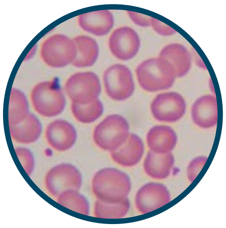
UNIT 1

THE MUSCULOSKELETAL SYSTEM

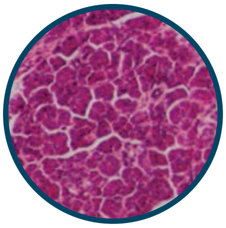
wonders of the HUMAN BODY

CELLS

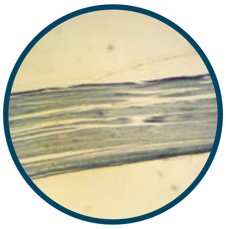
The cell is not only the basic building block of the body but also the basic "functional unit." What does that mean? Well, your body does a lot of things — some things you see and some that you don't. It moves. It grows. It digests food, turning some of it into energy, storing some of it, and discarding 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

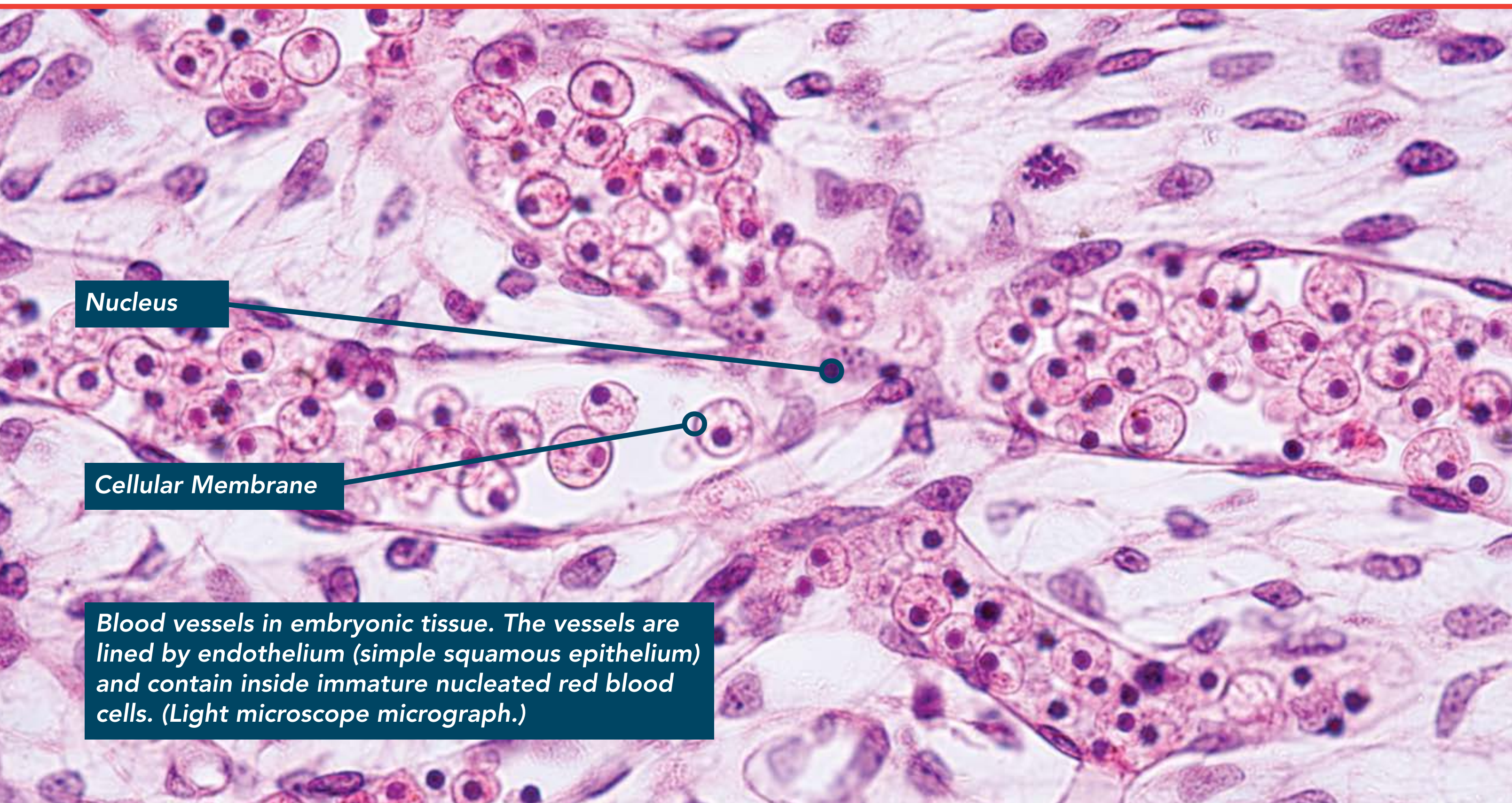


Liver Cell



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.

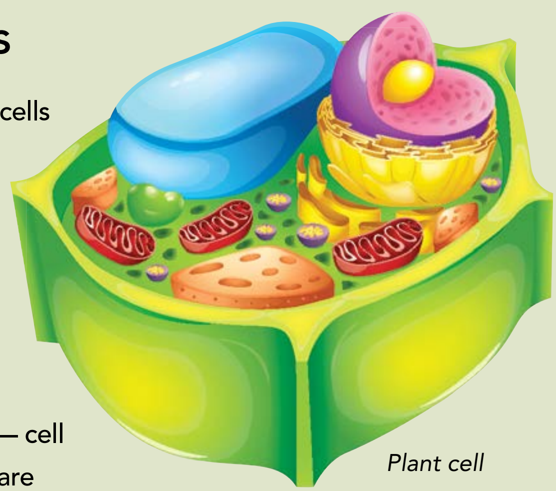
Each muscle cell is designed to contract, and you can move because muscle cells work together. Certain cells in the pancreas produce *insulin* that controls the amount of sugar in your blood, because either too much or too little is bad for you. Nerve cells transmit nerve impulses so that one part of 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

