ECOSYSTEMS & SPECIES

The Web of Nature

ROE DEER PEERING ABOVE THICK VEGETATION

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

–Job 38:4

GREEN SEA TURTLE

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PREFACE

When I think about the scientific study of the natural world, two phrases from the writings 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 people do in a big research facility while wearing lab coats.

But we are all scientists!

Anyone can study the living world in a scientific way. From an early age, each of us has a curiosity to understand the world. Think of babies 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.

There is always something new to learn in biology and all the natural sciences. Within biology, there is so much inspiring beauty in the endless forms continually evolving and unfolding. Life on Earth consistently exceeds the capacity of my imagination.

For example, did you know:

WOOD FROGS

- Like animals, plants can "sweat"? They release water through small pores in the leaf tissue called stomata, and the evaporation of this water cools the plant during periods of high temperatures.
- Wood frogs live throughout Canada and Alaska because they can survive even frozen solid in winter (like a frog Popsicle) and simply thaw out in warmer months?
- In addition to camouflage or disruptive coloration, organisms also use mimesis to look like something uninteresting or non-threatening, like a leaf or twig, or mimicry to look like something dangerous—like caterpillars that have eyespots to resemble a snake?

How could we not help but love to learn about this fascinating world we inhabit?

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

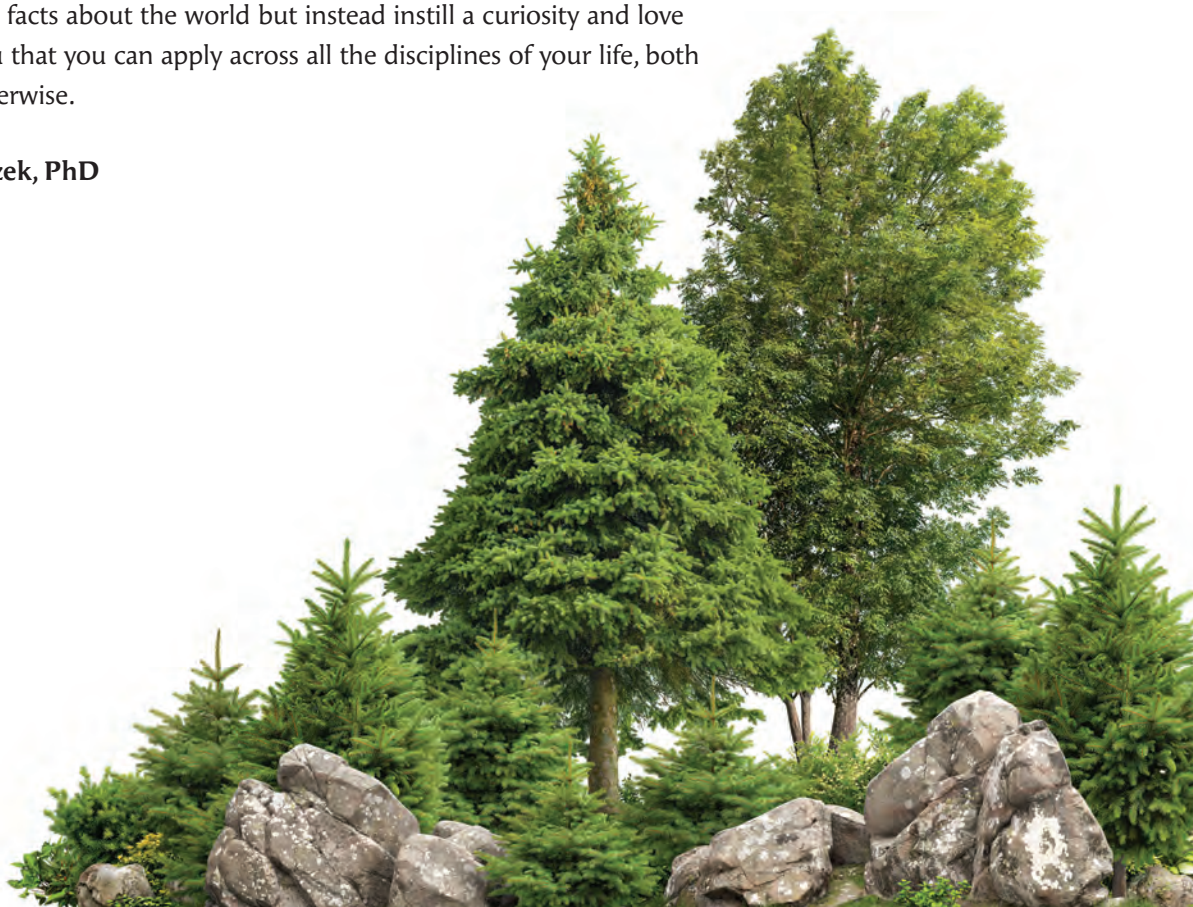
–Pope St. John Paul II in *Physics, Philosophy and Theology*

