Return to Product

JR. HIGH STUDENT

VOL. 1

INTRODUCTION TO ANATOMY & PHYSIOLOGY

The Musculoskeletal System

wonders of the HUMAN BODY

Dr. Tommy Mitchell

First printing: May 2015

Master Books®,
P.O. Box 726, Green Forest, AR 72638

Master Books® is a division of the
New Leaf Publishing Group, Inc.

ISBN: 978-0-89051-865-6
Library of Congress Number: 2015930890

Cover by Diana Bogardus
Interior by Jennifer Bauer

Unless otherwise noted, Scripture quotations are from the New King James Version of the Bible.

Please consider requesting that a copy of this volume be purchased by your local library system.

Printed in China

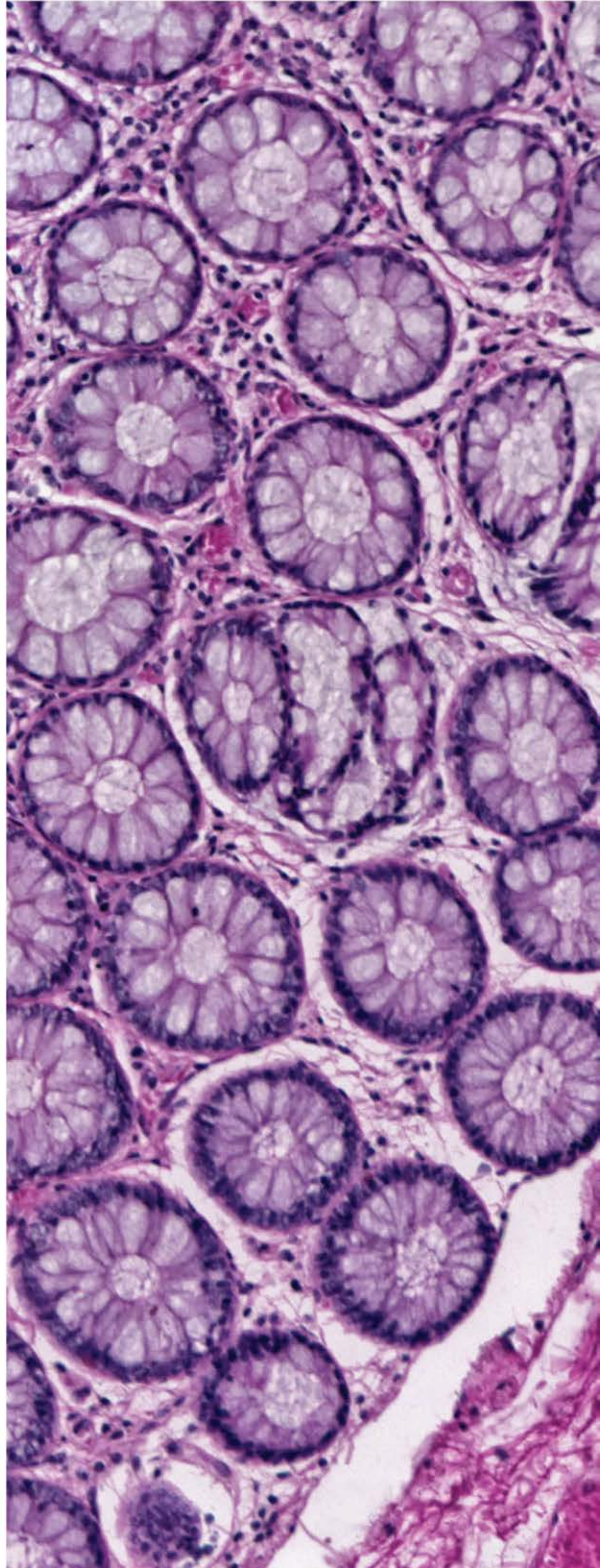
Please visit our website for other great titles:
www.masterbooks.net

For information regarding author interviews, please contact the publicity department at (870) 438-5288.

