Marine Science

Peter Castro | Michael E. Huber

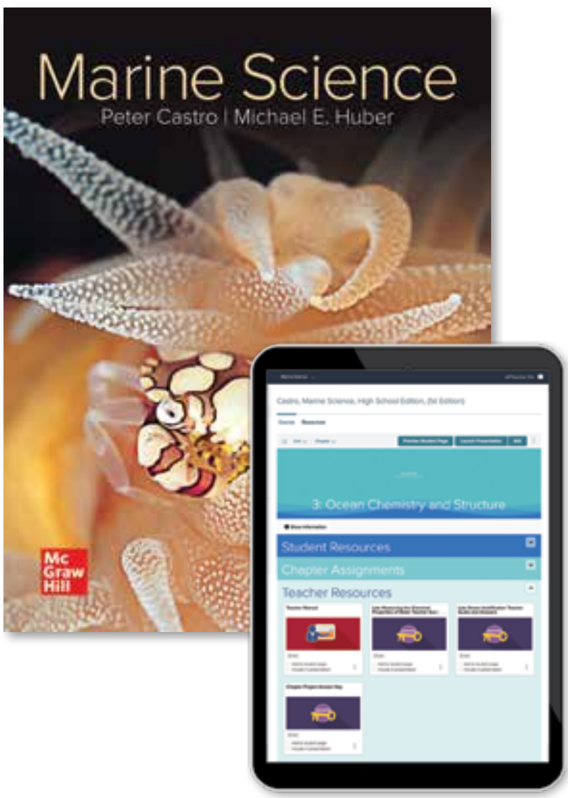
Print and Digital Overview

SECOND EDITION

EXPLORING

THE INTERCONNECTED AND GLOBAL PERSPECTIVE OF THE WORLD OCEAN

The first edition of *Marine Science* became an instant, beloved text with its full coverage of oceanography, stunning design, student-friendly learning system, and data analysis labs. Now in its second edition, the program further expands its coverage through chapter-level NGSS integration, more robust chapter reviews, additional unit projects, and ELL support.



Marine Science was written specifically for a high school course by field experts whose fascination with oceanography and marine biology is infused in every lesson of the text. The second edition offers an easy-to-read design, up-to-date scientific data, and an interdisciplinary focus. *Marine Science* offers a broader focus on human and environmental interaction by pinpointing the impact of human interaction with marine environment. The *Marine Science* Lab Manual allows every student to experience the wonder of the world's oceans, while the new Teacher's Manual helps guide instruction for any teaching style.

Students' and teachers' favorite features include:

- Study Strategy activities, including listening, speaking, reading, and peer interactions, that help to support a variety of learning styles.
- Vocabulary activities and support that help students acquire and understand the key terminology of marine science.
- Inquiry activities that allow students to expand upon what they've studied in the *Nature of Science, Marine Science in Action, Habitat Spotlight,* and *Humans* and the *Ocean* features.
- *Teacher's Manual*, available in print and online, includes a detailed pacing guide for each chapter, chapter summaries, answers to the section and chapter review questions, and differentiated instruction support and activities.
- A Lab Manual with 42 labs — no ocean needed!

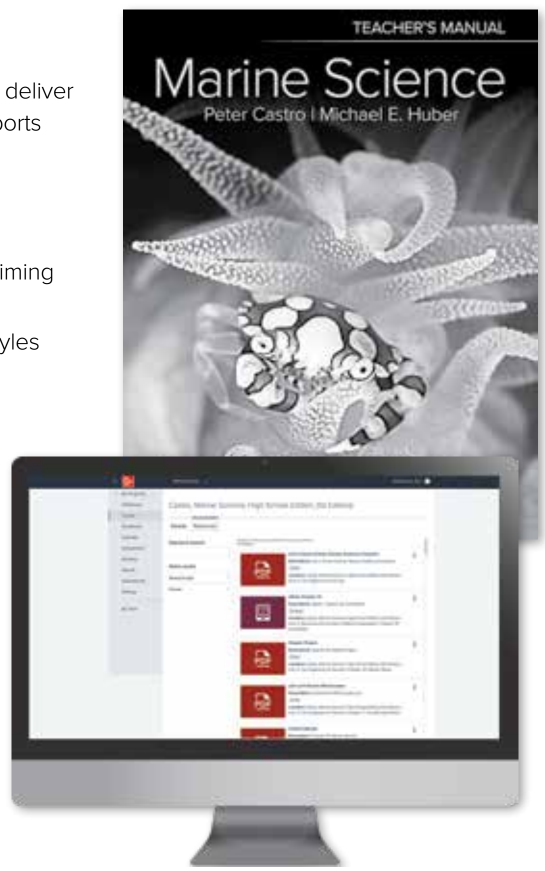
Supplementary Resources

Marine Science Laboratory Manual

The *Marine Science Laboratory Manual* offers 42 labs ideal for any marine science classroom. These labs are divided into two types—guided inquiry and open inquiry. These labs can be performed anywhere in the country and do not require access to the ocean. The *Marine Science* Teacher's Manual identifies the best time to use each lab in the course of chapter instruction.

