LESSON PLANS

UNIT 1
INTRODUCTION TO MARINE SCIENCE

UNIT 2
KINGDOMS OF LIFE IN THE SEA

UNIT 3
MARINE INVERTEBRATES

UNIT 4
MARINE VERTEBRATES

UNIT 5
THE WATER PLANET

UNIT 6
ENERGY IN THE OCEAN

UNIT 7
MARINE ECOLOGY

UNIT 1 INTRODUCTION TO MARINE SCIENCE

Chapter 1 / Exploring the Oceans

INTRODUCTION

In Chapter 1, the student learns about the history of ocean studies and travels, from exploratory worldwide sailing voyages to pioneering voyages into the ocean's depths. The story of the *Titanic* is told to introduce the student to concepts—such as buoyancy—that are related to early ocean travel and to the more recent advances in technology that have enabled greater exploration of "inner space."

- The incentive for early ocean travel was usually the search for new trade routes, riches, and knowledge about new lands.
- Technological innovations have increased scientific exploration of the oceans, facilitating charting of currents, location of shipwrecks, and investigations into deep-sea life-forms and seafloor features.

LESSON 1 *(page v: To the Student)*

Aim: What is marine science?

Instructional Objectives

Students will be able to:

1. Define marine science.
2. Distinguish between marine biology and oceanography.
3. Explain why Earth is called a water planet.

Motivation for the Lesson / Do Now

Show the class a map of Earth. Have each student make a simple sketch of the oceans and continents.

Development of the Lesson

1. Have one student spin a globe of Earth while another student (blindfolded) points to a spot on the globe. Repeat 10 times. On average, 7 out of 10 times, the spot touched will be an ocean.
2. KEY QUESTION: *Why is Earth called a "water planet"?* Ask students to estimate what percentage of Earth's surface is water. Tell them that the ocean covers about 71 percent of Earth's surface.
3. WRITE THE AIM: *What is marine science?* Explain that marine science is a field of knowledge about the ocean, composed of marine biology and oceanography.

   KEY QUESTIONS: *What is marine biology? What is oceanography?* Marine biology is the study of life in the ocean. Oceanography is the study of the physical characteristics of the ocean, such as temperature, pressure, density, salinity, light, sound, and movements of ocean water.
4. Do one or more of the following activities to show how various scientific disciplines tie in with a study of the oceans: show a photograph of a scuba diver to introduce the idea of pressure underwater (physics); discuss recent droughts, floods, and El Niño to illustrate the

influence of oceans on climate (meteorology); make "ocean water" by mixing sea salts with freshwater (chemistry). List and define on the board the following fields of science: *biology* (study of life); *chemistry* (study of matter in its molecular form); *physics* (study of energy and forces); *geology* (study of formation and structure of Earth); *meteorology* (study of weather and climate); and *astronomy* (study of objects and matter in outer space).

Summary of the Lesson

Marine science is an interdisciplinary field that is concerned with the study of the ocean and all the living things found in it. This study encompasses research in the major scientific fields, such as biology, chemistry, physics, and Earth and space sciences. Students will learn that the oceans have a great impact on life on land as well as on life in the water.

Homework Assignment

Read page *v (To the Student)* and pages 3–6. Answer Section Review questions 1–3 on pages 6–7.

LESSON 2 *(pages 4–6)*

Aim: Why did the *Titanic* sink?

Instructional Objectives

Students will be able to:

1. Define buoyancy (and Archimedes' principle).
2. Explain why some objects sink, while others float.
3. Explain what happened to the *Titanic* when it hit the iceberg.

Motivation for the Lesson / Do Now

Drop a coin such as a quarter and a ball of aluminum foil into a large container of water. Have students observe what happens to each object in the water. They should note that (although both are metallic) one objects floats, while the other sinks.

Development of the Lesson

1. Ask students to drop different items into the container of water, such as a paper clip, cork, pencil, pen, eraser, and so on.

   Key Question: *Why do some objects float, while others sink?* The coin sinks because it weighs more than the water it displaces. The aluminum-foil ball floats because it contains air within its folds. Air weighs less than water; so the ball weighs less than the water it displaces.

2. **Write the Aim:** *Why did the* Titanic *sink?* Have students examine the illustration of Archimedes' principle in Figure 1-1 on page 6.

   Ask the Class: (a) *How much does the object weigh in air?* (35 grams); (b) *How much does it weigh in water?* (15 grams); (c) *What is the apparent loss of weight in water?* (20 grams).

3. Introduce the concept of buoyancy. The ancient Greek scientist Archimedes discovered that floating objects are supported by an upward force called *buoyancy*. He stated that (a) the buoyant force on any object is equal to the weight of the liquid that the object displaces; and (b) an object immersed in a liquid appears to lose weight, and that apparent weight loss is equal to the weight of the liquid displaced. These ideas are known as *Archimedes' principle*.

4. **Key Question:** *How does Archimedes' principle explain how the* Titanic *sank?* A steel ship floats because it is constructed to have many air-filled compartments. The *Titanic* sank because its air-filled compartments filled with water after a collision with an iceberg. The added weight of the water combined with the weight of the ship became greater than the buoyant force supporting the ship, thus causing it to sink rapidly.

Summary of the Lesson

An object sinks when the weight of the object is greater than the buoyant force that supports the

object. An object floats when its weight is less than the buoyant force that supports the object.

Homework Assignment

Answer Chapter Review questions 9–12 on page 24. Read pages 7–10 (top of page). Answer Section Review questions 1–3 on page 10.

LESSON 3 *(pages 7–10)*

Aim: What is known about the early ocean explorers and navigators?

Instructional Objectives

Students will be able to:

1. Identify the early ocean navigators and ocean explorers.
2. Describe the accomplishments of these early explorers.
3. Explain what motivated the early explorers to travel by sea.

Motivation for the Lesson / Do Now

Have students review pages 7–10 in their textbooks; ask them to look at Figure 1-2 on page 9, which illustrates the path of Magellan's historic attempt to circumnavigate the globe.

Development of the Lesson

1. Organize the class into eight groups, each with a team leader. Walk around the room and have each team leader choose from a container a piece of paper that has the name of an early navigator or explorer on it.
2. **Write the Aim:** *What is known about the early ocean explorers and navigators?* Students should complete their review of pages 7–10. Then students should write as much information as possible in their notebooks about their group's assigned explorer. When they are ready, have the team leaders go up to the board to record the facts on a chart, as shown below. (Check for accuracy.) All students should copy the completed chart into their notebooks.
3. **Key Question:** *What were the routes taken by the early navigators and explorers?* Distribute copies of world maps on which students can draw lines to show the approximate paths sailed by each explorer. Have students write the appropriate explorer's name on each line.
4. **Key Question:** *What have you learned about the early explorers?* Have each group prepare a brief summary. Call on a student from each team to read their summary aloud to the class.

Summary of the Lesson

A sense of adventure, combined with the opportunity to expand trade routes, conquer lands, and

Explorer/Navigator	Country of Origin	Lands Explored
The Vikings	Scandinavian countries	Newfoundland, Canada
Batholomeu Dias	Portugal	South Africa
Christopher Columbus	Spain/Italy	Bahamas
John Cabot	England	Labrador, Canada
Vasco Núñez de Balboa	Spain	Panama
Ferdinand Magellan	Portugal	Americas to Philippines
Giovanni da Verrazano	Italy	North America (east coast)
Jacques Cartier	France	Canada (east coast)

obtain great wealth, motivated the early explorers to search for new lands by sailing the oceans.

Homework Assignment

Read pages 10–13. Answer Section Review questions 1–3 on page 14 (at top of page).

LESSON 4 *(pages 10–13)*

Aim: What do we know about the early scientific exploration of the ocean?

Instructional Objectives

Students will be able to:

1. Identify the early ocean scientists.
2. Describe the achievements of the early oceanographers.
3. Explain what motivated the early ocean scientists.

Motivation for the Lesson / Do Now

Have students review pages 10–13 in their textbooks. Briefly discuss the *Discovery* feature about the unusual ocean voyages of Thor Heyerdahl. Elicit answers to the three questions that are based on the feature (see page 12).

Development of the Lesson

1. Organize the class into six groups, each with a team leader. Walk around the room and have each team leader choose from a container a piece of paper that has the name of an early ocean scientist on it.
2. **Write the Aim:** *What do we know about the early scientific exploration of the ocean?* Students should complete their review of pages 10–13. Then students should write as much information as possible in their notebooks about their group's assigned ocean scientist. When they are ready, have the team leaders go up to the board to record the facts on a chart, as shown below. (Check for accuracy.) All students should copy the completed chart into their notebooks.
3. **Key Question:** *What did Benjamin Franklin discover about the Gulf Stream?* Have students look up information on the Gulf Stream in their textbooks. Have students draw the path of the Gulf Stream across the Atlantic Ocean.
4. **Key Question***: What conclusions can be drawn about interest in the ocean from our study of early oceanographic exploration?* Have each group prepare a brief summary of their findings about early ocean scientists. Call on a student from each group to read it aloud to the class.

Summary of the Lesson

The early ocean scientists continued in the path started by the early ocean navigators. However,

Scientific Ocean Explorer	Scientific Achievement
Capt. James Cook (mid-1700s)	Observed that citrus fruits prevent scurvy
Benjamin Franklin (in 1770)	Had first map of the Gulf Stream drawn
Charles Darwin (in 1830s))	Observed species on Galápagos Islands
Matthew Fontaine Maury (in 1855)	Wrote *The Physical Geography of the Sea*
Sir Charles Thompson (in 1870s)	Compiled 50-volume *Challenger Report*
Fridtjof Nansen (in 1890s)	Invented a water-sampling instrument

the scientists sailed in the quest for knowledge, rather than in a quest for wealth or new lands.

Homework Assignment

Read pages 14–18 (top of page). Answer Section Review questions 1–3 on page 18.

Trial	Correct Amount	Incorrect Amount
1		
2		
3		
4		
Total		
Average		

LESSON 5 *(pages 14–15)*

Aim: What is known about the history of inner space exploration?

Instructional Objectives

Students will be able to:

1. Describe how the early divers explored underwater.
2. Explain, briefly, how scuba gear works.
3. Identify a few pioneers of underwater exploration.

Motivation for the Lesson / Do Now

Display some snorkeling and/or scuba diving equipment. Ask students to describe vision underwater, with and without the use of a facemask.

Development of the Lesson

1. Elicit from students that a diver's vision is blurred underwater. A facemask is required in order to see objects clearly underwater.

   Write the Aim: *What is known about the history of inner space exploration?* The earliest-known instances of underwater, or inner space, exploration occurred 4500 year ago when ancient Greeks, using newly developed glass, made crude facemasks to help them see better when diving for ornamental shells.

2. **Key Question:** *How can we show that it is difficult to see underwater without a facemask?* Place a dollar's worth of change at the bottom of a bucket of warm water. Ask a few student volunteers to look underwater without a facemask (and without contact lenses) to try to determine the correct amount of change. Do several trials. Have another student record the results in a data table on the board by writing a check mark in the appropriate column (correct *vs.* incorrect amount guessed). Determine the percent correct.
3. **Key Question:** *How did diving technology evolve over the years?* Refer students to Figure 1-4 on page 14. One of earliest devices made for staying underwater was the *diving chamber*, a huge barrel that contained a limited supply of air. Simulate a diving chamber by putting a small beaker upside down inside a larger beaker half-filled with water.
4. Discuss advances in diving technology. The *diving suit* came next; it was made of watertight canvas with a heavy metal helmet, or hard-hat. Air was pumped from the surface through a tube into the helmet. The later development of the *scuba tank*, or *aqua-lung*, gave divers greater freedom of movement. (Have students refer to Figures 1-5 and 1-6 on page 15.)

Summary of the Lesson

Advances in diving technology (especially in the past 150 years) have given people the ability to

explore the ocean at greater depths, for longer periods of time, with more safety and mobility.

Homework Assignment

Read pages 15 (bottom)–20. Answer Section Review questions 1–3 on page 20.

LESSON 6 *(pages 16–20)*

Aim: How was the *Titanic* located?

Instructional Objectives

Students will be able to:

1. Explain how the *Titanic* was finally located.
2. Describe some of the technology used in locating the *Titanic*.
3. Identify other technologies used in underwater exploration.

Motivation for the Lesson / Do Now

Ask students why scuba divers were *not* used to try to locate the resting place of the *Titanic*.

Development of the Lesson

1. The crushing effects of deep-sea pressure and a limited air supply prevent scuba divers from attaining great depths.

   Write the Aim: *How was the* Titanic *located?* Show the class pictures of *submersibles*, the steel-hulled vehicles that are designed for underwater research. A submersible's thick hull and larger air supply enable researchers to dive deeper.

2. **Key Question:** *How well did people explore using the early submersibles?* In 1934, American oceanographer Dr. William Beebe reached a depth of 900 meters in a steel chamber called a *bathysphere*. In 1960, the Swiss team of Auguste and Jacques Piccard made the deepest dive in a submersible to the bottom of the Mariana Trench (10, 852 meters).

3. **Key Question:** *How do the modern submersibles explore the ocean floor?* American scientists have logged more than 900 dives aboard the submersible *Alvin*. (See Figure 1-7 on page 17.) In 1979, Dr. Sylvia Earle set a record for making the deepest solo dive, attaining a depth of 380 meters while in the high-tech personal submersible called the *Jim suit*.

4. Unmanned vehicles, called *robots*, are used for exploring in the deepest parts of the ocean. The robot *Argo* was tethered to a surface ship and used to photograph the *Titanic*. (See Figure 1-9 on page 19). The robot *Jason*, tethered to the *Alvin*, photographed the *Titanic*'s interior.

5. **Key Question:** *How is ocean depth determined?* Ships use the technology of sonar (sending and receiving sound waves) to determine ocean depth and to locate objects on the seafloor. *Sonar* stands for ***so***und ***na***vigation and ***r***anging.

6. **Key Question:** *Who located the resting place of the* Titanic? Using a combination of sonar and robot technology, the U.S.–French team led by Dr. Robert Ballard and Jean-Louis Michel was able to find the *Titanic* in 1985, resting 3600 meters deep on the North Atlantic seafloor.

Summary of the Lesson

The development of advanced technology, in the form of submersibles, robot vehicles, and sonar equipment, has culminated in such achievements as finding the sunken *Titanic* 3600 meters deep.

Homework Assignment

Answer Chapter Review questions 6–8 on page 23 and 13–23 on pages 25–26.

Chapter 2 / Marine Scientists at Work

INTRODUCTION

In Chapter 2, the student is introduced to the world of scientific research, particularly that of marine science. The scientific method is explained as the procedure by which scientists conduct valid research. Units of scientific measurement are discussed. Special characteristics of ocean water, such as salinity and density, are explained in relation to measurement procedures. The use of scientific tools for making accurate measurements and observations is discussed; different types of microscopes are described.

- While conducting research and experiments, scientists use a problem-solving approach called the scientific method, an organized way to gather, investigate, and present their data.
- Scientific resources, tools, procedures, and measurements are important elements in the lab work and fieldwork of a marine scientist.

LESSON 1 *(pages 27–35)*

Aim: What is the scientific method?

Instructional Objectives

Students will be able to:

1. Define the scientific method.
2. List the steps in the scientific method.
3. Formulate and test a hypothesis.

Motivation for the Lesson / Do Now

Show the class some live mud snails (*Ilyanassa*) in containers of ocean water. Have the class make a list of observations about the snails.

Development of the Lesson

1. Have a few students write their observations about the snails on the board. For example: snails move; snails respond to touch; snails have a shell; and snails use a muscular foot for locomotion. Next, ask students to identify scientific problems that can be generated from their observations. For example: How fast is a snail? Does the presence of food in the water affect the speed of a snail?
2. **Write the Aim:** *What is the scientific method?* Explain that an organized step-by-step approach, called the *scientific method*, is used to solve problems. The main steps in the scientific method are: (a) making observations; (b) stating the problem; (c) forming and testing a hypothesis; (d) selecting the materials; (e) designing a method or procedure; (f) obtaining results; and (g) drawing conclusions.
3. **Key Question:** *Can you formulate a problem related to food and locomotion (in snails)?* Write on the board the following problem: Does food affect the speed of a snail?
4. **Key Question:** *Can you offer a possible solution to this problem?* Formulate an educated guess, or *hypothesis*, to explain the movement of snails. Hypothesis: If food is in the aquarium, then the snails will move with greater speed (toward the food) than if food is not present.
5. **Key Question:** *What materials are needed to test this hypothesis?* Make a list on the board (under the term *Materials*) of the equipment or apparatus needed to solve the problem. For example: aquarium tanks, ocean water, graduated cylinders, marine snails, and food.

6. **Key Question:** *How should the materials be assembled to solve the problem?* The materials are assembled according to the set-ups shown in Figure 2-5 on page 35. Have students refer to this illustration.

Summary of the Lesson

There are many topics to be studied in marine science, and many tools (e.g., remote sensors) and institutions that aid in this research. Although people can investigate different topics in marine science, all scientists propose, hypothesize about, and research their problems in much the same organized way—generally known as the scientific method.

Homework Assignment

Read pages 27–32; answer Section Review questions 1–3 on page 33. Then read pages 33–36.

LESSON 2 *(pages 36–44)*

Aim: How is the scientific method used to solve problems?

Instructional Objectives

Students will be able to:

1. Analyze data in a table and in a graph.
2. Interpret the results of an experiment.
3. Conclude whether a hypothesis is to be accepted or rejected.

Motivation for the Lesson / Do Now

Give all students a copy of Table 2-1 (see page 36), and ask them to compare the data for the experimental and control groups. Have students calculate the average speed for each group of snails. (Give them the formula: Speed = distance/time).

Development of the Lesson

1. Review the "Do Now" with your students.

   Write the Aim: *How is the scientific method used to solve problems?* Introduce the terms *control group* and *experimental group*. Explain why a scientific experiment includes both groups (to test the *variable* and to ensure valid results).

2. The measurements that are made in an experiment are called *data*. The data collected make up the *results*. The results can be recorded in a *data table*. A table format makes the data better organized and easier to interpret. Each time an experiment is carried out, it is called a *trial*. More than one trial should be performed in an experiment. The average of many trials gives a more accurate result than just one or two trials.

3. **Key Question:** *How can data be displayed?* The results of an experiment can be displayed in the form of a *graph*. A graph shows relationships at a glance. Two kinds of graphs are the *bar graph* and the *line graph*. (Have students refer to Figures 2-6 and 2-7 on page 38.) Both graphs use two lines, or *axes*, to display relationships between sets of scientific data—the *vertical axis* (y-axis) and the *horizontal axis* (x-axis).

Summary of the Lesson

The scientific method is used when researchers carry out an experiment, organize the data they gather, and interpret the results. Data are organized in data tables and/or in line or bar graphs.

Homework Assignment

Read pages 36–39 and 42–45 (top of page). Answer Section Review questions 1–3 on page 45.

Chapter 3 / Marine Environments

INTRODUCTION

In Chapter 3, students will learn about marine life zones, about the four major types of marine environments, and about the different communities of organisms that are characteristic of those environments. Sandy beach and rocky coast environments are described and compared. The various communities found within estuary environments are described, i.e., salt marsh, mud flat, and mangrove. Finally, the coral reef environment is explored, with special attention given to the physical and behavioral adaptations of its diversified inhabitants.

- Coasts and oceans are composed of specific life zones. In each zone, there are characteristic groups of plants and animals, which have adaptations that are suited to survival in those areas.
- Factors such as substrate, wave action, and salinity affect the kinds of organisms that can live in a particular marine environment.
- Wetlands are nutrient-rich, biologically productive communities.
- Coral reefs are massive stony structures that form the basis for complex, productive, and biologically diversified communities in tropical seas.

LESSON 1 *(pages 61–67)*

Aim: What are the major life zones in the ocean and along the coast?

Instructional Objectives

Students will be able to:

1. Identify the major marine life zones.
2. Visualize the zones geographically.
3. Describe the characteristics of the life zones.

Motivation for the Lesson / Do Now

Show students a world map and ask them to describe the parts of the ocean that they think contain the most life and the least life.

Development of the Lesson

1. A *life zone* is a region that contains specific organisms that interact with one another and with their environment. The surroundings of a living thing are called its *environment.*

   Write the Aim: *What are the major life zones in the ocean and along the coast?*

2. Draw on the board a profile of the coast and ocean, going from the supratidal zone to the oceanic zone. Refer to Figure 3-1 on page 62, and Figure 3-3 on page 64.
3. Imagine walking from the upper part of a sandy beach down to the sea, and then boating out to sea for a short distance.

   Key Question: *What major marine life zones would you pass through?* Write on the board the following zones after identifying them on the diagram.

   - *Supratidal zone:* an area of the upper beach that gets a fine mist of salt spray from the crashing waves. Has beach plants, including grasses, shrubs, and trees.
   - *Intertidal zone:* the turbulent area between high tide and low tide, where clams, barnacles, mussels, worms, and seaweeds live. A long line of seaweed called the *strandline* marks the high tide on beaches. (See Figure 3-2 on page 63.)
   - *Subtidal zone:* the area below the intertidal zone. This zone includes the *surf zone*, an area of wave turbulence. Fish, crabs, sea stars, and sea urchins are typical inhabitants of this zone.

- *Neritic zone:* lies above the *continental shelf*, the shallow part of the seafloor that surrounds the continents. It is the main area of commercial fishing.
- *Oceanic zone:* extends beyond the neritic zone and includes most of the open ocean. Together, the neritic and oceanic zones make up the largest marine life zone, i.e., the *pelagic zone*. The upper part (or *photic zone*), which most light penetrates to about 100 meters, contains more life (due to photosynthesis by algae) than does the vast area below it (i.e., *aphotic zone*), which remains in darkness.
- *Benthic zone:* includes the entire ocean floor, from the intertidal zone to the *ocean basin*. Organisms that live on the seafloor are called *benthos*. Benthic organisms often show unique adaptations to conditions on the ocean floor.

4. Have students copy into their notebooks the labeled diagram of the marine life zones.

Summary of the Lesson

The ocean contains several different life zones, each one characterized by particular *communities* of plants and animals that are adapted to live in those environments. Have students write in their notebooks a brief description of each life zone discussed in the lesson.

Homework Assignment

Read pages 60–67 (top). Answer Section Review questions 1–3 on page 67, and Chapter Review question 7 on page 89. Complete the labeled diagram of the major ocean (and coastal) life zones.

LESSON 2 *(pages 67–69)*

Aim: What do we know about the sandy beach environment?

Instructional Objectives

Students will be able to:

1. Describe the sandy beach environment.
2. Identify the life zones of a sandy beach.
3. Discuss interactions of organisms and the environment.

Motivation for the Lesson / Do Now

Describe the characteristics of a sandy beach (or *shore*). Look at Figure 3-5 on page 69, which shows the surf zone on a sandy beach. **Ask students:** *Why is the water white?* Explain.

Development of the Lesson

1. When waves crash on a beach, air mixes with the water, producing white foam. The region where waves crash on a beach is called the *surf zone*. The surf zone is a characteristic feature of a sandy beach.
2. **Write the Aim:** *What do we know about the sandy beach environment?* The *sandy beach* environment contains loose, unstable sediment (i.e., sand), which is easily moved about by wind and water. Beaches that are characterized by large surf (i.e., breaking waves) are those that face the open ocean. The surf zone is not a fixed zone. It moves with the tide as it advances and retreats up and down the slope of the beach.
3. **Key Question:** *What kinds of organisms are found on a sandy beach?* Project Figure 3-1 (see page 62) on the overhead. Note the distinct life zones in which groups of organisms are found. On the upper beach, e.g., there is a zone of beach plants that includes trees, shrubs, and grasses. The roots of these plants hold the sand in place, preventing its erosion by wind and water, and forming small hills called *dunes*. The trees occupy the highest elevation in the dunes, followed by shrubs growing along the slopes, and then beach grasses at the lowest part of this (upper supratidal) zone.

4. KEY QUESTION: *How are marine animals adapted to life in the surf zone?* Organize the class into groups of three to four students. Have the students read their textbooks to find information on the following organisms: mole crab (pages 68–69), blue claw crab (page 69), and silverside fish (page 69).
   - Mole crab (*Emertia*): has smooth jellybean shape that helps it swim through sand and water; avoids wave impact by digging into the sand with its paddlelike appendages; feeds on microscopic organisms by sticking its feathery appendages up into the water.
   - Lady crab (*Ovalipes*): swims and digs into the sand by means of its paddlelike appendages; hides from predators by burrowing in the sand, leaving just its eyestalks exposed.
   - Silverside fish (*Menidia*): small fish that swims in schools in the well-oxygenated waters of the surf zone; feeds on invertebrates and crab eggs; are preyed upon by larger fish such as the striped bass (*Morone*).

Summary of the Lesson

Ask a student leader from each group to read aloud the information obtained by their group. Ask another student to write a brief summary about each animal on the board. Have students copy the completed information into their notebooks.

Homework Assignment

Read pages 67–69. Answer Section Review questions 1–3 on page 69.

LESSON 3 *(pages 70–74)*

Aim: What kinds of marine life are found on a rocky coast?

Instructional Objectives

Students will be able to:

1. Describe the zonation on a rocky coast.
2. Compare and contrast a rocky coast with a sandy beach.
3. Identify typical rocky coast marine organisms.

Motivation for the Lesson / Do Now

Show students some beach sand; then show students a rock that has barnacles or other marine organisms attached to it. **Ask students:** *In which environment are more organisms found—a sandy beach or rocky shore?* Explain.

Development of the Lesson

1. Shores made of solid rock, called *rocky coasts*, provide stable substrates on which organisms can attach. The irregular topography of the rocky coast, with its coves, crevices, and tunnels, also provides hiding places for marine life. Show the class a map of the United States; point out areas that have rocky coasts, e.g., Alaska, California, Maine, Oregon, Washington, and Hawaii.
2. WRITE THE AIM: *What kinds of marine life are found on a rocky coast?* Project Figure 3-8 (see page 71) on the overhead. Note that the characteristic organisms inhabit distinct bands, or life zones, along the coast. These bands of different communities in an environment make up a feature known as *zonation*. From the distance, these zones have a layered appearance when the tide is low (refer to Figure 3-7 on page 70).
3. The rocky coast zones are divided into the *upper intertidal*, the *mid-intertidal*, and the *lower intertidal* zones. Organize the class into groups of three to four students. Have the students read their textbooks to find information on the following rocky coast life zones: upper intertidal (pages 70–71), mid-intertidal (pages 72–73), and lower intertidal (page 73). The following information should be covered:

- *Intertidal zone:* is above the high-tide mark, receives wave splash; blue-green bacteria and algae grow on the moist rocks; when algae die, they stain the rocks black; periwinkle snails and limpets graze on the algae.
- *Mid-intertidal zone:* is inhabited by barnacles, mussels, and seaweeds; barnacles attach to the rocks by means of a natural glue; mussels produce sticky byssal threads that adhere to the rocks; rockweeds adhere to rocks by means of a holdfast attachment; at high tide, barnacles filter feed on plankton; at low tide, barnacles close their shells to avoid drying out.
- *Lower intertidal:* is dominated by seaweeds; at low tide, spaces between the rocks retain water, forming small living communities (of algae, invertebrates, small fish), called *tide pools*. When the tide is in, sea stars, sea urchin, and fish invade this zone to feed.

Summary of the Lesson

Have a student leader from each group read aloud the information their group has obtained. Ask another student to write a brief summary about each life zone on the board. Have students copy the completed information into their notebooks.

Homework Assignment

Read pages 70–74 (top). Answer Section Review questions 1–3 on page 74, and Chapter Review question 6 on page 89.

LESSON 4 *(pages 74–81)*

Aim: Why is the estuary considered such a vital marine environment?

Instructional Objectives

Students will be able to:

1. Describe what an estuary is.
2. Explain why estuaries are important.
3. Identify the communities in an estuary.

Motivation for the Lesson / Do Now

Sketch on the board or project on the wall a picture of the mouth of a river, i.e., an estuary (e.g., the Hudson River entering the ocean at the Narrows, in New York City). **Ask students:** *Why is this area so vital to marine life?*

Development of the Lesson

1. The area along the shore where a river enters the ocean forms an environment called the *estuary*. In the estuary, freshwater from the river mixes with salt water from the ocean, forming what is called *brackish* water.
2. **Write the Aim:** *Why is the estuary such a vital marine environment?* Draw on the board, or project on an overhead, a cross-sectional diagram of an estuary (see Figure 3-10 on page 74). Estuaries provide varied habits for marine life. Many estuaries have large offshore sandbars called *barrier beaches*. The barrier beach separates the ocean from the bay, creating natural sanctuaries for communities of aquatic (and terrestrial) animals.
3. **Key Question:** *What kinds of biological communities are found in the estuary?* Organize the class into groups of three to four students. Have the students read their textbooks to find information on three kinds of estuary (and shore) communities: salt marsh (pages 75–77), mud flat (pages 78–80), and mangrove swamp (pages 80–81). The following information should be covered:
   - *Salt marsh:* also called *wetlands*; its dominant species are the marsh grasses; the tall marsh grass *Phragmites*, with its brown tassels, grows in the upper supratidal zone; tough cordgrasses (*Spartina*) grow in the shallow waters and provide a haven for marine invertebrates and fish; when cordgrass dies, it forms dead matter, or *detritus*, which supplies nutrients for plankton; the

plankton are the basis of marine food chains, many of which originate in the salt marsh.

- *Mud flat:* is like the graveyard of the estuary; the sand is dark and contains organic debris carried in by the incoming tides; decomposers are abundant; bacteria decompose the wastes and turn them into the foul-smelling compound hydrogen sulfide (H_2S); invertebrates such as the mud snail (*Ilyanassa*) scavenge for food; inhabitants include a variety of worms and clams that burrow in the muddy sand, such as the clam worm (*Nereis*), the razor clam (*Ensis*), and the soft-shell clam (*Mya*); various shorebirds prey on these invertebrates.
- *Mangrove swamp:* the dominant species is the mangrove tree (*Rhizophora*), which grows in tropical regions (like Florida); a thick growth of mangrove trees lines the shores of bays and inlets, forming a mangrove community; the trees have arching *prop roots*, which anchor the trees and provide a haven for a variety of marine animals; inhabitants include the crown conch (a marine snail) and the mangrove snapper (a marine fish). Mangrove swamps protect the shoreline from erosion, and act like giant sponges, absorbing the water and impact of tropical storms.

Summary of the Lesson

Have a student leader from each group read aloud the information their group has obtained. Ask another student to write a brief summary about each coastal community on the board. Have students copy the completed information into their notebooks.

Homework Assignment

Read pages 74–81. Answer Section Review questions 1–3 on page 82 (top), and Chapter Review question 8 on page 89.

LESSON 5 *(pages 82–86)*

Aim: Why is the coral reef considered to be an underwater oasis?

Instructional Objectives

Students will be able to:

1. Explain why the coral reef is an important marine environment.
2. Identify the typical inhabitants of a coral reef.
3. Describe interrelationships among the reef inhabitants.

Motivation for the Lesson / Do Now

Display or project on an overhead a photograph of a coral reef. Ask students to count and identify as many living things as possible that are visible on the reef.

Development of the Lesson

1. There are probably at least a dozen (readily visible) different species of living things found on a small patch of reef.

   Write the Aim: *Why is the coral reef considered to be an underwater oasis?* The coral reef is like an "oasis" because it contains a fantastic assortment of marine life in what otherwise would be an area of low biodiversity. Coral reefs are found in tropical and subtropical regions (between 30 degrees north and 30 degrees south latitude). Warm, clear, sunlit, shallow ocean waters are necessary to promote the growth of coral reefs. Together, the *hard corals* and *soft corals* on a reef provide a varied habitat for marine life.
2. **Key Question:** *What kinds of marine organisms inhabit a reef?* Organize the class into seven groups, with each team reading in their textbooks about one of these typical reef organisms: staghorn coral (pages 82–84), spotted trunkfish (page 84), schooling reef fish (pages 84–85), queen angelfish (page 85), butterfly fish (page 85), and reef sharks (page 86).

