UNIT 2 KINGDOMS OF LIFE IN THE SEA

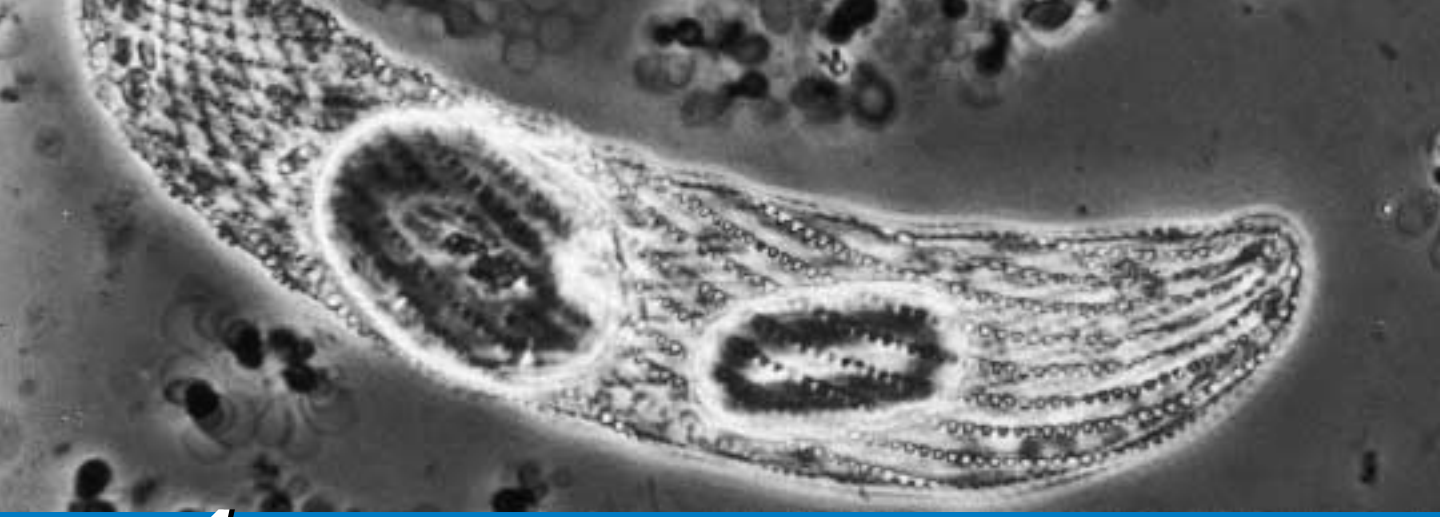
CHAPTER 4 *Unicellular Marine Organisms*

CHAPTER 5 *Marine Algae and Plants*

CHAPTER 6 *Simple Marine Animals*

When you go to a supermarket, you see that there are thousands of food items from which to choose. How is it possible for you to find the particular one you want to buy? In a supermarket, the food is organized into sections, making it easier for you to find and buy the items you want.

Likewise, millions of different kinds of organisms live on our planet; and many thousands of these organisms live in the sea. Scientists have developed a system for organizing all living things into various categories. This classification system has several important benefits. It enables people to study organisms more easily. It shows the evolutionary relationships among organisms. And it lets you make certain assumptions about organisms within a particular group. In this unit, you will start to learn about the diversity of marine organisms.



4 Unicellular Marine Organisms

When you have completed this chapter, you should be able to:

UNDERSTAND and **APPLY** the rules of classification.

IDENTIFY and **DESCRIBE** the major groups of living things.

COMPARE and **CONTRAST** the monerans and the protists.

DISCUSS basic cell structure and different types of nutrition.

Look at the organism shown above. For many years, scientists disagreed on the classification of this tiny aquatic organism, called a *euglena.* Zoologists placed the euglena in the animal kingdom. After all, the euglena has animal-like traits, such as an eyespot that is sensitive to light, the ability to move from place to place, and the ability to ingest nutrients (by absorption).

However, botanists thought that the euglena should be placed in the plant kingdom. They argued that since this organism is able to make its own food, it should be included with the other organisms that are able to perform this function.

Actually, many living things are difficult to classify, because they possess characteristics of organisms that belong in two different groups. The argument about the euglena was finally settled when it was placed in a new kingdom, Protista, which contains mostly single-celled organisms.

Protists are widely distributed in the ocean. They play important parts in marine environments, so it is worthwhile to learn about them. However, we first will explore how all organisms are classified.

4.1 CLASSIFICATION

In 1758, the Swedish botanist Carolus Linnaeus (1707–1778) published a book describing his system of classification, which is the grouping of organisms according to similarities in structure. The science of classification that developed from this work is called **taxonomy**. Linnaeus classified all living things as belonging to either of two large taxonomic categories: the animal kingdom or the plant kingdom.

Linnaeus then divided the animal and plant kingdoms into smaller groups. The units he used were kingdom, phylum, class, order, family, genus, and species. The kingdom is the most inclusive group; it contains the largest variety of related organisms. The species is the smallest group; it contains only one kind of organism.

According to the system developed by Linnaeus, each organism is given a two-part scientific name that consists of a genus name and a specific name. For example, the scientific, or species, name of the blue whale is *Balaenoptera musculus*. *Balaenoptera* is the genus name and *musculus* is the specific name. The words used for scientific names are from the Latin and Greek languages.

You might wonder why scientific names are necessary. They sometimes seem difficult to read and even harder to pronounce. Since the different species of organisms number in the millions, it is necessary for scientists around the world to have a common language to be able to identify any organism with accuracy. As you know, people in different countries have different names for organisms. For example, the blue whale is known by different names in different languages. However, for scientists the world over—no matter what language they speak—the blue whale is always referred to by its scientific name, *Balaenoptera musculus*. This naming system prevents confusion.

