Cells, Mitosis, and Stop Motion Animation

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Introduction to cells: Teacher's notes

When students learn biology, they are exposed to certain overarching concepts that define and shape modern scientific thought on how living things are organized, how they relate to each other and the environment, and how they have developed over their 4 billion years on the Earth.

Here are the main concepts condensed into five big ideas.

1. Cell Theory: There are three parts to cell theory — the cell is the basic unit of life, all living things are composed of cells, and all cells arise from pre-existing cells.

2. Energy: All living things require energy, and energy flows within and between cells, within and between organisms and between organisms and the environment.

3. Heredity: All living things contain DNA in their cells. The genetic information stored in the DNA codes the function of all cells, and is transmitted to subsequent generations.

4. Equilibrium: All living things must maintain homeostasis, a state of balanced equilibrium within and between cells, within the organism and between the organism and its environment.

5. Evolution: This is the overall unifying concept of biology. Evolution is the change over time that is the engine of biological diversity. Evolutionary change happens when a favorable mutation occurs in gamete cells. Yes, the egg, not the chicken, came first.

The following lessons will give students a basic understanding of the parts of a cell, what the organelles are called, and their role in the cell. We will also learn about Cell Theory and cell division or mitosis. It is assumed that the students have had previous lessons on the characteristics of living things and the six kingdoms of life, and know that some organisms are free-living single cells while others are multicellular.

The cell is like a city, with factories, energy plants, roads, trash collectors, repair crews, police, and truck drivers. Everything in the city is controlled from a city hall and the city has borders. Of course what I am talking about are organelles like ribosomes that make proteins, mitochondria that make energy, microtubules, enzymes, and motor proteins. The city hall is the nucleus where the DNA resides, and the borders are the cell membrane.

Organisms grow from just cells dividing. It's hard to believe, but we all start out as a single, tiny cell. In just 12 years or so your students have grown into behemoths containing trillions of cells!

The History of the Cell Theory:

Around the year 1620 the first microscopes were invented, and they opened up a new world for scientists to explore. Microscopes were the iPhone of their age, everyone wanted one! Very quickly scientists began making new discoveries.

- **Robert Hooke** observed many things using his microscope. One of the things he looked at was a thin slice of cork which comes from the bark of the cork oak tree. He saw what looked like tiny rooms all joined together by walls, and thought they looked like “cells” , what the little rooms in a monastery were called. Hooke is credited with first using the word “cell” to describe the tiny living things he found when using the microscope.
- **Anton van Leeuwenhoek**: made his own microscope and saw one-celled organisms swimming

in pond water and called them “animalcules” because they seemed like tiny animals to him.

- **Jakob Matthias Schleiden** was a botanist who started looking at plant parts with a microscope. After looking at many plants he realized that all plants he studied were made up of cells.
- **Theodor Schwann** was a zoologist who learned about Schleiden's discovery. He looked at animal parts with a microscope and concluded that all animals were made up of cells.

Using the work of these scientists and by making other discoveries, scientists concluded that all living things are made of cells. This idea has become a fundamental concept in biology and is called the Cell Theory.

There is a great TED Ed animated video that outlines the history of the microscope and cell theory called “The Wacky History of Cell Theory” by Lauren Royal-Woods
https://www.youtube.com/watch?v=4OpBylwH9DU&vl=en

As scientists studied cells in more depth, and as microscope optical power and resolution improved, it became clear that cells were full of structures. They also noticed that there seemed to be two types of cells, the very tiny bacteria and the larger cells found in plants and animals.
Using stains to selectively color the structures in cells made them easier to see, and they noticed that the same structures were present in most of the cells of plants and animals. The structures were dubbed “organelles” or little organs, because they seemed to relate in the functioning of the cell the way organs worked in the body.

Cells were separated into two groups, the prokaryotes and the eukaryotes, based on whether the nucleus organelle was present. In prokaryotes, there is no nucleus (*pro* means “before”, *karyon* means “nut” or “nucleus” in Greek). In prokaryotes the DNA just floats loose in the cytoplasm. They also don't have organelles except for ribosomes.

Eukaryotes (“true-nucleus”) have a membrane-bound nucleus, and many different kinds of organelles. The nucleus contains DNA, the master molecule which codes for all the functions of the cell.