- Material lists are provided to help students and teachers prepare the lab and save time.
- Each lab begins with a Problem that sets up the purpose of the lab.
- Objectives help to focus students on what should be learned from the lab.
- Questions and charts help students to demonstrate what they have learned from the lab.

Marine Science Teacher's Manual



The *Teacher's Manual*, available in print and online, will help create and deliver a marine science course that engages students in the content and supports success in concept application and mastery. The manual provides:

- Strategies to introduce, teach, and assess each chapter.
- Chapter-level Big Idea and section-level Main Idea activities.
- Pacing for each chapter, including guidance on the most effective timing for labs and activities.
- Differentiated instruction support to address a variety of learning styles and needs.
- Answers to all student-edition questions.

Additional online resources include:

- Auto-graded test banks.
- Chapter and Unit Projects.
- PowerPoint slides to help teachers build dynamic presentations.
- A searchable resources library that makes it easy to quickly find, display, and assign resources.
- A powerful gradebook to provide real-time access to the student data teachers need to inform classroom instruction.

Best-in-Class Digital Resources

Marine Science is enriched with multimedia content including videos, animations, and simulations that enhance the teaching and learning experience both inside and outside of the classroom.

Authored by the world's leading subject-matter experts and organized by chapter level, the resources provide students with multiple opportunities to contextualize and apply their understanding. Teachers can save time, customize lessons, monitor student progress, and make data-driven decisions in the classroom with the flexible, easy-to-navigate instructional tools.

Intuitive Design

Resources are organized at the chapter level. To enhance the core content, teachers can add assignments, activities, and instructional aids to any lesson. The chapter landing page gives students access to:

- Assigned activities.
- Resources and assessments.
- Interactive eBook.
- Adaptive SmartBook®.

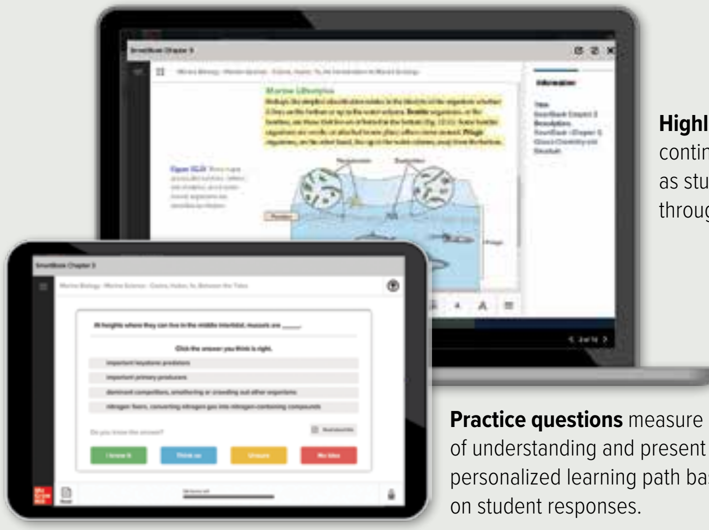
Chapter landing page links students to resources that support success.

Mobile Ready
Access to course content on-the-go is easier and more effective than ever before with the ReadAnywhere mobile app.

Adaptive Study Tools

SMARTBOOK® is the online adaptive study tool. The interactive features engage students and personalize the learning experience with self-guided tools that:

- Assess a student's proficiency and knowledge.
- Track which topics have been mastered.
- Identify areas that need more study.
- Improve reading comprehension by highlighting key content that needs additional study.
- Present focused content specific to the student's individual needs.



Highlighted content continuously adapts as students work through exercises.

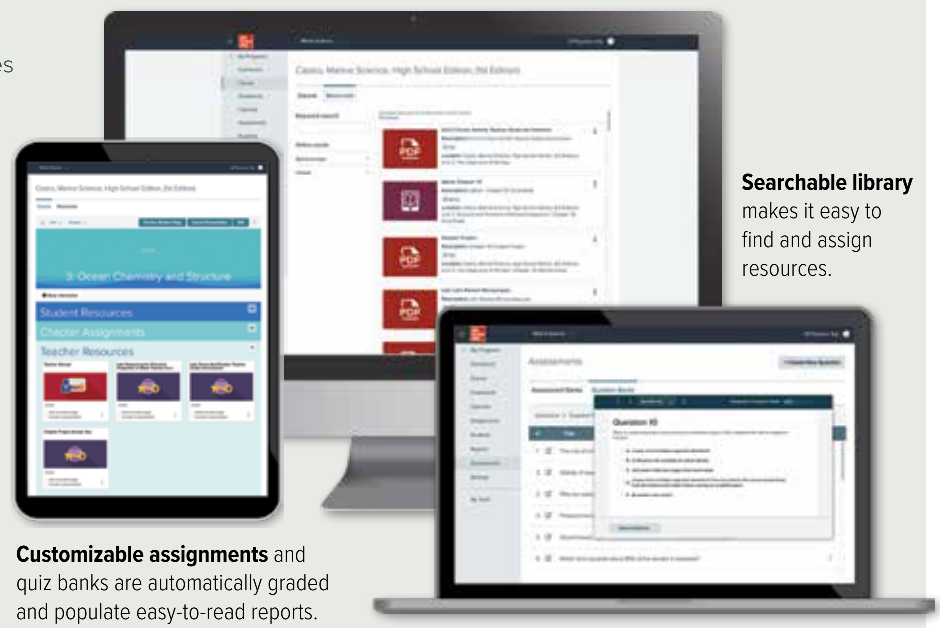
Practice questions measure depth of understanding and present a personalized learning path based on student responses.

