# Lesson 2: Cells

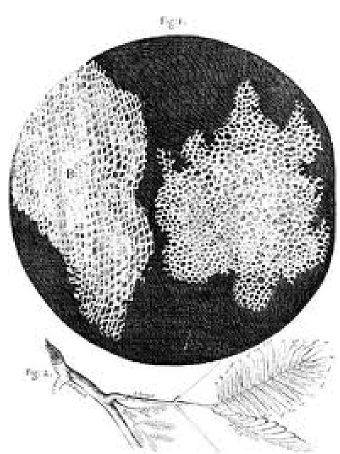
Take a look the world around you. As you look around, you will see many things that are alive. You probably know that people and animals are alive, and you might also know that plants are alive. What makes these things, and many other things, alive? There are actually many hints that tell us something is alive. One thing that is true about all living things is that they all have tiny structures called cells.

This tree, like all living things, is made of cells.

**Cells** are the smallest objects that can do all the things needed for life. Some people call cells the "building blocks" of life. If you've ever played with blocks, you can understand why people say this. When you play with blocks, each block gets put together to make giant towers, castles, or whatever else you can imagine. Cells get put together to make apple trees, elephants, or whatever other living thing you can imagine!

## How Were Cells Discovered?

Imagine if you took a rocket to another planet that nobody had ever been to, and saw things there that nobody else had ever seen. Can you imagine the feeling of excitement when you described what you discovered to everyone? About 450 years ago, a scientist named Robert Hooke got to do something kind of like that. Hooke took some cork (which comes from plants) and sliced it so it was very thin. Then he put the thin slice of cork under a microscope. Microscopes help people see things that are too small to see with just your eyes. When Hooke looked at the cork, he saw some things that looked like little boxes, or rooms. He called these things cells.



When Hooke looked at the cork, he saw little boxes.

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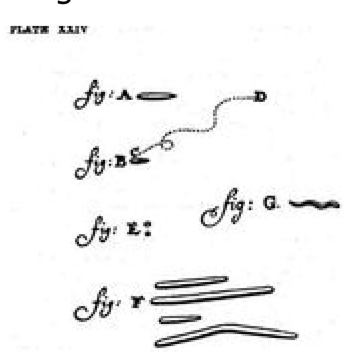
He couldn't see the cells very well, because his microscope wasn't as good as the microscopes we have today. But his discovery is still very important, because it helped us to understand that living things are made of cells.

Another scientist who looked at cells was Anton van Leeuwenhoek. Leeuwenhoek's microscope was almost as good as the microscopes we use to look at cells today, and he saw lots of things nobody had seen before. He saw animals that had never been seen. No one had seen them because they were too small to see with just your eyes. He also saw the cells that make up human blood. Leeuwenhoek even did an experiment where he scraped the plaque off his teeth and looked at it under his microscope. When he looked at the plaque, Leeuwenhoek saw tiny living things.



Van Leeuwenhoek drew these sketches of what he saw from the plaque in his mouth

Today we know that those things are bacteria. Think about that the next time you are brushing your teeth! (There are cool experiments that relate to this in the activities section!)

By the middle of the 1800's, several other scientists had studied cells, and this work led to a theory. In science, a **theory** is a group of ideas that explains why or how something happens. The **cell theory** says three things. These three things are:

1. All living things are made of one or more cells
2. All of the activities needed for life happen in cells
3. All cells come from other cells

The cell theory is a very important part of biology, which is the study of life.

## Cell Shape and Size

In order for your city or town to survive, people need to do different jobs. Police officers, construction workers, teachers, doctors, and fire fighters all do certain things to make sure everything runs smoothly. The different cells of your body also do different jobs that make things run smoothly in your body. In fact, you have trillions of cells, and each one plays

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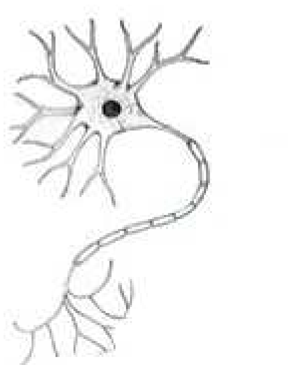
an important role in getting and using energy, responding to the world around you, and reproducing.