3. Students should find the following information and record it in their notebooks:
   - Staghorn coral: is a type of hard coral; named for its familiar shape; thin membrane covers and protects hard coral's surface; although made up of hard coral, the reef is very fragile, and pieces can break off easily. (See Figure 3-19 on page 83.)
   - Spotted trunkfish: depends on camouflage to avoid being detected by predators; lives at the bottom of the reef, where it is difficult to spot against the background of coral and speckled sand. (See Figure 3-22 on page 84.)
   - Schooling reef fish: such as the *grunt*, gain protection against predators by swimming together in a group, or *school*, of their own species. There is security in numbers; the chances of any fish being caught by a predator are reduced because of the large number in the school. (See Figure 3-23 on page 85.)
   - Queen angelfish: very colorful, like many other reef fish; its yellow and black colors stand out in sharp contrast to the background colors of the reef; the strong difference between its own body colors, called *color contrast*, enables fish of the same species to find one another in the maze of tunnels and crevices of the reef.
   - Butterfly fish: uses color to confuse predators; has two fake eyespots at the base of its caudal tail, which tricks predators into thinking that the back of the fish is its front; spots, bars, and stripes, which obscure the outline of a fish are called *disruptive coloration*. (See Figure 3-24 on page 85.)
   - Reef sharks: large, predatory fish that patrol an area of the reef to protect its resources from competitors; such behavior by an organism in defending its home area is called *territoriality*. (See Figure 3-25 on page 86).

Summary of the Lesson

Have a student leader from each group read aloud the information their group has obtained. Ask another student to write a brief summary about each of these reef organisms on the board. Have students copy the completed information into their notebooks.

Homework Assignment

Read pages 82–86. Answer Section Review questions 1–3 on page 86. (*See also* Chapter Review pages 90–91 for additional homework questions.)

UNIT 2 KINGDOMS OF LIFE IN THE SEA

Chapter 4 / Unicellular Marine Organisms

INTRODUCTION

Chapter 4 introduces the student to classification, the branch of science important for making sense of the diversity of life on Earth. Also described are the "simple" life-forms that are so abundant on land and in the sea: bacteria and unicellular algae. Algae are crucial in their role as producers and, as such, form the base of vast oceanic food chains. Methods of nutrition in unicellular algae are discussed.

- A scientific classification system helps scientists identify and understand the origins, adaptations, and relatedness of organisms.
- Bacteria play a crucial part in the functioning of the biological world, particularly in their role as decomposers of organic matter.
- Diatoms and dinoflagellates are important marine food producers. They also can cause harm to ocean life when algal blooms occur.

LESSON 1 *(pages 93–97)*

Aim: How can we classify marine organisms?

Instructional Objectives

Students will be able to:

1. Identify the five kingdoms of living things.
2. Describe organisms from each kingdom.
3. List the main characteristics of the organisms.

Motivation for the Lesson / Do Now

Show students a picture or model of the *euglena*. Ask them: *Is it an animal or a plant? Explain.*

Development of the Lesson

1. The euglena has both animal-like and plant-like characteristics, and is classified in the kingdom *Protista*. The process of organizing living things into groups based on similarities in structure is called *classification*. The Swedish botanist Carolus Linnaeus (1707–1778) is credited with being the founder of *taxonomy*, the science of classification.
2. **Write the Aim:** *How can we classify marine organisms?* Linnaeus classified living things into the taxonomic groups kingdom (contains the largest variety of related organisms), phylum, class, order, family, genus, and species. The ***species*** group consists of one kind of organism. The modern classification system recognizes at least five kingdoms—monera, protista, fungi, plant, and animal.
3. **Key Question:** *What kinds of organisms are found in the different kingdoms?* Organize the class into five groups. Assign to each group a different kingdom. Have the students read about their kingdom in the text (on pages 95–97). Distribute around the room various pictures, specimens, and/or models of different marine organisms from the five kingdoms.

Kingdom	Organisms	Characteristics
Monera	Bacteria, cyanobacteria (blue-green algae)	Single-celled; prokaryotes (lack a nuclear membrane); have a cell wall
Protista	Algae, protozoa, seaweeds	Mostly single-celled; eukaryotes (have a nuclear membrane)
Fungi	Molds, yeasts	Unicellular and multicellular eukaryotes; live off dead matter
Plantae	Sea grasses, mangroves, cordgrass	Multicellular; contain chlorophyll; have cell walls & vascular tissue
Animalia	Vertebrates and invertebrates	Multicellular; eukaryotic; lack cell walls; consume food; movement

Each student group should select the appropriate organisms from their kingdom.

4. Copy onto the board the above table; leave the "Characteristics" column blank. Have students from each group go to the board and fill in the information for their kingdom that they gathered from their observations and from their readings in the text.

Summary of the Lesson

Scientists use a classification system to study the five major groups, or *kingdoms*, of living things. The ocean contains organisms from all five kingdoms. Marine bacteria and algae play important an part in ocean life, from producing (food-making) to breaking down (decomposing) organic matter.

Homework Assignment

Read pages 93–97; answer Section Review questions 1–3 on page 97. Then read pages 98–100.

LESSON 2 *(pages 101–108)*

Aim: How can we classify the unicellular algae?

Instructional Objectives

Students will be able to:

1. Classify the different types of unicellular algae.
2. Distinguish between diatoms and dinoflagellates.
3. Describe the significance of the unicellular algae.

Motivation for the Lesson / Do Now

Tell the students to take a deep breath; then ask them to identify the source of most of the oxygen in the air that they breathe.

Development of the Lesson

1. Microscopic, one-celled organisms that contain chlorophyll and live on or near the surface of the ocean produce most of the oxygen that we breathe. These aquatic, plantlike organisms are called *algae*.

   WRITE THE AIM: *How can we classify marine algae?*

2. Have students look at the diatoms in Figure 4-4 (on page 103) and the dinoflagellates in Figure 4-6 (on page 106). Draw on the chalkboard one representative diatom and one dinoflagellate. One-celled organisms such as diatoms and dinoflagellates are classified in kingdom Protista. Diatoms and dinoflagellates float and drift on or near the ocean surface; they are part of the *plankton* population. Both kinds of protists have *chlorophyll* and carry out photosynthesis.
3. KEY QUESTION: *How can we distinguish between diatoms and dinoflagellates?* Diatoms have a transparent cell wall composed of *silica* (which lets in light for photosynthesis). The diatom's cell wall has two overlapping halves called

frustules. (See Figure 4-5 on page 102.) Point out that diatoms are classified according to their shape. The round ones are called *centric* and the pen-shaped ones are called *pinnate*; and some diatoms form long chains.

4. Dinoflagellates have animal-like and plantlike characteristics. That means they can both make (because they have chlorophyll), and take in, their food. Their cell walls are made up of cellulose (like plants), not silica. The dinoflagellates possess two microscopic hairs called *flagella*, which are used for locomotion.

Summary of the Lesson

Diatoms and dinoflagellates are unicellular marine algae that can make food by carrying out photosynthesis and which produce much of the planet's oxygen as a result of this activity. Their life activities and unique characteristics have a great impact on marine ecosystems.

Homework Assignment

Read pages 101–108. Answer Section Review questions 1–3 on page 108.

Chapter 5 / Marine Algae and Plants

INTRODUCTION

In Chapter 5, students will learn that many different kinds of plants and plantlike algae live in and near the ocean. The adaptive features that enable algae and plants to survive in a saltwater environment are explored. Also discussed are the ways in which marine plants and algae function as sources of food and shelter for marine animals.

- Hundreds of species of algae live in the sea, and a great variety of plants grow in and near the sea. These producers have characteristics that help them carry out photosynthesis and survive in the salty, and sometimes rough, conditions of an oceanic environment.
- Marine algae and plants are important for the survival of animals in a variety of undersea and coastal marine environments. They also contribute to the "biological richness" of these environments.

LESSON 1 *(pages 118–127)*

Aim: How can we classify the multicellular algae?

Instructional Objectives

Students will be able to:

1. Classify the main kinds of multicellular algae.
2. Distinguish between the different types of algae.
3. Describe characteristics and habitats of the algae.

Motivation for the Lesson / Do Now

Copy the following table onto the board; leave blank except for the three groups of algae: red, brown, and green. Have students copy the table into their notebooks. During the activity, they will fill in information about each phylum and its characteristics.

Development of the Lesson

1. Show specimens or pictures of seaweeds. Most of the algae that we read about and see are the multicellular algae, or *seaweeds*.

Algae	Phylum	Genus Name	Characteristics and Habitat
Green	Chlorophyta	*Ulva* (sea lettuce)	Thin, leafy, bright green; shallow water
		Enteromorpha	Filamentous, on rocks; intertidal zone
		Codium	Spongy, branching; subtidal zone
		Acetabularia	Umbrellalike; tropical waters
Brown	Phaeophyta	*Laminaria* (kelp)	Long fronds, holdfast on rocks; subtidal zone
		Sargassum	Floats, branching, provides cover; open sea
		Fucus (rockweed)	Air bladders, branching, holdfast on rocks; intertidal zone
Red	Rhodophyta	*Chondrus* (Irish moss)	Short, bushy, covers rocks; subtidal zone
		Porphyra	Thin leaves, attaches to rocks; intertidal zone
		Corallina	Hard, brittle, branching; intertidal zone

Write the Aim: *How can we classify the multicellular algae?* Algae are classified within the kingdom Protista.

2. Organize the class into three groups—the greens, the browns, and the reds—based on the three different groups (phyla) of algae. Distribute pictures and/or specimens of marine algae around the room. Have students observe the specimens and use their textbooks (pages 118–121 and 123–127) to get the information they need to fill in the table.
3. Call on a team leader from each group to make a report to the class on their findings. Have a student fill in the table on the chalkboard for the class to copy into their notebooks.

Summary of the Lesson

The multicellular algae are classified in three different phyla based on the color of their pigments: brown, green, and red. Seaweeds are adapted to live in a variety of marine habitats, from the intertidal and subtidal zones to the open ocean.

Homework Assignment

Read pages 117–127. Answer Section Review questions 1–3 on page 127.

LESSON 2 *(pages 127–134)*

Aim: How are marine plants adapted to their environment?

Instructional Objectives

Students will be able to:

1. Classify the various marine plants.
2. Identify adaptations among the plants.
3. Describe habitats of marine plants.

Motivation for the Lesson / Do Now

Copy the table that is on the chalkboard into your notebook. Read pages 127–134.

Development of the Lesson

1. Show students pictures or specimens of beach plants.

   Key Question: *What do these plants share in common with one another?* They have leaves for photosynthesis, roots for absorbing water from the sand, and stems for transport. Because beach plants and ocean plants possess true roots, stems, and leaves, they are called *vascular plants*. Structures such as stems and leaves that enable organisms to survive in their environment are called *adaptations*. The vascular plants are classified in the phylum *Tracheophyta* within the plant kingdom.

Common Name	Genus Name	Adaptations	Habitat
Beach grass	*Ammophila*	Deep roots, underground stems	Upper beach
Prickly pear cactus	*Opuntia*	Thick, waxy leaves	Upper beach
Seaside goldenrod	*Solidago*	Stores water in stems	Upper beach
Reed grass	*Phragmites*	Fluffy mass of brown flowers	Upper beach
Cordgrass	*Spartina*	Salt glands in leaves	Intertidal zone
Eel grass	*Zostera*	Grow close together in beds	Subtidal zone
Turtle grass	*Thalassia*	Underground stems (rhizomes)	Subtidal zone
Mangrove tree	*Rhizophora*	Prop roots	Intertidal zone

2. **Write the Aim:** *How are marine plants adapted to their environment?* Organize the class into two groups. One group will cover the beach plants; the other group will cover the ocean plants. Distribute pictures and/or specimens of marine plants around the room. Have students observe the specimens and use their textbooks (pages 127–134) to get the information they need to fill in the table.
3. Call on a team leader from each group to make a report to the class on their findings. Have a student fill in the table on the chalkboard for the class to copy into their notebooks.

Summary of the Lesson

Most marine plants are vascular plants. They possess a variety of adaptations in their roots, stems, and leaves that enable them to live in diverse habitats, from the upper beach to the subtidal zone.

Homework Assignment

Read pages 127–134. Answer all Section Review questions 1–3 on pages 129, 132, and 134. (Or: Answer Chapter Review questions 6–8 on page 137 and 13–22 on pages 139–140.)

Chapter 6 / Simple Marine Animals

INTRODUCTION

Chapter 6 introduces the student to the world of protozoans and "simple" marine animals. The text explains how they carry out their basic life functions, such as nutrition, sensitivity, and reproduction. The diversity and importance of zooplankton species are discussed. The protozoans (found throughout the water column) are described in detail, as are the sponges, rotifers, and bryozoans (i.e., the *benthic* animals).

- A protozoan is a unicellular, animal-like organism.
- An animal is a multicellular organism that consumes its food and is generally capable of movement. (Sponges and bryozoans are sessile.)
- The zooplankton community is composed of protozoans and marine animals. Zooplankton are moved, mostly, by winds and currents.
- The "simple" animals—sponges, rotifers, and bryozoans—are well-adapted to surviving the rigors of undersea life. They show a variety of feeding methods (filter feeding, scavenging, active predation) and they reproduce by various methods (including asexual and sexual means of reproduction).

LESSON 1 *(pages 146–148)*

Aim: How diverse are the marine zooplankton?

Instructional Objectives

Students will be able to:

1. Distinguish between vertebrates and invertebrates.
2. Identify temporary and permanent zooplankton.
3. Describe how plankton can be caught for study.

Motivation for the Lesson / Do Now

Have students observe pictures and/or specimens of a variety of vertebrates and invertebrates.

ASK THE CLASS: *How are these organisms similar to one another? How are they different?*

Development of the Lesson

1. WRITE THE AIM: *How diverse are the marine zooplankton?* First define animals, then invertebrates, and then zooplankton. Tell that multicellular organisms that ingest food are classified within the animal kingdom. The taking in of food by animals is called *heterotrophic nutrition*. The animal kingdom can be divided into two major subgroups, the *vertebrates* (animals with backbones) and the *invertebrates* (animals without backbones).
2. KEY QUESTION: *Where can you find an abundance of invertebrates?* Many invertebrates are part of the plankton population. Plankton are tiny organisms that float near the surface of the ocean. Animal and animal-like plankton are called *zooplankton.* Some species of zooplankton are unicellular organisms (protozoa); most others are small invertebrate animals.
3. Show students a plankton net, which is used to strain zooplankton from the water. Zooplankton are subdivided into two groups: ***temporary zooplankton*** and ***permanent zooplankton.*** The temporary zooplankton are the embryos or larvae of crabs, sponges, lobsters, clams, and other invertebrates. The permanent zooplankton are small invertebrate species, like copepods, which remain in the plankton population throughout their entire life cycle.

4. **Key Question:** *How can we compare the temporary and the permanent zooplankton?* Draw a crab larva and a copepod on the board, or project on a screen, for students to copy into their notebooks. Also, refer students to Figures 6-1 and 6-2 on page 147 in their text.
5. Organize the class into groups of three to four students. Each group should prepare a brief summary of the lesson. Have one student from each group write the summary on the board. Call on a student from each group to read their summary aloud.

Summary of the Lesson

The animal kingdom contains vertebrates and invertebrates. In addition, there are the protozoa, which are tiny animal-like organisms. Some protozoa and many marine invertebrates are found in the ocean's zooplankton population, which consists of temporary (invertebrate larvae) and permanent (protozoan) zooplankton.

Homework Assignment

Read pages 141–148. Answer Section Review questions 1–3 on page 149 (top).

LESSON 2 *(pages 149–150)*

Aim: How can we classify the protozoans?

Instructional Objectives

Students will be able to:

1. Classify the various protozoans.
2. Identify their means of locomotion.
3. Describe how the protozoans move.

Motivation for the Lesson / Do Now

Show the class pictures or models of unicellular animal-like organisms. Have students make a list of their observations.

Ask the Class: *What do all of these microorganisms have in common?*

Development of the Lesson

1. **Write the Aim:** *How can we classify the protozoans?* All of these organisms are microscopic, one-celled animal-like organism called *protozoans*. Protozoans live in bottom sediments, on the surface of substrates, and within the water column. Unicellular protozoans are classified in the protist kingdom and to the phylum *Protozoa*. The protozoa are subdivided into three different classes—ciliates, flagellates, and amebas—based on their means of locomotion.
2. **Key Question:** *How do the protozoa move about?* Draw on the board, or project on an overhead, a representative from each class of protozoans (ciliated, flagellated, and ameboid). List the following characteristics for each group:
   - *Ciliates:* Move through the water by means of the beating of their microscopic hairs called *cilia*.
   - *Flagellates:* Contain two whiplike tails called *flagella* (singular, *flagellum*). The actions of their flagella cause the organism to move in any direction.
   - *Amebas:* Live on the surface of substrates and move by means of a cytoplasmic streaming (called *amoeboid movement*) into extensions of their cell—the *pseudopodia* ("false feet").

Summary of the Lesson

The protozoans are grouped into three different classes, based on their means of locomotion. These are: the ciliates, the flagellates, and the ameboids. Protozoa include freshwater and marine species.

Homework Assignment

Read pages 149–150 (top). Answer Section Review question 1 on page 55 (top).

LESSON 3 *(pages 150–154)*

Aim: How does a unicellular organism carry out its life functions?

Instructional Objectives

Students will be able to:

1. Identify structures in the *Vorticella*.
2. Define the basic life functions of all organisms.
3. Explain how the *Vorticella* carries out its functions.

Motivation for the Lesson / Do Now

Have the students make a list of the basic life functions of living things.

Development of the Lesson

1. *Life functions* are the activities that are necessary for an organism to carry out in order to survive. The life functions include ingestion, digestion, growth, transport, excretion, respiration, locomotion, reproduction, and sensitivity.

   Write the Aim: *How does a unicellular organism carry out its life functions?* The *Vorticella*, a one-celled animal-like protozoan, carries out all its life functions within its single cell. The *Vorticella* is easier to observe than other protozoans because it is attached to a substrate. Mention that organisms that live attached to a substrate are called *sessile*.

2. Use a wall chart, drawing, or projection of the *Vorticella* on the board for the students to copy into their notebooks. Draw two columns on the board, labeled *Structure* and *Function*.

   Ask Key Questions: (e.g., *How does the Vorticella ingest its food?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns with the appropriate information.

Structure	Function
Cilia	Locomotion and food-getting
Mouth	Ingestion (taking in of food)
Food vacuole	Digestion (changing large molecules into small ones)
Cytoplasm	Transport (movement of nutrients throughout the cell)
Nucleus	Growth (increase in cell size) and reproduction (production of more cells)
Cell membrane	Respiration (taking in O_2, giving off CO_2)
Contractile vacuole	Excretion (elimination of cellular waste)
Stalk	Sensitivity (contraction of stalk in response to external stimulus)

Summary of the Lesson

The *Vorticella* is a unicellular, ciliated aquatic protozoan that carries out all its life functions (which are like those of multicellular organisms) within its single cell.

Homework Assignment

Read pages 150–154. Answer Section Review questions 2 and 3 on page 155 (top).

LESSON 4 *(pages 155–157)*

Aim: How is the sponge adapted to its environment?

Instructional Objectives

Students will be able to:

1. Explain why the sponge is considered "simple."
2. Describe the structure of a typical sponge.
3. Identify the classification of the sponge.

Motivation for the Lesson / Do Now

Pass a few (natural marine) sponges around the classroom. Have students make three observations about the structure of a sponge. Then give the classification of the sponge (i.e., phylum *Porifera*).

Development of the Lesson

1. List on the board some of the student observations on sponge structure, which may include the following: (a) the sponge has many holes; (b) the sponge is elastic; (c) all parts of the sponge look alike; and (d) the adult sponge does not move (i.e., it is sessile).

   WRITE THE AIM: *How is the sponge adapted to its environment?*

2. Use a wall chart, drawing, or projection of a sponge on the board for the students to copy into their notebooks. Draw two columns on the board, labeled *Structure* and *Function*. **Ask key questions** (e.g., *How does the sponge ingest its food?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns with the appropriate information.
3. KEY QUESTION: *Why is the sponge considered to be a simple organism?* The sponge is a simple animal (even though it is multicellular) because it has only two cell layers—an inner layer (the *endoderm*) and an outer layer (the *ectoderm*)—and it lacks (cellular) specialization.

Structure	Function
Ostia (small pores)	Ingestion (taking in of food and water)
Osculum (large pores)	Excretion (elimination of cellular wastes)
Collar cells (have flagella)	Digestion (changing large molecules into small ones); filter feeding (movement of flagella cause currents of water to enter and leave the sponge)
Ectoderm and endodermoff	Respiration (taking in O_2, giving CO_2)
Spicules	Providing structure and protection

Summary of the Lesson

The sponge is a simple pore-bearing, filter-feeding, multicellular organism that is composed of two layers of (mostly unspecialized) cells. The sponge is classified in phylum Porifera ("pore-bearing").

Homework Assignment

Read pages 155–157. Answer Section Review question 1 on page 164, and Chapter Review questions 6 on page 166 and 13–23 on page 168.

LESSON 5 *(pages 157–161 top)*

Aim: What do we know about the life cycle of the sponge?

Instructional Objectives

Students will be able to:

1. Describe the life cycle of the sponge.
2. Identify the stages in a sponge's development.
3. Explain how an adult sponge encrusts on a substrate.

Motivation for the Lesson / Do Now

ASK THE CLASS: *How does the (adult) sponge attach to a substrate if it cannot swim?*

Development of the Lesson

1. The adult sponge has no locomotion, but during its early development it lives as a swimming larva (embryo) within the plankton population. The period of time from early development and growth through maturity in an organism is called its *life cycle*.

2. **Write the Aim:** *What do we know about the life cycle of the sponge?* The life cycle begins with *reproduction*, the activity by which organisms produce offspring. Sponges may either have separate sexes or may have both male and female sex cells within the same sponge. Draw a zygote on the board, and show the class an adult sponge.

   Key Question: *How does a multicellular sponge develop from a single cell?*

3. Show the class pictures or models of each stage of sponge development, or have students refer to Figure 6-6, on page 157, in their textbooks. The rapid division of the fertilized egg cell, or *zygote*, is called *cleavage*. The organism during early stages of cellular development is called an *embryo*. When the embryo is a solid ball of cells it is in the *morula* stage. When it is a hollow ball of cells, it is in the *blastula* stage.

4. **Key Question:** *How and when does the embryo become a swimmer?* When the cells of a blastula develop whiplike flagella, the sponge embryo is able to swim. The swimming embryo is called a *larva*. When the larva attaches to a substrate, it develops into an adult sponge. The mature sponges release the gametes into the water. Fertilization and development are external.

Summary of the Lesson

The sponge's life cycle begins with the production of offspring. A sponge develops from a single, fertilized egg cell that goes through various stages of embryonic development. It becomes a free-swimming larva, which then settles onto a substrate and develops into a sessile adult sponge.

Homework Assignment

Read pages 157–161 (top). Answer Section Review question 2 on page 164, and Chapter Review question 7 on page 166.

LESSON 6 *(pages 161–164)*

Aim: How do simple, multicellular organisms carry out their life functions?

Instructional Objectives

Students will be able to:

1. Identify a bryozoan and a rotifer.
2. Describe how they carry out their life functions.
3. Explain how they are adapted to their environment.

Motivation for the Lesson / Do Now

Use an overhead projector to show the class a rotifer and a bryozoan. Have the students try to identify these organisms (i.e., what type of life-form each might be).

Development of the Lesson

1. The rotifer and the bryozoan are multicellular, microscopic marine organisms that are classified in two different phyla. The rotifer is in phylum *Rotifera* and the bryozoan is in phylum *Bryozoa*.
2. **Write the Aim:** *How do simple, multicellular organisms carry out their life functions?* Organize the class into six groups to do research on rotifers and bryozoans (on pages 161–164). Assign to each of five groups one of the following life functions: locomotion, ingestion, digestion, respiration, and reproduction. Assign "habitats" to the sixth group. Draw two columns on the board, labeled Rotifer *Structure* and Rotifer *Function*. Ask the team leader from each group to fill in the columns on the board with the appropriate information about rotifers. All students should copy the completed tables into their notebooks.
3. **Key Question:** *How would you describe the habitat of the rotifer?* Have the team leader from

Rotifer Structure	Rotifer Function
Cilia	Locomotion (moving from place to place)
Mouth	Ingestion (taking in of food)
Stomach, intestine, anus	Digestion (changing large molecules into small ones); one-way digestive system
Cell membrane	Respiration (taking in O_2, giving off CO_2)
Separate sexes: ovary (egg cells) and testes (sperm cells)	Sexual reproduction (external fertilization); asexual parthenogenesis may also occur

Bryozoan Structure	Bryozoan Function
Mouth	Ingestion (taking in of food)
Stomach, intestine, anus	Digestion (changing large molecules into small ones); one-way digestive system
Cell membrane	Respiration (taking in O_2, giving off CO_2)
Hermaphrodite (both ovaries and testes in same individual); Budding also occurs.	Sexual reproduction (self-fertilization may occur); Asexual reproduction (budding); a small part breaks off from the parent bryozoan to become a new organism.

group 6 provide the appropriate information. Rotifers live in the moist sands along the shore and in the gravel of aquarium tanks. They swim by means of *cilia* and they can telescope their bodies to facilitate movement. Some rotifers are predators, while others scavenge on debris.

4. Draw two more columns on the board, labeled *Bryozoan Structure* and *Bryozoan Function*. Ask the team leader from each group to fill in the columns on the board with the appropriate information about bryozoans. All students should copy the completed tables into their notebooks.
5. KEY QUESTION: *What do we know about the habitat of the bryozoan?* Have the team leader from group 6 provide the appropriate information. Branching colonies of bryozoans composed of hundreds of individuals cover the surfaces of rocks, seaweeds, and shells. Some species of bryozoans encrust on substrates, while other bryozoan colonies stand erect.

Summary of the Lesson

The rotifer and the bryozoan are examples of microscopic, multicellular animals that live in marine sediments and on the surfaces of substrates.

Homework Assignment

Read pages 161–164. Answer Section Review question 3 on page 164, and Chapter Review question 8 on page 166.

UNIT 3 MARINE INVERTEBRATES

Chapter 7 / Cnidarians

INTRODUCTION

In Chapter 7, students will learn about cnidarians, the marine animals that have stinging tentacles. At first glance, animals such as anemones, corals, and jellyfish look very different, but they have similar body structures and functions. Students will learn about feeding and reproduction in cnidarians. The polyp and the medusa are the basic body plans found in this phylum. Some cnidarians are colonial; in these species, many different polyps function together as a single organism.

- All cnidarians have stinging tentacles, some of which contain toxins.
- All cnidarians have a nerve net (simple nervous system) and exhibit radial symmetry (in both the polyp and the medusa phase).
- Some cnidarians, e.g., corals, have symbiotic algae living within them.

LESSON 1 *(pages 173–178 top)*

Aim: How does the jellyfish carry out its life functions?

Instructional Objectives

Students will be able to:

1. Describe the structure of the jellyfish.
2. Explain how the jellyfish carries out its life functions.
3. Compare and contrast different types of jellyfish.

Motivation for the Lesson / Do Now

Show examples or models of corals, sea anemones, and jellyfish to the class. Compare and contrast these organisms.

Development of the Lesson

1. The coral, sea anemone, and jellyfish are all animals with stinging tentacles. These invertebrates are classified in phylum *Cnidaria*. The jellyfish belong to class *Scyphozoa*.

   WRITE THE AIM: *How does the jellyfish carry out its life functions?* Have students look at the photographs of a moon jelly (*Aurelia*), Figure 7-2 on page 174, and of a lion's mane jellyfish (*Cyanea*), on page 177 (or use an overhead projector to show the class these images). Remind students that "jellyfish" are not fish at all, but are invertebrate animals in their own class.

2. KEY QUESTION: *How does the jellyfish float and move?* Draw a diagram on the board based on Figure 7-1 on page 173. The umbrella-shaped structure is called the *medusa*. The medusa is composed of two membranes, with a jellylike mass called the *mesoglea* between them. The shape of the medusa, and its thinness and low density, enable the jellyfish to float. The

medusa contracts in a rhythmic fashion, which causes these animals to pulsate gently through the water. Because they float along, jellyfish are considered part of the plankton population.

3. **Key Questions:** *How does the jellyfish obtain and digest food*? Their long transparent tentacles contain stinging cells, called *cnidoblasts*. Inside each cnidoblast there is a coiled thread with a barb at the end, called a *nematocyst*. Refer students to Figure 7-3 on page 174. The barb is coated with a paralyzing toxin that can immobilize small prey. Contracting tentacles bring the prey up to the mouth. Food is ingested through the mouth and digested in a saclike digestive cavity. Digestion in the jellyfish is *extracellular* and occurs in a *two-way digestive tract*, since waste products are eliminated through the mouth. The jellyfish can also catch food with its medusa, the underside of which has a sticky mucus membrane that catches plankton.
4. **Key Questions:** *How does the jellyfish breathe?* Since the jellyfish has thin membranes, oxygen can diffuse directly from the water into its body cells. The cellular waste product, carbon dioxide, diffuses in the opposite direction, from the cells into the water. This gas exchange occurs over the entire surface of the jellyfish.
5. **Key Question:** *How does the jellyfish reproduce?* The jellyfish have separate sexes. The ovaries and testes form a four-leaf-clover pattern, visible at the top of the medusa. The testes produce sperm cells, which swim out of the male's mouth and into the female's mouth and digestive sac. The sperm cells fertilize the egg cells in the ovary, producing embryos that pass through various developmental stages (see Figure 7-4 on page 176).
6. **Key Question:** *What have you learned from the study of the jellyfish?* Organize the class into five groups and assign one life function to each group (ingestion, food-getting, respiration, locomotion, and reproduction). Have each group prepare a summary from the information in their notes. Have the team leader from each group read the summary aloud in class.

Summary of the Lesson

The jellyfish is an invertebrate with stinging tentacles that floats near the surface of the ocean, where it feeds on plankton and other small animals. Like all cnidarians, it has radial symmetry.

Homework Assignment

Read pages 171–178 (top). Answer Section Review questions 1–3 on page 178, and Chapter Review questions 9–11 on page 190.

LESSON 2 *(pages 178–180 top; 184–186)*

Aim: How are sea anemones and hydroids adapted to their environment?

Instructional Objectives

Students will be able to:

1. Compare and contrast sea anemones and hydroids.
2. Explain how sea anemones carry out their life functions.
3. Describe different adaptive features of the hydroids.

Motivation for the Lesson / Do Now

Show the class a photograph of a sea anemone, an *Obelia*, and a *Physalia*. Have students compare and contrast their observable features with those of a jellyfish.

Development of the Lesson

1. The sea anemone is an animal with stinging tentacles that (superficially) looks like an upside-down jellyfish. But it is more closely

related to the corals and is placed in class *Anthozoa*. The mound of tissue that forms the main body of a sea anemone is the *polyp*.

