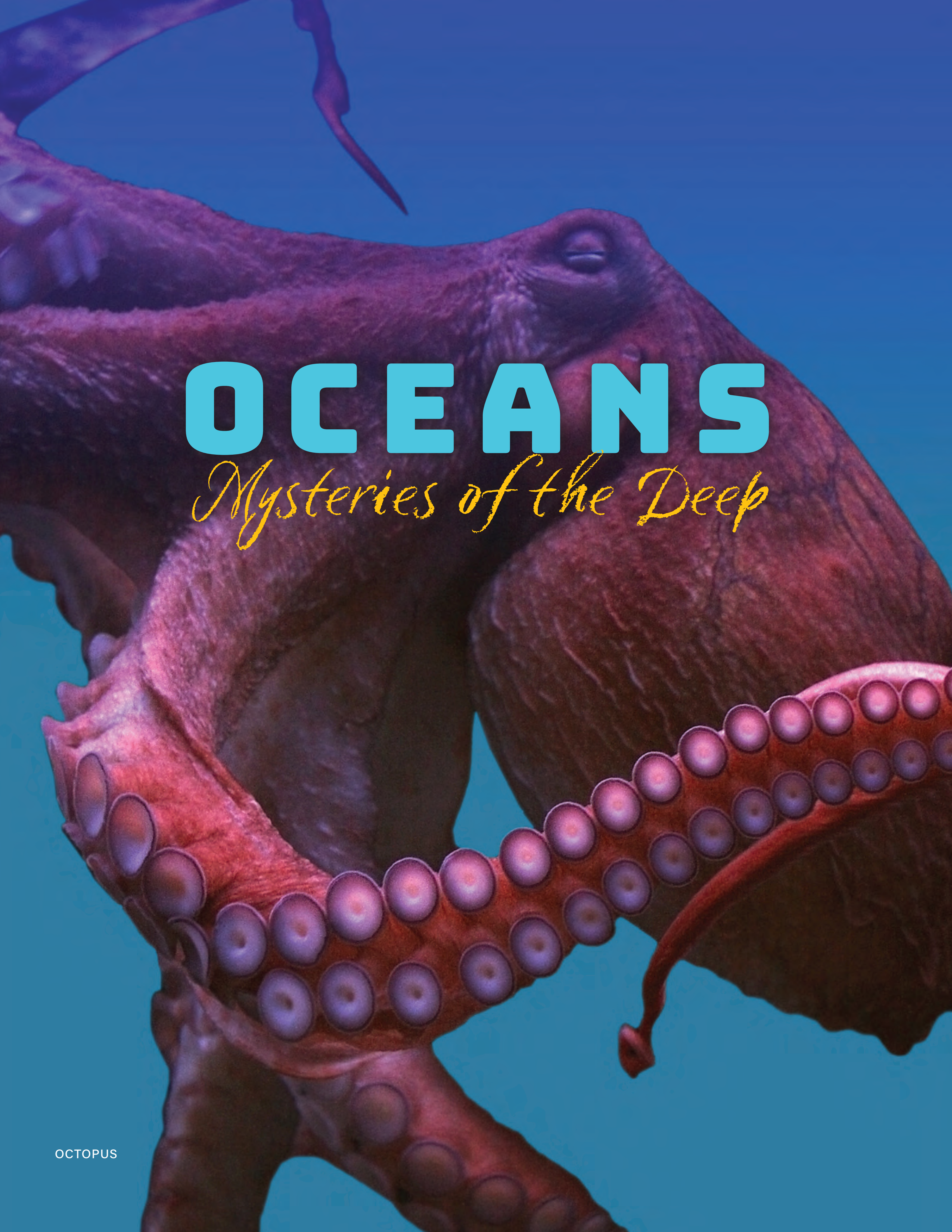

OCEANS

Mysteries of the Deep

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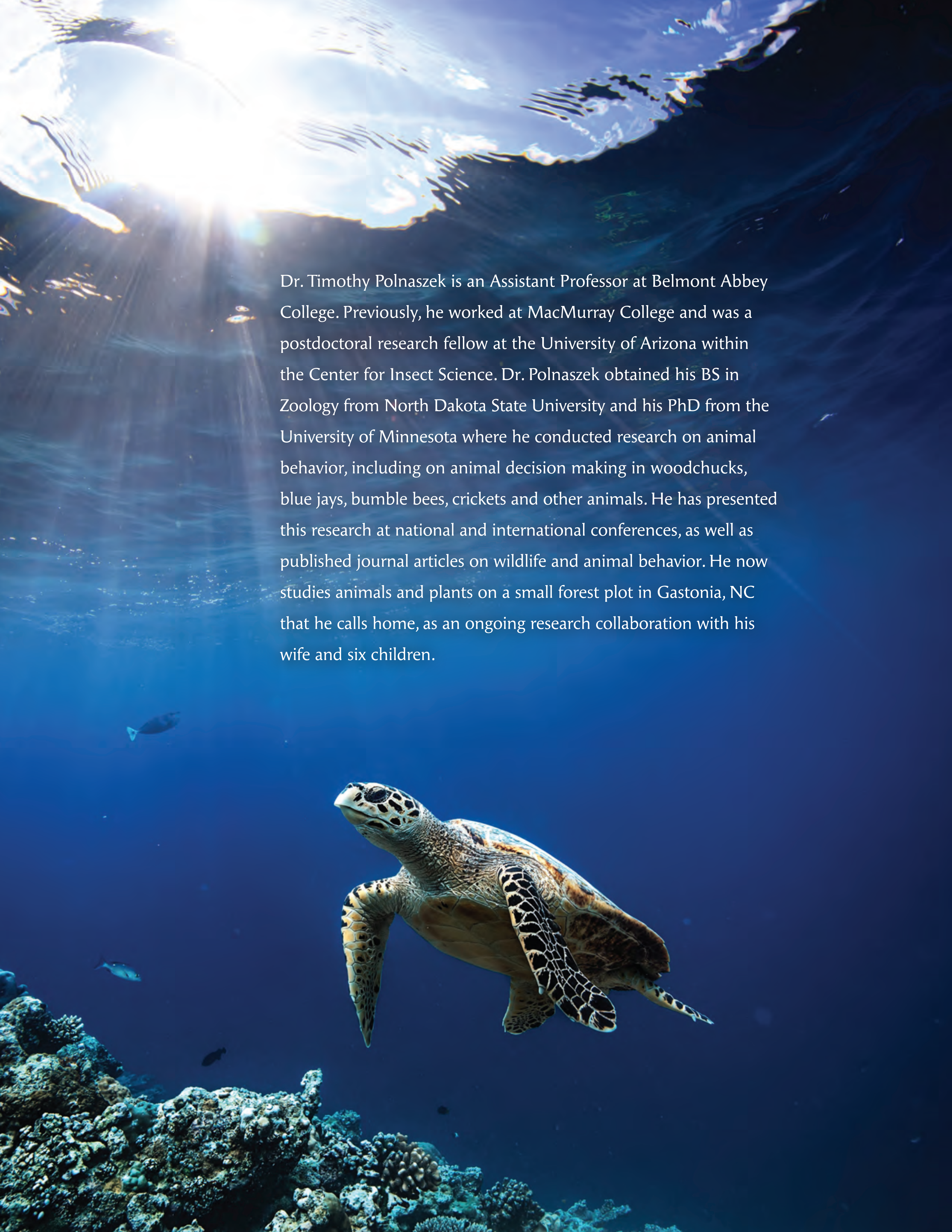

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The Foundations of Science

OCEANS

Mysteries of the Deep

Timothy Polnaszek, PhD

TAN Books
Gastonia, North Carolina

Cover & interior design and typesetting by www.davidferrisdesign.com

ISBN: 978-1-5051-1909-1

Published in the United States by
TAN Books
PO Box 269
Gastonia, NC 28053

www.TANBooks.com

Printed in the United States of America

"Where were you when I laid the foundation of the earth?"

