The Marine Biology
Learning System

Chapters

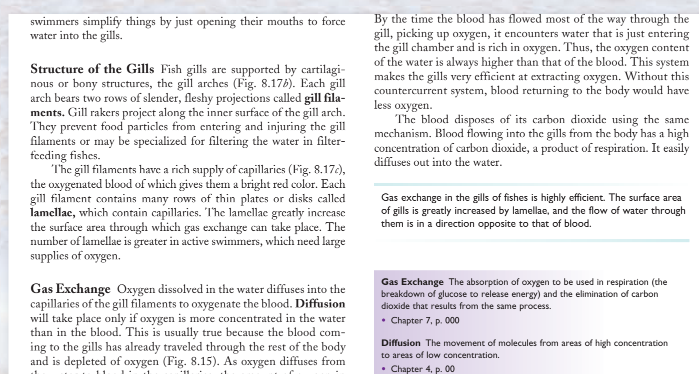
Are organized into four parts and written as short, readily absorbed units to increase instructor flexibility in selecting topics.

Key Concept Summaries

Highlight the most important terms and ideas presented in preceding paragraphs.

In-Text Glossary

Briefly explains key terms and concepts from other chapters. Chapter and page references point students to more detailed information. The extensive **glossary** in the back of the book provides complete definitions and often refers to illustrations or other key terms that help explain a concept.



swimmers simplify things by just opening their mouths to force water into the gills.

Structure of the Gills Fish gills are supported by cartilaginous or bony structures, the gill arches (Fig. 8.17*b*). Each gill arch bears two rows of slender, fleshy projections called **gill filaments.** Gill rakers project along the inner surface of the gill arch. They prevent food particles from entering and injuring the gill filaments or may be specialized for filtering the water in filter-feeding fishes.

The gill filaments have a rich supply of capillaries (Fig. 8.17*c*), the oxygenated blood of which gives them a bright red color. Each gill filament contains many rows of thin plates or disks called **lamellae,** which contain capillaries. The lamellae greatly increase the surface area through which gas exchange can take place. The number of lamellae is greater in active swimmers, which need large supplies of oxygen.

Gas Exchange Oxygen dissolved in the water diffuses into the capillaries of the gill filaments to oxygenate the blood. **Diffusion** will take place only if oxygen is more concentrated in the water than in the blood. This is usually true because the blood coming to the gills has already traveled through the rest of the body and is depleted of oxygen (Fig. 8.15). As oxygen diffuses from the water to blood in the capillaries, the amount of oxygen in