Master Books®
A Division of New Leaf Publishing Group
www.masterbooks.net

Dedication

For my beloved wife, Elizabeth



Cross section of glandular ducts

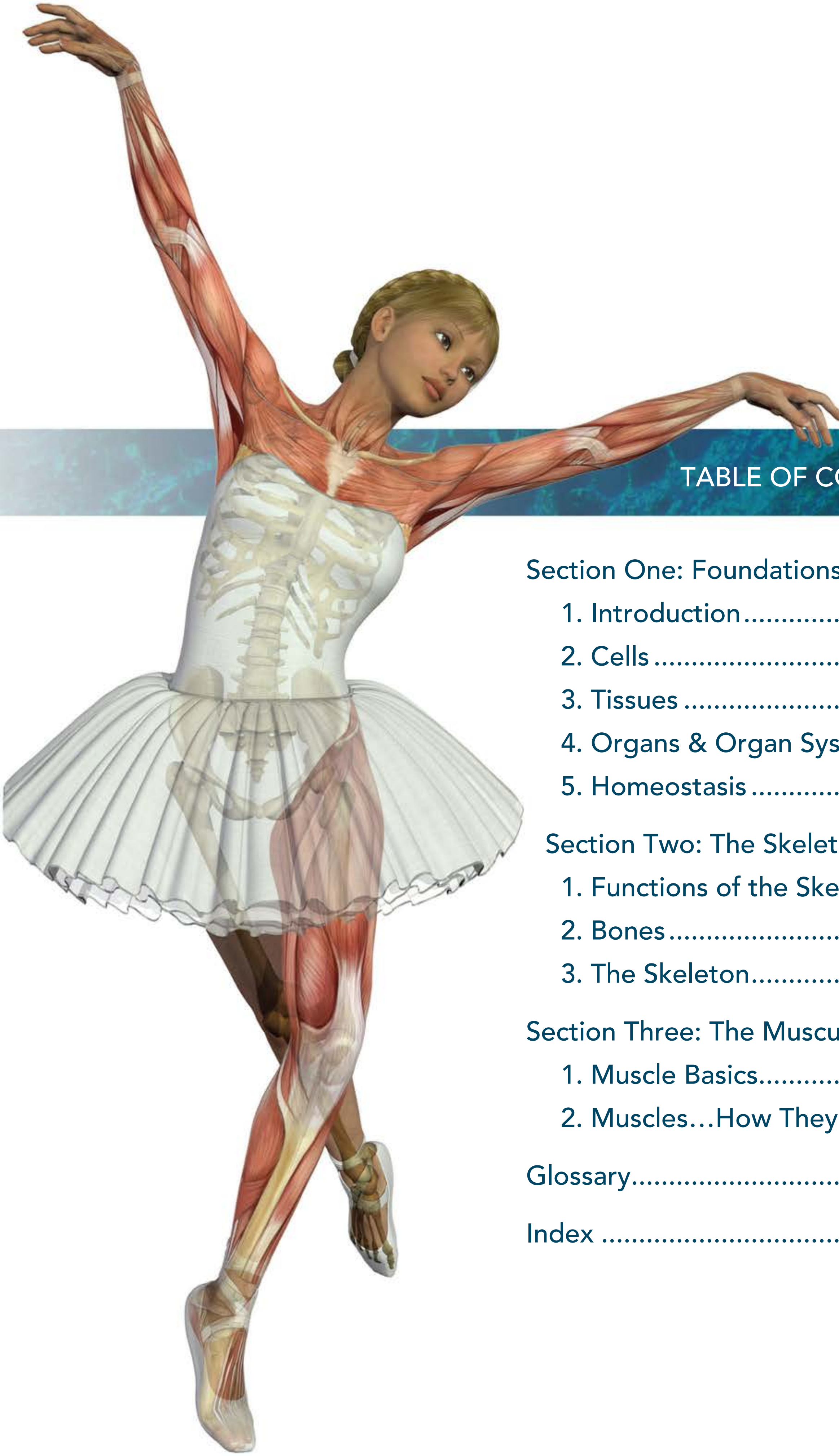


TABLE OF CONTENTS

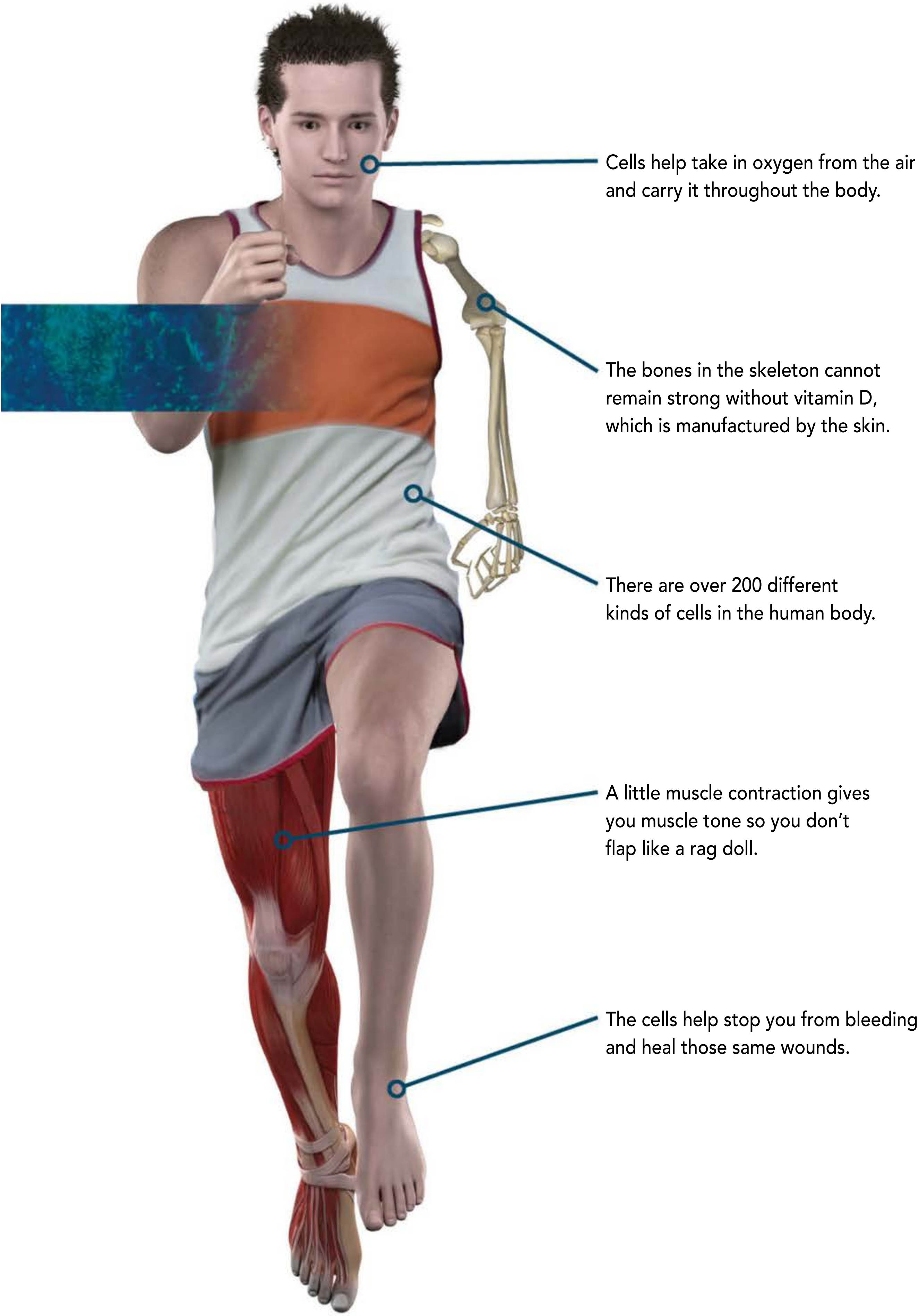
SECTION 1

FOUNDATIONS

This book is introductory to the anatomy and physiology series, so you've come to the perfect starting off place! You'll be learning about cells, the basic building blocks of the body; tissues, a group of cells that perform similar or related functions; organs, which are tissues that function together; and homeostasis, which is the balance found among all your body functions. God created us and so He knows best how to care for us through all He has made!

"Where were you when I laid the foundations of the earth?" God asked this questions of Job (38:4), referring to the creation of the world. A foundation is the starting place for building something, and a good foundation is needed to create something that will last. Just as God created the heavens and the earth, He created us as well, and knows us more deeply and intricately than science will ever be able to grasp.

For You formed my inward parts; You covered me in my mother's womb. I will praise You, for I am fearfully and wonderfully made; Marvelous are Your works, And that my soul knows very well. My frame was not hidden from You, When I was made in secret, And skillfully wrought in the lowest parts of the earth. Your eyes saw my substance, being yet unformed. And in Your book they all were written, The days fashioned for me, When as yet there were none of them (Psalm 139:13–16).


Cells help take in oxygen from the air and carry it throughout the body.
The bones in the skeleton cannot remain strong without vitamin D, which is manufactured by the skin.
There are over 200 different kinds of cells in the human body.
A little muscle contraction gives you muscle tone so you don't flap like a rag doll.
The cells help stop you from bleeding and heal those same wounds.

1

INTRODUCTION

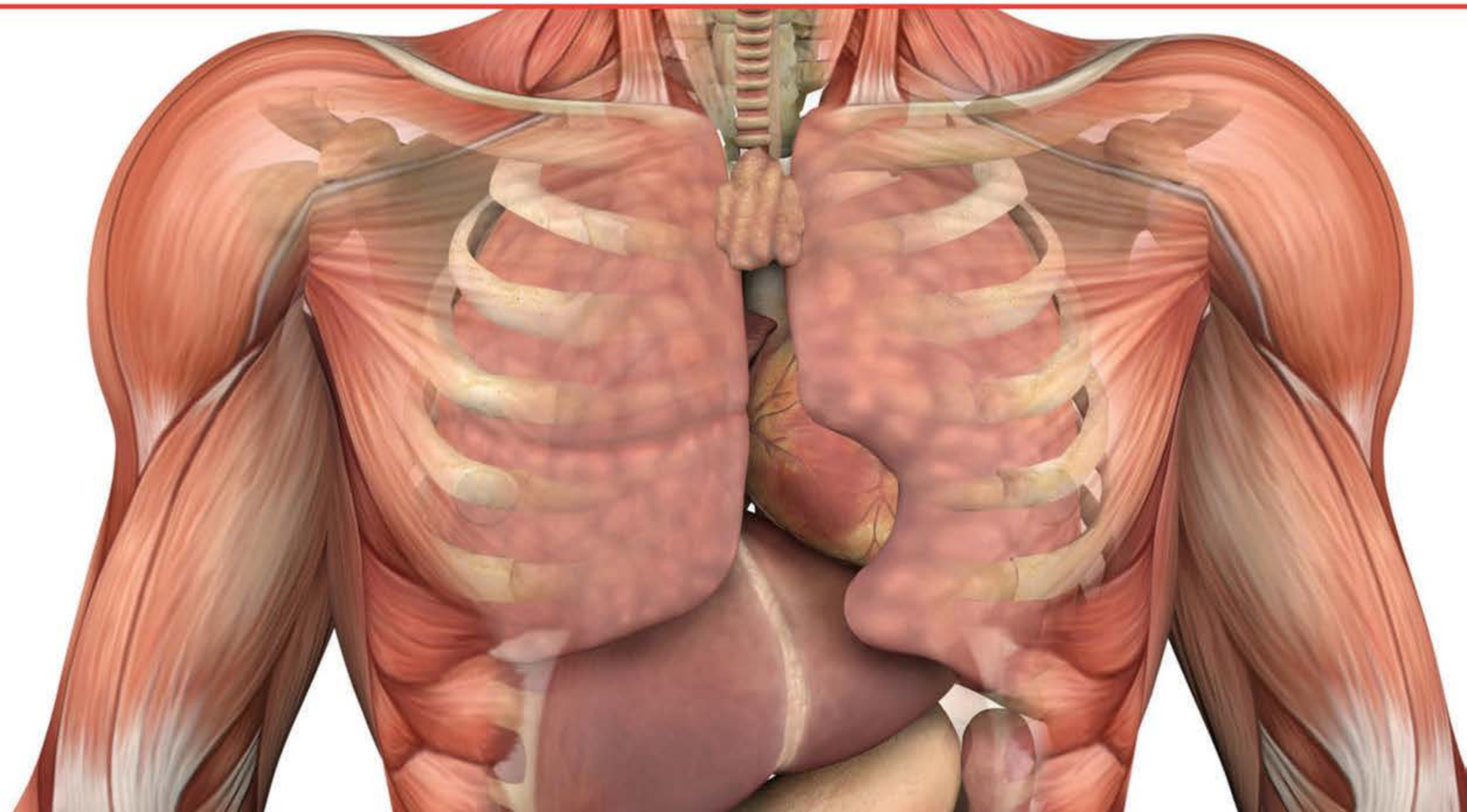
The human body — two arms and two legs, a head, chest, and tummy — seems simple on the surface. In reality, however, it is an incredibly designed orchestra of parts perfectly created to work together. Your body's parts — from the largest bones and organs to the smallest molecules and cells — are put together with a precision no engineer could design. Your body is able to do a remarkable array of things. And it must do many of them nonstop without your attention. This series of books will take you on a guided tour of your own body, giving you a peek into its secrets, large and small, and showing you how it works and how all its parts are designed to work together. Think of this as an owner's manual to the first birthday gift you ever received — the body with which you were born.