Cells: Lesson 1 overview of the types of cells

What does a maple tree, a frog and a mushroom have in common?

They are all made up of cells. All living things on earth are made up of at least one cell. A cell is the smallest part of you that is alive. Cells make up the structure of your body the way bricks and pipes and wires make up a house. The difference is that these bricks are alive, they use energy, grow and interact with the world using a complex system of biochemicals.

Some living things are made up of just one cell. There are two types of single-celled organisms: bacteria and protists. All animals, plants and fungi contain many cells, sometimes trillions. Humans, for example, have about 30 trillion cells.

Cells are divided into two main groups, prokaryotes and eukaryotes. This classification scheme is based on whether or not the cells contain a structure called the nucleus. "Prokaryote" comes from the Greek *pro,* which means "before", and *karyon* which means "nut" or "nucleus". "Eukaryote" means "true-nucleus", because their DNA is organized inside a membrane within the cell. Prokaryotes don't have their DNA organized inside a membrane. Instead, the DNA floats around inside the cell, which is full of a soft, jelly-like substance called cytoplasm.

Bacteria are classified as prokaryotes and are divided into two groups: Archebacteria and Eubacteria. Bacteria are the oldest type of life on earth, appearing in the prehistoric oceans about 3.5 billion years ago.

Like all cells, bacteria have a double-layered membrane that encloses the cytoplasm. The membrane has little pores or holes that allow certain substances to enter or leave. Most bacteria have a tough outer shell, called a cell wall, which protects them. Many bacteria also have tiny little hairlike structures all over the outside, called pili (from *pilus*, Latin for *hair*) which help bacteria stick to surfaces. Some bacteria also move around using whip-like structures called flagella. As mentioned before, prokaryotes do have DNA, but it is loosely clumped and not enclosed by a membrane like it is in the eukaryotes. Bacteria do have one structure besides the cell membrane that they share with eukaryotes, the ribosome. Ribosomes produce the proteins in cells using coded information from the DNA.

We will study the role of DNA, the nucleus and other parts of a cell in more depth when we study the eukaryotes in the following lessons.

Activity: Label the prokaryote and make a model

Students color and label the Prokaryote diagram.

They can also make a model using a snack size Ziploc bag to represent the membrane.

They add a loosely twisted pipe-cleaner for DNA and a few beads for ribosomes. (Note: the beads DO NOT go on the pipe-cleaner, they are free-floating).

For the cell wall, use modeling clay or cut a paper or plastic cup in half length-wise. Press the bag into the clay; if using a cup, tape it into place. Use short bits of yarn for pili, and a longer length of twine for flagella which can be pressed into the clay or taped on to the cup.

Press or tape the whole thing to a paper plate or square of cardstock and attach the the prokaryote coloring page.

Cells: Lesson 2 Parts of a Eukaryotic Cell

Teacher's Notes:

History of the early cellular life

Last lesson we talked about the differences between prokaryotes and eukaryotes. Prokaryotes are simple cells, and have lived on Earth for about 3.5 billion years. The Earth is about 4.5 billion years old, so the first bacteria appeared very soon after the Earth's crust cooled enough to hold the first liquid oceans.

It was the prokaryotes who first figured out photosynthesis about 3 billion years ago, and we have them to thank for the oxygen-rich atmosphere we have today. There was no atmospheric oxygen 3 billion years ago, all the oxygen on Earth was tied up in other compounds. It required photosynthesis of tiny cyanobacteria to release it.

About 1.5 billion years ago there was enough oxygen in the environment to make a new type of cell possible. It was bigger than bacteria and much more complex inside.

Modern theory postulates that the early eukaryotes arose when large prokaryotes ingested smaller ones but didn't digest them. Instead, the captured prokaryotes learned to live inside the larger host and contribute to the this hybrid cell in a beneficial way that was advantageous to both. The host and captives became dependent on one another for survival, resulting in a permanent relationship. The theory is called the Endosymbiosis Theory (endo=inside, symbio= living together). The theory is fascinating and would make an excellent research topic. Over time, some free-living single eukaryotic cells began to stick together after dividing instead of going their separate ways. This strategy turned out to be advantageous, resulting in groups of cells forming colonial organisms. The colonies of cells eventually evolved into primitive bodies with specialized parts. About 700 million years ago the first multi-celled creatures appeared with cells that were specialized for eating and moving. This was an extremely successful development in the evolution of life on Earth, leading to the explosion of diverse life forms we see today.