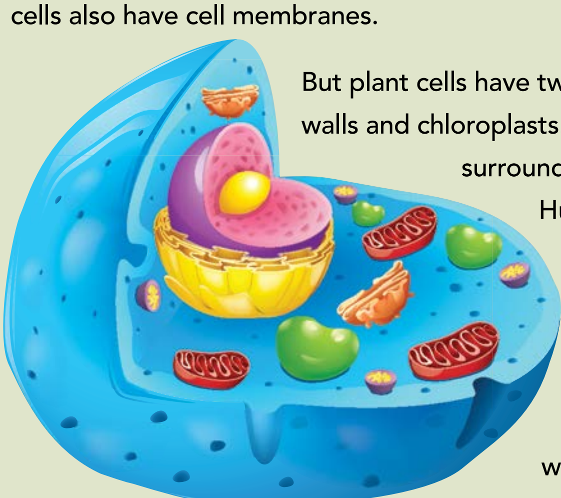
Human Cells and Plant Cells

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

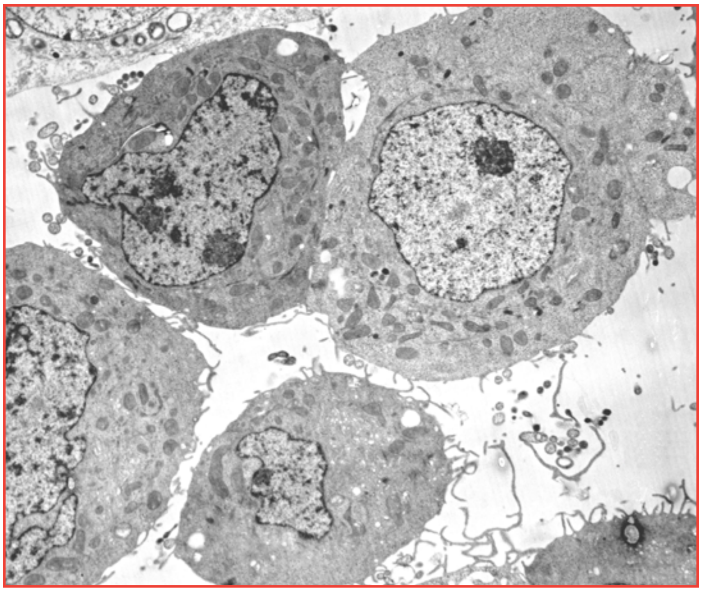
But plant cells have two things our cells lack — cell walls and chloroplasts. Plant cell membranes are surrounded by a tough cell wall made of cellulose. Humans cannot make cellulose. The cell wall provides a sturdy support for plant cells and helps maintain their shape. Plant cells, unlike our cells, 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!



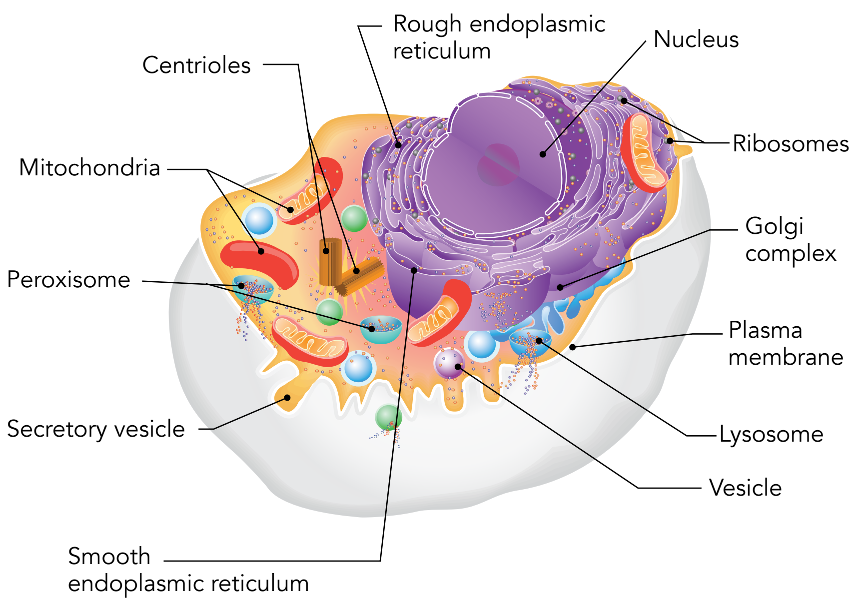
Electron microscopic view of cells

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

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.

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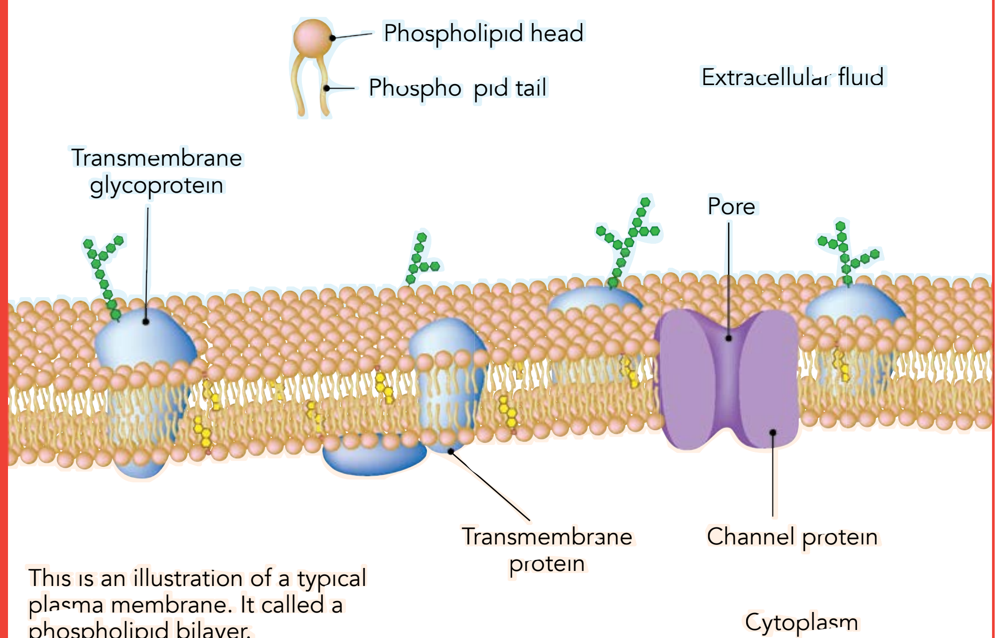
Plasma Membrane Structure



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

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.

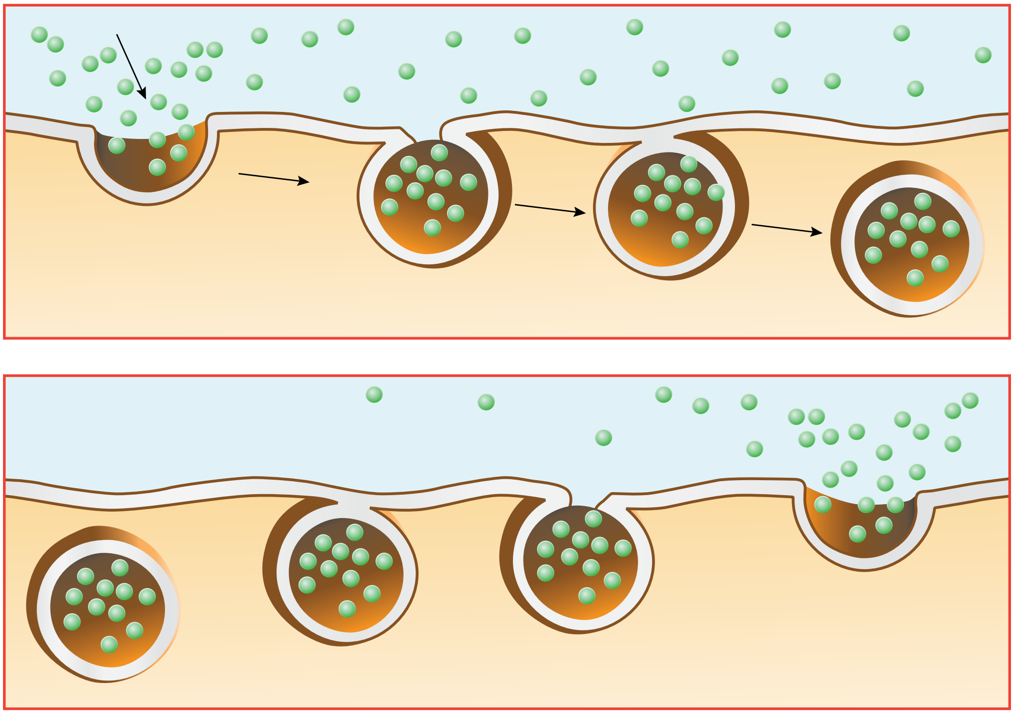
In addition to the phospholipids, the plasma membrane has a lot of protein molecules embedded in it. Some of these proteins extend completely through the plasma membrane. Some are only attached to its inner or outer surface. These proteins are vital to the normal function of the cell. Some of them ferry 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.