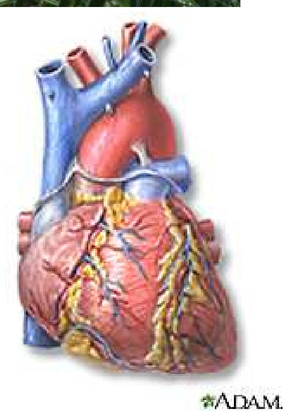
Many cells have special shapes that help them do their job well.  For example, one group of cells, called nerve cells, have the job of getting messages to other cells.  Nerve cells have long extensions coming out of them so they can easily reach the cells they need to give the message to.



The extensions on this nerve cell help it give messages to other cells

Although cells may have different shapes, they are all very small.  In fact, you could fit about 500 average-sized cells in the period at the end of this sentence.  Being small is good for cells, because it allows materials to get in and out of the cells very quickly.  Cells take in **nutrients**, which are substances that are helpful to people or other living things, and get rid of waste.  If it took a long time for the good stuff to get in or the bad stuff to get out, the cell could not survive.

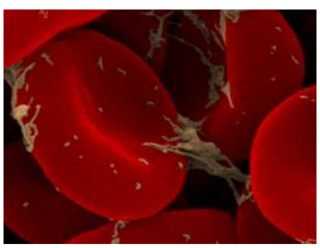
A group of cells working together to do the same job is called a **tissue**, and a group of tissues working together to do the same job is called an **organ**.  An example of a tissue is the stem of a plant.  In this tissue, many cells work together to get water and nutrients to the various parts of the plant.  You've probably heard of some organs, like your brain, heart, and lungs.  All of these organs are made of tissues, and all those tissues are made of cells.  Cells really are the building blocks of everything!

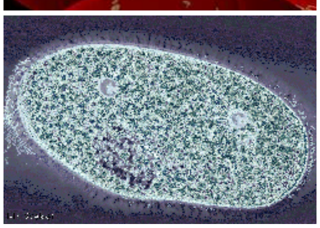


The stems of plants are tissues; the human heart is an organ.

## What's Inside of a Every Cell?

Take a look at your friends, and the other kids in your neighborhood.  You probably notice that even though you are all kids, and maybe even all about the same age, you look pretty different.  Even though we look different on the outside though, we know are made of a lot the same things, like bones, muscles, and organs, on the inside.  It's the same with cells.  Look back at the picture of the nerve cell in the last section.  Now look at the three pictures below.

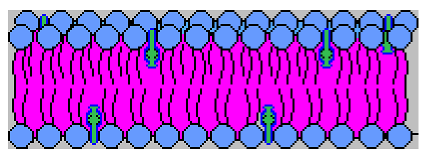




Red blood cells (left), a single-celled paramecium (center), and an amoeba (right) don't look the same. But they are all cells.

Although these pictures look very different, they are all pictures of cells.  Even though cells look very different on the outside, these cells, just like people, do have some things in common.  In fact, there are three things that every cell in the world has.

First, every cell has a **cell membrane**.  The cell membrane is made of **lipids**, which are fat molecules.  The cell membrane is located along the edge of the cell, and has a job like a security guard.  It allows things the cell needs to get into the cell and keeps out things that could hurt the cell.



The cell membrane acts like a guard, only letting certain things into the cell.

The second thing all cells have is **cytoplasm**.  Cytoplasm is all the material inside the cell membrane.  Cytoplasm is made of a watery material called cytosol.  Many structures are found inside cytoplasm.  These tiny structures are called **organelles**.  We will study some of the organelles later.

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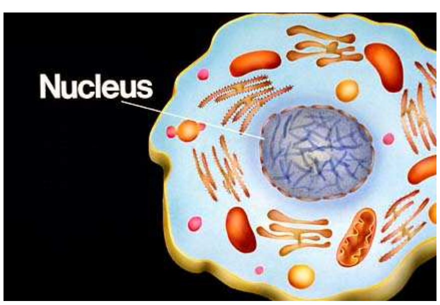
The third and final things that all cells have are **ribosomes.** Ribosomes are organelles where proteins are made. Proteins control everything that happens in a cell, from growth, to reproduction, to death. As you can see, proteins are very important for cells, so ribosomes have a very important job! Some ribosomes are found all alone, but others are found in groups, or attached to other organelles, as we will learn later.

