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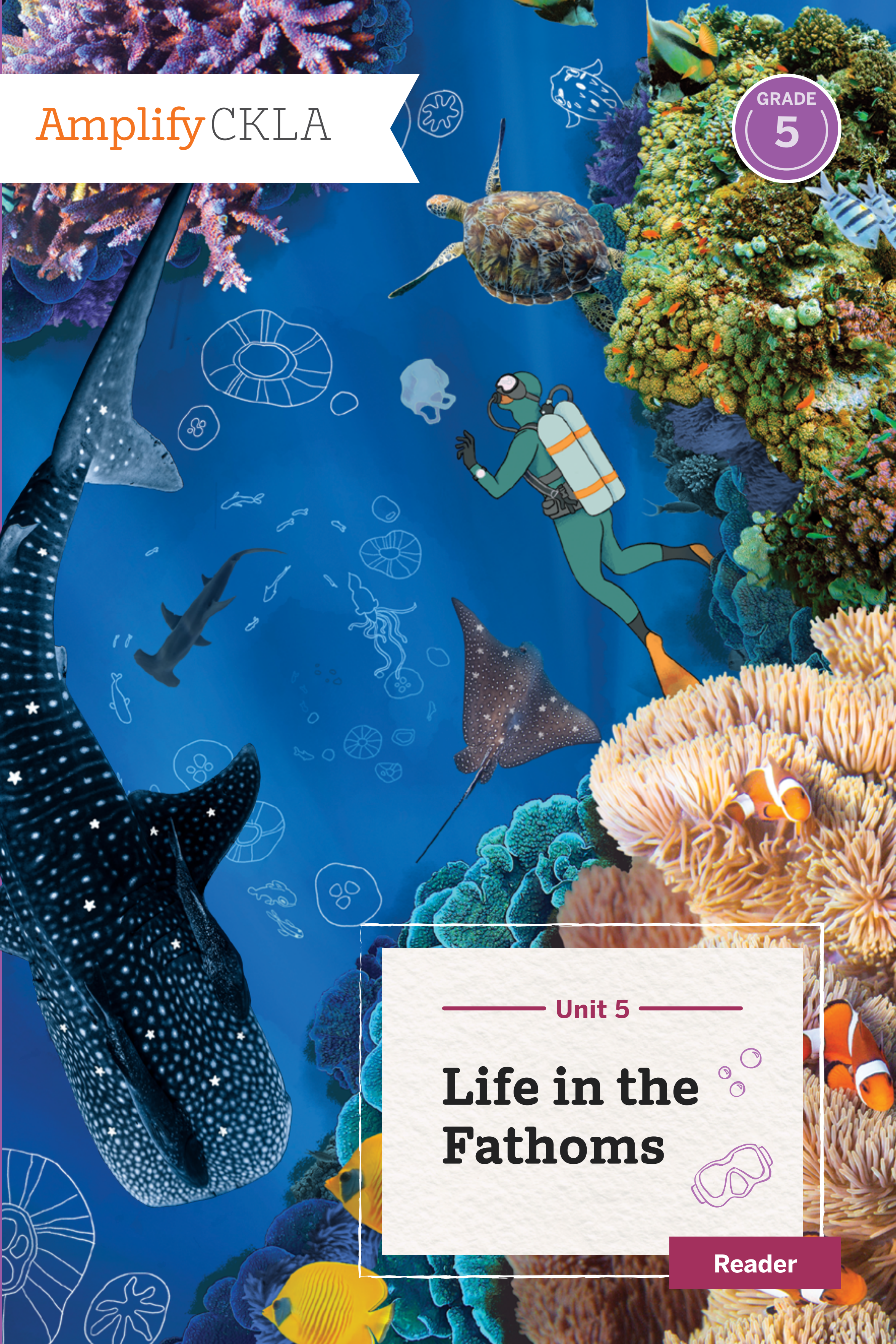

Unit 5

Life in the Fathoms

Reader

Grade 5 | Unit 5

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Reader

Amplify CKLA | Core Knowledge®

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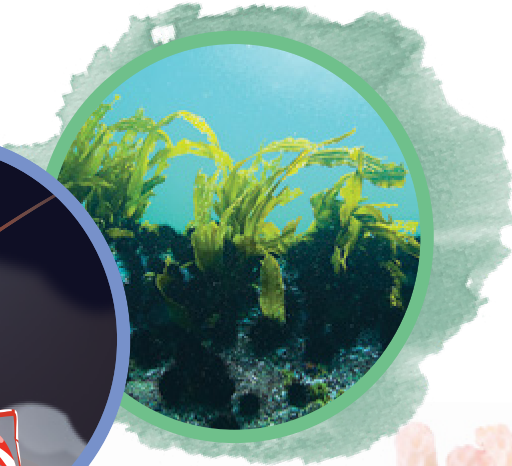
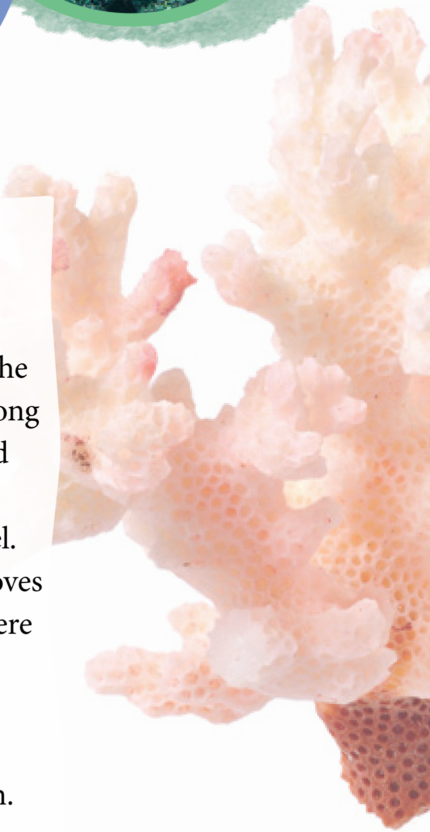
Reader

Chapter 1

Introducing Ocean Ecosystems and Their Inhabitants



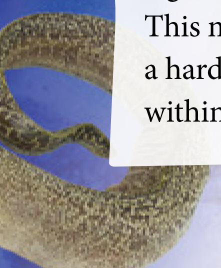


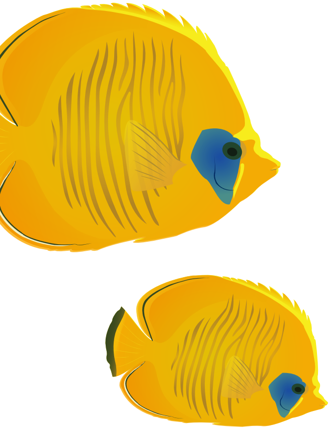
Picture this: you're snorkeling under the clear water somewhere off the coast of Australia when you spot bright pink and purple coral nestled in soft sand, surrounded by spiked sea urchins and starfish. Near the edges of the coral, delicate shrimp only a few inches long swim toward even smaller floating green specks called algae. There, within a swaying orange sea anemone, a striped clownfish hides from a predator: the moray eel. The eel slithers around the clownfish (phew!) as it moves toward the coral, on the lookout for dinner. From where you're floating above, you can see the whole thing.

What you've just seen is called a coral reef. It's one of the many types of **ecosystems** within the ocean. Everything in an ecosystem has some effect on other parts of the ecosystem. Consider the shrimp and algae we saw in our coral reef. If the shrimp don't have enough algae to consume, they'll reproduce in smaller numbers. This means larger consumers, such as our eel, will have a harder time finding enough shrimp to eat. **Organisms** within an ecosystem need one another to survive.

THE BIG QUESTION

Why is the ocean a place people want to explore and learn about?





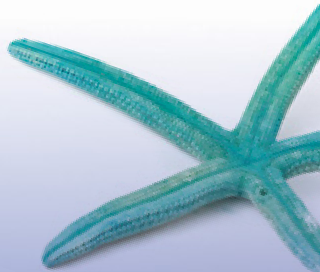
Abiotic Factors of the Ocean

How do we tell ocean ecosystems apart? Each ecosystem includes producers, consumers, and decomposers. These are the **biotic factors** in an ecosystem—living things like fish, algae, and bacteria. These biotic factors also coexist with **abiotic factors**, such as sunlight, salt levels, and soil. (You can think of biotic as living and abiotic as nonliving.) Each ecosystem has its own unique abiotic factors. On land, a desert has very different abiotic factors than ecosystems in the forest, or in the tundra. The abiotic factors in these ecosystems determine what kinds of life can thrive there. The same is true with ocean ecosystems.

One important abiotic factor in the ocean is the amount of salt in the water. Some organisms can survive in water that contains a lot of salt. Others need water with a very low salt content. Some ocean ecosystems contain very salty water, and others have much less salty water. Some ecosystems even contain a mixture of fresh water and salt water, which is called brackish water. Each type of water supports different organisms.

The spines of a sea urchin both protect it and help it spear food in the water.

The water temperature is another major abiotic factor in an ocean ecosystem. For example, warm temperatures and sunlight are ideal for algae growth. In warmer ecosystems, algae can grow thick and float to the surface, where they use photosynthesis to turn sunlight into energy. This provides food for many organisms, including coral. Ecosystems with colder water temperatures don't always have this easy source of food. This means they'll support very different organisms.



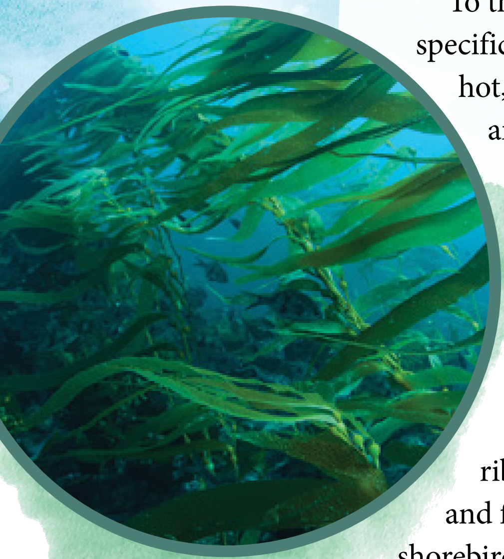
The distance between the surface and the ocean floor is a third major abiotic factor. We find coral reefs in shallow waters, where the water is warmer and where coral and other animals and plants receive more sunlight. If you were to dive deeper and deeper into the ocean, you would find other ocean **zones** much farther from the surface. There, the water is colder, and sometimes no sunlight reaches at all. The organisms that can survive in these deepest ocean zones have some very unusual **characteristics**, as you'll learn.

An Introduction to Six Ecosystems

How do these abiotic factors work in the six major ecosystems in the ocean? Let's put on our snorkeling gear—and in some cases, some serious deep diving equipment!—and see how abiotic and biotic factors work together to shape each.

We'll start with one we've already seen a little of: the coral reef. Most coral reefs grow close to the coastline, where the land meets the water. A coral reef's most distinctive biotic factor is the coral itself, which may look like a colorful rock, but which is actually a living organism. The coral and the algae that live inside it host many colorful small fish and other organisms.

To thrive, a coral reef needs salt water at very specific temperatures. If the water is too cold or too hot, the algae that support the coral and other animals in the reef won't grow. Because of this, coral is most often found in tropical waters.



Another ocean ecosystem that we find near coastlines is the kelp forest. Picture a huge forest with lots of green, leafy trunks that sway back and forth like ribbons. Now imagine it's all underwater! The large, swaying ribbons are kelp, a type of alga that shelters and feeds other living organisms, including otters, shorebirds, and sea lions.

The black-tailed godwit is one of many land animals that share the estuary ecosystem with organisms who live in the brackish water.

Kelp grows best in cooler waters, such as the water just off the Pacific coast of North America. Sunlight is one of the most important abiotic factors that helps to shape a kelp forest. Sunlight allows kelp to photosynthesize, which lets it grow enough to support other consumers in this ecosystem.

An **estuary** is an ecosystem found in places where fresh water from rivers and lakes meets salt water from the ocean. The level of salt in the brackish water of an estuary is one of its major abiotic factors. Because the salt balance of an estuary changes as the ocean tides change, the animals in an estuary behave differently as the tides change. For example, female blue crabs only lay their eggs during the spring high tides, when the salt level is high enough to support them.

Estuaries can form in a wide variety of temperatures. Some estuaries in the United States are found along the Gulf of Mexico, in Virginia's Chesapeake Bay, New York's Hudson River, and in the colder waters of Alaska. At any temperature, animals use them as habitats and migration stops.

Mangrove forests form in tropical estuaries, where the temperature is warm enough to support mangrove trees. Mangroves have tangled-looking roots that make the trees appear to be standing on water. These roots help shelter animals like shrimp, crabs, and oysters. Pelicans and spoonbills also create nests in the branches of **mangrove trees**.

The soil mangrove trees live in is full of salt water. Over many, many years, mangroves have adapted to their environment. Part of their roots are above the soil, which lets them take in oxygen from the air. Additionally, their roots slow down the tides, which helps limit erosion of the coastline.

Some mangroves filter out salt at their roots and others discard extra salt as crystals on their leaves.

Can you smell the salty mists of the ocean yet? Far from any coastline, the open ocean calls, and in it live thousands of different species. These include some of the most classic ocean animals, such as sharks, dolphins, tuna, jellyfish, and whales.

Most of the animals in the open ocean live close to the surface, where there's sunlight. Tiny producers, including plankton, nourish themselves from the sun. Consumers also live close to the surface, so they can feed on the plankton.

Adult white sharks can grow over 20 feet long!

The deep sea is the most **remote** of all the ocean ecosystems. In some places, it's over 20,000 feet from the surface to the ocean floor. That's nearly four miles. Imagine driving four miles straight down into the ocean!

No sunlight reaches the deepest parts of the deep sea. But the lack of sunlight doesn't mean there's no life here. At the very bottom of the ocean, **hydrothermal vents** release chemicals, which nourish many producers that can't get energy from sunlight. The deep sea also hosts many bottom-feeders that consume decomposing plants and animals that fall from the upper ocean zones.

There's More to Explore

The ocean is a unique and vast universe of organisms that have adapted to survive in their wonderfully diverse ecosystems. Many of those ecosystems are found in shallow waters close to us. But many others, like the deep sea, can't be studied without special tools. Because it's so far away from our lives on land, much of the ocean still holds mysteries. In this unit, you'll start to explore them.

The transparent flapping fins of the sea angel make it appear as though this slug has wings.

Chapter 2

Underwater Food Web: Producers, Consumers, and Decomposers

THE BIG QUESTION

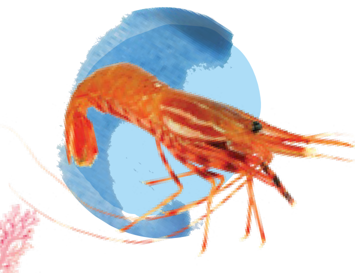
What role does energy play in food webs?

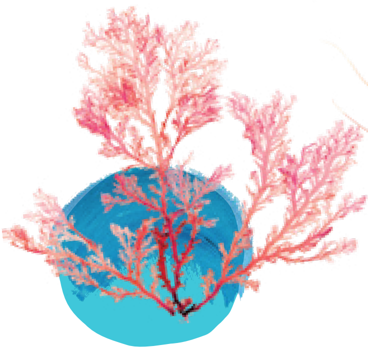
In the last lesson, we imagined we were snorkeling in a coral reef. Now, imagine that you're snorkeling in a different ecosystem altogether: the open ocean. This time there's no coral to study. Instead, you're looking at five organisms: algae, krill, herring, bluefin tuna, and great white sharks.

Krill are small crustaceans—that is to say, **aquatic** animals with hard exoskeletons, like insects. Krill resemble tiny shrimp, and they gather in large groups called swarms to feast on algae floating in the water. As you watch, a giant school of silver herrings, each six or seven inches, swims through the krill, gobbling up as many as they can. But some of the herring don't return to their school quickly enough, and soon a fast-swimming bluefin tuna, over ten feet long, manages to catch and eat them. It's then that you spot the fin of a white shark slowly moving in the tuna's direction.

Eating is how animals gain energy to live. Plants may gain energy by **absorbing** nutrients from the sunlight and soil, but most animals can't live on dirt and sunshine. They need to feed on other organisms.

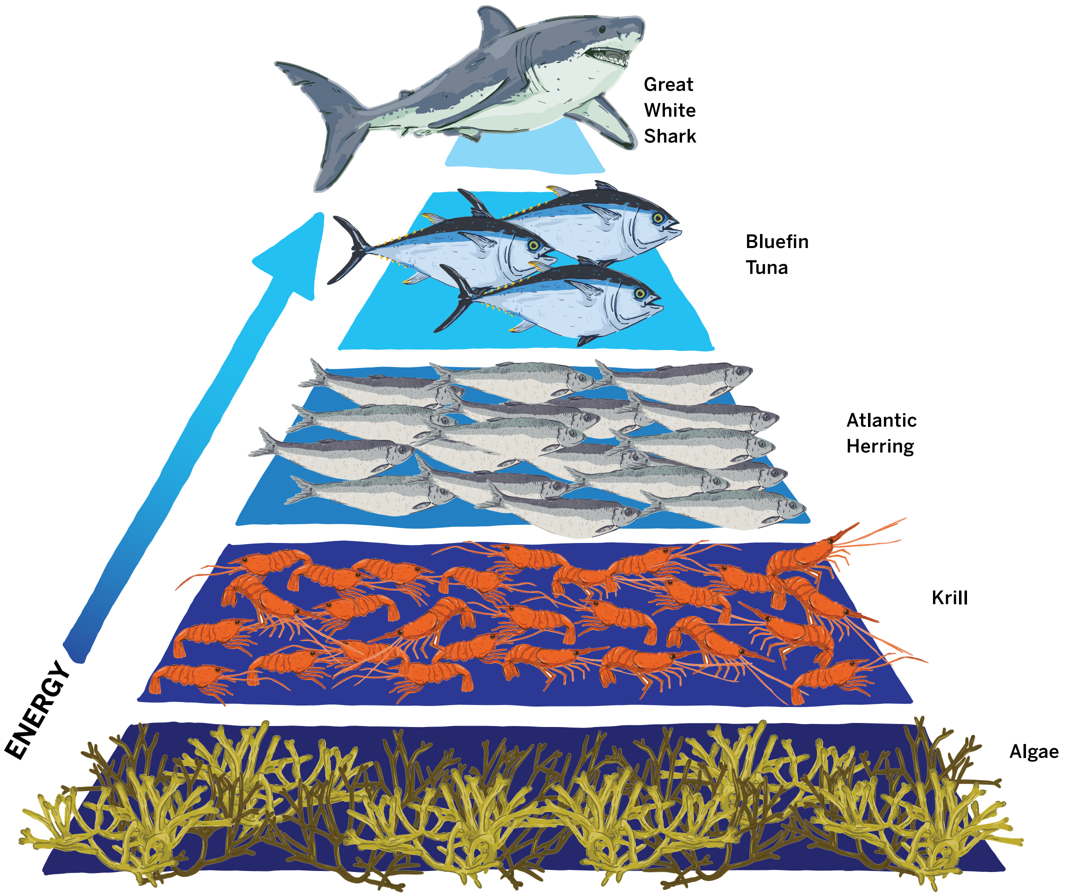
All animals need to eat. But over time, most animals have adapted to eat only certain kinds of organisms. The energy a great white shark gets from eating a tuna ultimately comes from algae, but algae are not something a great white likes to hunt. As it turns out, being a picky eater is completely natural.





What Is the Trophic Pyramid?

If you want to know who is eating who in the animal kingdom, whether on land or in the water, there is only one place to look: the trophic pyramid. Biologists use the trophic pyramid to model how animals get their energy. As you have learned, producers, consumers, and decomposers make up the key biotic factors in an ecosystem. The trophic pyramid lets us describe the relationships between these organisms in more detail. This gives us a better picture of just how the biotic factors in each ecosystem work.



Producers and Consumers

Each row in the trophic pyramid is called a **trophic level**. In any ecosystem, producers exist in the very bottom trophic level. Many producers, including plants and the algae we witnessed in the open ocean, get their energy directly from sunlight. They are where energy first enters the trophic pyramid. Producers are in the lowest level of the trophic pyramid because they do not need to eat other organisms. It comes from the sun instead!

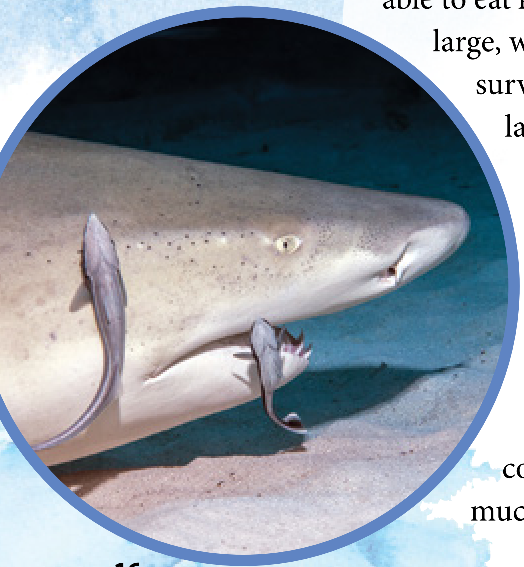
Above producers, the other levels of the trophic pyramid are filled with consumers. Most of the time, consumers are animals. Animals at the upper levels of the pyramid are called primary, secondary, tertiary, and even **quaternary** consumers. We classify these consumers based on how many steps away from producers they are on the trophic pyramid. (In our imaginary snorkeling trip, a secondary consumer like Atlantic herring is two steps away from the algae, a producer.)