The Five-Kingdom System

Since the time of Linnaeus, many new organisms have been discovered, and many classification systems have been proposed. Some of the systems have merit; all try to make sense of the great diversity of

TABLE 4-1 THE FIVE-KINGDOM CLASSIFICATION SYSTEM

Kingdom	Main Characteristics
Monera	Single-celled; lack nuclear membrane (bacteria, blue-green bacteria)
Protista	Mostly single-celled, some multicelled; have nuclear membrane (algae and protozoa)
Fungi	Single-celled and multicelled; have nuclei; absorb food from living and dead organisms
Plantae	Multicelled; have nuclei; make their own food through photosynthesis
Animalia	Multicelled; have nuclei; eat other organisms

life on our planet. However, most scientists now use the classification system that is composed of five kingdoms. (See Table 4-1.)

Monera: This group, commonly called the **monerans**, includes the bacteria and blue-green bacteria (formerly called blue-green algae). All **bacteria** are single-celled; all lack a nuclear membrane and thus their nuclear material is dispersed throughout the cell. Scientists call organisms that lack a nuclear membrane **prokaryotes**. These are probably among the most ancient organisms on Earth. The earliest fossil monerans are more than 3 billion years old. Even though they are composed of only a single cell, they are not such "simple" organisms. They are able to carry out all life functions and are remarkably successful to have survived on Earth for such a long time.

Protista: The kingdom of **protists** includes mostly single-celled, or **unicellular**, organisms, although some are composed of many cells or live together in small colonies. All protists have their nuclear material enclosed within a membrane; that is, they have a *nucleus*. Scientists call organisms with this feature **eukaryotes**. (All organisms on Earth other than those in the kingdom Monera are eukaryotes. See the section on diatoms for more information on eukaryotes.) The earliest fossil protists are about 1.5 billion years old. Tiny **protozoa** (animal-like organisms) and many kinds of **algae** (plantlike organisms) make up this group.

Fungi: The **fungi** include both unicellular and multicellular eukaryotic organisms that are not able to make their own food. Fungi absorb their nutrients from dead organic material and live tissues. The familiar mushroom is a type of fungus that you have probably seen. Certain diseases of the skin are caused by fungi, such as athlete's foot and ringworm. Like plant cells, fungal cells are en-

closed by a rigid cell wall. Unlike plants, fungi do not contain the green pigment chlorophyll (see below). Fungi play an important role in breaking down dead organisms and recycling organic material. Hundreds of species of fungi exist, both on land and in the ocean.

Plantae: Plants are multicellular, eukaryotic organisms that are able to make their own food out of simple chemical substances. Plants contain **chlorophyll**, the green pigment that is able to capture the energy in light. (A **pigment** is a coloring matter found in the cells and tissues of plants and animals.) Plants use this energy during photosynthesis to make organic compounds out of water and carbon dioxide. During this process, plants give off oxygen as a by-product. Plant cells are surrounded by a rigid cell wall.

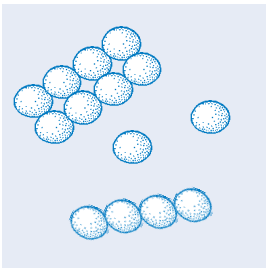
Animalia: Animals are multicellular, eukaryotic organisms. Unlike plant cells, animal cells lack cell walls. Also, unlike plants, animals are not able to make their own food, but must instead eat plants or other animals to obtain their nutrients. Most animals are capable of movement. We categorize animals in two main groups: those that lack a backbone and skull (the invertebrates) and those that have a backbone and skull (the vertebrates). Both groups are widely represented by animals that live in marine environments.

4.1 Section Review

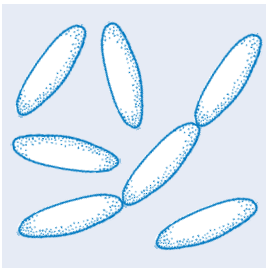
1. Why is it important to classify organisms?
2. How did Linnaeus classify organisms? Why is his system for naming organisms so useful?
3. How does the present system of classifying organisms differ from the system developed by Linnaeus?

4.2 BACTERIA

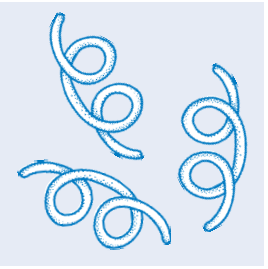
Bacteria are the most abundant organisms on Earth and are widely distributed in the ocean. Bacteria are microscopic single-celled organisms; they have a relatively thick outer cell wall that surrounds a thin cell membrane. If you examined some bacteria under a microscope, you would observe the three basic bacteria shapes.



Ball-shaped
(cocci)



Rod-shaped
(bacilli)



Corkscrew-shaped
(spirilla)

Figure 4-1 The three shapes of bacteria: bacilli, cocci, and spirilla.

There are round bacteria called coccus (plural, cocci), rod-shaped bacteria called bacillus (plural, bacilli), and spiral-shaped bacteria called spirillum (plural, spirilla). (See Figure 4-1.) The first organisms that lived on Earth were prokaryotic cells that resembled these present-day bacteria. Since bacteria are structurally different from all other cells and organisms, they are classified in their own kingdom, Monera.

Bacterial cells can reproduce at a rapid rate, some every 20 minutes. All the instructions for reproduction are contained within threadlike structures called **chromosomes**. Because bacteria are prokaryotic (lack a nuclear membrane), this nuclear, or hereditary, material is dispersed throughout the cell's cytoplasm. The chromosomes are made up of molecules of DNA (deoxyribonucleic acid), which contain all the directions for a cell's structure and function within segments called genes. The total genetic make-up of an organism, that is, all its genes, is known as its **genome**. Bacteria are often used in modern recombinant DNA technology (genetic engineering) because they reproduce so rapidly.