–Job 38:4

OCEAN WAVES ROLLING ONTO SHORE

CONTENTS

PREFACE

When I think about the scientific study of the natural world, two phrases from the writing of Pope St. John Paul II come to mind:

(1) a rigorous pursuit of truth and

(2) a love of learning.

The first—a rigorous pursuit of truth—describes science and its processes. Scientists make careful observations, design experiments, and collect data to learn more about how the world works. Too often, though, science may seem like something you do in a big research facility with a lab coat.

But we are all scientists!

Anyone can study the living world in a scientific way. From an early age, everyone has a curiosity to understand the world. Think of a baby repeatedly dropping something onto the floor; they are discovering how gravity works! It is this basic curiosity that drives science.

The second piece—a love of learning—also describes what science should inspire. Sometimes science is depicted as a dry, boring set of facts, but nothing could be further from the truth. The world is a fascinating place. I have been interested in the natural world my whole life. This love of nature led me to obtain undergraduate and postgraduate degrees that have allowed me to teach biology classes every day for a living, and yet I am still constantly amazed by the wonders of our world.

A school of garden eels sway in the currents the way grass sways in the wind.

There is always something new to learn in all the natural sciences, so much inspiring beauty and wonder all around us. Life consistently exceeds my capacity to imagine it.

For example, did you know:

- leatherback sea turtles have been known to migrate as many as 10,000 miles between egg-laying sites and feeding grounds?
- garden eels get their name because they look almost like a garden of grass swaying in the currents as they look for food?
- ocean currents in the Northern Hemisphere flow in a clockwise direction, while in the Southern Hemisphere, they flow counterclockwise?

How could we not love learning about this fascinating world we inhabit?

Finally, it is too often assumed in our society today that faith and science act in opposition to one another, that somehow if we learn enough about the world, it would disprove the existence of God. But it is important for each of us to be confident in our Faith and the fact that truth cannot be in opposition with itself.

"[Science and faith] each can draw the other into a wider world, a world in which both can flourish."

–Pope St. John Paul II in *Physics, Philosophy and Theology*

We read in the *Catechism of the Catholic Church*: "Methodical research in all branches of knowledge, provided it is carried out in a truly scientific manner and does not override moral laws, can never conflict with the faith, because the things of the world and the things of faith derive from the same God. The humble and persevering investigator of the secrets of nature is being led, as it were, by the hand of God in spite of himself, for it is God, the conserver of all things, who made them what they are" (CCC 159).

Holy Mother Church teaches us that we can pursue scientific knowledge unafraid. It is my hope that *The Foundations of Science* series will not simply give your family some facts about the world but rather instill a curiosity and love of learning in you that you can apply across all the disciplines of your life, both scientific and otherwise.

Timothy Polnaszek, PhD

YOUNG SEA LION

LIONFISH

INTRODUCTION

Welcome to our ocean voyage, where together we will explore some of the vast oceans that cover our planet. I say *some* of our oceans because they cover more than 70 percent of the earth's surface and can be more than six miles deep! That's an enormous area, and it's filled with plants, algae, tiny plankton, and all sorts of wild and remarkable creatures.