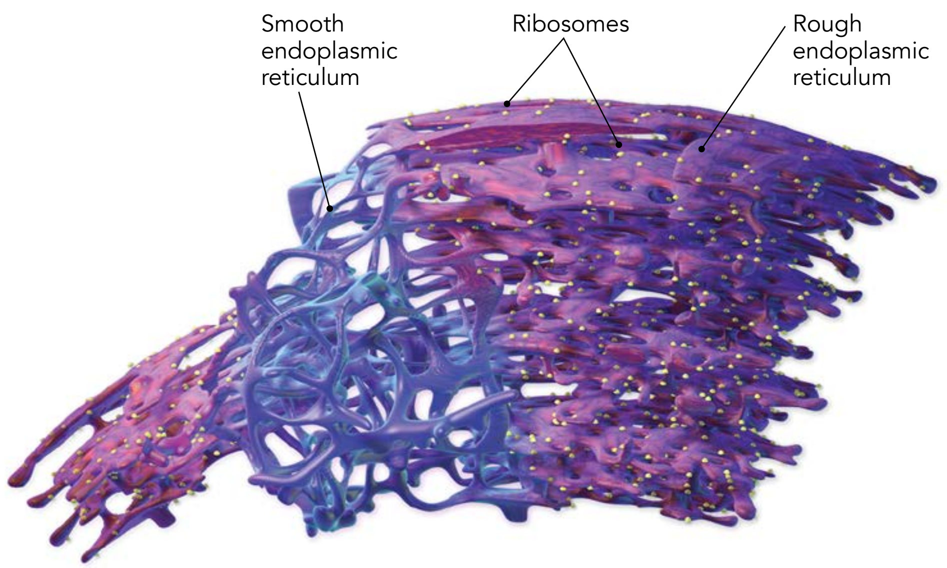
Endoplasmic Reticulum

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 break-down of some toxins that enter the cell.

Golgi Apparatus

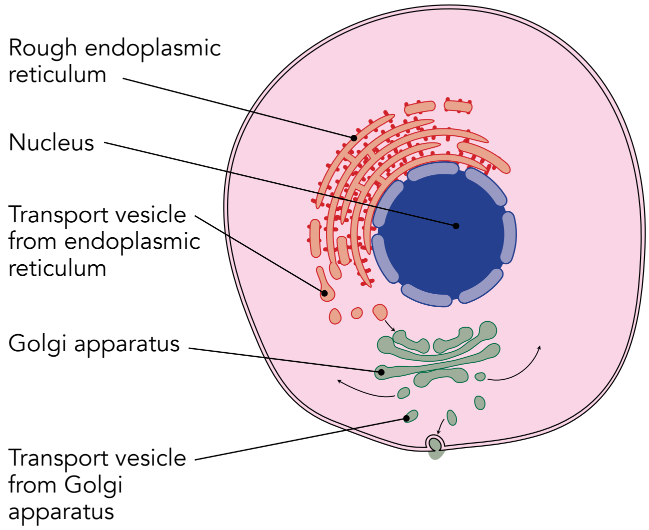
The Golgi apparatus is a collection of small flattened sacs that stack on one another. They tend to be flatter in the middle and more rounded on the ends.

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.

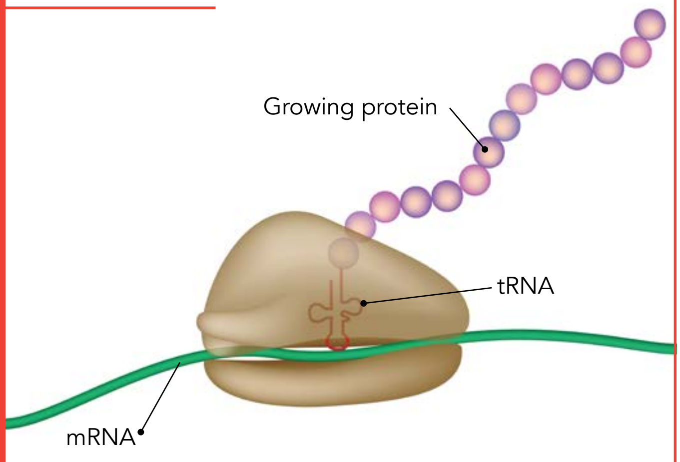
Ribosomes

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

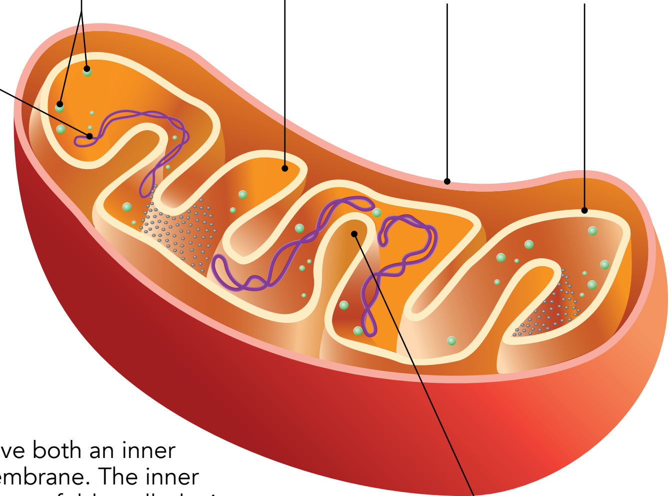
The *mitochondria* are often called the "powerhouses" of the cell. They are called that because they generate and store energy. Mitochondria are like super battery chargers. These are elongated bean-shaped structures with lots of folded membranes inside. Unlike the other organelles in the cell, mitochondria 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