Decay Bacteria

Bacteria play a very important part in the biological world. Bacteria are partly responsible for the decomposition, or breakdown, of dead organic matter. (Fungi also break down dead organic matter.) Dead matter is decomposed by a group of bacteria known as decay bacteria. In the ocean, decay bacteria break down organic matter into smaller molecules that are released into the water. These smaller molecules, such as phosphates, nitrates, and sulfates, are used as nutrients by different bacteria and other organisms. In this way, decay bacteria help recycle dead organic matter. Decay bacteria, and organisms like them, are called **decomposers**.

As you might suspect, decay bacteria are most abundant in bottom sediments where dead organic matter accumulates. There, the bacteria attach themselves to dead matter and secrete special chemicals that begin to break down organic matter in the sediments into nutrient molecules, some of which are taken in by the bacteria themselves. Feeding on organic matter in this way, the bacteria exhibit the type of nutrition normally found in fungi and animals.

Decay bacteria thrive in an environment that is warm, moist, dark, and rich in food. These conditions can be duplicated in the laboratory, where you can grow, or culture, marine bacteria. The food on which laboratory bacteria feed is a gel called nutrient agar (made from algae), which is put into a clear glass or plastic petri dish. An inoculating needle is used to transfer bacteria from water or from another sample to the nutrient agar. The inoculating needle is dipped into a sample that contains the bacteria to be cultured and then moved, or streaked, across the agar plate. The petri dish is covered and placed in an incubator (which keeps the dish warm) for a specified amount of time. During incubation, the bacterial cells along the streak will begin to multiply. They reproduce by dividing in two. After 24 hours, a single bacterial cell (bacterium) can grow into a colony, a bacterial population that contains millions of cells. Colonies on the agar may differ in color, form, and texture.

There are more than 5000 species of bacteria. One interesting group of bacteria is the so-called magnetic bacteria, found in some saltwater and freshwater marshes. Magnetic bacteria contain a string of magnetite (iron oxide) crystals that make the cell behave like a magnet. By clinging to the iron deposits in marshes, the magnetic bacteria can feed on dead matter in the sediments.

Some species of bacteria supply their energy needs in other ways. For example, the sulfur bacteria that live in marine mud use the compound hydrogen sulfide (H_2S), which is produced when organisms decay. (Hydrogen sulfide is the gas that smells like rotten eggs.) Oxidation of hydrogen sulfide provides energy that can be used by bacteria to form sugar from carbon dioxide and water. The hydrothermal vents on the deep ocean floor also contain bacteria that feed on sulfur compounds. The process by which organisms like sulfur bacteria derive energy from chemicals (that is, from inorganic raw materials) is called **chemosynthesis**.

Blue-Green Bacteria

Some microorganisms are not easily classified. The organism shown in Figure 4-2 on page 100 resembles an alga because it contains the green pigment **chlorophyll**. However, the organism also resembles a bacterium, because it lacks a membrane-bound nucleus. In fact, it

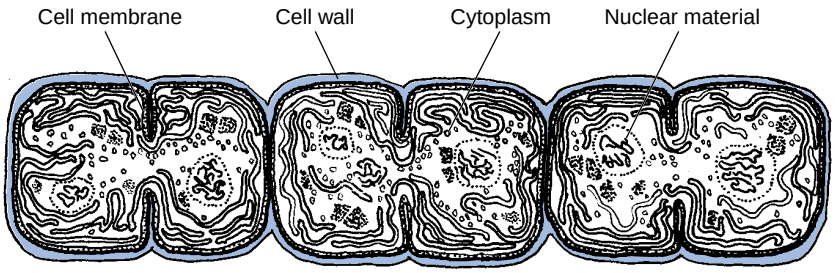


Figure 4-2 An example of a blue-green bacterium that is classified in a group with other cyanobacteria.

is classified in a group of organisms called **cyanobacteria**, also known as blue-green bacteria (formerly called *blue-green algae*). Most biologists classify cyanobacteria in the kingdom Monera with all other bacteria. Since they contain chlorophyll, cyanobacteria are able to make their own food. They are, in fact, the only moneran that is photosynthetic. In addition to chlorophyll, the cyanobacteria contain the blue pigment phycocyanin. The combination of green and blue pigments in the cyanobacteria produces their characteristic blue-green color. Some species of blue-green bacteria, such as the *Oscillatoria,* also contain the red pigment phycoerythrin. In shallow water, this species can produce a red color when a population bloom occurs. In fact, this cyanobacterium is responsible for periodically producing this effect in the Red Sea and may, in part, be responsible for giving this sea its name.

Cyanobacteria, which are found throughout the oceans, are very hardy organisms and can survive under a wide range of different environmental conditions. Some species of cyanobacteria live attached to rocks in the wave splash zone above the high tide mark. The cells are covered by a jellylike mass around their cell walls that prevents them from drying up when the tide is out. When these cells die, they stain the rocks black, a stain that resembles a recent oil spill. Other species of cyanobacteria secrete toxic chemicals that can produce a painful rash if they come into contact with skin. Cyanobacteria can also thrive in waters and sediments that are low, or lacking, in oxygen.

Scientists think that the first photosynthetic organisms to inhabit Earth were the cyanobacteria. The earliest cyanobacteria produced reeflike growths called stromatolites. Like coral reefs, the mushroom-shaped stromatolites built by cyanobacteria had a framework of calcium carbonate. Fossil stromatolites more than 3 billion years old have been found.