History of Cell Theory:

Before microscopes were invented in the early 1600's, no one knew that living things are made of cells because cells are too small to see with the eye alone. Once scientists had the magnifying power of the microscope, they quickly made new discoveries about what cells were made of, and how they worked. It seems strange to us today, but it was a startling revelation when the botanist Jakob Matthias Schleiden and zoologist Theodor Schwann announced that, based on their exhaustive study of plant and animal tissue, all living things were made of cells. The Cell Theory is now one of the main defining concepts of modern biology.

The Cell Theory states:

- All living things are composed of cells.
- Cells are the basic unit of life.
- All cells are produced from other pre-existing cells.

Scientists noticed that there were two general types of cells. Bacteria cells were very tiny, about ten times smaller than plant, fungi and animal cells. The cells also had interesting structures inside them. When scientists added certain coloring agents, called stains, to cells on a microscope slide, certain structures inside the cells would take on the color, making them easier to see and study. Over time, through careful study and experimentation, scientists determined the structure and function of the different parts of the cell. Scientists dubbed them “organelles”, which means “little organs”, because they seemed to relate in the functioning of the cell the way organs worked in the body. The study of cells is ongoing, and scientists are still making incredible new discoveries every day.

Lesson 2 Parts of a cell

When we modeled the prokaryote cell, there wasn't all that much to do. Inside the cell membrane was the DNA molecule floating loosely in the cytoplasm along with some ribosomes. The eukaryotic cell has these parts and much more. All prokaryotes are single-celled organisms, but eukaryotes can occur as free-living single-celled protists or as multi-celled organisms like plants, animals and fungi.

The nucleus of the eukaryotic cell contains all the DNA, which is the master molecule that controls all the functions of the cell. The nucleus is enclosed in its own double-layered membrane, similar to the cell membrane that encloses the entire cell. Besides a nucleus, eukaryotic cells also contain other structures, called organelles, or "little organs". Except for ribosomes, these structures are missing in prokaryotes.

Here is a partial list of organelles:

Nucleus:

- A large organelle enclosed by a double-layered membrane.
- It houses the genetic material in the form of DNA, a long molecule arranged in structures called chromosomes.
- It is the control center of the cell.

Mitochondria:

- Rod-shaped organelles that are the powerhouse of the cell.
- They make all the energy for the cell to carry out the functions of the cell.

Nucleolus:

- Found inside the nucleus.
- Center for ribosome production.

Endoplasmic reticulum (ER):

- This is the highway and industrial complex of the cell where most of the cell products like proteins and lipids are made.
- It carries protein and other materials from one part of the cell to another.

Ribosomes:

- Some are embedded in the ER, while others float freely in the cytoplasm.
- Their job is to make proteins and release them into ER which will send them to Golgi body

Golgi bodies:

- It looks like tubes and sacs because the membranes are infolded.
- It packages proteins in membrane-bound vesicles and sends it out of the cell to other parts of the body.

Chloroplasts (only in plant cells):

- The green color of the leaves is due to the pigment chlorophyll that is packed into chloroplasts.
- They take energy from the sun and convert it to food for the cell.

Centrosome:

- This is the center that produces the microtubules used as scaffolding in the cell.
- They contain the centrioles (animal cells only) that provide the spindle fibers used to separate the chromosomes during cell division.

Vacuoles:

- It is a storage area of the cell, storing either food for later digestion or waste for later disposal.
- Most plant cells have a large central vacuole that stores water and helps the plant stay rigid.

Lysosomes:

- These round organelles contain enzymes that break down large molecules so the cell can use them as nutrients.
- It is also a recycling center of the cell, breaking down worn-out organelles so that the parts can be reused.

Cell Membrane:

- It is a double layer of lipids and proteins that enclose the cell.
- The membrane has tiny holes called pores and is semipermeable, meaning that it lets in some chemicals but blocks others.
- It allows food and oxygen enter the cell and waste to leave it.

