As you read, add phrases or a sentence after each heading to provide key information.

Have you ever taken a walk along a rocky beach at low tide? As the water recedes, in many places it reveals a damp forest of green and brown "plants" clinging to the rocks. These seaweeds have the size, color, and appearance of plants, but they are not plants. They are actually algae. Unlike the algae in the previous section, most of these algae are multicellular, like plants. They also have reproductive cycles that are sometimes very similar to those of plants. Many of them have cell walls and photosynthetic pigments that are identical to those of plants. Many of these algae also possess highly specialized tissues.

The three phyla of algae that are largely multicellular are commonly known as red algae, brown algae, and green algae. The most important differences among these phyla involve their photosynthetic pigments.

Red Algae

Red algae are members of the phylum Rhodophyta (roh-duh-FYT-uh), meaning "red plants." **Red algae are able to live at great depths due to their efficiency in harvesting light energy. Red algae contain chlorophyll *a* and reddish accessory pigments called phycobilins.**

Phycobilins (fy-koh-BIL-inz) are especially good at absorbing blue light, enabling red algae to live deeper in the ocean than many other photosynthetic algae. Many red algae are actually green, purple, or reddish black, depending upon the other pigments they contain. Red algae are an important group of marine algae that can be found in waters from the polar regions to the tropics. The highly efficient light-harvesting pigments in these algae enable them to grow anywhere from the ocean's surface to depths of up to 260 meters.

Most species of red algae are multicellular, and all species have complex life cycles. Red algae lack flagella and centrioles. Red algae also play an important role in the formation of coral reefs, as shown in **Figure 20–14.** These microorganisms help to maintain the equilibrium of the coral ecosystem, providing nutrients from photosynthesis that nourish coral animals. Coralline red algae provide much of the calcium carbonate that helps to stabilize the growing coral reef.

Figure 20–14 **Red algae contain chlorophyll *a* and reddish pigments called phycobilins.** Coralline algae, a type of red alga, collect calcium carbonate in their cell walls, giving them a tough, stony texture.

SECTION RESOURCES

Print:
- ***Teaching Resources,*** Section Review 20–4
- ***Reading and Study Workbook A,*** Section 20–4
- ***Adapted Reading and Study Workbook B,*** Section 20–4
- ***Lesson Plans,*** Section 20–4

Technology:
- ***iText,*** Section 20–4
- ***Transparencies Plus,*** Section 20–4

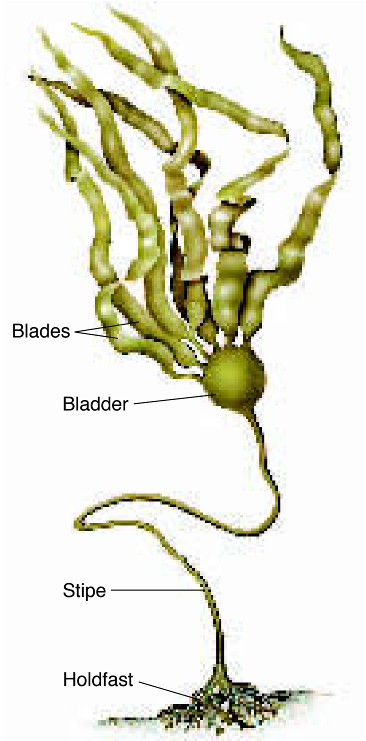
Brown Algae

Brown algae belong to the phylum Phaeophyta (fay-uh-FYT-uh), meaning "dusky plants." **Brown algae contain chlorophyll *a* and *c*, as well as a brown accessory pigment, fucoxanthin.** The combination of fucoxanthin (fyoo-koh-ZAN-thin) and chlorophyll *c* gives most of these algae a dark, yellow-brown color. Brown algae are the largest and most complex of the algae. All brown algae are multicellular and most are marine, commonly found in cool, shallow coastal waters of temperate or arctic areas.