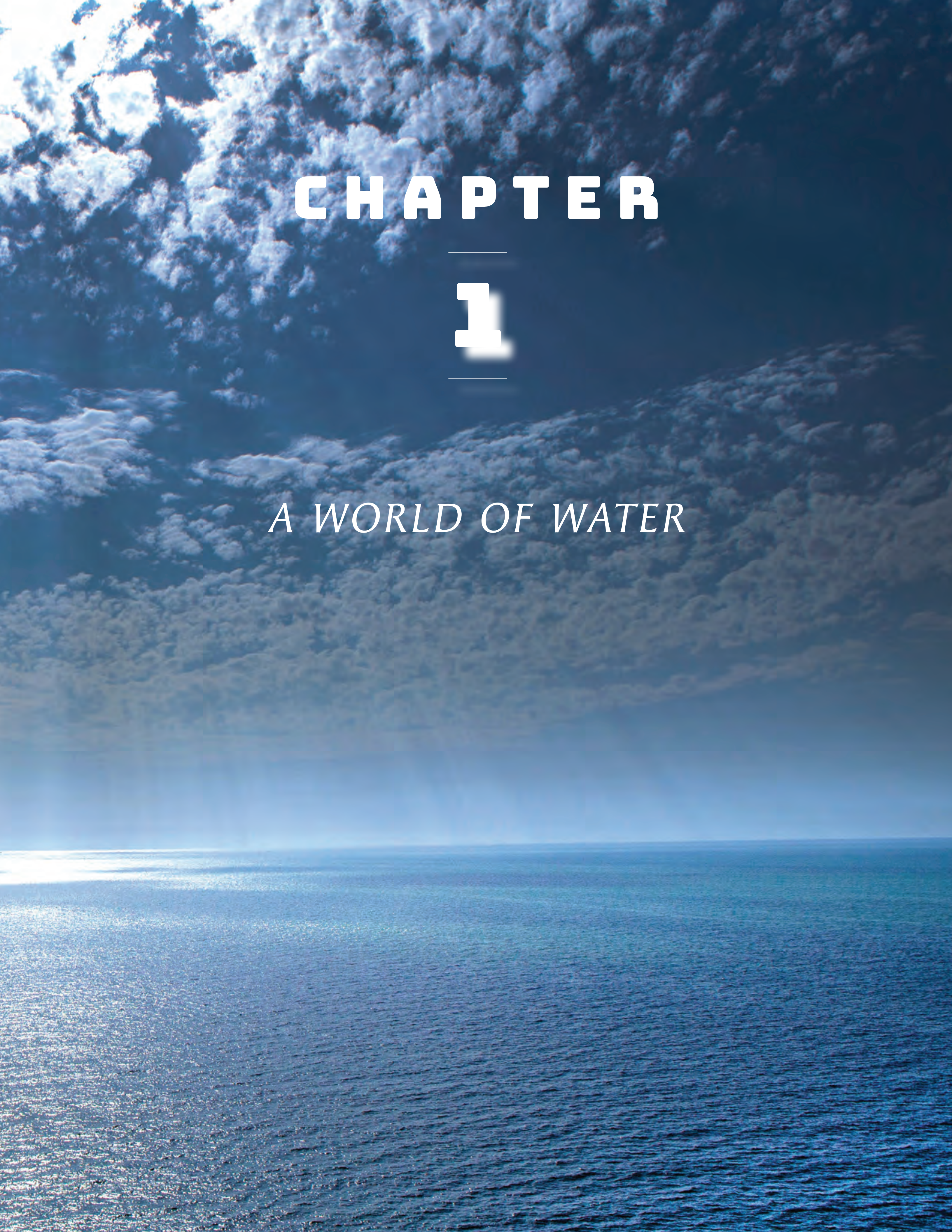
So there will always be more to learn (we are only now exploring some parts of our oceans!), but together we'll talk about various important topics regarding earth's oceans. The beginning of the book reviews some key features of water itself, and then we sneak in a little bit about freshwater. Then we'll embark on a tour of different parts of the ocean, discuss some of the physical factors in the oceans (temperature, pressure, etc.), and even talk about the history of ocean exploration. To close the book out, we'll take a quick look at how much we benefit from the ocean and how people can help protect it.

The oceans are truly remarkable—I even learned some amazing new things while writing this book! My hope is that you, too, will gain a new appreciation of the oceans and learn some things along the way.

Over 70 percent of the earth is covered in ocean water, most of which remains unexplored to this day.

CHAPTER 1

A WORLD OF WATER



WHAT IS WATER?