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Cytoplasm:

- A jelly-like substance that fills the inside of the cell.
- This jelly-like material streams around in the cell, keeping the organelles in motion and helping the cell to move and interact with other cells.

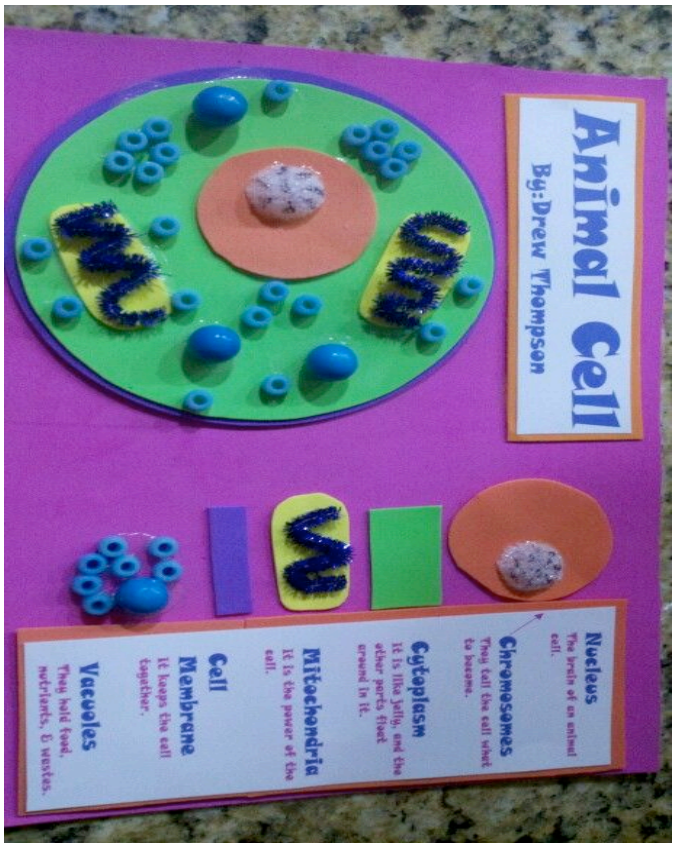
Activity

Students can label a printed diagram or draw and label their own picture based on one drawn on the board, from a poster or a reference book. Plant cells and animal cells have slight differences. Plants have chloroplasts, amyloplasts (starch), and a stiff cell wall made of cellulose; animal cells have neither. Animal cells have centrioles inside the centrosomes, plant cells do not. Students might want to research the differences and make a Venn diagram.

The diagram on the following page compares plant and animal cells. (To present it more simply, you can just use an animal cell diagram.) It should be mentioned that these are stylized representations of the organelles, and does not contain all of them, like microtubules, cytoskeleton, peroxisomes, pinocytotic vesicles, druse and raphide crystals (plants), microvilli and others. Students will study organelles in depth in high school and college.

The students should research the organelles and match them on the worksheet which gives the definitions.

Students might like to make a model of the cell after they have researched the organelles.
There are lots of clever ideas on Pinterest, of course:



Cells: Lesson 3 Observing Cells Under a Microscope

If the school has microscopes, students can observe different kinds of cells with them. A set of preserved specimens is nice to study, and you can also make your own. Show students stained human blood and frog blood and ask them to see the difference. Human red blood cells do not have nuclei, although white blood cells do. Red blood cells start out with nuclei but during the final phase of their development they lose it. They don't need a nucleus because they only have one job, carrying oxygen from the lungs to the rest of the body and without that bulky nucleus the cell is smaller and can fit into tiny, narrow capillaries. Frog blood cells, on the other hand, do have nuclei.

Using a dropper, students can make wet mounts once you have demonstrated the process. They should practice first with a hair. Lay the hair on the slide, add a drop of water and carefully place the coverslip over it. They can practice focusing the microscope and learning how to use the controls. They should start at lowest magnification first, and increase it as they get comfortable with the controls. Focusing the microscope and adjusting the specimen slide can be the most frustrating part of the process. Students should be patient and slowly turn the focusing knob. They should also check that the specimen is positioned under the objective lens.