Primary consumers, like the krill we saw, eat producers directly. Because many producers are plants, primary consumers are also often herbivores. In other words, they just eat plants!

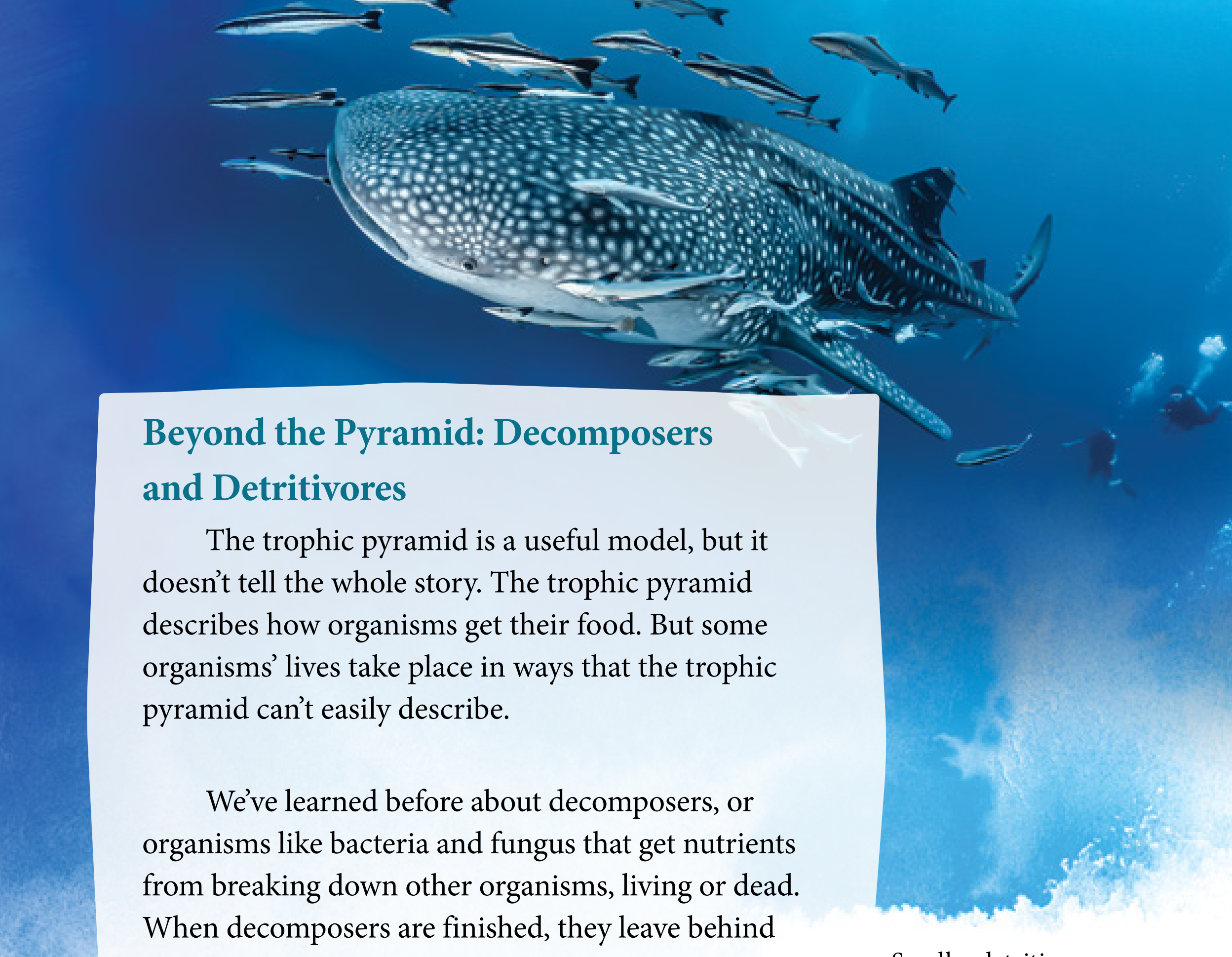
Secondary consumers mostly eat primary consumers. (In our case, the Atlantic herring fed on the krill.) Tertiary consumers, like our tuna, mostly eat secondary consumers. In turn, quaternary consumers mostly eat tertiary consumers. Secondary, tertiary, and quaternary consumers tend to eat other consumers, which makes them carnivores: meat eaters. We also call these consumers who eat other consumers predators.

Consumers at the top of the trophic pyramid, like our great white sharks, are a special kind of predator. The highest point of a pyramid is its apex, and so we call these animals apex predators. Apex predators like great white sharks and orcas eat many other types of animals, and they have no natural predators above them.

Animals on each level of the trophic pyramid can generally eat the organisms on the levels below. Krill are lower on the trophic pyramid than sharks. This means that krill can’t eat sharks. It also means that sharks are able to eat krill. However, great white sharks are very large, which means they need a lot of energy to survive. So, in addition to tiny krill, they’ll eat larger animals who are closer to them on the trophic pyramid.



This is why the trophic pyramid is so useful for understanding the biotic factors in an ecosystem. Knowing that an animal is a consumer tells you a little bit about that animal. But knowing whether it’s a tertiary consumer or a primary consumer tells you much more about its behavior and life.



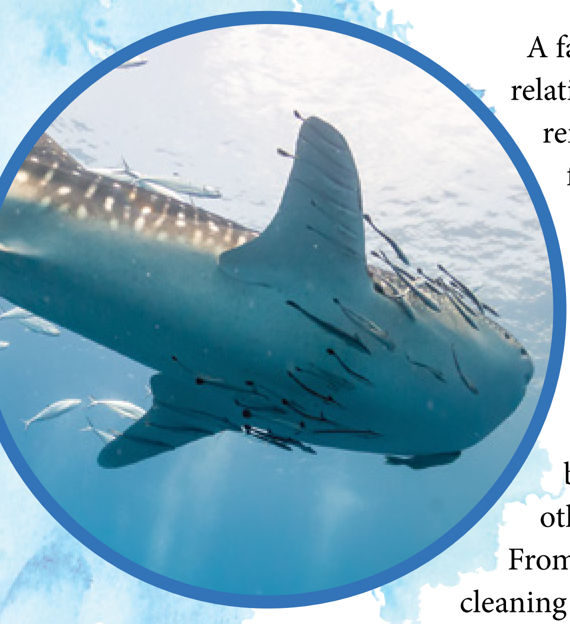
Beyond the Pyramid: Decomposers and Detritivores

The trophic pyramid is a useful model, but it doesn't tell the whole story. The trophic pyramid describes how organisms get their food. But some organisms' lives take place in ways that the trophic pyramid can't easily describe.

We've learned before about decomposers, or organisms like bacteria and fungus that get nutrients from breaking down other organisms, living or dead. When decomposers are finished, they leave behind remnants and waste products called **detritus**. If you're wondering whether there's anything that eats detritus, you're on the right track. Herbivores eat plants, carnivores eat meat, and a type of organism called a **detritivore** eats detritus: in other words, waste. Detritivores are important members of any ecosystem because they help recycle energy and nutrients back into the trophic pyramid.

Smaller detritivores have symbiotic relationships with larger organisms that drop bits of food to provide a meal.

Some detritivores have **symbiotic** relationships with carnivores. The beginning part of the word, *sym,* means together. Putting it together with biotic, which we know, we can see that the word symbiotic means living together. If two animals have a symbiotic relationship, it means that they cooperate in order to live.



A famous example of symbiosis is the relationship between great white sharks and remoras. A remora is a type of detritivore fish with a suction cup just below its head. Remoras use these suction cups to attach themselves to other animals, including great white sharks. Though a shark could easily eat a remora, they rarely do so. This is because when a remora attaches itself to a shark, it begins to eat dead skin, parasites, and other waste products from the shark's body. From the shark's point of view, the remora is cleaning it. From the remora's point of view, the shark is an easy source of food.

Remora use special suction cups to attach themselves to larger organisms and catch a ride, eating their leftovers on the way.

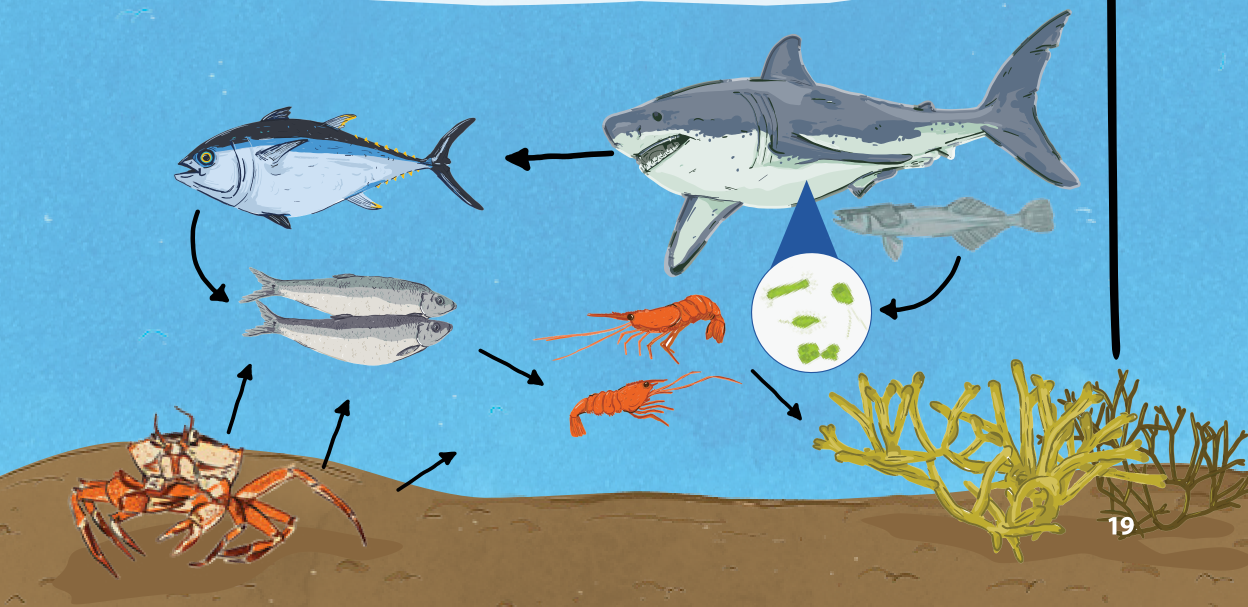
This relationship between remoras and sharks is symbiotic because it benefits both animals. Great white sharks aren't flexible enough to clean themselves, so without the remoras they might get sick. Remoras aren't very well suited to catching food on their own, so without the sharks they would go hungry. But because of the symbiosis between these two animals, they're both able to thrive.

Webs Below the Waves

Whether animals are eating each other or helping each other, they're all part of a set of relationships called a **food web**. Food webs are another model, like the trophic pyramid, that helps us understand more about how different organisms in an ecosystem behave. It also helps us understand how energy moves between different organisms when one eats another.

We need more than one model because as we've seen, a trophic pyramid doesn't show us everything. Sometimes biologists find it useful to organize the animals in an ecosystem into a one-way chain of consumers and producers. But a food web allows for a more complete picture that includes decomposers. Food webs help us notice symbiotic relationships, like the one between remoras and sharks. We can also ask questions about other types of animals we observe in an ecosystem and how they might fit into our food web. For example, if we place crabs in the food web, we can see that they eat waste from most of the other organisms in the web.

Food webs and trophic pyramids are key tools for explaining ocean ecosystems. In any ecosystem you're looking at, start by asking yourself: which consumers are eating which? What producers are creating the energy in the first place? And how do detritivores and decomposers work to recycle nutrients back into the ecosystem as a whole? These are the kinds of questions that biologists ask themselves. By learning to observe food webs and to ask these questions, you're well on your way to becoming a biologist yourself.



Chapter 3

In the Zone

Let's pay an imaginary visit to the ocean—only this time, forget the snorkel. Instead, we'll give ourselves an invincible submarine, a boat that can travel underwater. In reality, only a very few special submarines can voyage as deep into the ocean as we're about to go. So it's a good thing we're in the realm of imagination, even though the places we'll visit are very real.

Why would we want to explore such an unusual place as the bottom of the ocean? According to scientists who study the ocean, we still have a lot to learn from these deepest zones of the ocean. Each ocean zone is full of unique organisms that can thrive in environments full of darkness, poison smoke, and silence. We know so little about these other lives. Humans have only known since the mid-1800s that there was life in the deep sea at all, and we've only been exploring its deepest zones since the 1960s, less than a century ago. When it comes to the deep sea and the life in it, scientists still have many more questions than answers.

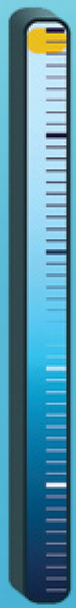
Let's start to explore some of those questions for ourselves. All systems are go, and we have the green light to proceed, so let's begin our trip beneath the waves.

THE BIG QUESTION

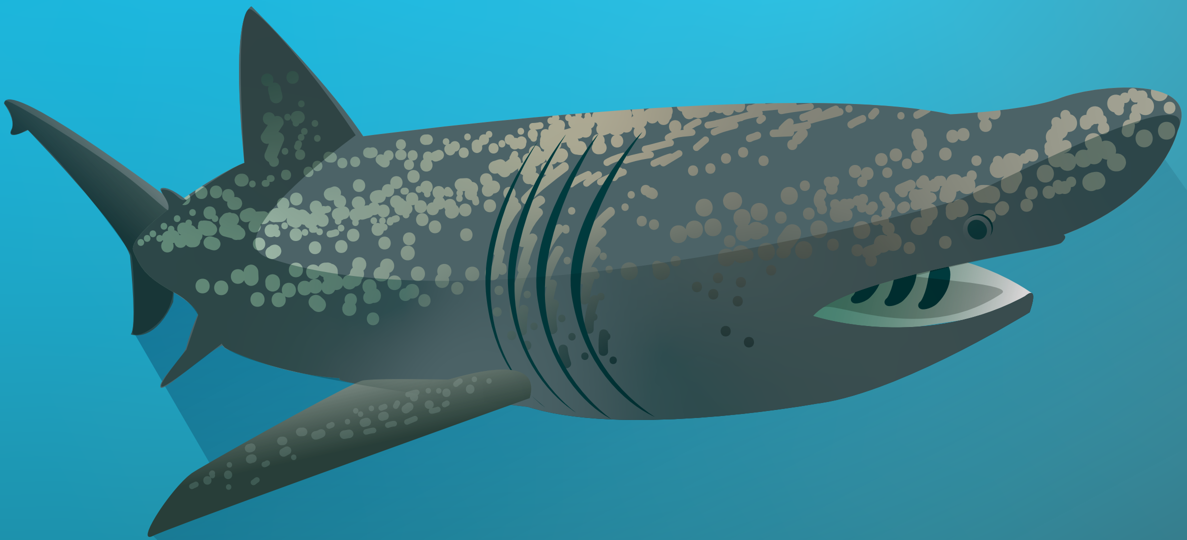
How does the amount of sunlight affect life in the ocean?

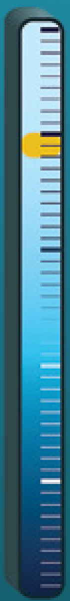
The Sunlight Zone

The **sunlight zone**, where we'll begin our descent, is the uppermost part of the ocean. The sunlight zone spans about two football fields of depth under the surface of the water. (For non-football fans, that's 200 meters, or 660 feet.) Here, the sun is just above us in the sky. One effect of the closeness between the sun and this zone is that the sun keeps the water temperature warm, although it can **fluctuate** with the seasons and the wind.



Living organisms thrive within all parts of the sunlight zone. A common producer here is phytoplankton. The sunlight here has a powerful **effect** on the phytoplankton, who thrive in the warm sunlight. Many consumers, such as zooplankton, eat phytoplankton. In turn, these consumers feed larger consumers. The number of phytoplankton **affects** the number and variety of consumers in this sunlight zone food web. That is to say: the more sun, the more phytoplankton thrive here, and the more bountiful the feast for consumers.





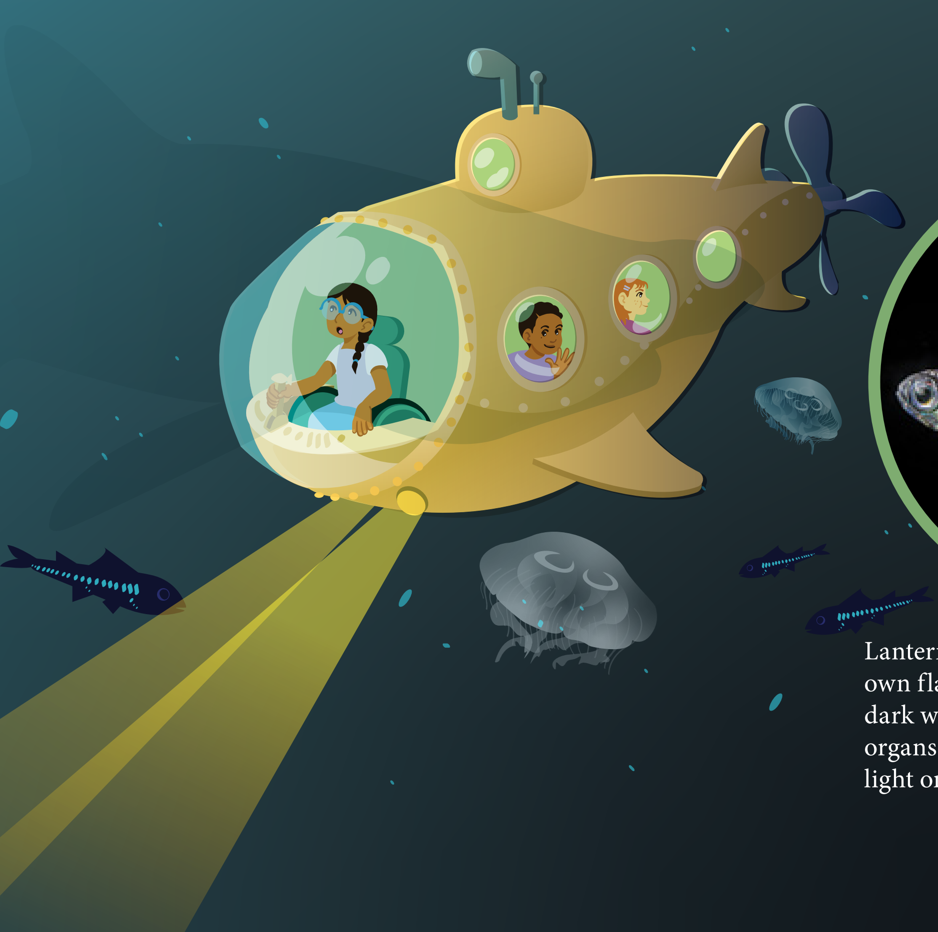
The Twilight Zone

Scientists also call the sunlight zone the **euphotic** zone, or photic zone. (Think of *photo*, meaning light, as in *photosynthesis*.) The **twilight zone**, which we'll reach around the point where our submarine drops below the 200-meter mark, is a dysphotic zone. When light passes through water, some of it filters out. This affects the light by making it more dim, and we start to have a real problem seeing. . To explore this place, we'll need to switch on our submarine's lamps.

As we move into the twilight zone, our temperature readings become very cold, very fast. Sunlight also creates heat, so the depth of water also affects the temperature. The twilight zone is a transition layer, or thermocline. It's a place where the temperature decreases very quickly as we pass from the warmer water of the sunlight layer to the much colder waters below.

The dark and the cold aren't the only things that take getting used to in the twilight zone. Some animals that thrive here are bioluminescent, or able to produce their own light! One such animal is the lanternfish, which produces light from its body. Can you imagine using your own body as a flashlight?

Bioluminescent animals in the twilight zone use their lights for many purposes. Some use them to attract prey. Others perform a type of camouflage called counter-illumination. These creatures use their lights to mimic the sunlight from the water's surface. This performance tricks predators into thinking they're simply looking at sunlight and passing the bioluminescent organism by.



Lanternfish are their own flashlights in the dark water, using special organs to produce blue light on their bodies.

The Midnight Zone

Instead of dim, blue waters, now we see only **constant**, black nothingness outside the windows of our submarine. We've descended 1,000 meters, or ten football fields end to end, and reached the **midnight zone**. The twilight zone was dysphotic, but now we're in an aphotic part of the ocean. Here, there's no sunlight at all, and the water is near freezing.

Through our dark windows, we might catch a flash of light from a bioluminescent anglerfish. Anglerfish look like they have a fishing rod attached to their heads. This rod-shaped body part has bioluminescent bacteria at the end of it. The glow attracts prey, including fish and small crustaceans. When they swim too close, the anglerfish snatches them up with its sharp teeth. Imagine that: a fish, fishing!

Female anglerfish use a glowing spine to lure prey close to their mouth like a fishing pole.

The Abyssal Zone

Below the deepest parts of the midnight zone, we find the **abyssal zone**, which reaches from 4,000 to 6,000 meters below the surface. The highest mountain peak in North America is Denali in Alaska, at just over 6,000 meters. The abyssal zone is as far below the ocean surface as Denali is above it. Over half of the seafloor is this far down, forming a vast, flat abyssal plain.