The largest known alga is giant kelp, a brown alga that can grow to more than 60 meters in length. Another brown alga called *Sargassum* 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 of the most common brown alga is *Fucus*, or rockweed, found along the rocky coast of the eastern United States. Each *Fucus* alga has a holdfast, a structure that attaches the alga to the bottom. The body of the alga consists of flattened stemlike structures called stipes, leaflike structures called blades, and gas-filled swellings called bladders, which float and keep the alga upright in the water. **Figure 20–15** shows the structures of a brown alga.

CHECKPOINT *What does a holdfast do?*



▲ **Figure 20–15** **Brown algae contain chlorophyll *a* and *c*, plus fucoxanthin, a brown pigment.**

Green Algae

Green algae are members of the phylum Chlorophyta (klawr-uh-FYT-uh), which means "green plants" in Greek. **Green algae share many characteristics with plants, including their photosynthetic pigments and cell wall composition.** Green algae have cellulose in their cell walls, contain chlorophyll *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 unit—looks remarkably like a tangled mass of green algae strands. All these characteristics lead scientists to hypothesize 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 think that mosses and green algae shared such a common algalike ancestor millions of years ago.

Green algae are found in fresh and salt water, and even in moist areas on land. Many species live most of their lives as single cells. Others form colonies, groups of similar cells that are joined together but show few specialized structures. A few green algae are multicellular and have well-developed specialized structures.

Go Online NSTA SCiLINKS
For: Links on algae
Visit: www.SciLinks.org
Web Code: cbn-6204

Brown Algae

Demonstration

Display a large map of North America or the Western Hemisphere for students to see. Point out the area of ocean called the Sargasso Sea, which is southeast of Bermuda. Explain that some brown algae, such as kelp, have a holdfast that attaches the seaweed to rocks or other surfaces. The *Sargassum* in the Sargasso Sea, by contrast, has no holdfast. Instead, this form of brown algae has gas-filled bladders—floats—at the base of the seaweed's blades that keep the algae afloat in the Sargasso Sea. Explain that some students may have seen this brown alga on the Florida shores of the Gulf of Mexico. After tropical storms, large quantities of *Sargassum* are washed up along the beaches there. L2

Green Algae

Build Science Skills

Classifying Before students read about green algae, divide the class into small groups and give each group several samples to observe, including a sample of "sea lettuce" or another kind of multicellular green alga, a fern, a mushroom, a flowering plant, and some kind of moss. Ask students to examine these organisms and speculate about the environment to which each organism is adapted. Have each group consider which of the samples could be considered a plant and which could not be. Then, have several groups present their findings to the class. Challenge groups to give reasons why they classified some organisms as plants but not others. L2

Go Online NSTA SCiLINKS
Download a worksheet on algae for students to complete, and find additional teacher support from NSTA SciLinks.

Differentiated Instruction — Solutions for All Learners

Inclusion/Special Needs
Emphasize that although the organisms discussed in this section have characteristics in common with plants, they are not plants. Remind students again of the definition of protists—eukaryotes that are not members of other kingdoms. L1

Less Proficient Readers
Ask students to make a concept map to organize information in the section about multicellular algae. The concept map should include the phylum names, the common names, and examples of members of each phylum. L1 L2

English Language Learners
Make sure students understand *alternation of generations.* After discussing the meaning of *generation* in this context, explain that *alternation* derives from a Latin word that means "by turns"—shifting from one thing to another and back again. The verb *alternate* is a related word. L2

Answer to . . .