Ribosomes have the important job of making proteins.

## The Nucleus

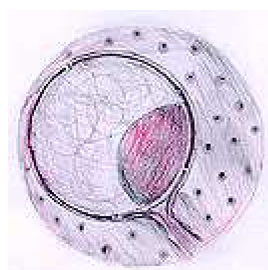
Some cells have an organelle called the **nucleus.** The nucleus is the largest organelle, and can be thought of as the "brain" of the cell.




The nucleus is thought of as the "brain" of the cell.

Just like your brain controls almost everything your body does, the nucleus controls everything the cell does. How does it do that? Well, you might remember that ribosomes make proteins, and proteins control everything that happens in a cell. The nucleus controls which proteins the ribosomes make. That's how it controls everything that happens in the cell.

The nucleus is so important that it has its own membrane around it, called the **nuclear membrane**. Just like the cell membrane controls what does or doesn't go into a cell, the nuclear membrane protects the nucleus by controlling what does or doesn't go into it.



The nuclear membrane controls what does or doesn't go into the nucleus.

Not all cells have a nucleus. In fact, there are two big groups of cells, and the big difference between them is that one group has nuclei (that's the plural of nucleus) and the other one doesn't.

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The cells with nuclei are called **eukaryotes** and the cells without nuclei are called **prokaryotes**. Most animal and plant cells are eukaryotes, and most bacteria cells are prokaryotes.

## Other Organelles

So far, you have learned about two organelles. First, you learned about ribosomes, the organelles all cells have for making proteins. Next, you learned about nuclei, the organelle some cells have for deciding what proteins should be made. Now let's talk about other organelles found in some cells.

## Endoplasmic Reticulum

Endoplasmic Reticulum (or ER for short) is kind of like the freeway of the cell. Like a freeway taking cars from one place in the city to another, ER carries lipids and proteins from one place in the cell to the other.

The endoplasmic reticulum transports lipids and proteins around the cell.

There are two kinds of ER. Rough ER (which is the kind shown in the figure above) has ribosomes attached to it. Smooth ER does not have ribosomes.

## Golgi Apparatus

The Golgi Apparatus is an organelle that is sometimes called the "post office" of the cell. To understand why it's called this, let's think for a minute about what a post office does. Imagine that you live in California, and you mail a birthday card to your friend who lives in New York. The post office gets your letter, separates it from all the mail going to other places, and then puts it in the pile with all the other mail going to New York (or somewhere near there.) Then it's shipped off and delivered exactly where it was supposed to go. The Golgi Apparatus doesn't get birthday cards from California. It gets proteins from the ER. Like a post office sending mail to the exact right place, it sends the proteins exactly where they need to go. Sometimes that means the proteins go to other places in the cell. Other times, the proteins are sent to the cell membrane so they can be sent out of the cell to other parts of the body.

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The Golgi Apparatus receives proteins and sends them where they need to go.

The Golgi Apparatus actually does more than a post office does, because it also labels the proteins to determine where they should go. If post offices were like the Golgi Apparatus, you could deliver a blank envelope to the post office, and someone at the post office would know where your mail was supposed to go and write the address on the envelope for you. It would be like a psychic post office!

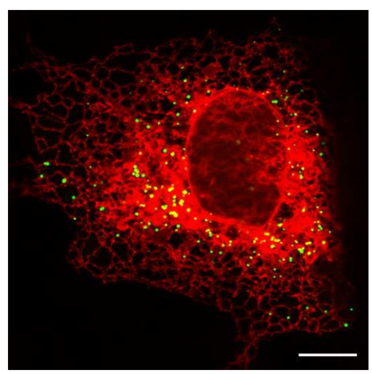
## Mitochondrion

The **mitochondrion** is the organelle that makes energy available for the cell to use for growing, reproducing, and anything else it needs to do. Mitochondria (that's the plural of mitochondrion) use compounds like glucose, which is a common type of sugar, to make ATP. ATP is an abbreviation for adenosine triphosphate, and is the most common source of energy for cells.