Down here, the water is near freezing, and like the midnight zone, there's no light at all. In addition, there's suddenly a whole lot of water above our invincible submarine. One drop of water doesn't weigh very much on our fingers. But there are many, many drops of water in the 6,000 meters of ocean above us. All that weight adds up to a constant and intense pressure.

Conditions on the abyssal plain are intense, and only a few organisms can live here. In particular, the lack of sunlight may make you wonder about the abyssal zone's food web. Detritivores can feed on debris that falls from the surface. But what about producers? Without sunlight as an energy source, who's doing the producing?

Across the abyssal plain, we find hydrothermal vents. These underwater vents release chemicals from within the Earth's crust. These chemicals would be toxic to humans. But some producers in the abyssal zone are able to use them to create energy through a process called chemosynthesis. (Photosynthesis means to create energy from sunlight, and chemosynthesis means to create energy from chemicals.) Deep-sea consumers, including sea pigs, yeti crabs, and Pacific hagfish, feed on these producers and often spend time near the hydrothermal vents. These are the missing pieces in this deep sea food web.

The Hadal Zone

The abyssal plain makes up most of the seafloor on Earth. But even deeper ocean trenches form the **hadal zone**. In Greek myths, the ruler of the underworld was named Hades. This zone is named after him. These deepest parts of the ocean are very difficult to explore, and very few people have visited them. Fortunately, our imaginary submarine is up to the task.

One of the most famous parts of the hadal zone is the Mariana trench, which is located off the coast of Japan. At its lowest point, the Challenger Deep, it's nearly 11,000 meters below the surface. That's nearly twice the height of the highest mountain in North America.

Life in the Dark

Long ago, the ancient Greeks believed that the ocean had no bottom at all. Today, we understand much more than they did about the ocean, but we still have a lot to learn. Even with advanced tools like sonar—or using sound and echoes to measure underwater distances—and submarines equipped with video cameras, scientists have only been able to map about one fourth of the seafloor. But looking at a map isn't the same thing as really being there. Almost none of the deepest parts of the ocean have ever been physically explored by any humans.

As a result, the deepest ocean zones and the lives of the organisms within them remain mysterious. All we can do is make what observations we can and build theories from that evidence. And of course, imagine.

Chapter 4

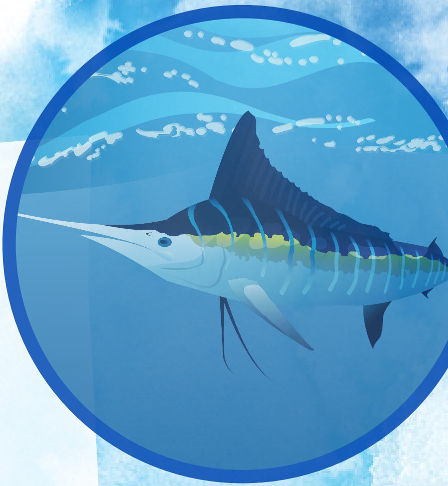
Unique Environments and Adaptations

THE BIG QUESTION

What is the connection between animal adaptations and their environment?

Underwater Investigation: Dolphins

As we've seen, there's a huge variety to the ecosystems in the world's oceans, both on the surface and deep under it. We've also started to see that there's a huge variety to the plants, animals, and other organisms that live in the oceans.



But what do these two observations have to do with one another? What's the relationship between the biotic and abiotic factors in the oceans? To investigate this question, let's look at a seemingly ordinary animal from the open ocean: the bottlenose dolphin.

Something Seems Fishy About Dolphins

Can you remember the last time you saw a bottlenose dolphin? You've probably seen one on television or in movies. You might have even seen one in real life. Bottlenose dolphins live in the sunlight zone of almost every ocean, near to the surface.

Almost everything about the bodies of bottlenose dolphins helps them live in the oceans they call home. The dolphin's long, streamlined body and pointy nose is similar to a type of fish called a marlin. This body shape allows both marlins and dolphins to swim at very high speeds (in the bottlenose dolphin's case, up to 38 miles per hour). The gray and white colors of their skin help them blend in with the water's surface. All these characteristics make them **agile** hunters, well-suited to life in any ocean.

So both dolphins and fish seem right at home, splashing beneath the waves. However, the bottlenose dolphin has a secret. Bottlenose dolphins may look like many other fish out there. But they aren't actually fish at all.

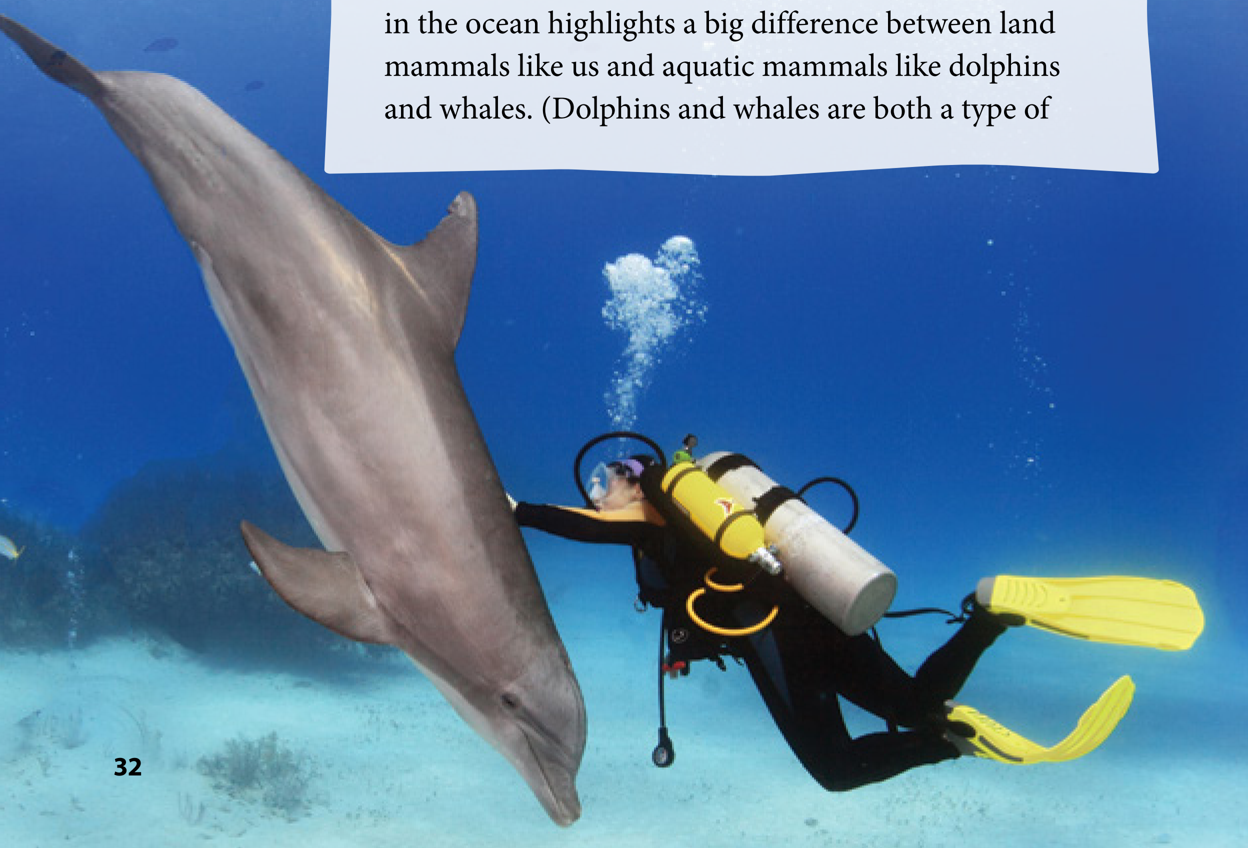
Mammals at Sea

Bottlenose dolphins have three times as much blood as humans to store lots of extra oxygen for diving underwater.

Bottlenose dolphins are a type of mammal. When you think about mammals, what do you imagine? Do you think about fuzzy woodland critters shuffling through long grass? Do you think about monkeys swinging through the treetops? Maybe you even imagine the most familiar of mammals: humans!

But here's the thing: dolphins are also mammals. Like other mammals, dolphins are warm-blooded, and they produce milk to feed their babies. And, like all other mammals, dolphins can't breathe in the water. They don't have gills like fish do. Instead, just like humans, they have to come to the surface of the water to take breaths of fresh air when they swim.

That question of how mammals breathe while in the ocean highlights a big difference between land mammals like us and aquatic mammals like dolphins and whales. (Dolphins and whales are both a type of

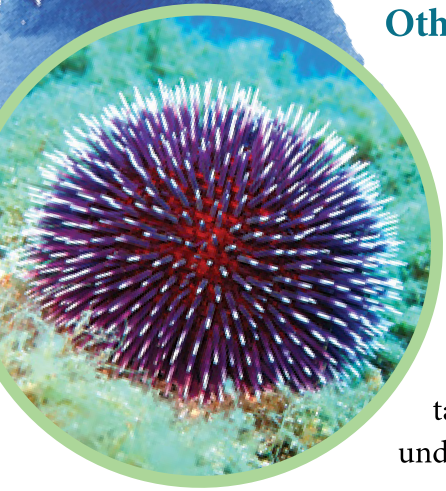


mammal called a cetacean.) Here's a question: how long can you hold your breath? Most adult humans can only hold their breath for up to 90 seconds (or one and a half minutes). Bottlenose dolphins are able to go for much longer periods of time without needing to take a breath. They can hold their breath for over ten times longer than humans. That would be like if you took one big breath, then waited 15 minutes to take another.

Dolphins and other cetaceans can hold their breath for much longer than humans because of a unique **adaptation** in their bodies. Oxygen travels through our bodies at the rate of our heartbeat. When we need more oxygen—for example, if we've been exercising—our hearts pump blood at a faster rate. If our bodies need less oxygen, our hearts slow down. When they dive, bottlenose dolphins can slow their heart rate. This lets them use oxygen more slowly, too, and that lets them stay underwater much longer than we can.

Thanks to this adaptation, dolphins can hunt, travel, and socialize underwater. And because of that, they can thrive in aquatic ecosystems like the open ocean. Not many mammals can say the same.

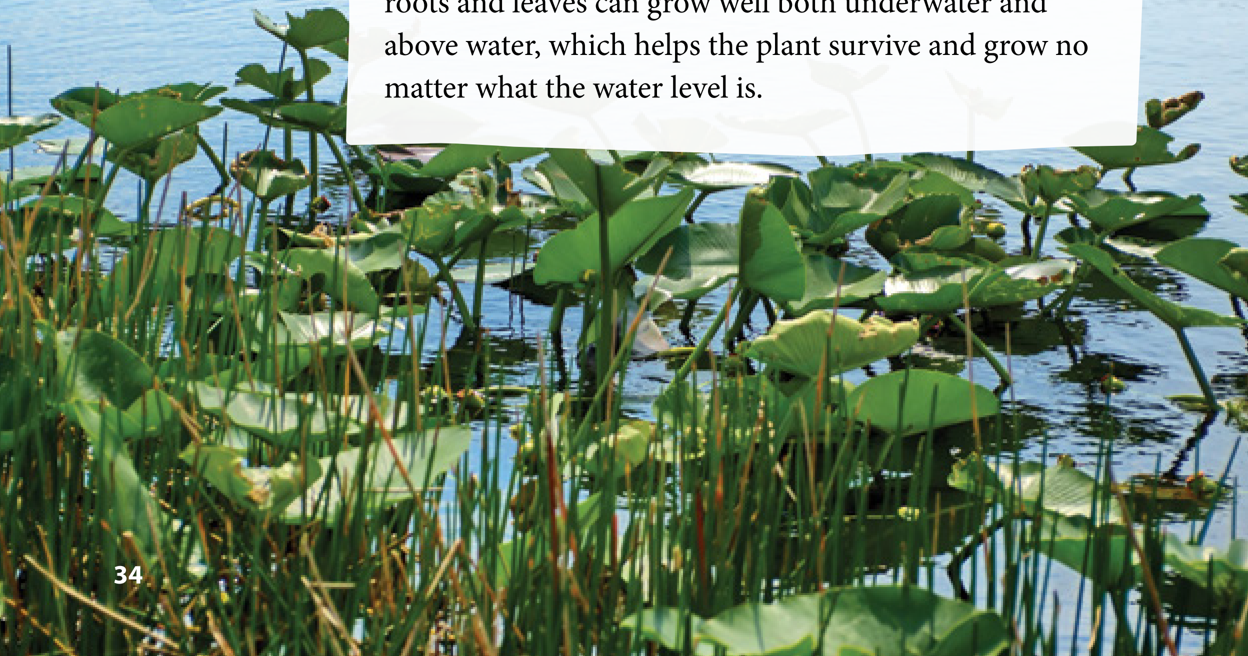
Other Ecosystems, Other Adaptations



Looking beyond the open ocean, we find that organisms have adaptations that help them live in the ecosystems where we find them. There are big differences between dolphins, marlins, and great white sharks, but they all have similar body adaptations. They have similar shapes, similar colors, and similar diets. And even though they take different approaches to the challenges of living underwater, in the end, all these animals can do it.

Many of the animals we'll look at in our ocean ecosystems have adaptations that match their environments. Sea urchins live in shallow water ecosystems like coral reefs and kelp forests, which are full of hungry fish. They look like plants, which hides them from some predators. The long spikes that grow from their bodies help them fight off the rest.

Spatterdock plants live in estuaries, where the water level rises and falls depending on the tides. Their roots and leaves can grow well both underwater and above water, which helps the plant survive and grow no matter what the water level is.



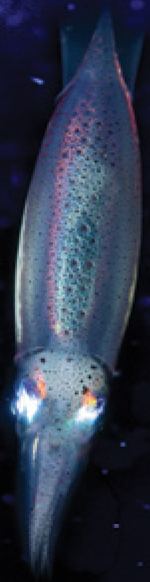
In all these cases and more, an organism's body, behavior, and other characteristics help it thrive within the place it lives. So, next time you go on a nature walk or visit the ocean, remember to take a second look at the world around you. What animals and plants do you see? And how do they function within the environment around them? If you watch carefully, you might discover a few secrets of your own.

Underwater Investigation: Bioluminescence

At 6,000 feet below the surface of the ocean, both light and life are scarce. Neither the warmth nor the light of the sun's rays can easily reach this depth. This depth of the ocean is the middle of the midnight zone. It is a cold, dark, and lonely place.

If you were a fish swimming through the midnight zone, you wouldn't see many other organisms. In the darkness, your other senses would take the lead. Sound and movement would lead you where you need to go to escape predators or catch prey. Even small hints of movement or light might help you find your next meal.

Bioluminescence is rare near the surface, but many organisms in deep ocean ecosystems have developed the amazing ability.



While scientists have collected information about the prickly dreamer, it lives in such dark, deep water that photographs are rare.

If you studied the darkness very carefully, eventually you might see a pair of flickering lights. Are they tiny bits of food, floating down from the surface? You might swim to investigate. But when you got close enough, you would find that the lights you'd seen weren't food at all. They were glowing bumps at the end of two stubby tentacles sprouting from the lips of a fat, black fish.

Introducing the Prickly Dreamer

The prickly dreamer is a type of angler fish, a well-known deep sea predator. This fish uses its glowing tentacles to trick other animals into drawing near. It's a great hunting trick for the angler fish, but not so great for the fish that finds it.

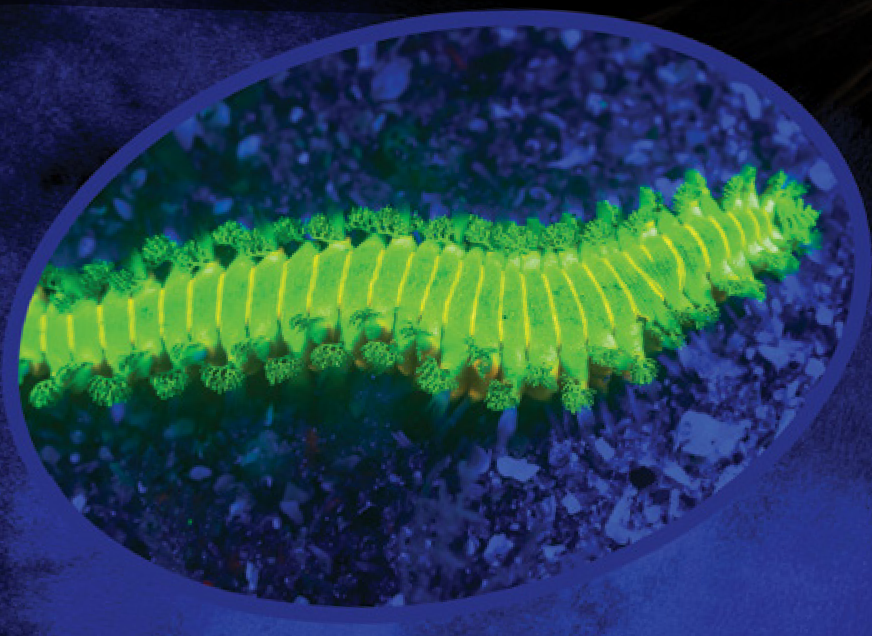
The prickly dreamer's tentacles glow because of an adaptation called **bioluminescence**. (Think "bio," as in biology and abiotic, and "lumin," as in illumination, or lighting up a room.) A prickly dreamer doesn't produce light on its own. Instead, small **microbes** called photobacteria live on the end of the fish's tentacles. The photobacteria are microscopic, living creatures, and their bodies naturally produce light. On its own, a single one of these microbes produces only a small amount of light. But a whole colony of them can glow bright enough to be seen at a distance.

The prickly dreamer and the bioluminescent microbes that live in its tentacles have a symbiotic relationship. The microbes help the prickly dreamer hunt, while the prickly dreamer gives the microbes somewhere safe to live in the mysterious depths of the midnight zone.

Bioluminescence Is Everywhere

Bioluminescence is everywhere under the ocean. Not every organism develops it in the same way. Some bioluminescent organisms, like the form of plankton called dinoflagellates, can produce light directly with their bodies. Others, like the prickly dreamer, form symbiotic partnerships with bioluminescent bacteria.

Many bioluminescent consumers from the deep sea, including the glowing sucker octopus and the kitefin shark, use bioluminescence the same way the prickly dreamer does: to hunt! But there are other uses for bioluminescence as well. Some species use it to create counter-illumination as a defense. Others, such as fireworms, light up to attract mates. In the deepest parts of the ocean, bioluminescence is a common adaptation for all these purposes and more. To humans, the lives of bioluminescent organisms like the prickly dreamer may seem strange. But sometimes an organism's strangest quality is what most helps it thrive.



Chapter 5

Marine Biologists

THE BIG QUESTION

What is the impact of a marine biologist's work on ocean ecosystems?

As we've started to see, marine life is fascinating and diverse. In fact, much of life on Earth is found in the world's oceans, a place humans don't inhabit. Oceans are home to organisms of all sizes, from tiny plants called phytoplankton, which you can only see under a microscope, to the world's largest creatures, such as the majestic blue whale, which can weigh up to 330,000 pounds!

The scientists who study marine life are called **marine biologists**. Like other biologists, marine biologists use tools like the trophic pyramid and food webs to study and understand organisms. Since marine biologists often work in an ecosystem they can't inhabit, gathering information on ocean species can be challenging. At the same time, that challenge makes the work rare and exciting. Imagine swimming through a bustling coral reef in special diving gear, waiting for an octopus to appear. Or imagine watching a dolphin give birth in the open ocean: a powerful experience few others get to see. As a marine biologist, you get to see these things and share them with the world.

The Work of a Marine Biologist: Observing

For most marine biologists, the majority of their work happens in the ocean. They often spend hours on boats or on long underwater dives to observe species from sharks to crabs in their habitats.

Taking notes underwater can be difficult. (Imagine what it would be like to read this chapter underwater.) Marine biologists record their observations on waterproof tablets and take photographs with waterproof cameras. For example, when studying a coral reef, they might measure and record a reef's size. They might also take photographs of the reef to document how vibrant it is. A coral reef's color gives important signs about the health of the algae that live in a symbiotic relationship with the coral. By making observations like these, marine biologists can monitor the health of our coral reefs. They might also take samples of the living reef to study back in their lab.

Marine biologists also gather and record data. They might use a global positioning system, or GPS, to study the population and migration patterns of leatherback turtles. Biologists can attach tags to turtles' bodies and receive a GPS signal from the tags. The biologist can then use satellites, or tiny machines that orbit the earth and send and receive messages, to track the tagged turtle's exact location. This lets the biologist know where the turtle is, no matter where on the planet it swims. By studying the turtles' movements and interactions with their habitats, scientists can predict turtle birth rates and population changes. A marine biologist might even track the movement of sea turtles to their nesting beaches, where young hatchlings are born.

After locating a turtle laying eggs, the marine biologist lends a helping hand.

The Ocean Floor

Along with studying marine species, marine biologists also study the ocean floor. One way they do this is through a process called coring. This process uses special tools called cores, which are similar to drills. Marine biologists use long wires to lower the cores to the bottom of the sea. The core works its way into the ocean floor and pulls up samples of sediment. Marine biologists study these samples to better understand the ocean floor.