CHECKPOINT *A holdfast is a structure that attaches the alga to the bottom.*

20–4 (continued)

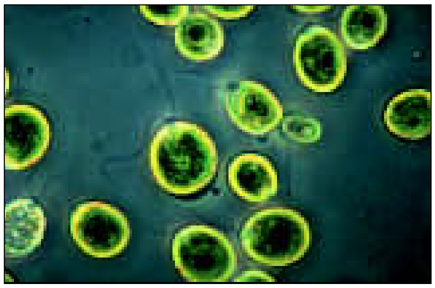
Build Science Skills

Comparing and Contrasting
Provide students with access to living cultures of different forms of green algae, such as *Chlamydomonas, Spirogyra,* and *Ulva*, and have them make slides from these cultures. (To make a slide from the *Chlamydomonas* culture, they can use a dropper pipette to place one drop of the culture on a slide and cover with a coverslip. To make a slide from the *Spirogyra* culture, they can separate a strand into a 2-centimeter segment using a dissecting needle, add a drop of water, and cover with a coverslip. To make a slide from the *Ulva* culture, they can separate a small piece of the alga from the sample, add a drop of water, and cover with a coverslip.) Ask students to observe the slides under a microscope and make labeled drawings of what they see. After students have concluded their observations, have them compare the different kinds of green algae in a class discussion. L2 L3

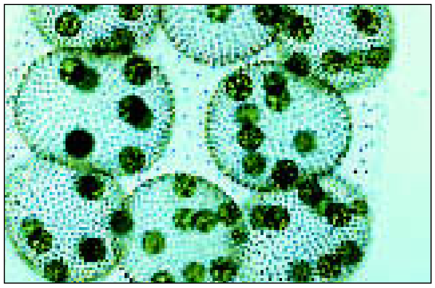
Reproduction in Green Algae

Address Misconceptions

The idea of alternation of generations may confuse some students. They might conclude that every other generation of an organism is radically different from the previous generation. Point out that this use of the term *generation* has a different meaning from what it might have in another context, such as the generations in a person's family. Synonyms for *generation* in this context include *phase* and *stage.* L1 L2



Chlamydomonas (magnification: 1000×)



Volvox (magnification: 450×)

Ulva

Figure 20–16 Green algae have the same photosynthetic pigments and cell wall compositions as green plants. *Chlamydomonas* is a unicellular green alga that lives in ponds. Delicate spherical colonies of the green alga *Volvox* live in fresh water. New colonies can develop within existing colonies and are released when an older colony ruptures. *Ulva* is a multicellular green alga that lives along seacoasts.

Unicellular Green Algae *Chlamydomonas* (kluh-mid-uh-MOHN-uz), a typical single-celled green alga, grows in ponds, ditches, and wet soil. *Chlamydomonas* is a small egg-shaped cell with two flagella and a single large, cup-shaped chloroplast. Within the base of the chloroplast is a region that synthesizes and stores starch. *Chlamydomonas* lacks the large vacuoles found in the cells of land plants. Instead, it has two small contractile vacuoles. *Chlamydomonas* and two other green algae are shown in **Figure 20–16.**

Colonial Green Algae Several species of green algae live in multicellular colonies. The freshwater alga *Spirogyra,* shown in **Figure 20–1,** forms long threadlike colonies called **filaments,** in which the cells are stacked almost like aluminum cans placed end to end. *Volvox* colonies are more elaborate, consisting of as few as 500 to as many as 50,000 cells arranged to form hollow spheres. The cells in a *Volvox* colony are connected to one another by strands of cytoplasm, enabling them to coordinate movement. When the colony moves, cells on one side of the colony "pull" with their flagella, and the cells on the other side of the colony have to "push." Although most cells in a *Volvox* colony are identical, a few gamete-producing cells are specialized for reproduction. Because it shows some cell specialization, *Volvox* straddles the fence between colonial and multicellular life.

Multicellular Green Algae *Ulva*, or "sea lettuce," is a bright-green marine alga that is commonly found along rocky seacoasts. *Ulva* is a true multicellular organism, containing several specialized cell types. Although the body of *Ulva* is only two cells thick, it is tough enough to survive the pounding of waves on the shores where it lives. A group of cells at its base forms holdfasts that attach *Ulva* to the rocks.