Teacher Resources

Teachers have access to the interactive eBook, adaptive *SmartBook*®, plus a wealth of customizable chapter resources and powerful gradebook tools.

Resources include:

- The *Teacher's Manual*, available in print and online, that will help create and deliver a marine science course that engages students in the content and supports success in concept application and mastery.
- Student performance reports to help teachers identify gaps, make data-driven decisions, and adjust instruction.
- Customizable PowerPoint presentations.
- Labeled diagrams, visual aids, animations, and additional ideas for lecture enrichment.



Searchable library makes it easy to find and assign resources.

Customizable assignments and quiz banks are automatically graded and populate easy-to-read reports.

*Harness technology, unlock success with the digital resources for **Marine Science.** **Visit My.MHEducation.com***

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Marine Science Learning System

Castro's *Marine Science* incorporates a variety of study aids to help students better understand the ocean and all its complexities.

The **Unit Opener** sets up chapter content that will be covered. It lists the chapters included in the unit to give the students a preview of what they will study.

Unit 2

The Organisms of the Sea

Chapter 6	Fundamentals of Biology
Chapter 7	The Microbial World
Chapter 8	Multicellular Primary Producers: Seaweeds and Plants
Chapter 9	Marine Animals without a Backbone
Chapter 10	Marine Fishes
Chapter 11	Marine Reptiles, Birds, and Mammals

The oceans are home to diverse assemblages or organisms adapted to the challenges of life in the sea. Kelp forests, like this one off the coast of Monterey, California, are composed of several species of kelp, a seaweed. Seaweeds are distinct from plants, but are still photosynthetic organisms that gain their energy from the sun. Kelp forest form an important habitat for many species of fish, mammals, and invertebrates, including this seven-gill shark.

UNIT PROJECT

Healthy oceans: how do we solve complex problems?

Global challenges are often too large and complex to address as a single problem. When viewed as collections of challenges that are smaller in scope, the grander problems can feel more approachable, with solutions more achievable. Some solutions might need simultaneous implementation, while others might need to be completed in a step-wise fashion.

GO ONLINE to break down one of the many marine challenges currently facing society into a more approachable problem. In this project, you will break a complex real-world problem facing the marine environment down into identified sub-problems and identify their stakeholders and constraints through research.

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Four **Unit Projects**, one for each unit, are introduced. These projects build upon each other and allow students to develop their research and analysis skills in the study of a global challenge related to the material they are covering in the text. Teachers can use these as independent study for individual students or groups of students or as a classroom activity.

Marine Science focuses on features like the **Big Ideas, Themes, Main Ideas, Key Questions, Vocabulary,** and **Ripple Effect** to help guide student instruction and learning.

Each chapter opens with a **Theme**. The themes highlight that marine science shares concepts applicable across all fields of science and engineering. These unifying concepts include themes such as patterns, cause and effect, energy and matter, and structure and function.

Chapter 4

Waves and Tides

4.1 Introduction to Wave Energy and Motion
4.2 Types of Waves
4.3 The Tides

THEME Patterns

By making observations and collecting and analyzing data, scientists can find patterns that help them better understand the nature of waves and tides and predict their patterns.