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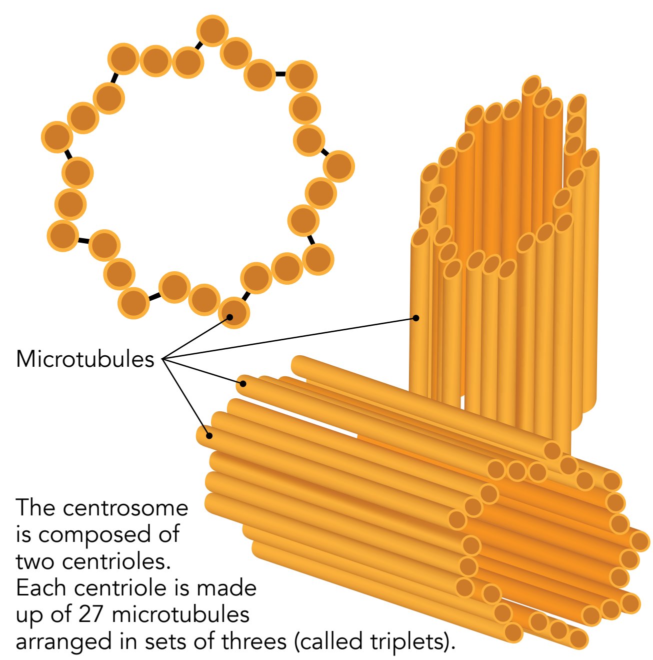
Centrosome



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.

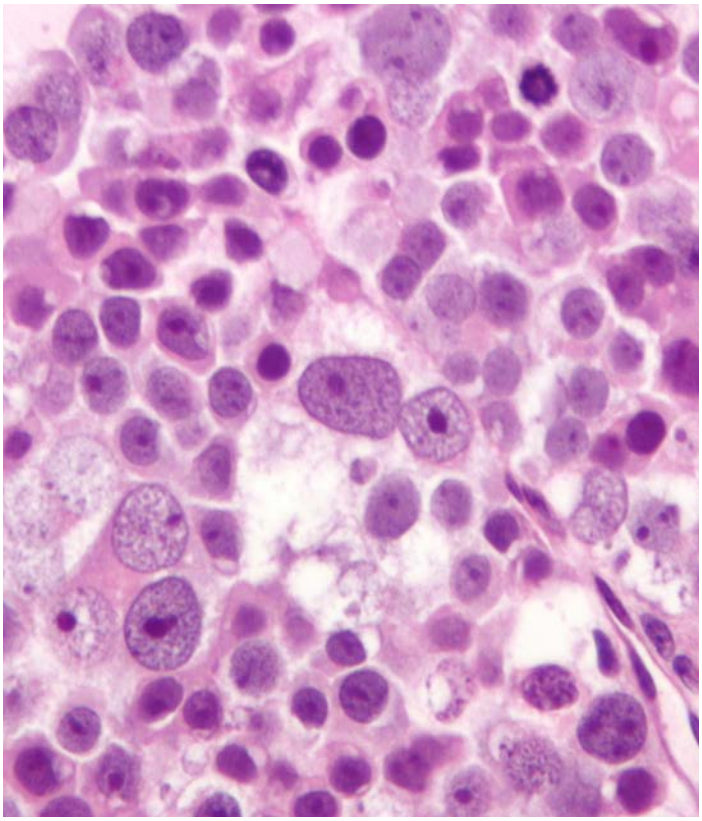
Another very special organelle, called the *centrosome*, is necessary for cellular reproduction. After all, most kinds of cells wear out and must therefore reproduce, or duplicate, themselves. We'll go into the complex process of how a cell divides in two later.

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 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.



Micrograph of a spermatocytic seminoma

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.

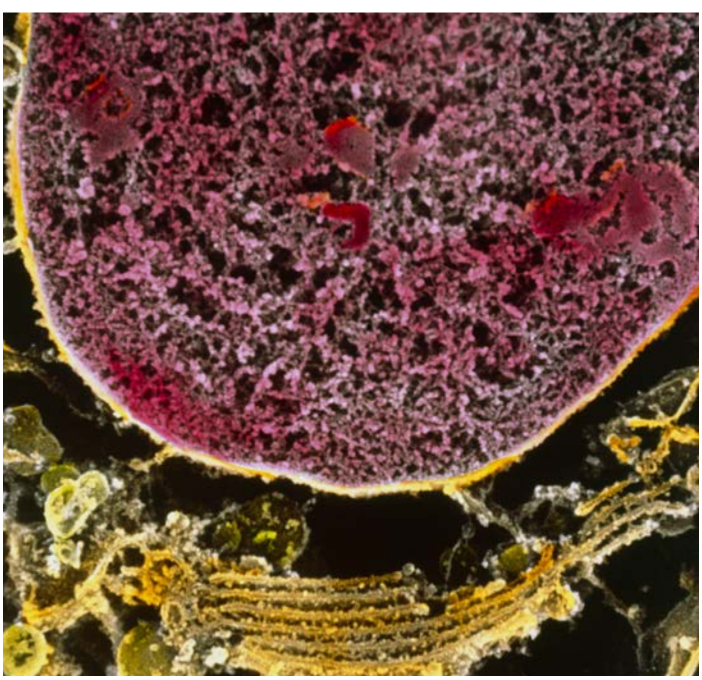
DNA

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.

