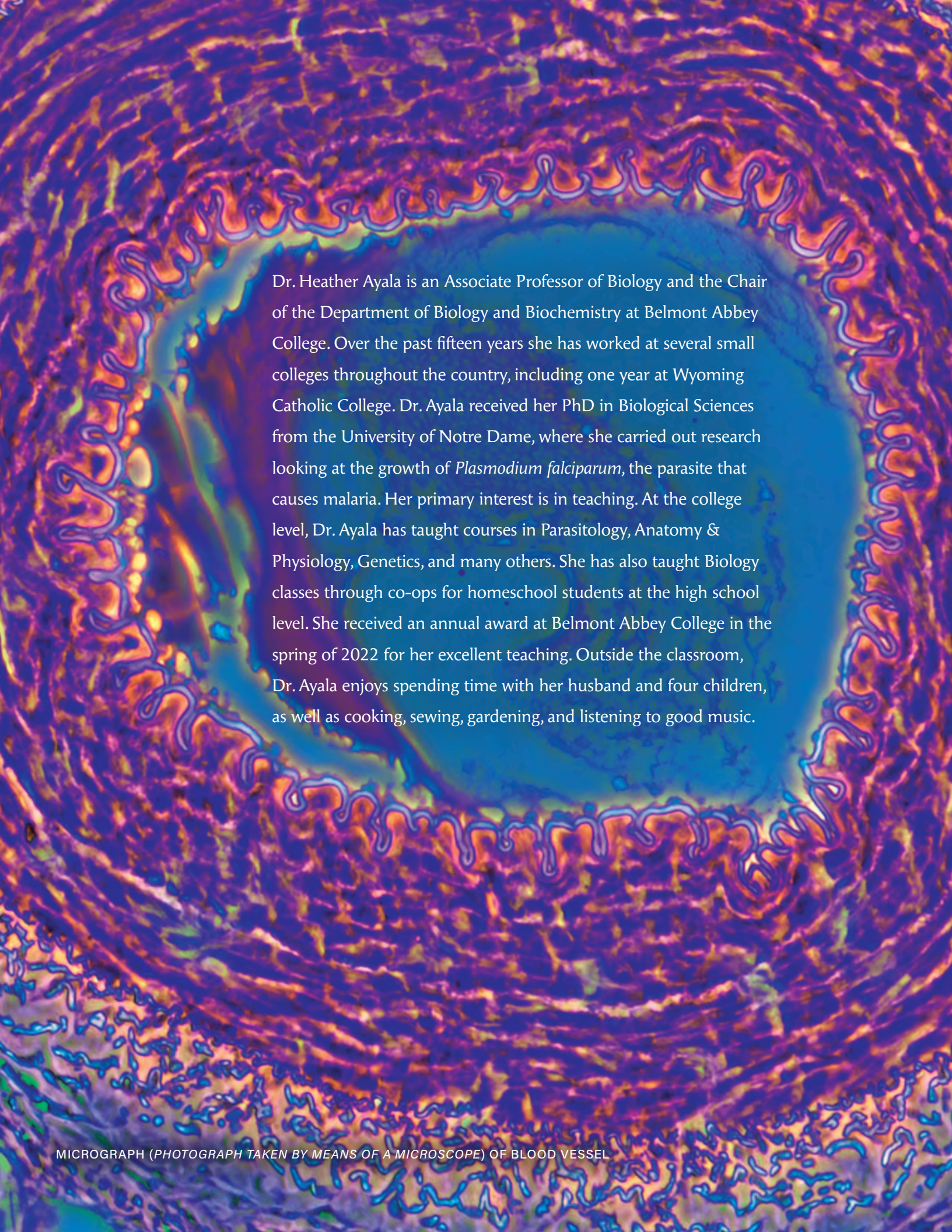
CELLS & SYSTEMS

Living Machines



Dr. Heather Ayala is an Associate Professor of Biology and the Chair of the Department of Biology and Biochemistry at Belmont Abbey College. Over the past fifteen years she has worked at several small colleges throughout the country, including one year at Wyoming Catholic College. Dr. Ayala received her PhD in Biological Sciences from the University of Notre Dame, where she carried out research looking at the growth of *Plasmodium falciparum*, the parasite that causes malaria. Her primary interest is in teaching. At the college level, Dr. Ayala has taught courses in Parasitology, Anatomy & Physiology, Genetics, and many others. She has also taught Biology classes through co-ops for homeschool students at the high school level. She received an annual award at Belmont Abbey College in the spring of 2022 for her excellent teaching. Outside the classroom, Dr. Ayala enjoys spending time with her husband and four children, as well as cooking, sewing, gardening, and listening to good music.