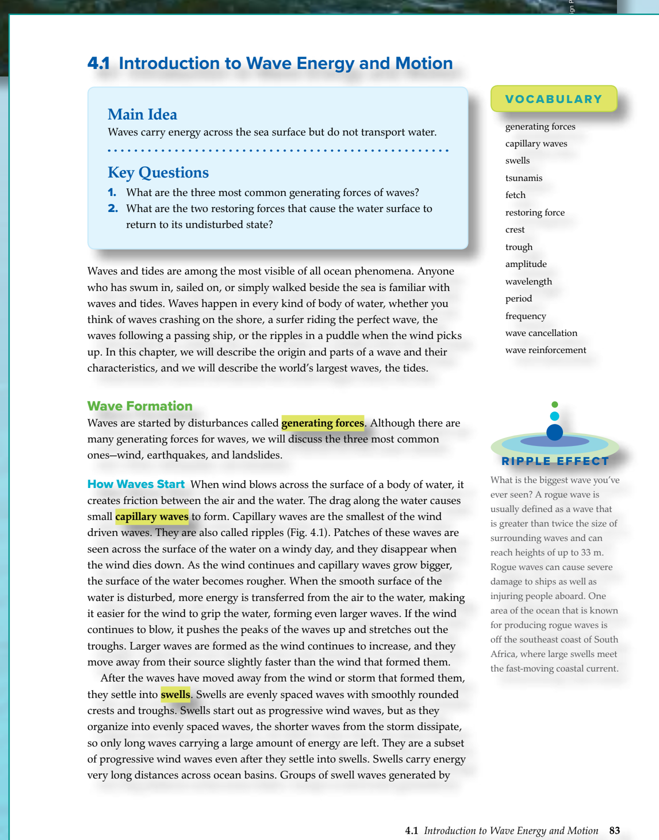
BIG IDEA

Waves and tides are influenced by many factors and, in turn, affect marine organisms as well as humans.

About the photo A wave breaks as it approaches the shore off Cape Kiwanda, Oregon.

The **Big Idea** is the core idea that students should take away from their study of the chapter. An activity to reinforce the Big Idea can be found in the Teacher's Manual.

Each section opens with a **Main Idea** that brings discrete focus to the section contents. The **Key Questions** are used to guide student reading and reinforce the main ideas of the chapter.



4.1 Introduction to Wave Energy and Motion

Main Idea

Waves carry energy across the sea surface but do not transport water.

Key Questions

1. What are the three most common generating forces of waves?
2. What are the two restoring forces that cause the water surface to return to its undisturbed state?

VOCABULARY

generating forces
capillary waves
swells
tsunamis
fetch
restoring force
crest
trough
amplitude
wavelength
period
frequency
wave cancellation
wave reinforcement

Waves and tides are among the most visible of all ocean phenomena. Anyone who has swum in, sailed on, or simply walked beside the sea is familiar with waves and tides. Waves happen in every kind of body of water, whether you think of waves crashing on the shore, a surfer riding the perfect wave, the waves following a passing ship, or the ripples in a puddle when the wind picks up. In this chapter, we will describe the origin and parts of a wave and their characteristics, and we will describe the world's largest waves, the tides.

Wave Formation

Waves are started by disturbances called **generating forces**. Although there are many generating forces for waves, we will discuss the three most common ones–wind, earthquakes, and landslides.

How Waves Start When wind blows across the surface of a body of water, it creates friction between the air and the water. The drag along the water causes small **capillary waves** to form. Capillary waves are the smallest of the wind driven waves. They are also called ripples (Fig. 4.1). Patches of these waves are seen across the surface of the water on a windy day, and they disappear when the wind dies down. As the wind continues and capillary waves grow bigger, the surface of the water becomes rougher. When the smooth surface of the water is disturbed, more energy is transferred from the air to the water, making it easier for the wind to grip the water, forming even larger waves. If the wind continues to blow, it pushes the peaks of the waves up and stretches out the troughs. Larger waves are formed as the wind continues to increase, and they move away from their source slightly faster than the wind that formed them.

After the waves have moved away from the wind or storm that formed them, they settle into **swells**. Swells are evenly spaced waves with smoothly rounded crests and troughs. Swells start out as progressive wind waves, but as they organize into evenly spaced waves, the shorter waves from the storm dissipate, so only long waves carrying a large amount of energy are left. They are a subset of progressive wind waves even after they settle into swells. Swells carry energy very long distances across ocean basins. Groups of swell waves generated by

RIPPLE EFFECT

What is the biggest wave you've ever seen? A rogue wave is usually defined as a wave that is greater than twice the size of surrounding waves and can reach heights of up to 33 m. Rogue waves can cause severe damage to ships as well as injuring people aboard. One area of the ocean that is known for producing rogue waves is off the southeast coast of South Africa, where large swells meet the fast-moving coastal current.

4.1 *Introduction to Wave Energy and Motion* 83

Ripple Effect features bring relevance to the learning and highlight how human society is connected to the ocean, no matter how close or far from the coast we might live.

Study Strategies, In Context, and **Reviewing the Main Idea** support a variety of student learning styles.

Study Strategies include listening, speaking, reading, and peer interactions.

Figure 4.12 Waves refracting as they approach a beach

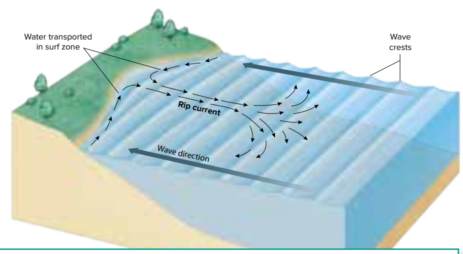
Figure 4.13 Various structures are built on beaches to prevent erosion due to longshore transport.

STUDY STRATEGIES

Concept Mapping Create a concept map comparing and contrasting deep water and shallow water waves. Add notes to your concept map after classroom discussions of Section 4.2, Types of Waves.

Wave Refraction Waves are **refracted**, or bent, as they move from deep water to shallow water. When waves approach the shore, they usually do so at an angle. When the bottom of the waves slow down as the water gets shallower, the part of the wave that remains in deeper water continues to move at the original speed. Because of this, the waves "bend" and the waves along the surf are parallel to the shore (Fig. 4.12). Waves can also bend and wrap around an island depending on the sea floor surrounding the island.