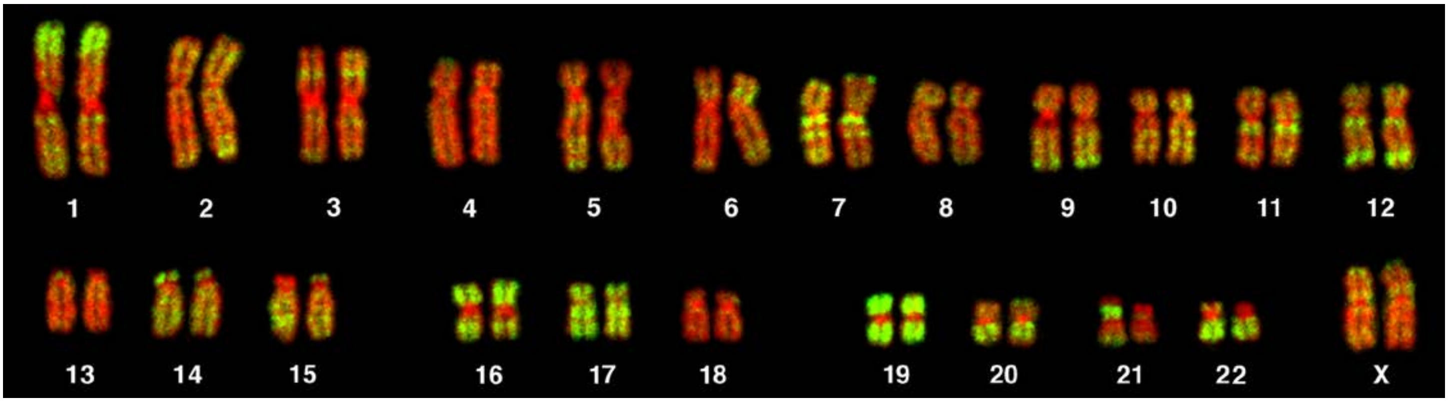
TAKING A CLOSER LOOK

DNA

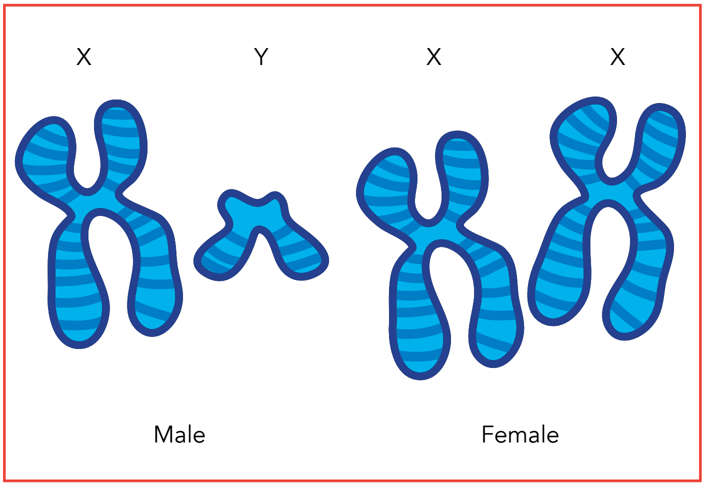
DNA is made of four different nucleotides

- 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.



This is a picture of a person's chromosomes. As you can see, humans have 23 pairs of chromosomes. The autosomal chromosomes are numbered according to their length. Number one is the longest and number 22 is the shortest. The remaining pair are the sex chromosomes.



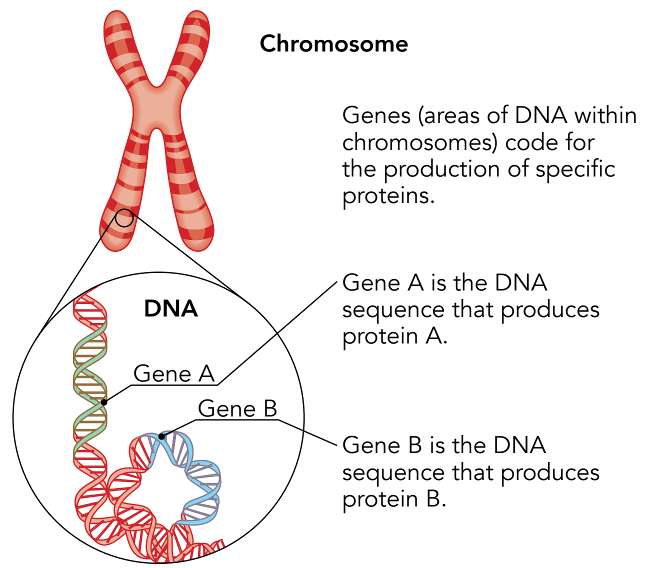
The sex chromosomes determine whether a person is male or female. A person who has an XY pair is male. Those who have an XX pair are female.

However, DNA also contains coded instructions for other things, like the directions for what kind of cell each cell is supposed to be or how busy it is supposed to be. Some scientists have claimed that the DNA that didn't code for proteins was leftover evolutionary junk with no purpose. Bible-believing scientists know that evolution did not create life, DNA, or the human body. Therefore, these scientists predicted that none of our DNA was evolutionary "junk." Now, scientists have begun finding that "junk" DNA really does have a purpose. The double-helix structure of DNA was discovered in 1953, but scientists are just beginning to figure out how much coded information is contained in each molecule of DNA.

So each strand of DNA is made up of many, many genes. Each gene gives the instructions for building a protein. Proteins are built out of amino acids. Proteins are a kind of biological molecule, and they do much of the "work" in your body. Lots of molecules you may have heard of are proteins. *Enzymes* that perform all the chemical reactions in your cells, *antibodies* that fight infectious invaders, *taste receptors* in your tongue, *collagen* that holds much of your body together, the *actin* and *myosin* molecules that make your muscles contract, the *clotting factors* that make your blood clot, and the transport proteins and identification proteins embedded in your cell

TAKING A CLOSER LOOK

Genes and Chromosomes



membranes are all proteins. Each and every protein molecule must be built in a cell, following the instructions from the nucleus.

Each double helix molecule of DNA is carefully organized and packaged into a chromosome. Each *chromosome* is like a section of a huge library where lots of books are stored. A chromosome consists of DNA — like the books — and special proteins that help package it and take care of it — like "shelves." Human beings have 46 chromosomes in each of the body cells.

The DNA in one of your cells would be about 6 feet long if it were stretched out. In just this tiny strand of DNA is contained enough information to fill hundreds of books, and the DNA in just one of your cells contains the coded information to build your whole body!

DNA at Work

So what exactly does DNA do?

