

- » Getting a big-picture view of the ocean and related bodies of water
- » Wrapping your brain around the water cycle
- » Sampling the vast diversity of ocean life
- » Building a mutually beneficial relationship with the ocean

Chapter **1**

Brushing Up on Ocean Fundamentals

Before you dive into any large or complex topic, you're wise to step back and look at the big picture. A general understanding provides a framework on which to hang the details. In this chapter, we provide that framework, establishing a context for understanding the many facets of the ocean and how they all fit together.

We start by introducing you to the ocean and breaking it down into its five "oceans." Then, we get into a few topics in the realm of *physical oceanography* — the water cycle, the shapes of the ocean basins, meteorology, and other properties and processes that explain what makes the ocean tick from a physical standpoint. We then introduce you to the various groups of life-forms that populate the ocean — plants, animals, and beings that fit in neither (or both) categories. Finally, we wrap things up with a discussion of the ocean's current state and the human-ocean relationship — the benefits we gain from the ocean and our responsibilities as environmental stewards in protecting and preserving it.

Get ready for a wild ride. In this chapter, we cover a lot of ground, not to mention all that water!

Taking a Nickel Tour of the Ocean(s)

The ocean is big. How big? Well, it covers about 360 million square kilometers (140 million square miles), which is just a smidgen more than 70 percent of Earth's surface. Volume-wise it contains approximately 1.3 billion cubic kilometers (321 million cubic miles) of water — that translates to about 352 quintillion gallons, which accounts for about 97 percent of Earth's water. In terms of living space, the ocean comprises about 99 percent of the *biosphere* — all land, water, and atmosphere where life on Earth exists.

Because it's so big, people have developed all sorts of ways to slice and dice it to better understand and describe the different areas that make it up.

Dividing the ocean into oceans . . . or not

Earth has only one ocean, which is why we will refer to it as *the ocean* (singular) throughout this book. Geographically, it's divided into four or five oceans, depending on who's doing the dividing. Prior to the year 2000, text books recognized four oceans: the Atlantic, Pacific, Indian, and Arctic. Sometime around the year 2000, the International Hydrographic Organization designated a fifth ocean the Southern Ocean — a band that wraps around the world from the coast of Antarctica to 60 degrees south latitude (see Figure 1-1). Here's a brief description of each of the five oceans, in order of size, because, well, size matters.

- » **Pacific Ocean:** The largest of the five "oceans," the Pacific stretches from the Arctic to the Southern Ocean and from east of Asia and Australia to the Americas. It covers more area than all the land on Earth combined and is more than double the surface area of the Atlantic Ocean. It also wins the deepest point in the ocean contest with the Mariana Trench, which is nearly 11 kilometers (about 7 miles) deep.
- » **Atlantic Ocean:** This next largest ocean lies between the Americas and the continents of Europe and Africa. It's home to the Bermuda Triangle, the Sargasso Sea, the Gulf Stream, and the hurricanes that rattle the Caribbean Islands and the southern and eastern coasts of the U.S. The North Atlantic is *by far* the most thoroughly explored, best understood, and most heavily fished of the five "oceans."
- » **Indian Ocean:** Nestled between Africa (to the west) and Australia (to the east) and between Asia (to the north) and the Southern Ocean (below it), the Indian Ocean ranks third in surface area but first in warmth.

- » **Southern Ocean:** The Southern Ocean is relatively small, but its average depth is greater than the average depth of any of the other four oceans — four to five kilometers (2.5 to 3 miles) deep! It's best known for its strong, sustained easterly winds, its huge waves (due to the strong, sustained winds), and its frigid environment; during its winter, nearly the entire surface of the Southern Ocean is frozen. It's also home to the world's largest ocean current — the Antarctic Circumpolar Current — and it is chock full of nutrients.
- » **Arctic Ocean:** Surrounding the North Pole and bordering the northern edges of North America, Asia, and Europe is the Arctic Ocean. Most of it is located within the Arctic Circle, from the North Pole down to about 70 degrees northern latitude. It's the smallest and shallowest of the five "oceans," and for most of the year, most of its surface area consists of ice 1 to 10 meters (3 to 33 feet) thick. The Arctic Ocean is best known for its wildlife (including polar bears, whales, and seals) and for its natural resources (primarily oil).