Reproduction in Green Algae

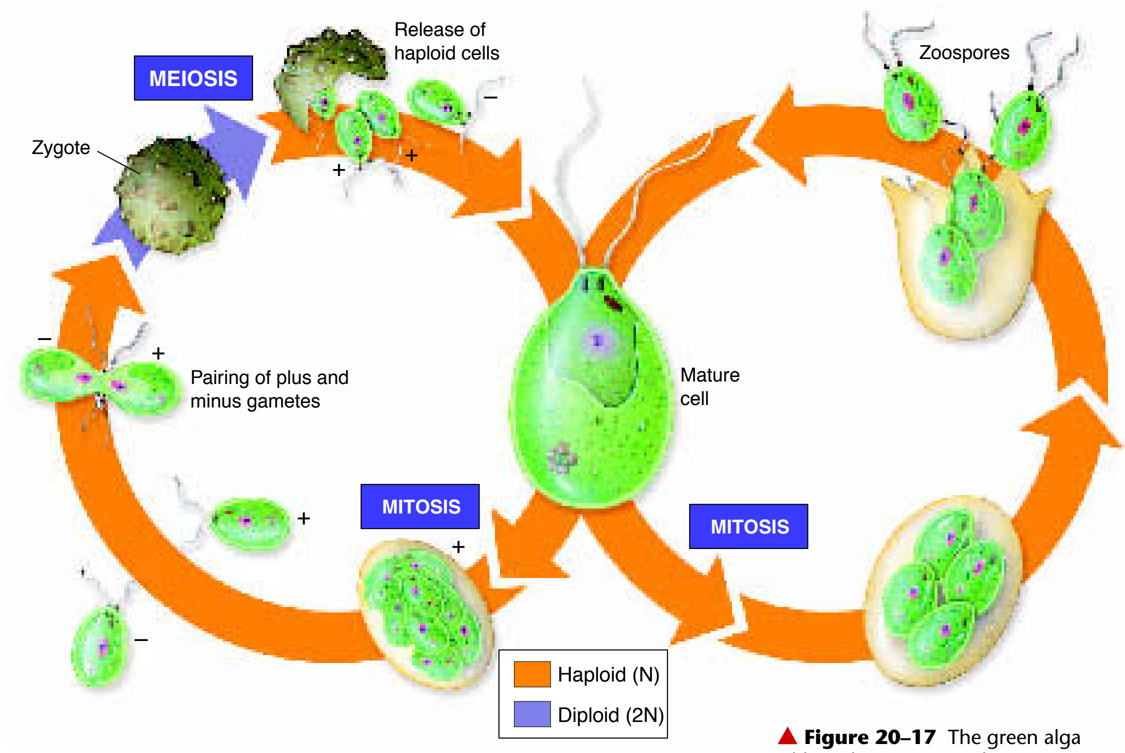
The life cycles of many algae include both a diploid and a haploid generation. Recall from Chapter 11 that diploid cells have two sets of chromosomes, whereas haploid cells have a single set. Many algae switch back and forth between haploid and diploid stages during their life cycles, in a process known as **alternation of generations.** Many species also shift back and forth between sexual and asexual forms of reproduction.

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, producing cells called zoospores by mitosis. Reproduction by mitosis is asexual. The two haploid daughter cells produced by mitosis are genetically identical to the single haploid cell that entered mitosis.

BIO INSIGHTS

FACTS AND FIGURES

Ancestors of land plants
It is generally believed that the chlorophytes, or green algae, are the group from which land plants evolved. Among the algae, only the chlorophytes have cellulose in their cell walls, contain chlorophylls *a* and *b,* and store their food in the form of starch, all of which are also characteristics of land plants. Because algae ordinarily do not form fossils, we do not have direct evidence of an evolutionary relationship. But one stage in the life cycle of mosses looks remarkably like a tangle of green algal filaments. Perhaps both mosses and the modern multicellular green algae descended from a common algalike ancestor.