If you have access to a pond or aquarium, there are often interesting single-celled and tiny multi-celled creatures found in the debris. Examining a leaf of an aquarium plant is another excellent choice. Pick the thinnest and youngest looking leaf for best results.

It is very interesting to make a wet mount of cheek cells and stain them to see the nuclei more clearly. Cheek cells are stratified squamous epithelial cells. Remind your students that scientists describe things as precisely as possible. Stratified means layered, squamous means flat and epithelial means surface. The epithelium lines the surface of the inner body.

Using a toothpick, gently scrape the inside of the cheek. There will be some whitish goo on the toothpick. The epithelial cells come off the cheek very easily.

Smear the goo onto the slide in a little circular pattern.

Add a small drop of water and place the coverslip over it.

Focus on the cells and look for thin patches with just a few cells so that you can see the outlines of the cell clearly.

After looking at the unstained cells, try staining them with food coloring, iodine or methylene blue (available at pet stores).

These substances will stain skin and clothing, so caution students to be careful when handling them.

Take the cheek cell wet mount and place a tiny drop of stain on the edge of the coverslip.

On the opposite edge dab a paper towel or tissue.

The water in the wet mount will get wicked onto the paper. As it is drawn out from under the coverslip, the stain will be drawn in.

After a minute or so, the nuclei in the cells will be very clearly visible as dark circles.

Another good choice is the papery inner skin of an onion. Staining the cells not only reveals the nucleus but the cell wall as well, which is present in plant cells but not animal cells. Onion skin cells have no chloroplasts, but staining with iodine might reveal the starch-filled amyloplasts, since iodine stains starch molecules black or dark brown.

Cells: Lesson 4 Mitosis

Teacher's note: DNA (standing for **deoxyribonucleic acid**) is an extremely long molecule, in humans the DNA in one cell's nucleus stretches 6 feet! If you took all the DNA in just one human, it would stretch the entire length of the solar system TWICE. But is is all wound up inside the nucleus in the form of chromosomes. When we say that DNA contains the genetic information of an organism, we mean that there are sections of DNA on the chromosomes that are called genes. The genes consist of a series of the bases **adenine**, **guanine**, **thymine** and **cytosine**, arranged in a specific order that code for certain proteins that the cells need to function and keep the body alive.

Lesson 4 Mitosis

Imagine if you had to make an exact duplicate of your bedroom. Everything in the room must be duplicated: the bed, the dresser, mirror, all the clothes, the books, lamps, nightstands, rug, clock-radio, game console, etc. Then you have to arrange all the pairs side by side in a neat row in the middle of the room. Once everything is in place you can push out the walls and move half of each set to one side and the other half to the other side. Starting at the middle of the other walls you build a new wall down the middle separating the two sides. You now have two rooms. If you hadn't made a copy of everything before you divided the rooms, each room would be missing something. One would have the dresser and clothing, the other would have the bed and lamps, etc. When a cell divides, it has to make a copy of everything also, otherwise the resulting daughter cells would have only half of what they had before, and would be unable to function properly.