FIGURE 1-1:
The ocean's
five "oceans."

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Recognizing the ocean zones

Oceanographers have divided the ocean into zones to better understand and describe the physical characteristics of the ocean, the *ecosystems* (biological communities) in each zone, and the inhabitants of those ecosystems. Zoning can be simple, such as dividing the ocean into two zones — photic and aphotic:

- » **Photic (light):** The top 200-meter (650-foot) layer of the ocean through which enough light penetrates enabling photosynthesis to occur. (*Photosynthesis* is the process of using the sun's energy to produce food from carbon dioxide and water.)

» **Aphotic (dark):** The part of the ocean from 200 meters down to the bottom, where it's totally dark.

Another simple zoning system involves dividing the ocean into pelagic and benthic layers:

» **Pelagic (top):** The water above the ocean floor.

» **Benthic (bottom):** The seafloor and the thick layer of sediments below the seafloor.

In Chapter 4, we cover two more-detailed approaches to zoning the ocean — one that divides it into five horizontal layers (like layers of a cake) based on depth, and another that divides it into three vertical zones from coast to open ocean.

Dropping in on the different ecosystems

An *ecosystem* is a biological community of organisms interacting with their physical environment as a whole. Think of it as a mostly self-contained, self-reliant neighborhood with a diverse population. Land-based ecosystems include grasslands, deserts, rainforests, and wetlands. Common marine ecosystems include coral reefs, estuaries (where fresh water and salt water mix), kelp (seaweed) beds and forests, mudflats, rocky shores, sandy shores, seagrass meadows, and more. Lesser known ecosystems develop near the bottom of the deep sea and include communities that form around *hydrothermal vents* (which spew hot, mineral-rich water that some bacteria feed on), *whale falls* (literally, dead whales that sink to the bottom), and *cold seeps* (where methane gas is released that some bacteria and archaea feed on).

What's so fascinating about ecosystems is that the community of residents that live within them evolved together, adapting to the unique conditions of a particular place as well as each other. In Chapter 5, we explore numerous marine ecosystems and introduce you to the plants, animals, and other organisms typically found in each.

Going with the Flow: The Physical Properties of the Ocean

Even without all the wonderful living organisms that call it home, the ocean is amazing. In fact, it is very much like a living thing itself; it breathes, it moves, it's constantly changing, and it interacts with everything around it — land, water,

and air. It plays a huge role in controlling Earth's climate and making the weather, and it distributes heat and nutrients around the globe, making the entire world more habitable for every living thing.

In this section, we get physical by focusing on the salt in seawater, the various processes that maintain a steady flow of water around the world, and the interactions among land, sea, and air.

Getting up to speed on the water cycle

While plants and animals have life cycles, water has a life cycle of its own. Following the rule of “what goes up must come down,” the life cycle of water, commonly referred to as the *hydrologic cycle*, describes the way water travels around the globe from ocean to air to land and back again to the ocean (see Figure 1-2).