Respiratory System


Skeletal System


Muscular System


Digestive System



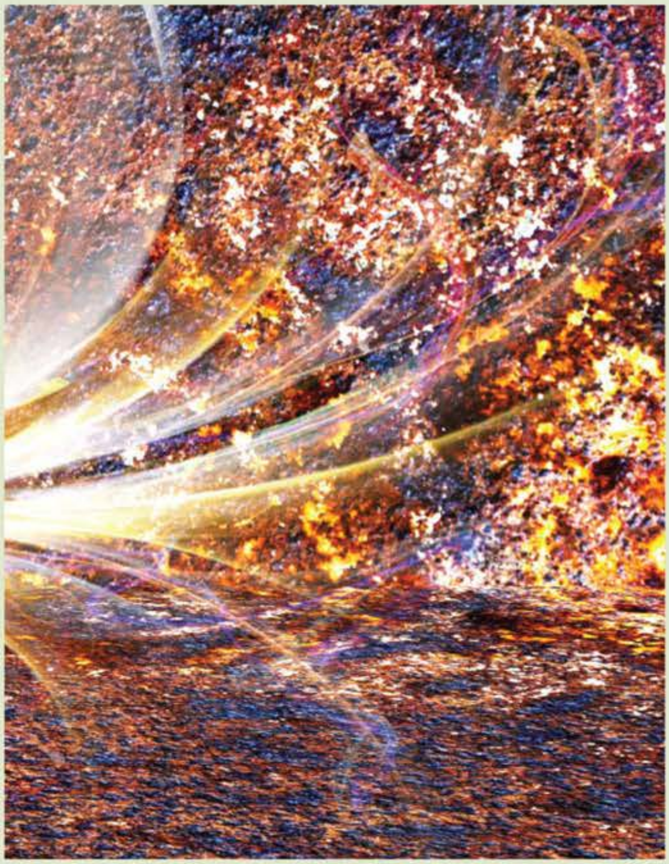
The same body that can use a hammer to drive a nail can hold a feather without crushing it. The same eyes can take in the expanse of the Grand Canyon yet detect faint light from stars many light years away. Your lungs enable you to talk and sing without forgetting to take in oxygen and release carbon dioxide. If you had to think about breathing, you could never go to sleep, for you would die within minutes.

Your digestive system breaks down food into the chemicals you need for energy. Your heart pumps blood through miles of blood vessels to deliver oxygen and nutrients to the most unseen places. Directed by your brain, you walk, run, throw a ball, play a video game, read a book, paint a picture, or even play an instrument. However, the same brain also controls many essential activities inside your body that you are probably not aware of.

What Is Evolution?

In the Bible we read, "In the beginning God created the heavens and the earth" (Genesis 1:1). This theme is repeated time and time again. God is called Creator. In John 1:2 it states, "All things were made through him."

However, there are many people, Christians and non-Christians alike, who do not acknowledge Him as the One who created all things. Instead, they believe in something called evolution.



Rather than accepting God as Creator, they believe that billions of years ago, matter just appeared out of nowhere. Then, they believe, there was a rapid expansion of the universe called the big bang. As this process progressed, the stars and galaxies formed themselves. Then about five billion years ago, our sun was formed and later all the planets in our solar system.

They believe our planet was at first a hot molten blob that eventually cooled and became covered with water. Then all the substances necessary for living things appeared. The first simple life form then sprang into existence by accident.

Then over the next few billion years, living things became more and more complex until at last man appeared on the scene. In this view, man is no more than a cosmic accident, the result of chemicals bumping together over millions of years. Basically, we are then just a highly evolved animal. What folly is a belief such as this!

As we go through our study of the human body, you will see how absurd it is to think that these marvelously complex systems assembled themselves by accident. We are not an accident. We are made in the image of our wonderful Creator God. God tells us in the Bible where we came from: "Then God said, 'Let Us make man in Our image, according to Our likeness' " (Genesis 1:26).

Your bones give your body shape and support even while they grow, your skin protects you from the outside world, your blood carries oxygen and the tiny tools to fight off harmful germs, your liver manufactures chemicals you need while it breaks down toxins, and your kidneys rid your blood of many waste products and help control the amount of water in your body. The amazing list of unseen and unceasing processes that must go on simultaneously for your body to work properly goes on and on.

Actually, the amazing thing is that many people think that the human body is a product of chance, that we are merely an accident. They believe that our bodies developed on their own as a result of chemical reactions occurring over billions of years through a process called evolution.

Imagine that . . . chemicals combined themselves to become alive, and then the human body, so complicated, so intricate, just assembled itself! Hard to believe, isn't it?

The truth is that we are not an accident. The human body was designed by a Master Designer, the Creator God of the universe. The human body He designed is simple enough that a newborn baby instantly begins making it work and quickly learns the most complex skills. He designed it with sufficient well-orchestrated complexity and built-in control systems so that even before a baby is born the cells in her body are performing chemical reactions she would need a college degree to even begin to understand, and many that the smartest scientists of all are only beginning to discover.

You are marvelously and wonderfully made. Psalm 139:14, says, "I will praise You, for I am fearfully and wonderfully made; marvelous are Your works." As you explore the incredible features of the human body, remember to praise the Creator God who designed the human body and gave one to you.

You will hear from many people that you are nothing more than an animal, a highly evolved one, but an animal nonetheless. This idea comes from people who wrongly believe that life evolved through random processes and all by itself produced increasingly complex animals until humans appeared. They believe that humans are just animals and not special at all. God's Word tells us otherwise.

In Genesis 1:26 it says, "Then God said, 'Let Us make man in Our image, according to Our likeness.'" Therefore, we are not merely animals. God made human beings in His own image.

But you might say, "Well, we look similar to some animals, so aren't we just animals, too?" No, we are not. Humans and some animals do share many similar features, but that does not mean that animals are our ancestors. All it means is that animals and humans were all designed by the same God. We share a common designer, not a common ancestor! A wise master designer would naturally use variations of many common designs in the living things He made.

Just as words are built of letters and books are built from words, so your body is built of organs and tissues, and all the organs and tissues are made of cells. Cells are even called the building blocks of life. We are going to begin exploring the amazing designs of the human body by finding out how the cells of the major organs work.

Anatomy

Anatomy is the study of the body's parts and how they are put together. Anatomy includes how the organs look, where they are, and how everything is connected. Anatomy is the structure of the body. For example, an anatomical study of the circulatory system includes a study of the heart itself and all the blood vessels and their connections to all the other organs.

Anatomy includes not just the things you can see with your eyes, like lungs and kidneys. Anatomy includes the microscopic structures — the cells and the tissues (collections of cells) that make up the larger parts. This study of microscopic anatomy is called histology.

Physiology

Physiology is the study of how the parts of the body function. Physiology is the study of how everything in the body works. For example, physiology of the circulatory system focuses on how the heart works, what controls blood circulation and blood pressure, how oxygen gets into the blood, and how blood delivers oxygen to the tissues and organs.

If we didn't understand some physiology, learning about the human body would just be the dull business of memorizing the names and locations of organs and bones. But when we find out how each part works and interacts with other parts, the study of the human body really does come alive!

Cells and Tissues and Organs, Oh My!

The best way to understand the human body is not just to memorize its parts but to begin with its building blocks and then to see how they form the more complex structures and how they work. We will begin with the most basic building block of the body, the cell. Cells are small but not simple. While cells have a simple list of parts — like nucleus, cytoplasm, and cell membrane — these are subdivided into a dizzying list of smaller parts. Many cells are like tiny factories. There are many types of cells in the body. For example, there are liver cells, muscle cells, kidney cells, nerve cells, skin cells, blood cells — well . . . you get the idea.

Groups of cells form tissues. Each kind of tissue can be thought of as one of four basic tissue types — epithelial, connective, muscle, and nervous. These tissues cover, connect, move, and communicate. More on that later.

Tissues combine to form more complex structures called organs. Organs are groups of tissues that have a particular function. Lungs, bones, and the brain are examples of organs.

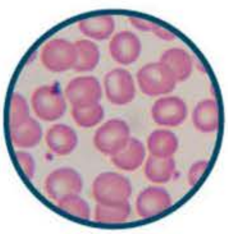
Lastly, we will deal with organ systems. This is where we will "put things together" by exploring groups of organs that work together to do specific things in the body. For example, the bones are all connected together as the skeletal system. And all the parts that process your food — from your mouth and stomach to your liver and intestines — are part of the digestive system.

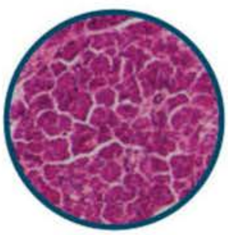
Before we can put it all together we need to go back to basics, so let's get going with the cell.