2. **Write the Aim:** *How are the sea anemones and hydroids adapted to their environment?* Organize the class into several groups of two to four students each. Half the groups will be the *Sea Anemones* and the other half will be the *Hydroids*. Have the Sea Anemones read Section 7.2 and copy Figure 7-6 (page 178) into their notebooks. Have the Hydroids read Section 7.4 and copy Figures 7-10 (page 185) and 7-11 (page 186) into their notebooks.
3. Draw two columns on the board, labeled *Sea Anemone Structure and Function* and *Hydroid Structure and Function*. Ask a team leader from each type of group to fill in the columns on the board with the appropriate information. For sea anemones, the following should be included: mouth/ingestion; epidermis/respiration; tentacles/food-getting; digestive cavity/digestion; muscular foot/attachment to substrate. For hydroids, the following should be included: mouth/ingestion; tentacles/food-getting; and float/locomotion (to aid sailing) or stalk/sessile (attachment to substrate). All students should copy the completed tables into their notebooks.
4. **Key Question:** *How can we compare and contrast the sea anemone and the hydroid?* The sea anemone and the hydroid are both cnidarians; they both have stinging tentacles and radial symmetry. The sea anemone is a solitary animal. Most hydroids, such as *Obelia* and *Physalia* (Portuguese man-of-war) are colonial animals, because they are made up of groups of specialized polyps joined together (on a stalk in *Obelia*; under a single float in *Physalia*). The colonial cnidarians are placed in class *Hydrozoa*. The dominant structure in the sea anemone is the polyp; it lives attached to a substrate in the intertidal and/or subtidal zones. Some hydroids, like *Obelia*, live attached to a substrate; others, like *Physalia*, float and drift on the ocean surface. Sea anemones can reproduce sexually and/or asexually. Hydroids contain reproductive polyps; in *Obelia*, these polyps form a brief medusa (sexual) phase.

Summary of the Lesson

The cnidarians, such as sea anemones and hydroids, are adapted to their environment by possessing stinging tentacles for food-getting. The solitary sea anemone has a muscular foot for anchorage to substrates. The colonial *Physalia* has a gas-filled float to aid in locomotion.

Homework Assignment

Read pages 178–180 (top) and 184–186. Answer Section Review questions 1–3 on page 180 and 1–3 on page 186.

LESSON 3 *(pages 180–184 top)*

Aim: How does the coral carry out its life functions?

Instructional Objectives

Students will be able to:

1. Explain how the coral animal builds a reef.
2. Identify the different kinds of coral.
3. Describe the structure of a coral polyp.

Motivation for the Lesson / Do Now

Display specimens or photographs of hard corals and soft corals in front of the class. Have students sketch and label them in their notebooks.

Development of the Lesson

1. The coral is a tiny animal with stinging tentacles. Corals often resemble familiar objects, so they have names such as brain coral, staghorn

coral, sea fan, and sea whip. Corals are divided into two types—hard corals and soft corals—both of which (along with the sea anemones) belong to class *Anthozoa*. The hard corals have an outer covering of limestone, which can grow into a massive stony structure called a *coral reef*.

2. **Write the Aim:** *How does the coral carry out its life functions?* The basic structure of the coral animal is the *coral polyp*. Draw on the board, or project on an overhead, a picture of the coral polyp. (Refer to Figure 7-8 on page 182.) In hard corals, the polyp sits in a cuplike depression on the surface of a reef. The stony depression is composed of the compound calcium carbonate, or *limestone*, which is produced by the polyps that live on the surface.
3. **Key Question:** *How does a coral polyp get the energy it needs to build a reef?* Specialized cells that live within the polyp, called *zooxanthellae*, provide some of the energy needed to extract calcium from the seawater and use it to construct the limestone skeleton. The zooxanthellae are unicellular algae, which are captured by the coral polyp from the surrounding seawater. The chloroplasts in the zooxanthellae carry out photosynthesis and produce energy-rich glucose.
4. **Key Question:** *What conditions are needed for corals to grow?* Coral reefs need warm, clean, shallow tropical oceans where the water is clear and receives abundant sunlight.

Summary of the Lesson

The coral is a tiny animal that has stinging tentacles. Its basic unit of structure is the coral polyp, which contains symbiotic algae. Over time, millions of coral polyps living together form a reef by secreting cup-shaped limestone depressions in which each polyp sits.

Homework Assignment

Read pages 180–184 (top). Answer Section Review questions 1–3 on page 184, and Chapter Review questions 7 on page 189 and 12–24 on pages 190–192.

Chapter 8 / Marine Worms

INTRODUCTION

The world of marine worms is explored in Chapter 8. Students will learn about the digestive and reproductive systems of marine worms and about their roles in the marine environment. Although marine worms tend to resemble one another in their general shape, this group is actually composed of many different types of organisms, with different levels of structural development and complexity. Worms vary in size from microscopic to many meters long, are all bilaterally symmetrical, and are found throughout the water column.

- There are flatworms, roundworms, and segmented worms. Worms are the first organisms to exhibit bilateral symmetry.
- Worms are found throughout the marine environment, from the ocean surface to intertidal sediments to the deep seafloor.
- Marine worms exhibit a variety of lifestyles: some are parasitic, some free-living; some filter feed, some are predatory; and some live in tubes, which they construct of proteins and minerals.

LESSON 1 *(pages 194–198, 200–205)*

Aim: What is known about marine worms?

Instructional Objectives

Students will be able to:

1. Explain why worms are classified in different phyla.
2. Describe characteristics of the different worm phyla.
3. Discuss similarities and differences among the worms.

Motivation for the Lesson / Do Now

Have students copy into their notebooks the first column and the four category headings from the following table, which profiles six major phyla of marine worms.

Development of the Lesson

1. Worms resemble one another in general shape. The body is longer than it is wide. Since worms are not a single taxonomic group, they are classified into several phyla.
2. **Write the Aim:** *What is known about marine worms?* Organize the class into six groups, with each team researching a different marine worm. Information on the worms can be found on the following pages: planarian (195–196), ribbon worm (197), roundworm (198), sandworm (200–202), giant tube worm (203–204), and arrow worm (204–205). Have students sketch their worm and describe its traits.
3. Send a student from each group to the board to read their findings aloud and to fill in the information. All students should copy the completed table into their notebooks.

Worm	Body Traits	Digestion	Habitat & Feeding	Reproduction
Planarian: Phylum *Platyhelminthes*	Flat; tiny to very large species	Two-way tract	Aquatic; eats micro-organisms & organic debris along bottom	Asexual (regenerate) & sexual (hermaphrodite); internal fertilization
Ribbon Worm: Phylum *Nemertea*	Flat; usually 1 meter, up to 12 meters long	One-way tract	Intertidal zone (in sand & water); eats small fish & worms	Asexual (regenerate) & sexual; external fertilization
Roundworm: Phylum *Nematoda*	Round; tapered at ends; up to 1 meter long	One-way tract	Intertidal zone (in sediments); eats organic debris	Sexual (usually separate sexes); internal fertilization
Sandworm: Phylum *Annelida*	Segmented; small (but not microscopic)	One-way tract (with fluid-filled coelom	Intertidal & subtidal zones (in sediments); eats organic debris & tiny invertebrates	Sexual (separate sexes) (*Note:* Earthworm, also an annelid, is a hermaphrodite)
Giant Tube Worm: Phylum *Pogonophora*	1 meter long; tube-dwelling	Gutless	Hydrothermal vents; rely on compounds from chemosynthetic symbiotic bacteria	(not discussed in text)
Arrow Worm: Phylum *Chaetognatha*	Few cm long; has tiny fins for swimming	One-way	Ocean surface; hunts copepods, fish eggs, & fish larvae	Sexual (hermaphrodite); external fertilization

4. Some important facts about the marine worms that may be overlooked by the students, but that you may want to mention, are:
   - Planaria: flattened bodies; some are microscopic, others are macroscopic; has a ventral mouth, branched digestive cavity, two-way digestive tract, and two eye spots.
   - Ribbon worm: largest worm in the ocean; averages one meter in length; inhabits the intertidal zone; burrows in the sand or swims gently; can break into many small pieces and regenerate; also has sexual reproduction.
   - Sandworm: segmented body, with paddle-like appendages called *parapodia*; burrows in marine sediments in intertidal and subtidal zones; captures prey with two sharp hooks in mouth; breathes through thin, moist skin; has ventral nerve cord and brain; closed circulatory system; is hermaphroditic; excretes wastes through *nephridia*.
   - Giant tube worm: lives near deep-sea hydrothermal vents; up to one meter in length; utilize energy from chemosynthetic bacteria that live inside them.
   - Roundworm: rounded body with tapered ends; most numerous of all worms; lives in moist sediments in intertidal zone; moves by whipping action of body; feeds on organic debris.
   - Arrow worm: tiny and transparent; has tiny fins; active swimmer; also floats with plankton; uses modified mouth bristles (hooks) to prey on plankton; has two eyes.

Summary of the Lesson

There are enough structural difference among the worms to justify their being classified into separate phyla. Worms are an important part of all marine ecosystems, from the ocean surface to the deep seafloor.

Homework Assignment

Read pages 193–198 and 200–205. Answer Chapter Review questions 13–25 on pages 210–212.

Chapter 9 / Mollusks

INTRODUCTION

The soft-bodied invertebrates discussed in this chapter are the mollusks, an extremely diversified phylum of aquatic animals. Students will learn about the important characteristics and life functions of the bivalves, gastropods, and cephalopods (and two other "lesser" mollusk groups). The distinguishing feature of this group is the external shell, although this has been lost in most cephalopods. Glands in the mantle secrete the mollusk's shell.

- Bivalves, e.g., the clam, are distinguished by having two shells, or *valves*.
- Gastropods, e.g., the snail, have one (usually coiled) shell.
- Cephalopods, such as the octopus, have lost the external shell; they are characterized by having a prominent head and long tentacles.
- Mollusks are found throughout the marine environment; they exhibit a variety of feeding methods, from filter feeding to grazing to hunting. Some mollusks live attached to a substrate; others are motile.

LESSON 1 *(pages 214–218)*

Aim: How does a bivalve carry out its life functions?

Instructional Objectives

Students will be able to:

1. Describe how the clam is classified.
2. Identify the main structures in a clam.
3. Discuss the life functions of a clam.

Motivation for the Lesson / Do Now

Distribute some clamshells for the class to observe. Have all students make a sketch of a clamshell in their notebooks.

Development of the Lesson

1. The snail, oyster, clam, and mussel all have a shell, or *exoskeleton*, that protects the soft-bodied animal inside. These soft-bodied animals are called *mollusks* and are classified in phylum *Mollusca*.
2. **Write the Aim:** *How does a bivalve carry out its life functions?* Display the clamshells. Mention that mollusks with two shells are called *bivalves* and belong to class *Bivalvia* (or Pelycepoda). Clamshells are hinged at one end, and are kept closed by short, tough *adductor muscles*. Point out the muscle attachment areas inside the shell. The outside of the shell has lines on it. Explain that each line is a new layer of shell that the clam produces as it grows. The lines form bands, and each band represents a year's growth.
3. **Key Question:** *What do we know about the internal anatomy of the clam?* Use a wall chart, drawing, or projection of the clam's internal anatomy for the students to copy into their notebooks. (You can also direct students to Figure 9-17 on page 230.) Draw two columns on the board, labeled *Structure* and *Function*. **Ask key questions** (e.g., *How does the clam ingest food?* and *How does the clam breathe?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns with the appropriate information. Have students copy the completed chart into their notebooks.

Structure	Function
Shell (Exoskeleton)	Protection
Adductor muscles	Contraction
Incurrent siphon	Water and food intake
Excurrent siphon	Waste removal
Gills	Breathing (gas exchange)
Mouth, stomach, intestines, anus	Digestion (one-way)
Kidney	Excretion
Heart	Transport (open system)

Summary of the Lesson

Bivalves such as the clam are soft-bodied animals that possess an exoskeleton (shell) to protect the internal organs, which carry out their life functions. Most (but not all) marine mollusks have an outer shell to protect their soft bodies.

Homework Assignment

Read pages 213–218. Answer Section Review questions 1–3 on page 218, and Chapter Review question 6 on page 232.

LESSON 2 *(pages 218–222)*

Aim: How does a gastropod carry out its life functions?

Instructional Objectives

Students will be able to:

1. Describe how the snail is classified.

2. Identify structures in the snail.
3. Discuss the life functions in the snail.

Motivation for the Lesson / Do Now

Distribute some snail shells (uninhabited!) for the class to observe. Have all students make a sketch of a snail shell in their notebooks.

Development of the Lesson

1. The snail is a type of mollusk that possesses a single shell, so they are commonly called *univalves* ("one shell"). Snails are placed in class *Gastropoda* and are also known simply as *gastropods* ("stomach-foot").
2. **Write the Aim:** *How does a univalve carry out its life functions?* Use a wall chart, drawing, or projection of the snail's internal anatomy for the students to copy into their notebooks. (You can also direct students to Figure 9-8 on page 219.) Draw two columns on the board, labeled *Structure* and *Function*. **Ask key questions** (e.g., *How does the snail move?* and *How does the snail ingest food?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns with the appropriate information. Have students copy the completed chart into their notebooks.

Structure	Function
Shell	Protection
Muscular foot	Locomotive
Anterior antennae (eyes)	Vision
Posterior Antennae	Sensitivity
Siphon	Water intake
Gills	Breathing
Radula	Ingestion
Mouth, stomach, intestines, anus	Digestion (one-way)
Kidney	Excretion
Heart	Transport (open system)

Summary of the Lesson

Gastropods such as the marine snail are soft-bodied mollusks that posses a univalve exoskeleton to protect their internal organs, which carry out all life functions. They use a toothed mouthpart called a *radula* to eat either algae or (living or dead) animal matter.

Homework Assignment

Read pages 218–223. Answer Section Review questions 1–3 on page 223, and Chapter Review question 8 on page 232.

LESSON 3 *(pages 222–229)*

Aim: How diverse are the mollusks?

Instructional Objectives

Students will be able to:

1. Identify the different classes of mollusks.
2. Describe the characteristics of each class.
3. Discuss diversity among the mollusks.

Motivation for the Lesson / Do Now

Distribute a variety of mollusks (specimens, models, or pictures) for students to observe. Have students make a list of similarities and differences.

Development of the Lesson

1. There are more than 100,000 different species of mollusks, which are placed into different classes based on the structural differences among them.
2. **Write the Aim:** *How diverse are the mollusks?* Organize the class into six groups, with each team researching a different mollusk. Information on the specific mollusks can be found

on the following pages: mussel (215–216), abalone (222), sea slug (223), squid (224, 226, 228), octopus (224, 226–227, 228), and chiton (229). Have students draw their mollusk and describe its characteristics.

3. Send a student from each group to the board to read their findings aloud and to write down some key facts about their mollusk. All students should copy the information into their notebooks.
4. Some important facts about the mollusks that you may want to see mentioned are:
   - Mussel (genus *Mytilus*, class *Bivalvia*): contains microscopic hairs called *cilia*, which beat back and forth, causing currents of water to enter and leave the mussel; secretes *byssal threads*, which enable it to attach firmly to substrates; has membrane, called the *mantle*, which secretes and lines the insides of both shells.
   - Abalone (genus *Haliotis*, class *Gastropoda*): largest of the flat-shelled gastropods; inhabits the rocky Pacific Coast where it grazes on algae on the rocks; mantle secretes a shiny, iridescent material (*mother-of-pearl*), which lines the insides of its shells.
   - Sea Slug (genus *Dendronotus*, class *Gastropoda*): also called a *nudibranch*, it is a snail without a shell; glides along seafloor in intertidal and subtidal zones, grazing on algae; sea hares (a type of nudibranch) grow up to 75 cm in length and weigh 16 kg (biggest marine gastropod).
   - Squid (genus *Loligo*, class *Cephalopoda*): swims in schools by means of a kind of jet propulsion; water is drawn into the mantle cavity and expelled through the siphon, causing squid to be propelled in the opposite direction; has ten tentacles; uses suction disks on tentacles to capture and grasp prey; releases ink cloud to avoid predators.
   - Octopus (genus *Octopus*, class *Cephalopda*): solitary animal; lives in crevices and under rocks on the seafloor; has eight tentacles, with suction disks to grasp prey; pigmented cells in its skin (*chromatophores*) expand and contract to change its skin color and pattern (for camouflage); releases ink cloud to avoid predators; intelligent.
   - Chiton (class *Polyplacophora*): has overlapping shells, a characteristic not found in any other mollusk (hence its own class); no eyes or tentacles; inhabits rocky intertidal zones around the world; uses its muscular foot to glide over rocks, where it scrapes off and grazes on algae with its radula.

Summary of the Lesson

The mollusks are a diverse group of invertebrates that are placed into several different classes. The members of each class share common structural characteristics yet show a variety of adaptations to the marine environment.

Homework Assignment

Read pages 224–229. Answer Section Review questions 1–3 on page 228 and 1–3 on page 229, and Chapter Review question 8 on page 232. (*See also* Chapter Review pages 233–235 for additional homework questions.)

Chapter 10 / Crustaceans

INTRODUCTION

The invertebrates that are discussed in Chapter 10 are the marine crustaceans, in particular, and the arthropods, in general. These "armored" animals are characterized by having a tough exoskeleton and numerous

jointed appendages. There is great diversity among the arthropods. The crustaceans, which includes lobsters, crabs, shrimp, copepods, barnacles, and the like, are found throughout the world's oceans and constitute an important food source for many marine animals. Students will learn about marine arthropods' structures and unique adaptations.

- All arthropods have an exoskeleton and jointed appendages. The protective exoskeleton is composed of chitin, a type of carbohydrate.
- Crustaceans have bilateral symmetry and two main body segments (the cephalothorax and the abdomen). They have five or more pairs of appendages-—some for food-getting, some for movement.
- Some crustaceans filter feed, some scavenge, and many are predatory.
- Tiny crustaceans, such as copepods and krill, form the basis of oceanic food chains.

LESSON 1 *(pages 237–240 top)*

Aim: How are the arthropods adapted to their environment?

Instructional Objectives

Students will be able to:

1. Explain how arthropods are adapted to the environment.
2. Describe how the lobster carries out its life functions.
3. Discuss body structures and functions in the lobster.

Motivation for the Lesson / Do Now

Display pictures or models of arthropods. Describe some common characteristics.

Development of the Lesson

1. Arthropods, such as the lobster, barnacle, and horseshoe crab, have several pairs of movable arms and legs, called *jointed appendages*. They also possess an *exoskeleton*, composed of a tough, fibrous material called *chitin*, which imparts strength and flexibility to the skeleton. These invertebrates are all classified within the phylum *Arthropoda* (meaning "jointed feet").
2. **Write the Aim:** *How are the arthropods adapted to their environment?* Show a wall chart, drawing, or model of a lobster (to serve as your representative arthropod) for the class to observe. Arthropods (like the lobster) that possess separate head (*cephalo*), chest (*thorax*), and abdominal regions, and which have five pairs of legs, belong to class *Crustacea*.
3. **Key Question:** *How does the external anatomy of a lobster adapt it to its environment?* Refer students to Figure 10-2 on page 239, which shows the external and internal anatomy of a lobster. The first pair of legs is called the *chelipeds*. These two claws are used for seizing food, while the other four pairs are the walking legs. The exoskeleton that covers the head and chest is called the *carapace*. The head contains the eyes, antennae, and mouthparts used for feeding. The thorax contains appendages used for food-getting and the walking legs. Crustaceans also swim, using their paddlelike *swimmerettes*, which are located in the abdomen.
4. **Key Question:** *How can the lobster grow if it is enclosed in a rigid exoskeleton?* The crustaceans can shed their outer covering once or more each year, a process called *molting*. Crustaceans can also regenerate body parts. If an appendage (such as a claw) is lost in a fight, another one will grow back in its place.
5. **Key Question:** *How does the lobster carry out its life functions?* Lobsters, like most crustaceans, are largely scavengers. Food is digested in a one-way digestive tract consisting of a mouth, esophagus, stomach, and intestine.

The rapid beating of the mouthparts sends currents of water over the *gills* (located under the carapace). Oxygen and nutrients are transported throughout the body by the blood, in an open circulatory system. The blood is blue, due to the presence of a copper-based pigment, *hemocyanin*. The nervous system includes a ventral nerve cord. Reproduction is sexual; fertilization and development are external.

Summary of the Lesson

Arthropods are a very successful phylum, comprising over a million species. The special adaptations of arthropods (and crustaceans in particular) include: several pairs of jointed appendages (for feeding, fighting, and locomotion); a tough exoskeleton that protects the internal organs; and the ability to shed and re-grow the exoskeleton, as the body grows.

Homework Assignment

Read pages 236–240 (top). Answer Section Review questions 1–3 on page 240.

LESSON 2 *(pages 240–249 top)*

Aim: How are crustaceans adapted to their marine environment?

Instructional Objective

Students will be able to:

1. Describe physical and behavioral adaptations of crustaceans.
2. Identify crustaceans that live in marine environments.
3. Explain how crustaceans carry out their life functions.

Motivation for the Lesson / Do Now

Display specimens or pictures of crustaceans such as the crab, shrimp, copepod, and barnacle. Have students observe and list some features these animals have in common.

Development of the Lesson

1. Point out that all of the specimens, which are crustaceans, have *bilateral symmetry* and are composed of three body segments: the head, thorax, and abdomen.

   Write the Aim: *How are crustaceans adapted to their marine environment?*

2. Organize the class into five groups, with each team researching a different crustacean. Information on the crustaceans can be found on the following pages: mole crab (241), fiddler crab (240–241), mantis shrimp (244), copepod (244), and barnacle (247, 249).
3. Have the students draw their crustacean and describe its characteristics. Send a student from each group to the board to read their findings and to write down some key facts about their crustacean. All students should copy the information into their notebooks.
4. Some important facts about crustaceans that you may want to have students mention:
   - Mole crab (genus *Emertia*): lives in the turbulent surf zone; has a smooth, streamlined body to deflect waves; uses paddlelike appendages for moving through sand and water; uses featherlike antennae to capture microscopic organisms between the sand grains.
   - Fiddler crab (genus *Uca*): digs tunnels in the sand along bays and inlets; leaves tunnels at low tide to search for food; is named for its large claw (only in males), which is used to threaten or fight with other males over territory.
   - Mantis shrimp (genus *Squilla*): the largest shrimp, it grows up to 25 cm in length; burrows in the sand, from where it spears prey such as worms and small fish with its spiny front appendages; found (in Atlantic) from Cape Cod to Brazil.
   - Copecod (genus *Calanus*): found floating and drifting on the ocean surface in tem-

perate zones; less than half a cm in length; eats mainly diatoms and is part of the plankton population; can be caught (for study) in a plankton net during spring and summer.

- Barnacle (genus *Balanus*): has overlapping sharp plates enclosing it; lives in the intertidal zone, glued to rocks and other hard substrates; filter feeds on plankton and organic debris by waving *cirri* (frilly appendages) through an opening on top of its shell; at low tide, the plates shut tight to prevent its drying out; is a hermaphrodite.

Summary of the Lesson

Crustaceans possess an exoskeleton (which they molt), three body segments, and bilateral symmetry. These "armored" arthropods are adapted to a variety of marine habitats.

Homework Assignment

Read pages 240–249 (top). Answer Section Review questions 1–3 on page 243 and 1–3 on page 249, and Chapter Review question 6 on page 255.

LESSON 3 *(pages 249–252)*

Aim: How diverse are the arthropods?

Instructional Objectives

Students will be able to:

1. Identify the different classes of arthropods.
2. Describe the characteristics of each class.
3. Discuss diversity among the arthropods.

Motivation for the Lesson / Do Now

Display specimens or show pictures of different arthropods. Have students describe the similarities among them.

Development of the Lesson

1. All arthropods possess an exoskeleton, jointed appendages, segmented body, and bilateral symmetry. But there are significant enough differences among them for taxonomists to classify the arthropods into three main classes. The three different classes are Crustacea, Merostomata, and Insecta.
2. **Write the Aim:** *What do we know about diversity among arthropods?* Organize the class into five groups, with each team researching a different arthropod. Information on the arthropods can be found on the following pages: spider crab (241–242), beach flea (245–246), sea roach (245–246), horseshoe crab (249–251), and sand fly (252). Have students draw their arthropod and describe its characteristics.
3. Send a student from each group to the board to read their findings aloud and to write down some key facts about their arthropod. All students should copy the information into their notebooks.
4. Some important facts about the arthropods that may be overlooked by the students, but that you may want to mention, are:
   - Spider crab (genus *Libinia*, class *Crustacea*): has two body segments (cephalothorax and abdomen); has five pairs of legs (like all true crabs); breathes by means of gills; has open circulatory system; has antennae, and eyes on stalks; has ventral nerve cord; lacks paddlelike appendages for quick swimming, so it crawls slowly along seafloor.
   - Beach flea (genus *Talorchestia*, class *Crustacea*): type of *amphipod*; body is compressed laterally; lives under moist seaweeds in the strand line on beaches, Canada to Florida; hops and darts about if disturbed.
   - Sea roach (genus *Ligia*, class *Crustacea*): type of *isopod*; body is flattened (top to bottom); swims and crawls among seaweeds and rock crevices along shore; is active at night, and hides during the day; some are parasitic, attaching to the skin and gills of cod and halibut.

- Sand fly (genus *Culicoides*, class *Insecta*): like all insects, has three pairs of legs; has three body segments; has wings; so tiny, it's commonly called "no-see-um", inhabits inland bays and marshes where wave impact is slight.
- Horseshoe crab (genus *Limulus*, class *Merostomata*): is not a true crab; lacks antennae and mouthparts; has six pairs of legs; in late spring, hordes of horseshoe crabs invade the beaches from Maine to California to lay their eggs in the sand. The horseshoe crab is referred to as a "living fossil" because it has hardly changed at all in its more than 400 million years on Earth.

Summary of the Lesson

The arthropods are organized into several classes, based on their structural differences. These include the Crustacea (e.g., lobsters, crabs, barnacles, and copepods), Merostomata (horseshoe crab, related to scorpions and spiders); and the Insecta (true insects).

Homework Assignment

Read pages 249–252. Answer Section Review questions 1–3 on page 252, and Chapter Review question 7 on page 255. (*See also* Chapter Review pages 257–258 for additional homework questions.)

Chapter 11 / Echinoderms

INTRODUCTION

In Chapter 11, students will learn about the echinoderms, an exclusively marine group of invertebrates. The echinoderms are characterized by their spiny skin (the spines are more pronounced in some members of the phylum) and their radial symmetry. There are five classes of echinoderms; they exhibit a range of feeding habits and adaptations. Students will learn about the water vascular system (in the sea star), the role of tube feet in feeding and locomotion, and about methods of reproduction and regeneration in echinoderms.

- All echinoderms are marine animals (no freshwater species).
- Echinoderms have a spiny skin, radial symmetry, and an internal skeleton.
- Some echinoderms are sessile; others are capable of movement.
- Tube feet are important in feeding and/or in locomotion. Some echinoderms are filter feeders; others are active predators.

LESSON 1 *(pages 260–265 top)*

Aim: How does the sea star carry out its life functions?

Instructional Objectives

Students will be able to:

1. Explain how the sea star carries out its life functions.
2. Classify the sea star in its correct taxonomic group.
3. Describe structures and their functions in the sea star.

Motivation for the Lesson / Do Now

Display drawings or specimens of sea stars. Elicit from students why the term "starfish" is not an appropriate name for this animal.

Development of the Lesson

1. The term "starfish" is not appropriate for the sea star because it is an invertebrate, not a fish. The sea star belongs to class *Asteroidea*, a group of spiny-skinned animals that is classified in phylum *Echinodermata*. Point out that *echinoderm* means "spiny skin." Most sea stars have five arms (some have more), which diverge from a central point, giving the animal *radial symmetry*. Sea stars are bottom-dwelling invertebrates with an internal skeleton. They are found from the subtidal zone to the deepest parts of the ocean.
2. **Write the Aim:** *How does the sea star carry out its life functions?* Use a wall chart, drawing, or projection of a sea star's anatomy for the students to copy into their notebooks. (You can also direct students to Figure 11-3 on page 262, and Figure 11-4 on page 263.) Draw two columns on the board, labeled *Structure* and *Function*. **Ask key questions** (e.g., *How does the sea star move?*, *How does it ingest food?*, and *How does the sea star breathe?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns with the appropriate information. Have students copy the completed chart into their notebooks.
3. **Key Question:** *How does the sea star reproduce?* Sea stars have separate sexes. Fertilization and development occurs externally. Sea stars can also reproduce asexually by *regeneration*. If an arm is torn off in a fight, a whole new sea star can grow back from the severed arm provided part of the central disk region is present.
4. **Key Question:** *How does the sea star move?* A network of water-filled canals and tubes called the *water vascular* (or *hydrovascular*) *system* carries out locomotion. Water enters the sea star through the *sieve plate* and passes through the *ring canal* and *radial canal* to the tube feet. The *tube feet*, located in grooves on the ventral side of each arm, are equipped with a suction disk, which they use to cling to hard surfaces. The exit of water from the tube feet (back into the ampullae) creates the suction that holds the sea star to a substrate. The sea star uses this suction force to push and pull itself along.

Structure	Function
Spines	Protection
Mouth	Ingestion
Water vascular system	Locomotion
Stomach	Digestion
Digestive gland	Digestion
Gonads	Reproduction
Skin	Breathing
Eyespots	Sensitivity

Summary of the Lesson

The sea star is a bottom-dwelling invertebrate that is characterized by having a spiny skin and radial symmetry. It has a unique water vascular system and tube feet that enable it to carry out a variety of life functions, such as feeding and locomotion.

Homework Assignment

Read pages 259–265 (top). Answer Section Review questions 1–3 on page 261 and 1–3 on page 265.

LESSON 2 *(pages 265–268, 270–271)*

Aim: How diverse are the echinoderms?

Instructional Objectives

Students will be able to:

1. Identify the different echinoderm types.
2. Discuss diversity among the echinoderms.
3. Compare and contrast form and function among the echinoderms.

Motivation for the Lesson / Do Now

Display specimens or show pictures of different echinoderms. Describe the similarities among them.

Development of the Lesson

1. All echinoderms possess an *endoskeleton* and have tube feet for locomotion and/or feeding. But they vary considerably in body form and in their ways of life.
2. **Write the Aim:** *How diverse are the echinoderms?* Organize the class into five groups, with each team researching a different echinoderm. Information on the five types of echinoderms covered in this lesson can be found on the following pages: sea urchin (265–267), and sand dollar (265, 267), brittle star (268–270), sea lily (270), and sea cucumber (270–271).
3. Have the students draw their echinoderm and describe its characteristics. Send a student from each group to the board to sketch the echinoderm, read their findings aloud, and write down some key facts about their echinoderm. All students should copy the information into their notebooks.
4. Some important facts about the echinoderms that you may want to see mentioned are:
   - Sea Urchin (Class *Echinoidea*): inhabits intertidal and subtidal zones along rocky coasts, grazing on algae on the rock surfaces; spines are attached to its endoskeleton, or *test*, which is left behind after it dies; its spines protect against most predators.
   - Sand Dollar (Class *Echinoidea*): looks like a large coin covered by a thin, spiny skin; oval disk is left behind after it dies; feeds by catching plankton and organic debris in sticky strings beneath its spines.
   - Brittle Star (Class *Ophiuroidea*): is a solitary animal that lives under rocks in the intertidal zone (from arctic to tropics); also inhabits deep seafloor to depths of 800 meters; has muscles in its long, flexible arms, which are used for quick movement along the seafloor and to help catch bits of food; has a flattened central disk; like the sea star, can regenerate missing arms.
   - Sea Lily (Class *Crinoidea*): its body is composed of feathery arms perched atop a stalk, which is attached to a substrate; filter feed by waving its arms and catching plankton in the tube feet (which then pass it to the mouth).
   - Sea Cucumber (Class *Holothuroidea*): lacks endoskeleton and spines, but has small bony pieces in its skin; has tube feet arranged in five rows, which it uses for movement and to catch food; lives on sandy and rocky seafloors in intertidal and subtidal zones and at great depths; uses sticky, branching tentacles around its mouth (which retract when disturbed) to trap bits of food; has one-way digestive tract.

Summary of the Lesson

The echinoderms are a diverse group of spiny-skinned marine invertebrates. All are bottom-dwelling animals; most are capable of movement; and they feed on organisms found in the sediment or in the currents of water.

Homework Assignment

Read pages 265–268, 270–271. Answer Section Review questions 1–3 on page 267 and 1–3 on page 271. (*See also* Chapter Review pages 276–277 for additional homework questions.)