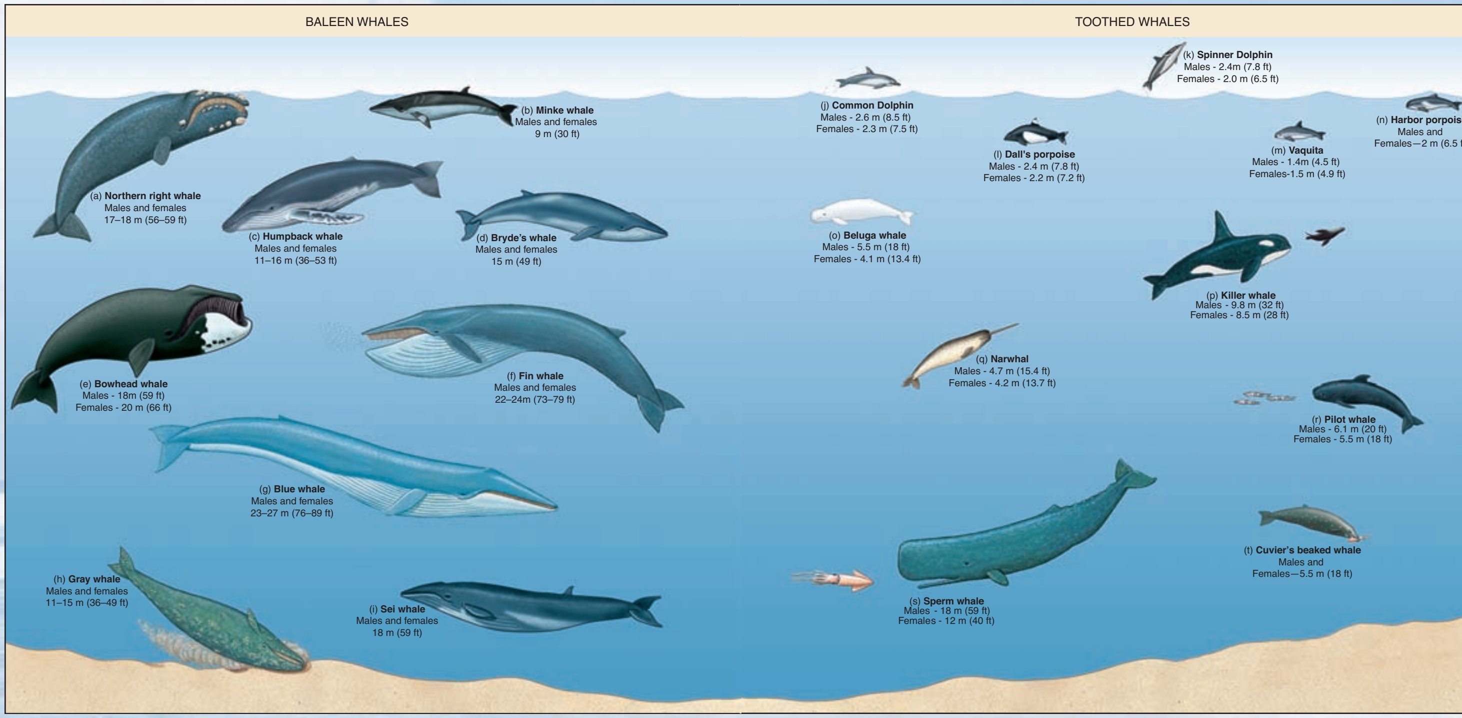
By the time the blood has flowed most of the way through the gill, picking up oxygen, it encounters water that is just entering the gill chamber and is rich in oxygen. Thus, the oxygen content of the water is always higher than that of the blood. This system makes the gills very efficient at extracting oxygen. Without this countercurrent system, blood returning to the body would have less oxygen.

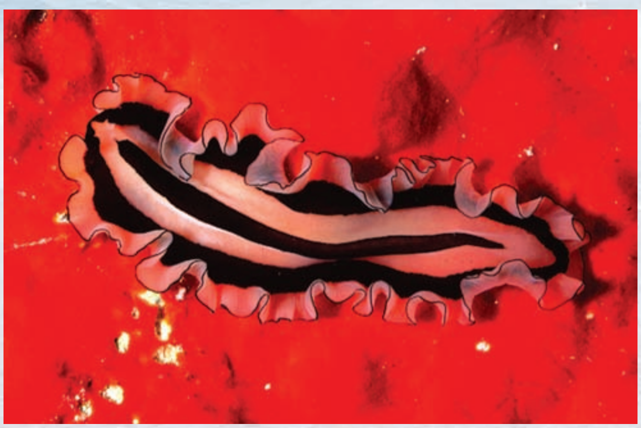
The blood disposes of its carbon dioxide using the same mechanism. Blood flowing into the gills from the body has a high concentration of carbon dioxide, a product of respiration. It easily diffuses out into the water.

Gas exchange in the gills of fishes is highly efficient. The surface area of gills is greatly increased by lamellae, and the flow of water through them is in a direction opposite to that of blood.

Gas Exchange The absorption of oxygen to be used in respiration (the breakdown of glucose to release energy) and the elimination of carbon dioxide that results from the same process.
- Chapter 7, p. 000

Diffusion The movement of molecules from areas of high concentration to areas of low concentration.
- Chapter 4, p. 00





Illustrations and photographs have been carefully designed and selected to complement and reinforce the text. The eighth edition contains many new illustrations and photographs.