The best place to start a book about the oceans is to talk about water, since over 70 percent of the earth's surface is covered by water (oceans, lakes, ice, etc.). Almost all of that water is held in the oceans, or just under 97 percent. This book is (mostly) about the water-filled oceans that dominate the surface of the earth, but we will also take a quick look at other aquatic habitats along the way. In this chapter, we will take a closer look at water itself, review some facts about the water cycle, and then begin to explore the places we find water on the earth.

Oceans Fun Fact:
Just under 97 percent of the earth's water is contained in the oceans. The rest is found in lakes, rivers, and ice.

We all know water is wet, right? And we know that plants and animals (including us!) need water to live. But there are also some fascinating, and less obvious, aspects of water that make it an important part of the world around us.

Technically speaking, **water** is a compound made up of several atoms. In a chemistry book, we would explore atoms and molecules in more depth, but here we can just say that **atoms** are the small building blocks of all of the matter ("physical stuff") we see around us (tables, balls, dogs, grass, this book you are holding, etc.). When atoms bond together, they form molecules. Water is specifically and exactly one **oxygen** atom bonded to two **hydrogen** atoms. This is where we get the chemical formula for water H_20: two hydrogens (H_2) and one oxygen (O). The chemical nature of water gives it several special properties that are important to the natural world around us, which we will look at in the next few paragraphs.

The First Special Property of Water: Cohesiveness

First, water is **cohesive**, which means that water molecules stick to each other. Each water molecule has a slight attraction to other water molecules. This is what creates surface tension. If you had two drops of water on your kitchen counter, very near to each other, and something happens to make the two drops touch, they will "pull" towards each other, joining together to create one larger drop. Here's another image: if you very slowly fill a glass of water, it can fill up past the top of the glass so that there is a small dome of water above

the top of the glass. This is because the water molecules stick together, which prevents them from spilling over the side. Eventually, if you keep pouring water in, the weight of the water would be too much and the water would spill out, but for a time, the water can actually "stick together" enough to keep it from spilling over.

The Second Special Property of Water: Adhesiveness

Another feature of water is **adhesiveness**. This means that water molecules also tend to stick to other things (other molecules besides water). This is why if you were to spread some water onto your arm, much of it will stick to you rather than all of it running off onto the floor.

Water has both cohesiveness and adhesiveness because of its chemical makeup. Remember, water is made up of one oxygen atom and two hydrogen atoms. The oxygen has a slight negative charge, and the hydrogen atoms have slight positive charges. These positive and negative charges are attracted to their opposite—like magnets, opposites attract.

But how can these small forces between molecules be important in nature? Well, we all know plants are important, right? They serve as the base of the food chain, feeding us and animals (and feeding the animals that we eat), and they give us oxygen through photosynthesis. The adhesive property of water helps plants stay alive, especially the tallest trees, because it allows them to bring water up into their topmost tissues against the force of gravity. If the water molecules didn't stick together, the water would not be able to travel up the plant. Another example of how helpful this quality is in nature involves small insects like water striders and other organisms, who can "skate" across the water surface because of the surface tension formed by the cohesion of water molecules.

These organisms, with their unique way of getting around, wouldn't be able to survive without surface tension (and even the smallest creatures can have important roles to play in the ecosystem).

The Third Special Property of Water: Solid Water (Ice) Is Less Dense

Another important feature of water is that solid water is less dense than liquid water. Solid water? Yes, that's **ice**! So what does this mean? **Density** is how tightly molecules are packed together. We used this analogy in another textbook, but let's use it again: a suitcase with three T-shirts tucked in it is less dense than one with thirty packed in it. Water molecules in ice are packed together less closely. This means that the same number of molecules of water would take up *more space* if they are frozen because, in a sense, they are spread further apart. You could demonstrate this at home—water in an ice tray or in a soda-pop can expands when it freezes (sometimes with explosive and messy results in the freezer!).