4.2 Section Review

1. Why are cyanobacteria placed in the kingdom Monera?
2. How do most species of bacteria obtain their nutrients?
3. What is the evolutionary significance of the cyanobacteria?

4.3 DIATOMS

Diatoms are among the most common organisms found in the ocean. These single-celled protists usually float and drift near the ocean surface, though many diatoms also live in deeper waters. Diatoms are part of the ocean's community of **plankton** (meaning "wanderers" that drift, rather than swim) and are more accurately classified as **phytoplankton** ("plant wanderers"). Some diatoms (called encrusting diatoms) live attached to solid substrates, while others alternate between attached and free-floating forms.

Cell Structures of Diatoms

Like all eukaryotic cells, diatoms have a variety of structures called **organelles** that carry out important functions in the cell. The nucleus, which was mentioned in the discussion of classification, controls the growth and reproduction of the cell. In the nucleus are the *chromosomes,* coiled threads of nuclear material that carry genes, which determine a cell's characteristics. Most of the time, the chromosomes cannot be observed in the nucleus. However, with the use of special dyes, scientists can observe chromosomes, which become more visible during certain stages of cell division. A nuclear membrane encloses the nucleus, which floats in the fluid portion of the cell, the cytoplasm. A thin cell membrane, called the *plasma membrane,* surrounds all cells and regulates the entry and exit of materials. (See Figure 4-3 on page 102.)

Diatoms, like other algae and plants, contain the green pigment chlorophyll within special structures called *chloroplasts*. Because diatoms have a transparent cell wall, you can see the chloroplasts inside the cell. In fact, the cell wall of a diatom is made of silica, the main ingredient of glass. Why is it an advantage for a diatom to

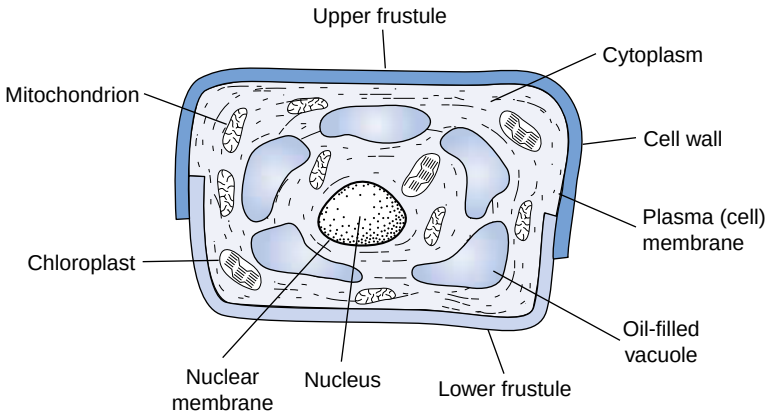


Figure 4-3 The cell structures of a diatom.

have a transparent cell wall? Such a cell wall allows light to enter the cell. Inside the diatom, the light energy is trapped by chlorophyll in the chloroplasts. Notice the position of the chloroplasts. They lie next to the cell wall, where the intensity of light is greatest. Both the glassy cell wall and the position of the chloroplasts are adaptations that increase the rate of photosynthesis due to greater light absorption.

What happens to the oxygen produced by diatoms during photosynthesis? (Remember that oxygen is produced as a by-product of photosynthesis.) The cell wall of diatoms contains tiny holes, or pores. The pores allow carbon dioxide to enter and oxygen to leave the diatom. The pores are so small that you would need an electron microscope to see them! In fact, many of the other structures inside cells can be observed only by using an electron microscope.

The *endoplasmic reticulum* is a network of channels in the cytoplasm through which important chemicals are transported. Tiny particles called *ribosomes* are attached to the endoplasmic reticulum. Ribosomes are the places in the cell where proteins are assembled. Proteins are substances that are used by cells for growth and repair. The making of proteins is controlled by ribonucleic acid (RNA), a chemical present in the nucleus of a cell. Ribonucleic acid moves from the nucleus to the ribosome. In the ribosomes, RNA directs the manufacture of proteins. By controlling the kinds of proteins that are assembled in the cell, the nucleus acts as the control center for the cell's activities.

Cells need energy to do work. Located throughout the cell's cytoplasm are organelles called *mitochondria* (singular, mitochon-

drion). Mitochondria are the cell's energy factories in which sugar is broken down and chemical energy in the form of ATP (adenosine triphosphate) is produced. Food manufactured by a diatom is stored as an oil droplet in a structure called a *vacuole*. Small oval bodies called *lysosomes* are attached to the vacuole and produce chemicals that digest the food stored inside it. Other important chemicals needed by cells to carry out life functions are contained in stacks of flattened membranes called the *Golgi apparatus*. The Golgi apparatus releases, or secretes, these substances as needed.

Diatom Diversity and Life Functions

There are more than 25,000 species of diatoms, most of which inhabit the cold waters of the world. They are classified in phylum Chrysophyta, which means "golden algae." Diatoms exhibit great variety in their shapes. Some diatoms even appear to be strung together, like beads on a chain. (See Figure 4-4.)