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

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 instead 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



EUROPEAN BEE-EATER

INTRODUCTION

> *"Praise the Lord from the earth,*
> *you sea monsters and all deeps,*
> *fire and hail, snow and frost,*
> *stormy wind fulfilling his command!*
> *Mountains and all hills,*
> *fruit trees and all cedars!*
> *Beasts and all cattle,*
> *creeping things and flying birds!*
> *Kings of the earth and all peoples,*
> *princes and all rulers of the earth!*
> *Young men and maidens together,*
> *old men and children!*
> *Let them praise the name of the Lord,*
> *for his name alone is exalted;*
> *his glory is above earth and heaven."*
>
> –Psalm 148:7–13

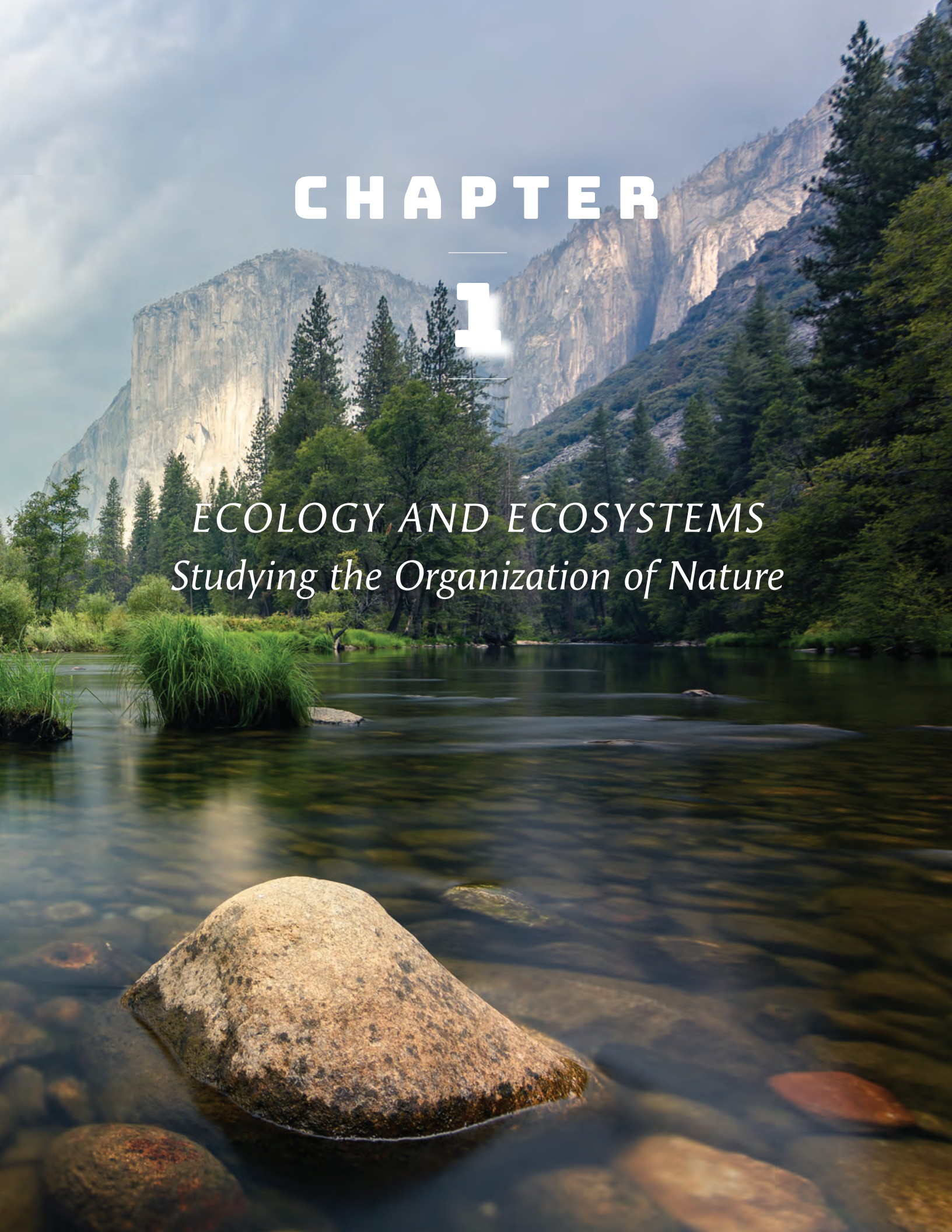
In this psalm, we hear about all of nature praising God. Saint Augustine discusses this passage by telling us that the beauty of creation is like a voice that sings out to confess God's greatness, but that nature *finds its voice through us*. The very beauty of all these things is like a voice that they raise to confess God. The sky cries to God, "You made me, I did not make myself." The earth cries out, "You founded me, I did not establish myself." How do these things cry out in worship? Whenever men and women observe them and discover the truth of them, all creatures cry out through people's appreciation of them; they shout with our voices.