Longshore Transport As discussed above, waves usually don't travel perpendicularly towards the shore. As a wave moves towards the shore, the particles of water are transported toward the shore and down the beach in the



(t)©iStockphoto.com/Wolfgang_Steiner; (b)Design Pics/John Doornkamp; (b)Source: Bill Ober

Wave Interaction **Wave cancellation** occurs when the crest of one wave meets the trough of another, and the sea surface ends up being intermediate between the two, effectively canceling out the waves. If the crests of two waves collide, however, they add together to produce a higher wave which is called **wave reinforcement** (Fig. 4.7). Wave reinforcement can cause very large waves to form seemingly out of nowhere. These rogue waves can be as high as a 10 story building and can cause great damage. Oceanographers once dismissed rogue waves as rare or even nonexistent and nothing more than a sailors' myth, but they have now confirmed that rogue waves do occur. They might account for a significant fraction of the 100 or so large ships that are lost, or disappear, at sea each year (Fig. 4.8).

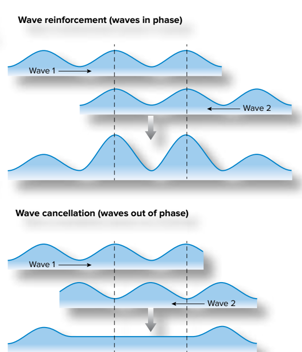


Figure 4.7 Wave cancellation results when waves meet out of phase. When waves meet in phase, however, wave reinforcement occurs.

Figure 4.8 Rogue waves – large waves in the open ocean that seemingly come out of nowhere – can be caused by wave reinforcement.

(t)Source: Bill Ober; (b)National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce.

IN CONTEXT

Hormones Molecules that act as chemical messengers within the body.

• 6.1, The Ingredients of Life

Reviewing the Main Idea

1. **Describe** how wind waves are generated.
2. **Explain** What two types of energy does a wave have? How can a wave have two different types of energy?
3. **Illustrate** Draw a wave and include the following labels: crest, *trough*, *wave height*, and *wavelength*.

4.1 *Introduction to Wave Energy and Motion* **87**

Reviewing the Main Idea questions help to ensure student understanding of section content.

In Context draws from prior learning introduced in previous chapters to help students effectively make connections between the prerequisite concepts and the learning ahead.

Marine Science Guided Tour

Throughout the text there are four feature strands — **Nature of Science, Marine Science in Action, Habitat Spotlight,** and **Humans and the Ocean**. Each strand includes Think Critically questions and explores a unique topic in marine science such as habitats, human and ocean interaction, and other relevant areas of interest. Each of these features has a corresponding activity available online that allows students to expand upon and further explore what they have studied in the text.

MARINE SCIENCE IN ACTION

CLIMATE CONNECTION

Carbonate Experiments on the Reef

Experiments performed in the ocean are as important to marine science as laboratory experiments. By combining laboratory and field experiments in the tropical Pacific, scientists are better understanding how anthropogenic carbon dioxide (CO_2) is affecting marine life. The diffusion of CO_2 into the ocean from the atmosphere can stimulate the growth of photosynthetic organisms, but also makes the ocean slightly more acidic. Acidity interferes with the formation of calcium carbonate skeletons and shells. These combined effects can negatively impact organisms such as reef corals and calcareous algae, but encourage the growth of "fleshy," non-calcareous algae.

The limitations of lab studies Laboratory data on the response of some reef corals and algae species to changes in CO_2 and acidity has been published. There are, however, hundreds of different reef coral and algae species, many of which are difficult to grow in the laboratory. Reef conditions are highly variable both temporally and geographically. In the

The scientists are also studying how changes in acidity affect the growth of unconfined corals and algae using "minireefs." The minireefs are cinderblocks on which small pieces of coral and algae are attached. The biologists place the minireefs where the acidity regime varies naturally, and install an acidity sensor. They measure organismal growth rates in the various acidity regimes. Early results indicate that calcareous algae grow best in near-constant acidity levels, and are inhibited by wide fluctuations in acidity.

The best of both worlds Even in the field, the laboratory has its uses. Light is one of the main factors controlling growth of corals and algae, and on a natural reef the light level is constantly changing. To measure how light affects organisms in the field, biologists take specimens onto a shipboard laboratory, where they measure their growth under precisely controlled light levels. This is typical of marine science, in which lab and field experiments complement each

NATURE OF SCIENCE

CLIMATE CONNECTION

do. This is where scientists turn to scientific modeling. Scientific models incorporate variables into a mathematical equation that can help to explain a phenomenon that cannot be directly measured. Scientific models are used in many

time, the temperature and depth of water blue whales are known to live, the amount of krill (the whales' food) in the area, how fast a blue whale swims, the life cycle of a blue whale, and more. Hurricane direction and intensity are also affected by many parameters. Wind speed and direction, humidity, pressure, and oceanic and atmospheric tempera-tures are just a few. Many models must be compiled and run on supercomputers, which can store and analyze thousands of data points at once.