Table 8.1 Most Important Characteristics of Marine Fishes

Group	Distinguishing Features	Skeleton	Feeding	Reproduction	Significance in the Marine Environment
Hagfishes	No paired fins; no scales; exposed gill slits; marine	Cartilaginous skull; no vertebrae, no jaws	Suction by round, muscular mouth with teeth	Oviparous	Predators of dead or dying fishes and bottom invertebrates
Lampreys	Two dorsal fins only; no scales; exposed gill slits; fresh-water or anadromous	Cartilaginous skull; no vertebrae, no jaws	Suction by round, muscular mouth with teeth	Oviparous	Suckers of fish blood or predators of bottom invertebrates
Rays, skates	Paired fins; placoid scales; pectoral fins greatly expanded; five ventral gill slits; mostly marine	Cartilaginous	Grinding plates to feed on bottom animals or gill rakers to filter plankton	Oviparous, viviparous	Predators of bottom animals or filter feeders
Sharks	Paired fins; placoid scales; exposed, 5–7 lateral gill slits; mostly marine	Cartilaginous	Teeth in jaws to capture prey or gill rakers to filter plankton	Oviparous, ovoviviparous, viviparous	Predators or filter feeders
Ratfishes	Paired fins; placoid scales; one pair of gill slits covered by flap of tissue; deep water	Cartilaginous	Grinding plates to feed on bottom invertebrates	Oviparous	Predators of bottom invertebrates
Coelocanth	Paired fins; large scales; gills covered by operculum; deep water	Bony	Teeth in jaws to capture prey	Ovoviviparous	Predators
Bony fishes	Paired fins; cycloid or ctenoid scales (absent in some); gills covered by operculum; marine and fresh water	Bony	Teeth in jaws to capture prey or graze or gill rakers to filter plankton	Oviparous, ovoviviparous, viviparous	Predators, grazers, and filter feeders

EVOLUTIONARY PERSPECTIVE

Symbiotic Bacteria—the Essential Guests

Some bacteria have evolved to live in close, or **symbiotic,** associations with other marine organisms. Some symbiotic bacteria are **parasites** that may cause a disease. Others, on the other hand, benefit their hosts. These symbiotic bacteria began their association by increasing the chances of survival of the host and evolved to become essential—hosts could not survive without them. In many cases the symbiotic bacteria are even sheltered in special tissues or organs that evolved in the host, an example of **coevolution,** in which two species evolve in response to each other.

All eukaryotic organisms, including humans, shelter bacteria without which they could not live. The chloroplasts and mitochondria of eukaryotic cells evolved from symbiotic bacteria (see "From Snack to Servant: How Complex Cells Arose," p. 00). These bacteria have become an integral part of all complex cells.

There are many cases of symbiotic bacteria among marine organisms. Symbiotic bacteria, for example, are involved in digesting the wood that is ingested by shipworms *(Teredo),* which happen to be bivalve molluscs, not worms. Like all wood-eating animals, shipworms lack cellulase, the enzyme needed to digest cellulose, the main component of wood. Wood is a surprisingly common habitat in many marine environments, so everything from driftwood to boat bottoms is exploited by shipworms, thanks to their symbiotic bacteria.

Symbiotic bacteria are also responsible for the light, or **bioluminescence,** that is produced by some fishes, squids, octopuses, and other animals of the deep (see "Bioluminescence," p. 000). The bacteria are usually sheltered in special light-producing organs, or **photophores.** These deep-sea animals, which live in darkness, use light to communicate with other members of their species, lure prey, blend with the light that filters from the surface, and perform other functions. Flashlight fishes *(Anomalops),* which live in shallow tropical waters, lodge their symbiotic bacteria in an organ beneath each eye. A shutter mechanism controls the emission of light, so that the fish can "blink" at night. Groups of fish blink in synchrony, a behavior that is involved in attracting prey.

Chemosynthetic bacteria symbiotic with mussels, clams, and tubeworms that live around deep-sea hydrothermal vents have a very particular role: manufacturing organic matter from CO_2 and the abundant hydrogen sulfide (H_2S) from the vents. The symbiotic bacteria live in a special organ, the feeding body, of the giant hydrothermal-vent tubeworm *Riftia* (see Fig. 16.29).