So, when we gaze with wonder upon nature's beauty and through that wonder seek to understand it and discover the hidden truths buried out in the wild (that is, by being scientists!), we give glory to God. All creatures cry out with joy to their Creator when we marvel at them and appreciate them. They join their voices to ours in praise!

Learning about nature and how natural systems operate also provides us with the knowledge we need to better harness and safeguard the benefits the natural world provides us with (food, water, natural resources, beautiful places to appreciate, and so much more!). In other words, we can be better stewards of creation the better we understand it.

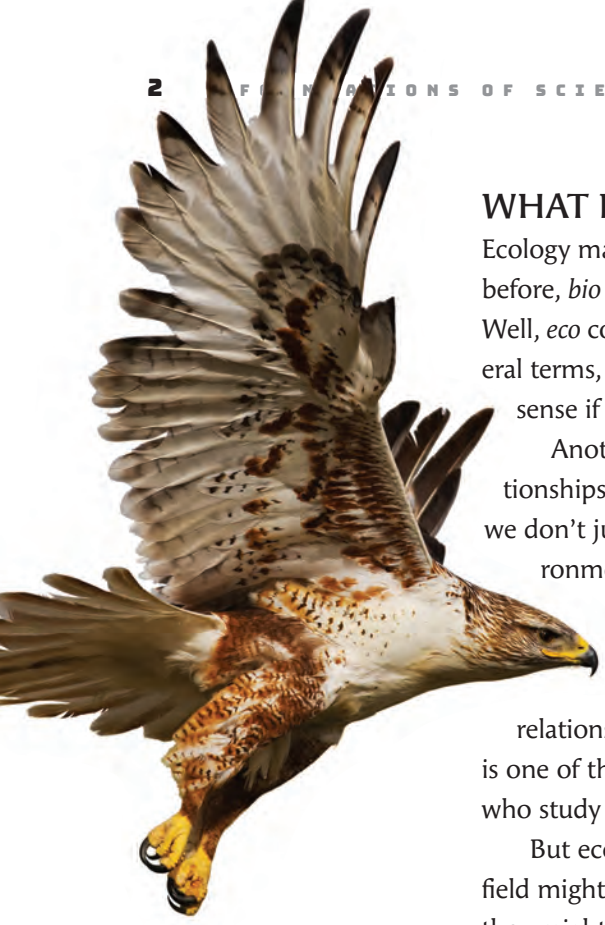
This book is filled with information about ecosystems—animals, plants, their relationships with one another, communities of organisms, the environment, the balance of nature, and more! As we will see, ecology is a field of biology that studies all of these things. It studies the physical environment and how animals and plants live within it. I hope this book generates a renewed interest in the natural world in you and your family, and that as you learn more about ecosystems you are filled with wonder and awe at God's creation, for in doing so, our wonder and awe brings greater glory to God!

Yosemite Valley in California is one of many awe-inspiring landscapes found all over earth. Beneath the surface of this beauty lies an intricate balance that supports a complex web of life.



CHAPTER 1

ECOLOGY AND ECOSYSTEMS
Studying the Organization of Nature



Hawks are just one of many birds of prey that influence the population of rodents in a given ecosystem as they hunt and capture them for a nice meal.

WHAT IS ECOLOGY?

Ecology may be a less familiar term than, say, biology. As you may have heard before, *bio* means "life," so biology is the study of life. What then is ecology? Well, *eco* comes from the Greek word *oikos*, which means "household." In literal terms, then, **ecology** is the study of the home or household—which makes sense if we consider our home to mean our planet—Earth.

Another definition for ecology is the study of living things and their relationships with their surrounding environment. But when studying ecology, we don't just explore organisms and how they relate to the physical environment (things like temperature or rainfall), but also their *relationships to one another*. You may have heard the terms "food chain" and "food web" to describe which organisms eat other organisms. For example, hawks eat mice, which in turn eat seeds and grasses. This relationship between an individual predator (a hawk) and its prey (a mouse) is one of those relationships that would be of interest to **ecologists** (scientists who study ecology).