▲ **Figure 20–17** The green alga *Chlamydomonas* reproduces asexually by producing zoospores and sexually by producing zygotes, which release haploid gametes. **Interpreting Graphics** *Which form of reproduction includes a diploid organism that can survive adverse conditions?*

If conditions become unfavorable, *Chlamydomonas* can also reproduce sexually. The life cycle of *Chlamydomonas* is shown in **Figure 20–17.** The haploid cells continue to undergo mitosis, but instead of releasing zoospores, the cells release gametes. The gametes, which look identical, are of two opposite mating types, + (plus) and − (minus). 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 zygote sinks to the bottom of the pond and grows a thick protective wall. Within this protective wall, *Chlamydomonas* can survive freezing or drying conditions that otherwise would 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. Thus, during its life cycle, *Chlamydomonas* alternates between a haploid stage, in which it spends most of its life, and a brief diploid stage, represented by the zygote cell.

CHECKPOINT *What two types of gametes does* Chlamydomonas *produce?*

Use Visuals

Figure 20–17 To understand the life cycle of *Chlamydomonas*, students may need to review what they have learned about reproduction. Ask students: **What is the difference between asexual and sexual reproduction?** *(Asexual reproduction involves the division of a single parent cell. Sexual reproduction involves the joining of two parent cells, or gametes.)* **What is the difference between cells with a diploid number of chromosomes and cells with a haploid number?** *(Diploid cells have the full complement of chromosomes for a particular species; haploid cells have half the complement.)* **What is meant by alternation of generations?** *(Shifting back and forth between haploid and diploid stages during the life cycle)* **In the life cycle of *Chlamydomonas*, which generation, the haploid or the diploid, produces zoospores?** *(Haploid)* **When *Chlamydomonas* does produce zoospores, is it reproducing sexually or asexually?** *(Asexually)* **What does the organism release when it is reproducing sexually?** *(Plus and minus gametes)* L2

BIO INSIGHTS — FACTS AND FIGURES

Alternating phases
The basic plan of alternation of generations is a life cycle in which diploid (2N) and haploid (N) phases alternate. Use of the term *generation* can be confusing, since these are phases in one complete life cycle of an organism rather than the production of offspring. The following are generalizations that apply to an alternation of generations in any organism, from algae to vascular plants:

- Any cell of the sporophyte generation is usually diploid (2N).
- Any cell of the gametophyte generation is usually haploid (N).
- The change from sporophyte to gametophyte occurs as the result of meiosis.
- The change from gametophyte to sporophyte occurs as a result of fertilization, or the fusion of gametes.

Answers to . . .

CHECKPOINT Chlamydomonas *produces two gametes of opposite mating types, + (plus) and − (minus).*

Figure 20–17 *Sexual reproduction*

20–4 (continued)