Diatoms are, in fact, classified according to their shape. Round diatoms are called centric diatoms, and pen-shaped diatoms are called pennate diatoms. Some diatoms also have spines projecting from their cell wall, which help to prevent sinking. This feature

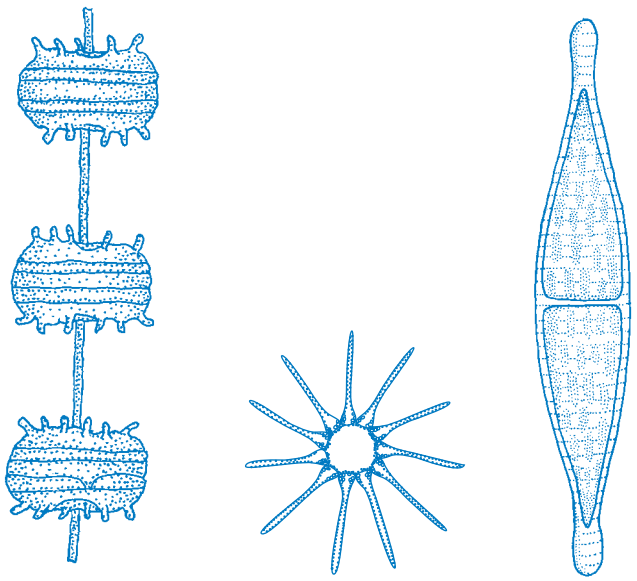


Figure 4-4 Three types of diatoms.

(along with the stored droplets of food oil, which decrease cell density) aids survival, because diatoms that float close to the water's surface can absorb more energy from sunlight.

How does an organism with such a hard, glassy shell reproduce? Diatoms reproduce both sexually and asexually. During **asexual reproduction**, which is the production of offspring by one parent, a diatom divides to form two new cells. The two halves of a diatom's shell normally overlap, making the diatom resemble a box with a lid. Each half is called a frustule. When a diatom reproduces, its two frustules separate. Each half secretes a new frustule to complete the formation of two new diatoms.

During **sexual reproduction**, in which two parents are needed, a diatom develops into either a male or a female cell. A male cell produces sperm. The sperm swims to and enters the female diatom, where it unites with an egg nucleus. The fertilized egg cell develops into a mature diatom, completing the reproductive cycle.

When diatoms die, they fall to the ocean floor. The living material inside the diatom's shell decays, but the glassy cell walls remain. The shells accumulate on the ocean floor. Over time, these deposits form layers that may be hundreds of meters thick. These deposits of silica are known as diatomaceous earth. Since diatoms are porous, diatomaceous earth makes an excellent filtering material for aquariums and swimming pools. Diatomaceous earth is also used to purify drinking water.

Although diatoms are extremely small, they play an important part in the life of the ocean. Almost all animals in the sea ultimately depend on diatoms as a source of food. Tiny invertebrates, such as copepods, feed on diatoms. Shellfish such as mussels, clams, oysters, and scallops consume diatoms by filtering them from the seawater. Even humans depend on diatoms to some extent, when they eat organisms that have fed on diatoms either directly or indirectly.

Yet, important as they are, diatoms sometimes cause problems. A sudden increase in the diatom population, called an **algal bloom**, may occur from time to time in shallow coastal waters. During several summers in the late 1980s, the coastal waters of Long Island, New York, became so clouded with algae that the waters turned brown. Marine biologists analyzed water samples and found as many as 800,000 diatoms of one particular species in 1 milliliter of water. This kind of algal bloom is called a **brown tide**. The brown tide devastated the scallop industry in eastern Long Island. Biolo-

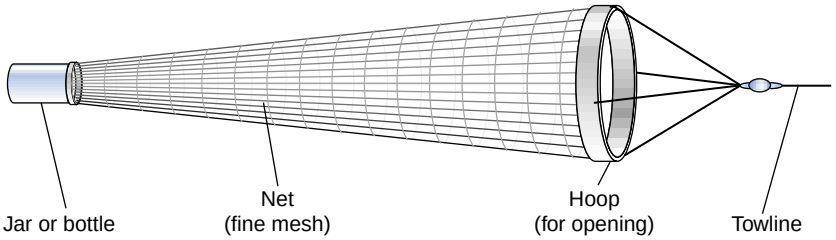


Figure 4-5 A plankton net, which is used to collect diatoms.

gists are still investigating the causes of these mysterious algal blooms.

Free-floating diatoms can be collected from seawater by use of a plankton net. (See Figure 4-5.) The plankton net can be pulled through shallow water, alongside a pier, or towed behind a moving boat. The plankton get caught in the mesh of the nylon net, and then fall into the collecting jar at the bottom of the net. A few drops from this sample can be observed under the microscope. In addition, encrusting diatoms can be scraped off the walls of a saltwater aquarium tank for observation in the classroom. You can view diatoms under the microscope by doing the lab investigation at the end of this chapter.

4.3 Section Review

1. What adaptations do diatoms have for photosynthesis?
2. Explain how marine animals are dependent upon diatoms.
3. How can an algal bloom be detrimental to people?

4.4 DINOFLAGELLATES

Members of another protist group often found near the ocean's surface are the **dinoflagellates**. Three types of dinoflagellates are shown in Figure 4-6 on page 106. They are classified in phylum Pyrrophyta, which means "red (or fire) algae." How do dinoflagellates compare with diatoms? Dinoflagellates have two flagella. A flagellum (singular) is a microscopic hairlike structure. Each flagellum whips back and forth, helping to move the dinoflagellate along, although it still floats with the currents. In contrast, diatoms are not

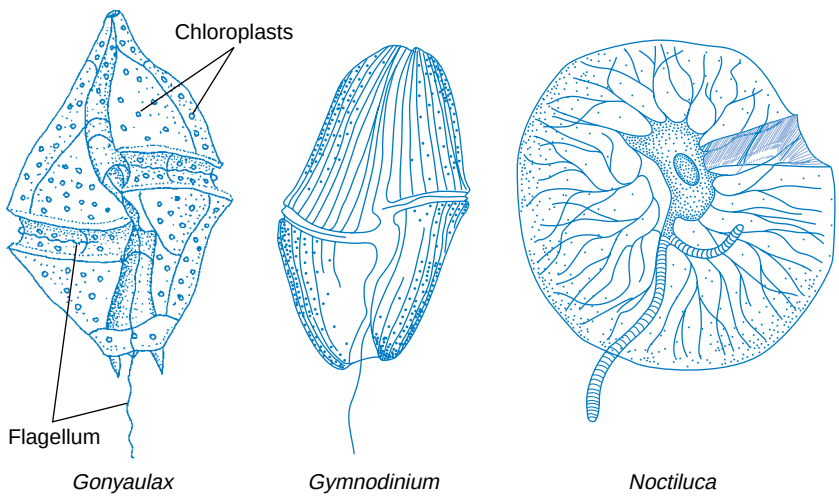


Figure 4-6 Three types of dinoflagellates.

able to propel themselves at all; instead, they are just pushed along by the movement of water.