But ecologists would also consider how the number of mice living in a field might change if there were an increase (or decrease) in hawks nearby. Or they might consider how runoff from fertilizer could increase the food available to mice, which could then increase the number of mice. These are only two examples of the questions ecologists might ask, and that's only when thinking about hawks and mice and seeds. Obviously, there are many more questions when considering all of nature and the links between the many organisms.

One last way to describe ecology is to say that ecologists are interested in the "interconnectedness" of life on Earth. When we look at the natural world, we see a system of interdependent parts. In the previous example, the number of mice depends on the number of hawks, but also on the number of seeds. In turn, the number of seeds produced by plants would depend on the temperature and rainfall in the local area. This interconnectedness can make it difficult to study ecology because whatever part of nature you're interested in may depend on many hundreds of other factors. Ecologists tend to define different levels of organization to help with this problem. Let's take a look at some of these.

NATURE'S LEVELS OF ORGANIZATION

Individuals: Ecologists might study individual organisms—their behavior, physiology, lifespan, food, natural predators, diseases, and more. Topics would include how individuals respond to other living organisms or to their environment (temperature, moisture, light, chemicals, etc.). For example, we could ask how well a blue jay remembers where it buried acorns. Or, how does increasing average temperature affect the lifespan of a pika?

Populations: You've probably heard this word before. Population can refer to how many people live in a given city or town. For our purposes in ecology,

population is a group of individuals of the same species within a given area. Some ecologists study populations and how they change over time—this could mean **population dynamics** (is the population increasing or decreasing in number) or the adaptation of a population to its environment. For example, we could ask how annual rainfall affects the number of mosquitoes in an area. Or, how does this population of crickets change when a new type of predator moves into the area?

Species: Each distinct type of organism is called a **species.** There may be multiple populations of the same species spread out across a continent. A good example is white-tailed deer. They live across North America, from Canada to Mexico. We probably wouldn't say that a deer in Canada is in the same *population* as one in Mexico. But both deer living in Canada and those that live in Mexico are part of the same species. Rather than asking questions about a particular population, scientists might be interested in the whole species.

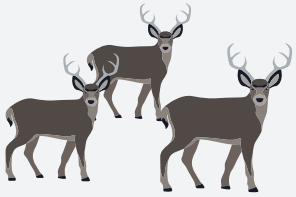
Each species has its own two-part scientific name: the first part is the genus and the second is the species. For white-tailed deer, this is *Odocoileus virginianus*. The mule deer is in the same genus—*Odocoileus*—but is a different species—*Odocoileus hemionus*. Some species have interesting names, including one jumping spider—*Indomarengo chavarapater*—named after St. Kuriakose Elias Chavara from India! When writing out these names, we use italics and capitalize the genus name, but not the species name. Throughout this book, we'll add in the scientific names of some of the animals and plants so that we become more familiar with this naming system.

This white-tailed deer buck (left) and mule deer buck (right) are of the same genus but are different species.

Community: Now that we have a definition of both population and species, we can look at communities. A **community** is the collection of populations of various species that interact with one another in a particular area. So the community in my backyard would include various bird species, squirrels, chipmunks, and mice that all interact to compete for seeds at or near my family's birdfeeder. We could study which species eats the most seed, and how that might change depending on what type of seeds we put out, how many seeds, or where we put them in the yard (i.e., on the ground versus in a tree).

LEVELS OF ORGANIZATION IN ECOLOGY

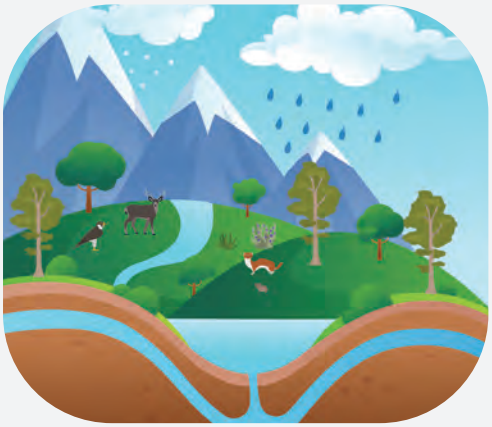
INDIVIDUAL



POPULATION/SPECIES

COMMUNITY

ECOSYSTEM



BIOME

BIOSPHERE

The community in my backyard would also include trees and other plants growing there, and hawks and owls that might prey on the seedeaters.