MICROGRAPH (*PHOTOGRAPH TAKEN BY MEANS OF A MICROSCOPE*) OF BLOOD VESSEL

CELLS & SYSTEMS

Living Machines

Heather Ayala, PhD

TAN Books
Gastonia, North Carolina

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

ISBN: 978-1-5051-2624-2

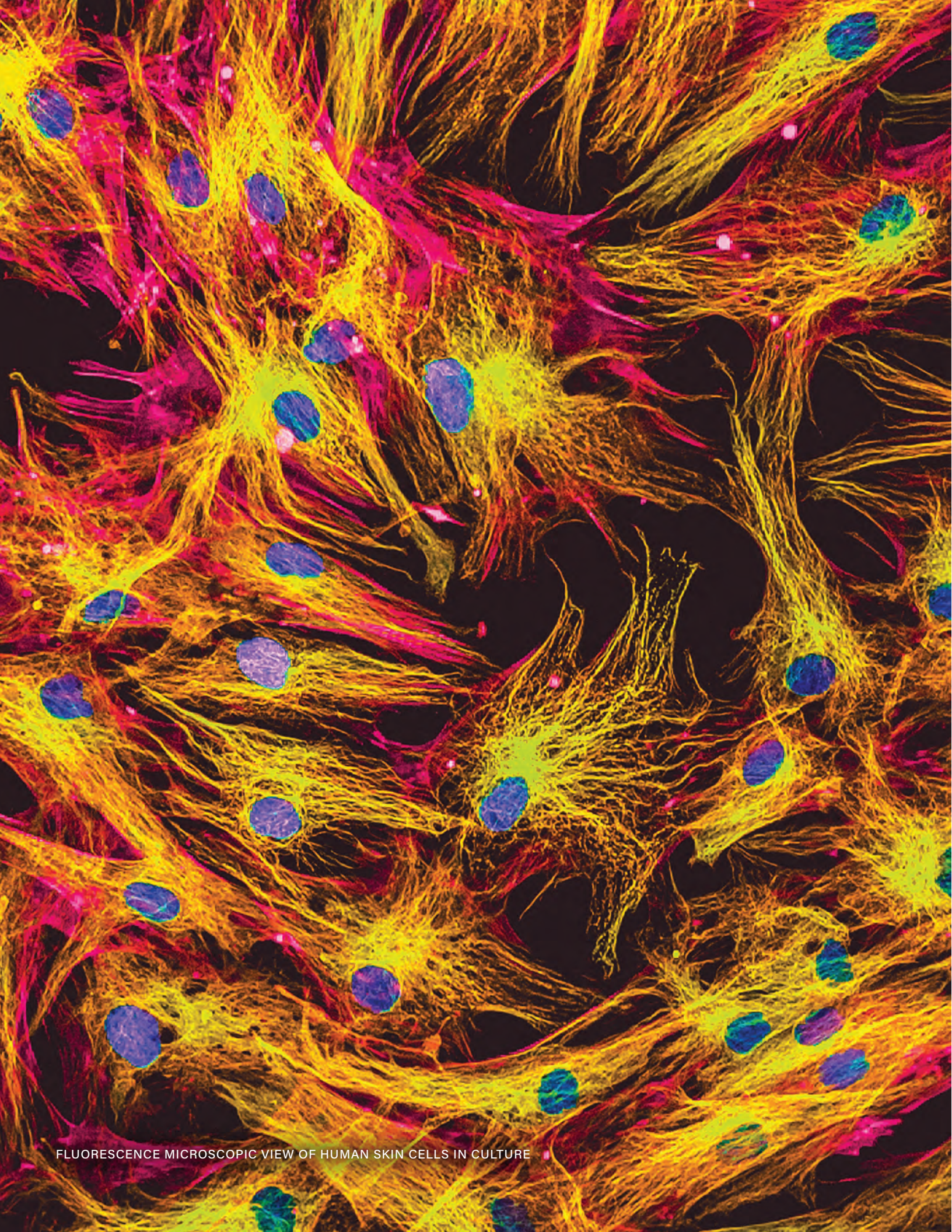
Published in the United States by
TAN Books
PO Box 269
Gastonia, NC 28053

www.TANBooks.com

Printed in the United States of America

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

–Job 38:4



FLUORESCENCE MICROSCOPIC VIEW OF HUMAN SKIN CELLS IN CULTURE

CONTENTS

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 you do in a big research facility with a lab coat.