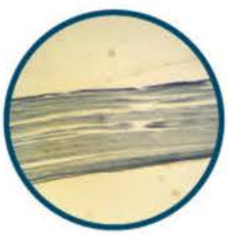
2

CELLS

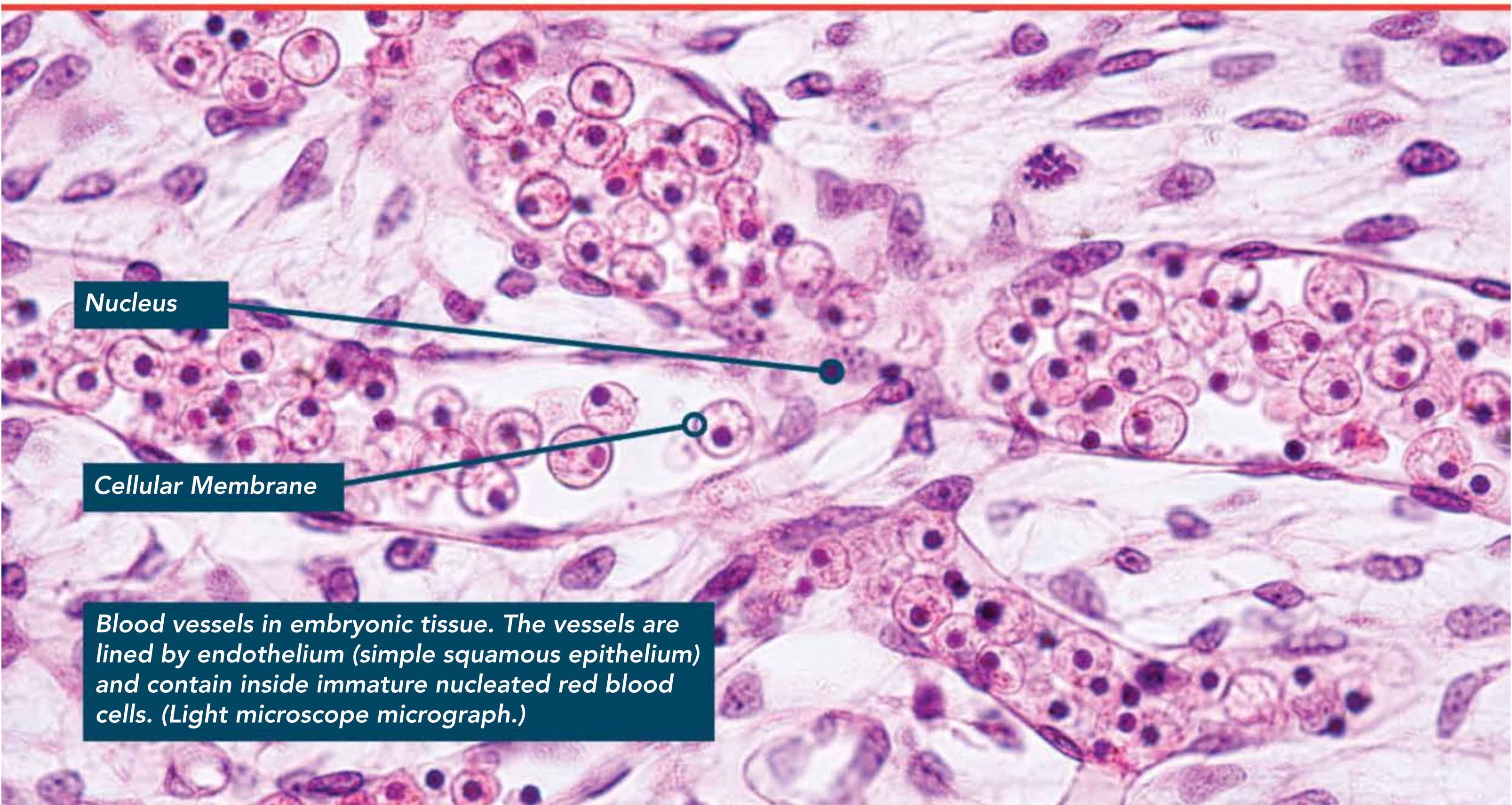
The cell is not only the basic building block of the body but also the basic "functional unit." What does that mean? Well, your body does a lot of things — some things you see and some that you don't. It moves. It grows. It digests food, turning some of it into energy, storing some of it, and discarding the leftovers. It manufactures many kinds of complex chemicals. It tastes, smells, sees, hears, touches, senses temperature, and feels pain. It takes in oxygen from the air and carries it all over your body. It fights infection and protects you from most germs. It stops you from bleeding when you get a cut, and later it heals the cut. All these "functions" are really performed by or inside cells. That's why we say the cell is the smallest "functional unit" of the body. The cell is where the action is!


Blood Cell


Liver Cell


Muscle Cell


Nerve Cell



Blood vessels in embryonic tissue. The vessels are lined by endothelium (simple squamous epithelium) and contain inside immature nucleated red blood cells. (Light microscope micrograph.)

Each cell is like a factory designed to carry out a specific function. There are over 200 different kinds of cells in the human body, and they come in all shapes and sizes. Most cells have three basic parts — a *nucleus* that directs most of the action, a *cell membrane* that forms the cell's outer border, and *cytoplasm* where most of the cell's work gets done. Most kinds of cells have many *organelles* that perform the various jobs in the cell.

Erythrocytes are red blood cells. Their main job is to carry oxygen. Red blood cells are packed with a red oxygen-carrying molecule (hemoglobin), which is why they are red. Erythrocytes are comparatively simple cells. The erythrocytes circulating throughout your body don't even have a nucleus or organelles.

In contrast, liver cells are much more complex. Liver cells process and store nutrients, manufacture important substances, and rid the body of some toxic chemicals. Because liver cells are involved in more complex activities than red blood cells, their structure is more complex.

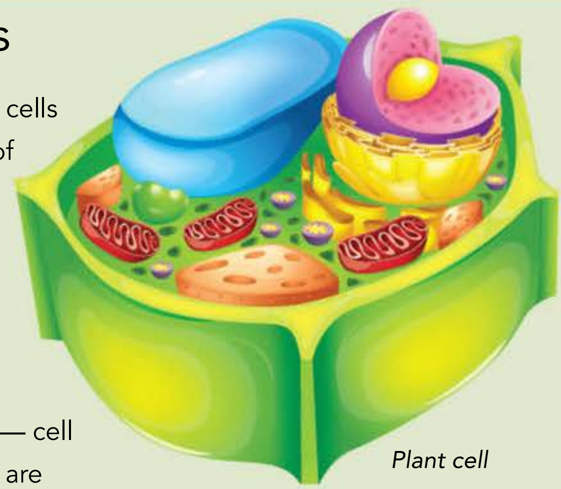
Each muscle cell is designed to contract, and you can move because muscle cells work together. Certain cells in the pancreas produce *insulin* that controls the amount of sugar in your blood, because either too much or too little is bad for you. Nerve cells transmit nerve impulses so that one part of your body can communicate with another. Otherwise, your hand would not "know" that your brain told it to move. And the list goes on. Each cell has an important job to do.

For all their many differences in structure and function, most cells have a lot of things in common. Here we'll learn about a "typical" cell. Then in our journey through the human body, we will examine specific cell types in more detail.

So Simple Yet So Complex — Designed by the Master

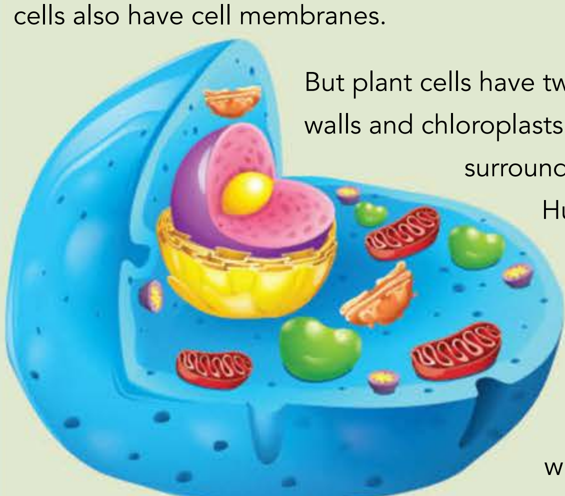
Human Cells and Plant Cells

You will soon learn about many different kinds of cells found in the human body. Plants are also made of cells. Plant cells have many things in common with our cells. Plant cells have nuclei containing chromosomes that direct the cellular activities. They have mitochondria and the other organelles we have. And plant cells also have cell membranes.