Dinoflagellates also possess chloroplasts and, like diatoms, are able to make and store their own food. Many dinoflagellate species have an eyespot that is sensitive to light. They use the eyespot to move toward the light, thus increasing their ability to make food. Unlike diatoms, dinoflagellates are also able to take in food. In this way they resemble the euglena, a freshwater protist that is able both to make food and to ingest it.

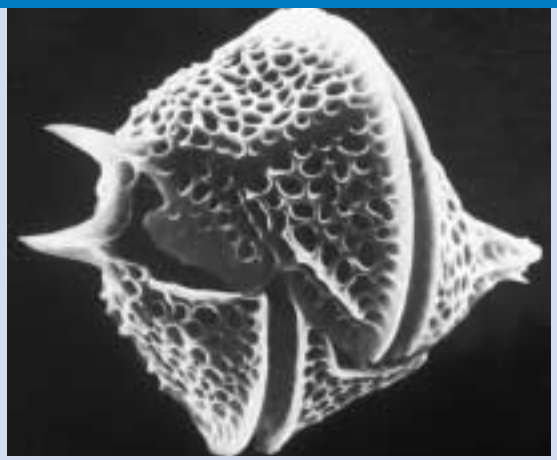
The cell walls of dinoflagellates and diatoms differ in structure and composition. Notice the plates and grooves of the dinoflagellates shown in Figure 4-6. Dinoflagellate cell walls are made of cellulose like those of plants, not of silica like those of diatoms. A cellulose cell wall is not as transparent as a diatom's glassy cell wall.

Effects of Dinoflagellates

Some dinoflagellates, like *Noctiluca* (meaning "night light"), are rather spectacular for so small an organism. Have you ever run your fingers through the ocean water at night and seen it sparkle? In places where many *Noctiluca* are present, the water will glow in the dark when it is disturbed mechanically. The movement of a boat propeller or the splashing of fish can cause the *Noctiluca* to emit a greenish-blue light. This ability of an organism to produce light,

ENVIRONMENT

Red Tides and Muddy Waters



Each year, various coastal regions around the world suddenly become "killing fields" as large numbers of fish and shellfish die. The only warning is the appearance of a reddish tint in the water, the result of a swift and unexpected increase in the population of dinoflagellates. These one-celled algae contain pigments that are responsible for producing the so-called "red tide" in the ocean. They also harbor toxic chemicals that cause death when ingested by marine animals. On windy days, a mass of toxic dinoflagellates on the ocean surface can even cause wheezing and eye irritation in people who are exposed to the sea spray.

To protect their countries' billion-dollar fishing industries, marine scientists in South Korea and Japan developed a new way to diminish the destructive effects of the red tide. What was their solution? Spray the ocean surface with muddy water! The muddy spray contains clay particles that cling to the toxic cells, causing them to sink to the bottom. Using this method, fisheries in Korea reduced their losses from $100 million in 1995 to just $1 million in 1996.

The National Oceanic and Atmospheric Administration (NOAA) estimates that the red tide will cost the U.S. economy approximately $1 billion over the next decade. So, American scientists are testing this new method in small-scale experiments. In one such experiment, seawater taken from a red tide site in the Gulf of Mexico was transferred to a large outdoor tank and sprayed with a fine mist of clay. Within two-and-a-half hours, the clay had removed about 70 percent of the toxic cells.

Despite the initial success, some researchers are worried that introducing clay particles that fall to the seafloor may harm bottom-dwelling organisms. In addition, other scientists think that some toxic dinoflagellates may still survive on the sea bottom, where they could cause another kind of killing field. The research continues in order to determine if muddying the waters is an ecologically safe and sound method for minimizing the negative effects of the red tide.

QUESTIONS

1. What natural occurrence is responsible for producing the red tide?
2. How does the red tide affect the economy of various countries?
3. Describe the new method used to reduce the effects of the red tide.
4. Why are some scientists worried about using mud to control the red tide?

called **bioluminescence**, is also seen in a few other species of phytoplankton and in some deep-sea fishes as well.

Another interesting, although unpleasant, phenomenon associated with dinoflagellates is the **red tide**. Suddenly, with no warning, some shallow coastal waters turn red during the summer. At the same time, many hundreds of fish die; this is called a fish kill. When the water is analyzed, marine biologists find large numbers of a dinoflagellate that belongs to the genus *Gymnodinium*. This dinoflagellate contains a pigment that produces the red color in the water. Powerful toxins (poisonous substances produced by living things) made by these organisms accumulate in shellfish such as clams and mussels, which eat the algae and then poison the other organisms that eat them, such as fish, marine birds, and even humans. The algal bloom also reduces oxygen levels in the water, which further contributes to the fish kill.