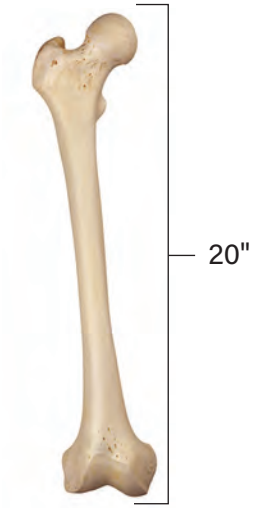
But we are all scientists!

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.

There is always something new to learn in biology and all the natural sciences. Within biology, there is so much inspiring beauty and wonder in the endless forms continually changing and unfolding. The intricate order found in the smallest of God's creations—the cell—is so complex that it can help form and run the complexities of the physical life He has given us. The inner workings of the human body are truly awe-inspiring!

FEMUR BONE



For example, did you know:

- If you stretched out a single chromosome, it would be about six feet long?
- A typical adult has 206 different bones in his body, from the largest, the femur in the leg just under twenty inches on average, to the smallest, at only a few millimeters inside our ears?
- A protein called hemoglobin found inside red blood cells is what gives blood its red color?

How could we not be fascinated by the cells and systems that make up our bodies? With this text, my friend and colleague, Dr. Heather Ayala, has done a marvelous job introducing you to this complex and intricate world, making it fun and edifying all at once. I have no doubt you will thoroughly enjoy this unit!

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

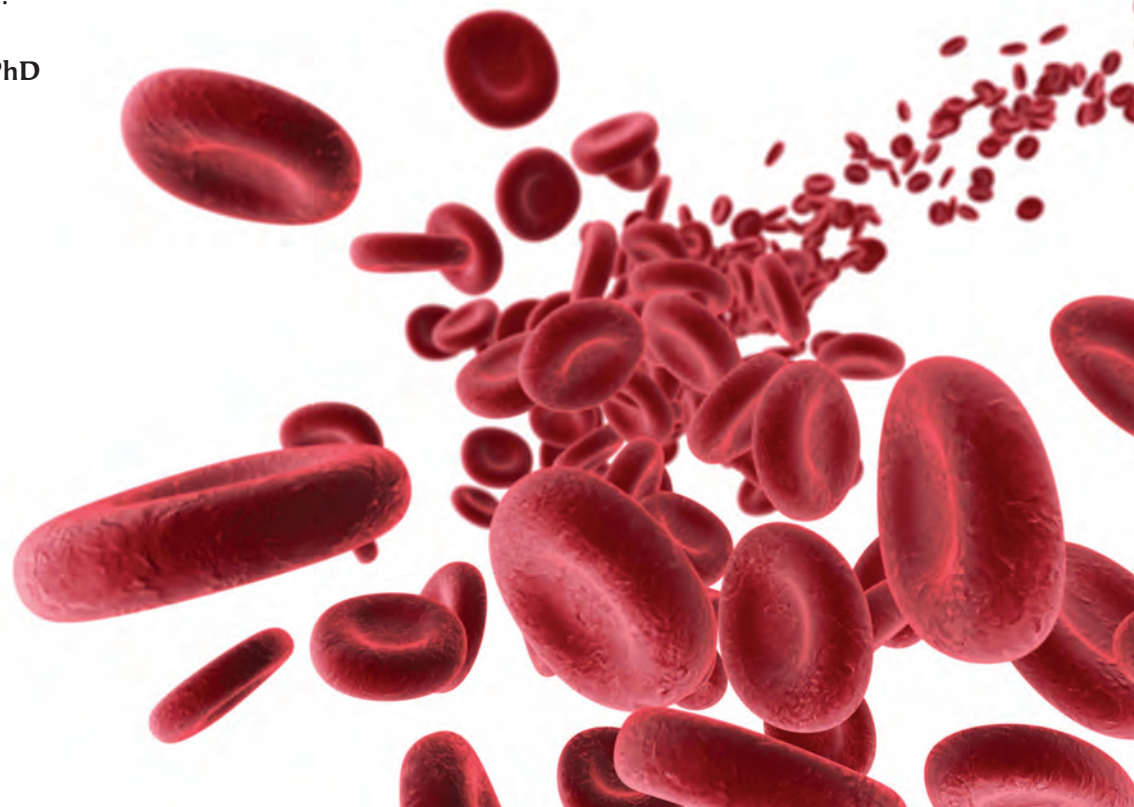
–Pope St. John Paul II in *Physics, Philosophy and Theology*

Finally, in closing, 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.