Marine biologists can also study the ocean floor by using geographic information systems, or GIS. A GIS is made up of satellites in space that take pictures and other data about the Earth below. These satellites give us information about the depth of the seafloor, which helps us better understand the behavior of animals in some ocean zones. A GIS can also map coral reefs, which helps marine biologists observe reefs that might be in danger of disappearing.

Collecting sample cores can be messy work!

Conservation and Community Work

Food webs in ecosystems can be delicate, and many factors can damage them. If key producer or primary consumer species decline, or if an abiotic factor like salt level or temperature changes, it may affect other consumers in the ecosystem. If severe damage to an ecosystem's food web continues, organisms in the food web may not be able to get the food they need to survive. In some cases, a species might become endangered. An endangered species, to a biologist, has a population so small that there's a risk of the species going **extinct**.

Part of marine biology is studying species to understand why they might be endangered. But another part of their work is **conservation**, the protection of species and their environments.

These two parts of a marine biologist's work go hand in hand. For example, in the 1930s, fishermen working in California's Monterey Bay caught so many sardines that the species became hard to find. Marine biologists who studied the local sardine population noticed and worried about the decline. They brought their facts to the government, which passed laws to limit the number of sardines that could be taken out of the bay. Thanks to the work done by marine biologists, the sardine population recovered, and the species is plentiful in California today.

Often, as part of their conservation work, marine biologists work with people who live in coastal areas to protect marine life. They may help teach people in communities near coral reefs that although coral looks like a rock, it is a living organism that they should be careful around. Marine biologists may also work with local fisheries to encourage safer fishing practices. Sometimes they can teach new ways to pole fish, and sometimes they can teach people how to make and use fishing nets that don't cause problems for organisms in an ecosystem. This conservation work helps people understand how to keep the ocean healthy for future generations.

Diving equipment is used to study organisms that cannot be easily seen from a boat.

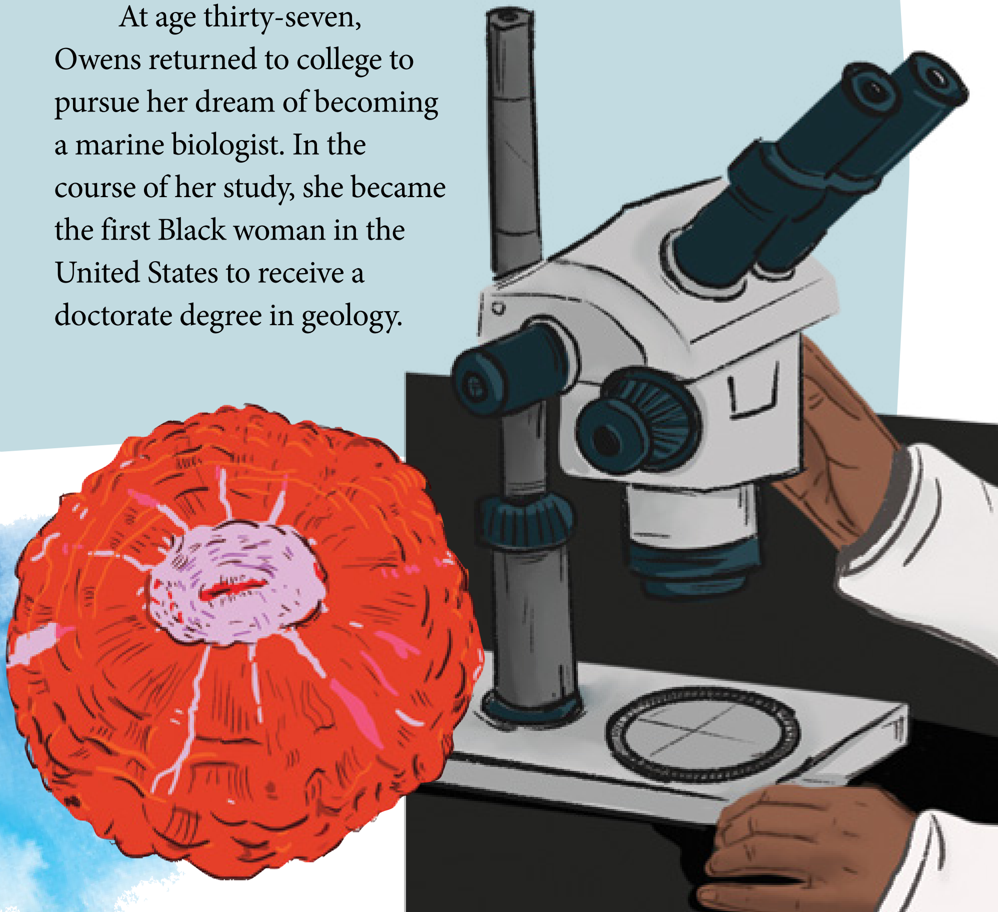
Challenges and Rewards

Scuba diving and underwater exploration can be dangerous, and hours upon hours of work go into research, study, and conservation efforts. But many marine biologists will tell you that the rewards are well worth facing these challenges. Marine biologists get a close and personal understanding of the mysterious world that thrives under the ocean's surface. And, not only that, marine biologists get to use their voice to protect that world and to help it thrive.

Joan Murrell Owens: A Marine Biologist Who Broke Barriers

Joan Murrell Owens was born in Florida in 1933. Her father was a fisherman, and while accompanying him and her siblings on fishing trips, Owens fell in love with the ocean. She was also fascinated by Eugenia Clark, a scientist who studied and swam with sharks. At a very young age, Owens decided she would become a marine biologist. Because her local university did not offer degrees in marine biology, Owens studied counseling and reading instruction instead. For a long time, she worked in education as a guidance counselor and a reading therapist. She was very successful in her education work. But she never forgot about the ocean.

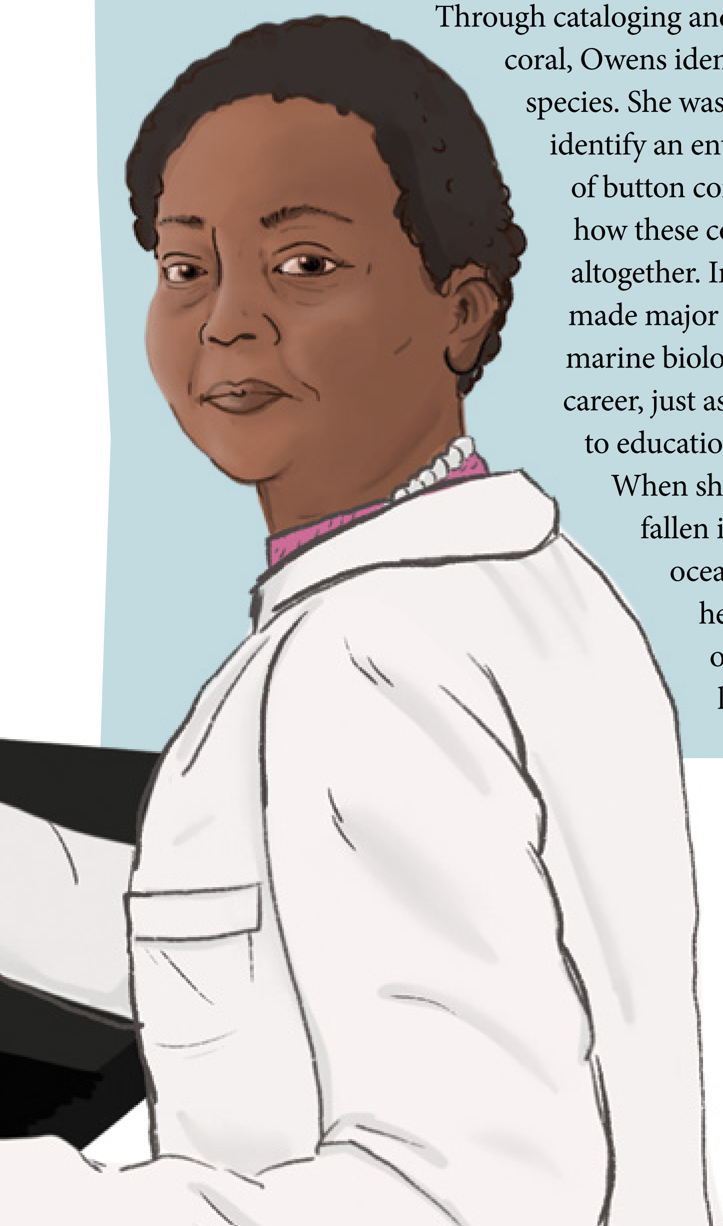
At age thirty-seven, Owens returned to college to pursue her dream of becoming a marine biologist. In the course of her study, she became the first Black woman in the United States to receive a doctorate degree in geology.



Owens had a disease called sickle cell anemia, which prevented her from diving. The higher water pressure in the deeper parts of the ocean can be dangerous for people with sickle cell. If something were to go wrong with her oxygen supply, it could be a disaster. Instead of working underwater, Owens worked to break ground with her research on land. She studied the Smithsonian Museum's collection of button corals, an isolated coral found in the deep sea.

Through cataloging and dissecting these coral, Owens identified three new species. She was also the first to identify an entirely new **genus** of button coral, changing how these corals are studied altogether. In the end, she'd made major contributions to marine biology in her second career, just as she'd contributed to education in her first.

When she was a kid, she'd fallen in love with the ocean. As an adult, her research helped other people fall in love with it too.



Owens wrote about new ideas, including how coral skeletons were different in shallow or deeper water.

Chapter 6

Coral Reefs and Kelp Forests

In the tangles of kelp forests and the ridges of coral reefs, life is as diverse as it is abundant. We've already heard one or two things about the ecosystems found within coral reefs and kelp forests. But of course, a good scientist knows there's always more to discover about these wondrous sea structures. To get a better idea of how these ecosystems provide shelter for the sea life around them, let's put on our marine biologist hats and go on a coastal **expedition**.

Life in the Kelp Forest

From the rugged shorelines of Alaska to the wild bays of Southern California, the Pacific coast of North America is home to many different species of kelp. Kelp may look like a plant, but it's neither a plant nor an animal. It's not a fungus, either. It's another type of organism called a protist. (Kelp is an alga, and all algae are also protists.) Kelp doesn't have roots like a plant. Instead, it attaches itself to rocks with a noodle-like structure called a holdfast.

Like plants, kelp gets its energy through photosynthesis. It prefers to grow in the shallow water of the sunlight zone, or euphotic zone. The sunlight that floods this zone is ideal for photosynthesis. When weather conditions are good, kelp grows quickly, sometimes as long as eighteen feet.

THE BIG QUESTION

How do stationary organisms support the kelp forest and coral reef ecosystems?

The southern sea otter is the smallest marine mammal in North America.

Kelp as Shelter

We find creatures big and small beneath the towering kelp. Crabs, birds, and even huge mammals like whales make their home here. Why is that? Well, like a forest on land, a kelp forest provides plenty of food and a great shelter for marine life. Consumers like sea urchins, fish, birds, and seals feast on the abundant life found there. Sea otters take great comfort in the thick leaves of kelp, where they can nap with less risk of floating away on the ocean waves while they snooze.

Sea otters are far from the only creatures kelp forests keep safe. Imagine being a fish hiding from your predators, or a tiny **amphipod**, like a shrimp, who needs protection in a storm. The tall and thickly packed kelp makes a great cover. Even some whales find safety from predators in a kelp forest. (Yes, even whales sometimes have predators.)

Kelp forests also protect human ecosystems. Storms and other factors can cause damage and erosion to the coastline. But kelp forests act as a barrier that shields coasts from destruction.

Food Webs in the Forest

As you might have guessed, the most common producer in a kelp forest is, well, kelp! But not every kelp forest is the same. Kelp comes in many different species, which thrive among other algae and phytoplankton. Two types of kelp that dominate North American coastlines are giant kelp and bull kelp. Giant kelp tends to thrive in rough Southern waters. It has long, thin blades of rubbery grass that grow from waving stems. Bull kelp—which looks nothing like a bull—thrives in Northern waters. This golden brown kelp floats near the surface of the water, a thick, tangly collection of strands that grow from round bulbs.

Sea stars, sea otters, and sea urchins are key consumers in the kelp forest. In a day, sea urchins can eat thousands of pounds of kelp. In turn, sea stars and sea otters eat the sea urchins.

Because sea urchins are primary consumers who are low on the trophic pyramid, you might think: the more sea urchins, the healthier the kelp forest. Right? But in fact, too many sea urchins can harm kelp forests,

creating dead zones called urchin barrens. To strike the right balance, there need to be plenty of large consumers like sea stars and sea otters (not to mention foxes and birds) who eat sea urchins. Marine biologists work to protect those consumers so that they'll keep sea urchin populations down. This prevents these spiny purple consumers from eating up too much kelp and creating urchin barrens. When kelp forests are in balance, they grow into wild, nutrient-rich canopies that provide shelter for so many living things.

Sea cucumbers can shoot their toxic organs at predators to save their bodies from becoming a meal!

Creeping slowly across the kelp forest floor, one of the major detritivores in the kelp forest searches for a snack. Behold the hairy sea cucumber. Sometimes brown or dark green, sea cucumbers are similar in size to cucumbers found on land. But unlike land cucumbers, sea cucumbers are living organisms covered in little tubes that help them feed. Their many tubes help them move like caterpillars. They also use their tubes to eat up uneaten kelp and other waste floating in the water. They even filter the sand by absorbing bacteria, releasing cleaner sand back into the ocean. Pretty helpful for a sea pickle!

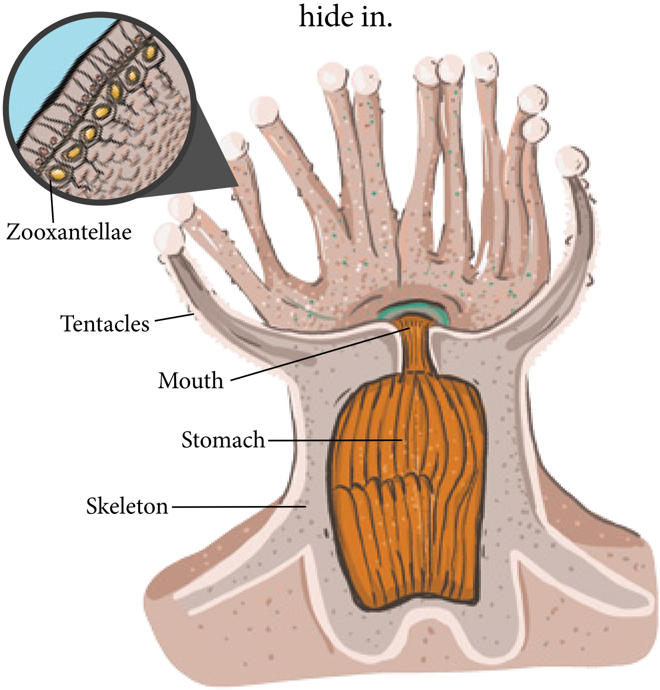
Can a Coral Reef Compare?

Kelp forests are a great respite for creatures who live in cooler waters. But now that our expedition to their weedy world is wrapped up, it's time to visit the warmer waters where coral reefs thrive. Just like kelp forests, coral reefs are amazing structures that provide food and coastal protection. In fact, millions of people around the world rely on coral reefs for protection from land erosion.

Corals That Stick Together Stay Together

Zooxanthellae use photosynthesis to produce the sugar that feed the coral polyps.

Coral doesn't move, and it can be hard like a rock. But coral isn't a rock: it's an animal that grows and eats, even as it stays in one place in the ocean! Coral grows in **clusters**, or colonies. When these colonies become large, we call them reefs. When corals stick together, they create these rock-like structures for other animals to live and hide in.



The soft part of a coral's body is called a **polyp**. The polyp is hollow and shaped like a cylinder, and it also has a mouth with tentacles. In deep water, corals use these to catch and eat food. A coral's polyp produces a stony skeleton made up of the chemical calcium carbonate, or limestone. This skeleton protects and supports the coral.

Some coral polyps don't have this hard skeleton, but they're still tough! We call these soft corals. Even though they are flexible, soft coral's bodies may grow spikes to deter predators.

How Does Coral Get Its Color?

Corals get their color from a kind of alga called zooxanthellae. These algae, like kelp, produce their own food through photosynthesis. Algae and coral have a symbiotic relationship that both organisms benefit from. Algae find shelter in the coral and in turn produces sugar. The coral then absorbs the sugar into its body. This gives coral an extra food source beyond what the polyp's tentacles can catch.

But remember that algae grow best in shallow waters, where they use sunlight to carry out photosynthesis. In deeper waters, where algae do not grow, the corals are not so colorful!

Food Webs in the Reef: Who Snatches the Catch?

The largest coral reef in the world is the Great Barrier Reef in Australia. It's so big that you can see it from space! The Great Barrier Reef is made up of more than 3,000 smaller reefs full of colorful coral (yellow, red, purple, and orange). In addition to coral, many different kinds of animals call the Great Barrier Reef home. These include more than a thousand species of fish and more than 200 kinds of birds.

The Great Barrier Reef also contains the largest mollusk in the world: the giant clam. How giant is it? At just over four feet tall, the giant clam weighs more than five hundred pounds—pretty big for a clam.

Other common consumers in the Great Barrier Reef range from small shrimps and crabs to large fish, giant turtles, octopus, and sharks. The smaller animals

feed on the algae, and the larger creatures feed upon the smaller ones. Reef sharks often feed in the same crevice over long periods of time, much as humans keep going back to their favorite restaurant. Generally, these sharks leave humans alone as they are not aggressive. But if you happen to be fishing, one might attempt to snatch your catch.

One of the most common detritivores in coral reefs are, again, sea cucumbers! There are more than 200 different types of sea cucumbers in the Great Barrier Reef, all working to clean up the waters and sand. Sea cucumbers are also a source of food for humans, and overharvesting has led to a decline in populations. Different countries, including the United States, have taken action to protect these detritivores from extinction.

Home Sweet Home

Our expedition into tangled webs of kelp forests and multi-colored ridges of coral reefs is over for now, but your exploration of ocean ecosystems is still well underway. As you continue to explore the different environments that marine organisms call home, try to ask two questions. What makes each ecosystem unique? And what similarities does it have to other ecosystems? You might be surprised by the answers. After all, who could have guessed that when it comes to both kelp forests and coral reefs, home is where the cucumbers are?

Giant clams, which can live for 100 years, depend on the zooxanthellae that live inside them.

Chapter 7

Estuaries and Mangrove Forests

THE BIG QUESTION

How do **terrestrial** and **aquatic organisms** contribute to ecosystems that support each other?

When the land and the ocean meet, they create coastlines. Coastlines have features of both the land and the ocean, and they come in many different forms. Sometimes they look like the warm, sandy beaches of Southern California, where people lounge and play. But they can also look like the cliffs of Reynisfjara (REY-niss-fya-ra) in Iceland, where cold and violent waves crash against tall, black rocks.

All coastal landscapes occur in the ocean's intertidal zone. The intertidal zone is any part of the ocean that's below water at high tide and above water at low tide. Coastal landscapes like estuaries and mangrove

forests often look very different at high tide than they do at low tide. But the organisms that live there can make homes in them, no matter what level the water may be at.

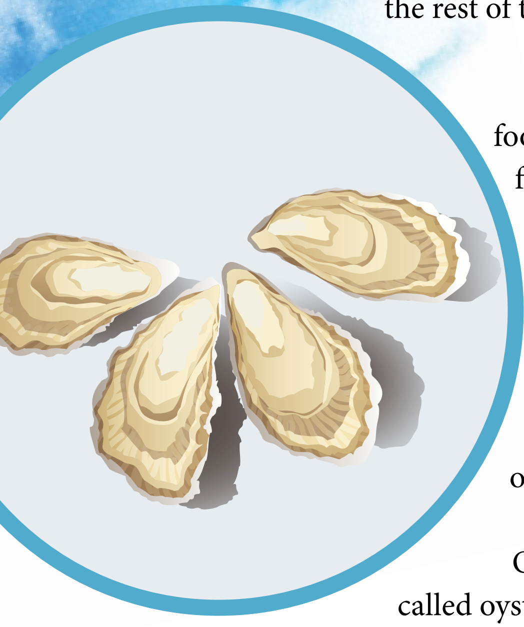
Estuary: The Chesapeake Bay

As you've read, an estuary is a place where salty seawater and cool freshwater mix into brackish water. Of the many estuaries in the United States, the Chesapeake Bay is the largest. Its shoreline is 11,684 miles long, or about two times as long as the Great Wall of China, and it contains over 15 trillion gallons of water.

Producers like trees, eelgrass, and plankton are the core of the Chesapeake's food web, and they feed scallops, sea turtles, and horseshoe crabs. Small fish that live in the bay also provide food for striped bass, snapping turtles, and even bald eagles. The Chesapeake's decomposers include the usual suspects: crabs, insects, fungi, and **microorganisms** like bacteria.

Oyster Reefs

One of the most common animals of the Chesapeake Bay are eastern oysters. Oysters, like clams and scallops, are **mollusks**. (Mollusks are a kind of soft-bodied animal that has a hard shell.) But unlike clams and scallops, oysters can't move around very easily. As larvae, or spat, they attach their shells to a single surface. It might be the seafloor of the bay, a large rock, or a piece of driftwood. Whatever they choose, oysters spend the rest of their lives in that one spot.