UNIT 4 MARINE VERTEBRATES

Chapter 12 / Marine Fishes

INTRODUCTION

Chapter 12 covers the three classes of fishes—the topic that may be of most interest to students of marine science. There are thousands of species of fishes; they are the most numerous vertebrates in the ocean. Students will learn about the distinguishing features of protochordates, jawless fishes, cartilaginous fishes, and bony fishes. Basic anatomy, life functions, and life cycles are covered, in addition to unusual adaptations in bony fishes.

- There are three classes of fishes: jawless, cartilaginous, and bony. Fish are aquatic; have scales, fins, and gills; and are (mostly) cold-blooded.
- Jawless fishes lack jaws and a backbone; the lamprey also lacks scales.
- Cartilaginous fishes have a skeleton of cartilage, visible gill slits, spiracles, placoid scales, a lateral line organ, and no swim bladder.
- Bony fishes have a skeleton of bone, mucus-covered scales over their skin, a swim bladder, and gills covered by an operculum.
- Some fishes bear live young; others lay eggs (or egg cases).
- Bony fishes are found in every type of aquatic environment.

LESSON 1 *(pages 281–284 top)*

Aim: What do we know about the protochordates?

Instructional Objectives

Students will be able to:

1. Identify the protochordates.
2. Classify the protochordates.
3. Describe structure and function in the protochordates.

Motivation for the Lesson / Do Now

Display or draw a picture on the board of a lancelet. **Ask the students:** *How would you classify this organism?*

Development of the Lesson

1. Animals that possess a *dorsal nerve cord*, a rodlike *notochord*, and *gill slits* at some point in their development are called *chordates* and belong to the phylum *Chordata*. The lancelet, tunicate, and acorn worm have these structures during development (only the lancelet retains all three in its adult form), but lack certain advanced traits; so they are classified in the subphylum *Protochordates*. The vertebrate (i.e., having a backbone) chordates include all fish, amphibians, reptiles, birds, and mammals. The protochordates represent an evolutionary link between vertebrates and invertebrates.
2. **Write the Aim:** *What do we know about the protochordates?* Organize the class into three

groups, with each team researching a different protochordate. Information on the lancelet, tunicate (sea squirt), and acorn worm can be found on pages 281–283.

3. Send a student from each group to the board to sketch their protochordate, write down some key facts about it, and describe its characteristics to the class. All students should copy the information into their notebooks.
   - Lancelet (genus *Amphioxus*): tiny and transparent; fishlike in appearance; adult form retains dorsal nerve cord, notochord, and gill slits; lives half-buried in the sand, with head sticking out to filter plankton; has sexual reproduction (via separate sexes).
   - Sea Squirt (genus *Molgula*): found worldwide; encrusts substrates such as the undersides of floating docks; squirts water when disturbed (hence its name); also called *tunicate* because of its clear, tough, outer membrane, or tunic; larval form has dorsal nerve cord, notochord, and gill slits, which disappear in the adult form; has sexual reproduction (hermaphrodite).
   - Acorn Worm (genus *Saccoglossus*): adult form retains dorsal nerve cord and gill slits; burrows in the sand in intertidal and subtidal zones, where it feeds on organic debris; expels the indigestible sand in small lumps (or casts) on the seafloor.

Summary of the Lesson

Have students read aloud the information about protochordates that they have written on the board and in their notebooks.

Homework Assignment

Read pages 281–284 (top). Answer Section Review questions 1–3 on page 284.

LESSON 2 *(pages 280, 283–285, 290–292)*

Aim: How are the marine fishes classified?

Instructional Objectives

Students will be able to:

1. Classify the marine fishes.
2. Compare and contrast the different types of fish.
3. Identify the fishes' distinguishing characteristics.

Motivation for the Lesson / Do Now

Display models or pictures of a jawless fish, a shark, and a typical bony fish. Have students observe and describe these different fishes.

Development of the Lesson

1. All fish possess gills for breathing, fins for swimming, and a scaly skin for protection. Tell students that the animals on display represent the three different classes of fish.
2. **Write the Aim:** *How are the marine fishes classified?* The fishes are placed in three different classes based on differences in structure (and evolutionary history). These groups are the jawless fishes, the cartilaginous fishes, and the bony fishes.
3. Organize the class into three groups, with each team researching a different class of fish. Information about these fish (and labeled diagrams of each type) can be found on the following pages: jawless fish (283–284), cartilaginous fish (284–286, 289), and bony fish (290–292).
4. Send a student from each group to the board to sketch their fish and to write down key facts about it. All students should copy the information into their notebooks.
5. Some important facts about these fish that you may want to see mentioned are:
   - Jawless Fishes (Class *Agnatha*): first jawless fish evolved from invertebrates; lack a true backbone; possess a notocord for support; live as parasites by attaching to, and feeding on the blood and tissues of, a host fish; includes sea lamprey and hagfish.

- Cartilaginous Fishes (Class *Chondrichthyes*): approximately 600 species; skeletons composed of cartilage; have placoid (teethlike) scales; lack gill covers (operculum); lack swim (gas) bladder; have spiracles (breathing holes) behind the eyes; have a ventral mouth; pores in shark's snout contain nerve receptors that pick up electrical currents; lateral line organ detects vibrations in water; have internal fertilization.
- Bony Fishes (Class *Osteichthyes*): more than 15,000 species of bony fishes (marine and freshwater); skeletons composed of bone; backbone made up of individual bones called *vertebrae*, which surround and protect the spinal cord; possess mucus-covered *scales*, which have growth lines that form bands (circuli), are used to determine the age of the fish; have gill covering called the *operculum*; have swim (gas) bladder.

Summary of the Lesson

Have a student leader from each group read aloud the information that has been written on the board.

Homework Assignment

Read pages 280, 284–286, 290–292. Answer Section Review questions 1–3 on page 290, and Chapter Review question 6 on page 304.

LESSON 3 *(pages 290–296)*

Aim: How does a bony fish carry out its life functions (re: external anatomy)?

Instructional Objectives

Students will be able to:

1. Identify a fish's external structures that carry out life functions.
2. Explain how these life functions of the fish are carried out.

Motivation for the Lesson / Do Now

Show a live bony fish (in classroom aquarium tank) or display a model of a typical bony fish. Elicit from students a list of the basic (external) life functions carried out by the fish.

Development of the Lesson

1. A fish exhibits observable life functions such as locomotion (swimming), nutrition (feeding), breathing (movement of gills), and response to stimuli in environment.
2. **Write the Aim:** *How does a bony fish carry out its life functions?* In this lesson, you will focus on an understanding of the *external anatomy* of a bony fish. Display a wall chart, diagram (see Figure 12-12, on page 292 in the text), or projection of a bony fish for the students to copy into their notebooks.
3. Draw two columns on the board, labeled *Structure* and *Function*. **Ask key questions** (e.g., *How does the fish sense its environment?*, *How does a fish swim?*, and *How does a fish breathe?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns with the appropriate information. Define each function on the board. Have students copy the completed chart into their notebooks.

Summary of the Lesson

Have a student go to the board and draw a bony fish. Call on students to name the different parts of the fish. Have other students define each structure and its function.

Homework Assignment

Read pages 290–296. Answer Section Review questions 1–3 on page 298, and Chapter Review question 21 on page 306.

LESSON 4 *(pages 294–298 top)*

Aim: How does a bony fish carry out its life functions (re: internal anatomy)?

Instructional Objectives

Students will be able to:

1. Identify a fish's internal structures that carry out life functions.
2. Explain how these life functions of the fish are carried out.

Motivation for the Lesson / Do Now

Display a model or chart that shows the internal anatomy of a typical bony fish. Elicit from students a list of the basic (internal) life functions carried out by the fish.

Development of the Lesson

1. Fishes, like all other vertebrates, have internal structures and systems that are needed to carry out their life functions (such as circulation, digestion, and reproduction).
2. **Write the Aim:** *How does a bony fish carry out its life functions?* In this lesson, you will focus on an understanding of the *internal anatomy* of a bony fish. Display a wall chart, diagram (see Figure 12-12 on page 292), or projection of a bony fish for the students to copy into their notebooks.
3. Draw two columns on the board, labeled *Structure* and *Function*. **Ask key questions** (e.g., *How does a fish digest food?*, *How are its nutrients transported?*, and *How does a bony fish reproduce?*) to introduce and discuss each life function. Point out each structure as you discuss its function, and elicit student response as you fill in both columns. Define each function on the board. Have students copy the completed chart into their notebooks.

Summary of the Lesson

Call on students to go to the board to point out and name important internal structures of a bony fish. Have other students define each structure and its function.

Homework Assignment

Read pages 294–298 (top). Answer Chapter Review questions 7 on page 304 and 12–20 on page 306.

LESSON 5 *(pages 298–301)*

Aim: What are some special adaptations of marine fishes?

Instructional Objectives

Students will be able to:

1. Identify adaptations in different types of marine fish.
2. Explain how the fishes' adaptations aid their survival.

Motivation for the Lesson / Do Now

Show the class a picture or projection of the porcupine fish (genus *Diodon*). Describe how this animal is adapted to survive in its environment.

Development of the Lesson

1. The porcupine fish is one of many fish that is equipped with unique structures that enable it to survive in its environment. Specifically, the porcupine fish can inflate its spine-covered body with water so that it becomes a spiky ball that deters predators.
2. **Write the Aim:** *What are some special adaptations of marine fishes?* There are many unique and surprising adaptations among the fishes, which aid survival in a variety of marine habitats. Organize the class into six groups, with

each team researching a different fish. Information on, and illustrations of, these unusual fish can be found on the following pages: flounder (298), sea horse (299), flying fish (299), anglerfish (299–300), mola (300–301), and coelacanth (300–301).

3. Send a student from each group to the board to sketch their fish and to write down key facts about it. All students should copy the information into their notebooks.
4. Some important facts about these fish that you may want to see mentioned are:
   - Flounder (genus *Platichthys*): flattened body shape; uses camouflage to match its benthic surroundings; pigments in its skin cells expand and contract to match the environment; adult has both eyes on the same (dorsal) side of its head.
   - Sea Horse (genus *Hippocampus*): uses its long tail to wrap around a piece of seaweed or marsh grass; uses its snout like a straw to suck up plankton and food particles; the female releases eggs into the male's brood pouch; after two weeks of incubation, the "pregnant" father expels baby sea horses into the water.
   - Coelacanth (genus *Latimeria*): up to two meters in length; once thought to be extinct, it was rediscovered in the deep waters of the Indian Ocean; has paddlelike fins similar to those of the ancestral lobefin fishes; considered rare, it is protected by law.
   - Flying Fish (genus *Cypselurus*): relatively small fish; can jump out of the water as high as 12 meters and "fly" for 30 meters, propelled by the action of its pectoral fins. which beat like wings.
   - Deep-sea Anglerfish (genus *Melanocetus*): lives at depths of 500 to 2000 meters; has huge mouth with spiky teeth to catch prey; has a dangling bioluminescent lure to attract prey and/or potential mates.
   - Mola (genus *Mola*): up to three meters in length; also called ocean sunfish; usually lies on its side near the ocean surface, feeding on jellyfish, small fish, and plankton; caudal fin and posterior region of the body are much reduced in size; slow-moving and vulnerable to predation by humans and killer whales; the female produces millions of eggs, thereby ensuring the species' survival.

Summary of the Lesson

Have a team leader from each group read aloud the description of their fish. Be sure to emphasize each fish's unique adaptations.

Homework Assignment

Read pages 298–301. Answer Section Review questions 1–3 on page 301, and Chapter Review questions 8 on page 304 and 22–24 on pages 306–307.

Chapter 13 / Marine Reptiles and Birds

INTRODUCTION

While reading Chapter 13, students may be surprised to learn the extent of marine adaptations that are seen among some birds and reptiles. Descended from land-adapted animals, the marine birds and reptiles exhibit a fascinating array of adaptations that reflect their adjustment to life in and around the sea. Marine reptiles, being cold-blooded, are found mainly in tropical regions; marine birds, being warm-blooded, are found throughout the world. Students will learn about adaptations of reptiles and birds to a range of marine habitats.

- Reptiles are ectothermic; birds are endothermic. Both exhibit specific adaptations to ocean environments, such as having salt glands.
- Marine reptiles live mainly in tropical and subtropical oceans.
- Reptiles have a dry, scaly skin that protects against water loss.
- Like birds, most reptiles lay eggs (some reptiles live-bear young).
- Aquatic birds have waterproof feathers that help insulate their bodies.
- Birds show a variety of adaptations in the structure and function of their beaks, wings, and feet, for feeding in and around the sea.

LESSON 1 *(pages 309–317)*

Aim: How are marine reptiles adapted to their environment?

Instructional Objectives

Students will be able to:

1. Identify the different marine reptiles.
2. Describe adaptations in marine reptiles.
3. Explain how these adaptations aid the reptiles' survival.

Motivation for the Lesson / Do Now

Show the class a picture or model of a marine reptile (e.g., a crocodile or sea turtle). Ask students to describe its (external) characteristics.

Development of the Lesson

1. All reptiles have a thick, dry scaly skin and belong to class *Reptilia*. Some reptiles, such as the specimen shown, live in saltwater habitats; so they are called *marine reptiles*. These include the crocodile, sea turtle, sea snake, and marine lizard.
2. **Write the Aim:** *How are marine reptiles adapted to their environment?* Most reptiles have to live in warm climates because they are *ectothermic*, and they cannot tolerate wide temperature ranges. Reptiles depend on the external temperature (of the air and water) to regulate the temperature of their "cold-blooded" bodies.
3. Organize the class into four groups, each team researching a different marine reptile. Information on the reptiles can be found on the following pages: saltwater crocodile (310–311), sea snake (310–311), marine lizard (311–312), and sea turtles (313–317). Have students draw their reptile and describe its adaptations in their notebooks.
4. Some important facts about marine reptiles that you may want to see mentioned are:
   - Crocodile (order *Crocodilia*): American saltwater crocodile (genus *Crocodylus*) lives in the Florida Keys; up to five meters in length; has a four-chambered heart (like birds); the female guards her eggs in nest until they hatch; is an endangered species, only about 1000 remain; hunts by remaining just below the water's surface (with only its eyes and nostrils protruding) to ambush prey; resembles alligators, except the crocodile's snout is longer and narrower.
   - Sea Snakes (order *Squamata*): about 50 different species; from one to two meters in length; all inhabit tropical oceans; some hunt fish, others eat fish eggs; are venomous, but not very aggressive; have a paddlelike tail to aid in swimming; salt glands in the mouth enable snake to excrete excess salts and maintain water balance; have a special flap of tissue to cover the nostrils during dives; the lungs can inflate to ¾ body length, to enhance capacity to hold air underwater; some live-bear young in the sea, others lay their eggs on land.

- Marine Lizard (order *Squamata*, genus *Amblyrhynchus*): only marine lizard is the *marine iguana*; inhabits the Galàpagos Islands; swims and feeds on marine algae that grow on rocks in the subtidal zone; movements underwater are very graceful; has a flattened tail to aid in swimming; when cold, warms up by basking on rocks on land.
- Sea Turtles (order *Chelonia*): six species, all are endangered; most widely distributed marine reptile; inhabit tropical and warm temperate oceans worldwide; species can be distinguished by the pattern of scales on their shell; have no teeth, but do have powerful jaws; feed on jellyfish, algae, crustaceans, and turtle grass; born on land, but spend their lives at sea; fertilization is internal and development is external.

Summary of the Lesson

Near the end of the period have a student from each group draw their marine reptile on the board and have another student describe its special adaptations. All students should copy the information into their notebooks.

Homework Assignment

Read pages 308–317. Answer Section Review questions 1–3 on page 317, and Chapter Review questions 6–7 on page 326 and 12–17 on page 328.

LESSON 2 *(pages 317–323)*

Aim: How are marine birds adapted to their environment?

Instructional Objectives

Students will be able to:

1. Identify the different marine birds.
2. Describe adaptations in marine birds.
3. Explain how these adaptations aid the birds' survival.

Motivation for the Lesson / Do Now

Show students a picture or model of a marine bird (e.g., a sea gull or cormorant). Ask students to describe its (external) characteristics.

Development of the Lesson

1. All birds have feathers and belong to class *Aves*. The feathers and hollow bones (found in nearly all species) are adaptations for flight. Marine birds have special adaptations for living in and near the sea, and for feeding in the sea or on shore. All birds reproduce on land (internal fertilization) and lay eggs (external development).
2. **Write the Aim:** *How are marine birds adapted to their environment?* All birds have *down feathers* (for insulation) and *contour feathers* (for flight). Some aquatic birds also have *powder feathers*, which help repel water and protect the underlying down feathers. Some birds also have a gland near the tail that produces a waterproof oil, which is used to condition their feathers. Birds are *endothermic*, so they can maintain a stable internal temperature even when the air or water temperature varies widely. Many aquatic and marine birds have webbed feet to aid movement in the water.
3. Organize the class into six groups, each team researching a different marine bird. Information on these birds can be found on the following pages: snowy egret (319), sea gull (320), brown pelican (320–321), black skimmer (321), osprey (321), and penguin (322–323). Have students draw their marine bird and describe its adaptations in their notebooks.
4. Some important facts about the marine birds that you may want to see mentioned are:
   - Snowy Egret (genus *Egretta*): inhabits salt marshes from Maine to California; has a long flexible neck and pointed bill, used to spear small fish; the long stiltlike legs for

wading give it the advantage of spotting fish from above.

- Sea gulls (genus *Larus*): several different species; prefer isolated nesting places on offshore islands; scavenge along the shore of mainland beaches for dead marine animals carried in by the tides; also eat crabs on the beach and garbage at landfills.
- Brown Pelican (genus *Pelecanus*): large, once-endangered bird; dives into the ocean to scoop up fish in its large throat pouch; water is squeezed out of the pouch and the fish is swallowed headfirst (so its dorsal spines don't get stuck in the bird's throat); found in tropical regions, e.g., Florida Keys.
- Black Skimmer (genus *Rynchops*): fishes "on the wing" by flying low over the water; the tip of its lower jaw, which juts out, skims the surface for fish; it swallows the fish whole, while still in flight.
- Osprey (genus *Pandion*): also called *fish hawk* (feeds only on fish), lives along U.S. coastlines; has keen vision to spot fish from high up; has strong curved claws (talons) for grasping fish; has long, powerful wings that enable it to swoop down from its nest and grab fish from the water, while it is still in flight.
- Penguins (several genera): several species; the most aquatic of all seabirds; native only to the southern hemisphere; have lost the ability to fly; their wings have evolved into flippers that let them "fly" through the water; bones are dense (not hollow), which gives them the weight necessary for deep dives; have several layers of down feathers and a thick layer of fat to trap body heat, which helps them survive in the Antarctic.

Summary of the Lesson

Near the end of the period have a student from each group draw their marine bird on the board and have another student describe its special adaptations. All students should copy the information into their notebooks.

Homework Assignment

Read pages 317–323. Answer Section Review questions 1–3 on page 323, and Chapter Review questions 8 on page 326 and 18–23 on pages 328–329.

Chapter 14 / Marine Mammals

INTRODUCTION

Chapter 14 covers the group of animals probably most beloved by students of marine science: cetaceans, pinnipeds, and other marine mammals. Like ourselves, the marine mammals are warm-blooded, air-breathing, nurse their young, and, in general, are intelligent. However, unlike humans, they spend their whole lives in, or very closely tied to, the sea. Thus, they have special adaptations for swimming, feeding, diving, and communicating in the ocean.

- Marine mammals are warm-blooded, air-breathing vertebrates.
- Whales and dolphins are fully aquatic, feeding and breeding in the water. They have blubber to keep them warm, and special adaptations for communicating underwater and for deep diving.
- Seals and sea lions, which are carnivores, swim and feed in the ocean, but come ashore each year to mate and rear their young.

- Other marine mammals, such as sea otters and manatees, breed in the water. They show other adaptations to marine habitats.
- Many species of marine mammals have become endangered or threatened due to human activities. Laws now protect them.
- The diving response is a special adaptation of marine mammals.

LESSON 1 *(pages 331–333, 341–346, 348–349)*

Aim: How are the marine mammals classified?

Instructional Objectives

Students will be able to:

1. Identify the marine mammals.
2. Classify the marine mammals.
3. Compare and contrast marine mammals.

Motivation for the Lesson / Do Now

Display several models or photographs of marine mammals, such as a whale, seal, otter, dolphin, walrus, and so on. Have the students compare and contrast their features.

Development of the Lesson

1. All mammals have mammary glands to feed their newborns, a four-chambered heart, and (usually) a fur or hair covering. Mammals are *endothermic* (warm-blooded); they have a stable internal body temperature. Mammals are all placed in class *Mammalia*.
2. **Write the Aim:** *How are the marine mammals classified?* The marine mammals are classified within several taxonomic categories called *orders* (and *suborders*). These include: order *Cetacea* (whales, dolphins, porpoises); order *Carnivora*, suborder *Pinnipedia* (seals, sea lions, walrus); order *Carnivora* (sea otter, polar bear, and many land carnivores); and *Sirenia* (manatees, dugongs).
3. Organize the class into four groups, with each team researching a different group of marine mammals. Basic information about each group can be found on the following pages: cetaceans (331–333), pinnipeds (341–344), marine carnivores (344–345, 349), and sirenians (346, 348–349). Have students draw their marine mammal and describe its adaptations in their notebooks.

- Cetaceans: about 80 different species; all have a completely aquatic way of life; the biggest is the blue whale; the smallest are dolphins and porpoises (See Figure 14-1); comprised of two main groups—*baleen* (suborder *Mysticeti)* and *toothed* (suborder *Odontoceti*). Baleen whales feed on plankton and small animals (see Figures 14-2 and 14-3); toothed whales (including dolphins & porpoises) have peglike teeth for catching larger animals such as fish, squid, and seals. The sperm whale is the largest toothed whale; the narwhal is the smallest toothed whale (see Figure 14-4).
- Pinnipeds: "feather-footed" marine carnivores include seals, sea lions, and walruses; come ashore each year to mate and bear young; sea lions have external ear flaps and seals do not; seals and sea lions eat fish and other marine life; the walrus (genus *Odobenus*) inhabits the Arctic and sub-Arctic; walrus has tusks, used to dig up mollusks, haul-out on ice, and for dominance (among males); feeds mostly on benthic mollusks and other invertebrates, which they locate with their sensitive whiskers.
- Marine Carnivores: all carnivores have sharp teeth for seizing and tearing flesh. The polar bear (genus *Ursus*): mainly terrestrial, but is most aquatic of all bears; excellent swimmer (has streamlined head); lives

on ice floes and along the coast in the Arctic; has dense fur and a thick layer of blubber for insulation; hunts seals and fish. The sea otter (genus *Enhydra*): smallest of all marine mammals; most aquatic member of the weasel family; lives in kelp beds along the coast from Alaska to California; feeds on shellfish (e.g., sea urchins, abalone), which it opens by smashing against a rock (held against stomach while floating on its back); has no blubber, but has very thick fur.

- Sirenians: inhabit warm coastal waters; manatee, or *sea cow*, (genus *Trichechus*) feeds on vegetation in shallow rivers and coastal waters of Florida, Caribbean, and the Amazon River; uses its upper *prehensile* lip to grasp vegetation; moves slowly through the water, using up-and-down movement of its flat tail; endangered, fewer than 1000 manatees left in Florida waters; many are injured and/or killed by speeding boats; dugongs (related marine herbivores) live off the coast of West Africa.

Summary of the Lesson

Have a student from each team go to the board and sketch a representative animal or two from their marine mammal group. Have another student describe its special adaptations. All students should copy the information into their notebooks.

Homework Assignment

Read pages 330–333, 341–346, 348–349. Answer Section Review questions 1–3 on page 350, and Chapter Review questions 6–8 on page 355.

LESSON 2 *(pages 331–336, 339–342)*

Aim: How are whales adapted to their environment?

Instructional Objectives

1. Identify adaptations in whales to the marine environment.
2. Explain how the adaptations enhance the whale's survival.
3. Describe how whale structures are related to their functions.

Motivation for the Lesson / Do Now

Display a photo or drawing of a baleen whale and of a toothed whale, or refer students to Figure 14-3 (on page 332) and Figure 14-5 (on page 335) in their textbooks. Have them copy and label drawings of these whales in their notebooks.

Development of the Lesson

1. Whales (whose ancestors lived on land 50 million years ago) have a variety of structures, or *adaptations*, that aid their survival in the marine environment. For example, whales have a blowhole for breathing, and flippers for swimming.
2. **Write the Aim:** *How are whales adapted to their environment?* Focus on the two types of whales shown in Figures 14-3 and 14-5.

   Key Questions: *What do whales eat?* Discuss the two main types of whales: *baleen* and *toothed*. Baleen whales use plates of baleen, which hang from the roof of their mouth, to filter plankton and small fish from the water. The throats of some baleen whales are pleated to expand while they are feeding. Toothed whales have peglike teeth (on either one or both of their jaws), which are used to catch prey such as fish, seals, penguins, and squid.
3. **Key Question:** *How does a whale breathe?* All cetaceans have a *blowhole* on the top of their head. The blowhole is the whale's nose; its dorsal location enables the whale to breathe while it remains submerged (and still able to see things underwater).
4. **Key Question:** *How does a whale swim?* Vigorous contractions of the body's muscles cause

up-and-down movements of the tail fluke, which propel the whale through the water. The pectoral fins (flippers) are used for steering and balance. The fastest of all marine mammals, the killer whale (*Orcinus*) has been clocked at 55 kph.

5. **Key Questions:** *How does a whale keep warm?* Besides being endothermic (like all other mammals), whales have a thick layer of fat, called *blubber*, under the skin, which traps body heat.
6. **Key Questions:** *How do whales communicate?* Whales use sound to communicate; smaller whales (e.g., narwhals and dolphins) produce higher-frequency sounds (like whistles). Larger whales produce lower-frequency sounds, which travel farther. Sounds are produced in the whale's airway and are emitted through a spongy mass of tissue in the forehead, called the *melon*. (Sound is also used in feeding behavior.)
7. **Key Questions:** *How do whales reproduce?* Whales reproduce in the water. Whales have special breeding grounds where they congregate to calve and mate. Fertilization and development are internal. The period of embryonic development may last from 11 to 18 months. There is a close bond between the mother and offspring; the calf nurses for six to ten months on a very high-fat, high-protein milk.

Summary of the Lesson

Organize the class into six groups; with each team assigned a different adaptation to summarize. Have a student from each group read their description to the class. All students should copy the information into their notebooks.

Homework Assignment

Read pages 331–336 (top) and 339–342 (top). Answer Section Review questions 1–3 on page 334 and question 3 on page 341.

LESSON 3 *(pages 336–340)*

Aim: How do whales behave?

Instructional Objectives

Students will be able to:

1. Describe behaviors in the whale.
2. Explain why whales migrate.
3. Compare migration in gray whales and humpback whales.

Motivation for the Lesson / Do Now

Project on an overhead the migratory routes of gray whales and humpback whales, as shown in Figure 14-8 on page 338. Have students copy this info into their notebooks.

Development of the Lesson

1. The kinds of responses that an organism makes to its environment are called *behavior*. Animals respond to their environment by behaving in a variety of adaptive ways.
2. **Write the Aim:** *How do whales behave?* Project or display to the class the following examples of whale behavior (as shown in Figure 14-7 on page 337).
   - *Diving:* Whales dive beneath the surface of the ocean largely in pursuit of food. The pectoral fins (flippers) are used to change from a horizontal to a vertical position. The head submerges first and then the body, propelled downward by the action of the tail fluke, which is the last part of the body to submerge.
   - *Lobtailing:* When lobtailing, a whale waves its tail in the air and then smashes it against the surface of the ocean, producing a sound that can be heard several kilometers away. Some marine scientists believe that lobtailing is a sign of aggression. Others think that it is the whale's way of announcing its presence.

- *Spyhopping:* When spyhopping, a whale raises its head above the water surface to look around for a few seconds. It appears that whales are curious about the world above the ocean. Scientists do not fully understand the purpose of this behavior.
- *Breaching:* This most spectacular kind of behavior occurs when a whale leaps almost completely out of the water and then crashes down, creating a huge, loud splash. Scientists are not sure why whales breach. There are several possible reasons for breaching, such as: to dislodge parasites from the skin, as a form of communication, or just a playful type of behavior.
- *Migrating:* Whales, like the humpback whale and gray whale, shown in Figure 14-2 on page 332, travel, or *migrate*, yearly over long distances in a group (the *pod)* to reach either their feeding or breeding grounds.

3. **Key Question:** *Why do whales migrate?* The California gray whale (genus *Eschrichtius*) migrates yearly from its from feeding grounds off Alaska to its breeding grounds off Baja California, and back again—a round-trip distance of more than 12,000 km. Gray whales spend the summer months feeding in the cold Arctic Ocean, where the nutrient-rich waters produce an abundance of plankton. During the winter, they migrate to the warm, shallow waters around Baja California, where they breed and bear their young. The Atlantic population of the humpback whale (genus *Megaptera*) migrates yearly from its feeding grounds off Iceland to its breeding grounds in the Caribbean Sea. The Pacific populations of humpbacks migrate from the Bering Sea to southern Mexico; others breed in the protected waters of Hawaii.

Summary of the Lesson

Divide the class into five groups, with each team preparing a summary of one of the following behaviors: diving, spyhopping, breaching, lobtailing, and migration. Have the team leaders from each group read their summaries aloud to the class. Encourage class discussion and have the students take notes.

Homework Assignment

Read pages 336–340 (top). Answer Section Review questions 1–2 on page 341, and Chapter Review questions 13–17 and 23–24 on pages 356–357.

LESSON 4 *(pages 350–352)*

Aim: How are marine mammals adapted for deep and prolonged dives?

Instructional Objectives

Students will be able to:

1. Define the diving response (diving reflex).
2. Describe how the diving response works.
3. Explain how marine mammals can make deep dives.

Motivation for the Lesson / Do Now

Project on an overhead or write on the board a copy of Table 14-1, "Depth and Time of Breath-Hold in Diving Marine Mammals," on page 350, for students to copy into their notebooks.

Development of the Lesson

1. Ask students how long they think humans can stay underwater on a single breath-hold. The maximum breath-hold for humans is approximately three minutes. Point out the maximum breath-holds of the five marine mammals listed in the table. Have students hold their breath for 15 seconds as a means of comparison.
2. **Write the Aim:** *How are marine mammals adapted for deep and prolonged dives?* The sperm whale can dive more than 2000 meters in

depth on a single breath, and stay underwater for more than one hour, to pursue prey such as the giant squid. The physiological changes that take place in the whale, which enable it to make such deep and prolonged dives, make up what is called the *diving response* (or *diving reflex*).

3. **Key Question:** *What are the parts of the diving response?* Part of the diving response is the detouring, or *shunting*, of blood that contains food and oxygen from the rest of the body to the vital organs. The heart rate also slows down as blood is shunted because there is less blood circulating around the body. The slowing of the heart rate, called *bradycardia*, during dives in marine mammals, is another part of the diving reflex. This slowing helps to conserve the animal's energy and oxygen.
4. Have students examine the data table. Ask why some marine mammals, such as the seal and the sperm whale, have a longer breath-hold than others. The duration of a breath-hold is related to the oxygen-carrying capacity of an animal's body.
5. **Key Question:** *Why do marine mammals have a higher oxygen-carrying capacity?* Diving mammals have a higher blood volume and greater concentration of oxygen-binding red blood cells than do non-diving mammals. The protein *hemoglobin*, in red blood cells, holds and transports oxygen. Diving mammals also have another oxygen-binding protein, called *myoglobin*, located in the muscles. Together, the hemoglobin and myoglobin increase the oxygen-carrying capacity of the body. In addition, elastic tissue in the lungs and chest permits greater lung expansion during inhalation, and enables more complete and rapid inhalations and exhalations between dives.