Ecosystem: In our definition of communities, there was no mention of the abiotic factors that affect living things. **Abiotic** means non-living (the prefix "a" means "non" and bio = life, so abiotic = non-living). An **ecosystem** involves the biological communities living in an area and how these communities (with all their populations of organisms) are affected by abiotic factors and the physical environment. So as we scale up in organization and levels of study, the ecosystem includes abiotic factors such as average temperature or rainfall or the amount of nutrients in the soil.

Biome: **Biomes** are particular types of ecosystems found in particular geographic regions. These biomes are defined, in large part, by average temperature and rainfall in the area. Examples of biomes include tropical rainforest, savanna, desert, and tundra. Each biome type has defining characteristics which all of the biomes of that type share. For example, the tropical rainforest ecosystems across the globe are not identical, but they all share similarities with one another (lots of rainfall and high temperatures year-round). Similarly, different species live in each rainforest, but each species would have specialized traits or adaptations that allow them to thrive in this biome.

Biosphere: The entirety of all the ecosystems on Earth form our planetary ecosystem, or **biosphere.** A forest in northern Minnesota or in Canada is quite far away from a rainforest in Indonesia or a desert in South Africa, such that these places seem unconnected. But there are ecological processes which we can study even at a global scale. Ecological relationships between living organisms and the abiotic environment affect the movement of water, nutrients

Clockwise from the top left we discover four extremely different examples of biomes that make up our biosphere: a river cutting through a gorge in the Wadi Mujib Biosphere Reserve, a tropical jungle in Costa Rica, the busy metropolis of Bangkok, Thailand, and a winter landscape in the Austrian Alps.

(like nitrogen or phosphorus), energy, and other factors. These interactions that occur at a local level can add up to effects at a global scale. For example, plants all over the planet, in each type of biome, help us by producing oxygen and absorbing carbon dioxide from the atmosphere.

THOSE WHO STUDY ECOLOGY

As we mentioned before, ecologists are those scientists who study ecology. These men and women may specialize on a particular level we just discussed or they may study questions that span multiple levels. Ecology is also a very interdisciplinary science, which means that many fields of science are important in helping us understand the relationships between organisms and the environment and ecological processes. Examples include physical sciences such as chemistry, meteorology, and atmospheric sciences, and biological sciences like physiology, genetics, and animal behavior. The scale of study for ecological research could also range from the microscopic (how microorganisms interact in a small scoop of soil) to global (how plant life in our forests affects the atmosphere on Earth).

In this book, we will explore these levels of organization in a little more detail. Understanding each level of nature's "system" can help us better understand the whole. We'll learn a lot along the way, but more importantly, I think we'll have a lot of fun on this adventure!

FOUNDATIONS REVIEW

- ✓ Ecology is the study of living things and their relationship with their surrounding environment. When studying ecology, we don't just mean organisms and how they relate to the physical environment (things like temperature or rainfall), but also their relationships to one another.
- ✓ The interconnectedness we see in nature can make it difficult to study ecology because whatever part of nature you're interested in may depend on many hundreds of other factors. Ecologists tend to define different levels of organization to help with this problem. These levels include: Individuals, Populations, Species, Communities, Ecosystems, Biomes, and Biospheres.
- ✓ Ecologists are scientists who study ecology. These men and women may specialize on a particular level or they may study questions that span multiple levels.

Ecology and Stewardship

In this book on ecology and ecosystems, we will see how God's creation is a dynamic, interconnected system, like how food webs rely on the connections between organisms, or how predators keep prey populations in balance. There are also times when this balance is thrown off, for example when invasive species invade a new community. As stewards of creation, and as scientists, we all can study ecosystems to better understand how to protect their beauty and biodiversity.

Several recent popes have highlighted this in their writings and teachings. Pope Benedict XVI once said, "The created world, structured in an intelligent way by God, is entrusted to our responsibility and though we are able to analyze it and transform it we cannot consider ourselves creation's absolute master. We are called, rather, to exercise responsible stewardship of creation, in order to protect it, to enjoy its fruits, and to cultivate it, finding the resources necessary for every one to live with dignity" (General Audience August 26, 2009).

In the encyclical *Centesimus Annus*, Pope Saint John Paul II discusses how natural systems have order, organization, and proper functioning (or that nature works in a balance). Finally, the USCCB tells us, "We show our respect for the Creator by our stewardship of creation. Care for the earth is not just an Earth Day slogan, it is a requirement of our faith. We are called to protect people and the planet, living our faith in relationship with all of God's creation." By working with the environment and respecting God's creation, we can grow closer to Him and better care for our brothers and sisters.

Pope Saint John Paul II designated Saint Francis of Assisi as the patron saint for ecology and ecologists—so we can ask for his intercession as you read through this book and learn more about these topics!