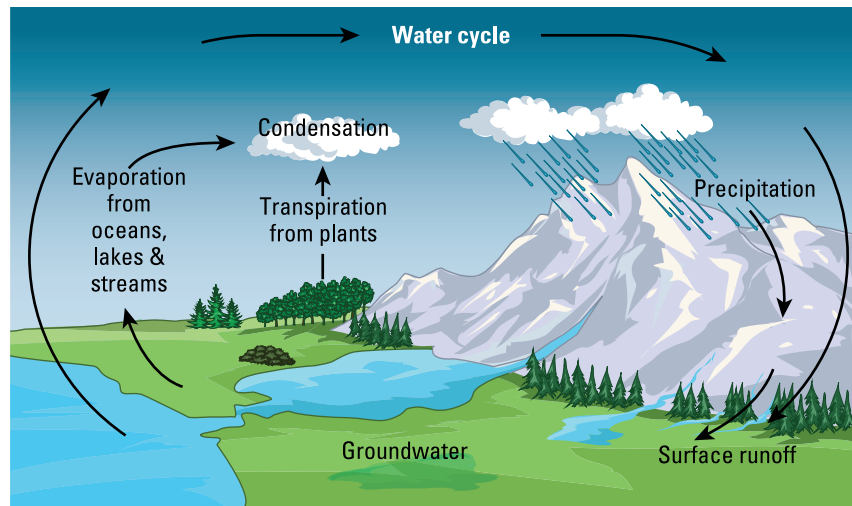


FIGURE 1-2:
The hydrologic
(water) cycle.

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Water is a wonderful element which can take on three different states of being. It can exist in a solid state (ice), a liquid form (water), or a gaseous state (steam), in which it evaporates and becomes vapor (humidity). When humid air is cooled, the water forms droplets and falls back to the earth as *precipitation* — in either liquid form (as rain) or in solid form (as snow or hail).

Knowing what makes seawater salty

Why are most lakes, rivers, ponds, and streams all freshwater, whereas the ocean is salty? Mostly because of the water cycle. Most of the salt in the ocean comes from freshwater rivers and runoff from land. As the water moves over the land and rocks and through the earth, it picks up minute traces of salt and other minerals, which it then carries to and deposits in the ocean.

When water evaporates from the ocean, the salt remains, while the water vapor either precipitates over the ocean or is carried over and deposited as precipitation on land, where it washes more minerals into the ocean. This process “quickly” (that is, on a geological time scale) increased the concentration of salt in seawater to the level at which it is today — on average about 3.5 percent.

Investigating variations in salt concentrations

Because water evaporates faster from some parts of the ocean than others and rainfall and river discharge to the ocean isn’t uniform around the globe, certain parts of the ocean are saltier than others. For example, salinity in the Red Sea ranges from 36 ppt (parts per thousand) to 41 ppt (about 3.6 to 4.1 percent). In the Mediterranean Sea, surface waters average 38 ppt but can approach 40 ppt in the extreme western parts. Saltwater taffy, anyone?

Salinity also fluctuates in certain areas of the ocean. For example, in polar regions, the salinity of water near the surface increases as ice forms, leaving much of the salt behind. As the ice melts, salinity decreases due to the influx of fresh water. Likewise, in coastal areas, salinity is lower in areas where freshwater from rivers and streams enters the ocean. When the salinity dips below about 30 ppt, the water is often called *brackish*.

Realizing that sea water is more than just salty water

The recipe for cookin’ up a batch of seawater might seem quite simple: Start with 1 gallon (about 4 liters) of water, add about 4 tablespoons (60 grams) salt, and shake till dissolved. However, seawater is more complex than mere salt and water — it contains a very large number of chemical elements and compounds, including dissolved organic materials, particulates, and dissolved gasses, including oxygen. (Marine mammals can’t breathe the gasses dissolved in seawater, but apparently the crew of the movie *The Abyss* can.)

Don’t worry, we’re not going to deliver a lecture on the chemical composition of seawater, but knowing that seawater is more than just salty water is important for when we get into discussions about certain issues related to preserving the ocean’s health, such as climate change and ocean acidification (see Chapter 21).

Checking out what's at the bottom of the ocean (and below)

At the bottom of the ocean is a landscape that's as varied as what you see above the ocean, complete with plains, ridges (mountain ranges), seamounts (mountains), hills, canyons, trenches (valleys), cliffs, volcanoes, hydrothermal vents (underwater geysers), and even rivers and massive “waterfalls” of sand and sediment that you do indeed want to go chasing.

The shape of the ocean floor (as well as all land) is largely determined by a process called *plate tectonics* — the bumping, grinding, and separating of *tectonic plates* (massive sections of rock that form Earth's crust). These plates ride atop a semi-liquid layer of molten rock (imagine heating a rock till it melts — that's HOT). Convection currents in the molten rock move the plates at three to five centimeters (one to two inches) per year. (See Chapter 6 for more about plate tectonics.)