Plant cell

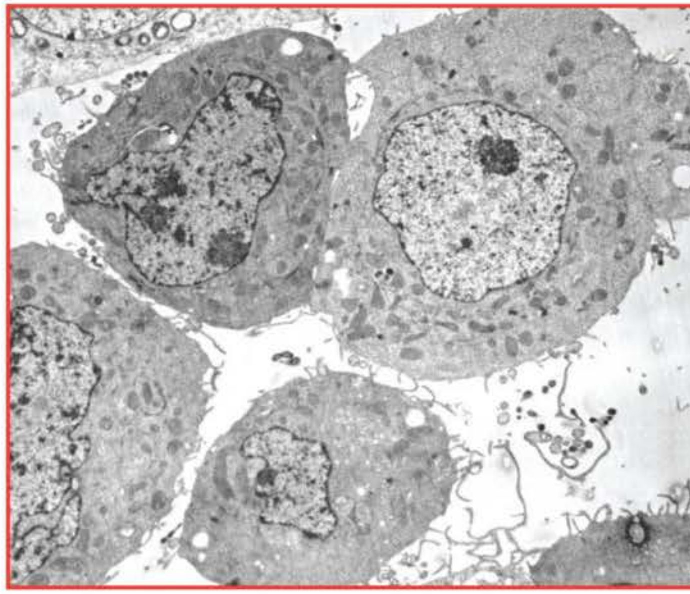
But plant cells have two things our cells lack — cell walls and chloroplasts. Plant cell membranes are surrounded by a tough cell wall made of cellulose. Humans cannot make cellulose. The cell wall provides a sturdy support for plant cells and helps maintain their shape. Plant cells, unlike our cells, are also able to capture energy directly from sunlight and use it to manufacture sugar. This process is called photosynthesis. Photosynthesis takes place in special organelles called chloroplasts. The chloroplasts in plant cells contain the green pigment chlorophyll, which captures the sun's energy. God designed plant cells to produce sugars and other important foods for humans and animals to eat.



Human cell

Basic Cell Structure

Regardless of size, shape, or complexity, most human cells have, as we mentioned, three main parts. The *cell membrane*, also called the *plasma membrane*, encloses the cell, forming the boundary with its *extracellular* surroundings. One could look at the plasma membrane as the bag or sack that holds all the other parts. This is no ordinary "bag" though. Even the membrane surrounding the cell is specially designed to perform a lot of vital jobs. The cell membrane keeps some things in and keeps other things out, while letting some things travel across it and actively helping other things to pass through. The cell membrane is like the ultimate doorkeeper, and then some!



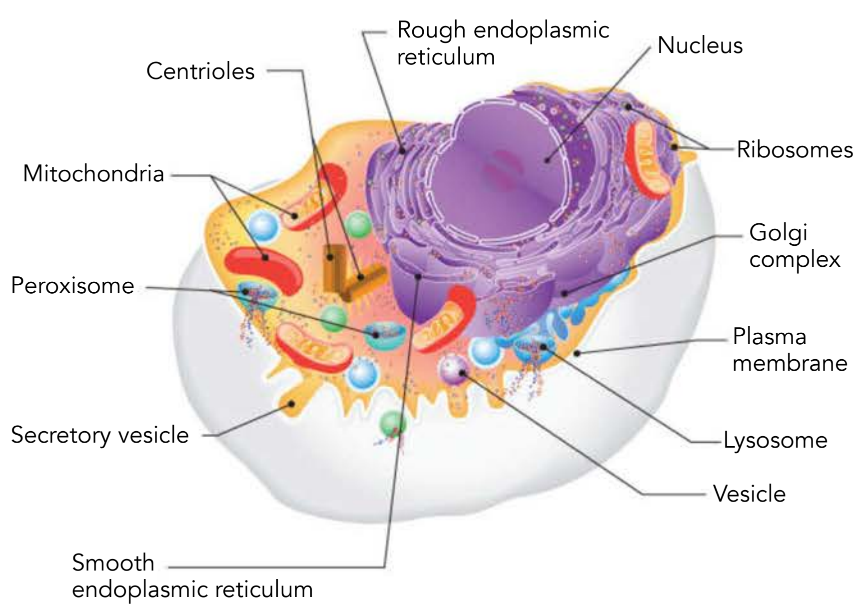
Electron microscopic view of cells

The control center of the cell is the *nucleus*. It directs the activities of the cell. The nucleus stores all the instructions the cell needs to function. These instructions are in code. The code is written into the structure of DNA, long chain-like molecules that are stored in the nucleus. The blueprint for making each protein the cell it is supposed to make is written in a *gene* in this DNA. Except for mature red blood cells, all cells in the body have at least one nucleus. Some have several *nuclei*.

In between the cell membrane and the nucleus, or nuclei, is the *cytoplasm*. All the parts of the cell that are not part of the nucleus or cell membrane are part of the cytoplasm. Many little "workstations" called *organelles* float in the *cytosol*, which is the cytoplasm's fluid. Dissolved in the cytosol are also many substances like sugars and electrolytes. (*Electrolytes* include sodium ions, potassium ions, calcium ions, and so forth. *Ions* are charged chemicals, and we'll learn later that the way they move into and out of cells is very important.) Large molecules such as enzymes also float around in the cytosol, each doing an important job.

TAKING A CLOSER LOOK

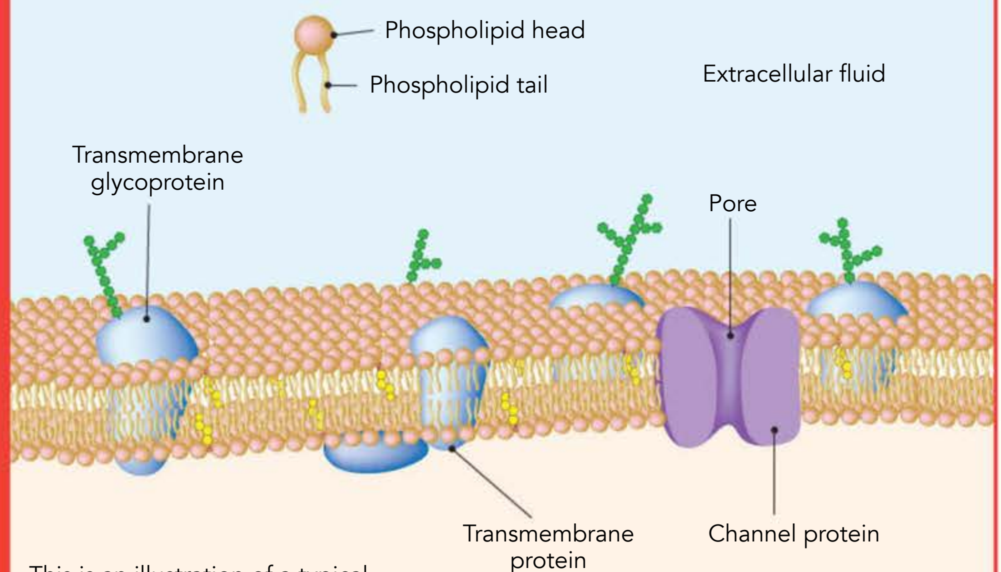
Human Cell Structure



The Plasma Membrane

TAKING A CLOSER LOOK

Plasma Membrane Structure



This is an illustration of a typical plasma membrane. It called a phospholipid bilayer.

The plasma membrane is the envelope that contains the other components of the cell. Within it is the cytoplasm, its organelles, and the nucleus. Without the plasma membrane, the cell would have no form or structure. The plasma membrane holds the cell together.

However, the plasma membrane is far more than just a container. It helps separate the two major fluid compartments of the body, the *intracellular fluid* — fluid inside cells — from the *extracellular fluid* — fluid that is outside cells. The plasma membrane is also involved in moving fluid, nutrients, and other substances into and out of the cell while forming a barrier to things that should stay out.

Most of the intracellular fluid and most of the extracellular fluid is water, but the concentration of the chemicals dissolved in them makes them very, very different. The chemicals dissolved in these fluids are "water soluble," which means they can dissolve in water. You probably already know that sugar and salt dissolve in water, and oil does not. Well, sugar molecules are water-soluble. Salts are made of ions, like sodium ions and potassium ions and chloride ions, and such salts are also water-soluble. Fats and oils, however, are not water-soluble: they do not dissolve in water. Another name for a fat is *lipid*.

Its Structure

The plasma membrane is actually made up of two layers of molecules. These molecules are called *phospholipids*, and they have a very interesting shape, as you can see in the illustration.

These molecules have what can be described as a "head" and two "tails." The "head" of the molecule is charged. This portion of the molecule is water-soluble (known as *hydrophilic*, a word that literally means "water-loving") and is therefore attracted to water. The tail portion is uncharged and avoids water (known as *hydrophobic*, a word that literally means "water-fearing"). These characteristics of phospholipids are important not only in the structure of the plasma membrane, but also for its function.

The plasma membrane is composed of these two layers of phospholipids, creatively called a *phospholipid bilayer*, which means "two layers of phospholipids." The phospholipid molecules are lying with the heads facing the outer and inner surface of the plasma membrane and the tails pointing to the interior of the membrane. The hydrophilic (water-loving) heads of the molecules are in contact with the watery fluid inside and outside the cells. The hydrophobic (water "fearing") tails are pointing toward each other, as far from the watery fluids as possible. This helps maintain the integrity of the membrane.