Refinement A well-made model may give a close approxi-mation to the number of blue whales in a certain area or the location where a Category 4 hurricane may hit, but it is only an approximation. If a model turns out to be inaccurate, scientists need to evaluate why this was the case. Scientific models are always a work in progress and can be updated and amended as new discoveries are made.

Historical data are also important. By incorporating

HABITAT SPOTLIGHT

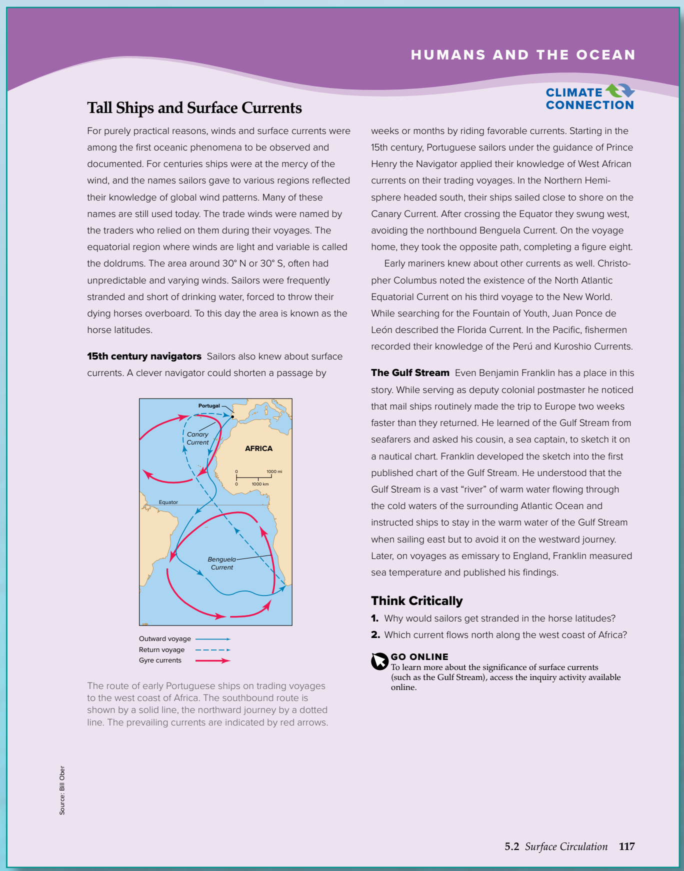
pounded by rough waves or completely dry. During low tide, tide pools can become isolated from the surrounding ocean. Sun exposure may drive up the temperature of the water, and evaporation leaves the pool much saltier than the ocean. Alternately, rain can introduce fresh water, lowering the

zone, is exposed to the air most of the time but is submerged during very high tides. Barnacles are often found in this zone. The middle intertidal zone is usually submerged, except for extreme low tides. Organisms common to the middle intertidal zone include sea urchins and sea stars. The low intertidal zone is submerged most of the time. It has the greatest number of organisms and an abundance of seaweeds.

Marine scientists know a lot about the intertidal zone because it is easily accessible. Many seminal experiments in marine ecology have been conducted in this ecosystem. The habitats and organisms of the intertidal zone will be further explored in Chapter 13.

Think Critically

1. What causes the extreme differences in salinity in the intertidal zone?



HUMANS AND THE OCEAN

CLIMATE CONNECTION

Tall Ships and Surface Currents

For purely practical reasons, winds and surface currents were among the first oceanic phenomena to be observed and documented. For centuries ships were at the mercy of the wind, and the names sailors gave to various regions reflected their knowledge of global wind patterns. Many of these names are still used today. The trade winds were named by the traders who relied on them during their voyages. The equatorial region where winds are light and variable is called the doldrums. The area around 30° N or 30° S, often had unpredictable and varying winds. Sailors were frequently stranded and short of drinking water, forced to throw their dying horses overboard. To this day the area is known as the horse latitudes.

15th century navigators Sailors also knew about surface currents. A clever navigator could shorten a passage by weeks or months by riding favorable currents. Starting in the 15th century, Portuguese sailors under the guidance of Prince Henry the Navigator applied their knowledge of West African currents on their trading voyages. In the Northern Hemi-sphere headed south, their ships sailed close to shore on the Canary Current. After crossing the Equator they swung west, avoiding the northbound Benguela Current. On the voyage home, they took the opposite path, completing a figure eight.

The route of early Portuguese ships on trading voyages to the west coast of Africa. The southbound route is shown by a solid line, the northward journey by a dotted line. The prevailing currents are indicated by red arrows.

Source: Bill Ober

Early mariners knew about other currents as well. Christo-pher Columbus noted the existence of the North Atlantic Equatorial Current on his third voyage to the New World. While searching for the Fountain of Youth, Juan Ponce de León described the Florida Current. In the Pacific, fishermen recorded their knowledge of the Perú and Kuroshio Currents.