I wonder if what you just learned is the opposite of what you would expect? If you saw a glass of water and a block of ice, you might think the ice has its molecules packed closer together since it is solid. But the opposite is true. Having low density as a solid is a special feature of water because, generally speaking, matter has *higher* density when it's solid.

But why would this be important or relevant to life on earth? Consider this: as a lake or pond freezes in the winter, ice forms at the top of the body of water. This happens because ice is less dense than water, which makes it float. (Things that float go to the top, right? Think of the ice cubes in your drink that float to the top.) This would explain why icebergs float, because solid ice is less dense. If ice formed at the bottom of the lake first, it would be harder for plants

Since solid water is less dense than liquid water, ice will float on the surface, like this hunk of glacier found in Greenland.

and animals to live in aquatic environments. For example, plants growing along the bottom of lakes (which some fish might eat) would need to be able to survive in freezing cold ice.

The Fourth Special Property of Water: High Heat Capacity

Another special property of water is its high **heat capacity**; this means that it heats up and cools down slowly (and takes a lot of energy to heat up). The heat capacity of water is part of the reason why coastal areas have less variation in temperature year-round, or throughout the day, meaning towns near the beach tend to have steadier temperatures than those that are more inland. The ocean changes temperature less than land across the year, which means it's cooler than the land in summer (the land heats faster) and the ocean is warmer in winter (the land cools faster). The relatively cooler ocean water has a cooling effect on the land in summer, and heat from the ocean keeps coastal areas warmer in winter, overall keeping temperature more stable.

The Fifth Special Property of Water: A Good Solvent

One last special property of water is that it is a good solvent; this means substances tend to dissolve easily into water. A **solution** is a liquid mixture made of solute and solvent. *Solutes* are the things dissolved into *solvents*; so if you make a solution of Kool-Aid, the sugar is a solute and the water is the solvent. This quality is what makes water good at cleaning things, because the dirty things we want to get off our bodies, clothes, and dishes dissolve into the water we clean them with.

We might ask why this is important in nature. Well, because there is a lot more out in nature that is more important than Kool-Aid. All sorts of biologically important solvents (organic material, nutrients) dissolve into water and can be moved around in the water cycle. For example, many nutrients are carried by streams, eventually reaching the ocean. Relevant to our book topic, salts also dissolve in water, making the ocean salty.

Isn't water fascinating? Next, we'll quickly review some of the ways that water travels around the world.