Summary of the Lesson

Divide the class into five groups, with each team recording a description of one marine mammal adaptation for deep and prolonged dives (bradycardia, shunting of blood, higher blood volume, myoglobin, elastic tissue in lungs). Have a leader from each group read aloud their description. All students should copy the information into their notebooks.

Homework Assignment

Read pages 350–352. Answer Section Review questions 1–3 on page 352, and Chapter Review questions 9–12 on pages 355–356 and 18–22 on page 357.

UNIT 5 THE WATER PLANET

Chapter 15 / World of Water

INTRODUCTION

Chapter 15 introduces students to the world of ocean water—its volume, properties as a solvent, variations in dissolved oxygen levels, pH levels, salinity, and the importance of such chemical characteristics to the survival of life in the sea.

- About 97 percent of Earth's total water budget is salt water.
- The special chemical properties of water enabled the evolution and survival of life in the ocean and, ultimately, on the land, too.

LESSON 1 *(pages 360–365)*

Aim: What do we know about the geography of the ocean?

Instructional Objectives

Students will be able to:

1. Define latitude and longitude.
2. Locate geographical regions using latitude and longitude.
3. Compare and contrast the sizes of oceans and landmasses.

Motivation for the Lesson / Do Now

Have students draw a pie graph showing the major oceans: Pacific, Atlantic, Indian, and Arctic.

Development of the Lesson

1. The body of water known collectively as the *ocean* covers about 71 percent of Earth's surface.

   WRITE THE AIM: *What do we know about the geography of the ocean?* The oceans surround landmasses called *continents*. When two continents enclose a part of the ocean, a smaller body of water called a *sea* is formed. (Refer to Figure 15-1 on page 361.)

2. The continents divide the ocean into four main parts. Draw on the board a pie graph that shows the relative sizes of the world's four major oceans: Pacific (the largest ocean), Atlantic, Indian, and Arctic oceans. (Refer to Figure 15-2 on page 364.)

3. KEY QUESTION: *What is Earth's water budget?* The total amount of water contained in and on Earth is called the *water budget*. The oceans contain about 97 percent of all the water on Earth. The remaining 3 percent is freshwater (i.e., rivers, lakes, and groundwater). The *sea level* is the point at which the surface of the ocean touches the land. About 12,000 years ago, during the last ice age, the sea level was much lower because so much water was in glaciers.

4. KEY QUESTION: *How is Earth's surface mapped?* Display a wall map and globe of Earth. The part of the earth above the equator is the *northern hemisphere*. The part below the equator is the *southern hemisphere*. The lines that

Location	Latitude	Longitude
Gulf of Mexico	20 degrees N	80 degrees W
Mediterranean Sea	30–35 degrees N	5 degrees W
Iceland	60 degrees N	20 degrees W
Madagascar	20 degrees S	40 degrees E
Japan	30 degrees N	130 degrees E
Alaska	60 degrees N	160 degrees W
Florida	25 degrees N	75 degrees W
Baja California	25 degrees N	105 degrees W
New Zealand	40 degrees S	170 degrees E
Galápagos Islands	0 degrees (equator)	90 degrees W

run parallel are called the lines of *latitude*. Latitude is the distance north and south of the equator, as measured in degrees. The measure, in degrees, of the distance east and west of the prime meridian is the called the *longitude*.

5. **Key Questions:** *How can we locate areas on Earth's surface?* Distribute handouts of maps, showing Earth's lines of latitude and longitude, or refer students to Figure 15-1 (page 361).
6. Write the following table on the board for your students to copy into their notebooks; give only the names of the locations. Organize the class into five groups, with each team finding the approximate latitude and longitude of the locations listed in the table.

Summary of the Lesson

Have a team leader from each group go to the board to write in the approximate latitude and longitude of two geographical regions. Based on the data in table, have students discuss the distribution of landmasses above and below the equator.

Homework Assignment

Read pages 359–362 and 364–365 (top). Answer Section Review questions 1–3 on page 362 and 1–2 on page 366.

LESSON 2 *(pages 365–367)*

Aim: What is known about the ocean's water?

Instructional Objectives

Students will be able to:

1. Draw and label the water cycle.
2. Explain how a constant sea level is maintained.
3. Define solute, solvent, and solution.

Motivation for the Lesson / Do Now

Draw the water cycle on the board (as shown in Figure 15-3 on page 365), but omit the labels and arrows for evaporation, condensation, and precipitation. Have the students copy the diagram into their notebooks, and then connect and label the parts as the lesson proceeds.

Development of the Lesson

1. **Write the Aim:** *What is known about the ocean's water?* The circulation of water—from the ocean, into the atmosphere, and back down again—is called the *water cycle*. The three stages of the water cycle are evaporation, condensation and precipitation. The process

by which liquid water changes to gas (water vapor) is called *evaporation*. The process of cloud formation is called *condensation*. When that water changes to rain, snow, sleet, or hail, it is called *precipitation*. As a result of the water cycle, a *constant sea level* is maintained.

2. KEY QUESTION: *What is the composition of ocean water?* Before class begins, evaporate some ocean water (or salt water) from an evaporation dish or glass plate. Show the residue to the class. The residue is *salt*.
3. Salt, or any other substance that mixes with water, is called a *dissolved substance*. A dissolved substance is also called a *solute*. The liquid (such as water) that holds dissolved substances is called a *solvent*. The combination of water and its dissolved substances is called a *solution*. The relationship between solute, solvent, and solution can be seen in the following word equation: salt (solute) + water (solvent) → salt water (solution).
4. Many solutions like seawater are also called *mixtures*. A mixture contains two or more substances that can be separated by ordinary physical means. In other words, water (the solvent) can be evaporated off from the salt water (solution) to leave salt (the solute).

Summary of the Lesson

Have the students write brief explanations of (a) how the water cycle maintains a constant sea level and (b) why ocean water is called a solution (and also a mixture). Call on volunteers to read their descriptions to the class.

Homework Assignment

Read pages 365–367. Answer Section Review question 3 on page 366, and Chapter Review question 8 on page 380.

LESSON 3 *(pages 367–369)*

Aim: What is the composition of ocean water?

Instructional Objectives

Students will be able to:

1. Draw a diagram of the water molecule.
2. Explain how salt dissolves in water.
3. List four compounds found in sea salts.

Motivation for the Lesson / Do Now

Show the class a glass of ocean (salt) water. Describe a simple experiment to demonstrate that ocean water contains salt.

Development of the Lesson

1. Show students the residue on an evaporation dish. Note that ocean water contains dissolved substances.

   WRITE THE AIM: *What is the composition of ocean water?* About 96.5 percent of ocean water is freshwater. Dissolved substances, consisting mainly of salts, make up the remaining 3.5 percent.
2. KEY QUESTION: *What kinds of salts are found in ocean water?* The salts dissolved in ocean water are called *sea salts*. Artificial ocean water can be prepared by dissolving sea salts in tap water. Sea salts include the compounds listed in Table 15-1 on page 368. Ordinary table salt, sodium chloride (NaCl) is the most common of the sea salts. When table salt is added to water, the NaCl breaks up, or *ionizes*, to form charged atoms called *ions*. In seawater, the NaCl compound ionizes to form the positively charged sodium ion (Na^+) and the negatively charged chloride ion (Cl^-).
3. KEY QUESTION: *How does salt dissolve in water?* Before this question can be answered, the students need to know about the *water molecule*. The chemical, or molecular, formula for the water molecule is H_2O. A *molecule* is defined as the smallest quantity of an element or compound. One water molecule, H_2O, is composed of two atoms of hydrogen joined with one atom of oxygen. (See Figure 15-4 on page 369.) The oxygen side of the water molecule

(which has more electrons) has a negative charge, while the hydrogen side (which has fewer electrons) has a positive charge. Salt dissolves in water because the opposite charges on the water molecules attract ions from the salt. The sodium ions and chloride ions separate and become surrounded by the water molecules.

Summary of the Lesson

Organize the class into groups of three to four students, with each team writing a paragraph that explains how salt dissolves in water. Have one student from each group write their explanation on the board and another student read it aloud to the class.

Homework Assignment

Read pages 367–369. Answer Section Review question 1 on page 373. Draw and label a diagram of a water molecule to accompany your answer.

LESSON 4 *(pages 369–372)*

Aim: What is known about the pH of ocean water?

Instructional Objectives

Students will be able to:

1. Define the term acid rain.
2. Describe the pH of ocean water.
3. Explain the buffering effect in ocean water.

Motivation for the Lesson / Do Now

Show students a glass of rainwater. Have students explain in writing why (in certain regions) rainwater has been harmful to some aquatic organisms, such as freshwater fish and frogs.

Development of the Lesson

1. Some bodies of water can become acidic due to *acid rain*, or acid precipitation. Acid rain forms when chemicals released by the burning of fossil fuels are absorbed by moisture in the air. The degree of acidity or alkalinity of a liquid is called its *pH*.
2. **Write the Aim:** *What is known about the pH of ocean water?* The term *pH* means the power of the hydrogen ion concentration. The pH of a substance is measured on a scale from zero (most acidic) to 14 (most alkaline), called the *pH scale*. The pH of ocean water is, on average, about 8, making it slightly alkaline. (See the pH scale in Figure 15-9, on page 370.)
3. **Key Question:** *Why is ocean water slightly alkaline?* A small number of water molecules dissociate into positive ions and negative ions. The ion with the positive charge is the *hydrogen ion* (H^+) and the ion with the negative charge is called the *hydroxyl ion* (OH^-). A solution that contains a large number of hydrogen ions is an *acid*. A solution that contains a large number of hydroxyl ions is a *base*, or *alkaline* solution. If a substance contains an equal number of hydrogen and hydroxyl ions it is called *neutral*. Ocean water is slightly alkaline because the hydroxyl ions outnumber the hydrogen ions.
4. **Key Question:** *Why is acid rain less of a problem in the ocean than it is in a pond or lake?* Chemicals in ocean water, called *buffers*, help to maintain a stable pH. A *buffer* is a substance that lessens the tendency of a solution to become too acidic or too basic. One of the buffers in ocean water is the *carbonate buffer* (CO_3^-). The buffering action in ocean water can be seen in the following reaction (which goes to the left in ocean water): $CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow HCO_3^- + H^+ \rightarrow CO_3^{2-} + 2H^+$
5. The carbonate buffer can absorb hydrogen ions from acid rain, thus maintaining a stable

pH of 8. Another reason that acid rain is not a serious problem in the ocean is because of the ocean's vast size. The large volume of ocean water helps to dilutes the acid rain.

Summary of the Lesson

Organize the class into groups of three to four students. Have students answer the two key questions in paragraph form. Ask two students to write their explanation on the board (one key question each), and have another student read them aloud to the class.

Homework Assignment

Read pages 369–372 (top). Answer Section Review question 2 on page 373, and Chapter Review questions 9–11 on page 381.

LESSON 5 *(pages 372–373)*

Aim: What is known about molecular oxygen and its distribution in the ocean?

Instructional Objectives

Students will be able to:

1. Write the word equation for photosynthesis.
2. Explain the origin and importance of DO in the ocean.
3. Describe the relationship between DO and depth.

Motivation for the Lesson / Do Now

Tell students to take a deep breath. **Ask students:** *What important substance is entering your lungs? Where does it originate?* Explain.

Development of the Lesson

1. In order to survive, we need to breathe in air. The air contains molecules of oxygen, or O_2, the gas produced by algae and plants. Marine animals need oxygen to survive, too.
2. **Write the Aim:** *What is known about molecular oxygen and its distribution in the ocean?* Most of the oxygen in the ocean comes from algae and other aquatic plants that live in the sea and along the shore. The process by which green plants produce food and oxygen is called *photosynthesis*.
3. Write on the board the *formula equation* and *word equation* for photosynthesis. Call on a student to read the equation aloud to the class: six molecules of carbon dioxide, plus twelve molecules of water, in the presence of light and chlorophyll, yield one molecule of glucose, plus six molecules of water, plus six molecules of oxygen.
4. **Key Question:** *How does the oxygen enter the water?* After oxygen leaves the aquatic algae, some enters the atmosphere and some dissolves in the seawater. Molecular oxygen that enters ocean water is called *dissolved oxygen* (DO); and the amount of O_2 dissolved in the water is expressed in units of *parts per million* (ppm) or *milligrams per liter* (mg/L). Ocean water can hold from 1 ppm to 12 ppm of dissolved oxygen. (In contrast, the amount of O_2 in the air is about 200 ppm.)
5. **Key Question:** *How is dissolved oxygen distributed in the ocean?* As depth increases, the DO decreases down to a depth of about 1000 meters. The lowest amount of oxygen (in ppm), called the *O_2 minimum zone*, is found at 1000 meters, not at the ocean bottom. Most of the oxygen is produced in the sunlit (photic) zone near the surface, where algae are found. In the depths, where it is too dark, no photosynthesis occurs. However, the ocean is not calm; waves and currents circulate oxygen to the depths.

Summary of the Lesson

Organize the class into groups of three to four students. Have the students write in their notebooks the word equation for photosynthesis

along with a brief explanation of the origins of DO in ocean water. Have a student from each group write their information on the board and then read it aloud. Compare and discuss the explanations.

Homework Assignment

Read pages 372–373. Answer Section Review question 3 on page 373, and Chapter Review questions 6 on page 380 and 14–19 on page 382.

LESSON 6 *(pages 48–50, 373–374)*

Aim: What do we know about the density and salinity of ocean water?

Instructional Objectives:

Students will be able to:

1. Define density and salinity (of water).
2. Explain how to measure density and salinity.
3. Convert density units into percent salt values.

Motivation for the Lesson / Do Now

Ask students: *Is it easier to float in a lake or in the ocean?* Explain.

Development of the Lesson

1. Floating in the ocean is easier than floating in a lake because the ocean contains salt. The amount of salt dissolved in ocean water is called its *salinity*. Salt increases the *density* of water. Density is defined as *mass per unit volume*. The denser ocean water can support your body's weight better than freshwater can.
2. **Write the Aim:** *What do we know about the density and salinity of ocean water*? The density of a liquid can be measured by using an instrument called a *hydrometer*. The hydrometer is an air-filled glass tube that has a weight at its bottom, to keep it floating upright in a liquid. When hydrometers are placed in graduated cylinders of freshwater and salt water, they come to rest at different levels. (Refer students to Figure 2-12 on page 49.) The hydrometer in ocean water floats higher in the cylinder than does the hydrometer in freshwater.
3. The density of a liquid can be measured by reading the scale inside the hydrometer. The numbers on the scale represent the range of densities of water. The hydrometer reading for distilled water (pure freshwater) is 1.000. The value of 1.000 represents the density, or *specific gravity*, of distilled water. Specific gravity is defined as the ratio of the density of a substance to the density of distilled water. The hydrometer in the freshwater rests at 1.000. The hydrometer in the ocean water rests at 1.0250.
4. **Key Question:** *How is salinity measured?* Since the greater density of ocean water is almost entirely due to the presence of salt, density and salinity are often used interchangeably. However, salinity is expressed in percent. The average salinity of the ocean is about 3.5 percent. Salinity is also expressed in parts per thousand (ppt). A salinity of 3.5 percent is equivalent to 35 ppt, also written as 35‰. Since salinity is given in percents, and the hydrometer uses specific gravity units, a conversion table is needed to find the percent salt.
5. Suppose the hydrometer in your aquarium has a reading of 1.030. What would be the salinity of the water? As you can see in Table 2-4 on page 50, the salinity would be 42 ppt, or 4.2 percent. A salinity of 4.2 percent is high for a saltwater aquarium.

Summary of the Lesson

Ask students: *How can you lower the aquarium water's salinity to the recommended 3.5 percent (35 ppt)?* Also, have students explain why leaving the cover off a saltwater tank would lead to an increase in salinity.

Homework Assignment

Read pages 48–50 and 373 (bottom)–374. Answer Section Review questions 2–3 on page 51, and Chapter Review questions 7 on page 57 and 17–18 on page 59.

LESSON 7 *(pages 374–377)*

Aim: How does salinity vary in the ocean?

Instructional Objectives

Students will be able to:

1. Interpret an ocean salinity chart.
2. Describe how salinity varies in the ocean.
3. Explain why salinity varies in the ocean.

Motivation for the Lesson / Do Now

The water salinity under the Verrazano Bridge is slightly greater than the water salinity under the George Washington Bridge. Point out the bridges on a map of New York City, and elicit from students a possible explanation for this difference.

Development of the Lesson

1. The Verrazano Bridge is situated closer to the ocean, whereas the George Washington Bridge is located farther upriver. Therefore, there is more freshwater (and a lower salinity) under the George Washington Bridge.
2. **Write the Aim:** *How does salinity vary in the ocean?* Project on the wall or draw on the board a copy of the graph in Figure 15-10 (on page 376). Note that the salinity at the bottom of the ocean is greater than at the surface. Salinity varies with depth; however, the change is not uniform. A layer of water called the *halocline*, located between 100 and 200 meters deep, shows a rapid change (i.e., increase) in salinity.
3. **Key Question:** *Why does salinity increase with depth?* Water is much colder deep in the ocean than closer to the surface. In cold water, molecules and salt ions move closer together, thus increasing the salinity. (In warmer surface waters, the salt ions are farther apart.)
4. **Key Question:** *How does salinity vary on the ocean surface?* Distribute copies of Figure 15-8 on page 375, or have students turn to that page in their textbooks. Lines on the map connect places of equal salinity. Draw two columns on the board, labeled *Geographic Region* and *Surface Salinity (ppt)*. Organize the class into groups of four to five students and have them determine the salinities for the following regions: equator, 20 degrees N latitude, 20 degrees S latitude, south polar region, north polar region, 40 degrees N latitude, 40 degrees S latitude, and (approximate) middle of the Pacific Ocean. Record the data in the appropriate columns on the board. Have students copy the table into their notebooks.
5. **Key Question:** *Based on your observations, what factors do you think affect the salinity of ocean water?* Have the students in each group work together to answer this key question.

Summary of the Lesson

Have a student from each team write their answer on the board and then read it aloud. The following points should be mentioned.

- *Latitude:* The highest salinities are recorded at 20 degrees N and 20 degrees S, because those regions have more evaporation and less precipitation. Salinity is lower at the equator, due to high levels of precipitation.
- *Proximity to land:* Water along the shore often has a lower salinity than that of the open ocean, due to freshwater runoff from the land and rivers.
- *Depth:* As depth increases, the salinity increases, due to cold water holding more salt ions.

Homework Assignment

Read pages 374 (bottom)–377. Draw in your notebook a copy of Figure 15-10 (salinity/depth graph) on page 376. Answer Section Review questions 1–3 on page 377, and Chapter Review questions 7 on page 380 and 22 on page 382.

Chapter 16 / Geology of the Ocean

INTRODUCTION

In Chapter 16, students will learn about the formation of the oceans and continents, and about the geologic forces that have shaped, and continue to shape, the oceans and oceanic landforms. The interaction of land and sea is an ongoing process. Such geologic processes affect the characteristics of marine environments and the organisms living in them.

- Most of Earth is covered by water. The oceans surround the continents that formed as a result of the break-up of Pangaea.
- The theory of plate tectonics explains the mid-ocean ridge, seafloor spreading, and continental drift.
- Islands, coastlines, and reef structures all form as a result of geologic processes.
- Sonar is used to learn about ocean-floor topography.

LESSON 1 *(pages 385-390)*

Aim: How can we explain the formation of the oceans and continents?

Instructional Objectives

Students will be able to:

1. Discuss the conditions on early Earth.
2. Explain where the oceans came from.
3. Describe the theory of continental drift.

Motivation for the Lesson / Do Now

Show the class a map or globe of Earth. **Ask students:** *Where did the oceans and continents come from?* Explain.

Development of the Lesson

1. Earth was born from a molten mass that slowly cooled, producing gases, one of which was water vapor. The water vapor condensed into rain, which filled depressions on Earth's surface, eventually forming the oceans. Some of the ocean water also came from Earth's crust, in the form of water-containing compounds, called *hydrated compounds*, such as copper sulfate ($CuSO_4 \bullet 5\ H_2O$), which gives off water when it is heated.
2. **Write the Aim:** *How can we explain the formation of the oceans and continents?* Display on the overhead a copy of Figure 15-3 (or have students look at it in the text, on page 389), which illustrates continental drift. More than 200 million years ago, all the continents existed as a single supercontinent (surrounded by ocean), which scientists call *Pangaea*. Over time, Pangaea broke into several smaller continents that drifted apart, eventually attaining the shapes and positions that they occupy today. This idea of the break-up and separation of landmasses over time is called the *theory of continental drift* and was first proposed by the German meteorologist Alfred Wegener in 1912. Wegener was actually ridiculed by other scientists at that time, since he could not explain *how* drift occurred.
3. **Key Question:** *What powerful forces caused the landmasses to split apart?* Show diagram of Earth's interior. (See Figure 16-4 on page 389.) The interior layers consist of the inner core, outer core, and mantle. The molten rock material in the mantle, called *magma*, ranges in temperature from 1200°C to 5000°C. Powerful, upward forces generated by these high

temperatures in the magma caused the outer layer, or crust, to crack.

4. **Key Question:** *What is the effect of these powerful forces on Earth's crust?* When the crust cracks, the ground above it moves, producing *earthquakes* (or *seaquakes*, if they occur on the ocean floor). If the opening is big enough, magma may flow out as *lava*, producing a *volcanic eruption*. Disturbances in Earth's crust, such as volcanic eruptions and earthquakes, are examples of *seismic activity*. On a global scale, when large sections of crust have broken apart, they float on the molten mantle (which moves below them), causing continental drift.

Summary of the Lesson

Organize the class into groups of three to four students, with each team preparing a brief summary of the lesson. Call on a volunteer to read aloud their group's summary statement to the class. Encourage discussion about this once-controversial topic.

Homework Assignment

Read pages 384–390 (top). Answer Section Review questions 1–3 on page 390, and Chapter Review question 6 on page 412.

LESSON 2 *(pages 390–391)*

Aim: How can we describe the movements of Earth's crust?

Instructional Objectives

Students will be able to:

1. Define the process of plate tectonics.
2. Identify Earth's major crustal plates.
3. Explain why the Atlantic Ocean widens each year.

Motivation for the Lesson / Do Now

Show the class a world map. Mention that the Atlantic Ocean widens by a few centimeters each year. Explain.

Development of the Lesson

1. The Atlantic Ocean gets slightly wider each year because the continents are still moving apart.
2. **Write the Aim:** *How can we describe the movements of Earth's crust?* Earth's crust is divided into floating segments called *plates*. Project on the overhead the crustal plates. (Refer to Figure 16-5 on page 391.)
3. Organize the class into groups of three to four students. Hand out sheets of paper ($8\frac{1}{2} \times 14$) to each group. Have the students draw the plates on the paper, cut the plates out, then mix them up and put them back together like the pieces of a jigsaw puzzle.
4. **Key Question:** *How many plates are there and what are their names?* Count the plates and list their names on the board. There are nine major plates: Pacific, North American, Nazca, South American, Eurasian, Arabian, African, Indian, and Antarctic. Students should copy these names onto their plates, and paste the reassembled set into their notebooks.
5. **Key Question:** *How (i.e., in what direction) do the plates move?* Place your left index finger and thumb on the North American and South American plates. Place your right index finger and thumb on the Eurasian, Arabian, and African Plates. Move the two sets of plates away from each other (i.e., in the direction of the arrows, as shown in Figure 16-5). The *theory of plate tectonics* describes the process by which Earth's crust breaks into plates and how the plates move (due to activity in the mantle) in their specific directions.

Summary of the Lesson

Have students in each group define the process of plate tectonics. Call on a volunteer from each group to read their definition to the class.

Homework Assignment

Read pages 390–391. Answer Section Review question 1 on page 394. Students should finish labeling and reassembling in their notebooks the copies of Earth's crustal plates.

LESSON 3 *(391–394)*

Aim: How can we explain the movement of Earth's crust?

Instructional Objectives

Students will be able to:

1. Cite examples of seismic activity.
2. Explain how oceanic ridges are formed.
3. Describe the process of subduction.

Motivation for the Lesson / Do Now

Sketch on the board a picture of the Mid-Atlantic Ridge. Explain how this underwater "mountain range" originated.

Development of the Lesson

1. Mountain formation, earthquakes, volcanic eruptions are examples of seismic activity. Seismic activity is evidence that Earth's crust is moving.
2. **Write the Aim:** *How can we explain the movement of Earth's crust?* Project on the overhead a copy of Figure 16-6 (on page 359). The crust moves as a result of high temperatures generated in the mantle. The big difference in temperature between the upper mantle and the lower mantle creates the *convection currents*, which cause the magma to rise up through the mantle and into the crust.
3. **Key Question:** *How is the Mid-Atlantic Ridge formed?* The upward movement of magma into the crust produces the Mid-Atlantic Ridge, a mountain range that runs the entire length of the Atlantic Ocean. This flow of magma through the crust also causes *seafloor spreading*—the process that is moving apart the (oceanic) crustal plates.
4. **Key Question:** *How are the trenches formed?* A *trench* is the geological feature found in the deepest parts of the ocean. Trenches form at the margins of plates. When plates collide as a result of seafloor spreading, one plate plunges downward below the other plate, in the process called *subduction*. The area at which this occurs forms the trench. The deepest trench, at nearly 11,000 meters, is the Mariana Trench in the Western Pacific Ocean.

Summary of the Lesson

Have students work in groups to explain the following seismic activities: seafloor spreading, ridge formation, and subduction/trench formation. Have a student from each team read their descriptions to the class.

Homework Assignment

Read pages 392–394. Answer Section Review questions 2–3 on page 394, and Chapter Review questions 9–11 and 15–16 on pages 412–413.

LESSON 4 *(pages 395–396)*

Aim: How is sonar used to learn about the ocean floor?

Instructional Objectives

Students will be able to:

1. Define sonar.

2. Explain how sonar works.
3. Describe how depth is calculated.

Motivation for the Lesson / Do Now

Draw a diagram of an undersea trench on the board. Ask how scientists know that the Mariana Trench is nearly 11,000 meters deep.

Development of the Lesson

1. Oceanographers use *sonar*, an acronym for *so*und *na*vigation and *r*anging, to measure ocean depth. Sonar is also used to determine what features are found on the ocean floor. The study of Earth's features on land and on the ocean floor is called *topography*.
2. **Write the Aim:** *How is sonar used to learn about the ocean floor?* Project on the overhead a copy of Figure 16-11 (on page 395). Modern ships are equipped with sonar. A ship's sonar device beams a continuous signal downward. After the sound wave hits the bottom, the returning signal, or *echo*, is received by a depth recorder in the ship. This produces a line tracing of the ocean floor (as shown in the bottom diagram). Ocean depth is calculated by knowing the speed of sound in water (1454 meters/second) and the time it takes for the signal to reach the bottom. The following formula is used to calculate the depth: Depth (D) = 1454 meters/second × time (t) ÷ 2.
3. **Key Question:** *How deep is the ocean if a signal takes one second to return to the ship after being sent?* Have a student work out the problem on the board. Substituting into the formula we have: D = 1454 m/second × 1 second ÷ 2; D = 1454 m × ½; D = 727 meters.
4. **Key Question:** *How deep is the ocean if a signal takes one-half second to return?* Have the class work out this problem; then call on a student to write it on the board, as follows: D = 1454 m/second × 0.5 second ÷ 2; D = 1454 m/second × 0.25; D = 363.5 meters.

Summary of the Lesson

Have students work in groups to determine ocean depth in various assigned problems. Call on volunteers to do the problems on the board and explain their answers to the class.

Homework Assignment

Read pages 395–396. Answer Section Review question 1 on page 404.

LESSON 5 *(pages 397–399, 401–404)*

Aim: How can we describe the topographical features found on the ocean floor?

Instructional Objectives

Students will be able to:

1. Identify various seafloor features.
2. Describe the topographical features.
3. Explain how these features are formed.

Motivation for the Lesson / Do Now

Display a topographical map of the ocean floor. Point out and describe several features.

Development of the Lesson

1. There are two ways to observe topographical features: from above and from the side (profile view). Both views are useful in determining what the ocean floor looks like.
2. **Write the Aim:** *How can we describe the topographical features found on the ocean floor?* Project on the overhead a profile (or side view) of seafloor topographical features. (See Figure 16-12 on page 396.) Have students copy this profile into their notebooks.
3. **Key Question:** *What do we know about these topographical features?* Organize the class into eight groups of students, with each team researching and writing about a different topographical feature. Information on the features

can be found on the following pages: continental slope (397), submarine canyon (397–398), continental rise (398), seamount (398–399), guyot (399), trench (399), island arc (401), and mid-ocean ridge (401–402).

4. The following are some facts that you may want to see mentioned:
   - *Continental slope:* is the area where the seafloor drops steeply; located at the outer edge of the continental shelf.
   - *Submarine canyon:* is a steep V-shaped depression that cuts through the continental shelf; is an extension of a sunken river valley.
   - *Continental rise:* is the slightly elevated region that forms at the base of a continental slope from the accumulation of mudslide sediments.
   - *Seamount:* is a small undersea mountain formed by lava piling up on the seafloor; forms over hot spots in the mantle; the Hawaiian Islands are actually a chain of seamounts.
   - *Guyot:* is a flattened undersea structure formed when waves and currents erode the top of a seamount.
   - *Trench:* is a steep, deep V-shaped depression on the seafloor; found at margins of crustal plates (in subduction zones); is the deepest feature on the ocean floor.
   - *Island arc:* is a group of islands that forms an arc in the ocean; many are volcanically active; associated with trenches.
   - *Mid-ocean ridge:* is an undersea volcanic mountain range that encircles the globe; along its crest is the rift valley, through which molten rock from the mantle is expelled; the rift zone also contains hydrothermal vents from which hot mineral-laden waters emerge.

Summary of the Lesson

Call on eight students to come up to the board (one at a time) to sketch and describe one topographical feature from the list you gave them. Have another student from each group write a brief description on the board.

Homework Assignment

Read pages 397–399, 401–404 (top). Answer Section Review questions 2–3 on page 404.

LESSON 6 *(pages 404–409)*

Aim: How can we describe shoreline topography?

Instructional Objectives

Students will be able to:

1. Identify various shoreline features.
2. Describe how shoreline features develop.
3. Explain how a coral reef evolves.

Motivation for the Lesson / Do Now

Have students write a physical description of a beach that they have visited. (For landlocked areas, students can describe lakeshore beaches.)

Development of the Lesson

1. Approximately 70 percent of the U.S. population lives within 80 km of a coast. The coast, or shore, is the boundary between land and sea. Shorelines are composed of different kinds of substrates. Some coasts, like Maine and Oregon, are rocky, while others, like Florida, have sandy beaches. Some tropical islands have shorelines made up of coral.
2. **Write the Aim:** *How can we describe shoreline topography?* Organize the class into groups of three to four students, with each team researching a different shoreline feature. Information on the different shoreline (coastal) features can be found on the following pages: sandy beach (404–405), delta (405–406), rocky

coast (404, 406–407), fjord (407), fringing reef (408), barrier reef (408), key/cay (409), and coral atoll (409).

- *Sandy beach:* has loose sediments or sand eroded by waves from rocks along the shore, or from rocks eroded from mountains and transported by rivers down to the shore.
- *Delta:* is a fan-shaped deposit of sediments that piles up at the mouth of a large river where it enters a calm ocean.
- *Rocky coast:* is usually a very steep shoreline formed by the carving action of glaciers.
- *Fjord:* is a steep, deep narrow inlet from the sea formed by the action of glaciers.
- *Fringing reef*: is a reef that grows a few kilometers offshore, parallel to the mainland.
- *Barrier reef:* is a coral reef that grows farther (25 km) offshore than a fringing reef.
- *Key (Cay):* is a small island that forms when chunks of coral stone break off from a reef and accumulate on the seafloor; e.g., the Florida Keys and the Cayman Islands.
- *Coral atoll:* is a string of islands that forms a circle (around a lagoon); represents the final stage in reef evolution (around a sunken volcanic island); e.g., Midway and Eniwetok.