Marine symbiotic bacteria can also affect human health. Pufferfishes store a toxin that is deadly to any predators (including humans) that eat them. The fish, or *fugu,* is a delicacy in Japan. Licensed chefs must prepare the fish; otherwise, the toxin **(tetrodotoxin)** will kill anyone feasting on fish that has been improperly prepared. Tetrodotoxin is a deadly neurotoxin (that is, it affects the nervous system). In fact, it is one of the most powerful poisons known, and there is no antidote. The deadly toxin is stored mostly in the liver and gonads of the fish, so the internal organs must be expertly removed. Mistakes do happen and numerous deaths (including the suicides of disgraced cooks) take place every year in Japan. Cooks may still be guilty, but not the puffers: the toxin is not produced by puffers but apparently by symbiotic bacteria. The fish are actually resistant to tetrodotoxin as a result of a genetic mutation that changes the site where the toxin binds to nerve cells.

Tetrodotoxin and very similar toxins have also been found in a variety of marine organisms, including flatworms, snails, crabs, sea stars, and several species of fishes. It has also been found in the blue-ringed octopuses, notoriously toxic animals. Tetrodotoxin of an unknown source has also been found in dead sea urchins and is suspected as their cause of death. We are not yet sure if in all these animals the toxin is produced by symbiotic bacteria or if it is accumulated from their food. In arrow worms, however, symbiotic bacteria in the mouth do produce tetrodotoxin that is used to paralyze prey.

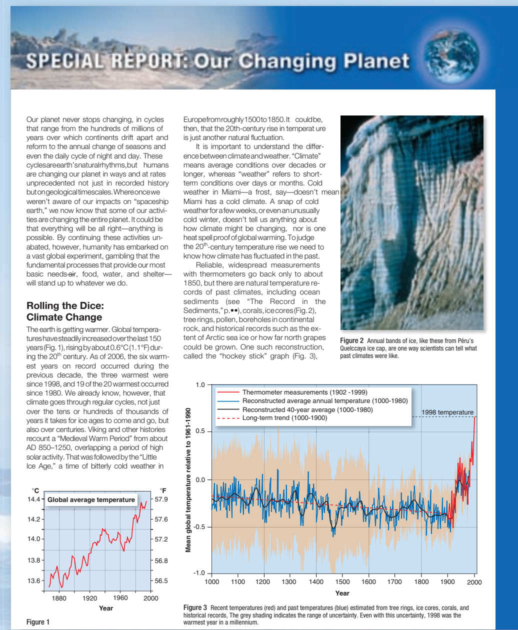
Being a neurotoxin, tetrodotoxin may block pain signals in humans. A derivative being tested as a pain reliever for cancer and other diseases would have the advantage of not being addictive, as are morphine and similar drugs.

The production of powerful toxins that are used by other organisms is just one example of the amazing abilities of bacteria—invisible to the eye but powerful giants when it comes to their role in the environment.

A Japanese pufferfish, or *fugu (Takifugu niphobles).*

Boxed Essays present interesting supplemental information on varied subjects such as deep-water coral communities, tsunamis, and red tides. A number of boxes have been highlighted as "Evolutionary Perspective" boxes to emphasize the central role of an evolutionary perspective in biology.

New! Illustrated tables at the end of each chapter in Part Two provide a consolidated review of major taxonomic groups and their characteristics.



Our planet never stops changing, in cycles that range from the hundreds of millions of years over which continents drift apart and reform to the annual change of seasons and even the daily cycle of night and day. These cycles are earth's natural rhythms, but humans are changing our planet in ways and at rates unprecedented not just in recorded history but on geological timescales. Where once we weren't aware of our impacts on "spaceship earth," we now know that some of our activities are changing the entire planet. It could be that everything will be all right—anything is possible. By continuing these activities unabated, however, humanity has embarked on a vast global experiment, gambling that the fundamental processes that provide our most basic needs—air, food, water, and shelter—will stand up to whatever we do.

Rolling the Dice: Climate Change

The earth is getting warmer. Global temperatures have steadily increased over the last 150 years (Fig. 1), rising by about 0.6°C (1.1°F) during the 20th century. As of 2006, the six warmest years on record occurred during the previous decade, the three warmest were since 1998, and 19 of the 20 warmest occurred since 1980. We already know, however, that climate goes through regular cycles, not just over the tens or hundreds of thousands of years it takes for ice ages to come and go, but also over centuries. Viking and other histories recount a "Medieval Warm Period" from about AD 850–1250, overlapping a period of high solar activity. That was followed by the "Little Ice Age," a time of bitterly cold weather in Europe from roughly 1500 to 1850. It could be, then, that the 20th-century rise in temperature is just another natural fluctuation.