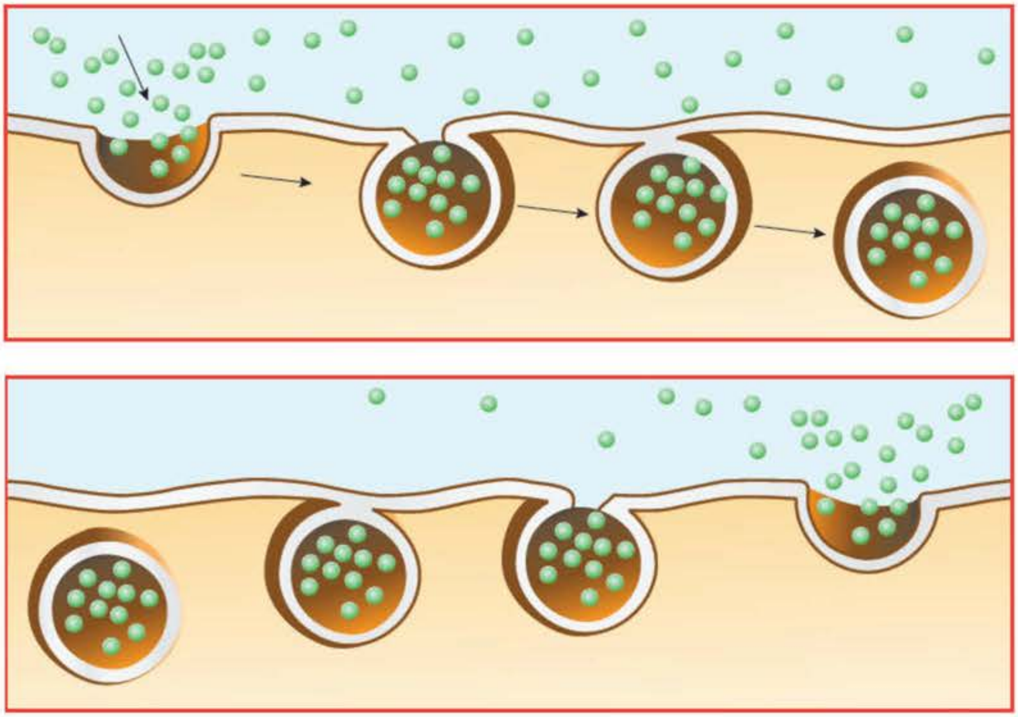
In addition to the phospholipids, the plasma membrane has a lot of protein molecules embedded in it. Some of these proteins extend completely through the plasma membrane. Some are only attached to its inner or outer surface. These proteins are vital to the normal function of the cell. Some of them ferry certain substances across the membrane. Some form a doorway allowing particular sorts of molecules to pass through. Some of them are like name tags that identify the cell to other cells. Some even form attachments to other neighboring cells.

Its Function

So beyond just holding the contents of the cell in one container, what is the function of the plasma membrane? Well, among other things, it helps regulate what goes into and out of the cell.

Some substances, like water and certain lipid (fat) molecules, can pass directly through the plasma membrane and get into or out of the cell. However, many other substances cannot easily get into cells. Often, these can gain access to the cell by means of some of the proteins in the plasma membrane. These special proteins have a channel in them to allow things into a cell that could not pass directly through the plasma membrane.

Some things, however, are too large even for protein channels. So in the case of the largest molecules, there is a special mechanism called *endocytosis*. In this case, a portion of the plasma membrane folds into the cell, surrounds the molecules needed, and then the membrane pinches off, forming a small bubble-like *vesicle*, which is then processed inside the cell. Occasionally this process is reversed and vesicles formed within the cell merge with the plasma membrane and release products made by the cell. The process of releasing material from inside the cell is called *exocytosis*.



Vesicles can transport material into and out of cells. During endocytosis, shown on top, material is transported into a cell by packaging it into a vesicle. Exocytosis is shown in the bottom illustration. There, a vesicle merges with the cell membrane and the material it contains is released.

Further, the plasma membrane is able to respond to cellular signals because of some of the proteins on its outer surface. These proteins bind to certain molecules that cause the cell to react in a specific way.

There are also special proteins on the outer surface of the plasma membrane that help identify the cell. In other words, these proteins are like an identification tag for the cell, so the body itself can know which cells are which. When we study the immune system, you will see this in action. So the plasma membrane isn't just any old bag, is it?

Cell Markers

The plasma membrane contains some special proteins called glycoproteins. These proteins have carbohydrate (sugar) groups attached that protrude into the extracellular fluid. These carbohydrate groups along with other special molecules called glycolipids form a coating on the cell surface known as the glycocalyx.

The pattern of the glycocalyx varies from cell to cell. It is distinctive enough that it forms a molecular "signature" for a cell. This is one way that cells can recognize one another.

Cytosol

Cytosol is the liquid found inside the cell. It surrounds the organelles and the nucleus. The *cytosol* plus the *organelles* make up the *cytoplasm*.

The cytosol is mostly water. Water makes up 70 to 75 percent of the volume of the cell. The cytosol contains many substances, and the cell works hard to maintain the appropriate balance of the substances found there.

There are lots of ions (charged atoms or molecules) in the cytosol, mostly potassium, sodium, chloride, and bicarbonate ions. These ions help maintain the electrical balance between the inside and outside of the cell (called the *membrane potential*, as we will explore later), as well as help maintain the correct water concentration inside the cell.

The cytosol also contains lots of proteins and *amino acids*. (Amino acids are the building blocks of proteins; we'll get more into that later.) These proteins and amino acids provide the raw materials for many of the activities of the cell.

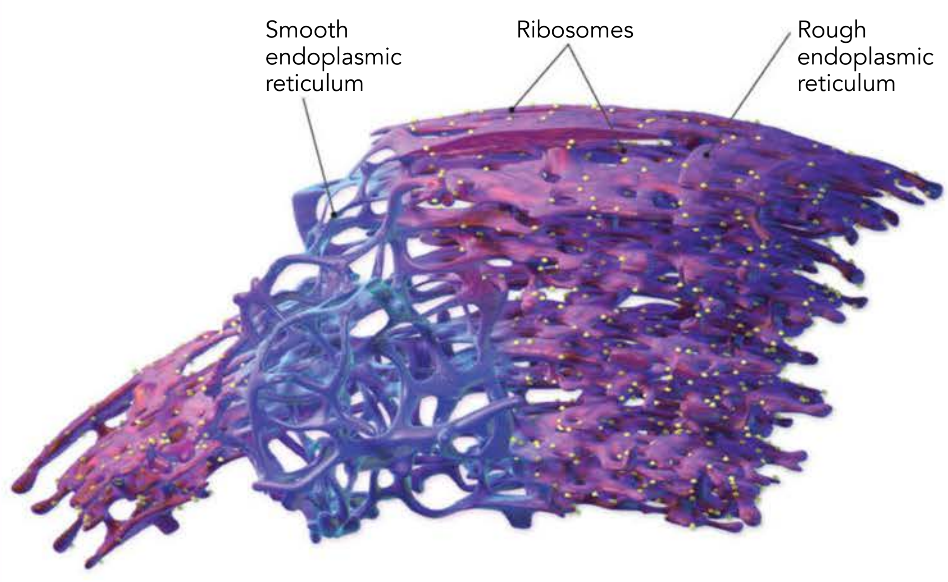
Endoplasmic Reticulum

The *endoplasmic reticulum* is a network of tubes and membranes that is connected to the nuclear membrane. The endoplasmic reticulum, or ER, comes in two forms, *rough ER* and *smooth ER*.

Rough ER is bumpy because it is covered with *ribosomes*. Ribosomes are little factories for making protein. Rough ER is primarily involved with protein production. Proteins that are made in the ribosomes can be modified by the endoplasmic reticulum to fit them for their particular jobs. The particular proteins and lipids that make up the plasma membrane are made in the rough ER.

TAKING A CLOSER LOOK

Endoplasmic Reticulum



Smooth ER is more tube-like in appearance and is not covered with ribosomes. It is more involved with production of fats, certain hormones, and the breakdown of some toxins that enter the cell.

Golgi Apparatus

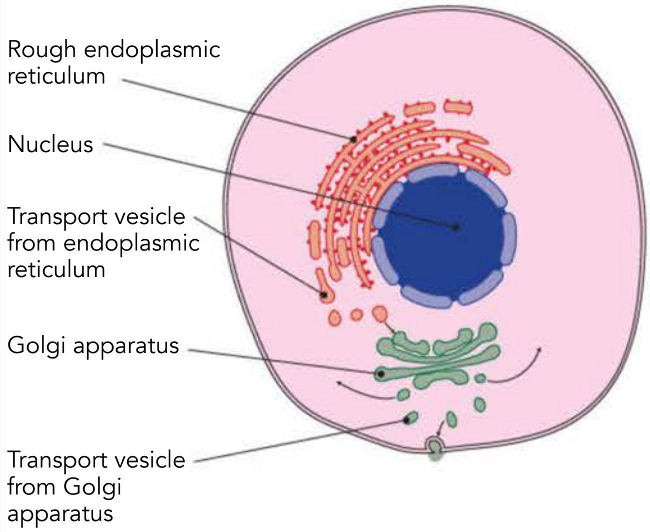
The Golgi apparatus is a collection of small flattened sacs that stack on one another. They tend to be flatter in the middle and more rounded on the ends.