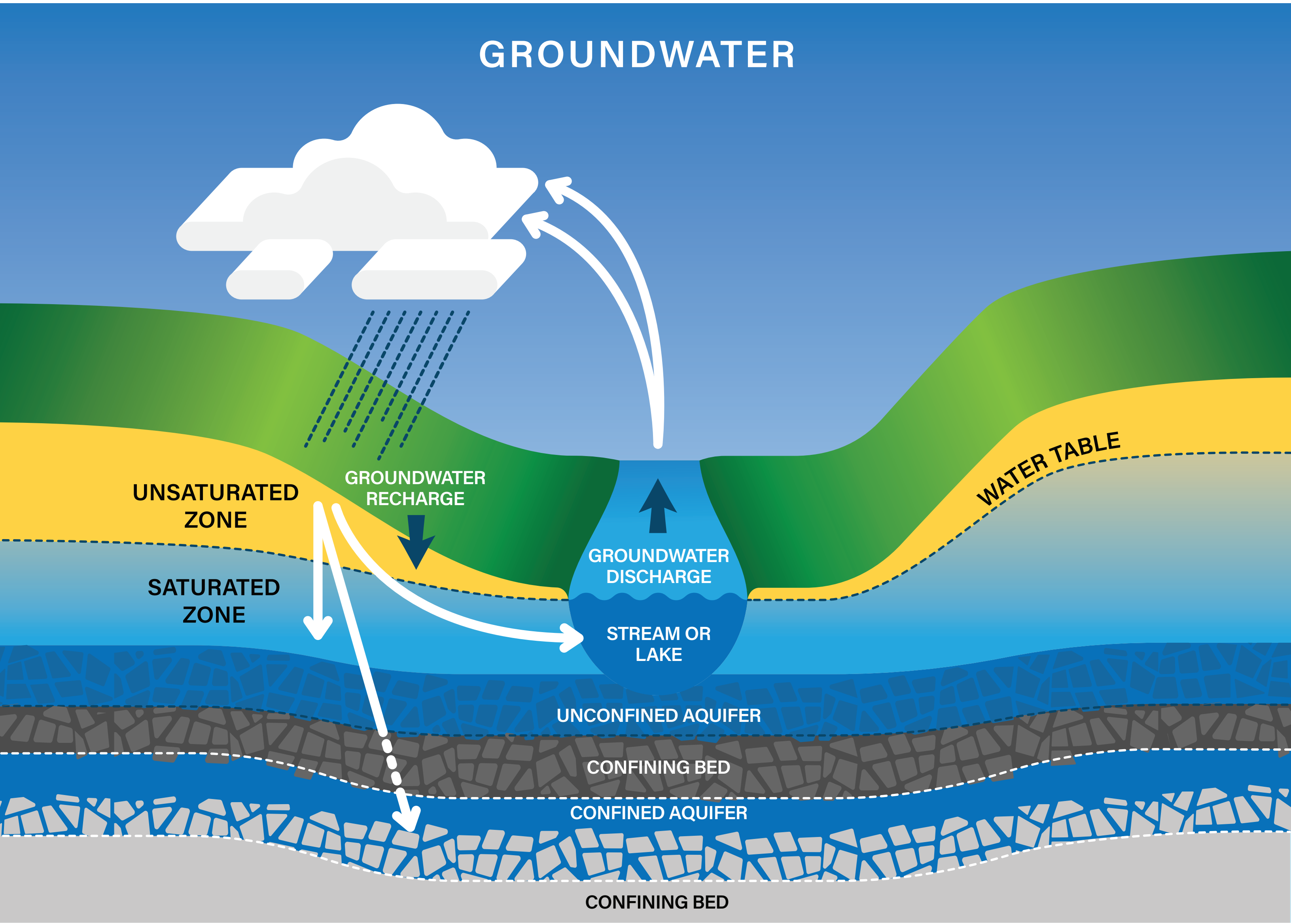
Temperature Ranges Near Water and Inland

The difference in temperature variation may be easiest to see through examples. In Miami, on the coast of Florida, the average temperature in January is 74 degrees and the average in July is 87, a difference of only 13 degrees from the coldest to the warmest month. But in Lebanon, Kansas, the middle of the North American continent, very far from any ocean, the average January temperature is 34 degrees and the average July temperature is 89—a difference of 59 degrees! Even if we pick a place in the center of Florida to compare, say Gainesville, it still has a January-July difference of 24 degrees on average, almost double the coastal city of Miami. This helps demonstrate the high heat capacity of water. Think of it this way: the ocean near Miami *slows down the speed* at which the temperature rises and falls so that it doesn't move very much.

THE WATER CYCLE

If you've read through our *Earth* textbook, you know all about the water cycle. But because this chapter focuses on water, and because the water cycle will be important in this book, we will revisit this topic here.

The transition of water between its three forms (gas=water vapor, liquid=water, solid=ice) are given specific names. **Evaporation** is when, heated by the energy of the sun, water "moves," or becomes a gas (water vapor), from a body of water into the atmosphere (and **transpiration** is a related process where liquid water from plants enters into the atmosphere through evaporation). Water can then also condense (**condensation**) from vapor back into liquid droplets, which is how rain forms. Rain falling onto the earth returns the water into lakes, streams, and oceans. In this way, water can cycle through different bodies of water on earth: up into the atmosphere through evaporation and back down via rain after condensation.