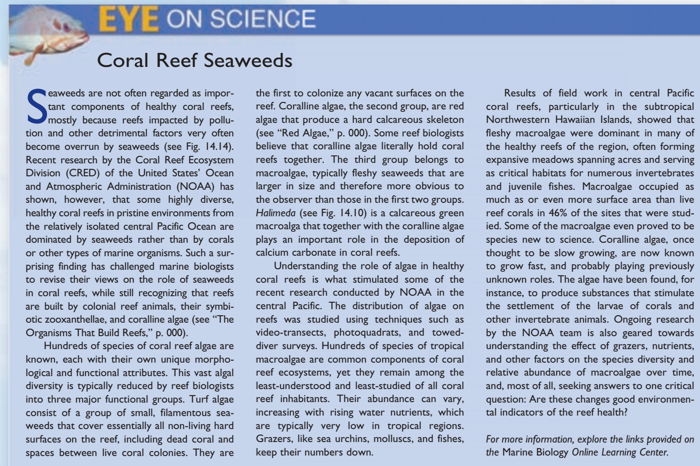
It is important to understand the difference between climate and weather. "Climate" means average conditions over decades or longer, whereas "weather" refers to short-term conditions over days or months. Cold weather in Miami—a frost, say—doesn't mean Miami has a cold climate. A snap of cold weather for a few weeks, or even an unusually cold winter, doesn't tell us anything about how climate might be changing, nor is one heat spell proof of global warming. To judge the 20th-century temperature rise we need to know how climate has fluctuated in the past.

Reliable, widespread measurements with thermometers go back only to about 1850, but there are natural temperature records of past climates, including ocean sediments (see "The Record in the Sediments," p. ••), corals, ice cores (Fig. 2), tree rings, pollen, boreholes in continental rock, and historical records such as the extent of Arctic sea ice or how far north grapes could be grown. One such reconstruction, called the "hockey stick" graph (Fig. 3),

Figure 1

Figure 2 Annual bands of ice, like these from Peru's Quelccaya ice cap, are one way scientists can tell what past climates were like.

Figure 3 Recent temperatures (red) and past temperatures (blue) estimated from tree rings, ice cores, corals, and historical records. The grey shading indicates the range of uncertainty. Even with this uncertainty, 1998 was the warmest year in a millennium.



EYE ON SCIENCE

Coral Reef Seaweeds

Seaweeds are not often regarded as important components of healthy coral reefs, mostly because reefs impacted by pollution and other detrimental factors very often become overrun by seaweeds (see Fig. 14.14). Recent research by the Coral Reef Ecosystem Division (CRED) of the United States' Ocean and Atmospheric Administration (NOAA) has shown, however, that some highly diverse, healthy coral reefs in pristine environments from the relatively isolated central Pacific Ocean are dominated by seaweeds rather than by corals or other types of marine organisms. Such a surprising finding has challenged marine biologists to revise their views on the role of seaweeds in coral reefs, while still recognizing that reefs are built by colonial reef animals, their symbiotic zooxanthellae, and coralline algae (see "The Organisms That Build Reefs," p. 000).

Hundreds of species of coral reef algae are known, each with their own unique morphological and functional attributes. This vast algal diversity is typically reduced by reef biologists into three major functional groups. Turf algae consist of a group of small, filamentous seaweeds that cover essentially all non-living hard surfaces on the reef, including dead coral and spaces between live coral colonies. They are the first to colonize any vacant surfaces on the reef. Coralline algae, the second group, are red algae that produce a hard calcareous skeleton (see "Red Algae," p. 000). Some reef biologists believe that coralline algae literally hold coral reefs together. The third group belongs to macroalgae, typically fleshy seaweeds that are larger in size and therefore more obvious to the observer than those in the first two groups. *Halimeda* (see Fig. 14.10) is a calcareous green macroalga that together with the coralline algae plays an important role in the deposition of calcium carbonate in coral reefs.