Summary of the Lesson

Have a volunteer from each group describe their shoreline feature and write a brief description on the board. Have another student volunteer to draw the feature on the board. Students should copy the completed descriptions into their notebooks.

Homework Assignment

Read pages 404 (bottom)–409. Answer Section Review questions 1–3 on page 409.

Chapter 17 / Climate and the Ocean

INTRODUCTION

In Chapter 17, students will learn how the ocean exerts a great influence on Earth's weather and climate. The interaction of air, water, and land—and, particularly, the cycling of water through these layers—determines local weather conditions and global climate patterns. The impact of El Niño events on marine animals and on humans and the impact of humans on global warming trends are also explored.

- Ocean temperatures depend on the heating of Earth's surface by the sun. The ocean is warmest at the equator, coldest at the poles.
- The ocean heats more slowly and retains heat longer than land does. This leads to formation of sea breezes and land breezes.
- Humidity is the amount of moisture in the air. Fogs, dew, and hurricanes all form as a result of temperature differences (in air and water) and levels of moisture in the air.
- El Niño events are caused by a warm ocean current in the Pacific; they affect global weather patterns and disrupt local fisheries.
- The greenhouse effect (and global warming) results from the trapping of heat in Earth's atmosphere by carbon dioxide and water vapor. Burning of fossil fuels may have caused this trend, which has led to increased melting of polar ice caps and a subsequent rise in sea level.

LESSON 1 *(pages 416–419)*

Aim: How can we explain variations in ocean surface temperatures?

Instructional Objectives

Students will be able to:

1. Define angle of isolation and explain its importance.
2. Explain why ocean temperature varies with latitude.
3. Describe how Earth's tilt causes seasonal changes in ocean temperature.

Motivation for the Lesson / Do Now

Show the class a globe or map of Earth. Ask students where they think the *warmest* land and ocean surfaces are, and where the *coldest* land and ocean surfaces are. Explain.

Development of the Lesson

1. Temperature is a measure of the average kinetic energy of a substance. Parts of the ocean surface vary in temperature based on latitude and/or based on the time of year (season).

2. **Write the Aim:** *How can we explain variations in ocean surface temperatures?* Energy from the sun (*radiant energy*) that reaches Earth's surface may be reflected or absorbed. Some of the absorbed energy is transferred into heat. The amount of energy absorbed depends on the angle at which the sun's rays strike Earth's surface, called the *angle of insolation*. The surface temperature of the ocean varies according to latitude (the distance north and south of the equator), due to the differences in the angle of insolation. Refer students to the diagram in Figure 17-2 on page 417, which illustrates this effect.
3. **Key Question:** *Why does ocean temperature vary with the seasons?* Ocean temperature also varies by season as a result of the inclination of Earth's axis 23½ degrees. Project on the board Figure 17-3 on page 418. Have students copy the diagram into their notebooks. Explain how Earth's tilt affects where and when the sun's direct rays strike Earth.

Summary of the Lesson

Organize students into groups to consider the following question: *How does the angle of insolation, and the tilt of Earth's axis, determine ocean surface temperature differences?* Have a student from each group read their answer to the class.

Homework Assignment

Read pages 415–419 (top). Answer Section Review questions 1–2 on page 421, and Chapter Review questions 6 on page 436 and 9–11 on page 437.

LESSON 2 *(pages 419–421)*

Aim: Why is it windy along the coast?

Instructional Objectives

Students will be able to:

1. Define convection currents (in water and in air).
2. Explain how convection currents cause winds.
3. Distinguish between a sea breeze and a land breeze.

Motivation for the Lesson / Do Now

Describe some weather conditions on a day at the beach.

Development of the Lesson

1. The conditions in the atmosphere, such as temperature, moisture, and wind velocity, are called *weather conditions*. Weather will vary from place to place, but over a large geographical area there is an average or prevailing pattern of weather called *climate*. One common

weather condition along coastlines is the wind.

2. **Write the Aim:** *Why is it windy along the coast?* The *wind* is a mass of moving air. Air moves when there is a difference in temperature between adjoining air masses. Along coasts, there is a difference in air temperature over the land and over the ocean.
3. Set up the smoking chimney demonstration illustrated in Figure 17-5 on page 420, or refer students to the diagram in their textbook.

   Key Question: *Why does smoke go down one chimney and go up the other chimney?* Explanation: Smoke goes down one chimney and up the other one because air warmed by the candle rises, and the cooler air entering the other chimney sinks (along with the smoke) to take its place. These movements of air, caused by a difference in temperature, are called *convection currents*.
4. **Key Question:** *How can we explain the breezes that occur along the coast?* A gentle wind is called a *breeze*. There are two kinds of breezes that occur along the shore: a *sea breeze* and a *land breeze*. (Refer students to Figure 17-4 on page 419.) Explanation: During the day, the land heats up more quickly than the water does. The hot air above the beach rises, and the cooler air above the ocean flows landward, producing a *sea breeze*. At night, the opposite occurs. The air over the ocean is warmer because water holds heat longer than land does. The warmer air over the ocean rises, and the cooler air above the land flows seaward to take its place, producing a *land breeze*. These are examples of convection currents (in the air).

Summary of the Lesson

Have students work in groups to explain, in writing, why land and sea breezes occur along the coast. Have a student from each group read their explanation to the class.

Homework Assignment

Read pages 419–421. Answer Section Review question 3 on page 421, and Chapter Review questions 12, 14, and 17 on pages 437–438.

LESSON 3 *(pages 422–424)*

Aim: Why is it foggy along the coast?

Instructional Objectives

Students will be able to:

1. Distinguish between the dew and a fog.
2. Explain how a fog is produced.
3. Describe fog formation in different localities.

Motivation for the Lesson / Do Now

Take a glass of ice water from a refrigerator and place it on your desk. Ask students to write their observations and try to explain what they see.

Development of the Lesson

1. A glass of cold water appears to "sweat" when placed in a warm room. The moisture on the outside of the glass comes from the air. When water vapor in the air makes contact with a cold surface, it condenses (changes from vapor to liquid) to form moisture called *dew*. Warm air that is saturated with moisture near the (cooler) ground is called *fog*.
2. **Write the Aim:** *Why is it foggy along the coast?* The temperature at which water vapor condenses as a cloud or fog is called *dew point*. Coastal fog forms at the surface of the ocean when the dew point is reached; i.e., the cold surface water cools the warm, moist air above it to the point at which the air cannot hold all the water vapor.
3. **Key Question:** *How can we explain fog in different parts of the world?* Describe the following instances of fog formation on coastlines:

- *San Francisco fog:* occurs when the cold California Current moving south along the coast meets the warm, moist air carried in by the prevailing westerly winds; the cold water cools the moist air above it to the point at which the excess water vapor forms a fog.
- *London fog:* occurs when the warm Gulf Stream reaches the coast of Great Britain; the warm, moist air above the current meets the cool land surface of England, forming a fog.
- *Newfoundland fog:* occurs when the warm Gulf Stream (heading north) meets the cold Labrador Current (heading south), causing condensation into a thick fog; this coast is the foggiest place in the world, averaging about 120 foggy days each year.

Summary of the Lesson

Have students work in groups to explain how fog forms in different localities. They can use a map (showing currents) as a guide. Ask volunteers to read their explanations to the class.

Homework Assignment

Read pages 422–424. Answer Section Review questions 1–3 on page 424, and Chapter Review questions 13 and 16 on page 438.

LESSON 4 *(pages 424–429)*

Aim: How can we explain stormy weather along the coast?

Instructional Objectives

Students will be able to:

1. Discuss the dynamics of a hurricane.
2. Explain why hurricanes are less destructive today.
3. Describe El Niño (and La Niña) currents.

Motivation for the Lesson / Do Now

Ask the students if they have ever experienced a hurricane or some other stormy weather. Have them describe their experience.

Development of the Lesson

1. Two of the most destructive climate events that can occur along coastlines are hurricanes and El Niño currents. A *hurricane* is a coastal storm that has a wind velocity of more than 120 km per hour.
2. **Write the Aim:** *How can we explain stormy weather along the coast?* Hurricanes develop in tropical seas where warm, moist air contains the heat needed to fuel the storm. As the hot, moist air rises, it forms a whirlwind of air that moves up in a spiral direction around a core of calm air, known as the *eye*. Hurricane intensity is rated on a scale from one to five, called the Saffir-Simpson Damage Potential Scale. A category-one hurricane causes "minimal" damage, while a category-five (with winds over 250 km per hour) causes "catastrophic" damage. Hurricanes lose their intensity as they move inland due to the lack of moisture; and they lose intensity as they move over cooler waters due to the lack of sufficient heat.
3. **Key Question:** *Why have fewer people died in hurricanes in recent years (than in previous decades)?* Fewer people die as a result of hurricanes nowadays because of the development of early warning systems provided by the National Hurricane Center in Florida and federal agencies such as NOAA (which fly into the storms and monitor them continuously).
4. **Key Question:** *How can we explain the many climate-related disturbances that have occurred in recent years?* An unpredictable current of warm water, called *El Niño*, which flows eastward across the equatorial Pacific (when the trade winds weaken), is considered responsible for disrupted fisheries off South America, floods and stormy weather in North America,

droughts in Australia, and even famine in Africa.

Summary of the Lesson

Climate events that result from the interplay of oceanic and atmospheric forces have a great impact on coastal communities of marine animals and humans. Have students write in their notebooks brief definitions for hurricane, storm surge, El Niño, and La Niña. Read to class.

Homework Assignment

Read pages 424 (bottom)–429. Answer Section Review questions 1–3 on page 429, and Chapter Review questions 15, 20, and 21 on page 438.

LESSON 5 *(pages 430–433)*

Aim: How can we explain Earth's current warming trend?

Instructional Objectives

Students will be able to:

1. Define the greenhouse effect.
2. Explain causes of the greenhouse effect.
3. Discuss implications of the warming trend.

Motivation for the Lesson / Do Now

Have students copy into their notebooks the graphs in Figure 17-17 on page 432. Ask them to write a conclusion based on a comparison of the data in both graphs.

Development of the Lesson

1. The planet's mean global temperature has increased 1 degree Celsius (1°C) over the past 100 years.

   Write the Aim: *How can we explain Earth's current warming trend?* Examine the two graphs, one of which shows the atmospheric warming trend, and the other which shows the rising sea level. It is thought that this warming trend, commonly called *global warming*, has caused some melting of the polar ice caps and the subsequent rise in the sea level.

2. **Key Question:** *What is causing this warming trend?* Carbon dioxide (CO_2) is called a *greenhouse gas* because it traps heat in the atmosphere in much the same way that glass walls trap infrared heat within a greenhouse. The heating of the atmosphere as a result of the accumulation of greenhouse gases is called the *greenhouse effect*. (Refer to Figure 17-16 on page 430, and Figure 17-18 on page 433.)

3. **Key Question:** *How does* CO_2 *accumulate in the atmosphere?* Much of the CO_2 accumulated in our atmosphere as a result of the burning of *fossil fuels*, such as coal, oil, and gas, brought on by the Industrial Revolution, which began over 100 years ago. Some scientists claim that the current warming trend is part of a natural cycle that will eventually reverse itself through CO_2 uptake by photosynthetic plants and algae.

Summary of the Lesson

Organize the class into several groups, with each team presenting a written argument for or against the notion that global warming is taking place. Have volunteers present their arguments (and supporting evidence from the textbook) to the class.

Homework Assignment

Read pages 430–433. Answer Section Review questions 1–3 on page 433, and Chapter Review questions 8 on page 436 and 22 on page 439.

UNIT 6 ENERGY IN THE OCEAN

Chapter 18 / Temperature and Pressure

INTRODUCTION

In the previous chapter, students learned about the interaction of ocean surface temperatures and the atmosphere. In Chapter 18, they will learn about variations in ocean temperature, from the surface to the seafloor, and about its impact on marine organisms. Animals have a variety of adaptations that enable them to survive in cold waters. Water pressure also has a great impact on the lives of marine creatures. Animals have evolved ways to withstand the crushing pressures of the ocean depths. Also discussed is how aquatic animals have to regulate their water balance with regard to osmotic pressure.

- Temperature differences affect water density. The temperature of the ocean varies (generally decreasing) with depth.
- Colder water temperatures decrease metabolic activity. Marine creatures have special adaptations for living in cold waters.
- The water's mass exerts hydrostatic pressure. This underwater pressure, along with the atmospheric pressure above it, is called ambient pressure, which increases at regular intervals with depth.
- Marine animals have special features that enable them to withstand differences in pressure underwater and to adjust to the effects of deep-sea pressure.

LESSON 1 *(pages 443–446)*

Aim: How does temperature affect the change in state of ocean water?

Instructional Objectives

Students will be able to:

1. Identify water in its different states.
2. Explain why water changes its state.
3. Describe changes in state in different parts of the ocean.

Motivation for the Lesson / Do Now

Display to students an evaporating dish from which ocean water has evaporated, and some ice in a tray. Describe changes in state that occur in water.

Development of the Lesson

1. When water evaporates, or when ice melts, there is *change in state* of the water that is caused by a transfer of heat energy from one substance to another substance.
2. **Write the Aim:** *How does temperature affect the change in state of ocean water?* Temperature is a measure of the amount of heat energy possessed by a substance. *Heat energy* is the energy possessed by a substance as a result of the molecular activity of that substance. Heat energy is measured in *calories*. A calorie is the amount of heat required to raise the temperature of

one gram of water one degree Celsius. The temperature in the ocean varies so much that (at certain times and in certain locations) the water can exist in its three different phases, or states, of matter: solid (ice), liquid (water), and gas (steam).

3. KEY QUESTION: *How can we describe energy transfer during a change in state?* The change for one gram of water to steam requires 540 calories of heat (absorbed by the water), called the *heat of vaporization*. The change for one gram of water to ice (i.e., freezing) requires 80 calories of heat (removed from the water), called the *heat of fusion*. (The melting of one gram of ice into water also requires 80 calories of heat.) (See Figure 18-1 on page 444.)
4. KEY QUESTION: *Where in the ocean does a change of state occur?* When water evaporates from the ocean surface, there is a change of state from liquid to gas, and heat is released into the atmosphere. On active volcanic islands like Hawaii, hot molten lava sometimes flows into the ocean, causing it to boil and produce billowing clouds of steam. When water on the ocean surface falls below the freezing point, it changes into ice.
5. KEY QUESTION: *What kinds of ice occur in the ocean?* There are two kinds of ice in the ocean: *sea ice* and *icebergs*. Sea ice is formed when the temperature of water on the ocean surface drops below the freezing point (at about –2°C). An iceberg is a chunk of ice that breaks off from the end of a glacier and floats into the ocean. Both can be hazards to navigation.

Summary of the Lesson

Divide the class into groups of three to five students. Have each group describe a change in state (for water) and give one example of it that occurs in the marine environment.

Homework Assignment

Read pages 442–446 (top). Answer Section Review questions 1–3 on page 446.

LESSON 2 *(pages 446–446)*

Aim: What do we know about ocean temperature and its effect on living things?

Instructional Objectives

Students will be able to:

1. Explain what the thermocline is.
2. Describe the relationship between temperature and depth.
3. Discuss how marine animals are adapted to cold temperatures.

Motivation for the Lesson / Do Now

Draw the water column on the board. **Ask students:** *Where (in the ocean's water column) would the temperature be warmer—closer to the surface or at the bottom?* Explain.

Development of the Lesson

1. Much of the sun's radiant energy that penetrates the ocean surface is absorbed in the upper layers and changed into heat. Since less heat energy reaches the depths, the temperature is much lower (colder) there. A variety of marine organisms have successfully adapted to the differences in temperature throughout the water column.
2. WRITE THE AIM: *What do we know about ocean temperature and its effect on living things?* Ocean temperature varies with depth. As depth increases, water temperature decreases. But the decrease is not uniform. There is a more rapid drop in temperature between 200 and 1000 meters, in a layer of water called the *thermocline*. Oceanographers get an accurate temperature profile of the ocean by using an instrument called the *bathythermograph*.
3. KEY QUESTION: *How do marine animals adjust to differences in temperature?* In many marine animals (including fish), when the temperature of the environment changes, their internal

body temperature also changes. Animals that have a variable, or unstable, body temperature are called *ectothermic*, or cold-blooded, animals. When the water temperature increases, their energy level or (metabolic activity) also increases. Cold-blooded animals can only live in environments that have narrow temperature ranges. If the temperature is not suitable, they move to either warmer or cooler waters.

4. KEY QUESTION: *How do organisms adapt to extremely cold environments?* The *icefish* (of Arctic and Antarctic waters) has a natural "antifreeze" chemical in its blood that prevents its tissues from freezing. (See illustration on page 448.) Some warm-blooded, or *endothermic*, animals such as whales and seals have a thick layer of fatty tissue (blubber) under the skin, which helps insulate against heat loss. Pinnipeds and other marine mammals also have thick fur. Humans are warm-blooded, but do not have heat-retaining structures. Thus, exposure to cold water can lead to an excessive loss of body heat, which can cause a life-threatening condition called *hypothermia*. If heat loss continues, the drop in body temperature can lead to unconsciousness. A person can restore their normal body temperature by getting out of the water quickly, removing all wet clothing, and keeping warm and dry.

Summary of the Lesson

Organize the class into groups of four to five students. Have each team pick a different animal described in the chapter and answer Chapter Review question 6 on page 463 for that organism.

Homework Assignment

Read pages 446–450. Answer Section Review questions 1–3 on page 450.

LESSON 3 *(pages 451–453)*

Aim: How is underwater pressure measured?

Instructional Objectives

Students will be able to:

1. Explain why water has pressure.
2. Define units of pressure and units of force.
3. Calculate water pressure on the bottom of a container.

Motivation for the Lesson / Do Now

Fill with water a milk container in which you have already cut and plugged three holes. (See Figure 18-5 on page 451.) Pull out the three plugs. From which hole (or holes) does the water spurt farthest? Explain.

Development of the Lesson

1. The water spurts farthest from the hole at the bottom of the container because there is more pressure at the bottom than at the top.

   WRITE THE AIM: *How is underwater pressure measured?* The pressure is defined as a *force* (F) applied over a given *area* (A), and can be calculated by using the following formula: Pressure = force/area, or P = F/A, where pressure is measured in units called *pascals*. One pascal is equal to one newton of force per square meter (m^2). The force (F), or weight, of an object is defined as the product of its *mass* (m) times *acceleration* (a), and can be calculated by using the following formula: F = ma, where acceleration due to gravity is 9.8 m/s^2. Force is measured in units called *newtons*.

2. KEY QUESTION: *If the mass of water in a container is 0.5 kilograms (kg), what is the water pressure* (P) *at the bottom of the container?* First find the *force*, using the formula F = ma:

   F = (0.5 kilograms) (9.8m/s^2); F = 4.9 newtons.

   Substituting the 4.9 newtons force (F) into the formula for pressure (P), you have:

   P = F/A; P = 4.9 newtons/A.

   To find the *area* (A) at the base of the container, multiply the length, which is 100 mm (or 0.1 m) times the width, which is also 100 mm (or 0.1 m), using the formula A = l × w:

$A = 0.1m \times 0.1m$; $A = 0.01\ m^2$.

Substituting the 0.01-m^2 area (A) into the formula for pressure (P), you have:

$P = F/A$; $P = 4.9$ newtons$/0.01m^2$;
$P = 490$ pascals.

Summary of the Lesson

Organize the class into groups of four students. Have them work on problems to calculate pressure. Vary the values for the size of the container and/or magnitude of the water mass for each team. Have volunteers from each group come to the board to write out the problems.

Homework Assignment

Read pages 451–453 (top). Review the units of measurement for force (newtons) and for pressure (pascals), and the formulas for finding force (F), area (A), and pressure (P).

LESSON 4 *(pages 453–454)*

Aim: How does pressure vary with depth?

Instructional Objectives

Student will be able to:

1. Define ambient pressure.
2. Describe the relationship between pressure and depth.
3. Explain why pressure varies with depth.

Motivation for the Lesson / Do Now

Draw on the board a picture of a diver underwater and a person in a rowboat. Which person is under greater pressure? Explain.

Development of the Lesson

1. The diver is under greater pressure because the water's mass exerts more pressure than the atmosphere does.

   Write the Aim: *How does pressure vary with depth?* The pressure exerted by a mass of water is called *hydrostatic pressure*. The pressure exerted by air is called *atmospheric pressure*. Under normal conditions, the atmospheric pressure at sea level is equal to approximately 101 kilopascals (kPa). For every 10 meters of depth, hydrostatic pressure increases by 101 kPa (one atmosphere). The total pressure, or *ambient pressure*, on a diver is the sum of the atmospheric pressure plus the hydrostatic pressure. Pressure can also be expressed in *atmospheres*, where one atmosphere equals 101 kPa. (See Table 18-2 on page 453.)

2. **Key Question:** *How can the relationship between pressure and depth be described?* The relationship between pressure and depth is shown in Figure 18-6 on page 454. There is a direct relationship between depth and pressure. As depth increases at regular intervals, pressure also increases at a uniform rate (and vice versa).

3. **Key Question:** *What is the ambient pressure on a diver at a depth of 60 meters?* The ambient pressure would be the sum of the atmospheric pressure (101.325 kPa) plus the hydrostatic pressure (607.950 kPa), which equals a total (ambient) pressure of 709.275 kPa.

4. **Key Question:** *Why is there a pressure of one atmosphere at zero depth (i.e., at the ocean surface)?* Air exerts pressure on the ocean surface equal to one atmosphere (101.325 kPa).

Summary of the Lesson

Organize the class into groups of three to four students. Have each team determine the ambient and hydrostatic pressures at seven different depths, going from 70 meters to 130 meters. Have each group leader write an answer on the board and explain it to the class.

Homework Assignment

Read pages 453–454 (top). Answer Section Review question 1 on page 457, and Chapter Review questions 14–16 on page 465.

LESSON 5 *(pages 454–457)*

Aim: Why does water pressure limit the depth to which humans can descend?

Instructional Objectives

Students will be able to:

1. Explain how ambient pressure affects humans.
2. Discuss the three kinds of barotraumas.
3. Describe how decompression illness occurs.

Motivation for the Lesson / Do Now

Why can't humans explore deep-sea wrecks, such as the *Titanic*, in scuba gear? Explain.

Development of the Lesson

1. Pressure limits the depths to which humans can descend. The Ama pearl divers of Japan have the greatest endurance of any free divers; they can make repeated dives to 18 meters and stay down for one minute. The record for a single free dive is about 105 meters, whereas the record for scuba diving is 132 meters.
2. **Write the Aim:** *Why does water pressure limit the depth to which humans can descend?* As soon as a diver goes underwater, ambient pressure exerts a force over the entire surface of his or her body. The body's thin membranes are the first to feel the effects of pressure.
3. **Key Question:** *How does water pressure affect the body's membranes?* Display a wall chart or model of the ear. Point to the eardrum (tympanic membrane) and the sinus cavities in the facial bones, which are lined with membranes. As a diver descends, pressure increases on these membranes, causing discomfort or pain. Pain in the ear is called *ear squeeze* and pain in the forehead is called *sinus squeeze*. This pain can be eliminated by equalizing the pressure, which is done by blowing through the nose while pinching the nostrils closed. When the discomfort is eliminated, the diver can continue to descend. Ear squeeze and sinus squeeze are injuries that occur only when the diver descends. Any diving injury associated with pressure changes (on descent or ascent) is called a *barotrauma*.
4. **Key Question:** *What kinds of injuries occur during ascent?* Coming up too quickly can cause a serious injury to scuba divers called the *bends*. If a diver ascends too quickly, there is a sudden decrease in pressure. This decrease, called *decompression*, can cause gases to form bubbles in the tissues in the same way that bubbles appear in a bottle of soda when it is opened. The gas bubbles accumulate in the joints, causing the diver to bend over in pain. The bends is an example of a *decompression illness*.
5. **Key Question:** *Can a decompression illness be fatal?* Another decompression illness is called an *air embolism*. This potentially fatal condition occurs when gas bubbles develop inside the blood vessels, blocking circulation to vital organs such as the heart or brain. To prevent decompression illness, scuba divers must ascend slowly, while breathing at a normal rate. Explain that decompression illness does not occur in snorkelers because they are not breathing in compressed air. A diver can be treated for decompression illness by being placed inside a *decompression chamber* for several hours.
6. **Key Question:** *What other factors limit the depth to which divers can descend?* Scuba divers who make deep dives below 30 meters may experience *nitrogen narcosis*, a condition that resembles alcohol intoxication. The diver appears drunk and is not able to carry out simple tasks, a threat to the diver's safety. Nitrogen narcosis results from breathing nitrogen gas (N_2) under pressure from a compressed air tank. Removing nitrogen and adding helium reduces the incidence of nitrogen narcosis.

Summary of the Lesson

Organize the class into four or five groups. Have each team research (in their textbook) and write

about one type of barotrauma or diving illness. Have each group leader write their brief description on the board. Encourage discussion.

Homework Assignment

Read pages 454–457. Answer Section Review questions 2–3 on page 457, and Chapter Review question 7 on page 463.

LESSON 6 *(pages 457–460)*

Aim: How do aquatic organisms maintain a proper water balance?

Instructional Objectives

Students will be able to:

1. Define osmoregulation.
2. Describe how the process of osmosis occurs.
3. Explain why some aquatic organisms are poor osmoregulators.

Motivation for the Lesson / Do Now

If a goldfish is accidentally placed in a saltwater tank, it will die. Likewise, if a sea star is accidentally placed in a freshwater tank, it will die. Explain.

Development of the Lesson

1. The goldfish would die because, in a saltwater tank, it would lose too much water from its body. The sea star would die because, in a freshwater tank, it would gain too much water from the environment.
2. **Write the Aim:** *How do aquatic organisms maintain a proper water balance?* The ability of an aquatic organism to maintain a proper (internal) water balance is called *osmoregulation*. This ability depends on the process of *osmosis*, which is the movement of water molecules (through a semi-permeable membrane) from an area of higher concentration to an area of lower concentration.
3. **Key Questions:** *How can we explain why the goldfish and the sea star would die?* The following explains how osmoregulation works (or *doesn't* work) in aquatic organisms:
   - *Goldfish in salt water:* The concentration of water molecules is greater inside the fish than outside, because the salt outside takes the place of water molecules. Since the osmotic pressure is greater inside the fish than outside, water will leave the fish through its gill membranes by outward osmosis. The goldfish, unable to compensate for the water loss, dies of dehydration (severe water loss).
   - *Sea star in freshwater:* The water molecules move from where they are more concentrated (outside the sea star) to where they are less concentrated (inside the sea star). The sea star is unable to eliminate the excess water that enters due to inward osmosis. The increased water pressure, or osmotic pressure, inside the sea star upsets cell function and causes death.
4. Aquatic animals such as the goldfish and sea star, which cannot adjust to environments that vary greatly in salinity, are considered to be poor *osmoregulators*. Salmon, on the other hand, are considered to be extremely good osmoregulators.
5. **Key Question:** *Why is the salmon such a good osmoregulator?* The salmon is a migratory fish that spends its juvenile stage in the river where it is born (freshwater), and its adult stage in the ocean (saltwater). When the salmon are in the ocean, the salinity of their body tissues is 18 parts per thousand (ppt), while the surrounding water is 35 ppt. There is a big difference in salinity between the fish and its environment, with the concentration of water molecules greater inside the fish than outside. As a consequence, outward osmosis occurs; water leaves the fish through its gill membranes. To counter this water loss (and

avoid dehydration), the salmon drinks seawater but excretes the excess salt from its gills and in its urine.

6. When the salmon swims upstream to spawn in the river, it encounters zero salinity, while the salinity of its body tissues is still 18 ppt. Since the salinity is greater inside the fish than outside, the concentration of water molecules is greater outside the fish (in the freshwater). This difference in the concentration of water molecules causes water to enter the fish by inward osmosis. To counter this intake of freshwater, the salmon excretes the excess water in the form of dilute urine.

Summary of the Lesson

Organize the class into groups of four to five students. Have them write an answer, in their own words, to the following question: *Is the salmon a good osmoregulator or a poor osmoregulator?* Explain. Call on students to write their answers on the board. Read the responses aloud. Correct for spelling and grammar. Encourage discussion.

Homework Assignment

Read pages 457 (bottom)–460. Answer Section Review questions 1–3 on page 460, and Chapter Review questions 12 and 17 on pages 464–465.

Chapter 19 / Light and Sound in the Sea

INTRODUCTION

In Chapter 19, students will learn how two forms of energy—light and sound—affect the lives of marine organisms. First, students will learn about the properties of light and how light behaves in water. Oceanic lifeforms have evolved many structures and behaviors that relate to light in the water, such as vertical migration, camouflage, bioluminescence, and unusual color patterns. The basic properties of sound are explained, since sound is an important form of energy underwater. Animals use sound to communicate in the ocean. Sonar is another form of sound used underwater by animals and people.

- Light is a form of solar energy; it penetrates best in clear, shallow waters. The area of light penetration in the ocean is called the photic zone.
- Phytoplankton, algae, and marine plants depend on light to carry out photosynthesis.
- Some deep-sea animals produce their own light to help them see in the dark, attract mates, find prey, and communicate.
- Sound is a form of energy produced by the vibration of air molecules. Sound travels faster in water than it does in air.
- Marine animals use sound for communication, navigation, to deter enemies, and to stun prey. Sonar is an important form of sound.

LESSON 1 *(pages 467–470)*

Aim: What is light and how does it behave in the ocean?

Instructional Objectives

Students will be able to:

1. Define the electromagnetic spectrum.
2. Describe how light behaves in water.
3. Explain why the ocean looks blue.

Motivation for the Lesson / Do Now

Ask students to list some different sources of light (both natural and artificial). Explain how one of them is produced.

Development of the Lesson

1. Different sources of light include the sunlight, incandescent light, fluorescent light, moonlight, "glo-stick" light, light from bioluminescent organisms, and so on. The sun, of course, is the major source of light for Earth.
2. **Write the Aim:** *What is light and how does it behave in the ocean?* Light is a form of *radiant energy* that comes to us from the sun. Visible light is the light that we can see and is one of several forms of radiant energy, collectively called the *electromagnetic spectrum*. (Refer students to Figure 19-1 on page 467.) Light that reaches the ocean can be reflected or absorbed, and some of it is changed to heat energy in the water.
3. **Key Question:** *What happens to light when it reaches Earth?* About 20 to 50 percent of the light that reaches Earth either bounces off the atmosphere into space or is taken up by the atmosphere. Light that bounces off a surface is called *reflected light*. Light that is taken up by a substance is called *absorbed light*. The remaining light (about 50 percent) passes through the atmosphere and reaches Earth's surface. Light that passes through a substance is called *transmitted light*.
4. **Key Question:** *What happens to light that strikes the ocean surface?* When sunlight strikes the ocean surface at an angle of 90 degrees (as at the equator), it penetrates the surface and continues in a straight line. When light enters the water at an angle of less than 90 degrees, it does not continue in a straight path, but bends. This bending of light as it passes through substances of different densities, at an angle of less than 90 degrees, is called *refraction*. (Refer students to Figure 19-2 on page 468.)
5. **Key Question:** *Why does the ocean look blue?* Visible light is made up of a series of colors (i.e., different wavelengths), called the *spectrum*. The color of any substance is actually the color of the wavelength of light that is reflected from that object back to the observer's eyes. When the ocean appears blue (or blue-green), it is because the blue wavelength has more energy than do the other colors and therefore can penetrate the water more deeply. The blue color is scattered and reflected from deeper in the ocean ("deep blue sea") back to the observer's eyes. (Other colors are absorbed.)