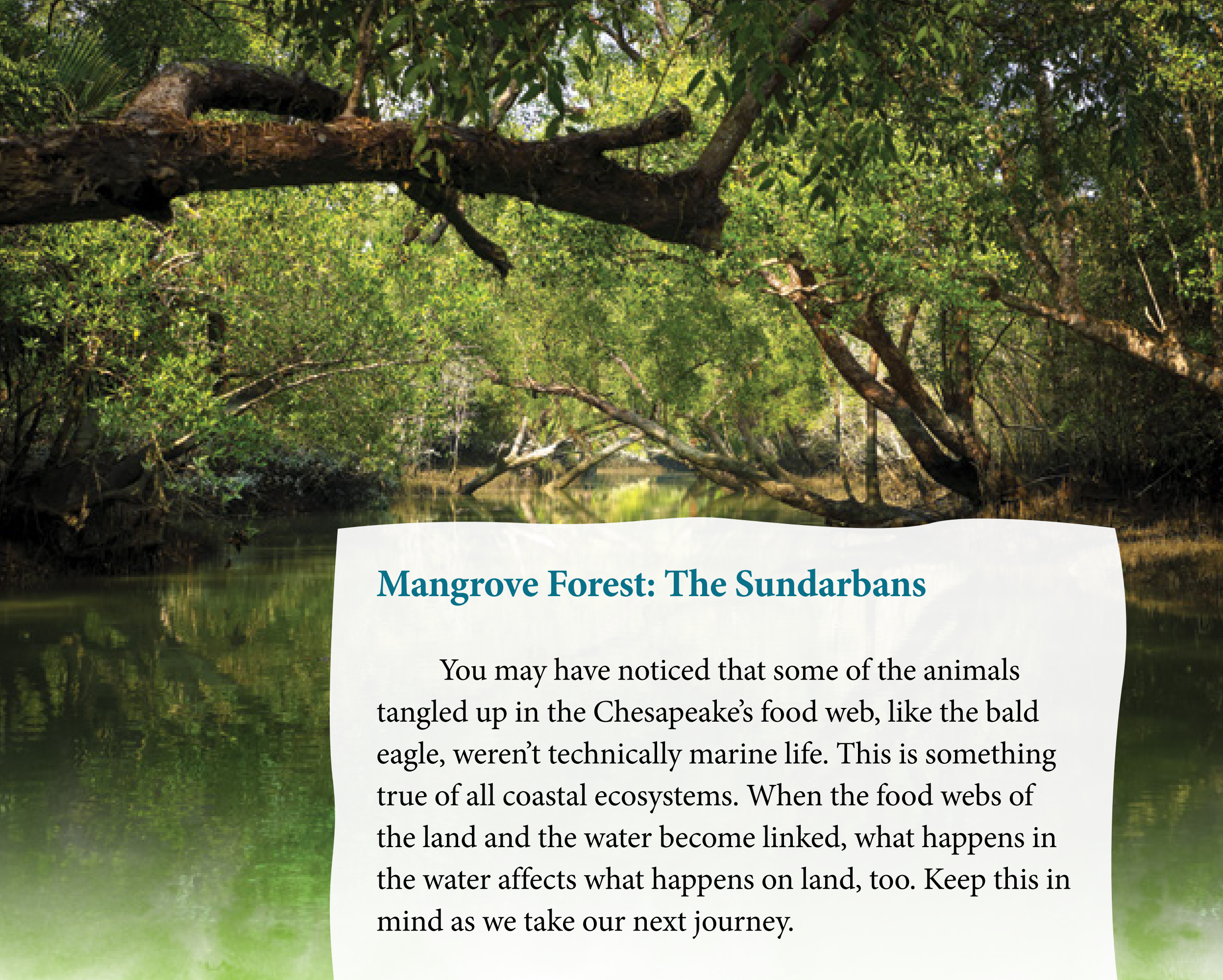
Oysters provide clean water for their neighbors by filtering up to 50 gallons each day.

Oysters are a major part of the Chesapeake's food web, and not just as food. Oysters are filter feeders. In order to eat, they pump water through their bodies and strain it in search of algae and nutrients. When they do this, oysters also remove algae and chemicals from the water, making it very clear and clean. This helps keep other organisms in the Chesapeake healthy and strengthens the overall food web.

Oyster shells also form into hard habitats called oyster reefs. Other animals in the Chesapeake use these for shelter, and they also help protect coasts. When the tide fills an estuary, the ocean's waves crash onto the shore. Sometimes they cause the rocks and soil of the coast to break up and slide into the ocean, which we call **erosion**. Coral reefs and kelp forests help protect coastlines from erosion. In estuaries with high oyster populations, so do oyster reefs.

Unfortunately, being stuck in one place means that oysters can't run away from predators. Blue crabs, flatworms and seagulls can all break through oyster shells to get to the meat. Humans near the Chesapeake Bay also eat oysters. In the past, humans have eaten so many that the oyster population has shrunk to a tiny percentage of what it once was. This affects the other animals that use the oyster for food. Because oyster reefs protect against erosion, it can also affect the coastline itself.

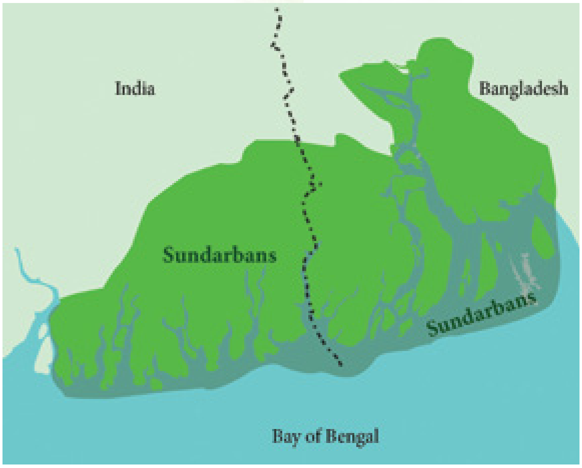
To help keep the Chesapeake Bay healthy, a group of activists, ecologists, and politicians called the Chesapeake Bay Foundation (CBF) have worked to restore the oyster population of the bay. How do they do it? Naturally—or perhaps unnaturally—they create artificial oyster reefs. These are formed from old, broken oyster shells tied together with mesh. Fish hatchery workers then add oyster spat to the artificial reefs. Over time, the baby spat attach themselves to the old shells, where they start to grow new ones. And this slowly repopulates the artificial reef with real, live oysters.



Mangrove Forest: The Sundarbans

You may have noticed that some of the animals tangled up in the Chesapeake's food web, like the bald eagle, weren't technically marine life. This is something true of all coastal ecosystems. When the food webs of the land and the water become linked, what happens in the water affects what happens on land, too. Keep this in mind as we take our next journey.

In Bangladesh and eastern India, there's a stretch of coast where dozens of rivers, including the Ganges, meet the ocean. Together, they create brackish water that connects a network of islands, inlets, and peninsulas. Here, sturdy grasses and mangrove trees with huge, snaking roots coat the patches of dry land. Monkeys screech and play in their branches, while shrimps, small fish, and amphibians dart around their underwater roots.



When the Ganges River and the Indian Ocean meet an estuary is created.

The lush coastal landscape you're imagining is part of the Sundarbans, one of the largest mangrove forests in the world. As with any coastal ecosystem, the combination of fresh water and salt water keeps the ecosystem constantly changing. The tides come in and out, and the rivers swell and flood with regular monsoons, or seasonal rain storms.

Mangrove roots help prevent excessive erosion during monsoons.

A mangrove tree's roots grow in long, thick tangles. They use these roots to hold their trunks above the surface of the brackish water, like a person standing on their tippy toes. The roots extend all the way through the water and deep into the mud beneath. Being anchored in the mud like this keeps the trees steady while the water around them raises, lowers, rushes, and stops.

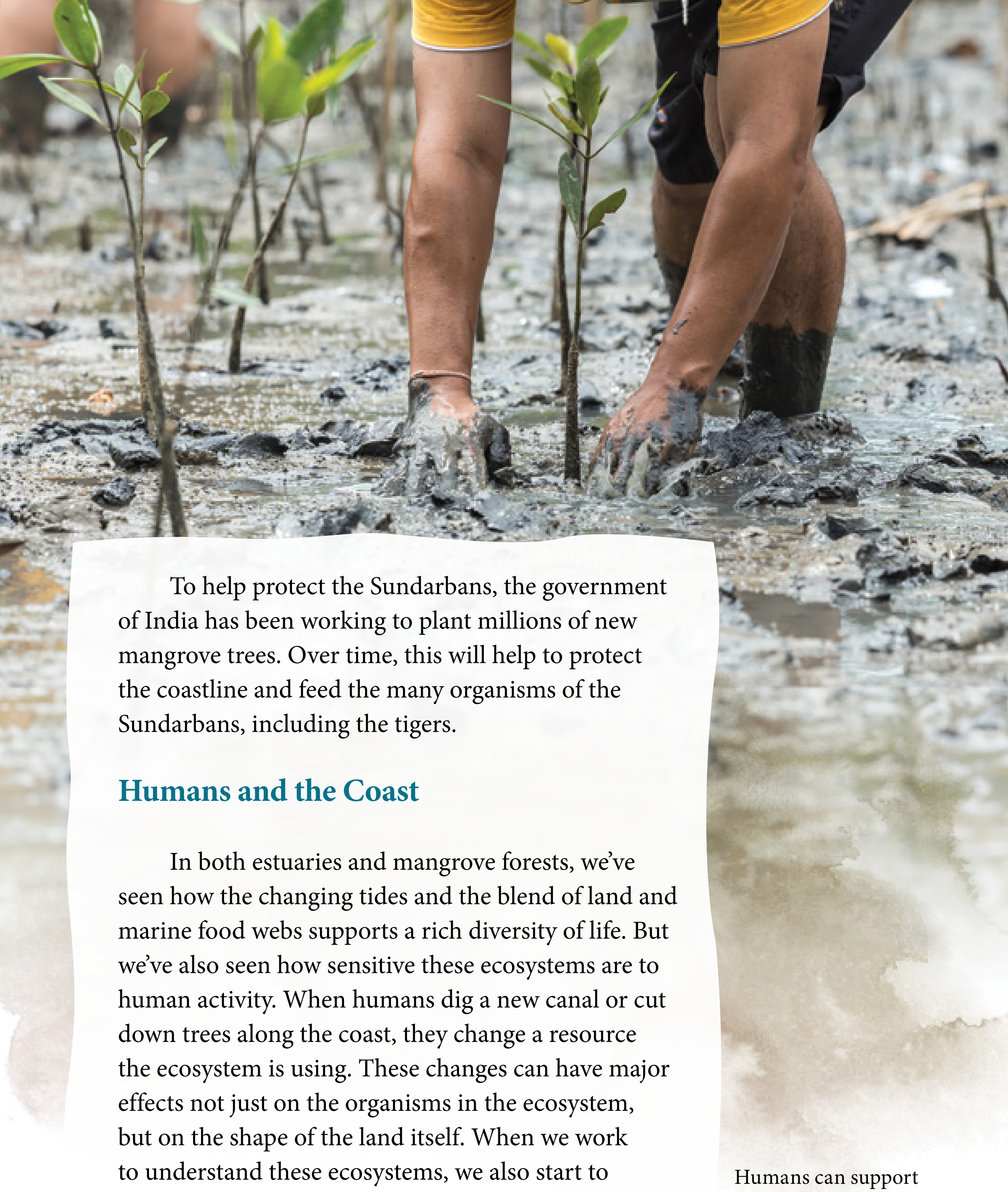
Mangrove roots also help the mangrove tree filter the water around it. You might think that since mangrove trees live in brackish water, they prefer its high salinity, or level of salt. But mangrove trees actually need fresh water to live. Over time, they've adapted to using their roots to filter out salt. Where does the salt from the water go? You can find crystals of it coating the leaves of some mangrove species.

Mangroves and Dolphins and Tigers (Oh My)

The bright red flowers, sour mangrove apples, and salty leaves of mangrove trees provide food to a range of consumers, including crabs and rhesus monkeys. (Mangrove apples are lime green and tangy, and they're very different from the apples we find in orchards.) Fungi and other detritivores break down the waste from these consumers, and shrimp and oysters prey on them in turn. Larger consumers like monitor lizards and humpback dolphins eat everyone else.

However, the apex predator of the Sundarbans is the Bengal tiger. As expert swimmers, climbers, and runners, they can hunt high and low, from treetops to river bottoms. But despite their status as top cat, Bengal tigers are an endangered species. Although some Bengal tigers live in other areas, researchers have counted fewer than 100 tigers left in the Sundarbans.

Why are the Bengal tigers disappearing? One reason is deforestation. Deforestation occurs when humans cut down trees to make room for farms or cities. When there is no forest, the Bengal tigers can't climb, hide, or hunt. Remember, also, how central mangrove trees are to this food web. If people remove the trees, smaller consumers and producers don't have as much food, and the tigers have less to hunt. The mangrove trees also protect the coastline, just like oyster reefs in the Chesapeake.



To help protect the Sundarbans, the government of India has been working to plant millions of new mangrove trees. Over time, this will help to protect the coastline and feed the many organisms of the Sundarbans, including the tigers.

Humans and the Coast

In both estuaries and mangrove forests, we've seen how the changing tides and the blend of land and marine food webs supports a rich diversity of life. But we've also seen how sensitive these ecosystems are to human activity. When humans dig a new canal or cut down trees along the coast, they change a resource the ecosystem is using. These changes can have major effects not just on the organisms in the ecosystem, but on the shape of the land itself. When we work to understand these ecosystems, we also start to understand more of what it takes to keep them healthy. In the end, the health of our land ecosystems depends on the health of our coasts.

Humans can support estuary ecosystems by replacing lost mangrove trees through replanting.

Chapter 8

The Open Ocean and the Deep Sea

Out past the kelp forests, mangroves, coral reefs, and estuaries, the open ocean and its creatures have their own story to tell.

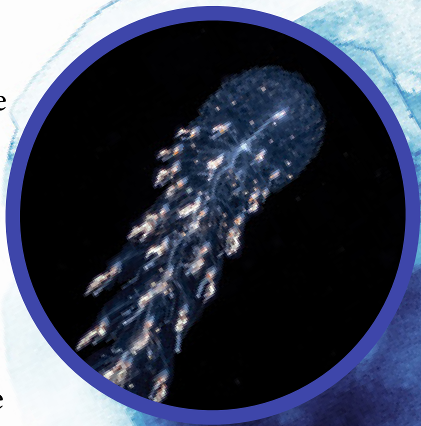
Ocean Currents

Each of the four ecosystems we've talked about so far have had one big, defining feature. Kelp forests are full of kelp. Coral reefs form among coral. Estuaries are where salt and fresh waters meet. And when mangrove trees grow in an estuary, it becomes a mangrove forest.

The open ocean has two big, defining features. One is its size: the open ocean covers over 70 percent of the surface of the planet. The other big factor is the ocean's current. The current is the direction of the water flowing in the ocean. If you dropped a small paper boat somewhere in the ocean, the current would cause it to move to somewhere else on the ocean's surface.

Have you heard the saying "it's easier to swim with the current"? This is very true for organisms in the open ocean. Animals and plants tend to travel with the ocean currents in search of food, resources, and warmer waters. Sometimes they travel great distances. Some humpback whales, for example, use ocean currents to help them swim nearly 5,000 miles with the changing seasons. This is one of the longest migration cycles on our planet.

These two factors, size and currents, combine to make the open ocean a dynamic, or rapidly changing place. Some animals in a coral reef or estuary might live their entire lives in the same ecosystem. Whatever food web they're born into, they stay in. The open ocean, with its currents, is different. You can think of it as the ocean's highway. The animals who live in it are always traveling. Again and again, they have to find their place in different food webs.



Plankton

Some animals ride the ocean current when they choose and swim against it when they don't. Scientists call the open ocean organisms who can't fight the current plankton. Plankton doesn't refer to a single species. Instead, it's a category that refers to many different species of all sizes, from bacteria so tiny you need a microscope to see them to animals as large as jellyfish. Plankton's mode of travel has earned them the scientific name *drifters*.

THE BIG QUESTION

How do the unique characteristics of the open ocean and deep sea affect how organisms move and eat in those ecosystems?

The red octopus can change its color to stand out, or blend in with its environment.

Plankton make up the base of the open ocean's food chain. If you think of the open ocean as a highway, plankton are the fuel that keeps everyone going.

Plankton can be found floating near the surface of the ocean where the light is strong. The plants of the plankton world are referred to as phytoplankton, while the animals are called zooplankton. All the different species of phytoplankton require sunlight to survive and photosynthesize, so they aren't as abundant in deeper waters. But when all is right in the marine world, there's enough phytoplankton for open ocean zooplankton to eat.

All zooplankton are born as drifters, weak swimmers at the mercy of the ocean waves. Some, like jellyfish, will stay drifters all their lives, traveling with the currents and catching whatever smaller plankton they come across. But some zooplankton are only drifters when they're babies, or larva. When they grow up, these zooplankton, which include sea stars and octopus, will become strong swimmers, able to fight the current. But to get to their final form, they first have to float where the phytoplankton is flourishing and fuel up.

Nekton

We call the organisms who can swim against the current nekton. These creatures are able to swim hundreds of miles through the ocean's waves and currents in search of food. Because nekton have more freedom to travel the open ocean, their hunting and feeding patterns adapt to their environment. Even the way these open ocean creatures communicate sometimes changes depending on where they are.

Nekton eat plankton, as you might have guessed, but the open ocean's animals have other dining interests as well. The smaller fish, like cod, who consume plankton are in turn consumed by larger creatures like dolphins. And at the top of the trophic pyramid, of course, are some of the open ocean's most well-known apex predators: orcas.

Orcas are sometimes called killer whales, but they're actually part of the dolphin family. Of all the dolphin species, orcas are the largest. Orcas live in groups called pods, which can have as many as thirty members. By nature, orcas care for each other within these pods, helping out injured orcas.

Orcas are powerful swimmers who can surround and attack groups of other ocean animals, including much larger whales. Orcas will change their migration patterns to follow the paths of salmon. They're the long haul truckers of the ocean highway, able to travel as far as 7,000 miles, round trip, in a single year. That's nearly as far as the Earth is wide.

Some species have dining interests that are difficult to compare to any human highway experience. For example, one of the largest squid in the open ocean is the Humboldt squid. In addition to eating smaller fish, Humboldt squid will also consume other Humboldt squid! At night, these predators rise from the twilight zone, some 2,000 feet down in the ocean. They hunt all night, then return to the depths during the day to hide from larger predators.

Currents and the Deep Sea

The Humboldt squid's eight arms are covered with 100–200 suckers, each with a hook inside.

Up to now, we've only talked about currents that move across the ocean's surface. But there are also currents that move like the Humboldt squid does every night, first rising to the surface, then descending to the deep. When a current moves from the seafloor to the surface, we call it an upwelling current. When it moves from the surface to the seafloor, we call it a downwelling current. These currents connect the open ocean to the deep sea.

Food Webs in the Deep

The huge numbers of phytoplankton and zooplankton in the open ocean support a large number of complicated consumers and predators. In the deep sea, food is much scarcer, and the organisms that live there have to rely on complex adaptations to survive. Some, like the prickly dreamer and other angler fish, rely on bioluminescence to hunt their prey. But in general, there are far fewer large consumers in the deep sea than in the open ocean. Organisms in the deep rely on other food sources.

One of the common food sources in the deep is called marine snow. Despite its name, marine snow isn't actually snow, but scraps and waste that animals in the upper zones of the ocean discard. Pulled by downwelling currents and gravity, scraps sink to the lower zones of the ocean, where deep sea detritivores gobble them up. One of these is the sea pig, which is not an actual pig that oinks in the mud, but a type of sea cucumber. Another is the Pacific hagfish. These slick, pink decomposers are covered in a slime that helps them wiggle onto deep sea debris and soak up all the nutrients. Even without eyes, jaws, or even a stomach, hagfish can smell quite well and feel their food in the water.

Another major deep sea detritivore is the brittle star. There are many of them found clinging to the sea floor or crawling over it on their five long arms. By one count, there are around 2,000 different species of brittle star. They get their name because of how they handle predators. When a predator fish or crab grabs a brittle star by its arm, the brittle star lets its own arm break off. The arm **regenerates** later, when the brittle star reaches safety.

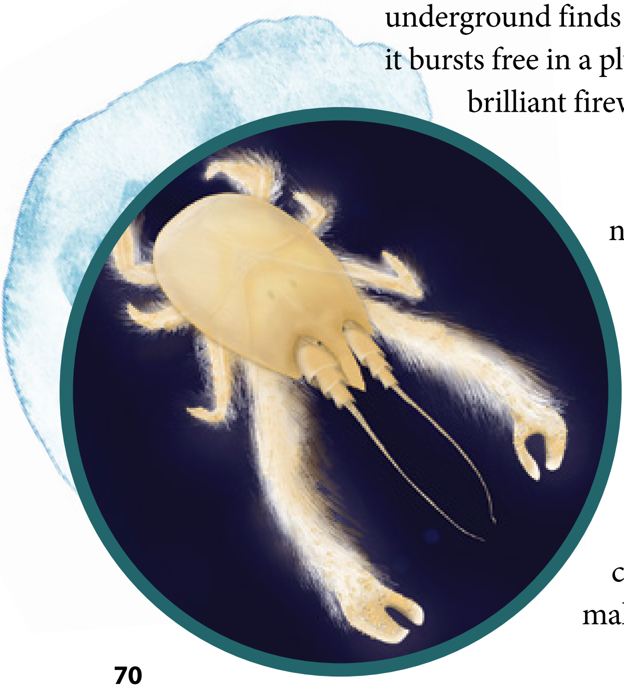
Brittle stars blur the lines between detritivore and consumer. Some are detritivores who filter feed, holding their arms up to catch marine snow and other debris floating down from the open ocean. Others are active consumers who hunt prey, including deep sea crustaceans.