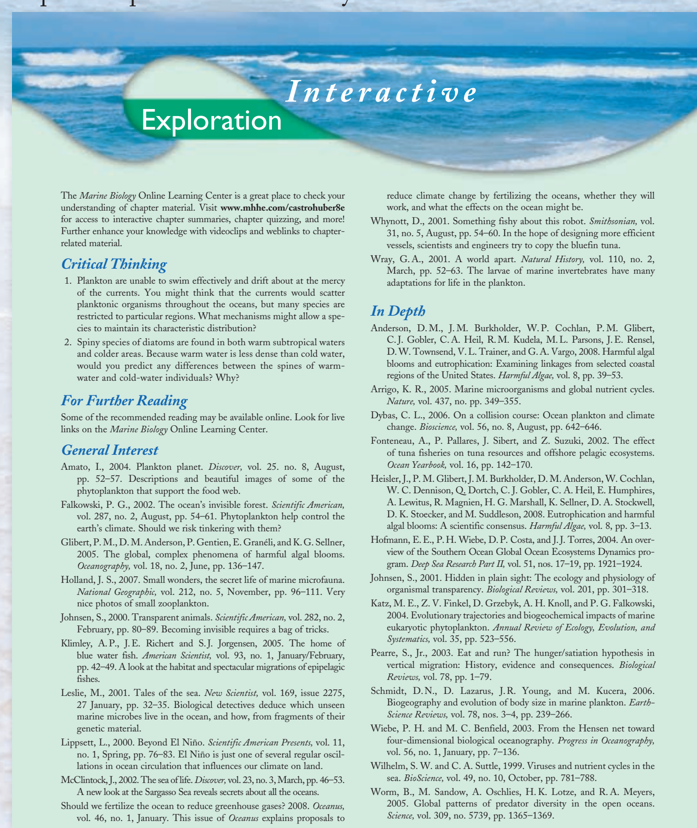
Understanding the role of algae in healthy coral reefs is what stimulated some of the recent research conducted by NOAA in the central Pacific. The distribution of algae on reefs was studied using techniques such as video-transects, photoquadrats, and towed-diver surveys. Hundreds of species of tropical macroalgae are common components of coral reef ecosystems, yet they remain among the least-understood and least-studied of all coral reef inhabitants. Their abundance can vary, increasing with rising water nutrients, which are typically very low in tropical regions. Grazers, like sea urchins, molluscs, and fishes, keep their numbers down.

Results of field work in central Pacific coral reefs, particularly in the subtropical Northwestern Hawaiian Islands, showed that fleshy macroalgae were dominant in many of the healthy reefs of the region, often forming expansive meadows spanning acres and serving as critical habitats for numerous invertebrates and juvenile fishes. Macroalgae occupied as much as or even more surface area than live reef corals in 46% of the sites that were studied. Some of the macroalgae even proved to be species new to science. Coralline algae, once thought to be slow growing, are now known to grow fast, and probably playing previously unknown roles. The algae have been found, for instance, to produce substances that stimulate the settlement of the larvae of corals and other invertebrate animals. Ongoing research by the NOAA team is also geared towards understanding the effect of grazers, nutrients, and other factors on the species diversity and relative abundance of macroalgae over time, and, most of all, seeking answers to one critical question: Are these changes good environmental indicators of the reef health?

For more information, explore the links provided on the Marine Biology Online Learning Center.

Eye on Science boxes reflect current scientific research and technology in the field of marine biology. Sample topics include the evolution of tetrapods, the use of ocean observations in forensic science, common ground between ecology and economics, and deep-sea exploration in the Cayman Trench.

New Feature! A major highlight, introduced in the seventh edition, is an insert located after Chapter 10, ***Special Report: Our Changing Planet.*** This current and informative insert highlights several key aspects of global change, including global warming, ocean acidification, eutrophication, hypoxic zones, and stratospheric ozone depletion. The global depletion of fisheries, and loss of critical habitats.



Interactive Exploration

The *Marine Biology* Online Learning Center is a great place to check your understanding of chapter material. Visit **www.mhhe.com/castrohuber8e** for access to interactive chapter summaries, chapter quizzing, and more! Further enhance your knowledge with videoclips and weblinks to chapter-related material.