Summary of the Lesson

Project Figure 19-3 (on page 469) on the overhead. **Ask students:** *Where should the person aim the spear—directly at the fish, in front of the fish, or in back of the fish?* Explain. To avoid missing due to refraction, the person should aim in front of the fish.

Homework Assignment

Read pages 466–470. Answer Section Review questions 1–3 on page 470, and Chapter Review questions 6 on page 482 and 14–15 on pages 483–484.

LESSON 2 *(109–110)*

Aim: How do marine organisms use light to make food?

Instructional Objectives

Students will be able to:

1. Define the process of photosynthesis.
2. Explain how photosynthesis occurs.
3. Discuss the light and dark reactions.

Motivation for the Lesson / Do Now

Explain the following statement: All the energy in living things can be traced back to the sun.

Development of the Lesson

1. Algae and plants capture sunlight to make food. Animals feed on plants to satisfy their energy needs. Nearly all forms of life need light, either directly or indirectly.
2. **Write the Aim:** *How do marine organisms use light to make food?* Project on the overhead or draw on the board a marine alga or phytoplankton, with labels showing the intake of carbon dioxide and water and the production of the glucose and oxygen. The process by which algae and plants produce food and oxygen is *photosynthesis*.
2. **Key Question:** *How can we describe the process of photosynthesis?* Write the word equation for photosynthesis on the board:

   Six molecules of carbon dioxide plus twelve molecules of water, in the presence of light and chlorophyll, yields one molecule of glucose plus six molecules of oxygen plus six molecules of water.

   Now write the chemical equation for photosynthesis on the board:

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

3. **Key Question:** *Where does the process of photosynthesis occur in a plant?* The process of photosynthesis begins when light (radiant energy) is captured inside a plant cell by its *chloroplasts*. The chloroplasts contain a green pigment called *chlorophyll*.
4. **Key Question:** *How does the process of photosynthesis occur?* Photosynthesis can be divided into two phases: the light reaction, during which oxygen is produced; followed by the dark reaction, during which glucose (sugar) is made. When light enters chlorophyll, it excites the electrons to a higher energy state, causing them to split water molecules. The electrons are transferred from one special molecule to another inside the chlorophyll in a stepwise fashion known as the *electron transport system*. During electron transport, energy is released and converted into two energy-rich chemical compounds: $NADPH_2$ and ATP. The production of ATP and oxygen occurs during the first phase (i.e., light reaction) of photosynthesis.

Summary of the Lesson

Have students write out the word and formula equations for photosynthesis. In a chorus response, have all the students read the formula equation aloud.

Homework Assignment

Read pages 109–110. Answer Section Review question 2 on page 111, and Chapter Review question 16 on page 484.

LESSON 3 *(pages 471–474)*

Aim: What role does light play in the lives of marine animals?

Instructional Objectives

Students will be able to:

1. Define bioluminescence.
2. Explain how bioluminescence occurs.
3. Discuss the role of light and color in fish.

Motivation for the Lesson / Do Now

Compare and contrast the following statements: *Light makes life. Life makes light.*

Development of the Lesson

1. Light makes life during photosynthesis. But life can also make light.

   Write the Aim: *What role does light play in the lives of marine organisms?* In the ocean, some

living things can make their own light, in a process called *bioluminescence*. *Noctiluca*, a dinoflagellate that glows in dark water, makes light within its cell as a result of the following chemical reaction:

$$\text{Luciferin} + \text{Luciferase (enzyme)} \longrightarrow \text{Light}$$

$$(O_2 + H_2O + \text{ATP at } 25^\circ C)$$

2. The chemical compound *luciferin* reacts with the enzyme *luciferase* in the presence of oxygen and water (at a temperature of about 25 degrees Celsius) to produce light. Some shrimp, squid, and fish that inhabit the dimly lit waters of the mid-ocean region have patches of bioluminescent tissue called *photophores*. The flashlight fish (genus *Photoblepharun*) produces light by means of light-emitting bacteria that live within a special organ located below each eye. (Refer students to Figure 19-5 on page 473.)
3. **Key Question:** *How is color used by marine life?* Marine organisms display all the colors of the spectrum. Color is due to the presence of chemical compounds called pigments, found in the cells called *chromatophores*. One type of pigment, melanin, may have its granules either dispersed or contracted within the chromatophores, making the cells look either darker or lighter. The pattern of dark cells and light cells helps an organism blend in with the color and texture of its natural background, providing camouflage. Some fish have *countershading*, a coloration that helps them match their background in the sea. By contrast, some fish, like the rock beauty with its black and yellow coloration, has what is called *color contrast*—a feature that makes a fish stand out against its background, which helps in species recognition and as advertisement for the purpose of successful propagation.

Summary of the Lesson

Organize the class into groups of four to five students. Have some teams describe the role of light and bioluminescence in the lives of various sea creatures; have the other teams describe the role of color in different marine animals. Read summaries aloud to the class.

Homework Assignment

Read pages 471–474. Answer Section Review questions 1–3 on pages 474–475, and Chapter Review questions 12–13 on page 483 and 17–18 on page 484.

LESSON 4

Aim: What role does sound play in the ocean environment?

Instructional Objectives

Students will be able to:

1. Describe the characteristics of a sound wave.
2. Explain how whales and dolphins echolocate.
3. Discuss the use of sonar by people.

Motivation for the Lesson / Do Now

Give students coiled (empty) seashells to hold up to their ears. Ask the students if they really hear the sound of the sea inside the shells. Explain.

Development of the Lesson

1. It may sound like the sea, but what you really hear inside the coil of a shell is the sound of air molecules vibrating.

   Write the Aim: *What role does sound play in the ocean environment?* Many ocean animals (e.g., fish, seals, and whales) use sound to help them survive.
2. Sound is a form of energy produced by objects (molecules) that *vibrate*, or move rapidly back and forth. Strike a tuning fork and touch the vibrating fork to the surface of a jar of water.

Notice the splash and the compression wave that is transmitted (through the water) in all directions. When a compression wave reaches a receptor (e.g., an ear), the quality of sound is perceived.

3. The parts of a sound wave in which the air molecules are farther apart are called *rarefactions*. The parts of a sound wave in which the air molecules are closest together are called *compressions*. (Refer students to Figure 19-7 on page 476.)
4. **Key Question:** *How can we describe the characteristics of a sound wave?* Sound can be recorded in the form of a sound wave on an instrument called an *oscilloscope*. The highest point of a sound wave is the *crest*; the lowest point of a wave is the *trough*. The loudness, or *volume*, of a sound is represented by the height, or *amplitude*, of its wave. The *pitch*, or *frequency*, of a sound wave is represented by its *wavelength*, which is the distance between two successive crests. (Refer to Figure 19-8 on page 476; project or draw this diagram on the board as you describe its characteristics.)
5. **Key Question:** *How do marine mammals use sound?* In the depths of the ocean, where there is little or no light, marine mammals (cetaceans) use sound to find their way and to locate prey. The (underwater) use of sound for navigation and for locating objects is called *echolocation*. Cetaceans have no ears. Instead, cetaceans such as dolphins *echolocate* by sending out sound waves (clicks) through a mound of tissue in their forehead, called the *melon*, and receiving the returning sound waves, called *echoes*, through the lower jaw, where their nerve receptors for hearing are located.
6. The famous songs of the humpback whale have a deep (low) pitch because they are composed of low-frequency sound waves. In contrast, the squeaking sound of the porpoise is recorded as a high-frequency sound wave. Cetaceans are known to produce low-frequency sounds when they want to scan the environment, and emit high-frequency sounds when they wish to focus on a particular object.
7. People use an artificial form of echolocation, called *sonar*, to locate objects underwater and to learn more about ocean topography. However, the use of low-frequency sonar by people can have a harmful impact on cetaceans and other marine organisms.

Summary of the Lesson

Ask students the following question (to test their understanding of sound): *If a wave crashes on the beach and there is no one around to hear it, is a sound produced?* Organize the class into several groups to prepare their answer. Have the group leader from each team read their answer aloud. Encourage debate among the students.

Homework Assignment

Read pages 475–480. Answer Section Review questions 1–3 on page 480, and Chapter Review questions 9–11 on page 483 and 20–23 on page 484.

Chapter 20 / Tides, Waves, and Currents

INTRODUCTION

The great motions of the seas—tides, waves, and currents—are discussed in Chapter 20. Students will learn how Earth's movements in space affect the movements of the ocean's waters. Tides are produced by the gravitational pull of the moon and, to a lesser extent, the sun. Waves are produced by the force of the winds,

which results from Earth's rotation. Students will learn about the properties of waves. The spin of the Earth is also responsible for global ocean currents. Different types of currents are discussed in this chapter.

- The tides are produced by the gravitational pull of the moon.
- Winds produce waves; stronger winds cause larger, faster waves. However, tsunamis are caused by geologic activity on the seafloor (not by winds or tides).
- The Coriolis effect states that winds from Earth's rotation cause the specific movements of surface waters (global ocean currents).
- Other types of currents form as a result of differences in water density, seafloor topography, wave action, and shore interactions.

LESSON 1 *(pages 486–488)*

Aim: How can we explain the tides?

Instructional Objectives

Students will be able to:

1. Define high tide and low tide.
2. Describe tidal change.
3. Explain and interpret a tide table.

Motivation for the Lesson / Do Now

Imagine that you go to the beach, drop your towel on the sand, and then go into the water for a swim. You come out a while later and find that your blanket is wet. Explain.

Development of the Lesson

1. A towel that is left on a beach can get wet from the rising tide. The ocean waters are always in motion. Currents circulate around the world. Waves crash on the beach. And water is pushed and pulled by the tides.
2. **Write the Aim:** *How can we explain the tides?* The periodic rise and fall of the surface of the ocean is called the *tide*. The highest point reached is called *high tide*, and the lowest point reached is called *low tide*. The vertical distance between the high tide and low tide is called the *intertidal range*. (Refer to Figure 20-1 on page 486.)
3. **Key Question:** *Why is it important to know the tides?* The tides affect various aspects of life along the shore. Storms hitting the coast at high tide cause more damage (from flooding) than do storms hitting at low tide. Ships coming into port have to wait in deeper water for the high tide before docking. The best time to schedule a field trip to observe living creatures along the shore is at low tide.
4. **Key Question:** *How do you know when it is high tide or low tide?* Local papers often print the daily tide table for a region. An area that has two high and two low tides each day has a *semidiurnal tide*. The East Coast (Atlantic) of the United States has a semidiurnal tidal pattern. The Gulf Coast has one high and one low tide each day, called a *diurnal tide*. The West Coast (Pacific) has a pattern of *mixed tides* (similar to that of the East Coast), with two high and two low tides each day.

Summary of the Lesson

Hand out a map of a local coastal area (or well-known coastal area if you are landlocked). Have students work in groups to locate on the map the sites listed in that area's tide table. Write in the high tides and low tides for each site. Compare students' findings.

Homework Assignment

Read pages 485–488 (top). Answer Chapter Review questions 1 on page 510 and 17 on page 512.

LESSON 2 *(pages 488–491)*

Aim: How can we explain the rhythm of the tides?

Instructional Objectives

Students will be able to:

1. Explain how gravity causes tides.
2. Describe the tidal changes.
3. Discuss the role of the moon and the sun in tidal change.

Motivation for the Lesson / Do Now

Project or write on the board the tide table shown on page 487 (Table 20-1). Why do tides change? Explain.

Development of the Lesson

1. The tide table shows that the ocean advances and retreats along the shore in a periodic fashion. Refer to the photographs in Figure 20-2, on page 487, which show the big difference between high tide and low tide at Mont-Saint-Michel near France.
2. **Write the Aim:** *How can we explain the rhythm of the tides?* A pulling force called *gravity* is responsible for the tides. Sir Isaac Newton (1642–1727) discovered that gravity is a pulling force exerted between any two bodies in space. Earth and the moon exert a pulling force on each other. The pull of the moon on Earth causes the ocean water that is facing the moon to be pulled toward the moon, producing a *tidal bulge*, which is a high tide. (Refer to Figure 20-3, on page 488.)
3. **Key Questions:** *How does the tide vary during the month?* When the sun and the moon are aligned with Earth, and pulling on it from the same side, the highest tides, called ***spring tides***, are produced. Spring tides occur during the phases of the moon called *new moon* and *full moon*, which are exactly two weeks apart. When the pull of the sun and the moon on Earth are at right angles, a moderate *neap tide* is produced. (Refer students to Figures 20-4 and 20-5, which show spring tides and neap tides, on page 489.) The highest tides occur at *perigee*, when the moon is closest to Earth; and the lowest tides occur at *apogee*, when the moon is farthest from Earth. In addition, Earth moves closest to the sun in January, called *perihelion*, and farthest away in July, called *aphelion*. The combination of perigee (close to moon) and perihelion (close to sun) will produce the highest tides of all.

Summary of the Lesson

Organize the class into groups of four to five students. Have each team sketch diagrams that show how high tides and low tides are produced during the new and full moons. Ask the group leaders to draw them on the board. Students should copy the correct diagrams into their notebooks.

Homework Assignment

Read pages 488–491. Answer Section Review questions 1–3 on page 491, and Chapter Review questions 6 on page 510 and 21–22 on page 512.

LESSON 3 *(pages 491–493)*

Aim: What is an ocean wave and how is it produced?

Instructional Objectives

Students will be able to:

1. Describe an ocean wave.
2. Explain how a wave is produced.
3. Calculate the height of a wave.

Motivation for the Lesson / Do Now

Imagine blowing on a bowl of hot soup. Describe what happens to the soup's surface.

Development of the Lesson

1. When you blow on a bowl of soup, you see ripples in the liquid's surface. A *ripple* is a small wave. Waves are also produced in the ocean.
2. **Write the Aim:** *What is an ocean wave and how is it produced?* An ocean wave is an up-and-down movement of water on the ocean surface. The wind produces waves when it blows across the surface of the ocean. A gentle wind will produce a small wave or ripple; a strong wind will produce a larger wave.
3. **Key Question:** *How does the wind produce a wave?* When the wind blows, it pushes on the ocean surface, causing the water to lift. In general, the greater the speed and length of time and distance that a wind blows, the greater the size and speed of the waves it produces. (Project or draw on the board a copy of Figure 20-8, page 492.)
4. **Key Question:** *How can wave height be measured?* The *height* of a wave is the vertical distance from the top, or *crest*, of the wave to the bottom, or *trough*, of the wave. *Wave height* can be measured using geometry. Refer to the diagram in Figure 20-9 on page 493. When the stern of a ship is in the trough, an observer on the deck can line up the crow's nest with the crest of the wave. The reference points form a right triangle, in which *BC* is the height of the crow's nest, *AC* is the length from the stern to the base of the mast, and *AB* (length from stern, in trough, to crow's nest) is the hypotenuse. The hypotenuse, which is the side of the right triangle opposite the right angle (*AB*), would equal the height of the wave. You can use the Pythagorean theorem ($a^2 + b^2 = c^2$), where *BC* is *a*, and *AC* is *b*, to calculate the height of side *AB*, or *c*, as shown on page 493.

Summary of the Lesson

Organize the class into groups of four students each. Have the students calculate different wave heights. Substitute new values for sides *BC* and *AC*.

Homework Assignment

Read pages 491 (bottom)–493. Answer Section Review question 1 on page 499, and Chapter Review questions 9–11 on page 511.

LESSON 4 *(pages 493–499)*

Aim: What are the characteristics of ocean waves?

Instructional Objectives

Student will be able to:

1. Calculate the speed of a wave.
2. Explain what causes a wave to break.
3. Discuss the different causes of waves.

Motivation for the Lesson / Do Now

Have students do "the wave" (a group activity) in class. Describe how you would calculate the speed of the wave.

Development of the Lesson

1. By doing "the wave," the class is exhibiting certain wave characteristics.
2. **Write the Aim:** *What are the characteristics of ocean waves?* A group of people standing up in sequence to do "the wave" illustrates a characteristic of waves called a *wave train*. A wave train is a series of waves, each followed by another one moving in the same direction, which is caused by the blowing of a steady wind.
3. **Key Question:** *How can we calculate the speed of a wave?* The speed, or velocity, of any object is found by dividing the distance traveled by the time. When calculating wave velocity, you need to know the distance (in meters) between two successive waves, i.e., the *wavelength*, and the time (in seconds) it takes for a wave to pass a given point, i.e., the *period*. Thus, velocity (*V*) = wavelength (*W*)/period (*P*).

4. Have students solve the following problem: *If the wavelength is 10 meters and the period is 5 seconds, what is the speed of the wave?* Call on a student to work out the problem on the board.

   $V = W/P$

   $V = 10$ meters/5 seconds

   $V = 2$ meters/second

5. Another characteristic of a wave is that it "breaks" on a beach.

   KEY QUESTION: *What causes a wave to break on the beach?* Project or draw on the board a copy of Figure 20-11, on page 496. As a wave approaches the shore, it enters shallow water, makes contact with the seafloor, and slows down due to friction. The wave breaks when the water depth below it is less than one-half its wavelength.

6. KEY QUESTION: *How can we explain waves breaking on the open seas?* Strong winds produce steep waves with narrow crests. The narrow crests are easily blown off by the winds, creating a mixture of air and water known as a *whitecap*. Whitecaps are a sure sign of very windy weather.

7. KEY QUESTION: *In which direction do waves move?* Create waves in a large tank or aquarium. Drop in a cork. Have students observe that the cork moves up and down, but does *not* horizontally. Ocean waves move up and down. The *energy* of the wave moves out from the point of origin (recall the *ripples*), but the water itself stays in place.

8. KEY QUESTION: *What other conditions produce waves?* The energy of an incoming tide can generate a high wave that travels several kilometers up the mouth of a river with a gentle slope and high tidal range. This advancing wave, called a *tidal bore*, may cause flooding upriver. A much more destructive wave is the *tsunami*, or *tidal wave*, caused by undersea earthquakes or volcanic activity. The origin, or *epicenter*, of a tsunami generates a great deal of energy, which reaches the ocean surface through the water column and produces high velocity waves. A tsunami slows as it approaches shore, and its energy is converted into a lifting force that produces the giant wave.

Summary of the Lesson

Organize the class into several groups. Have each group perform a wave train in class and then calculate its velocity.

Homework Assignment

Read pages 493 (bottom)–499. Answer Section Review questions 2–3 on page 499, and Chapter Review questions 7 on page 510 and 15–16, 18, and 23 on pages 512–513.

LESSON 5 *(pages 499–501)*

Aim: What do we know about ocean currents?

Instructional Objectives

Students will be able to:

1. Identify global ocean currents.
2. Describe the location and direction of ocean currents.
3. Explain how ocean currents move.

Motivation for the Lesson / Do Now

Display a world map. Point to the coast of Peru, in South America, and to the island of Tahiti, in the Pacific Ocean. Ask how Thor Heyerdahl sailed on a raft from Peru to Tahiti. Explain.

Development of the Lesson

1. In 1947, the Norwegian explorer Thor Heyerdahl sailed on a raft from Peru to Tahiti, a distance of 7000 km. He accomplished this by "hitching a ride" on an ocean current.
2. WRITE THE AIM: *What do we know about ocean currents?* An ocean current is a mass of moving

Ocean Current	Location	Direction
Gulf Stream	East Coast of U.S.A.–No. Hemisphere	Clockwise
Canary Current	West Coast of Africa–No. Hemisphere	Clockwise
No. Equatorial Current	North of Equator–No. Hemisphere	Clockwise
West Wind Drift	Mid-Atlantic & Pacific Ocean–No. Hemisphere	Clockwise
No. Atlantic Drift	North Atlantic Ocean–No. Hemisphere	Clockwise
So. Equatorial Current	South of Equator–So. Hemisphere	Counter-clockwise
Brazil Current	East Coast of So. America–So. Hemisphere	Counter-clockwise
East Australia Current	East Coast of Australia–So. Hemisphere	Counter-clockwise
Benguela Current	West Coast of Africa–So. Hemisphere	Counter-clockwise
Peru Current	West Coast of So. America–So. Hemisphere	Counter-clockwise

seawater. The largest currents that move across the ocean are called *global ocean currents*. Provide handouts of Figure 20-15, which shows the major ocean currents, or refer students to the map on page 500.

3. **Key Question:** *How can we describe the location and direction of the ocean currents?* Organize the class into several groups. Provide handouts that list the major ocean currents. Have students fill in the information on each current's location and direction.
4. **Key Question:** *Why do some ocean currents move clockwise, while others move counter-clockwise?* The global ocean currents move in a clockwise direction in the northern hemisphere and in a counter-clockwise direction in the southern hemisphere. The spinning of Earth causes the winds to move in these directions; and the winds drive the ocean's *surface currents*. This circular drift of the oceans in opposite directions in the two hemispheres is known as the *Coriolis effect*. The continents deflect the ocean currents, causing them to move in giant circles called *gyres*.

Summary of the Lesson

Have students identify the location and direction of five more ocean currents. Group leaders should fill in the information on the board and read it aloud to the class.

Homework Assignment

Read pages 499 (bottom)–501. Answer Section Review question 1 on page 507, and Chapter Review questions 12 and 19 on pages 511–512.

LESSON 6 *(pages 502–507)*

Aim: *What conditions promote the development of ocean currents?*

Instructional Objectives

Students will be able to:

1. Identify the different types of ocean currents.
2. Explain how temperature and salinity differences cause ocean currents.
3. Describe how and where upwellings occur.

Motivation for the Lesson / Do Now

When you tread water in the ocean (or in a lake), why is the water noticeably colder at your feet than at your shoulders? Explain.

Development of the Lesson

1. Surface water is warmer than the water below, because the sun heats the surface more.

2. **Write the Aim:** *What conditions promote the development of ocean currents?* Temperature differences can produce vertical (subsurface) ocean currents. Just as air does, warm water rises and cold water sinks, which promotes the development of ocean currents. Picture the ocean as a giant pool heated by the sun. At the equator, the water is warmer, so it rises. At the poles, the water is colder, so it sinks. As the warmer water rises at the equator, the colder water from the poles flows in to take its place, creating giant cycles of flowing water. This movement of water caused by a temperature difference is called a *convection current*, and it produces a type of ocean current. Refer students to Figure 20-19 on page 503.
3. **Key Question:** *How does a difference in salinity produce ocean currents?* Differences in salinity between two bodies of water can produce subsurface ocean currents. For example, the Mediterranean Sea (3.9%) has a higher salinity than the Atlantic Ocean (3.5%), because the Mediterranean region is hot and dry, and its sea is enclosed, so more evaporation takes place. When seawater evaporates, its salt is left behind, increasing its salinity. The saltier Mediterranean water is denser, so it sinks and flows out toward the ocean; the less-salty Atlantic is less dense, so its water flows in above the Mediterranean's to take its place. (See the NASA photo, Figure 20-17 on page 503, which shows this flow of the Atlantic.)
4. **Key Question:** *What do we know about deep ocean currents?* Fast-moving currents that move along the continental slope are called *turbidity currents*. Turbid means cloudy, and the cloudiness is due to the presence of sediments in the current as it rushes down the slope. Turbidity currents are responsible for carving V-shaped canyons in the floor of continental slopes. In addition, there are slow-moving deep ocean currents, called *countercurrents*, which flow in a direction opposite to that of the ocean surface currents above them.
5. **Key Question:** *How do ocean currents benefit ocean life?* Vertical ocean currents caused by differences in temperature and salinity can bring nutrient-rich waters from the seafloor up to the surface. The rising of such water from the deep is called an *upwelling*. Upwellings are significant because they transport phosphates and nitrates (nutrients on which plankton depend) to the ocean surface. In turn, marine fish, birds, and mammals benefit from the abundance of plankton. As a result, upwellings that occur along a coast create excellent fishing grounds for people. (Refer to Figure 20-20 on page 504.)
6. **Key Question:** *How do waves and tides produce ocean currents?* After a wave breaks on the beach, its forward momentum transports water up the slope of the beach. The returning seaward current, or backwash, is called an *undertow*. A fast-moving current of water (from a breaking sandbar) that flows seaward from the beach is called a *rip current*. When the tide enters and leaves bays and inlets, the tidal change produces swift-moving currents of water that run parallel to the shore, called *tidal currents*.

Summary of the Lesson

Organize the class into groups of four to five students. Have each team draw and describe a different type of ocean current. Ask the group leaders to read their descriptions to the class.

Homework Assignment

Read pages 502–507. Answer Section Review questions 2–3 on page 507, and Chapter Review question 8 on page 510 and 13–14 and 20 on pages 511–512.

UNIT 7 MARINE ECOLOGY

Chapter 21 / Interdependence in the Sea

INTRODUCTION

The interactions of biotic and abiotic factors and the relationships among different kinds of marine organisms are discussed in Chapter 21. Students will see how the constant recycling of nutrients and resources is essential to biological productivity in the ocean. Nutrient cycles are discussed, as are food chains, food webs, food pyramids, symbiotic relationships in the sea, and ecological succession in marine environments.

- The study of the interaction of living things with each other and with their ocean environment is called marine ecology. Biotic and abiotic factors interact within an ecosystem.
- Nutrient cycles are crucial for the survival of organisms. Bacteria play an important role in the breakdown and recycling of nutrients.
- Food chains are composed of producers, several (trophic) levels of consumers, and decomposers. Food webs are composed of many interconnected food chains, which include many predators and prey.
- Food pyramids show the transfer of energy through food chains.
- There are many examples of symbiotic relationships in the ocean. The three types of symbiotic relationships are mutualism, commensalism, and parasitism.
- Ecological succession occurs in marine environments, such as coral reefs and rocky shores, with each community of organisms slowly replacing the previous community.

LESSON 1 *(pages 516–517)*

Aim: What kinds of interdependence are seen in a marine environment?

Instructional Objectives

Students will be able to:

1. Define interdependence.
2. Describe a food cycle.
3. Explain how an ecosystem works.

Motivation for the Lesson / Do Now

Give two examples of how you depend on others and how others depend on you.

Development of the Lesson

1. Life consists of relationships in which people depend on one another for their everyday needs, such as food and shelter. In the marine world, too, there are relationships among living things in which organisms depend on one another for survival. A relationship in which organisms interact to ensure survival is called *interdependence*.
2. **Write the Aim:** *What kinds of interdependence are seen in a marine environment?* Display, project, or draw on the board a diagram of a balanced marine aquarium tank. (Or refer to an aquarium that you may have set up in your classroom.)

3. **Key Question:** *What marine organisms are found in this aquarium?* The living things in the aquarium may include algae, marine plants, snails, mussels, sea stars, fish, and bacteria. The living organisms in an environment are called *biotic* factors.
4. **Key Question:** *What are some nonliving factors in this environment?* The nonliving factors include temperature, pH, light, substrate, and dissolved gases. The nonliving factors in an environment are called *abiotic* factors. The interacting biotic and abiotic factors within the environment make up an *ecosystem*. This balanced aquarium is its own ecosystem, and so is a tide pool or a coral reef. There are many different ecosystems in the marine world. The study of the interrelationships between living things and their environment is called *ecology*. The study of these relationships in the ocean is called *marine ecology*.
5. **Key Question:** *Why is the aquarium considered to be a "balanced" environment?* In a balanced aquarium, nutrients (in foods) are recycled. The green algae and plants produce food via photosynthesis, so they are called *producers*. Animals such as the snail, sea star, fish, and mussels eat the algae and plants (food), so they are called *consumers*. When producers and consumers die, their remains are broken down and fed upon by bacteria, which are called *decomposers*. This movement of nutrients through the organisms in a balanced aquarium illustrates a *food cycle*.

Summary of the Lesson

Organize the class into groups of four students each. Have each team draw an aquarium that illustrates interdependence through a food cycle. Ask the group leaders to draw the food cycles on the board.

Homework Assignment

Read pages 515–518 (top). Answer Chapter Review questions 5 on page 538 and 14 on page 539.

LESSON 2 *(pages 518–522)*

Aim: How does nutrient recycling occur in a marine ecosystem?

Instructional Objectives

Students will be able to:

1. Identify the major nutrient cycles.
2. Explain how important elements are recycled.
3. Discuss the role of bacteria in the decay process.

Motivation for the Lesson / Do Now

Ask students to describe a recycling program that they participate in.

Development of the Lesson

1. In certain neighborhoods, useful consumer items such as glass, aluminum, plastic, and paper are recovered and used again through a process called *recycling*.
2. **Write the Aim:** *How does nutrient recycling occur in a marine ecosystem?* Organize the class into five groups. Have each team read about, and draw in their notebooks, one of the following nutrient cycles described in the textbook: carbon cycle (page 518), oxygen cycle (pages 518–519), nitrogen cycle (pages 519–520), sulfur cycle (pages 520–521), and phosphorus cycle (pages 521–522). Have the group leaders draw the cycles on the board while the other students copy them into their notebooks.
   - *Carbon cycle:* occurs as photosynthesizing plants and algae take in carbon, in the form of carbon dioxide (an inorganic compound), and produce carbohydrates (organic compounds); animals take in carbon compounds when they eat plants, then they give off this carbon, again in the form of carbon dioxide, as a waste product of cellular respiration; the carbon once again becomes available to plants for photosynthesis.

- *Oxygen cycle:* releases this crucial element as a by-product of photosynthesis from algae and plants; oxygen is taken up by animals and plants for cellular respiration; the carbon and oxygen cycles together are called the *carbon-dioxide–oxygen cycle*, which shows how plants and animals are dependent upon one another.
- *Nitrogen cycle:* makes available this element, through a natural decay process, for the manufacture of proteins; nitrogen moves from dead matter in the sea back into marine plants through a series of chemical reactions controlled by bacteria; one product of the nitrogen cycle is *nitrate*, which is produced through the action of bacteria on ammonia (detoxified); nitrates are then absorbed by plants to synthesize proteins.
- *Sulfur cycle:* recycles this important element for protein molecules; sulfur moves from dead matter in the sea back into marine plants through a series of chemical reactions controlled by bacteria; first, bacterial reaction breaks down wastes into hydrogen sulfide (H_2S); next, bacteria convert H_2S into sulfur, not yet suitable for absorption by plants; other bacteria convert the sulfur into sulfate (SO_4), which is absorbed by algae to make proteins; animals get their sulfur when they eat plants and other animals.
- *Phosphorus cycle:* supplies phosphorus to two of the most important molecules in living things, ATP and DNA; living things need phosphorus for growth and energy; phosphorus moves from dead matter in the sea back into marine plants through a series of chemical reactions controlled by bacteria; this produces phosphate (PO_4), which is absorbed by algae and plants to make DNA and ATP; animals get their phosphorus when they eat plants, etc. The droppings, or *guano*, of many sea birds, is also rich in phosphorus and is harvested and sold commercially as fertilizer.

Summary of the Lesson

Have each group leader read aloud the description of their team's nutrient cycle.

Homework Assignment

Read pages 518–522. Answer Section Review questions 1–3 on page 522, and Chapter Review questions 13, 15, and 17 on pages 539–540.

LESSON 3 *(pages 522–524)*

Aim: What kinds of food relationships occur in a marine ecosystem?

Instructional Objectives

Students will be able to:

1. Define food chain.
2. Describe food relationships in a food chain.
3. Construct a marine food chain.

Motivation for the Lesson / Do Now

Write on the board the following organisms: snail, algae, shark, crab, and octopus. Arrange these animals in a correct sequence, going from prey to predator.

Development of the Lesson

1. The correct sequence (from prey to predator) for the "Do Now" is algae, snail, crab, octopus, and shark. Relationships between organisms that are based on nutritional needs are called *food relationships*.
2. **Write the Aim:** *What kinds of food relationships occur in a marine ecosystem?* A food relationship where one organism serves as food for another organism is called a *food chain*. The ocean is made up of many food chains. Project on the overhead or draw on the board a diagram that shows the following food chain:

Phytoplankton → Zooplankton → Shrimp → Herring.