Cells produce lots of things, especially fats and proteins. The Golgi apparatus helps the cell transport these products to where they are needed. It does this by forming little sacs, or vesicles, around the needed items. These vesicles pinch off from the Golgi apparatus and travel to their destination. Sometimes this is within the cell itself. Sometimes the vesicle moves to the plasma membrane and releases its contents outside the cell via *exocytosis*.

The Golgi apparatus is an exquisitely designed delivery system. Without it, the cell could not function.

TAKING A CLOSER LOOK

The Golgi at Work



Here we see vesicles carrying material from the rough ER to the Golgi apparatus. In the Golgi these materials are modified and packaged into new vesicles. Some of these vesicles then release material to the outside.

Lysosomes

Lysosomes are small vesicles containing enzymes that can digest many kinds of molecules and debris. This may seem surprising. After all, aren't these types of substances dangerous to the cell itself? Yes, they can be, but they are still very necessary.

Lysosomes break down worn-out organelles, bacteria, and toxic substances. For example, white blood cells contain a large number of lysosomes. That is how they are able to help rid the body of invading bacteria.

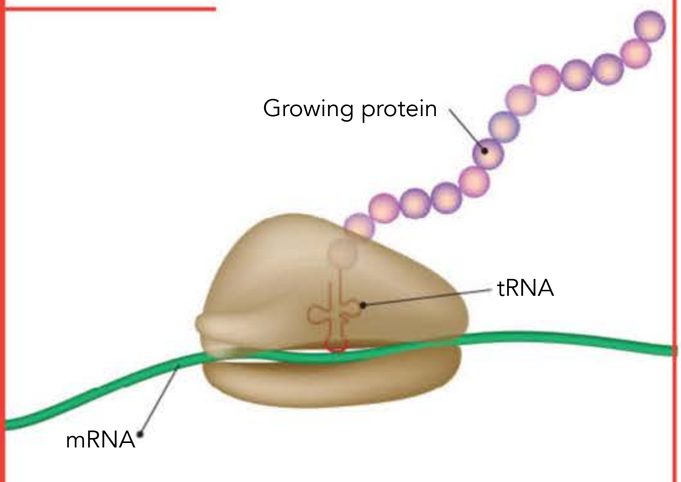
Lysosomes also aid the cell by breaking down substances the cell needs for nutrition, particularly large molecules the cell takes in. In fact, the lysosome is sometimes called the "stomach" of the cell. And by breaking down organelles that are worn out or no longer needed, the lysosomes recycle valuable materials.

Ribosomes

Ribosomes are found floating in the cytoplasm and attached to the rough endoplasmic reticulum. These are little structures, but they have a very big job. *Ribosomes* are where proteins are made. Let's consider where a ribosome gets its protein-building instructions.

You may remember that the nucleus of a cell directs the cell's activities. The instructions for what the cell is supposed to do are stored in the nucleus. The "blueprints" for how to build the proteins a cell is supposed to build are mostly stored in the nucleus. These "blueprints" or "recipes" for building proteins are called genes.

TAKING A CLOSER LOOK
Ribosomes



Genes with protein-building instructions are in the nucleus, but the protein-making ribosomes are located in the cytoplasm. How can the ribosomes get their instructions? Well, copies of the instructions, called *messenger RNA*, are made in the nucleus. Those messages move from the nucleus into the cytoplasm. There, ribosomes read the messenger RNA's instructions and build the protein described, stitching together a string of *amino acids*, which are the building blocks of proteins. The ribosome follows the "recipe" stored in the nucleus and copied onto messenger RNA.

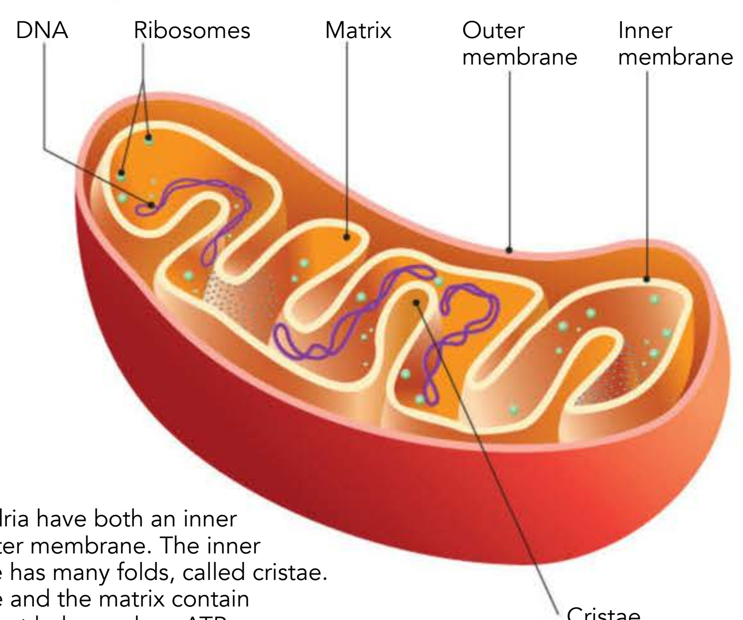
Mitochondria

The *mitochondria* are often called the "powerhouses" of the cell. They are called that because they generate and store energy. Mitochondria are like super battery chargers. These are elongated bean-shaped structures with lots of folded membranes inside. Unlike the other organelles in the cell, mitochondria even contain some genes used to reproduce themselves! (Remember, all the rest of the genes in your body's cells are stored in the nuceli.)

The mitochondria are responsible for producing high-energy molecules. Those high-energy molecules are like batteries: they store energy until the cell needs the energy for something. One of the most important high-energy molecules is ATP (which stands for *adenosine triphosphate*, if you want to show off to your friends . . .). This molecule stores energy needed to fuel cellular activities.

ATP is actually built from ADP, *adenosine diphosphate*. ADP is like a battery that needs to be recharged. And ATP is like a fully charged battery. As you might guess from the names *triphosphate* and *biphosphate*, ATP contains three "phosphates" and ADP contains two "phosphates." The bonds that hold phosphate onto ADP and ATP store a lot of energy,

TAKING A CLOSER LOOK
Mitochondria



Mitochondria have both an inner and an outer membrane. The inner membrane has many folds, called cristae. The cristae and the matrix contain enzymes that help produce ATP.

SO SIMPLE YET SO COMPLEX — Designed by the Master

Making Mitochondria

The nucleus is not the only place that DNA is found in the cell. Mitochondria have multiple copies of their own DNA. This DNA exists as a circular molecule containing 37 genes. Interestingly enough, mitochondrial DNA is inherited only from the mother. In addition, mitochondria contain RNA and ribosomes. During times of increased energy needs, the mitochondria can reproduce themselves to increase their number. They grow and divide by pinching in half.

much like a battery stores energy until it is needed. When energy is needed, a high-energy bond in ATP (or in other similar high-energy molecules) is broken and the energy released from it is used to power whatever the cell needs to do.

But where does the mitochondria get the energy to charge these chemical batteries? After all, you've learned before that energy cannot be created or destroyed but only transformed from one form to another. The fuel that provides the energy for the mitochondria's charging operation comes from sugar.

The process of providing energy to the cell is kind of like putting wood in a stove or putting gasoline in a car. Wood and gasoline are both fuels. The wood in the stove burns to make heat that can be used to cook food or heat your home. The gasoline in a car is burned by the engine and provides energy to make the car move. It is not all that different to make energy for a cell. The cell's favorite fuel is not wood or gasoline but the sugar *glucose*. The energy produced when it is *metabolized* — a sort of very controlled way of "burning" the fuel — must be captured and stored in chemical "batteries" like ATP.

Remember, think of ATP and ADP like rechargeable batteries. The primary fuel for cells is the sugar glucose. Glucose is taken into the mitochondria through a series of chemical reactions, and the molecule ATP is produced by recharging ADP with energy from glucose. Just as burning wood or gasoline depends on oxygen, this chain of chemical reactions in the mitochondria also requires oxygen (so thank your lungs here!).