Critical Thinking

1. Plankton are unable to swim effectively and drift about at the mercy of the currents. You might think that the currents would scatter planktonic organisms throughout the oceans, but many species are restricted to particular regions. What mechanisms might allow a species to maintain its characteristic distribution?
2. Spiny species of diatoms are found in both warm subtropical waters and colder areas. Because warm water is less dense than cold water, would you predict any differences between the spines of warm-water and cold-water individuals? Why?

For Further Reading

Some of the recommended reading may be available online. Look for live links on the *Marine Biology* Online Learning Center.

General Interest

Amato, I., 2004. Plankton planet. *Discover,* vol. 25. no. 8, August, pp. 52–57. Descriptions and beautiful images of some of the phytoplankton that support the food web.

Falkowski, P. G., 2002. The ocean's invisible forest. *Scientific American,* vol. 287, no. 2, August, pp. 54–61. Phytoplankton help control the earth's climate. Should we risk tinkering with them?

Glibert, P. M., D. M. Anderson, P. Gentien, E. Granéli, and K. G. Sellner, 2005. The global, complex phenomena of harmful algal blooms. *Oceanography,* vol. 18, no. 2, June, pp. 136–147.

Holland, J. S., 2007. Small wonders, the secret life of marine microfauna. *National Geographic,* vol. 212, no. 5, November, pp. 96–111. Very nice photos of small zooplankton.

Johnsen, S., 2000. Transparent animals. *Scientific American,* vol. 282, no. 2, February, pp. 80–89. Becoming invisible requires a bag of tricks.

Klimley, A. P., J. E. Richert and S. J. Jorgensen, 2005. The home of blue water fish. *American Scientist,* vol. 93, no. 1, January/February, pp. 42–49. A look at the habitat and spectacular migrations of epipelagic fishes.

Leslie, M., 2001. Tales of the sea. *New Scientist,* vol. 169, issue 2275, 27 January, pp. 32–35. Biological detectives deduce which unseen marine microbes live in the ocean, and how, from fragments of their genetic material.

Lippsett, L., 2000. Beyond El Niño. *Scientific American Presents,* vol. 11, no. 1, Spring, pp. 76–83. El Niño is just one of several regular oscillations in ocean circulation that influences our climate on land.

McClintock, J., 2002. The sea of life. *Discover,* vol. 23, no. 3, March, pp. 46–53. A new look at the Sargasso Sea reveals secrets about all the oceans.

Should we fertilize the ocean to reduce greenhouse gases? 2008. *Oceanus,* vol. 46, no. 1, January. This issue of *Oceanus* explains proposals to reduce climate change by fertilizing the oceans, whether they will work, and what the effects on the ocean might be.

Whynott, D., 2001. Something fishy about this robot. *Smithsonian,* vol. 31, no. 5, August, pp. 54–60. In the hope of designing more efficient vessels, scientists and engineers try to copy the bluefin tuna.

Wray, G. A., 2001. A world apart. *Natural History,* vol. 110, no. 2, March, pp. 52–63. The larvae of marine invertebrates have many adaptations for life in the plankton.

In Depth

Anderson, D. M., J. M. Burkholder, W. P. Cochlan, P. M. Glibert, C. J. Gobler, C. A. Heil, R. M. Kudela, M. L. Parsons, J. E. Rensel, D. W. Townsend, V. L. Trainer, and G. A. Vargo, 2008. Harmful algal blooms and eutrophication: Examining linkages from selected coastal regions of the United States. *Harmful Algae,* vol. 8, pp. 39–53.

Arrigo, K. R., 2005. Marine microorganisms and global nutrient cycles. *Nature,* vol. 437, no. pp. 349–355.

Dybas, C. L., 2006. On a collision course: Ocean plankton and climate change. *Bioscience,* vol. 56, no. 8, August, pp. 642–646.

Fonteneau, A., P. Pallares, J. Sibert, and Z. Suzuki, 2002. The effect of tuna fisheries on tuna resources and offshore pelagic ecosystems. *Ocean Yearbook,* vol. 16, pp. 142–170.