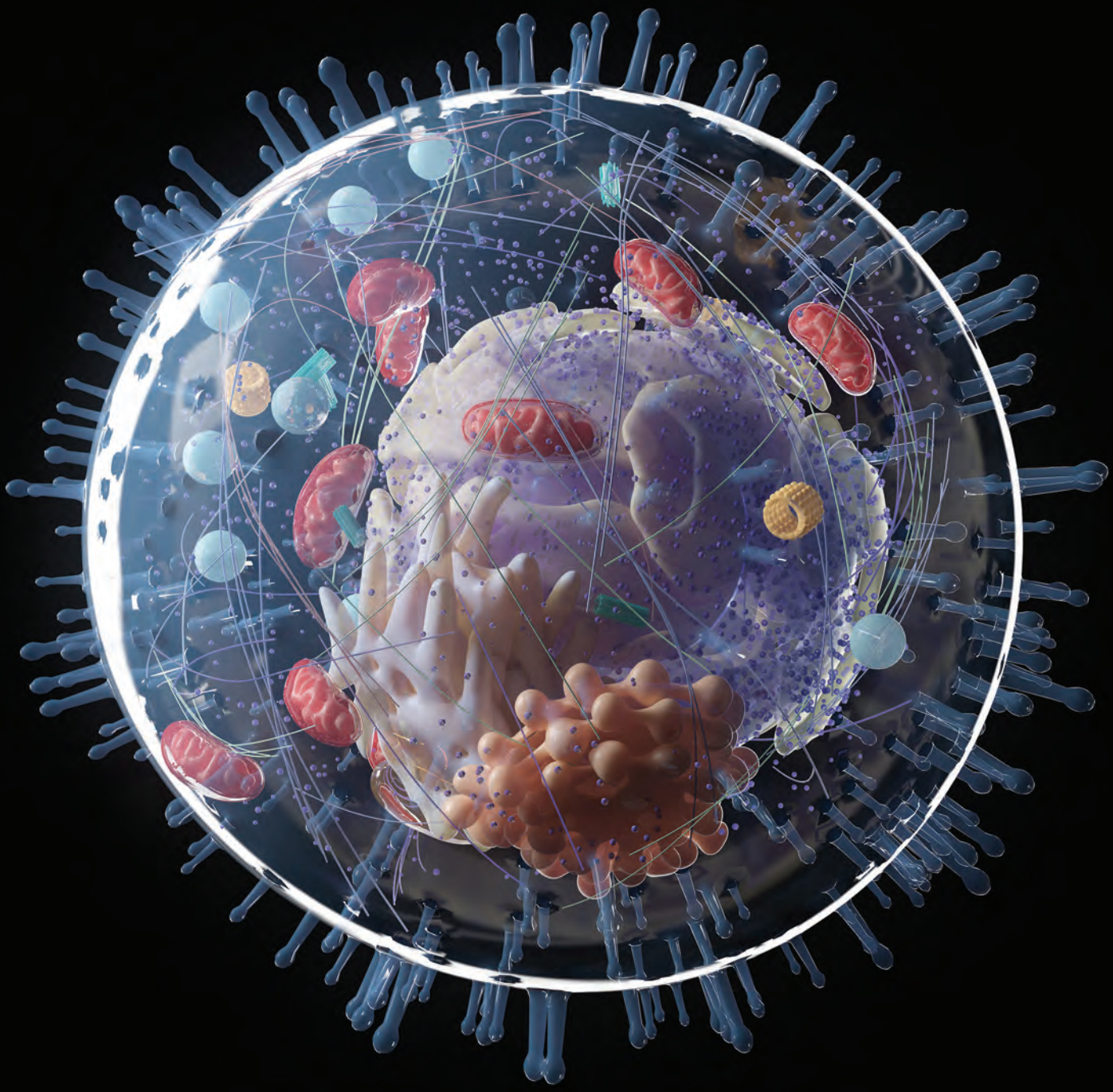
We read in the *Catechism of the Catholic Church*: "Methodical research in all branches of knowledge, provided it is carried out in a truly scientific manner and does not override moral laws, can never conflict with the faith, because the things of the world and the things of faith derive from the same 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 also 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



RED BLOOD CELLS



HUMAN CELL ANATOMY

INTRODUCTION

So far in *The Foundations of Science* curriculum, we have explored many different things found in our world. Some of them have been living organisms, like plants and animals, while others have been non-living, like when we learned about the earth, the skies, and outer space. But all of the things we have explored so far, we have been able to see with our eyes.

That's all about to change!