The Gulf Stream Even Benjamin Franklin has a place in this story. While serving as deputy colonial postmaster he noticed that mail ships routinely made the trip to Europe two weeks faster than they returned. He learned of the Gulf Stream from seafarers and asked his cousin, a sea captain, to sketch it on a nautical chart. Franklin developed the sketch into the first published chart of the Gulf Stream. He understood that the Gulf Stream is a vast "river" of warm water flowing through the cold waters of the surrounding Atlantic Ocean and instructed ships to stay in the warm water of the Gulf Stream when sailing east but to avoid it on the westward journey. Later, on voyages as emissary to England, Franklin measured sea temperature and published his findings.

Think Critically

1. Why would sailors get stranded in the horse latitudes?
2. Which current flows north along the west coast of Africa?

GO ONLINE
To learn more about the significance of surface currents (such as the Gulf Stream), access the inquiry activity available online.

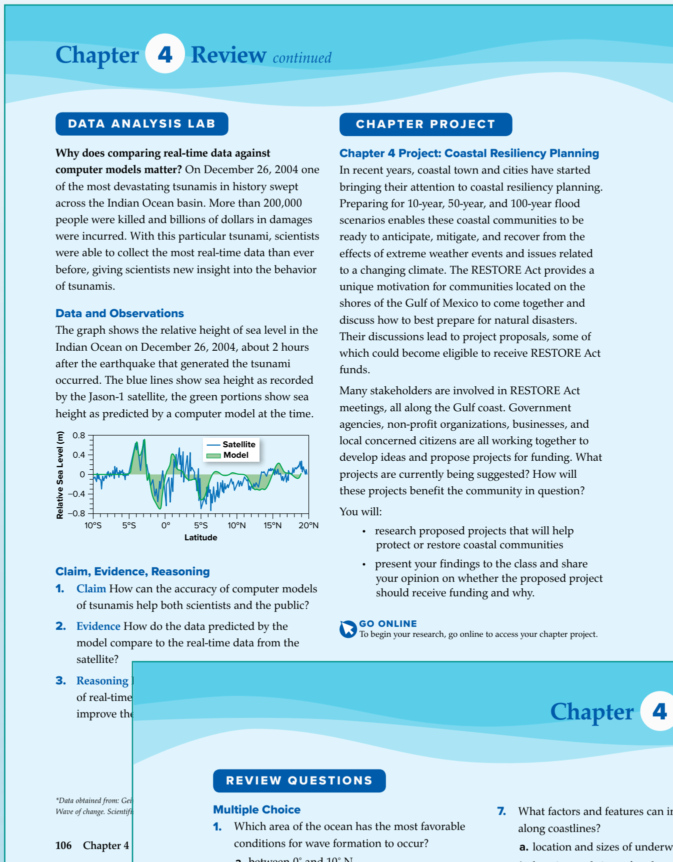
5.2 *Surface Circulation* 117

The **Climate Connection** icon calls special attention to the features where climate plays a role in the topic being discussed.

Think Critically questions assess student understanding of the specific topic covered in the feature.

Chapter Reviews have been expanded to two pages, with new and revised multiple-choice, short-answer, and critical-thinking questions. The chapter reviews also includes a **Data Analysis Lab** and a **Chapter Project.**

Data Analysis Lab uses real-world, current data directly related to the content covered in the chapter. Students must use the data provided to state claims, collect evidence, and defend their reasoning while answering questions.



Chapter 4 Review *continued*

DATA ANALYSIS LAB

Why does comparing real-time data against computer models matter? On December 26, 2004 one of the most devastating tsunamis in history swept across the Indian Ocean basin. More than 200,000 people were killed and billions of dollars in damages were incurred. With this particular tsunami, scientists were able to collect the most real-time data than ever before, giving scientists new insight into the behavior of tsunamis.

Data and Observations

The graph shows the relative height of sea level in the Indian Ocean on December 26, 2004, about 2 hours after the earthquake that generated the tsunami occurred. The blue lines show sea height as recorded by the Jason-1 satellite, the green portions show sea height as predicted by a computer model at the time.

Claim, Evidence, Reasoning

1. Claim How can the accuracy of computer models of tsunamis help both scientists and the public?
2. Evidence How do the data predicted by the model compare to the real-time data from the satellite?
3. Reasoning ... of real-time ... improve th...

CHAPTER PROJECT

Chapter 4 Project: Coastal Resiliency Planning

In recent years, coastal town and cities have started bringing their attention to coastal resiliency planning. Preparing for 10-year, 50-year, and 100-year flood scenarios enables these coastal communities to be ready to anticipate, mitigate, and recover from the effects of extreme weather events and issues related to a changing climate. The RESTORE Act provides a unique motivation for communities located on the shores of the Gulf of Mexico to come together and discuss how to best prepare for natural disasters. Their discussions lead to project proposals, some of which could become eligible to receive RESTORE Act funds.