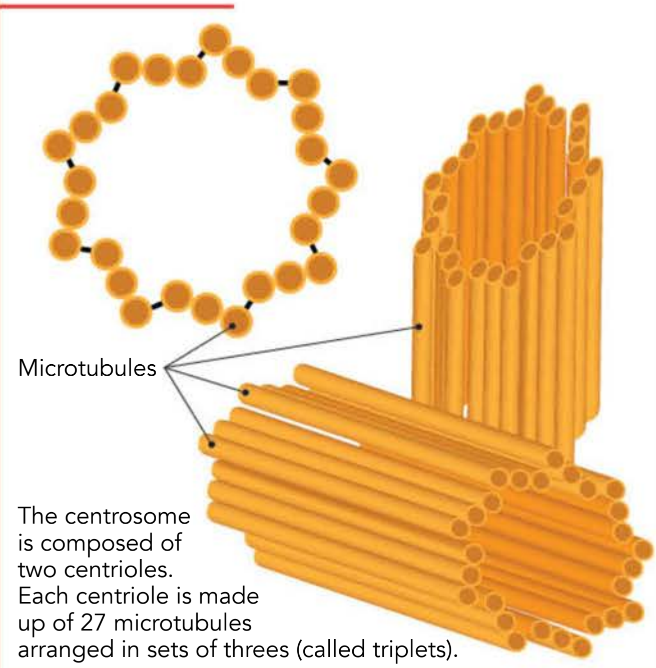
The number of mitochondria in a cell depends on the energy needs of the cell. Liver cells, for example, are involved in making proteins, making cholesterol and other lipids (fats), making and secreting bile, and many other things. So you may well imagine that it takes lots of energy to perform all these functions. In fact, a liver cell can have as many as 2,000 mitochondria!

Centrosome and Cytoskeleton

You might ask yourself, "What keeps all this stuff in place?" Well, there is an answer! The cell has a sort

TAKING A CLOSER LOOK

Centrosome



The centrosome is composed of two centrioles. Each centriole is made up of 27 microtubules arranged in sets of threes (called triplets).

of skeleton, called a cytoskeleton, that helps with that task. This cytoskeleton is composed of a network of tubes and filaments that run throughout the cell. Though not pictured in most diagrams of cells, these fine tubes and filaments provide support for the organelles.

But this support system does more than just hold things in one place. Along with the cytoskeleton, there are special motor proteins that help organelles move around. Mitochondria, lysosomes, and vesicles all move around the cell with the help of these amazing structures.

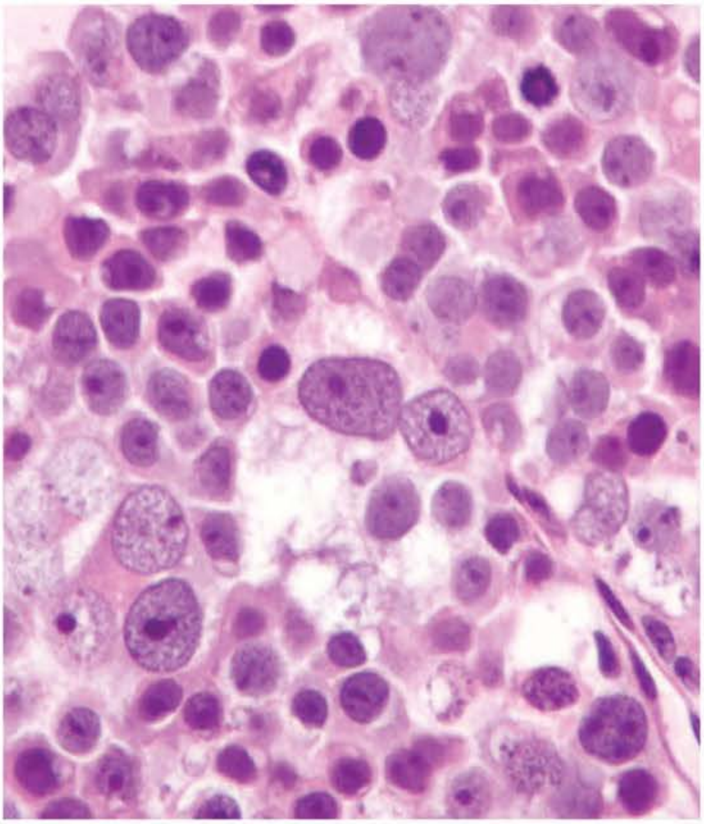
Another very special organelle, called the *centrosome*, is necessary for cellular reproduction. After all, most kinds of cells wear out and must therefore reproduce, or duplicate, themselves. We'll go into the complex process of how a cell divides in two later.

Sometimes it seems like all the action is in the nucleus when we talk about cell division. But if it weren't for the centrosome, which is located outside the nucleus in the cytoplasm, cellular reproduction would be a disorganized chaotic mess. Nothing would end up in the right place!

The centrosome is an L-shaped structure made up of two barrel-shaped *centrioles*. These centrioles are responsible for helping form a complex of *microtubules*, called the *mitotic spindle*, which guides the cell's chromosomes during cell division.

Nucleus

The nucleus is the control center of the cell. Stored in the DNA (deoxyribonucleic acid) in each cell's nucleus are the genetic instructions needed to make all the proteins in the body. The genes — the little recipes for building proteins — and even the regulations that determine how and when those genes are to be used are part of the DNA. The nucleus regulates the types of proteins made by its cell and their



Micrograph of a spermatocytic seminoma

amounts. Even though the nucleus contains a copy of your entire *genome*, only the information needed by each cell type is ever turned on and used.

The majority of cells have one nucleus. However, there are exceptions. Skeletal muscle cells (and a few other cell types) have more than one nucleus, and mature human red blood cells have none.

Just as the cell has a cell membrane, so the nucleus has a *nuclear membrane*. You recall that messages — in the form of messenger RNA — must pass from the nucleus into the cytoplasm to deliver instructions to the ribosomes. Did you wonder how the message gets through? Well, the outer part of the nuclear membrane connects to rough endoplasmic reticulum. Through tiny pores in the nuclear membrane, substances can pass from the nucleus into the cytoplasm. That way the instructions from the nucleus can reach the cytoplasm where they can be implemented.

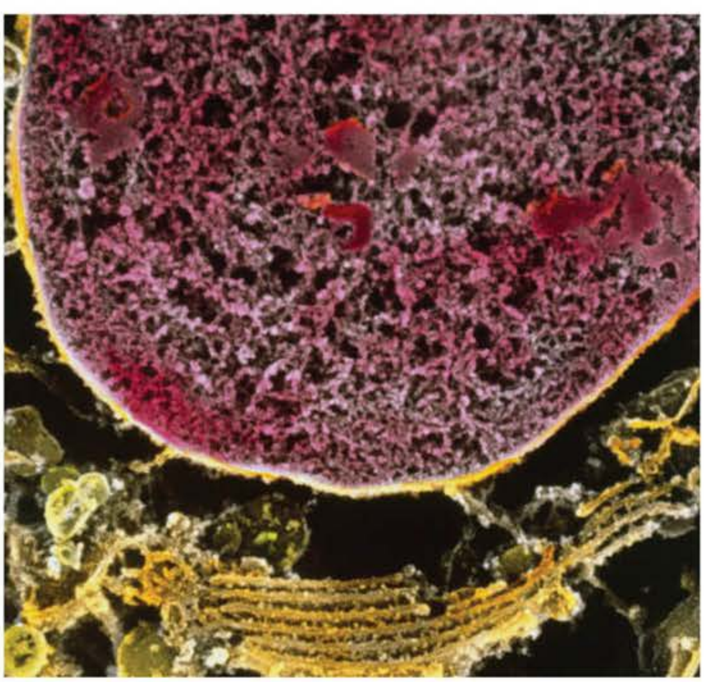
DNA

DNA — deoxyribonucleic acid — is one of the most amazing molecules in the universe. In your DNA is contained all the information needed to make your body!

DNA is a big molecule made up of two long strings of smaller molecules called *nucleotides*. There are four different kinds of nucleotides present in DNA. These four nucleotides are the building blocks of DNA. Two long strands of nucleotides are attracted to each other and form a structure that looks like a twisted ladder. That structure is called a *double helix*.

So what is so amazing about long strings of chemicals?

Well, it turns out that the order in which the nucleotides are found in DNA is very, very important. Those four nucleotides in DNA aren't just DNA's building blocks. They are the "letters" in a code — the genetic code of life that is used not only in the human body but in all the living things God designed!



Colored high resolution scanning electron micrograph of the nucleus and rough endoplasmic reticulum of a primordial testis germ cell.

You see, DNA is not just a string of chemicals. It is a very complex system of information! For decades now, scientists have studied the "letters" and "words" in the DNA and how they work.

Imagine each nucleotide as a "letter." Three "letters" form a "word." And a group of "words" can give coded instructions for building a protein or even for regulating how those instructions are carried out. The DNA in a human cell contains over 3 billion nucleotides. The instructions coded in your DNA determine which proteins can be made.

Each section of DNA that has the information for a particular protein is called a "gene." Another way of looking at this is to think of a certain group of nucleotide "words" combining to make up a genetic "book." Other sets of nucleotide words make up other books, and so on.

TAKING A CLOSER LOOK

DNA

DNA is made of four different nucleotides

- Adenine
- Thymine
- Cytosine
- Guanine

A simplified view of the structure of DNA. You see it does look like a twisted ladder. This type of structure is called a double helix.