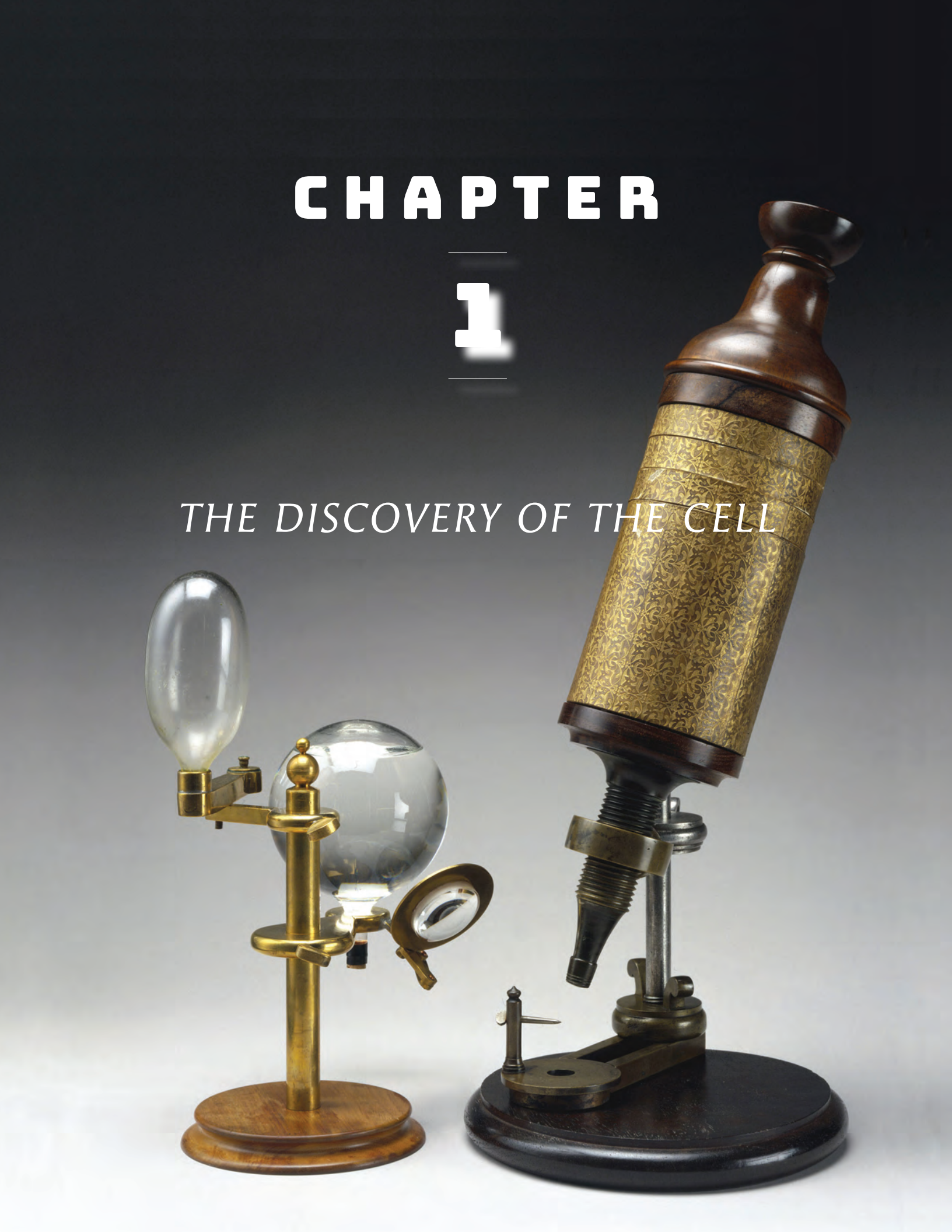
All living things are made up of very small (so small you cannot see them!) units called cells. These **cells** are the basic building blocks of life; they make up all living organisms and the tissues of our bodies. You can think of cells kind of like LEGO bricks. They are different, but similar, and you can put many of them together to make an infinite number of different structures. Even though you cannot see them with the naked eye, there is an incredible amount of activity that goes on inside of every single cell. The structure of a cell is so intricately made that it can perform the functions needed for life to exist. We will explore some of these special roles in the first few chapters of our book.

Then, we will move on to tissues. When cells "work together" for a common purpose, they make up tissues. These tissues are the fabric used to create the organs such as your stomach, brain, heart, muscles, and bones. The remainder of this book will then look at many of the organs and organ systems that come together to make up your own body. By the time our journey is complete, I hope you will have a greater appreciation of the care God took in creating you!

Our study of cells dates all the way back to the 1600s, when Robert Hooke developed his own microscope to study ants, fleas, plant material, and many other things. He would pen a book called Micrographia *that contained drawings like this one of what he observed.*

CHAPTER 1

THE DISCOVERY OF THE CELL



HOOKE'S MICROSCOPE

The Dutch father and son Hans and Zacharias Janssen, in the late sixteenth century, were the first to develop the microscope. This invention, refined through the centuries, has expanded our knowledge of the world around us and the human body in unimaginable ways.