Another dinoflagellate that produces a red tide belongs to the genus *Gonyaulax*. This organism causes paralytic shellfish poisoning, which leads to illness and death in fish and in humans. *Gonyaulax* contains a toxic substance called saxotoxin. This toxin interferes with the functioning of the nervous system in vertebrates. Saxotoxin is transferred from one organism to another during feeding. For example, mussels feed on *Gonyaulax* in the water. The mussels are not affected by the saxotoxin, but it accumulates in their body tissues. People who eat mussels that are contaminated by saxotoxin become sick and may even die.

4.4 Section Review

1. Why are dinoflagellates classified as protists?
2. How can some dinoflagellates harm humans?
3. How does a dinoflagellate bloom cause a fish kill?

4.5 NUTRITION IN ALGAE

The food that is made by **producers**, such as diatoms and other algae, is used by them for all their growth and energy needs. Utilization of food by living things for growth and energy is called

nutrition. Producers are also called **autotrophs**, a word that means "self-feeders." Their method of obtaining food is called autotrophic nutrition. The food that is made by producers is also used by other organisms; that is, it is used by the **consumers**, which are unable to make their own food. Organisms that live on the food made by other organisms—by eating them—are called **heterotrophs**, a word that means "other-feeders." This type of food-getting is known as heterotrophic nutrition. Since dinoflagellates both make and ingest food, they are considered to be autotrophs as well as heterotrophs.

Photosynthesis

Diatoms and dinoflagellates have chloroplasts—food factories in which photosynthesis takes place. The word *photo* means "light," and *synthesis* refers to the process of manufacturing large molecules from smaller ones. When you combine the two words, you have *photosynthesis,* the process by which autotrophs can, in the presence of sunlight, make food (glucose, or sugar) from simple raw materials (carbon dioxide and water). During this reaction, oxygen gas is produced as a by-product. The following chemical equation summarizes the process of photosynthesis.

$$6\ CO_2 + 12\ H_2O \xrightarrow[chlorophyll]{sunlight} C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$$

The chemical equation can be put into words as follows: six molecules of carbon dioxide plus twelve molecules of water, in the presence of sunlight and chlorophyll, yields one molecule of glucose plus six molecules of water plus six molecules of oxygen.

After the oxygen is released by the protists or algae, some of its molecules dissolve in the water. The rest of the oxygen enters the atmosphere at the water's surface (some of which goes back into the sea). The oxygen you take in with every breath probably includes some molecules that come from marine algae!

How do producers use light to make food? Look again at the structure of the diatom shown in Figure 4-3. Since the diatom lives in water, the surrounding water (H_2O) moves directly into its cell. And since carbon dioxide gas is dissolved in water, the CO_2 also

moves directly into the diatom. After entering the cell, carbon dioxide and water are taken up by the chloroplasts. The chloroplasts contain the green pigment chlorophyll. It is this green pigment that is able to absorb energy present in light. Chloroplasts use this energy to put together the molecules of water and carbon dioxide to produce or synthesize sugar.

Without photosynthesis, life as we know it could not exist on Earth. Why is photosynthesis so important for living things? During photosynthesis, plants are able to turn the light energy in sunlight into the chemical energy in the sugar glucose. Glucose is used by plants for their own energy needs. Since animals are unable to make their own food from simple compounds, they use the energy present in the compounds made by plants instead. When an animal eats a plant, the chemical energy present in the plant is transferred into the animal, that is, from the producer into the consumer. The next time you eat a filet of fish, remember that the energy in the food you are eating came originally from the energy that is present in sunlight.

Where on the planet does most photosynthesis occur, on land or in the ocean? Many people would probably say on land. After all, people are most familiar with the plants found on farms and in fields and forests. However, land makes up only about 29 percent of Earth's surface, and a large percentage of this land does not even support plant life. So this guess is incorrect. The ocean covers most of Earth's surface. It can support algae and plant life in the areas where light penetrates. So that is where most photosynthesis occurs.

The Cell Theory

So far, you have learned three important facts about living things. First, all living things are composed of one or more cells. Second, all cells perform the same basic life functions; for example, they make or obtain their food, they get rid of wastes, and they reproduce. And third, all cells (and, therefore, all organisms) come from preexisting cells. These three fundamental facts are part of what is called the **cell theory**. In the following chapters, you will see how the cell theory applies not only to unicellular forms of marine life but to all other marine organisms as well.

4.5 Section Review

1. How is the nutrition of dinoflagellates more complex than the nutrition of diatoms?
2. Explain why protists that obtain food by photosynthesis are so important for other organisms.
3. Why does more photosynthesis take place in the ocean than on the land?

Laboratory Investigation 4

How Diatoms Perform Their Life Functions

PROBLEM: How are diatoms adapted for carrying out their life functions?

SKILL: Using a microscope to observe unicellular organisms.

MATERIALS: Slides, medicine droppers, live diatoms, microscope, coverslips.

PROCEDURE

1. Place a drop of water that contains diatoms on a clean slide. Cover the sample with a clean coverslip. (*Note*: If fresh diatoms are not available, use a prepared slide of diatoms.)
2. Place the slide on your microscope stage. Move the low-power objective into position. Focus the lens. Move the slide until you observe cells that contain green, yellow, or orange pigments. These cells are diatoms.
3. Move the high-power objective into position. Focus on a single diatom. Notice the pigment color in the diatom you are viewing. The green pigment is chlorophyll, the yellow pigment is xanthophyll, and the orange pigment is carotene. All are involved in nutrition.
4. Make a sketch of the diatom you are observing. If possible, color it in appropriately and label any parts you can identify. Check to see if you recognize any of the diatoms shown in Figure 4-4 or in Figure 4-7.
5. Move the slide to locate other types of diatoms. Sketch each one you observe.