Hydrothermal Vents

Hydrothermal vents form in the deep sea in places with high tectonic activity, including earthquakes. They're most often found in parts of the ocean with active volcanoes, such as the "Ring of Fire" in the Pacific Ocean.

Hydrothermal vents happen when the sea floor cracks. Seawater flows into the crack and becomes trapped inside, close to the magma underneath the earth's crust. The magma heats the water, which causes the water to change into something called a vent fluid. The vent fluid eats away at the metals and minerals buried underground. Eventually, the vent fluid trapped underground finds its way back up to the seafloor, where it bursts free in a plume of colorful smoke. Imagine brilliant fireworks in the deep.

A yeti crab's arms may look furry, but they are really covered with bristles called setae.



The vent fluid is toxic to many, but not all, organisms. Some producers can feed on the metals and minerals drawn up from underground. They perform **chemosynthesis** to turn these into energy. Consumers in the deep sea surround and feed on these **chemosynthetic bacteria** on the ocean floor. One of these is the Yeti crab, a crab with huge, furry arms that makes its home near ocean vents.

Upwelling currents also carry some of the chemicals vented from underground up to the surface. From there, the surface currents carry them to other parts of the ocean, where they become parts of other ecosystems. In other words, resources pass back and forth between the open ocean and deep sea in many ways, linking the two ecosystems into one. The deep sea is one of the most mysterious parts of our planet. Yet at the same time, what we do here on the surface has an effect on it, and it affects us in turn. Nothing on the planet is as far away from us as we think.

Warm, mineral-rich water around hydrothermal vents allows life to survive in the cold, dark water.

Chapter 9

Sharing the Seas

THE BIG QUESTION

How does a marine biologist's work impact marine ecosystems?

My name is Leena Jung, and I've been passionate about the ocean ever since I was a kid. I grew up swimming, surfing, and snorkeling in the Pacific Ocean that surrounds my island home of O'ahu. I learned so much about respecting and protecting the ocean and its life.

In the end, I loved the ocean so much that I grew up to become a marine biologist. I specialize in both marine mammal science and marine conservation, so my work changes day to day. Some days, I'm out taking samples of coral to make sure it's healthy. Other days, you can catch me riding my **water scooter** out to survey turtle nests, or listening to the melodious song of a humpback whale.

You can be sure that whatever I'm doing, my job as a marine biologist lets me make incredible discoveries every day. Let me tell you about just one day.

First: Gearing Up for the Dive

At least once a week, I get to spend all day in the water. Yesterday was my day, so I started by heading out on a boat from the eastern coast of O'ahu with the rest of my team to get ready for a dive.

Before getting in the water, I put on my scuba gear. Usually that includes a wetsuit, a mask, a snorkel, and fins. Did you know the word "scuba" is actually an acronym? It stands for "self-contained underwater breathing apparatus." All my gear will help me when I'm in the water, but the most important part of scuba gear is my oxygen tank, or cylinder. Without it, I'd start to suffer from **hypoxia**, or a lack of oxygen. And that is not something I want to do while on a dive.

My oxygen tank is attached to a special pack that I wear called a BCD, or buoyancy control device. Buoyancy is how we measure whether something in the water will float or sink. I can use my BCD to help me float higher in the water, or sink lower. It all depends on whether I want to dive deeper or come back up to the surface! My BCD is also a great place to store cutting tools, a compass, and a dive light. Last but not least are weights. Even with all that gear strapped to our BCDs, divers still need weights to help us dive deep.

While I'm getting ready, my team measures the water's **clarity**, or how easy it is to see through. They use a tool called a **Secchi disk** to check this. The Secchi disk is a black and white disk. The team lowers it into the water, and at the point where it's no longer possible to see the disk, they take a measurement. The team also checks other features of the water. One of these is its pH level, or how acidic the water is.

Once I'm geared up and ready, I dive in and get to work! Today, I'm working in the sunlight zone, just 25 feet below the ocean's surface. One part of my job is just to measure the quality of the water.

For the rest of my dive, I work to remove debris that's hazardous to marine life. We collect all kinds of trash on our dives. You'd be shocked by what we find—everything from camera equipment to old toys to plastic bottles.

The most common marine debris we find is plastic, which includes things like lost fishing line, nets, and hooks. These fishing tools can harm and trap sea turtles, birds, and other mammals. Did you know that 70 percent of the turtles rescued in the waters off the coast of Hawaii are tangled in fishing gear? When we find injured turtles, we use our cutting tools to gently help them get free. Plastic is unhealthy in a lot of ways for coral reefs and other marine ecosystems. That's why I like doing debris removal dives. Even though it often makes me sad, I know the work my team and I do directly protects the environment we love.

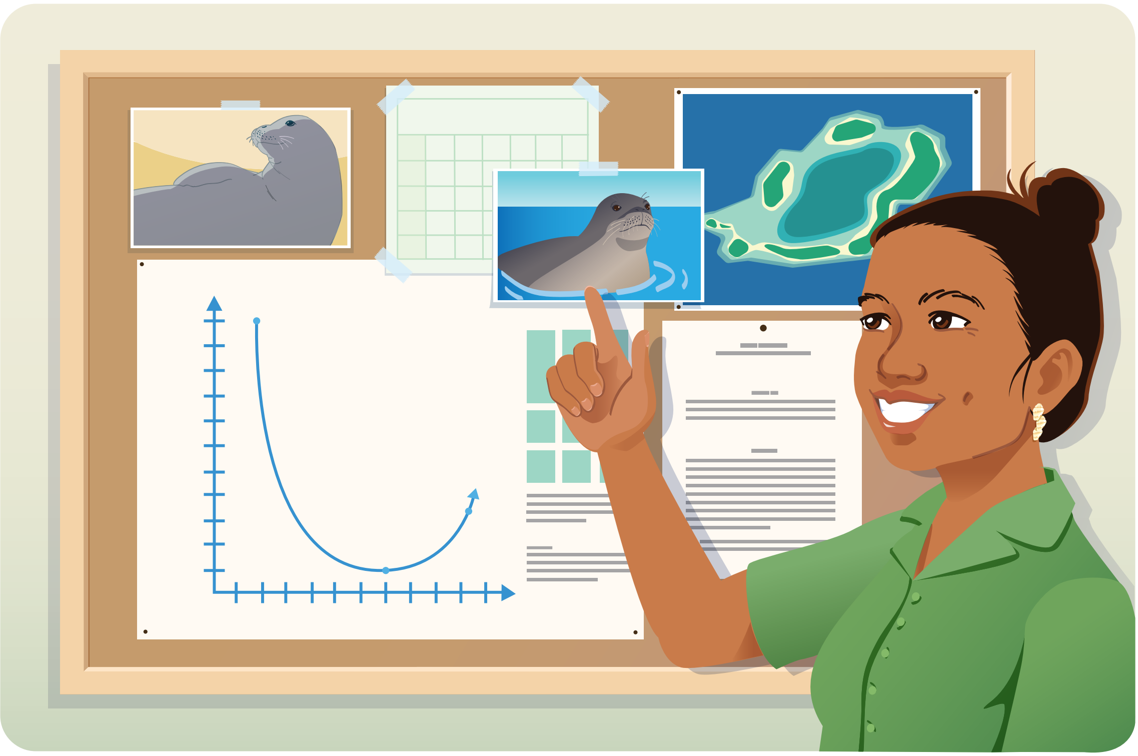
Next, Conservation Work

I love diving, but my favorite part of the job involves working with a majestic seal only found in the waters around Hawaii: the Hawaiian monk seal. When I was younger, it was pretty rare to see monk seals resting on our shores. That's because there were so few of them! Today, monk seals are one of the most endangered species in the world. But it was much worse a few decades ago, when their population was at its lowest.

Part of my work is to help other scientists explain why there were so few monk seals then. One reason is that there were fewer octopus, squid, and eels nearby for them to eat. Sharks also prey on monk seals, which is another reason why we found so few of them in our oceans. In the past, I've worked with teams to help move monk seals from places where lots of sharks live to other nearby islands.

Some of my conservation work also involves measuring atolls, which are ring-shaped coral reefs. At the center of the reefs are islands just below the surface of the water. In the past, monk seals have made their homes on atolls. As environmental patterns shift, some scientists predict that some atolls may be lost because of rising sea levels. And that worries me: after all, if there are changes to a monk seal's habitat, that may have effects on the monk seals.

Lots of different groups in Hawaii have worked together to try to help the Hawaiian monk seal. Thanks to everyone's conservation efforts, they're a much more common sight. But we still need to do more to get **clarity** about how the changes in our ecosystems are affecting these animals I love.



And Then, Rescue Work

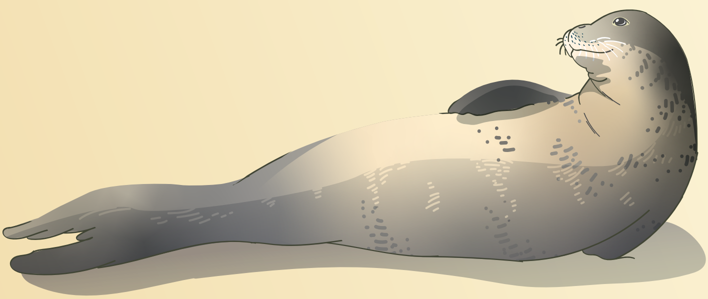
Part of my job is also to help people understand how to coexist with the monk seals. I partner with the Marine Animal Response team to educate the public about monk seals and to take care of them when they swim to our shores. It's natural to admire these curious creatures, with their silvery, slippery bodies and their expressive faces. But even though they seem friendly, it's important to give them their space! Because they're a protected species, it's against the law to get too close to them. So, if you happen to spot a monk seal on the sand and it doesn't look like anyone else is aware of it yet, remember to call for help from Marine Animal Response.

Today, our team got a call about a monk seal who had "hauled out" on Halona Blowhole, a popular and crowded beach. ("Hauled out" is marine biologist speak for "swum up on the beach.)" We drove to the site in our trucks, along with the equipment we'd need to move the monk seal. I was hoping we wouldn't have to take it to a hospital, but it's good to be ready for anything.

We quickly found the monk seal resting on the beach. Our first step is always to protect the animal from the public. A few beachgoers had gotten close, so my team and I put up cones to help keep them out. We also put up some signs to help teach people about the monk seal, as well as answered a few questions folks on the scene had. I also assigned someone to watch for dogs and other animals who might bother the seal. (It’s good to be on the safe side.)

Once we’d created a secure space, my team and I triaged the monk seal, or checked it for injuries. We keep our distance when we do this part. Unless it’s absolutely necessary to move an animal, it’s better to leave them alone! Instead, my team took cell phone photos of the seal, zooming in to make sure we caught photos of her markings and spots. We use these to help us identify the animals we work with. To identify monk seals, we use an app that has photos and descriptions of all the Hawaiian monk seals other marine biologists have spotted and recorded. That’s how we found out that this seal’s name was Kiko.

Kiko seemed unharmed, so we checked to see if she was pregnant or in labor. Pregnant seals have definitely been a big attraction on our shores! Another seal, Rocky, even became a kind of hometown hero. In 2017, Rocky “hauled out” on Kaimana beach to rest. It took her about seven months to birth her seal pup, enough time for everyone around here to become really familiar with the sight of her.



But anyone expecting a sequel to Rocky's story would have to wait, because Kiko wasn't pregnant. She'd just come up on the beach to rest. We had enough volunteers signed up to watch her for a few days, so I left them to do their work and drove back to my office to finish my day.

And Finally, Paperwork

A marine biologist's work isn't all exciting adventures and animal encounters. It also involves a great deal of laboratory time, as well as lots and lots of paperwork. The paperwork might sound less important than diving for debris or triaging seals. But I'm just as proud of what I accomplish at my desk as what I accomplish in the water.

I spend a lot of time speaking with government leaders about laws that might help protect our oceans. I also spend a lot of time building local efforts to protect marine wildlife. For example, right now I'm working on a program that will help my team vaccinate seals against a really harmful marine disease. To make my new program work, I'll need to get a lot of reports together, to say the least. But as long as I'm making a difference in the health of our oceans, I know I have one of the best jobs in the world.

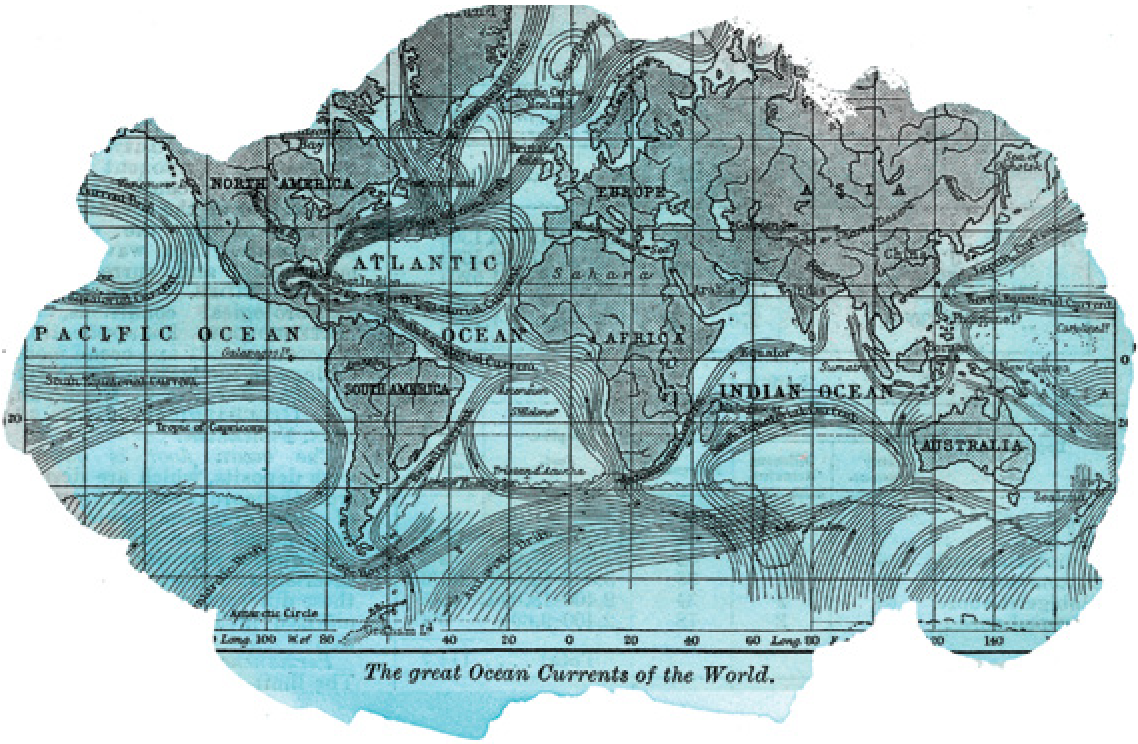
I think a lot about what I was like as a kid, back when I used to spend days swimming, surfing, and snorkeling in the Pacific Ocean. I think the kid I used to be then would really be proud of who I am today. When I was a kid, I had a dream, and I worked hard to make that dream come true. And at the end of the day, I'm proud that the work I do teaches people how to protect the ocean for future generations of kids, too.

Chapter 10

Gyres

The open ocean is full of currents, but where do they come from? Many factors come together to create a current. When air temperatures change and the wind blows, this has an effect on the current. The way fresh water and salt water flow into one another also affects the current. The shape of coastlines, ridges and trenches in the seafloor, and the Earth's rotation all play their part. Even earthquakes have an effect on which way a current flows.

The currents that come from wind and weather don't last very long. But when a current results from a



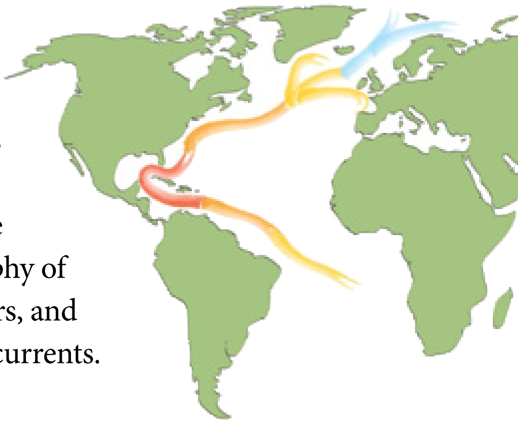
The great Ocean Currents of the World.

deep ocean valley, an underwater temperature change, or from the way fresh and salt water mix, it's likely to stick around for a long time. Many of the currents in the ocean are permanent. For example, the Gulf Stream is a fast-moving, permanent current of warm water. It travels from the Gulf of Mexico and the West Indies, all the way up the United States's East Coast, and onward to Canada and Europe. Sailors have known about the Gulf Stream for over 500 years. (After all, currents carry plankton and nekton around the ocean, but they can also carry boats.)

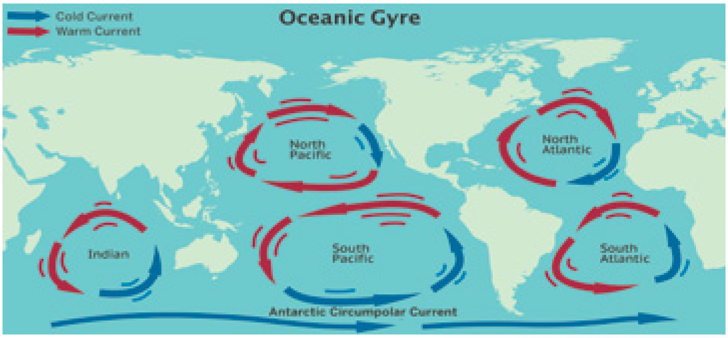
THE BIG QUESTION

How does the North Pacific Garbage Patch impact the open ocean ecosystem?

Over time, all these permanent currents add up to create a specific geography of the ocean. It's tempting to imagine the ocean as one big, unchanging expanse of seawater. But plankton, nekton, and the sailors who share the ocean with them know differently. The geography of a continent on land is made of mountains, rivers, and coasts. The geography of the ocean is made of currents.



The swirling ocean currents that cover the Earth result in gyres in a few places in the world.



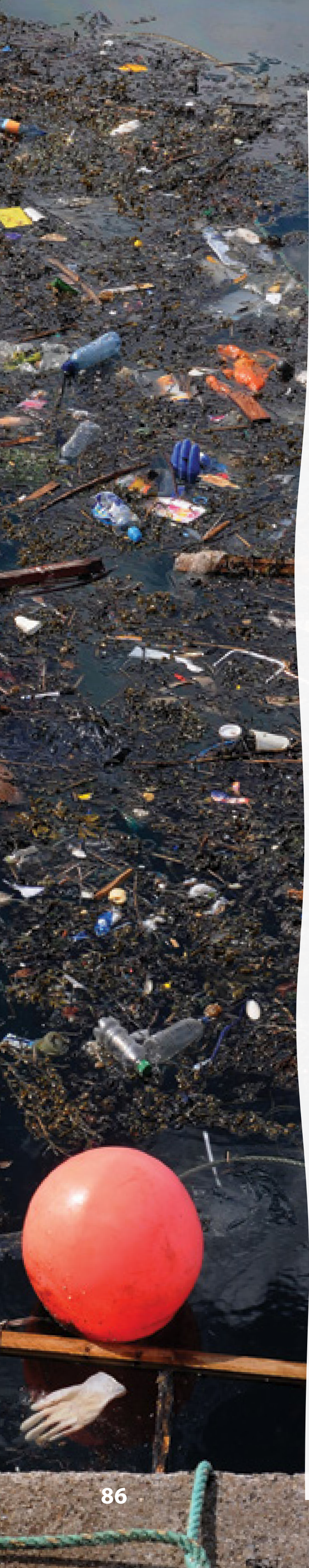
The Five Major Gyres

Sometimes permanent currents are linked. When the warm water of the Gulf Stream flows toward Europe, it pushes out the colder water around the European coast. This forms a new current that travels south. On its way, that cold water current starts to push areas of warm water aside, which forms other currents.

When permanent currents form a stable cycle, they create a **gyre**. Gyres are systems of large, swirling ocean currents. All the currents in a gyre feed into one another, which makes the gyre move in a circular path called a

vortex. Objects in the vortex slowly circle through the water, around and around, until they come back to the point where they started.

There are five major gyres in the open ocean. Two are in the Atlantic Ocean: the North Atlantic Gyre and the South Atlantic Gyre. Two in the Pacific Ocean: the North Pacific and South Pacific Gyres. There's also the Indian Ocean Gyre. Three of these gyres are in the Southern Hemisphere, and their currents rotate in a counter-clockwise direction. The other two are in the Northern Hemisphere, and their currents rotate clockwise. If you are wondering why the currents rotate differently in different hemispheres, it's because of something called the Coriolis Effect. The Earth's rotation causes the Coriolis Effect.



The five gyres are one of the main ways all ecosystems in the ocean are connected. Minerals and nutrients from the coastal ecosystems flow on currents into the open ocean. Once there, currents will carry them to the gyres, where they circulate the planet.

Unfortunately, minerals and nutrients aren't the only things gyres carry.