Have you ever used a magnifying glass to look at something small? Perhaps you used one to look at the fingerprints on your hand or at the veins on a leaf. If so, you know that by using the magnifying glass, it makes the thing you are looking at seem bigger. By doing this, it lets you see things that you may not have seen if you had not used the magnifying glass.

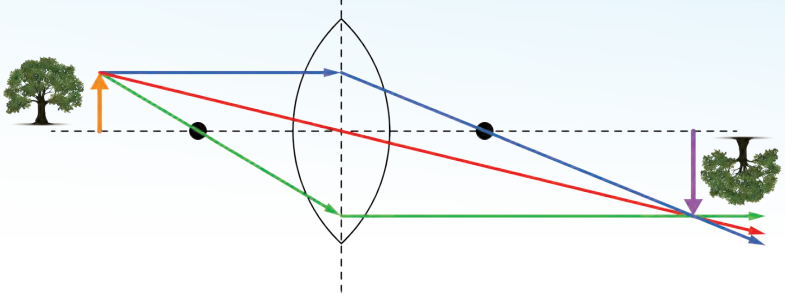
A **magnifying glass** is a lens, similar to the lens you would find in a pair of eyeglasses. The lens is a curved piece of glass. Because it is curved, when light passes through the lens, it causes the light to bend just a little bit. The bending of the light changes how we see the object on the other side of the lens, making it look bigger.

In the late 1500s, there lived a Dutch man by the name of Hans Janssen who made eyeglasses. Hans had a son named Zacharias. In 1590, Hans and Zacharias started to experiment with lenses, putting two lenses together in a tube. They found that when they looked at something through the tube of lenses, it looked even bigger! This was the first microscope.

We don't know a lot about Hans and Zacharias, but they are given credit for inventing the compound microscope. A **compound microscope** is an instrument that uses more than one lens to make objects look bigger than they really are. The invention of microscopes opened up a whole new world to people. Now scientists could look at small things that they had never seen before.

How Do Microscopes Work?

Most microscopes you see today are compound light microscopes, meaning that they use two or more lenses and light. The light passes through a very thin object on a slide and is directed through the lenses. As it passes through the lenses, the light bends before it reaches your eye. This produces an image that looks bigger than it actually is. The lenses used in a compound light microscope are called **converging lenses**, like the one pictured here. Notice that the image formed is not only bigger but also upside down and backwards from the original object. This means that when you look through a microscope, if you move the slide to the right, you will see the image move to the left. And if you move the slide up, you will see the image move down!



Unfortunately, microscopes were expensive, and most people never had a chance to see one or look through one. But in 1665, about seventy years after the microscope was invented, an English scientist by the name of Robert Hooke made his own microscope. He had a practice of observing ants, fleas, plant material, and many other things. Hooke made detailed drawings and descriptions of what he saw, and he published all of these together in a book called *Micrographia.* In one part of his book, Hooke describes his observations of an ant. In order to make these observations, he first had to find a way to keep the ant from moving around. If he killed the ant, then it would be squished, and he would not be able to see its proper shape. He tried to use glue to hold the ant in place, but the ant kept wiggling about so that Hooke could not observe it under the microscope. Finally, Hooke put the ant in some strong alcohol to put it to sleep. This worked for about an hour, but then the ant suddenly woke up and started to run away before Hooke could finish his observations! The people found Hooke's book to be very interesting to read and fun to look at because of the beautiful drawings. This made it a very popular book.

Another of Hooke's famous sketches was of dead plant material, called cork. Hooke cut a thin slice of a piece of cork and looked at it under his microscope. He saw that the cork looked like little boxes, or pores, like what you might find in a honeycomb. Hooke called these boxes cells. This is where we get the word for cells!