Plate tectonics are also responsible for creating most tsunamis. Whenever land shifts at the bottom of the ocean or an underwater volcano erupts, the resulting displacement of water can send a wave thousands of miles across the ocean in a matter of only a few hours. (See Chapter 16 for more about waves and tsunamis.)

Riding waves, tides, and currents

Ocean water is constantly in motion thanks to a variety of forces, including the rotation of Earth; the gravitational fields of the sun, Earth, and moon; wind; and variations in the temperature and salinity of ocean water.

On a cosmic scale, the interaction of the Earth's, moon's, and sun's gravitational forces cause *tides* that move water toward and away from coastlines once or, more often, twice daily.

At the ocean's surface, wind, along with other forces (including Earth's rotation and variations in water temperature and salinity) drive the formation of large rotating waters called *gyres* that generally spin clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere. (And no, this has no effect on the direction water swirls down your bathtub drain.)

Below the surface, differences in water density drive currents. Near the poles, when water freezes at the surface, it leaves behind its salt. This colder, saltier water near the surface is denser than the warmer, fresher water below it, so it dives down, hits the seafloor, and heads toward the equator. As this cold water moves down and away from the poles, warmer surface water rushes in toward the poles to replace it, resulting in a continuous current that transports water, heat, and nutrients around the globe. This process is called *thermohaline circulation*, and the resulting system of currents is called the *global ocean conveyor belt*. It is one of

the many reasons the poles are so important. They literally drive our entire ocean system, supporting marine life (and seafood) all around the globe.

See Chapter 16 for more about waves, tides, currents, and gyres and how water, heat, and nutrients are circulated around the world via ocean currents.

Recognizing the ocean's role in climate control and weather

The ocean plays a critical role in keeping our planet at a steady temperature as it transports heat (and energy) around the globe. Of course, it's not that simple, and the ocean doesn't do this all by itself; it works together with the atmosphere and land to create our climate and influence the ever-changing weather patterns:

- » **Climate:** The prevailing weather over a long period of time (usually more than 30 years), such as tropical (warm and wet), desert (hot dry), polar (cold and dry), and temperate (neither extremely hot nor extremely cold).
- » **Weather:** Atmospheric conditions over a short period of time in respect to temperature, sunshine, storms, wind, and precipitation (rain, snow, sleet, hail).

The impact of the ocean on weather is most dramatic when the ocean releases some of its energy in the form of a *tropical cyclone* (a hurricane, cyclone, or typhoon). See Chapter 17 for more about how the ocean influences climate and weather.

Meeting the Ocean's Inhabitants

The ocean is teeming with life, from coastline to open ocean and from surface to seafloor. These living beings can be broken down into six groups (technically known as *kingdoms*) — Plants, Animals, Protists, Fungi, Archaeobacteria, and Eubacteria. In this book, we break them into three groups — microbes (generally too small to see with the naked eye), plants (and other organisms that require sunlight for energy and growth), and animals. Each of these groups can be broken down further; for example, the animal kingdom includes simple invertebrates (such as sponges and jellies), mollusks (such as snails and clams), crustaceans (such as crabs and lobsters), fish, reptiles, birds, and mammals.

In this section, we cover the bare bones of *taxonomy* — the classification system used to assign organisms to specific groups — and introduce you to the groups of organisms we cover in Part 3.