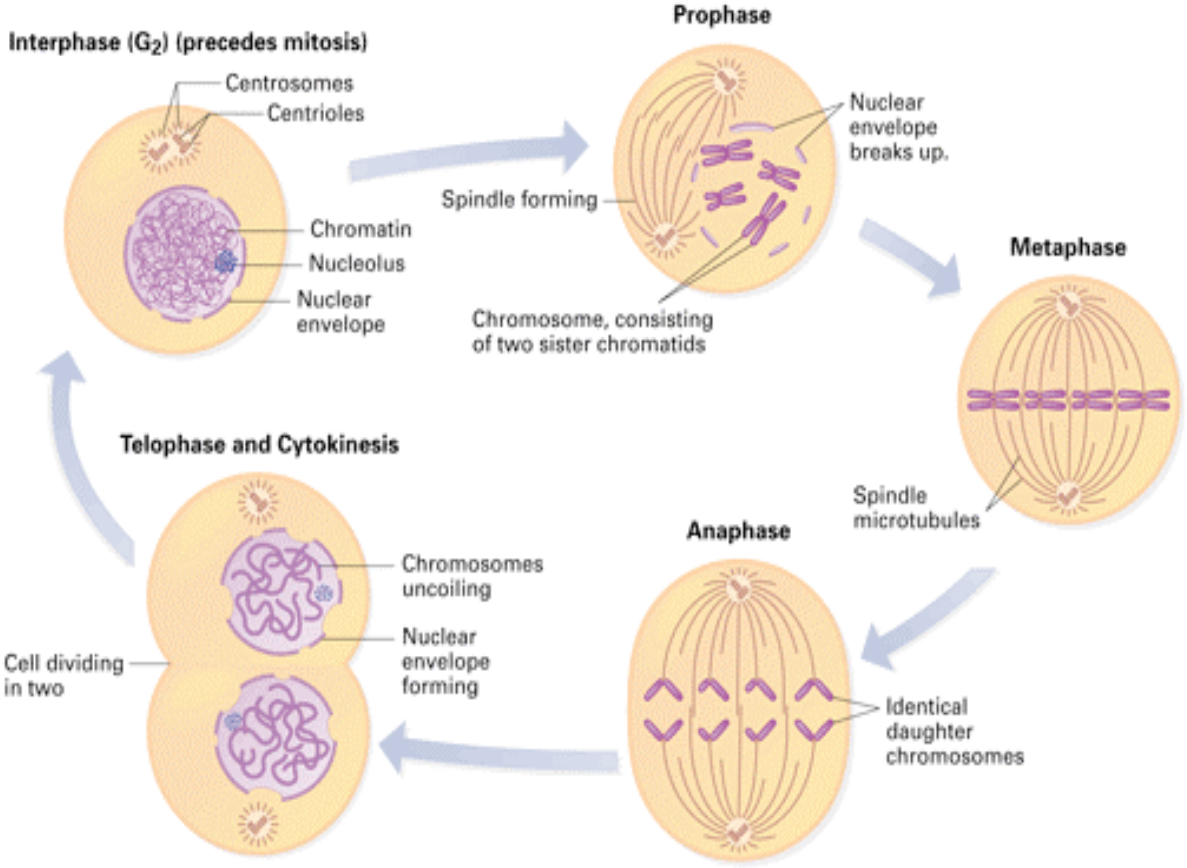
In order for an organism to grow, its cells must divide and increase in number. Every multi-celled organism started out as one single cell that divided over and over, one cell became two, two became four, four became eight and so on. Cells also die when they reach the end of their useful life and must be replaced with new cells. As postulated in the Cell Theory, all new cells come from pre-existing cells.

As a cell grows it goes through a cycle of phases. The first is called **interphase** and the cell spends most of its life in this phase. During interphase the cell grows to its full size and begins the process of duplicating its structures. The nucleus contains chromatin, which is DNA wrapped with proteins. The DNA is in the form of chromosomes. During the middle of interphase the chromosomes are replicated, creating two sister chromatids that are joined in the middle by a structure call a centromere.

At the end of interphase the cell is ready to begin the division process called **mitosis**. The first phase is **prophase**. The centrioles move to opposite sides of the cell and begin producing long microtubules called spindle fibers. Meanwhile, inside the nucleus the chromosomes start to coil up and condense, and the nucleolus disintegrates. The nuclear membrane dissolves and the spindle fibers grow until they connect to the kinetochores on the centromeres. The centromeres hold the two sister chromatids together for now. This second part of prophase is also called **prometaphase**.

The next phase is **metaphase**. The spindle fibers, which are firmly attached to the kinetochores, tug the chromosomes until they are all lined up along the central plane of the cell. Once they are all in place the next phase can begin. This phase is **anaphase**. The centromeres divide and each sister chromatid is drawn apart by the spindle fibers to opposite sides of the cell.

The next phase is **telophase**. The chromatids are gathered together on opposite sides of the cell, the spindle apparatus disintegrates and the new nuclear membrane reforms around each new set of chromosomes. The cell then begins **cytokinesis**, or cell splitting. The elongated cell begins to pinch in the center. The cell cleaves down the middle into two equal daughter cells, completing the cell division. The cells returns to interphase.