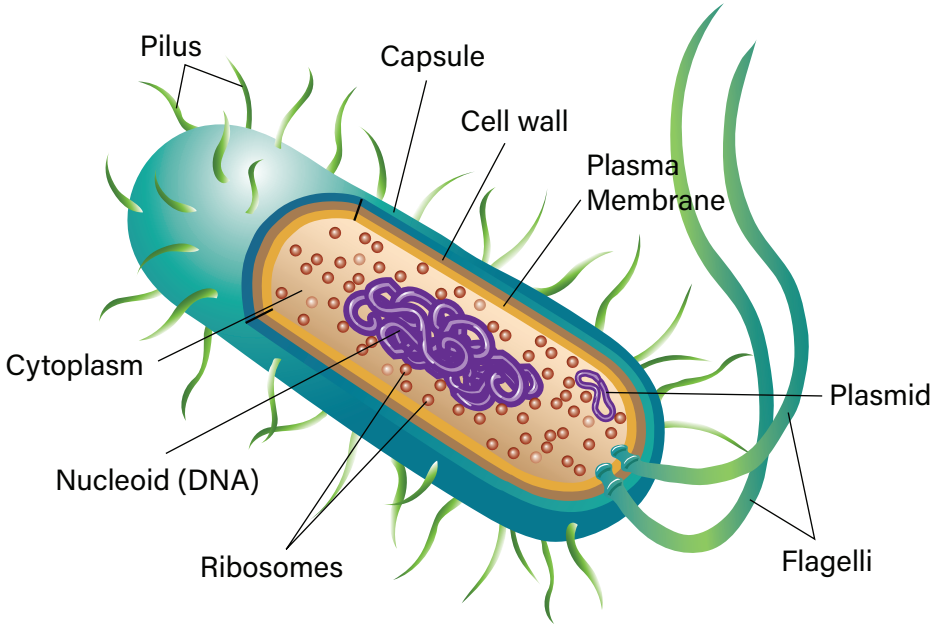
BASIC CELL STRUCTURE

When Hooke made his sketch and description of the cells in cork, he was observing the shell, or outer walls of a plant cell (the inside of the cell was no longer present). This outer wall gave the cork a boxlike or square appearance, but not all cells contain an outer wall. Animal cells (which include our cells, since we humans are animals too) do not have a cell wall. As a result, they come in many different shapes and sizes. We will discuss more about the different types of cells in chapter 2. For now, let's focus on some of the things that are common to *all* cells.

Every cell has an outer skin of sorts (think like the peel of an apple) that holds it together. This is called the **cell membrane** (sometimes also called the **plasma membrane**). The cell membrane helps control what can move in and out of the cell. Inside of living cells is a gel-like fluid made mostly of water. We call this the **cytoplasm** of the cell. Floating in the cytoplasm are other small structures. We call these structures **organelles**, or "little organs." We will talk about these in more detail in chapter 2.

The last thing we find in every cell is genetic material in the form of **DNA (Deoxyribonucleic acid)**. This genetic material contains the "instructions" that tell the cell what organelles to build and how to carry out its job. DNA is like the directions that make you who you are (how tall you are, the color of your skin, etc.), like blueprints for how to build a house.

BACTERIAL CELL ANATOMY



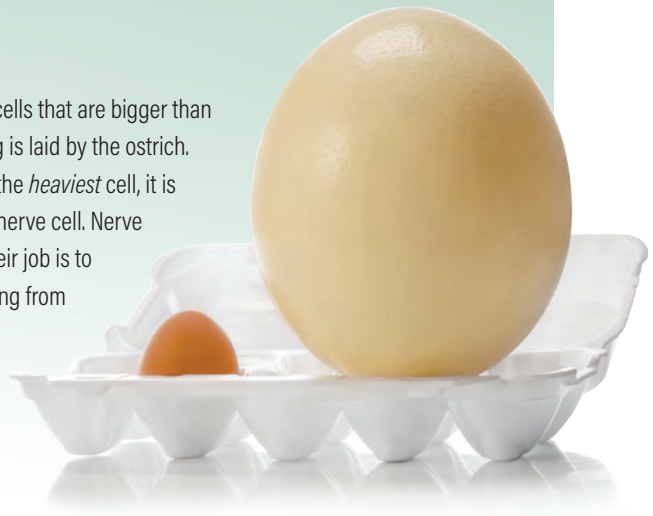
DEVELOPMENT OF THE CELL THEORY

Scientists continued to improve on the microscope in the years following its invention. This allowed them to make discoveries that helped increase our understanding of the cell and its role in making up living organisms. There were several very important observations made about cells during this time. We will just mention a few of them here.

- Henri Dutrochet was a French military doctor living in the early nineteenth century. In examining plant cells, he noted that cells are the basic structural component making up plants. He also observed that the functions carried out by the plant cells are the basis for the function of the plant.

How Big Is the Biggest Cell?

Most cells are too small to be seen without a microscope, but there are some cells that are bigger than others. For example, did you know that an egg is a single cell? The biggest egg is laid by the ostrich. It is about six inches long and weighs about three pounds! While this may be the *heaviest* cell, it is not the *biggest* cell. One type of cell we will learn more about in chapter 7 is a nerve cell. Nerve cells make up our brain and other nervous structures throughout our body. Their job is to carry messages from one part of our body to another. We have nerves stretching from our spine to the bottom of our toe. That is a long nerve cell. But giraffes have even longer nerve cells. They have nerves that run the entire length of their long necks, between six and eight feet long! However, the longest nerve cell is found in the giant squid. These sea animals can be up to forty-three feet long and have nerves up to thirty-nine feet long. Now that is a big cell!