The mitochondrion provides the energy cells need.

## Vesicles and Vacuoles

**Vesicles** are small sac-like organelles. They store materials in the cell, and help move proteins wherever they need to go. For example, vesicles move proteins from the ER to the Golgi Apparatus for sorting. Special vesicles also break down dead cells, material that doesn't belong in a cell, or poisons.



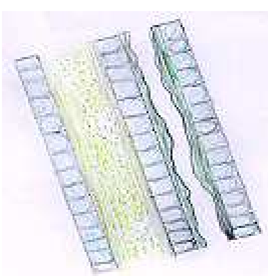
This vesicle has the important job of breaking down poisons in the cell.

**Vacuoles** are similar to vesicles, but are larger in size. In plant cells, a large vacuole is located in the center of the cell. This central vacuole stores such things as water and salt. It also helps some of the tissues in plants, like stems and leaves, keep their shape, and helps give flowers their colors.

The central vacuole of a plant cell has many jobs.

## Cell Wall and Chloroplast

There are two organelles that are very important in plant cells, but not found in animal cells. The first one of these is the **cell wall**. This organelle supports and protects the cell. Cell walls have small holes, called pores, in them. This lets water, nutrients, and other substances into the cell.



The cell wall surrounds plant cells, giving the cells protection and support.

The other organelle that only plants have is the **chloroplast**. These organelles have a pigment called chlorophyll, which allows the plant to take sunlight and make its own food. Imagine if we could make our own food from the sun. Anytime you were hungry, you could just stand outside and soak in some rays. You could try this some time, but since your cells don't have chloroplasts, standing out there will only make you hungrier!

Chloroplasts allow plants to make their own food from sunlight.

## Getting Into the Cell

In the last section, we talked about the cell membrane. We talked about how this structure let in the things the needed and didn't let in the things it didn't need, like a security guard deciding who should or shouldn't get into a building. There are two ways substances can get into a cell.

The first way substances can get into a cell is called **passive transport**. This process does not require any energy, because of the **concentration** of the substance inside and outside the cell. Concentration is how much of a substance there is in a certain area. In passive transport, the substance is going from an area of

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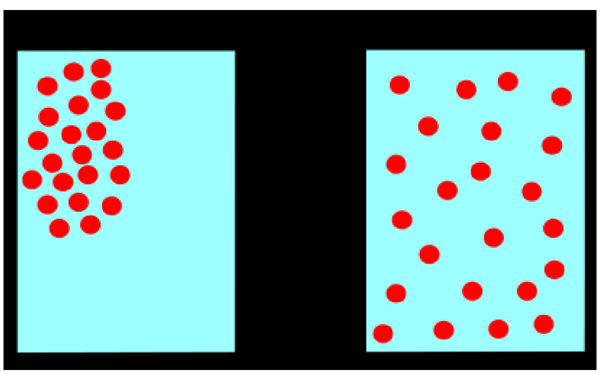
high concentration to low concentration.

To understand how this works, imagine blowing up a balloon and then letting the air out. When you do this, the air flows out quickly and without any extra energy because it is going from a place where there are a lot of air molecules (inside the balloon) to a place where there are fewer air molecules (outside the balloon.) In other words, it is going from an area of high concentration to low concentration.

Look at the figure below if you're having trouble with this idea.



The red dots are all in the top left corner. This is where the concentration is the biggest. The dots will move down and to the right, until they are spread out evenly.

Sometimes substances undergo passive transport all by themselves. They just slide right through the cell membrane. Other times they need a protein to help them make it across the membrane. But they *never* need energy, because they are going from high to low concentration. One special kind of passive transport is **osmosis,** when water crosses into the cell.

You probably can figure out the second way substances can get into a cell. Since the first way was getting in *without energy*, the second way is getting in *with energy*. Since "active" is the opposite of "passive," this method is called **active transport**. As you might expect, active transport happens when the substance wants to go from an area of low concentration to high concentration. Think back to the balloon with air shooting out of it. If you want to get air to go into the balloon, where the concentration is high, that's going to require some energy. ATP, the molecule created by the mitochondria in the cell, provides the energy for active transport. Just like with passive transport, proteins are sometimes needed to help out with active transport.