Use Visuals

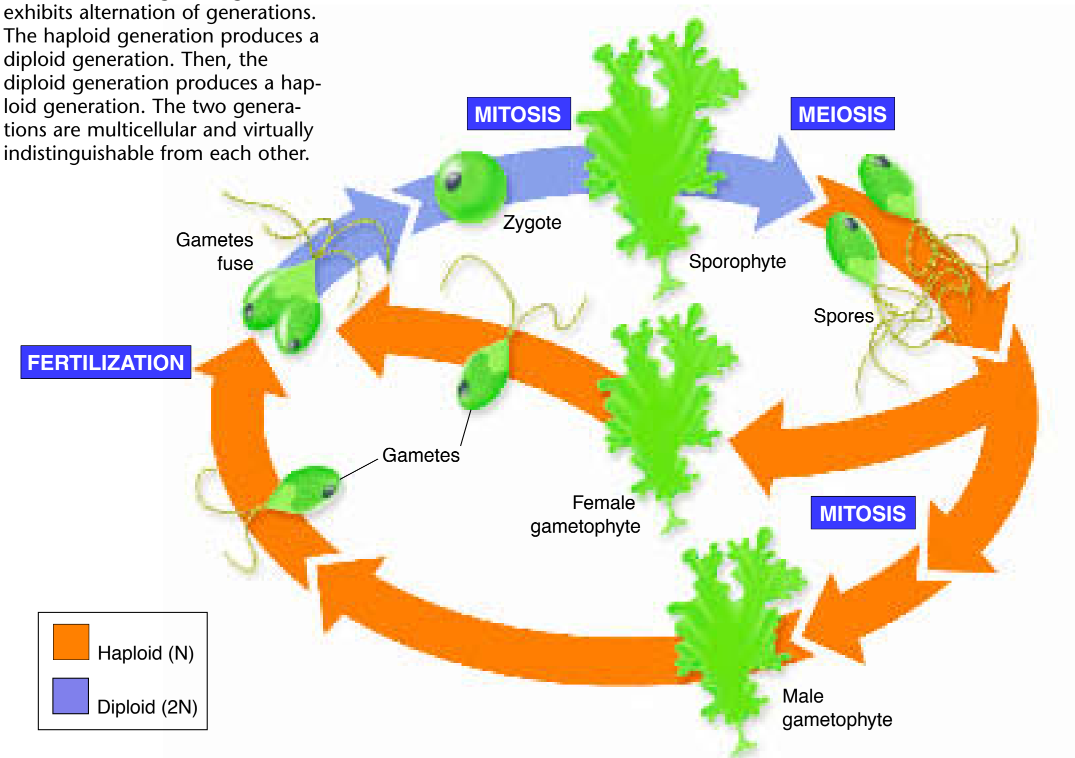
Figure 20–18 Ask students: **What is the term for the pattern by which *Ulva* reproduces?** *(Alternation of generations)* **Which generation, or phase, produces haploid spores?** *(The sporophyte generation)* **What cellular process is involved in producing these spores?** *(Meiosis)* **Which generation produces gametes?** *(The gametophyte generation)* **Does this generation undergo meiosis to produce gametes?** *(No. It is already haploid, which is how most fungi spend their life cycles.)* **What does the fusion of the gametes produce?** *(A zygote)* **What does the zygote grow to become?** *(The sporophyte generation)* L2

Reproduction in *Ulva* The life cycle of the green alga *Ulva* involves an alternation of generations in which both the diploid and haploid phases are large, multicellular organisms. In fact, the haploid and diploid phases of *Ulva* are so similar that only an expert can tell them apart!

The haploid phase of *Ulva* produces two forms of gametes—male and female. Because they produce gametes, the haploid forms of *Ulva* are known as **gametophytes** (guh-MEET-uh-fyts), or gamete-producing plants.

When male and female gametes fuse, they produce a diploid zygote cell, which then grows into a large, diploid multicellular *Ulva*. The diploid *Ulva* undergoes meiosis to produce haploid reproductive cells called **spores.** Each of these spores is able to grow into a new individual without fusing with another cell. Because the diploid *Ulva* produces spores, it is known as a **sporophyte** (SPOH-ruh-fyt), or spore-producing organism.

Take a close look at the life cycle of *Ulva* in **Figure 20–18,** because the alternation of generations it displays is a pattern you will see repeated over and over again in the plants. *Ulva*'s life cycle includes two separate phases that alternate in a regular pattern: sporophyte, then gametophyte, then sporophyte again. Complex life cycles involving alternation of generations are characteristic of the members of the plant kingdom. This is one of the reasons some biologists favor classifying multicellular algae such as *Ulva* as plants.



▼ **Figure 20–18** **The life cycles of most algae include both diploid and haploid generations.** The multicellular green alga *Ulva* exhibits alternation of generations. The haploid generation produces a diploid generation. Then, the diploid generation produces a haploid generation. The two generations are multicellular and virtually indistinguishable from each other.

BIO INSIGHTS — FACTS AND FIGURES

An evolutionary link

The characteristics of the green alga *Ulva*—often called sea lettuce—demonstrate an evolutionary link between simpler green algae and more complex land plants. Although only two cells thick, *Ulva* is truly multicellular, forming such specialized structures as holdfasts. *Ulva* exhibits isomorphic alternation of generations, in which sporophytes and gametophytes are similar in shape and size.