Heisler, J., P. M. Glibert, J. M. Burkholder, D. M. Anderson, W. Cochlan, W. C. Dennison, Q. Dortch, C. J. Gobler, C. A. Heil, E. Humphires, A. Lewitus, R. Magnien, H. G. Marshall, K. Sellner, D. A. Stockwell, D. K. Stoecker, and M. Suddleson, 2008. Eutrophication and harmful algal blooms: A scientific consensus. *Harmful Algae,* vol. 8, pp. 3–13.

Hofmann, E. E., P. H. Wiebe, D. P. Costa, and J. J. Torres, 2004. An overview of the Southern Ocean Global Ocean Ecosystems Dynamics program. *Deep Sea Research Part II,* vol. 51, nos. 17–19, pp. 1921–1924.

Johnsen, S., 2001. Hidden in plain sight: The ecology and physiology of organismal transparency. *Biological Reviews,* vol. 201, pp. 301–318.

Katz, M. E., Z. V. Finkel, D. Grzebyk, A. H. Knoll, and P. G. Falkowski, 2004. Evolutionary trajectories and biogeochemical impacts of marine eukaryotic phytoplankton. *Annual Review of Ecology, Evolution, and Systematics,* vol. 35, pp. 523–556.

Pearre, S., Jr., 2003. Eat and run? The hunger/satiation hypothesis in vertical migration: History, evidence and consequences. *Biological Reviews,* vol. 78, pp. 1–79.

Schmidt, D. N., D. Lazarus, J. R. Young, and M. Kucera, 2006. Biogeography and evolution of body size in marine plankton. *Earth-Science Reviews,* vol. 78, nos. 3–4, pp. 239–266.

Wiebe, P. H. and M. C. Benfield, 2003. From the Hensen net toward four-dimensional biological oceanography. *Progress in Oceanography,* vol. 56, no. 1, January, pp. 7–136.

Wilhelm, S. W. and C. A. Suttle, 1999. Viruses and nutrient cycles in the sea. *BioScience,* vol. 49, no. 10, October, pp. 781–788.

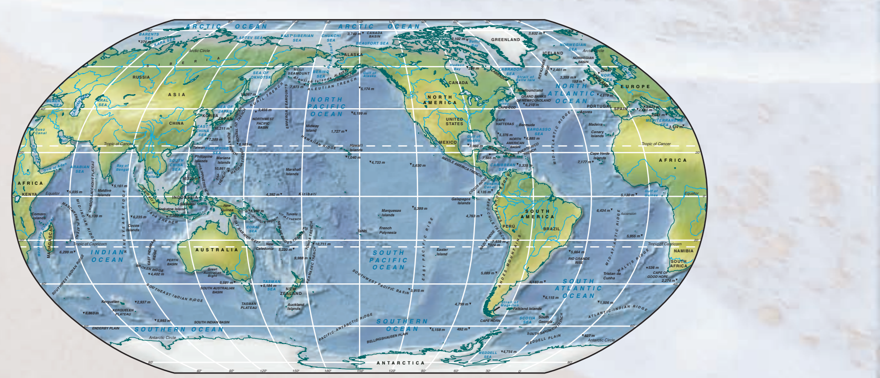
Worm, B., M. Sandow, A. Oschlies, H. K. Lotze, and R. A. Meyers, 2005. Global patterns of predator diversity in the open oceans. *Science,* vol. 309, no. 5739, pp. 1365–1369.

Each chapter ends with an **Interactive Exploration** to be used in conjunction with the ***Marine Biology Website.*** Students are encouraged to visit **www.mhhe.com/castrohuber8e** for access to chapter quizzing, interactive chapter summaries, key term flashcards, marine biology video clips, and web links to chapter-related material.

Critical thinking questions challenge students to think more deeply about the chapter material and also help stimulate class discussion.

For Further Reading lists "General Interest" articles in publications such as *Scientific American, Discover,* and *National Geographic,* which are appropriate for students with limited backgrounds in science and "In Depth" readings for students who want to study particular topics in detail.

The World Ocean



A foldout map at the end of text provides quick reference to the World Ocean and the major coastal marine ecosystems and marine protected areas of North America.