## Photosynthesis

In the last section, we talked about active transport needing energy. When you hear the word energy, you might think about playing sports or running in a race.

Although both of these things do require energy, they don't tell us what energy is. In science, **energy** is the ability to cause a change. Some of the changes energy can cause are changes in temperature (something getting hotter or colder), changes in state (going from a solid to a liquid, liquid to a gas, etc.) or a change in location (moving from one place to another.)

**The heat energy from the stove makes the water in this pot hotter, and then changes it from liquid water to steam.**

Several common kinds of energy are light, heat, sound, electricity, kinetic energy (the energy of motion) and chemical energy (energy stored up in things like batteries or cells.) Energy cannot be created or destroyed, but you can change energy from one type to another.

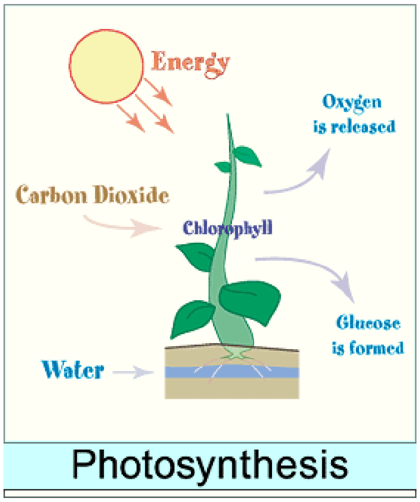
**When a match is struck, the chemical energy in the match is changed to light and heat.**

**Photosynthesis** is a process where light energy is changed into chemical energy. As we said in the last section, this process happens in the chloroplast of plant cells. Photosynthesis is one of the most important things that happen in cells. In fact, photosynthesis is considered one of the most important processes for all life on Earth. It makes sense that photosynthesis is really important to plants, since it gives them energy, but why is it so important to animals? Let's learn a little more about photosynthesis and see if we can answer that question.

There are many steps to photosynthesis, but if we wanted to sum it up in one equation, it would be carbon dioxide ($CO_2$) + water ($H_2O$) makes glucose ($C_6H_{12}O_6$) and oxygen ($O_2$). These words can be written like this:

$6CO_2 + 6H_2O + \text{Light Energy} \rightarrow C_6H_{12}O_6 + 6O_2$

It can also be shown in a picture like this:




Carbon dioxide, water, and energy combine to form glucose and oxygen.

We learned in the last section that glucose is a kind of sugar. This sugar is important for energy, so the plant stores all the glucose it creates. However, the plant releases the oxygen it creates.

Now we can see two reasons why photosynthesis is so important not just to plants, but to animals too. First, all animals need oxygen to live. Photosynthesis produces oxygen, so without this process, animals could not survive. Also, don't forget that since animals can't make their own food, they have to eat plants, or eat other animals that have eaten plants. So without plants, animals would quickly run out of food.

## Cellular Respiration

Plants get glucose from photosynthesis, and animals get it from eating. Glucose is a great type of energy for storage, and energy is stored as glucose in both plants and animals. However glucose is not good for actually providing the power for the processes in a cell. It is too powerful. ATP, which we learned about earlier, has exactly the right amount of power to do everything the cell needs to do. So, cells need some way to change the chemical energy in glucose to chemical energy in ATP. This process is called **cellular respiration**. Cellular respiration happens in both animal and plant cells, and happens in the mitochondrion.

In cellular respiration, glucose and oxygen combine to make carbon dioxide, water, and ATP. An equation showing this would be:

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ ATP

You should notice that this is almost exactly the opposite of photosynthesis. Even so, plants need to go through both steps, so that they have glucose to store energy.

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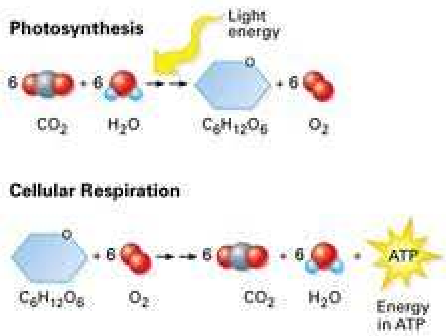


Photosynthesis and cellular respiration combine to change light energy to energy in the form of ATP.