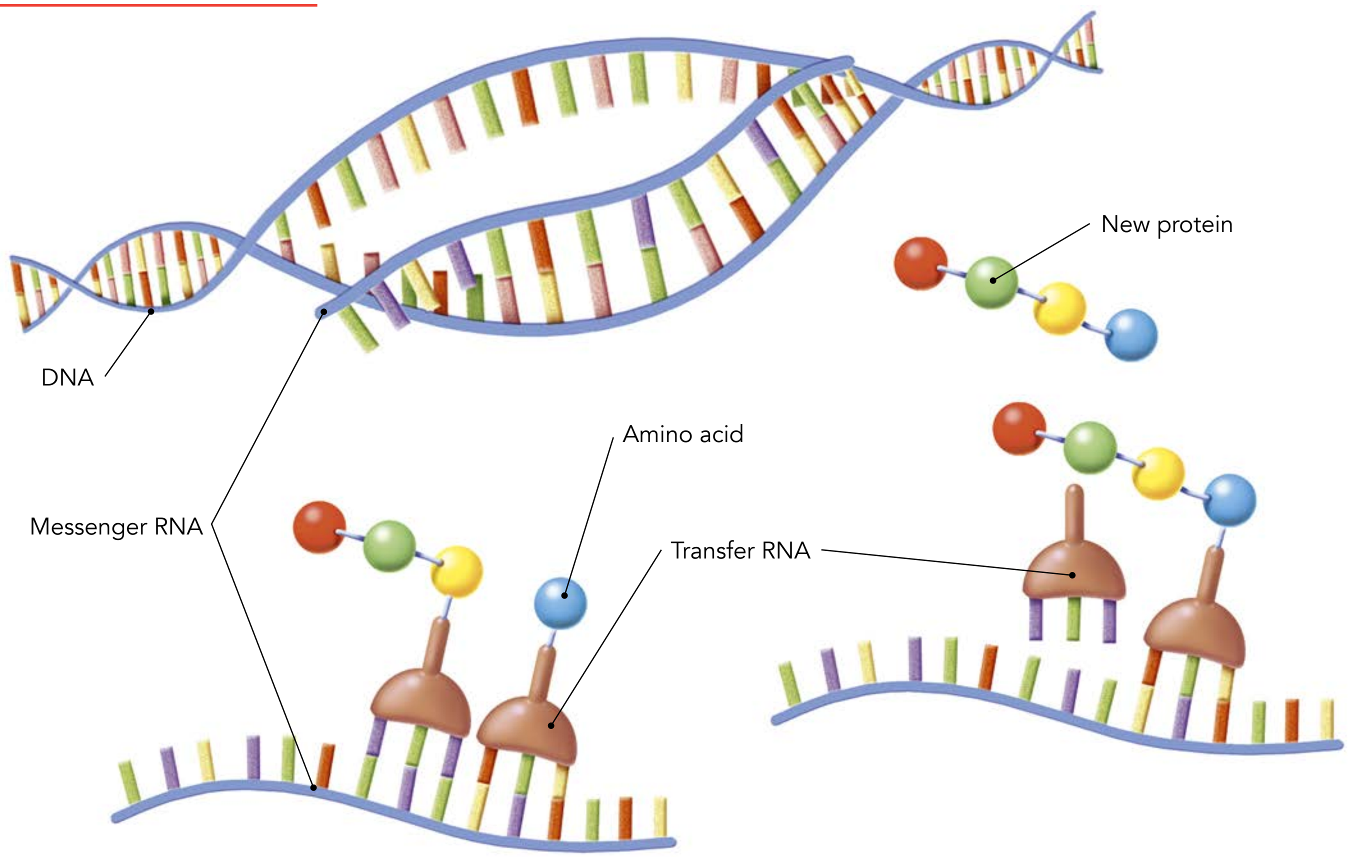
DNA Can Make Proteins

We said that DNA was more than just a string of molecules. It is a complex system of information. This information is used primarily to make the proteins in our body.

Proteins are one of the most important substances in the body. Proteins are made up of long chains of molecules called *amino acids*. For proteins to function properly, the order of these amino acid building blocks must be correct. So there must be a very precise process to make proteins.

TAKING A CLOSER LOOK

Building a Protein



The process of protein making is incredible. DNA uncoils and exposes the gene that contains the necessary instructions. Then the particular segment of the DNA "ladder" that contains the information about the protein splits to expose its nucleotides. (Remember the "words" and "letters"!) Then these nucleotide "words" are read and a special molecule is made. This special molecule is called messenger RNA (mRNA). The mRNA takes the information from the DNA and leaves the nucleus through the pores in the nuclear membrane. Outside the nucleus, the mRNA connects to ribosomes.

Once they're on a ribosome, the mRNA is "read" by another type of RNA, called *transfer RNA* (tRNA). Each kind of tRNA carries the code for a particular amino acid and an attachment for that amino acid. As each segment of the mRNA is read, the tRNA brings the correct amino acid, in the correct order, and the protein is assembled. The ribosome stitches together each protein, folding it carefully so that it will work just right.

What Is "Junk DNA"?

Only a small portion of our DNA actually contains the information that codes for proteins. So what, then, is the purpose of the rest of our DNA?

Many scientists over the last few decades have felt that if any portion of DNA did not actually code for proteins, it had no purpose. For that reason, many scientists began to refer to this part of our DNA as "junk DNA." They felt that these useless regions of DNA were merely left over from our evolutionary past.

However, in recent years, it has been shown that junk DNA is not junk at all. These regions of our DNA are quite active and serve many functions, such as helping switch genes on and off. Every day, researchers are discovering more about how "junk DNA" actually works!

You see, our Master Designer does not make "junk!"

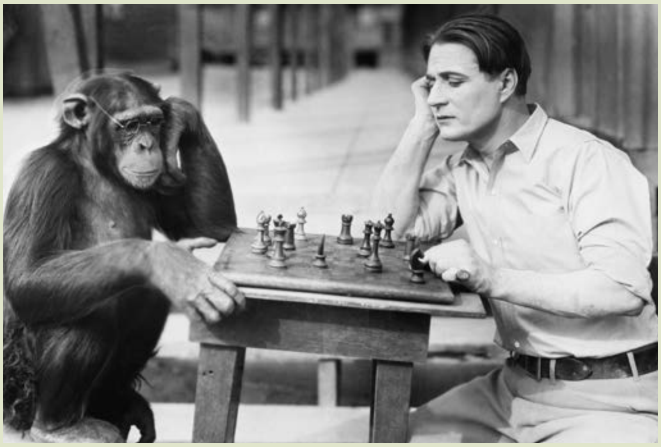
Do Humans and Chimps Have Similar DNA?

It is often said that the DNA of humans and chimps are 98 percent alike. This popular notion has been repeated and repeated so often that most people believe it to be true. Many scientists promote this idea to support their mistaken idea that humans and chimps evolved from a common ancestor a few million years ago. This supposed similarity in DNA is used as "proof" of an evolutionary link between humans and chimps.

Actually, when you really examine the data, you find that the similarity between human and chimp DNA is more like 70 percent. It is nowhere near the 98 percent that some people claim.

Even though there is a 70 percent similarity, that 30 percent difference means an awful lot. Between humans and chimps there are millions and millions of sequences in the DNA that are different. That is obvious as humans and chimps are distinctly different creatures.

So how can we explain the 70 percent of our DNA that is similar to the chimp's? This is simple for the Christian. We understand that all living things have a common Designer, not a common ancestor, as evolution would suggest. This amazing Designer would allow for many design similarities in the creatures he created. These similar features would be reflected in similarities in our DNA.



This process occurs thousand of times each second, and countless proteins are made in our cells each day.

If that were all DNA could do, it would be amazing. But there's more. . . .

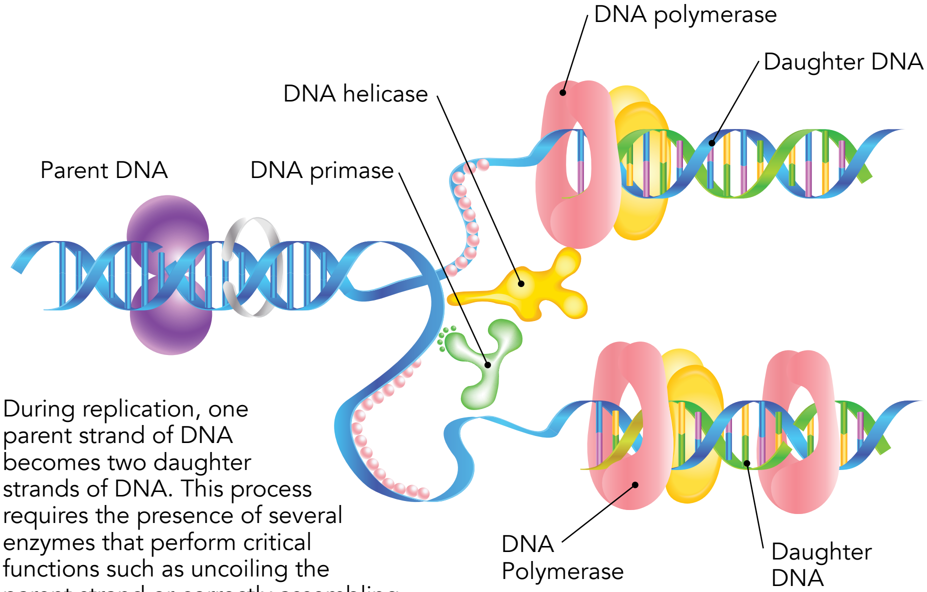
DNA Can Make DNA

Well, DNA is able (with the help of a series of proteins and enzymes) to reproduce itself. By doing this, the information contained in the DNA can be passed on when the cell divides.