The Pacific Garbage Patches

In 1997, a man named Charles J. Moore was sailing his yacht between Hawaii and California when a hurricane blew him off course. As he studied the water to try to get his bearings, he and his crew noticed millions of plastic objects floating just over the rails of their boat. While traveling toward home, he kept checking the ocean to see whether the plastic would run out. It never did.

Charles Moore had sailed into the Great Pacific Garbage Patch. The Great Pacific Garbage Patch is located in the **North Pacific Subtropical Convergence Zone**, or the NPSCZ. Technically, there are two garbage patches that make up the Great Pacific Garbage Patch. One is close to Japan. The other, which Charles Moore sailed into, is between Hawaii and California. There are other garbage patches in other gyres as well.

The garbage patches are formed from **marine debris**, or trash in the ocean. You might ask: why are so many people throwing their trash in the ocean? Very little marine debris is put into the ocean directly. When people litter, at first the trash stays in the place where it's dropped. But over time, rain, wind, and weather carry it into water systems, including rivers and coastlines. Once it's in the water, the currents take it, and eventually it finds its way into one of the gyres. There, the vortex motion of the gyre captures it, and it continues to circle. After this has happened to many pieces of debris, they form a patch.

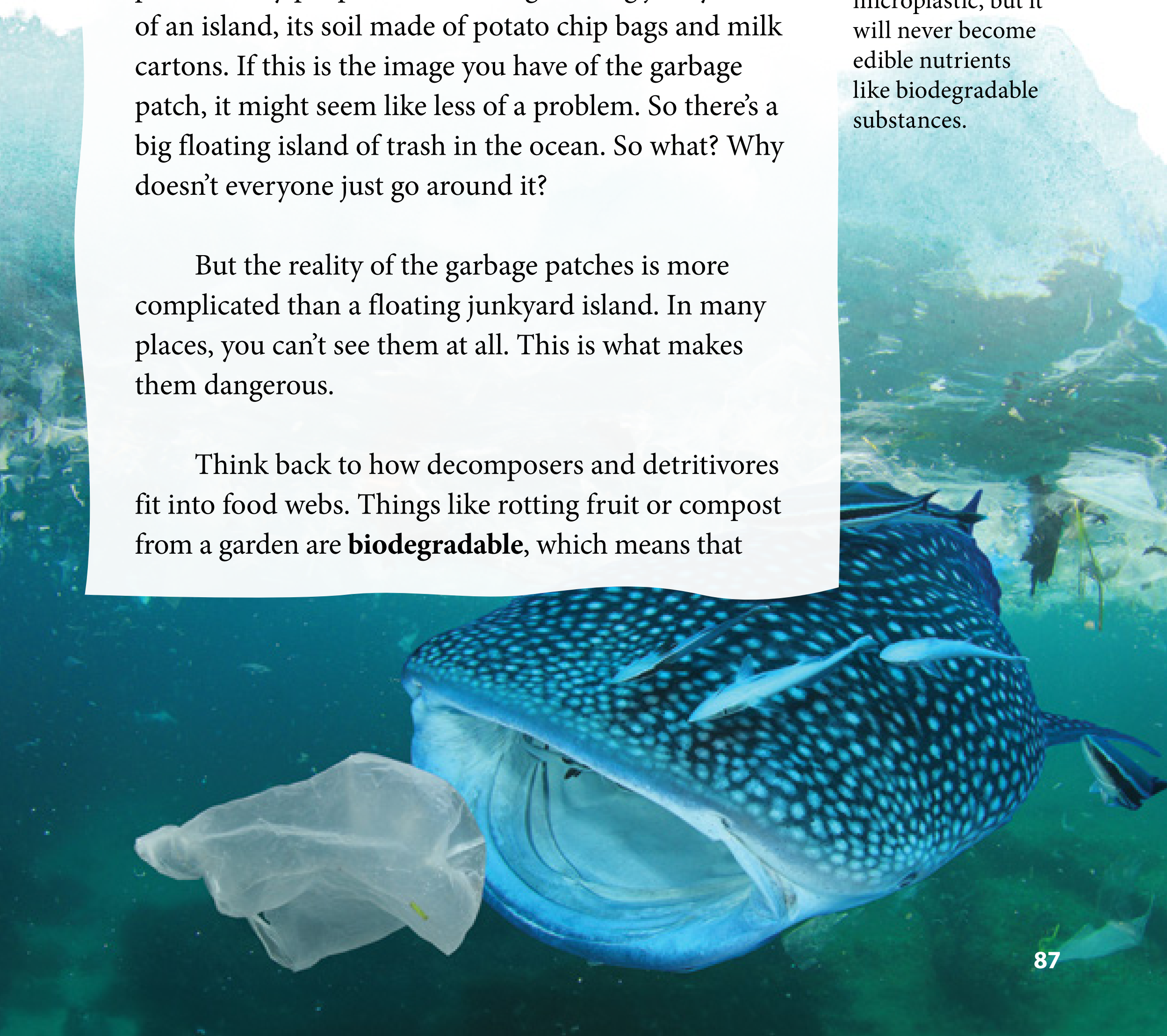
All plastic trash eventually breaks down into microplastic, but it will never become edible nutrients like biodegradable substances.

Microplastics

What do you imagine when you imagine a garbage patch? Many people think of a big floating junkyard of an island, its soil made of potato chip bags and milk cartons. If this is the image you have of the garbage patch, it might seem like less of a problem. So there's a big floating island of trash in the ocean. So what? Why doesn't everyone just go around it?

But the reality of the garbage patches is more complicated than a floating junkyard island. In many places, you can't see them at all. This is what makes them dangerous.

Think back to how decomposers and detritivores fit into food webs. Things like rotting fruit or compost from a garden are **biodegradable**, which means that



decomposers can break them into nutrients and edible detritus. In the end, biodegradable things all find their way back into the food web.

But plastic isn't biodegradable. There are no decomposers who can get energy from breaking it down, and there are no detritivores who can **digest** it. For weeks, for months, sometimes for years, it floats over the ocean currents. Eventually, it deteriorates, or breaks down, from sun, from wind, and from collisions with other ocean debris.

Much of the ocean's plastic eventually breaks all the way down into tiny pieces called **microplastics**. Pieces of microplastic can be as large as the tip of a little finger or so small that you'd need a microscope to see them. These nearly invisible microplastics are what make up much of the garbage patches.

And microplastics don't just stay near the surface. Downwelling currents carry them, like marine snow, to all levels of the ocean. Organisms in any depth zone can accidentally eat them through filter feeding. Because there are **toxins**, or dangerous chemicals, in plastic, organisms who eat it can get very sick.

Mr. Trash Wheel can collect thousands of plastic bottles each month.

Clouds of tiny microplastics can also block sunlight. This makes it harder for phytoplankton to perform photosynthesis, which leads to fewer phytoplankton. In 2021, Charles Moore returned to the Pacific garbage patch to study how it was affecting sea life. He found that there was six times as much plastic in the garbage patch as there was plankton. As we know, fewer producers means less food for consumers. Because the open ocean connects to the deep sea and to all the coastal ecosystems, big changes in the open ocean's food web can have major impacts on food webs throughout the ocean.

What Can We Do?

Fortunately, we now know about the garbage patches, which means we can do something about them. There are many groups using technology to try to shrink the ocean's garbage patches and restore healthy food webs. These groups face major challenges. Some groups have investigated using a system of nets to scoop out marine debris. But there are problems with this. One is that the nets that scoop trash also capture animals. The other is that much of the garbage patch is made of microplastics, which can't easily be scooped.

We haven't yet found the best solution, but there's hope. Some scientists are investigating new technologies that filter the water for microplastics. Others are experimenting with chemicals to pull microplastics from the water, like magnets pull metal. One marine biologist has even created a robot, Mr. Trash Wheel, to patrol the harbors and coasts near the city of Baltimore. Mr. Trash Wheel is solar powered, meaning his energy comes from the sun. He scoops up plastic floating in the harbor so it can't get to the gyres in the first place.

It's clear that marine biologists play a key role. Part of that role is studying the health of the ocean and its food webs. But the greater part might be their work to teach communities more about how the ocean connects all ecosystems.

Marine debris is a major problem for our planet. It's not just scientists who're working to solve the problem. Community groups work to organize beach cleanups and to raise awareness. The companies that produce plastic are researching new ways to make safe and biodegradable materials. And the governments of different countries have passed laws that make it harder to use unsafe plastic. All these groups, working together, will make up part of the solution.

Our job starts by understanding the problem, which means understanding how all the parts of the ocean work together. When we do that—and when we pass on what we understand to others—we become part of the solution, too.

A beach cleanup is a simple way to take care of our shorelines.

The Great Pacific Garbage Patch

There are some small islands of trash in the Great Pacific Garbage Patch! But most of it is a soupy mix of water, marine debris, and microplastic.

The Great Pacific Garbage Patch stretches over 600,000 square miles. That's larger than the state of Alaska.

There are about 79,000 metric tons of plastic in the Great Pacific Garbage Patch. Around 80 percent of the plastic comes from litter dropped on land.

Thousands of larger mammals get **entangled**, or stuck in synthetic fishing nets that float in the garbage patch. Scientists call this "ghost fishing." In response, the United States's National Ocean Service collects old gear and nets from fishers so that it doesn't end up in the ocean. As of 2023, they've kept 4 million tons of fishing gear out of the ocean.

The garbage patch doesn't just float on the surface. About 70 percent of marine debris sinks to the ocean floor.

Chapter 11

Organisms of the Coral Reef and Kelp Forest

You've now spent time swimming in kelp forests and coral reefs. These are two ecosystems full of soft kelp and tough coral, each of which provide structure and habitat. But just who lives in those habitats? What are those organisms like?

Organisms of the Coral Reef

While coral reefs make up less than 1 percent of the ocean, they're home to a quarter of all marine life—everything from microscopic phytoplankton to the world's largest clam. Here are some of the most fascinating creatures of the coral reef.

Brain Coral

Coral can take many shapes. It can look like a mushroom, a leaf, a bubble, or deer antlers. Sometimes, it even looks like a human brain.

How do brain corals grow into their amazing shapes? Unlike other corals, the polyps of brain corals don't cluster in separate sections. The tissue of their polyps like to connect, which gives the coral their brain-like appearance. Because the polyps of brain corals are connected, brain corals can communicate with one another. They can even share oxygen.

Brain corals can grow up to six feet, and they're considered massive corals. (Massive is another word for really big.) These massive corals have the **ability** to grow very strong, which makes them great **foundations**, or building blocks, for reefs.

Whale sharks are covered in a pattern of spots which are unique to each animal. Just like our fingerprints!

Whale Shark

We can't talk about marine animals of the coral reef without talking about sharks. You may be surprised to learn that not all sharks bite! Take the spotted whale shark, for example. It's the largest fish in the world, and it can grow up to more than 60 feet! Not only is it huge, but it has 300 rows of teeth! With all those teeth, you'd think that whale sharks would be constantly biting and chewing their prey. But the opposite is true. The whale shark's teeth work like a food filter. When it's hungry, the whale shark simply opens its mouth, letting in only **particles**, or tiny pieces, of food. These include the plankton and smaller nekton, like krill, that they like to eat.

THE BIG QUESTION

How do organisms obtain energy and food from a specific ecosystem?

Dugong

Think of a dugong as a type of sea cow. Like cows, dugongs are slow-moving herbivores that graze all day and night. These marine animals are the largest vegetarians in the ocean. Because their vision isn't strong, they use sound and touch to locate their food. Brushing their bristly lips along the ocean floor, they locate their beloved seagrass and uproot it with their strong snouts. In addition to their snout, dugongs use their molars, or flat back teeth, to chomp on the grass and plants they find around coastal seagrass beds.

A reef octopus may create a net by spreading out its webbed arms to capture prey.

A fun fact about the dugong is that a long time ago, when humans didn't know as much about marine life, dugongs spotted in the wild were believed to be mermaids. This is because they tend to swim in packs and show off their tails. In reality, dugongs are closely related to a land animal, but it's not humans: it's elephants.

Camouflage Expert: Reef Octopus

Our next creature, the Caribbean reef octopus, is hard to see in pictures. That's because it's always camouflaging itself. The reef octopus is known as one of the smartest invertebrates, or animals without spines, found in the ocean. It has special cells called chromatophores that allow it to blend in with its surroundings instantly. This ability to quickly change its appearance is important when a predator like a shark or large fish is nearby. Protecting itself lets the reef octopus swim for hours in search of clams and crabs to eat.

But changing color isn't the only way the Caribbean reef octopus protects itself. When a predator gets close enough to pose a threat, our octopus spews out a cloud of ink. In the confusion, our octopus has enough time to swim away.

Organisms of the Kelp Forest

Red Coralline Algae

You may think of algae as long and flexible, bending and swaying underwater. But our first creature of the kelp forest, red coralline algae, is as stiff as a branch. It also has a rough texture, similar to a coral reef. That's because it has cell walls that contain calcium carbonate, a hard substance found in rocks like limestone. These algae are so hard and unpleasant to eat that most herbivores skip snacking on it altogether. But there is the occasional hard-mouthed creature who dares to digest this crusty plant.

Of course, before it can be eaten, it's got to grow. It takes red coralline algae up to nine years to grow just eight inches. (To compare, in that same time, an ordinary maple tree on land grows nearly fifteen feet.) Part of the reason these algae grow so slowly is the amount of energy it takes to produce their coral-hard branches.

Despite their slow growth, these plants create solid places for other residents of the kelp forest to live in, just as the **crevices**, or cracks, in coral shelter the animals who live in the reef.

Bat Stars

You may be wondering why an ocean creature has *bat* in its name. Between a bat star's arms is a kind of webbing that resembles a bat's wing. (Most bat stars have five arms. But some have as few as four arms, while others have as many as nine.) These arms come in handy, particularly when two bat stars meet, and they engage in a bit of arm wrestling!

The plate-shaped structures that cover the bat star's body are called ossicles. A bat star's ossicles work like gills to help the bat star breathe. Their ossicles also give the creature a fuzzy appearance. Despite their fuzziness, these colorful creatures are more rough than cuddly.

The bat star plays an important role in this ecosystem by eating the remains of other organisms. Bat stars find their food by smelling it with their tube-like

feet, then extending one of their two stomachs out of their mouth to eat. When the bat star is done feeding, the leftover bits of food are consumed by the twenty or so worms that live in their mouths! Luckily the bat stars don't mind a little symbiotic help, and the worms get to enjoy a snack.

Rockfish

We can't leave the kelp forest without introducing the rockfish. Unlike other fish in the kelp forest, the rockfish does not swim rapidly from one area to the next, darting between waving kelp. In fact, it hardly moves. Instead, it hovers in the water, staying afloat with the help of its swim bladders, or air-filled pockets within its body. When they're not hovering in the water letting out gas, rockfish like to hang out closer to the rocks at the bottom of the ocean, where they feast on crabs. Despite their many predators, rockfish enjoy a very long natural lifespan. Some rockfish **specimens**, or examples, have been known to live for 200 years.

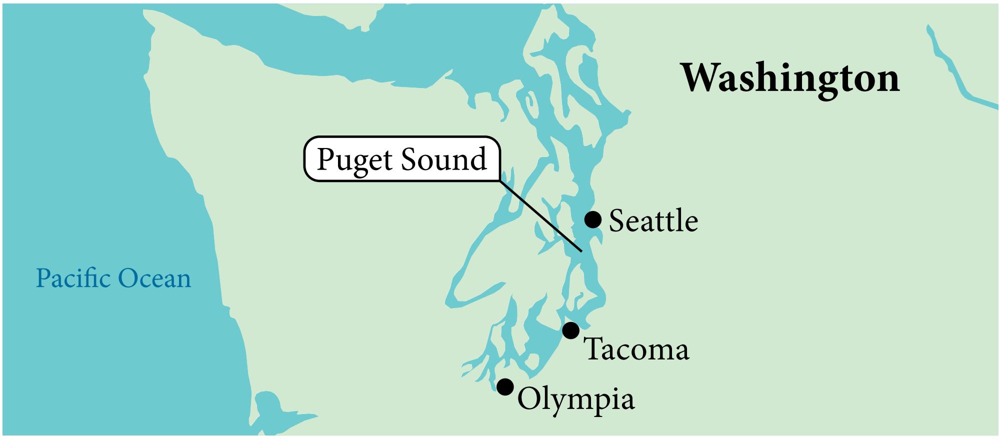
Marine biologists must empty a rockfish's swim bladder to prevent excess air pressure inside when tagging them outside of the water.

These creatures are only a few of the wondrous residents who make their homes around the stony coral reefs and flowing kelp forests. If you were given the chance to experience life as one of these sea creatures, which one would you choose?

Chapter 12

Organisms of Estuaries and Mangrove Forests

By now, you're no stranger to the wildlife that thrives in different oceanic ecosystems, including some of the creatures that call our coastal waters home. Let's travel to two more coastal ecosystems to learn about some more important residents of each.



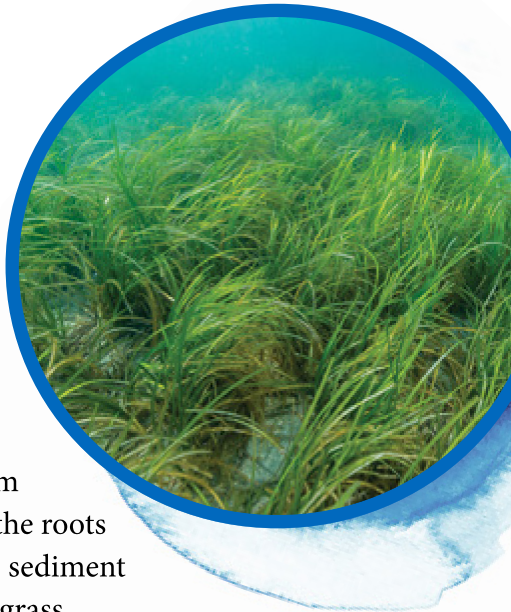
THE BIG QUESTION

How do organisms obtain energy and food from a specific ecosystem?

Organisms of the Puget Sound

In the northwest of Washington state, there's an estuary called the Puget Sound. (Sound is a very old word that describes a body of water partially connected to the ocean.) On one end, the Puget Sound connects to the Pacific Ocean. On the other, it's fed by dozens of freshwater rivers and streams. These waters come together to create a large and complex estuary where many species **flourish**.

Eelgrass



The highly productive eelgrass is a long, aquatic grass found in the Puget Sound, as well as many other estuaries. Like kelp, eelgrass provides a source of food and shelter for many animals. But it does more than provide food and shelter for our coastal communities. It also protects the shoreline from erosion. Like the Chesapeake oyster reefs and the roots of mangroves, eelgrass's ribbon-like leaves trap sediment and soften the force of waves. What's more, eelgrass filters out pollutants and harmful chemicals in the water. This helps keep the Puget Sound's water healthy and balanced.

However, human changes to the coastline affect the eelgrass just as they do oyster reefs and mangrove roots. To make sure the sound stays strong, the government of Washington state runs programs to transplant eelgrass into Puget Sound from other estuaries. The state government also has laws to make sure docks and buildings built near eelgrass are careful where the shadows they create will fall. This way, the eelgrass gets the sunlight it needs to thrive.

Pacific Herring

Pacific herrings lay their eggs in beds of eelgrass. When the eggs hatch into baby herrings, they begin eating the larva of mollusks and insects that feed on

the eelgrass. After two or three months of enjoying this relaxed youth in the estuary, it's time for them to go to school. This doesn't mean a building full of teachers who ask you to study marine life. In ocean ecosystems, a school is a large group of fish that travel together for protection. Pacific herring schools can be made up of thousands of fish, all seeming to move in **unison**, or at once. There's no leader in a school to tell the fish which way to go. Instead, each fish looks to its neighbor to know which way to swim next. Herring will stay with their school sometimes for three years, traveling together in the open ocean. Then they'll return to the estuaries to lay eggs, and the cycle of life repeats.

Coho Salmon

River dams can make it difficult for coho salmon to reach streams where they will lay their eggs.

Coho salmon live in both salt water and fresh water, but at different times. They hatch from eggs in the gravel beds of freshwater rivers, where they feed on insects and plankton. Once they grow strong enough, they make their way downstream to the salt water, where they prey on small fish. (Unfortunately, this includes Pacific herring.) They spend their early years traveling the open ocean, and then they navigate back to the streams where they were born. There, they dig holes in the gravel to lay their eggs. Coho salmon live in many other estuaries along the Pacific Coast. They're sometimes called "silver salmon" because of their brilliant, metallic scales.

Geoducks

Despite what you might think, a geoduck isn't a duck at all. (The word is actually pronounced "gooey-duck." It was originally borrowed from Lushootseed, a language spoken by Native Americans who live near Puget Sound.) A geoduck is a type of clam that buries itself deep beneath the mud in the shallow waters of the sound. To feed on phytoplankton, they have to stick a long, carrot-like neck up out of the mud. These "necks" are more like long tubes that allow geoducks to draw water into their bodies. Their bodies then filter that water for phytoplankton before releasing the leftover water back to the sea. Because they hide beneath the mud, geoducks have very few predators. In the wild, geoducks can live up to *140 years*.