3. All food chains begin with a producer. The producer (phytoplankton) in the food chain converts radiant energy into the chemical energy of glucose. The first consumer in the food chain is called a *primary consumer* (the zooplankton). The animal that feeds on the primary consumer is called a *secondary consumer* (the shrimp). A food chain may have other consumers, such as a third-level or *tertiary consumer* (the herring), and so on. Each feeding level in a food chain is called a *trophic level*.
4. KEY QUESTION: *How can we distinguish among the different consumers in a food chain?* Consumers that only feed on plants or algae are called *herbivores*. Snails that graze on algae, and zooplankton that eat phytoplankton, are herbivores. Animals that consume only animals are called *carnivores*. The meat-eating shark is an example of a carnivore. A sea turtle that consumes both plants and animals would be called an *omnivore*. Humans also are omnivores.

Summary of the Lesson

Organize the class into several groups. Have each team draw a marine food chain and identify the trophic levels. Students can use the textbook as a guide. Ask the group leaders to draw their food chain on the board and read its description to the class.

Homework Assignment

Read pages 522 (bottom)–524. Answer Section Review question 1 on page 527, and Chapter Review question 16 on page 540.

LESSON 4 *(pages 524–527)*

Aim: How do food relationships illustrate interdependence?

Instructional Objectives

Students will be able to:

1. Define food web and food pyramid.
2. Describe the relationships in a food web.
3. Explain energy dynamics in a food pyramid.

Motivation for the Lesson / Do Now

Project on an overhead the marine food web shown in Figure 21-7 on page 525, but first delete the arrows. Ask students to use a pointer to show the feeding relationships.

Development of the Lesson

1. In this food relationship, several food chains are interconnected with one another.

   WRITE THE AIM: *How do food relationships illustrate interdependence?* When many food chains are interconnected, they form a giant *food web*. The consumers can be categorized as predator and/or prey. *Predators* are the animals that kill and eat other animals. *Prey* are the animals that are killed and eaten.
2. KEY QUESTION: *Which animals in this food web are both predator and prey, and which ones are only predator or only prey?* All the animals are both predator and prey, except for the copepods (herbivores that graze on diatoms) and the orca (a top predator that is not preyed on by any other animal).
3. KEY QUESTION: *What might happen to this food web if the larvae were suddenly wiped out by insecticide spraying along the coast?* It might appear that killifish would decline in numbers, because they feed on the (mosquito) larvae. However, killifish also eat copepods (which might decline due to increased feeding on them by killifish). In food webs, predators often feed on more than one type of prey. This increases their ability to survive when one food source becomes scarce.
4. KEY QUESTION: *How do the organisms in food chains and food webs compare in terms of their numbers?* Organisms in a food chain can be

arranged in a diagram called a *food pyramid*. In a food pyramid of numbers, the population at each higher trophic level is smaller than the one below it. The producers, e.g., plankton, would outnumber the primary consumers, e.g., snails. Likewise, there are more snails than there are lobsters that prey on them. Top predators, e.g., sharks, are the least numerous of all. In other words, each prey population outnumbers the predator population above it. (Refer to Figure 21-8 on page 526.)

5. **Key Question:** *What would happen if predators outnumbered prey?* Large populations of producers and prey are needed to sustain the consumers at each higher trophic level. Otherwise, too many predators would die from a lack of food.
6. **Key Question:** *Which population of organisms in a food pyramid has the lowest amount of available energy?* Since animals cannot get their chemical energy directly from the sun, they need to consume plants and/or other animals. However, at each trophic level, the animals lose a great deal of energy (about 90 percent) as heat in the process of carrying out their life functions. Only about 10 percent of the energy is stored in body tissues. Since there is energy lost at each step in the food pyramid, the population of animals at the top of the food chain, such as sharks, would have the lowest amount of available energy.

Summary of the Lesson

Organize the class into groups of four to five students. Have each group make up a food pyramid, using the textbook as a guide. Ask the group leaders to draw their pyramid on the board and read their description to the class.

Homework Assignment

Read pages 524–527. Answer Section Review questions 2–3 on page 527, and Chapter Review questions 7 and 9–11 on pages 538–539 and 18–21 on page 540.

LESSON 5 *(pages 527–530)*

Aim: What kinds of symbiotic relationships have marine organisms evolved?

Instructional Objectives

Students will be able to:

1. Define symbiosis.
2. Explain why symbiosis evolved.
3. Compare mutualism, commensalism, and parasitism.

Motivation for the Lesson / Do Now

Draw on the board the following diagrams (in each, have two fish facing each other): (a) two fish smiling; (b) one fish smiling, the other with no expression; and (c) one fish smiling, the other fish frowning. Describe the relationships that these three drawings represent. (Remind students that these are "cartoon fish"; real fish do not smile or frown!)

Development of the Lesson

1. In their struggle for existence, marine organisms have evolved a variety of different relationships that aid their survival. When organisms of different species live in close association with each other, it is called *symbiosis*, or a *symbiotic relationship*.
2. **Write the Aim:** *What kinds of symbiotic relationships have marine organisms evolved?* There are three main types of symbiotic relationships: mutualism, commensalism, and parasitism. These are found in terrestrial and marine species.
3. Examples of symbiotic relationships in marine organisms include the following:
   - *Mutualism:* is a relationship in which both species benefit; e.g., the clownfish living among the stinging tentacles of the sea anemone is involved in a mutually beneficial relationship. The clownfish benefits

because it is protected from predators by the sea anemone's stinging tentacles (which do not harm the clownfish); the sea anemone benefits by receiving scraps of food left over by the clownfish.

- *Commensalism:* is a relationship in which one species benefits, while the other is not affected by the association; e.g., the remora (a bony fish) often swims below (or attached to) the underside of a shark–the remora benefits by eating leftovers from the shark's meals; the shark appears to be neither helped nor harmed by the remora.
- *Parasitism:* is a relationship in which one species (the parasite) benefits, while the other species (the host) is harmed; e.g., in fin rot disease, bottom-dwelling fish such as the flounder get infected by a disease-causing microorganism. The fish is harmed (its fins rot); the microbe lives by causing the infection in host fish.

Summary of the Lesson

List on the board the following symbiotic relationships: barnacles on the back of a whale; sea lamprey and lake trout; cleaning wrasse and grouper. Identify and match their types of symbiosis with those of the cartoon fish from the "Do Now." Have students go to the board to write their answers and explain them aloud to the class.

Homework Assignment

Read pages 527–530. Answer Section Review questions 1–3 on page 531, and Chapter Review questions 12 on page 539 and 22 on page 540.

LESSON 6 *(pages 531–534)*

Aim: How do marine communities succeed one another over time?

Instructional Objectives

Students will be able to:

1. Define ecological succession.
2. Describe succession on a bare island.
3. Explain why succession occurs.

Motivation for the Lesson / Do Now

Describe the changes that have taken place over time on your street or in your town.

Development of the Lesson

1. Neighbors and neighborhoods change over time. Likewise, changes occur in the natural world. Marine communities can undergo changes over time.
2. **Write the Aim:** *How do marine communities succeed one another over time?* The process by which one community of organisms gradually replaces, or succeeds, the previous community of living things is called *ecological succession*.
3. Ecological, or biological, succession can occur undersea and on islands, as follows:
   - *Succession underwater:* If you place an object such as a rock or glass bottle in a tide pool and examine it weeks later, you'll see that a thin coat of algae has begun to cover the object, making it feel slimy. Over time, it will be covered by small barnacles, then by seaweeds, and later still by mussels. The same process occurs on the hull of a ship. Organisms like barnacles that attach to a substrate are called *encrusting organisms*.
   - *Succession on an island:* New volcanic islands appear each year in the South Pacific, born when the flow of molten lava from the seafloor reaches the ocean surface. After the lava cools into rock, conditions for life become favorable. Winds and water bring spores and seeds. First, the lichens appear: plantlike organisms composed of an alga and fungus growing together. Acids in the lichen erode the rock, making it more suitable for mosses to grow. The mosses erode

the rock into sediments, a condition suitable for the germination of seeds. Grasses succeed the mosses and then eventually give way to shrubs and, finally, to communities of trees. (Refer students to Figure 21-11 on page 532 and Figure 21-12 on page 534.)

4. **Key Question:** *What causes one community to replace another community over time?* When chemical and physical conditions in an area are no longer suitable for the existing group of organisms (such as after a natural disaster occurs), a new community takes over. The first community to establish itself is called the *pioneer community*. The pioneer organism in underwater succession is the alga; on a volcanic island, it is the lichen. The last stable community to appear in any succession is called the *climax community*. On a volcanic island, the climax community is composed of trees. On an underwater substrate such as the hull of a ship, the climax community could be a bed of mussels. In other underwater regions, it could be a coral reef or a kelp forest.

Summary of the Lesson

Organize the class into groups of four students each. Have each group list, in correct sequence, the ecological succession of organisms in an underwater area and on a volcanic island. Have group leaders explain why succession occurs in these habitats.

Homework Assignment

Read pages 531–534. Answer Section Review questions 1–3 on page 535, and Chapter Review questions 8 on page 538 and 23 on page 540.

Chapter 22 / Pollution in the Ocean

INTRODUCTION

In Chapter 22, students will explore the impact of pollution in the marine environment. They will learn the importance of clean waters to marine organisms and, ultimately, to people as well. The dumping of sewage, toxic chemicals, and solid wastes into the ocean has had adverse effects on various marine environments and marine organisms, causing everything from algal blooms to fish kills, declines in seabird populations, and illnesses in marine mammals and humans. Actions being taken to prevent ocean pollution are also discussed.

- Sewage treatment is essential for preventing the release of toxic microorganisms into the marine environment.
- Toxic chemicals from industrial and agricultural sources have had negative impacts on marine organisms the world over. Solid wastes (litter) also injure marine life.
- Toxic chemicals also reach humans by biomagnifying through the marine food chain.
- Oil pollution, thermal pollution, and radioactive wastes all have an impact on the marine environment.
- Clean, clear, well-oxygenated, non-acidic waters are essential for aquatic life-forms.
- Government and private organizations have been working to reduce pollution and to protect the marine environment.

LESSON 1 *(pages 542–544)*

Aim: What is water pollution?

Instructional Objectives

Students will be able to:

1. Define water pollution.
2. Explain why sewage treatment is necessary.
3. Calculate the coliform levels in water.

Motivation for the Lesson / Do Now

Why have some local beaches been closed to swimming in recent years? Explain.

Development of the Lesson

1. Some local waterways of New York City have been closed to swimming in recent years because of water pollution, which poses a health threat to the public.
2. **Write the Aim:** *What is water pollution?* Pollution describes a degraded condition in the environment that can cause harmful effects on living things, including humans. The substances that degrade the environment are called *pollutants*. Water pollution occurs when harmful substances enter the aquatic environment. One kind of water pollution is caused by *sewage*. Sewage is composed of human *fecal wastes* that are discharged into the ocean and which may contaminate the water with harmful, or *pathogenic*, bacteria. These pathogens can cause life-threatening diseases such as typhoid fever, cholera, dysentery, and hepatitis.
3. **Key Question:** *How is it determined that water is contaminated with sewage?* Water samples are taken and tested for *coliform* bacteria, the microorganisms that are found in the human colon. The water samples are incubated for 24 hours in petri dishes containing a nutrient media. After 24 hours, a single coliform bacterial cell will multiply into millions of cells that form a raised mass of cells called a *colony*. If coliform bacteria colonies are present, they indicate contamination by sewage. The number of colonies is counted and compared with the Public Health Dept. Standards.

Type of Water	Health Standards re: Number of Coliform Colonies
Drinking water	Zero coliforms allowed
Swimming water	Should not exceed 200 coliforms/100 mL
Harbor water	Should not exceed 2000 coliforms/100 mL

4. *Example:* A 10-mL water sample was taken from a public beach and incubated for 24 hours. After 24 hours, the petri dish contained nine coliform bacterial colonies.

   Key Questions: *What is the bacterial colony count per 100 mL? Is the water safe enough to swim in?*

5. *Calculations:* Count the number of colonies in the petri dish that contains the 10-mL water sample and multiply by 10 to get the number of colonies per 100 mL of water. Or calculate as follows: 9/10 mL = x/100 mL; $10x = 900$; $x =$ 90 per 100 mL.
6. *Result:* If there are nine colonies in 10 mL, then there would be 90 colonies in 100 mL.
7. *Conclusion:* The water is safe enough for swimming in, because a count of 90 colonies does not exceed the 200-colony limit (standard) set by the Public Health Department.

Summary of the Lesson

Draw on the board several petri dishes, each with a different number of hypothetical bacterial colonies (per 10-mL sample). Organize the class into groups and have each team calculate the number of colonies per 100 mL of water for each sample. Ask each group leader to state whether their water would be safe for drinking, swimming, or just boating?

Homework Assignment

Read pages 541–544. Answer Section Review questions 1–2 on page 546, and Chapter Review questions 9–11 on pages 565–566.

LESSON 2 *(pages 544–546)*

Aim: How good or bad is the water quality in New York City waters?

Instructional Objectives

Students will be able to:

1. Interpret a graph on water-quality trends.
2. Describe how a sewage-treatment plant works.
3. Discuss sewage treatment's impact on NYC waters.

Motivation for the Lesson / Do Now

Do you think New York City's coastal waters are getting better, staying the same, or getting worse? Explain.

Development of the Lesson

1. There is a difference of opinion among the general public concerning the quality of New York's coastal waters. However, the overall quality seems to be improving.
2. **Write the Aim:** *How good or bad is the water quality in New York City waters?* Project on the overhead, or draw on the board, a copy of Figure 22-4 on page 546, which shows coliform trends since 1970 in NYC waters. Have students copy the graph into their notebooks.
3. **Key Question:** *What conclusions can be drawn from the graph about the overall quality of New York City waters?* Overall, NYC coastal waters continued to improve in quality from 1970 through the 1990s. Sudden increases in fecal coliforms coincide with periods of heavy rainfall. During heavy rains, the sewage-treatment plants cannot handle the flood of water that comes in from storm drains in the streets. This runoff water, and the wastes that it contains, is dumped untreated into local waterways.
4. Contamination of water by sewage can be reduced or eliminated in a *sewage-treatment plant*.

   Key Question: *How does a modern sewage-treatment plant work?* Project on an overhead (or issue handouts of) a schematic diagram of a sewage-treatment plant. A typical sewage-treatment plant contains large tanks that digest the fecal wastes. The solids settle to the bottom of the tanks, forming *sludge*, which is recycled after further treatment and used as a fertilizer for crops. The liquid part of the sewage is treated with chlorine to kill pathogens before it is discharged into waterways; this liquid discharge, or *effluent*, is greatly reduced in pathogens compared to the raw sewage.

Summary of the Lesson

Have students write a brief description of the sewage-treatment process based on the diagram and/or the class discussion. Ask a volunteer to read their description to the class.

Homework Assignment

Read pages 544–546. Answer Section Review question 3 on page 546, and Chapter Review questions 6 on page 565 and 22 on page 567.

LESSON 3 *(pages 546–555)*

Aim: How have toxic substances become part of the marine environment?

Instructional Objectives

Students will be able to:

1. Define toxic chemicals.

2. Cite examples of toxic wastes.
3. Describe the health effects of toxic chemicals.

Motivation for the Lesson / Do Now

Write the following terms on the board: DDT, PCBs, mercury, crude oil, and radioactive wastes. What do all of these substances have in common?

Development of the Lesson

1. All of these substances are pollutants when they enter the marine environment. In her 1962 book *Silent Spring*, marine biologist Rachel Carson warned about the potential dangers of chemical pollutants, or *toxic substances*, to wildlife and the environment.
2. **Write the Aim:** *How have toxic substances become part of the marine environment?* Organize the class into five groups, with each team researching a different pollutant. Information on the pollutants can be found on the following pages: DDT (pages 547–548), PCBs (page 548), mercury and other heavy metals (pages 550–551), crude oil (pages 551–553), and radioactive wastes (pages 553–554).
   - *DDT:* is a toxic chemical used as an insecticide; was sprayed for more than 20 years on farms, swamps, and coastal areas in the U.S.; has passed along food chains, from mosquito larvae to marine birds, and caused thinning of eggshells; resulted in the decline of several marine birds; has been banned in the U.S. since 1971, resulting in population recovery among threatened birds.
   - *PCB's:* is a toxic chemical used in a variety of consumer products; has been found to cause cancer in laboratory animals and is suspected of causing cancer and birth defects in humans; has been discharged into waterways from industrial plants from the 1950s through the 1980s; has passed along marine food chains, biomagnifying at each trophic level; toxic levels have been found in the striped bass and the Canadian beluga whales; U.S. banned dumping of PCBs into our waterways; resulted in a gradual decline in the PCB level in waterways such as the Hudson River.
   - *Mercury:* is a toxic element used in industrial processes; first known to be a pollutant in Minamata Bay, Japan, in the 1950s and early 1960s. Hundreds of people developed tremors, fell into comas, and died after eating fish contaminated with mercury that was discharged from an industrial plant. Mercury can also enter the ocean from factories in the form of smoke emissions, which are absorbed by moisture and fall as toxic rain. Mercury passes up the food chain and biomagnifies in large fish, such as tuna. The U.S. government sets a health limit of no more than 0.5 ppm per fish. Other heavy metals that are dumped into the sea can be toxic when ingested in seafood.
   - *Crude oil:* is spilled into the sea as a result of tanker accidents and nonpoint source pollution (e.g., discharge of consumer products); destroys marine life by suffocating fish; coating marine birds and marine mammals with oil, and sinking to the seafloor and burying shellfish beds.
   - *Radioactive wastes:* have been dumped in large containers onto the seafloor; some have begun to leak; have contaminated fish and invertebrates; rays can pass through living tissue, causing molecular damage; dumping in the ocean has been banned.

Summary of the Lesson

Ask each group leader to read the information gathered about their toxic substance. Have students copy the important facts into their notebooks. Encourage discussion. *Note:* You may want to assign the topic of *thermal pollution* to a sixth group, if time permits.

Homework Assignment

Read pages 546–555. Answer Section Review questions 1–3 on page 555, and Chapter Review questions 7 on page 565 and 12–13, 15, and 17–19 on pages 566–567.

LESSON 4 *(pages 556–562)*

Aim: How can we get clean, clear waters in the marine environment?

Instructional Objectives

Students will be able to:

1. Define turbidity and hypoxia; describe how hypoxia occurs.
2. Explain water quality standards for dissolved oxygen.
3. Discuss the role of an individual in cleaning up the environment.

Motivation for the Lesson / Do Now

Can an individual make a difference in cleaning up the environment? Explain.

Development of the Lesson

1. Individuals *can* make a difference. For example, use paper bags instead of plastic bags. Participate in recycling projects. Organize an "Adopt-A-Beach" program in your community and clean the beach on a regular basis. Form a water-watch team and monitor the quality of a local body of water on a regular basis.
2. **Write the Aim:** *How can we get clean, clear waters in the marine environment?* Organize the class into five groups. Have each team read in their texts, and write in their notebooks, about one of the following water pollution-related topics: turbidity (pages 556–557), dissolved oxygen (pages 557–558), litter in the water (pages 559–560), solutions to pollution (pages 560–561), and groups against pollution (pages 561–562).
3. Points that you may want to see mentioned by students could include the following:
   - *Turbidity:* is the level of clarity or murkiness of water; suspended particles cloud the water, reducing light penetration and making it difficult for aquatic plants to carry out photosynthesis; natural as well as unnatural conditions can cloud waters; coastal waters may turn cloudy from an algal bloom (caused by runoff containing fertilizers); turbidity can be measured using a *Secchi disk*.
   - *Dissolved oxygen (DO):* is the amount of oxygen dissolved in the water; DO levels in ocean water range from about 1 to 12 ppm; the minimum DO level needed by fish and other aquatic animals to breathe is 4 ppm; below this level, a condition called *hypoxia* (low oxygen) occurs, leading to fish kills; hypoxia results from the activities of aerobic bacteria associated with algal blooms and/or the dumping of sludge; low DO levels cause the fish to suffocate.
   - *Litter in the water:* is solid waste or garbage, consisting of plastic, glass, or metal that cannot be broken down by bacterial action; this is called *nonbiodegradable litter*; thousands of marine mammals, birds, reptiles, and fish die each year from getting entangled in plastic netting and other litter.
   - *Solutions to pollution:* include getting rid of solid wastes by recycling them, i.e., changing them into useful products; incineration of wastes; placement in landfills; and using more biodegradable products; e.g., some plastics manufacturers have introduced photodegradable plastics to prevent injuries to marine animals.
   - *Groups against pollution:* include the International Maritime Organization, a U.N. group that regulates the disposal of chemicals, sewage, and trash by ships at sea; the EPA and NOAA, which are cosponsors of the Center for Marine Conservation and its

Beach Cleanup Campaign; other government and non-profit environmental agencies that work to regulate and eliminate the debris in the marine environment.

Summary of the Lesson

Ask each group leader to read the information they have gathered, and to write a brief summary on the board. Have students copy the important facts into their notebooks. Encourage discussion.

Homework Assignment

Read pages 556–562. Answer Section Review questions 1–3 on page 558 and 1–3 on page 562; and Chapter Review questions 14, 16, and 20 on page 567.

Chapter 23 / Conservation of Resources

INTRODUCTION

In Chapter 23—the last, but certainly not least, of all chapters—students will learn about the conservation, as well as utilization and exploitation, of marine resources, both living and nonliving. The conservation of marine fisheries is discussed, in addition to the exploration for nonliving resources such as oil and minerals. Students will read about desalination techniques—important because most water on Earth is salt water. Different methods of mariculture are described. Finally, the protection of rare and endangered marine animals is discussed.

- Humans depend on many living and nonliving resources from the ocean. Some resources are renewable; other resources are nonrenewable.
- The marine fisheries catch reached a peak by about the year 2000, but it is now declining due to overfishing. Most commercial fishing occurs in the neritic zone.
- Oil from the seafloor is a valuable resource. High technology is used to locate and recover deposits of oil from seafloor sediments.
- The ocean contains minerals that people mine and use, such as salt, manganese (in nodules), and other metals.
- Desalination of seawater is an important process for acquiring freshwater.
- Mariculture is the farming of marine seaweeds, shellfish, and fishes.
- Overhunting of marine animals has led to the extinction and endangerment of numerous species. Now there are special laws and marine sanctuaries to help protect endangered marine species.

LESSON 1 *(pages 570–576)*

Aim: What are the marine resources and how can they be conserved?

Instructional Objectives

Students will be able to:

1. Describe how fish are caught commercially.
2. Discuss measures to conserve fish resources.
3. Define maximum sustainable yield.

Motivation for the Lesson / Do Now

Make a list of natural resources that are found in the ocean. Describe one in detail.

Development of the Lesson

1. Items such as fish, oil, gas, minerals, and other materials that come from Earth are called *natural resources*. The ways that people care for, protect, and manage these natural resources are called *conservation*.
2. **Write the Aim:** *What are the marine resources and how can they be conserved?* One of our most important resources from the ocean is fish because they provide food for the human population. The commercial harvesting of fish is the *fisheries industry*.
3. **Key Question:** *How are fish caught commercially?* Large numbers of fish are caught by ships using hooks and long lines, and by huge "factory ships" using nets, such as trawling, purse seine, and gill nets. (Refer students to Figure 23-2 on page 573.) Japan, Russia, the United States, and China are the leading fishing nations.
4. **Key Question:** *What effect has intensive fishing had on the fisheries?* Project on an overhead (or refer students to) the graph in Figure 23-1 on page 571. The widespread use of large nets by commercial fleets has increased the world's average fish catch between the years 1950 and 2000. The largest number of fish that can be taken from a species' population without threatening its future population and harvest is called its *maximum sustainable yield*. Unfortunately, the stocks of popular food fish, such as flounder, cod, and haddock, have been declining in recent years due to overfishing.
5. **Key Question:** *What conservation measures are being used in marine fisheries?* Fish populations need time to recover before they can increase their stock and be fished again. So, to reverse the decline in fish populations, the U.S. Congress passed the Magnuson Act, which forbid foreign fishing fleets from working within 333 km of our coast. In addition, the federal government limited the catch size for several fish, such as salmon on the West Coast and swordfish in the North Atlantic; and they temporarily closed the fishing grounds for cod, haddock, and flounder off Cape Cod, Mass. These measures have helped some fish populations increase their numbers.

Summary of the Lesson

Have students work in groups to prepare a list of measures that may help conserve and manage global fish stocks. Encourage discussion among groups.

Homework Assignment

Read pages 569–576 (top). Answer Section Review question 1 on page 581, and Chapter Review questions 6, 9–11, 14–16, and 19 on pages 595–597.

LESSON 2 *(pages 576–586)*

Aim: How are we utilizing the natural resources from the sea?

Instructional Objectives

Students will be able to:

1. Define aquaculture and mariculture.
2. Describe how mariculture has increased food resources.
3. Explain how other marine (non-food) resources are used.

Motivation for the Lesson / Do Now

Give students commercially packaged seaweed to taste. Have them describe the flavor.

Development of the Lesson

1. Seaweeds are a good source of nutrients. Although relatively new as a food in the West, they have been eaten in the East for thousands of years. Marine scientists are researching new

ways to use and wisely manage the ocean's natural resources.

2. **Write the Aim:** *How are we utilizing the natural resources from the sea?* Organize the class into five groups. Have each team research in their textbooks, and copy into their notebooks, information about the following resources that come from the sea: fossil fuels (pages 576–578), minerals (page 578–580), freshwater (pages 580–581), animal mariculture (pages 582–585), and plant mariculture (pages 585–586).
3. **Key Question:** *How are we utilizing the ocean's nonliving resources?* Have students come up to the board to write brief summaries about the use of fossil fuels, minerals, and water from the sea.
   - *Fossil Fuels:* include (in marine environments) *oil* and *gas*, which come from the remains of long-dead organisms, mostly plankton; *hydrocarbons* in the remains accumulate in layers on the seafloor and form thick deposits in the sedimentary rock; over time, high temperatures and pressures from Earth's interior change the hydrocarbons into *petroleum* (either gas or oil).
   - *Minerals:* are solid, nonliving substances consisting of elements and compounds; the most common mineral extracted from the ocean is *salt*; another valuable resource is *manganese nodules*, which lie on the ocean floor (see Figure 23-4, page 579); they are rich in manganese, iron, nickel, and cobalt; some nodules are too deep to mine.
   - *Freshwater:* can be produced from ocean water by removing the salt, a process called *desalination*; one method, called a *solar still*, uses the sun's energy to produce freshwater (students can examine Figure 23-5, page 581); a new process called *reverse osmosis* is also used to produce freshwater from seawater.
4. **Key Question:** *How are we utilizing the ocean's living (animal and plant) resources?* Overharvesting of fish, due to the demands of an ever-increasing human population, has stimulated an interest in alternative ways of obtaining food from the sea. One such method is to "farm" aquatic organisms, a process called *aquaculture*. The process of farming organisms from the sea is called *mariculture*. Have students come up to the board to write brief summaries about the use of the following food sources.
   - *Animal mariculture:* started in Japan with the raising of oysters along the shore; oysters produce more than 100 million eggs at a single spawning; the embryos, or *veligers*, attach to hard surfaces and develop into baby oysters, which are cultivated in vast numbers; techniques of oyster mariculture have been adapted to raising mussels; crustaceans are more difficult to farm because they are cannibalistic; the most widely cultured saltwater fish is the milk fish *Chano,* an important food item in Asia; the Japanese farm a popular ocean food fish, the red sea bream, in saltwater ponds. (Two types of fish farming are shown in Figures 23-6 and 23-7, on pages 584 and 585.)
   - *Plant mariculture:* farming of seaweeds is a big business; many popular consumer goods are made from seaweeds; *carrageenan*, an extract from Irish moss (seaweed), is used to manufacture toothpaste and ice cream; algin, an extract from kelp, is used as a thickener and stabilizer in many processed foods; the green alga *Ulva* is used by Hawaiians in salads; the red alga *Porphyra* is used to wrap boiled rice in *sushi*.

Summary of the Lesson

Have each group leader read aloud the information their group has placed on the board. Students should copy the information into their notebooks. Encourage discussion.

Homework Assignment

Read pages 576–586. Answer Section Review questions 2–3 on page 581 and 1–3 on page 586, and Chapter Review questions 7, 12, 17–18, and 22–23 on pages 595–598.

LESSON 3 *(pages 586–588)*

Aim: What do we know about the population sizes of marine species?

Instructional Objectives

Students will be able to:

1. Cite examples of extinct and endangered marine species.
2. Distinguish between threatened and endangered species.
3. Explain how the manatee became an endangered species.

Motivation for the Lesson / Do Now

Project on an overhead the illustrations of the great auk (Figure 23-8, page 587) and of the manatee (Figure 14-12, page 346). Ask which one is extinct. Explain.

Development of the Lesson

1. The great auk is extinct. When a species becomes *extinct*, it is completely gone from Earth, never to be seen again. More than 500 animal species (some of them marine) have become extinct in the Americas, just in the past 500 years.
2. **Write the Aim:** *What do we know about the population sizes of marine species?* Some extinct marine bird and mammal species are shown in Table 23-2 on page 587. By the mid-1800s, the great auk—a large, flightless seabird—was already extinct due to overhunting by hungry sailors.
3. **Key Question:** *How are animals whose populations are decreasing categorized?* Animals that are threatened with extinction are classified as *endangered species*. Animals that are at risk of becoming endangered are classified as *threatened species*. An example of an endangered species is the manatee, the slow-moving marine mammal that lives along the Florida coast. Rapid development along Florida's coast is responsible for the decline in the manatee population; and many are struck and killed by the propellers of powerboats.
4. **Key Question:** *What marine animals are threatened and endangered?* Project on an overhead, or write on the board, the threatened and endangered marine animals listed in Table 23-3, on page 589. Encourage students to discuss the various reasons for the endangerment of these different species.

Summary of the Lesson

Organize the class into groups of four or five students. Have students consider the following questions: *Do humans have a responsibility to act as stewards in protecting wildlife? Are human populations more important than populations of marine animals?* Have each team present its pros and cons. Encourage discussion and debate.

Homework Assignment

Read pages 586 (bottom)–588 (top). Answer Section Review question 1 on page 592, and Chapter Review questions 20–21 on pages 597–598.

LESSON 4 *(pages 588–591)*

Aim: What measures have been undertaken to protect marine animals?

Instructional Objectives

Students will be able to:

1. Describe conservation measures to protect endangered species.
2. Discuss the importance of habitat protection in conservation.
3. Cite specific conservation laws that protect marine species.

Motivation for the Lesson / Do Now

What is being done to protect endangered marine animals, like the manatee?

Development of the Lesson

1. Various measures have been undertaken to protect marine species like the manatee.

   Write the Aim: *What measures have been undertaken to protect marine animals?* The U.S. Congress has passed several acts to protect wildlife and their habitats, e.g., the Wildlife Preservation Act, the Endangered Species Act, and the Marine Mammal Protection Act. The Endangered Species Act prohibits the interstate trafficking in endangered species obtained illegally in their country of origin. This act prohibits trade in items made, e.g., from endangered whales, sea turtles, and so on.

2. **Key Question:** *What is being done to protect the habitats of endangered and threatened species?* One way to protect endangered and threatened species is to eliminate or reduce human intrusion into their habitats. The Florida Manatee Sanctuary Act was established to stop the decline in the manatee population. A *marine sanctuary* is a protected area in which no commercial activities are permitted, so that it provides a safe habitat for marine organisms. The federal government has proposed and designated numerous marine sanctuaries in U.S. waters as part of its National Marine Sanctuary Program. (Refer students to Figure 23-10 on page 591.)

Summary of the Lesson

Organize the class into groups of four or five students. Have students consider the following question: *Are you for or against economic development along the coast in areas where there are threatened or endangered marine species?* Have each team present its pros and cons. Encourage discussion and debate.

Homework Assignment

Read pages 588–591. Answer Section Review questions 2–3 on page 592, and Chapter Review questions 8 on page 595 and 13 on page 597.