Recognizing strength in numbers: Marine microorganisms

Microorganisms are (mostly) life-forms too small to see with the naked eye. Many of these are smaller than the cells that make up our bodies, but what they lack in size, they more than make up for in numbers. The ocean is home to an estimated 44 octillion microbes — more than all the stars in the known universe. Perhaps more amazing is that microbes comprise somewhere between 90 and 98 percent of the marine biomass (the total mass of all marine life)! These microorganisms can be broken down into four groups:

- » **Viruses** are infectious agents that invade cells and use them to replicate. They're not even classified as living beings (*burn!*).
- » **Bacteria** are single-celled organisms that have a cell wall but no *nucleus* (a container for most of the cell's genetic material) or *organelles* (specialized structures in a cell that perform various functions).
- » **Protists** are single-celled organisms equipped with a nucleus and organelles. They're not animals, plants, or fungi, but some are similar to plants in that they perform photosynthesis, some are similar to animals in that they move around and eat stuff, and some are more of a cross between the two — moving around, eating stuff, *and* performing photosynthesis.
- » **Fungi** are single-celled or multicelled organisms that feed on organic matter. They include yeasts, molds, mushrooms, and toadstools.



REMEMBER

Microorganisms are a vital component of oceans. They serve as *producers*, making food for consumers at the bottom of food chains, and they serve as *decomposers*, breaking down animal waste into chemicals that can be reused. See Chapter 7 for more about microbes and the important roles they play.

Going green with marine plants and plant-like organisms

Oceans aren't exactly known for their floral arrangements, but they do have a few recognizable plants and plenty of other important photosynthetic microorganisms that provide food, oxygen, and habitats for other marine organisms. Here's a list of some of the more notable marine plants and photosynthetic organisms covered in Chapter 8:

- » **Phytoplankton** are single-celled photosynthetic organisms sometimes described as "floating plants." Most are single-cell algae (micro-algae), but phytoplankton also include a type of photosynthetic bacteria called *cyanobacteria*.

- » **Macro-algae** are several species of macroscopic, multicellular marine algae commonly referred to as “seaweed.” They look like plants and can be very large, but they have no vascular system for distributing nutrients. All the cells that make up the seaweed absorb liquids and nutrients from the surrounding water.
- » **Seagrass** is a plant, complete with a vascular system, leaves, roots, and *rhizomes* (just like lawn grass); they’re pollinated under water, and they produce seeds.
- » **Mangroves** are highly salt-tolerant trees and shrubs that grow along shorelines in tropical locations. In addition to providing food, shelter, and breeding areas for other marine organisms, mangroves play an important role in protecting and even building land.
- » **Zooxanthellae:** Pronounced zo-uh-zan-thel-ee, these are single-celled photosynthetic organisms that live inside the cells of many marine animals, including coral polyps and some jellyfish, nudibranchs (sea slugs), and sponges, providing them with food in exchange for a place to live.

Grouping the ocean’s animals

Although microbes and plants play a vital role in keeping the ocean clean and fed, they don’t draw the crowds. The stars of the show are the animals, and the cast of marine creatures is truly incredible.

Unfortunately, this book can’t possibly cover all the amazing creatures that inhabit the ocean, so what we’ve done is break them down into taxonomic groups and subgroups, describe the common traits of each group, and then present one or more representatives of each group. We cover the following groups, progressing from least to most complex, and point out where to find them in this book:

- » **Simple invertebrates** are basic animals that have no backbone, including sponges, jellyfish, anemones, starfish, sea urchins, sand dollars, and a few different types of worms (yes, worms) that prefer the ocean over your lawn or garden. Wiggle over to Chapter 9 for more in simple invertebrates.
- » **Mollusks** (covered in Chapter 10) are soft-bodied invertebrates, most of which have recognizable shells but some of which don’t. You may know them better as snails, slugs, clams, oysters, mussels, octopus, and squid. And some of these are colossal.
- » **Crustaceans** (Chapter 11) are more advanced invertebrates with hard external skeletons, such as crabs, lobsters, shrimp, and krill. Just think “crusty,” like a good baguette: hard on the outside, soft on the inside.