It works like this.

TAKING A CLOSER LOOK

DNA Replication



During replication, one parent strand of DNA becomes two daughter strands of DNA. This process requires the presence of several enzymes that perform critical functions such as uncoiling the parent strand or correctly assembling nucleotides to make the daughter strands.

You have seen that DNA looks sort of like a twisted ladder. When it is time for a cell to divide, the membrane around the nucleus temporarily dissolves and the DNA duplicates itself.

First, the DNA in each chromosome uncoils. Then it splits into two strands (almost as if the rungs of the ladder were split in two). With the help of a special set of enzymes, each strand of DNA is copied. When the process is finished, there are two complete sets of chromosomes where there was one set before. Each set of chromosomes is then placed in the newly formed nucleus of a new "daughter cell."

How Cells Divide

While we are on the subject, let's take a closer look at how cells divide. After all, we continually need more cells as we grow and worn-out cells need to be replaced. How does this happen? Let's explore the cell cycle and see how this works! The *cell cycle* is sort of like the life cycle of a cell. There is a time for a cell to focus on its job, whatever that happens to be. And then for most kinds of cells there is a time for it to copy itself and become two "daughter cells."

The part of the cell cycle when a cell is not actually splitting into two cells is called *interphase*. That's when a cell simply does its job, or jobs. During this time, most of the protein-making activity of the cell occurs. The substances that the cell makes for the body's use are manufactured during interphase. Also, during interphase more organelles are made so that there are enough to supply both daughter cells after division. Near the end of interphase, the cell prepares to divide. The DNA in the nucleus duplicates during this part of interphase. For a short period of time, then, the cell has twice its normal amount of DNA — 46 *pairs* of chromosomes rather than just 46 chromosomes! Because these duplicated chromosomes are stuck together, we often use another name to describe them here — a *chromatid*. A chromosome and its copy, stuck together, is called *a pair of sister chromatids*. Remember, the DNA gets duplicated during interphase so that it is all ready to be split between the two new cells that will be formed during cell division.

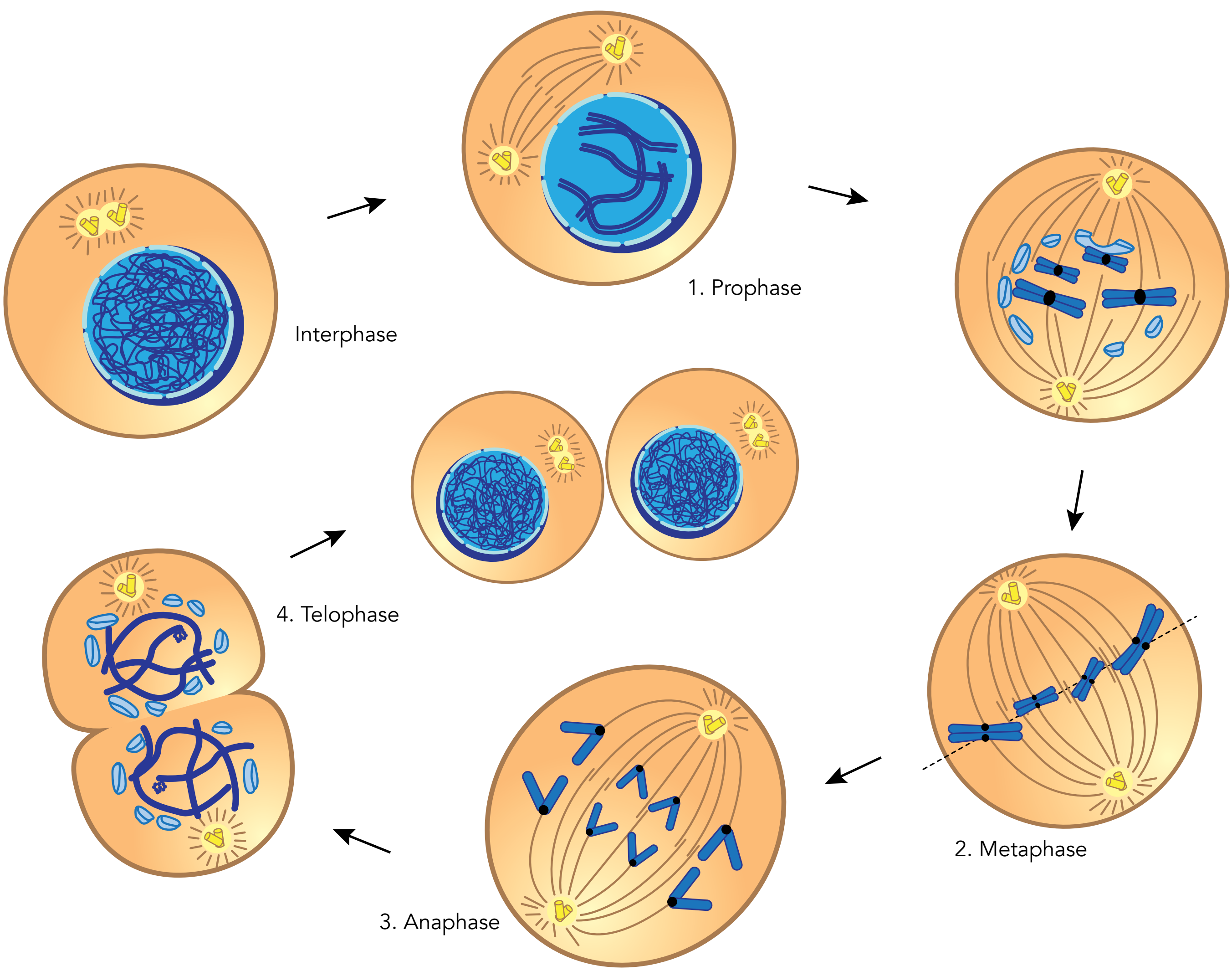
The part of the cell cycle that is directly involved with dividing the cell into two daughter cells is called *mitosis*. So the working phase of a cell's cycle is interphase, and the dividing phase of a cell's cycle is mitosis. Mitosis can be broken down into four steps, called phases (wouldn't you just know it . . .). We will examine each in turn.