Water can also move without changing form. This is obvious whenever we look at a rushing river, which is carrying billions of water molecules downstream and eventually to the ocean. Water also travels across land through runoff or in groundwater. **Runoff** is when water runs across the surface of the ground, picking up dirt, debris, and chemicals along the way. Water is also found under the ground, held in the soil, gaps in rocks, and in **aquifers** (an underground pocket of rock that can hold water). If you dig deep enough in most places, you'll find a point where the ground is saturated with water, aptly named the **saturated zone**. The location of this saturated zone, or how far down you need to dig to reach it, is the **water table**. When it rains, this water table gets closer to the surface as the ground fills with water, similar to how you could fill an empty pool up with a hose and watch the water level rise. Water can move through these underground spaces and eventually make it to lakes and streams.

From this review of the water cycle, we can see that the places water is held on earth are all connected—water moves from place to place and in different forms. This becomes important when discussing the aquatic habitats on earth because it shows how pollution could travel with water from habitat to habitat, affecting the plants and animals in each place. As we continue this book, we will explore the remarkable aquatic habitats formed by lakes, streams, estuaries, and yes, oceans!

With our discussion of water complete, let's move now to discuss some of the freshwater ecosystems found on planet earth.

FOUNDATIONS REVIEW

- ✓ Our world is one dominated by water. Water covers 70 percent of the earth's surface, with 97 percent of it being contained in the oceans.
- ✓ Technically speaking, water is a compound. It is made up of one oxygen atom and two hydrogen atoms (H_20). The physical components of water give it several unique features, including that it is cohesive and adhesive (it bonds to itself and to other things), that it is less dense when it is a solid (ice), and that it has a high heat capacity (it takes a long time for it to heat up or cool down). All these features of water have effects on our environment. For example, the adhesiveness of water makes it possible for plants to move water up into its higher regions, and water's high heat capacity affects temperatures in coastal regions.

- ✓ One important aspect of water on earth is the water cycle, which refers to the ways in which water moves throughout the environment. This can be through evaporation and condensation, and through rivers and runoff and other aquatic habitats. Plants and animals alike depend on the water cycle for survival (including us!).

Water: A Physical and Spiritual Gift

Here in our first chapter, we heard about some unique properties of water, which make water important to many features of our natural world. This importance of water is only amplified by the fact that organisms (plants, animals, fungi, and more) need water to survive. Even aquatic organisms rely on water, though maybe in a slightly different way. Fish take in water through their gills, or some even drink water. Animals in the water do not need to seek out water to quench their thirst since they swim in an abundance of it all the time. But the water does provide their habitat, and they "breathe" oxygen from the water (fish do this through gills), sort of like how we breathe in oxygen from the air surrounding us.

Most of this book, though, is specifically about oceans, which has many important features and provides many services to us and to ecosystems. As you probably know if you have gone swimming in the ocean, drinking water (for us) is not one of the ways the ocean helps us. Oceans contain salt water, and most organisms require freshwater to live, including humans. Even saltwater fish need to filter out the salts from the water they drink to survive. Since we, and many other organisms,

rely on freshwater to live, it is important to conserve freshwater in lakes and streams. Most of the water on earth is salt water, so we don't want chemicals or pollutants ruining what water we have.

Our reliance on water *physically* also helps explain why it is used by the Catholic Church and by Jesus to symbolically describe spiritual things. We feel thirsty when we haven't had enough water or are dehydrated from a long day of running outside. Jesus explains to the Samaritan woman at the well that he is the "living water" (Jn 4:10) that will allow us to never thirst again. This means he will quench our "thirst"—by that, we mean our longing for God to be in our lives and our natural desire for goodness, holiness, and justice.

As we learned in chapter 1, water also has an important property of being a good solvent (things dissolve in it easily), which makes it good at cleaning and washing. We use water to wash ourselves, laundry, dishes, and many other things. This should remind us of the sacrament of Baptism, the first sacrament we receive, which washes the stain of original sin, not symbolically, but actually, from our souls and adopts us into God's family.