- » **Fish (bony and not)** comprise the first group of vertebrates (animals with a backbone or something like it). You usually know a fish when you see one — most have a head and tail, fins, gills, and scales. We break them down into two groups: *cartilaginous* (the real softies, as in soft-boned) such as sharks and rays, and *bony* (hard boned, that is) which includes just about everyone else, such as tuna, salmon, and cod. Swim over to Chapter 12 for more details.
- » **Reptiles** (chillin' in Chapter 13) are scaly, cold-blooded, air-breathing vertebrates that lay soft eggs on land or give birth to live young. The ocean is home to only a handful of reptiles, including sea turtles, marine iguanas, saltwater crocodiles, and a few species of sea snakes (the latter of which you really don't want on your airplane).
- » **Birds** are warm-blooded, air-breathing vertebrates with two legs, two wings, feathers, and a beak. Most fly, though some, such as the penguin, don't. Most marine birds have special adaptations, such as the ability to secrete salt, oily wings to keep them from getting waterlogged, and webbed feet. Some have solid bones that enable them to dive more easily. Seabirds that dive-bomb their prey are even equipped with internal airbags to cushion their crash landings. In Chapter 14, we divide marine birds into two groups — seabirds, which spend most of their time on or flying over the ocean, and shorebirds, which spend most of their time on or near land or wading in the shallows of estuaries or marshes.
- » **Mammals** (covered in Chapter 15) are warm-blooded vertebrates that have at least some hair or fur and must surface to breathe air. Females have mammary glands and give birth to live young. Marine mammals include everyone's favorites — whales, dolphins, walruses, seals, sea otters, sea lions, manatees, dugongs, and polar bears.

Exploring the Complex and Evolving Human-Ocean Relationship

Every relationship requires some give and take, and this is certainly true regarding the relationship between humans and the sea. For millions of years, humans have been taking from the ocean without giving much in return. We've used it for food, transportation, vacation, recreation, and exploration. In the past 100 years or so, we've come to rely on it as a source for energy, minerals, and medications. And the ocean has always been a source of mystery, inspiring scientists, artists, and writers. (See Chapter 19 for more about the many ways the ocean makes a positive impact on our lives — economically and in other ways.)

Tragically, the ocean and its inhabitants are suffering, and it's time we give back to the ocean which has given us so much. We humans have caused most of the ocean's problems — ocean warming and acidification from greenhouse gas emissions, a steep decline in fish populations, devastating pollution like plastic and runoff, harmful coastal development resulting in the destruction of marine habitats, mining and drilling, and the introduction of invasive species.

Despite all these negatives, we have high hopes for a brighter future. The ocean is resilient and can help us solve many of these problems, but we all need to work together to reduce and reverse the damage. Here are some of the steps we must take to preserve this precious and irreplaceable resource:

- » **Achieving net-zero greenhouse gas emissions:** Human-caused greenhouse gas emissions include dioxide, methane, ozone, nitrous oxide, and chlorofluorocarbons. Achieving net-zero greenhouse gas emissions by 2050, at a minimum, is critical to slowing and stopping human-caused climate change, ocean acidification, and warming ocean temperatures.
- » **Reduce pollution:** Pollution in the air, water, and even on land ends up in the ocean. Sources of pollution include plastics (which never really biodegrade), sewage, industrial chemicals, agricultural fertilizers and pesticides, land runoff (especially from streets and parking lots), oil spills, ocean mining, littering, and the use of certain sunscreens.
- » **Fish sustainably:** Overfishing combined with destructive fishing methods are devastating marine wildlife populations risk. International legislation and enforcement are crucial for ensuring a sufficient supply of seafood for ourselves as well as marine ecosystems.
- » **Create marine protected areas (MPAs):** MPAs are areas where certain consumptive or destructive activities are prohibited for the purpose of protecting ecosystems, sustaining fisheries production, or preserving cultural resources.
- » **Engage youth:** The best way to make lasting change is from the ground up. It starts by educating the youth. They're best equipped to change their own behaviors and influence the minds, hearts, and actions of parents, teachers, government representatives, community members, and business leaders.

For more about threats to the ocean and what we can do to preserve it for future generations, see Chapter 21.

Pretty cool, huh? The ocean is an amazing place, and we hope that reading this book makes you fall in love with the ocean for the first time . . . or all over again; that you learn, laugh, maybe even shed a tear; and, most importantly, that you're inspired, knowing *YOU* have the power to help our mighty ocean.