Many stakeholders are involved in RESTORE Act meetings, all along the Gulf coast. Government agencies, non-profit organizations, businesses, and local concerned citizens are all working together to develop ideas and propose projects for funding. What projects are currently being suggested? How will these projects benefit the community in question?

You will:

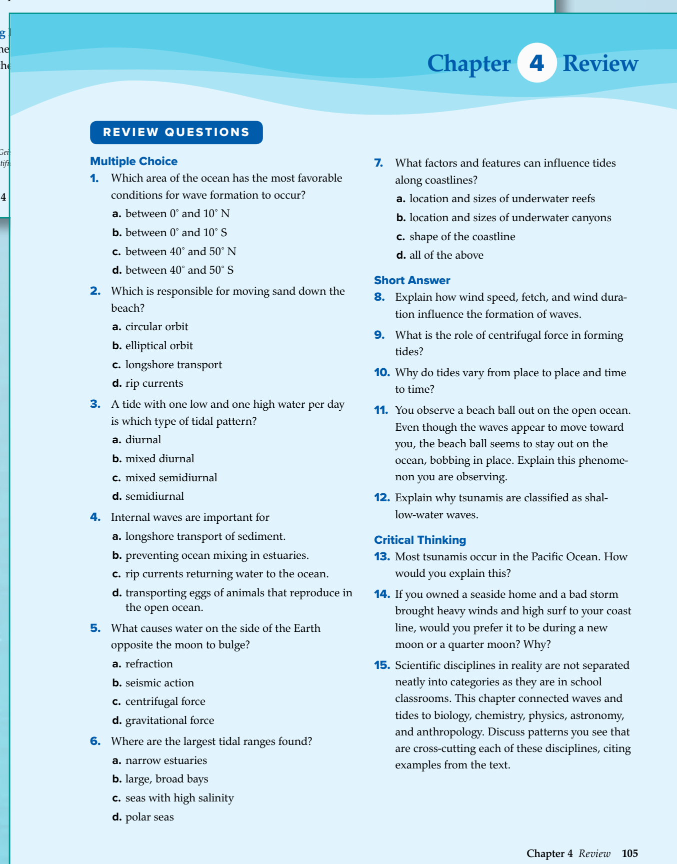
- research proposed projects that will help protect or restore coastal communities
- present your findings to the class and share your opinion on whether the proposed project should receive funding and why.

GO ONLINE
To begin your research, go online to access your chapter project.

*Data obtained from: Ge... Wave of change. Scientif...

106 Chapter 4

Each chapter review introduces the **Chapter Project.** This project asks students to apply the science and engineering practices they have developed to explore the chapter in depth. Additional information about the project can be found online.



Chapter 4 Review

REVIEW QUESTIONS

Multiple Choice

1. Which area of the ocean has the most favorable conditions for wave formation to occur?
   a. between 0° and 10° N
   b. between 0° and 10° S
   c. between 40° and 50° N
   d. between 40° and 50° S
2. Which is responsible for moving sand down the beach?
   a. circular orbit
   b. elliptical orbit
   c. longshore transport
   d. rip currents
3. A tide with one low and one high water per day is which type of tidal pattern?
   a. diurnal
   b. mixed diurnal
   c. mixed semidiurnal
   d. semidiurnal
4. Internal waves are important for
   a. longshore transport of sediment.
   b. preventing ocean mixing in estuaries.
   c. rip currents returning water to the ocean.
   d. transporting eggs of animals that reproduce in the open ocean.
5. What causes water on the side of the Earth opposite the moon to bulge?
   a. refraction
   b. seismic action
   c. centrifugal force
   d. gravitational force
6. Where are the largest tidal ranges found?
   a. narrow estuaries
   b. large, broad bays
   c. seas with high salinity
   d. polar seas
7. What factors and features can influence tides along coastlines?
   a. location and sizes of underwater reefs
   b. location and sizes of underwater canyons
   c. shape of the coastline
   d. all of the above

Short Answer

8. Explain how wind speed, fetch, and wind duration influence the formation of waves.
9. What is the role of centrifugal force in forming tides?
10. Why do tides vary from place to place and time to time?
11. You observe a beach ball out on the open ocean. Even though the waves appear to move toward you, the beach ball seems to stay out on the ocean, bobbing in place. Explain this phenomenon you are observing.
12. Explain why tsunamis are classified as shallow-water waves.

Critical Thinking

13. Most tsunamis occur in the Pacific Ocean. How would you explain this?
14. If you owned a seaside home and a bad storm brought heavy winds and high surf to your coast line, would you prefer it to be during a new moon or a quarter moon? Why?
15. Scientific disciplines in reality are not separated neatly into categories as they are in school classrooms. This chapter connected waves and tides to biology, chemistry, physics, astronomy, and anthropology. Discuss patterns you see that are cross-cutting each of these disciplines, citing examples from the text.

Chapter 4 *Review* 105

Review Questions include multiple choice, short answer, and critical thinking questions to reinforce important concepts addressed in the chapter. Critical-thinking ask students to connect the core ideas in each chapter to other disciplines of science.

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