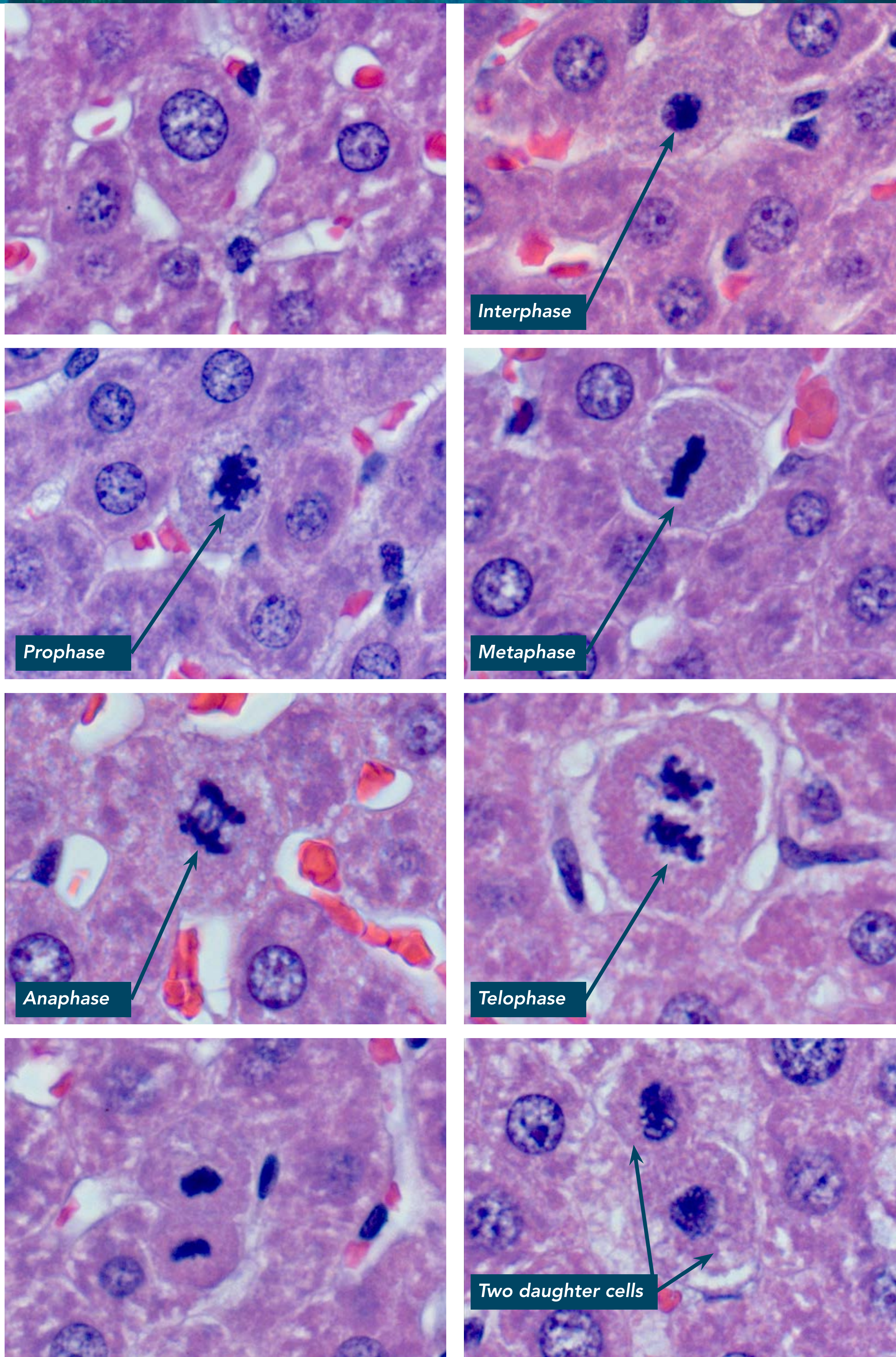
The first phase of mitosis is called *prophase*. Remember that the DNA gets duplicated before interphase is over. That DNA is a tangled mess like spaghetti, however, and it must be sorted out before the chromosomes can be assigned to each daughter cell. During prophase, the DNA coils and tightens, or *condenses*, so that the chromosomes are dark enough to be visible under a microscope.

Remember the centrioles in the cytoplasm? Well the membrane around the nucleus dissolves, allowing

TAKING A CLOSER LOOK

Mitosis





Hepatocytes (liver cells) undergoing mitosis the centrioles to build a scaffold on which the chromosomes can be organized. The centrioles separate, moving to opposite ends of the cell. A series of microtubules form and anchor to the centrioles. These microtubules attach to the duplicated chromosome pairs — *the sister chromatids* — and begin moving them to the center of the cell.

When all the chromosomes, traveling along the microtubules strung between the centrioles, arrive at the center of the cell, the cell is in *metaphase*. Metaphase is the second phase of mitosis.

The third phase is called *anaphase*. This is the shortest phase of mitosis. At this time, the sister chromatids are pulled apart, each chromatid, or chromosome, moving to opposite ends of the cell. Anaphase ends when the chromosomes reach opposite poles of the cell. Now there is a complete complement of genetic material, enough for one new cell, gathered together. Because the sister chromatids stayed attached to each other until they were all lined up in the middle, and then were pulled apart in opposite directions, each daughter cell should contain identical copies of the genes in the original "parent" cell.

The final phase of mitosis is called *telophase*. During this phase, the chromosomes uncoil and become much less visible. New nuclear membranes form at each end of the cell, encircling the group of chromosomes. Thus, for a brief time the cell has two nuclei (each identical to the original nucleus in the parent cell). Then the cell pinches off in the center, forming two daughter cells.

Moving On . . .

So we have taken a look at the cell and its parts. It is difficult to imagine how people can call the cell "simple," because it certainly isn't. As we continue our journey exploring the human body, there will be many examples of the complex functions performed by cells.

So Simple Yet So Complex — Designed by the Master

Is DNA Just an Accident?

Many people think so. One common evolutionary belief is that millions of years ago, DNA just formed itself from chemicals, building the complex DNA molecule itself as well as the complex coded messages in it.

You see, many people believe that millions of years ago there was no life on earth. They believe earth's oceans were full of chemicals that, all by themselves, formed the nucleotides from which DNA is made. Then they believe DNA assembled itself from the nucleotides. Yep, they believe that strands of DNA, millions of nucleotides long, just came together . . . in exactly the right order . . . by chance.

But even if that could happen — and nothing in science has ever discovered any way that it could — the evolutionary story still wouldn't make sense. After all, DNA is not just a string of chemicals; it is a very complex information system. So even if DNA could have assembled itself, where did the coded language contained in the DNA come from? Without a source of information and a language code to record that information, the nucleotides in DNA really would just be a string of nonsensical chemicals. You see, information does not come from matter. Information only comes from a higher source of information. And who is the highest source of information?

DNA is not the result of random chance processes. It is another testimony to the magnificent Creator God, the source of all information.