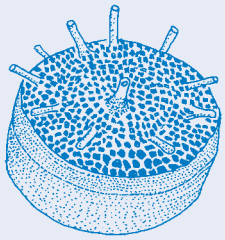


Figure 4-7
An example of a diatom.

OBSERVATIONS AND ANALYSES

1. Why are the pigments in the diatom visible?
2. Identify two life functions carried out by diatoms.
3. How are diatoms adapted for making their food?

Chapter 4 Review

Answer the following questions on a separate sheet of paper.

Vocabulary

The following list contains all the boldface terms in this chapter.

algae, algal bloom, asexual reproduction, autotrophs, bacteria, bioluminescence, brown tide, cell theory, chemosynthesis, chlorophyll, chromosomes, consumers, cyanobacteria, decomposers, diatoms, dinoflagellates, eukaryotes, fungi, genome, heterotrophs, monerans, nutrition, organelles, phytoplankton, pigment, plankton, producers, prokaryotes, protists, protozoa, red tide, sexual reproduction, unicellular

Fill In

Use one of the vocabulary terms listed above to complete each sentence.

1. The ability of an organism to produce light is called _____.
2. The plantlike marine protists are known as _____.
3. The animal-like marine protists are known as _____.
4. The glassy-shelled algae that cause brown tides are the _____.
5. Phytoplankton that have two flagella and cause red tides are _____.

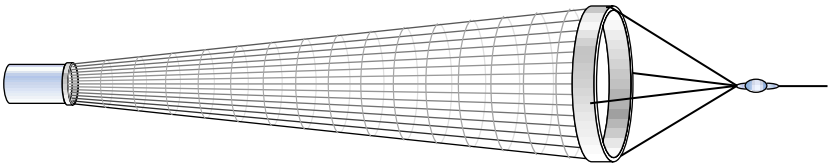
Think and Write

Use the information in this chapter to respond to these items.

6. Why is it important to use Greek or Latin words for scientific names?
7. What very important part do bacteria play in the biological world?
8. Name two ways diatoms and dinoflagellates are similar and two ways they are different.

Inquiry

Base your answers to questions 9 through 12 on the diagram below, which shows a device used by marine biologists, and on your knowledge of marine science.



9. (a) Identify the item that is illustrated. (b) What is its main function? (c) Name two of its important parts.

10. Which of the following kinds of organisms are intentionally caught using this device? *a.* monerans *b.* red tide algae *c.* free-floating diatoms *d.* crustaceans

11. Of the following methods listed, which one is *not* used with this device? *a.* pulling alongside a pier *b.* towing behind a moving boat *c.* pulling through shallow water *d.* dragging along the seafloor

12. The best way to observe the organisms that are obtained with this device is to *a.* snorkel underwater with a sample of them *b.* observe them under the microscope *c.* place them in a saltwater aquarium *d.* place them in a petri dish.

Multiple Choice

Choose the response that best completes the sentence.

13. The utilization of chemicals from food for growth and energy is called *a.* photosynthesis *b.* nutrition *c.* reproduction *d.* bioluminescence.

14. Marine phytoplankton are not found at great depths in the ocean because of the lack of *a.* animal life *b.* warm temperatures *c.* sunlight *d.* nutrients.

15. The monerans include the unicellular organisms known as *a.* seaweeds *b.* fungi *c.* bacteria *d.* diatoms.

16. If you scoop seawater from the ocean surface and examine a drop under the microscope, you may not see any plankton. The most reasonable explanation is that *a.* the cells were not stained *b.* the plankton were too widely dispersed *c.* a red tide wiped them out *d.* the water was too rough.

17. An important factor for classifying organisms together in a taxonomic group is their similarity in *a.* color *b.* habitat *c.* body structure *d.* body size.

18. Organisms whose cells lack a nuclear membrane are placed in the kingdom *a.* Monera *b.* Protista *c.* Plantae *d.* Fungi.

19. Which of the following statements is *not* true? *a.* Diatoms and dinoflagellates both carry out photosynthesis. *b.* Diatoms have cells walls made of silica. *c.* Dinoflagellates have cells walls made of cellulose. *d.* Diatoms and dinoflagellates both have flagella for locomotion.

20. Organisms that live on food that is made by other organisms are called *a.* producers *b.* heterotrophs *c.* autotrophs *d.* cyanobacteria.

21. Of all the pigments involved in photosynthesis, the most important one found in all marine algae is *a.* carotene *b.* xanthophyll *c.* chlorophyll *d.* phycocyanin.

22. A protist that can both make and take in its food is the *a.* diatom *b.* dinoflagellate *c.* cyanobacterium *d.* ameba.

23. An algal bloom of dinoflagellates that causes fish kills is called the *a.* saxotoxin *b.* brown tide *c.* bioluminescence *d.* red tide.

24. Organisms such as decay bacteria that help recycle dead organic matter are called *a.* autotrophic *b.* decomposers *c.* phytoplankton *d.* eukaryotes.

Base your answers to questions 25 and 26 on the following chemical equation and on your knowledge of marine science.

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6H_2O + 6O_2$$

25. This chemical equation represents the process known as
a. respiration *b.* decomposition *c.* photosynthesis
d. chemosynthesis.

26. In which of the following organisms is this reaction carried out? *a.* decay bacteria *b.* diatoms *c.* blue whales
d. fungi

27. By what means does the organism shown here satisfy its nutritional needs?
a. heterotrophic only
b. autotrophic only
c. heterotrophic and autotrophic
d. chemosynthetic only

Research/Activity

Construct a plankton net from household materials. Show the net to your classmates and explain how you built it. If possible, use the net to obtain plankton from the seashore. Bring live plankton back to the classroom to be viewed.