- In 1832, the Belgian scientist Barthelemy Dumortier was making observations when he saw that a plant cell divides into two new plant cells. He concluded that all new cells come from pre-existing cells.
- In the years 1838–39, two German scientists named Schwann and Schleiden were studying a variety of plant and animal cells. Schleiden saw that all of a plant's structure is composed of plant cells. Schwann's work, meanwhile, focused on studying animals. Like Schleiden, he noted that all the structural parts of animals are made of animal cells. In short, Schwann concluded that plants and animals are similar in that they are both made of up of cells and these cells work in the same basic way.

If that seems like a lot to remember, don't worry. The most important thing to understand is that all of these discoveries combine to form what we call the **Cell Theory**. The Cell Theory says:

1. All living things are made of cells.
2. Cells are the basic unit of structure and function for all living things.
3. All cells come from pre-existing cells.

These ideas form the foundation for our current understanding of cells and their role in making up all living things. In chapter 2, we will look more closely at different types of cells and what makes up these small building blocks of life.

Remember:
The DNA (Deoxyribonucleic acid) found in cells is like the "directions" that make you who you are (physically speaking).

FOUNDATIONS REVIEW

- ✓ The invention of the magnifying glass, which enlarges what you are looking at, and more specifically the compound microscope, helped scientists see things that otherwise would have been too small. This led to the discovery of cells, the basic building blocks of life.
- ✓ Though different types of cells possess different qualities, every cell has an outer skin that holds it together. This is called the cell membrane. Also common to all cells is the cytoplasm, the gel-like fluid made mostly of water, and floating in this cytoplasm are little structures called organelles, or "little organs." The last thing we find in every cell is genetic material in the form of DNA (Deoxyribonucleic acid). This genetic material contains the "instructions" that tell the cell what organelles to build and how to carry out its job.
- ✓ Across many, many years of research, scientists from all over the world contributed to the development of what is known as the Cell Theory. It states that: (1) All living things are made of cells; (2) Cells are the basic unit of structure and function for all living things; (3) All cells come from pre-existing cells.

Disproving Spontaneous Generation

The idea that cells come from pre-existing cells was astounding in 1750. Prior to the 1700s, many people believed that small, simple living things like worms and maggots (fly larvae) could just spontaneously arise out of nonliving material. This idea was known as "spontaneous generation." Does that sound strange to you?

One of the earliest records we have of the theory of spontaneous generation comes from the Greek philosopher Aristotle. He lived about 350 years before Christ was born. Aristotle suggested that life could come from nonliving things. Aristotle observed a pond that did not appear to have any living animals, and yet within a few days or weeks, fish could be seen swimming about. This led him to believe that the fish spontaneously appeared from the water itself!

Of course, we now understand that the fish came from eggs that were in the pond. But other scientists made similar observations over the years that seemed to support Aristotle's idea. They would observe frogs "appearing" along the banks of the Nile River. Really, the frogs were developing from tadpoles that were already in the water. Another observation noted that rotting meat left out would soon start to have maggots growing on it!

This idea of spontaneous generation was very popular for hundreds of years. It was not until the 1600s that scientists started to question it. The first person to perform an experiment that showed spontaneous generation to be wrong was a Catholic Italian doctor named Francesco Redi in 1668. Redi lived towards the end of the time of Galileo. He was inspired by Galileo's approach of gathering observations to answer a scientific question. Redi decided that he would use a similar approach to investigate the idea of spontaneous generation.

Redi developed an experiment to test if maggots spontaneously appeared on rotting meat. He put some rotting meat into several different containers. Some of these containers he left open to the air. A second set of containers were sealed. A third set of containers were covered with gauze. This allowed air to move in and out of the container, but no flies could get to the meat. After some time, Redi observed that the uncovered meat had maggots growing on it, but the meat in the sealed container and the meat in the gauze-covered container did not. Redi observed maggots hatching from eggs that were laid on the gauze covering but not on the meat within the gauze-covered container. Based on his observations, Redi concluded that the maggots were not arising out of the meat but that they were hatching from the eggs laid by the flies on the meat.

Redi's experiment was the first of many performed in the 1600s and 1700s that showed the theory of spontaneous generation was incorrect. His work was also very important because it introduced the idea of a **controlled experiment**, which is when multiple experiments are carried out with one variable or factor being changed in order to observe the effects of the change in variable. This is very important in how we answer scientific questions today.