Human Uses of Algae

Algae are a major food source for life in the oceans. Algae have even been called the "grasses" of the seas, because they make up much of the base of the food chain upon which sea animals "graze." The enormous brown kelp forests off the coasts of North America are home to many animal species.

Algae produce much of Earth's oxygen through photosynthesis. Scientists calculate that about half 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. Chemicals in algae are used to treat stomach ulcers, high blood pressure, arthritis, and other health problems.

Have you ever eaten algae? Almost certainly, your answer should be yes. In Japan, the red alga *Porphyra* is grown on special marine farms. Dried *Porphyra*—called *nori* in Japanese—is dark green and paper-thin. Nori is used to wrap portions of rice, fish, and vegetables to make sushi, as shown in **Figure 20–19.** You say you've never had sushi? Well, you've probably eaten ice cream, salad dressing, pudding, or a candy bar. Other products from algae are used in pancake syrups and eggnog.

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 even have an important use in scientific laboratories. The compound agar, derived from certain seaweeds, thickens the nutrient mixtures scientists use to grow bacteria and other microorganisms.

▲ **Figure 20–19** People have found many different uses for algae. The red alga *Porphyra* is used as a wrapper in Japanese sushi rolls. Ice cream often contains algin, a thickener made from brown algae. **Predicting** ***How would your life be different without products made from algae?***

20–4 Section Assessment

1. **Key Concept** Describe the main features of the major phyla of multicellular algae.
2. **Key Concept** What is alternation of generations?
3. How are multicellular algae important at a global level?
4. Why can red algae live in deeper water than green algae?
5. **Critical Thinking Comparing and Contrasting** Choose a green alga and illustrate its life cycle. Identify which parts are haploid and which are diploid. Show where meiosis and mitosis occur. Illustrate which part of the life cycle involves sexual reproduction and which involves asexual reproduction.

Thinking Visually

Organizing Information
Make a poster illustrating three types of multicellular algae. Your poster should have detailed drawings or photographs of each group. Each illustration should show the correct classification and list two written characteristics of each group.

20–4 Section Assessment

1. Students should describe the main features of algae in the phyla Rhodophyta, Phaeophyta, and Chlorophyta.
2. A process in which algae switch back and forth between haploid and diploid during their life cycles
3. Multicellular algae provide food and generate oxygen and are an important part of the food chain along coastal waters and in the Sargasso Sea.
4. Red algae contain the reddish accessory pigments known as phycobilins, which are especially good at absorbing blue light, which penetrates deeper, enabling red algae to live deeper in the ocean than other algae.
5. Students may choose any of the examples of green algae discussed in the section. A typical response will illustrate either *Chlamydomonas* or *Ulva* and use Figure 20–17 or 20–18 for reference.

Human Uses of Algae

Use Community Resources

Some seaweeds, or multicellular algae, are edible and part of the cuisine of Japan and other countries. Have students look for seaweed foods at a specialty market and report to the class about the products they found. Also encourage students interested in cooking to make an appointment to interview a chef at a local Japanese restaurant about how seaweed is used in Japanese recipes. You might ask these students to prepare a seaweed dish for the class. L2 L3

3 ASSESS

Evaluate Understanding

Ask students to make a table that contains information about the three phyla of multicellular plantlike protists. This table should include the phylum names, the common names, characteristics, and examples of each.

Reteach

Ask students to make their own drawings of the life cycle of the multicellular green alga *Ulva,* using Figure 20–18 as a model. Then, call on students to define the terms *alternation of generations, gametophyte,* and *sporophyte.*

Thinking Visually

A student's poster should show several drawings or photographs of multicellular algae, including at least one example each of red algae, brown algae, and green algae. Each illustration should be clearly labeled with the phylum the alga is in as well as the alga's scientific name.

iNteractive Textbook

If your class subscribes to the iText, use it to review the Key Concepts in Section 20–4.

Answer to . . .

Figure 20–19 *Many products might be different, including ice cream, salad dressing, and pudding.*