Sea Otters

Sea otters are carnivorous marine mammals with short legs and a long tail. They are experts at swimming and holding their breath, just like dolphins and whales. But unlike dolphins and whales, otters can use their

Sea otters feast on clams while floating in the water.

small legs to travel between the land and the water. They also use these legs to dig deep into the mud of the Puget Sound to find geoducks and other mollusks. To crack these clams open, sea otters sometimes use rocks as tools. And when they're not cracking clams, sea otters have been known to use these rocks for a much more playful purpose: juggling.

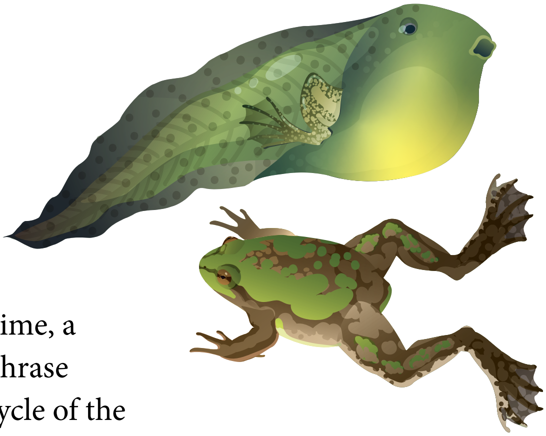
Dungeness Crabs

Whenever other organisms leave behind waste or scraps, the Puget Sound's cleanup crew rolls in. Detritivores of all kinds make their homes here, including the Dungeness crab. Though these crabs hunt for their own food, many survive as scavengers. Why do the work of hunting if sea otters leave behind perfectly good chunks of geoduck? When they do get hungry enough to hunt, Dungeness crabs sometimes slink through the eelgrass, looking for smaller fish and mollusks to eat.

Organisms of the Guianan Mangroves

If you were to sail across the northern coast of South America, you would eventually find your way to the shores of a country named Guyana. The rivers of Guyuana's coast mix with the ocean water and warm climate to create the perfect environment for the dense and swampy Guianan mangroves.

Paradoxical Frogs



The paradoxial tadpole's shrinking body makes it very different from other frogs.

What's a paradox? It's something—often a common saying—that seems to **contradict**, or disagree with itself. But at the same time, a paradox is always somehow true. The phrase "less is more" is one paradox. The life cycle of the paradoxical frog of the Guianan mangroves is another. As a tadpole, paradoxical frogs grow to be ten inches long. That's almost as long as a piece of paper! But as the tadpoles mature, they shrink in size to just three inches. To shrink as you get older is the opposite of what most animals do. Yet this is the truth of the paradoxical frog.

As tadpoles, paradoxical frogs only eat plants and algae. But when the tadpole shrinks into an adult frog, it switches its diet to a carnivorous one, eating small insects, crabs, and shrimp. Why do paradoxical frogs first grow and then shrink? Scientists don't know, although some believe it may help adult frogs hide from predators in the forest.

Hudsonian Godwit

Among the predators of paradoxical frogs is the Hudsonian godwit. Godwits are birds with long legs and slim beaks. Many migratory birds visit the Guianan mangroves, but the godwit may travel the farthest of any of them. Hudsonian godwits breed and lay their eggs in the very northern parts of Canada and Alaska, close to the Arctic Circle. To spend their winters in Guyana, which is near the Earth's equator, Hudsonian godwits must travel over 5,400 miles. What's more impressive is that they fly non-stop for several days in a row. That would be like if you were able to run from New York City to Los Angeles, then turn around and run all the way back without even stopping for a snack.

Pemecou Catfish

The pemecou catfish swim near the soft sediment created by sand and decomposing mangrove leaves. They swim between the sprawling, aquatic roots of the mangrove trees to hunt shrimp, tadpoles, and other small animals. When it comes to protecting their young, pemecou catfish have a unique approach. After a female pemecou catfish has laid her eggs, the male seems to gobble the eggs up. But the pemecou catfish isn't

eating the eggs at all. Instead, the male pemecou gently holds the eggs in his mouth until they hatch into babies.

West Indian manatee calves weigh about 40–60 pounds and grow up to weigh 800–1,200 pounds.

West Indian Manatee

While the pemecou catfish swims among the mangrove's roots, West Indian manatees ramble between beds of seagrass. These large, round animals have also earned the nickname "sea cow" due to their shape and feeding habits. (How do you tell a manatee from a dugong? The answer is the tail. Dugongs have tails with a fluke, like a whale's tail. Manatees have tails shaped like paddles.) Though they are omnivores, the manatees of the Guianan mangroves primarily eat aquatic plants. Their size makes them difficult to hunt, and they have few natural predators to fear. Because of this, manatees are generally gentle and curious creatures. They have been known to wander up to human divers or boaters just to say "hello!"

Eccentric Education of the Estuaries

The diverse species that share estuaries and mangroves can teach us a lot about adapting to our own ever-changing environments. And whether you're studying the shrinking paradoxical frogs of Guyana, the long-lived geoducks of Washington, or the waving eelgrass of the Puget Sound, it's clear that even the smallest being has an important role to play.

Chapter 13

Organisms of the Deep Sea and the Open Ocean

Not every organism is able to thrive in the intense pressure and lonely darkness of the deep sea, and not every organism can make its home in the vast and churning open oceans. But those that can are among the most fascinating on the planet. We'll conclude our tour of the ocean ecosystems with a look at a few key residents of both.

THE BIG QUESTION

How do organisms obtain energy and food from a specific ecosystem?

Organisms of the Deep Sea

Giant Isopod

The giant isopod is a distant cousin to the crab. Imagine a long underwater bug with a beetle-like body, fourteen legs, and a giant exoskeleton. The isopod uses its two large eyes and two types of antennae to navigate its surroundings in the dark. One pair is almost as half as long as the isopod's body, which is about sixteen inches. While this creature doesn't roll around, it does swim using its fanlike tail. The giant isopod is a detritivore, eating parts of dead crabs and marine worms. It's estimated that this isopod is one of 10,000 different species of isopods.

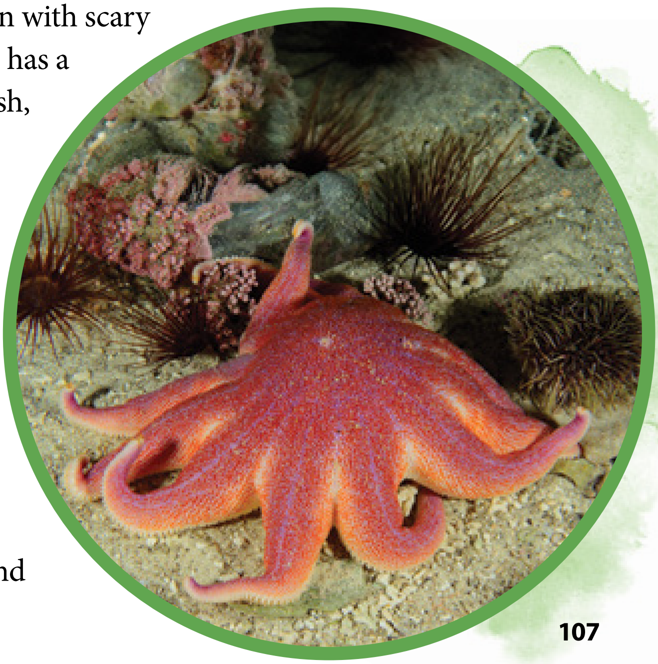
Vampire Squid

The first thing you may notice about the vampire squid are its eyes. They're bright blue from the reflected water around them, and they appear gigantic on its body. The name vampire squid is a little bit misleading. For one, our vampire squid isn't a squid at all. Scientists used to believe it was a species of octopus, but more recently they decided it was in a category all its own. For another, vampire squid don't hunt live prey or drink blood. Instead, they eat marine snow that floats through the ocean. There are some similarities to movie vampires, however. For one, when startled, it uses its webbed arms to cover itself like a cloak. For another, the vampire squid is very ancient. Scientists have found fossil evidence showing that there may have been vampire squid living over 165 million years ago.

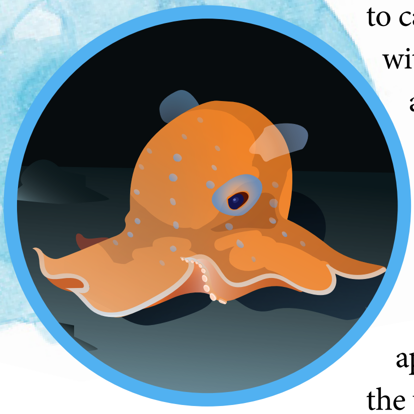
The vampire squid is covered in tiny hairs that help it sense food.

California Sun Star

Vampire squid aren't the only marine creatures that have something in common with scary movies. The California sun star has a feature common to many starfish, including the deep sea brittle star: it can **detach**, or remove, its arms! Even off of the sun star's body, the detached arms can move and distract predators, allowing the sun star to escape. The California sun star is a detritivore with a big appetite for rotting food. In addition to detritus, its diet includes worms, crustaceans, and



sometimes even fish. To hunt, a sun star moves along the seafloor on the tube feet that line its arms. When prey is within grasping distance, it raises its curled arms to catch it. If you're wondering how a sun star can hunt with missing arms, don't worry. They often start with as many as fifteen to twenty arms, and they can grow back any arms they lose.



The flapjack octopus uses small sucking discs to find food on the ocean floor.

Flapjack Octopus

This shape-shifting octopus is named for its appearance when it rests in the deep sea mud. Asleep, the webbing between its tentacles makes it look like an orange pancake! Yet when this creature floats through the underwater currents, it looks more like an umbrella with long, rabbit-like ears. (These are actually fins that help the octopus swim.) The scientists who discovered and named this octopus found it so charming that they considered giving it the species name *adorabilis*. But one should not be fooled by its cute appearance: the flapjack octopus is an excellent predator. Its tentacles are lined with small filaments, or tiny, threadlike arms, that help the octopus find food on the ocean floor. Flapjack octopuses catch small worms, crustaceans, and other invertebrates. They don't have as many defenses against predators, such as ink sacs or color-changing camouflage, as other octopuses do. But flapjack octopuses are quick swimmers, and their unique shape helps them steer themselves into undersea currents and sail away for an escape.

Sea Spider

Like a land spider, sea spiders have eight legs and a hard exoskeleton. But they don't spin underwater webs. Instead, they use a tube called a proboscis to suck out the insides of soft-bodied creatures. Sea spiders feed on worms, jellies, sponges, or softer corals. Sea spiders are eaten by crabs, other fish, rays, or sea stars. In many parts of the ocean, they're tiny. But near the North and South Poles, they can grow as large as cats.

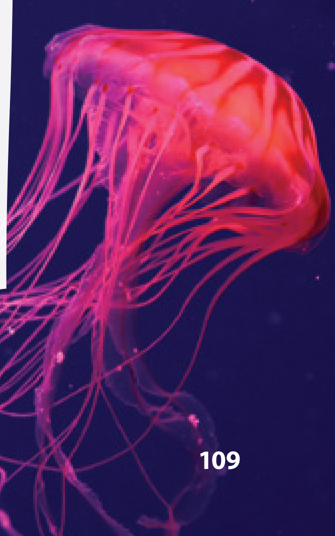
Sea spiders eat soft-bodied foods such as sponges and soft corals.

Whatever their size, all sea spiders carry some of their vital organs in their legs. They breathe through their legs, and they keep their intestines there, too. It would be difficult to play sports if a human were to do that.

Big Red Jellyfish

The name for this one explains itself: it's a big red jellyfish! Growing up to a meter wide (about the width of a doorway), this jelly floats in the dimness of the twilight zone. Many other jellyfish use their tentacles to sting their prey, but big red jellyfish do things a little differently. These jellyfish use the long, fleshy, arms that hang from their bells to hunt. (A jellyfish's bell is the large bowl-shaped part of its body.)Whether an individual big red jellyfish has as little as four arms or as many as seven, they're just the right amount to grab and capture its prey.

One of the most interesting things about the big red jellyfish is how recently scientists discovered it. Researchers from the Monterey Bay Aquarium first sighted the big red jellyfish in 1993, less than forty years ago. It makes one wonder: what other large organisms are out there to be discovered?



Organisms of the Open Ocean

The currents of the open ocean are ever changing, and many different organisms make this ecosystem their own. They range from fast-swimming predators to gentle drifters. Here are just a few of them.

Great White Shark

Great white sharks are ambush predators. This means they rush at prey as quickly as they can, biting to do as much damage to them as possible. Great white sharks hunt many different types of prey, including sea turtles, seals, sea lions, porpoises, and dolphins. Female sharks only give birth once every three years. These sharks are also migratory animals, as they swim routes from California to the Hawaiian islands, and South Africa to Australia. If sharks find themselves in colder waters (where much of their food likes to hang out), they use a process called thermoregulation to heat up their blood and keep themselves warm. Imagine being able to warm yourself up by heating your blood temperature!

Octopus

There are many species of octopus in the open ocean, all of which have a unique defense mechanism. When they feel threatened, they use

their ink sacs to expel black clouds of fluid that block a predator's vision. This buys an octopus time to escape. Their ink clouds aren't their only means of protection, however. For instance, scientists have observed one species, the veined octopus, using coconut shells from the seafloor as a form of armor.

Manta rays are able to make mental maps and recognize themselves in a mirror.

Octopuses of the open ocean have another unique trait in common: these cephalopods have three hearts. With three hearts working at once, an octopus has more energy to do things like hunt. Feeding at night, they use the hard beaks on the underside of their bodies to consume a variety of creatures, including clams, crabs, small fish, and sea stars.

Giant Manta Rays

Imagine holding your mouth open in an O shape to inhale as much food as you can. This is how a giant manta ray consumes zooplankton. The giant manta ray follows its prey on migration routes that change with the seasons. Their long wings reach up to 26 feet, which is about the length of a moving truck. They can feed from the surface of the ocean, but also dive into the thermocline, the area where the temperature starts to drop that makes up a large part of the twilight zone, in search of food.

Leatherback Sea Turtle

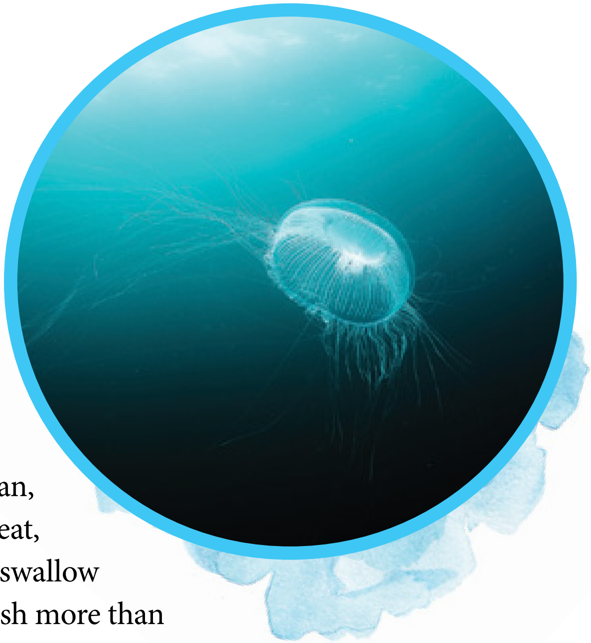
Not all marine animals in the coral reef are born in the water. The leatherback sea turtle, for instance, hatches from an egg on land. From the moment they hatch, sea turtles quickly **embark**, or set out, on a dangerous journey to the ocean water. They hurry across the sand, trying to avoid predators like sea birds and land animals.

What's more, female leatherback turtles swim thousands of miles to lay eggs, or nest, on the very beach where they were born. How do leatherbacks know how to return to this special place? By using GPS tags to track leatherback migrations, marine biologists have learned that leatherbacks can sense the Earth's natural magnetic field. They combine that "inner compass" with their strong memories to find their way back to their home beach.

Leatherbacks also use their amazing ability to navigate to take epic migrations many times a year in search of food like jellyfish and seagrass. You might call them born travelers.

Crystal Jelly

Crystal jellyfish are almost entirely see-through and have long, thin tentacles. Not only are they see-through but they are bioluminescent too, with lights that surround their bells to signal distress. These jellyfish spend their time drifting through the open ocean, stinging and catching what they can. To eat, the crystal jelly can expand its mouth to swallow other jellyfish! It can even swallow jellyfish more than half its size.



Crystal jellyfish grow to about ten inches in diameter.

Discovering Your Inner Marine Biologist

There are thousands more species in the open ocean and deep sea, far more than we can cover in one brief tour. In fact, based on how little of the ocean humans have explored so far, scientists calculate that we probably only know about 9 percent of the total number of species in the ocean. So little of the ocean has been explored, and there's plenty left to find.

As you read, study online, and learn more about the world, you'll encounter plenty of unusual ocean organisms. Fortunately, you now know some of the key tools marine biologists use to understand the ocean and the organisms in it. Whenever you're looking at a sea creature, ask: where does it live? What depth zone does it make its home in? Who does it eat, and who eats it? And what features does it have that help it hunt and survive? By asking yourself these questions, you can learn even more about one of our planet's biggest everyday mysteries.

Glossary

A

ability, ***n.*** the state of being able to do something

abiotic factors, ***n.*** characteristics of an ecosystem that are not connected to living things

absorbing, ***v.*** taking in

abyssal zone, ***n.*** the area of the ocean between 4000 and 6000 meters in depth

adaptation, ***n.*** a characteristic that adjusts to the environment or situation

affect, ***v.*** how something is impacted

agile, ***adj.*** the characteristic of moving with speed and grace

aquatic, ***adj.*** related to being in or on water

aquatic organism, ***n.*** a living thing whose habitat is in or around water

amphipod, ***n.*** a type of animal with a shell and flat body that lives in the water

B

biodegradable, ***n.*** the ability to break down over time in nature

bioluminescence, ***n.*** the ability for an organism to generate light

biotic factors, ***n.*** characteristics connected to living things

C

characteristics, ***n.*** traits or properties that describe something

chemosynthesis, ***n***. the act of using chemicals, instead of light, to make food

chemosynthetic bacteria, ***n***. bacteria that use chemicals, instead of light, to make their own food

clarity, 1.***n***. the characteristic of being clear or transparent, 2.***n***. the characteristic of being easily understood

clusters, ***n***. groups positioned close together, or clumps

conservation, ***n***. the protection of species and their environments

constant, ***adj***. occurring all the time

contradict, ***v***. to appear as the opposite

crevices, ***n***. narrow openings or cracks

D

detritus, *n.* loose or broken down natural material

detach, *v*. to remove

detritivore, *n*. an organism that feeds on dead matter

digest, *v*. to break down food inside the body

E

ecosystems, *n.* systems formed by the interaction of communities of organisms with their environments

effect, ***n***. the result of an affect, or impact

embark, ***v***. to begin

entangled, ***v***. became tangled or wrapped up; involved in something complicated

erosion, ***n***. process in nature where land is worn away by water running over it, again and again, over a period of time

estuary, ***n***. an area where salt water and fresh water meet

euphotic, ***adj***. relating to water with enough sunlight for photosynthesis

expedition, ***n***. a trip for the purpose of exploration

extinct, ***adj***. no longer living or existing

F

flourish, ***v***. to thrive or to experience health and growth

fluctuate, ***v***. to change back and forth

fluke, ***n***. wing-shaped part of a whale's tail

food web, ***n***. an interconnected system of food sources between producer, consumer, and decomposer organisms

foundations, ***n***. the bases of buildings

G

genus, *n.* a group that contains living organisms with common characteristics

gyre, ***n***. an area moving in a circular manner, such as those formed in the ocean by currents

H

hadal zone, *n.* trench areas of the ocean, located below the abyssal plain and between 6000 and 11000 meters in depth

hydrothermal vents, ***n***. cracks in the ocean floor that release hot water

hypoxia, ***n***. a lack of enough oxygen in the body

M

mangrove trees, *n.* types of trees or shrubs with roots that provide a place for underwater ecosystems

marine biologists, ***n***. people who study living organisms in the ocean

marine debris, ***n***. pieces of plastic that are found in the ocean

microbe, ***n***. an extremely small organism that can be seen under a microscope

microorganisms, ***n***. organisms that are too small to be seen without a microscope

microplastics, ***n***. extremely small bits of plastics

midnight zone, ***n***. the area of the ocean between 1000 and 4000 meters in depth

migration, ***n***. the act of traveling from one location to another

mollusks, ***n***. animals with soft bodies that live in shells

N

North Pacific Subtropical Convergence Zone, *n*. a gyre located in the northern Pacific Ocean

O

organisms, *n*. living structures made up of systems working together

P

particles, *n*. very small pieces of something

polyp, *n*. a soft growth

primary, *adj*. first in order or importance

Q

quaternary, *adj*. fourth in order or importance

R

regenerates, *v*. to return to a previous form

remote, *adj*. far away from civilization, isolated

S

Secchi disk, *n.* a flattened black and white circle put into water to measure the water's transparency

secondary, ***adj***. second in order or importance

specimens, ***n***. examples of something

symbiotic, ***adj***. having a close, cooperative relationship

sunlight zone, ***n***. the area of the ocean between the surface and 200 meters in depth

T

terrestrial organism, *n.* a living thing whose habitat is in or around land

tertiary, ***adj***. third in order or importance

toxins, ***n***. a substance that is poisonous to living things

trophic level, ***n***. a level of food web where all the organisms are the same level away from the primary producers

twilight zone, ***n***. the area of the ocean between 200 and 1000 meters in depth

U

unison, *adj.* at the same time

W

water scooter, *n.* a single-passenger, ride-on water vehicle

Z

zones, *n.* areas

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