## Cell Division

Every living thing, from tiny bacteria to giant oak trees, began life as a single cell. That's right, just one cell. So how do living things go from one cell to the trillions of cells some living things are made of? The answer is cell division! **Cell division** is a process in which one cell becomes two cells. The cell that starts cell division is called the **parent cell** and the cells that the parent cell makes are called **daughter cells** (even though cells are not male or female.)

This parent cell is in the process of cell division.

There are several different kinds of cell division that we will talk about.

One thing that all cell division has in common is that all the **DNA** in the parent cell must be passed on to each of the daughter cells. DNA is the genetic material that provides all the information about the cell.

If the cell has a nucleus, the DNA is located in the nucleus. If not, it is found in the cytoplasm. In order to make a daughter cell that is an exact copy of the parent cell, all of this information must be passed on.

## Binary Fission

One simple form of cell division is binary fission. This process has three steps. In the first step, the DNA doubles, so that the daughter cells will each have all of the DNA fount in the parent cell. Next, the two sets of DNA move to the sides of the cell. Finally, a new cell membrane begins to grow in the middle of the parent cell. Eventually the cell breaks apart, and, just like that, daughter cells have formed.

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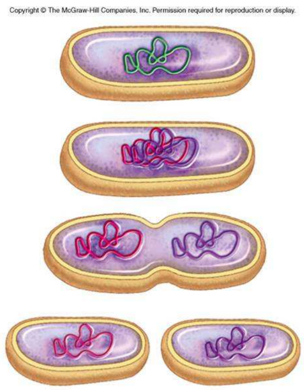
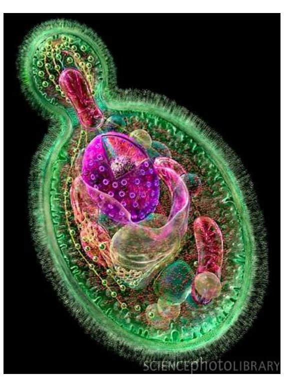



Binary fission is a simple three-step process.

Binary fission is common in bacteria.

## Budding

Another method of cell division is called budding. In this method, a small "bud" forms on the parent cell. The bud looks kind of like a bubble sticking out of part of the cell. Eventually, the bud develops all the material it needs and breaks off, forming a daughter cell.




In this yeast cell, the bud is visible at the top of the cell.

## Mitosis

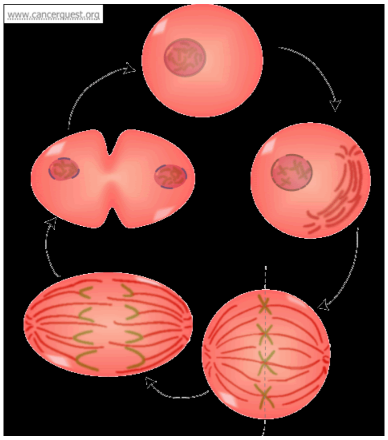
You may have noticed that when we talked about binary fission and budding, we didn't say anything about the nucleus. That's because these types of cell division happen in prokaryotes. Remember that prokaryotes don't have nuclei. This makes cell division a lot easier, because it's easier to get a complete set of DNA into each daughter cell. In eukaryotes, there is a nucleus, so a more complex process is needed. This process is called mitosis, and is divided into four parts, or phases.

Phase 1 – Prophase: In this phase the nuclear membrane begins to break down and the DNA forms structures called chromosomes.

Phase 2 – Metaphase: In this phase the chromosomes line up along the center of the parent cell

Phase 3 – Anaphase: In this phase, the chromosomes break apart, with a complete set of DNA going to each side of the cell

Phase 4 – Telophase: In this phase, a new nuclear membrane forms around each of the sets of DNA




The four stages of mitosis (the cell at the top has not started mitosis) lead to two daughter cells.

A little after telophase, the cytoplasm splits and a new cell membrane forms.  Once again, two daughter cells have formed.  Take a look at this animation for a good overview of mitosis and see if you can identify all the phases.

Cells continue to divide until a protein tells them to stop.  As they divide, they become different and specialized, eventually making the tissues and organs found in the many different living things we see every day.  There are many living things all around us, and it all starts with cells!