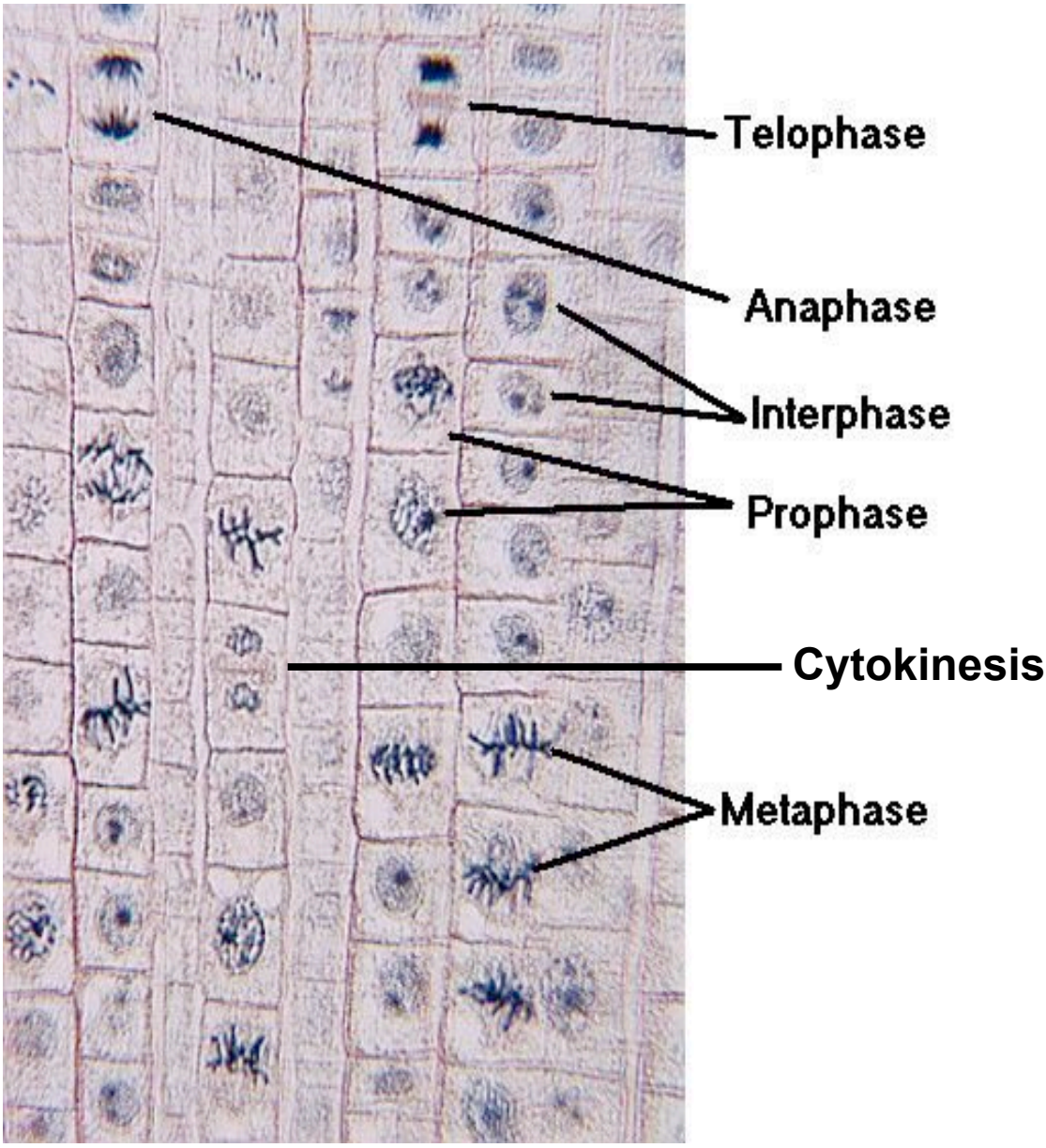
Mitosis is a dynamic process and showing animations of cell division makes it easier to understand than the static pictures on a whiteboard. If you have access to computers in the classroom, showing mitosis videos will help. There are many videos, some show actual cells dividing, others are stylized animations:

Mitosis NDSU VCell Production's animation "Mitosis".
https://www.youtube.com/watch?v=C6hn3sA0ip0

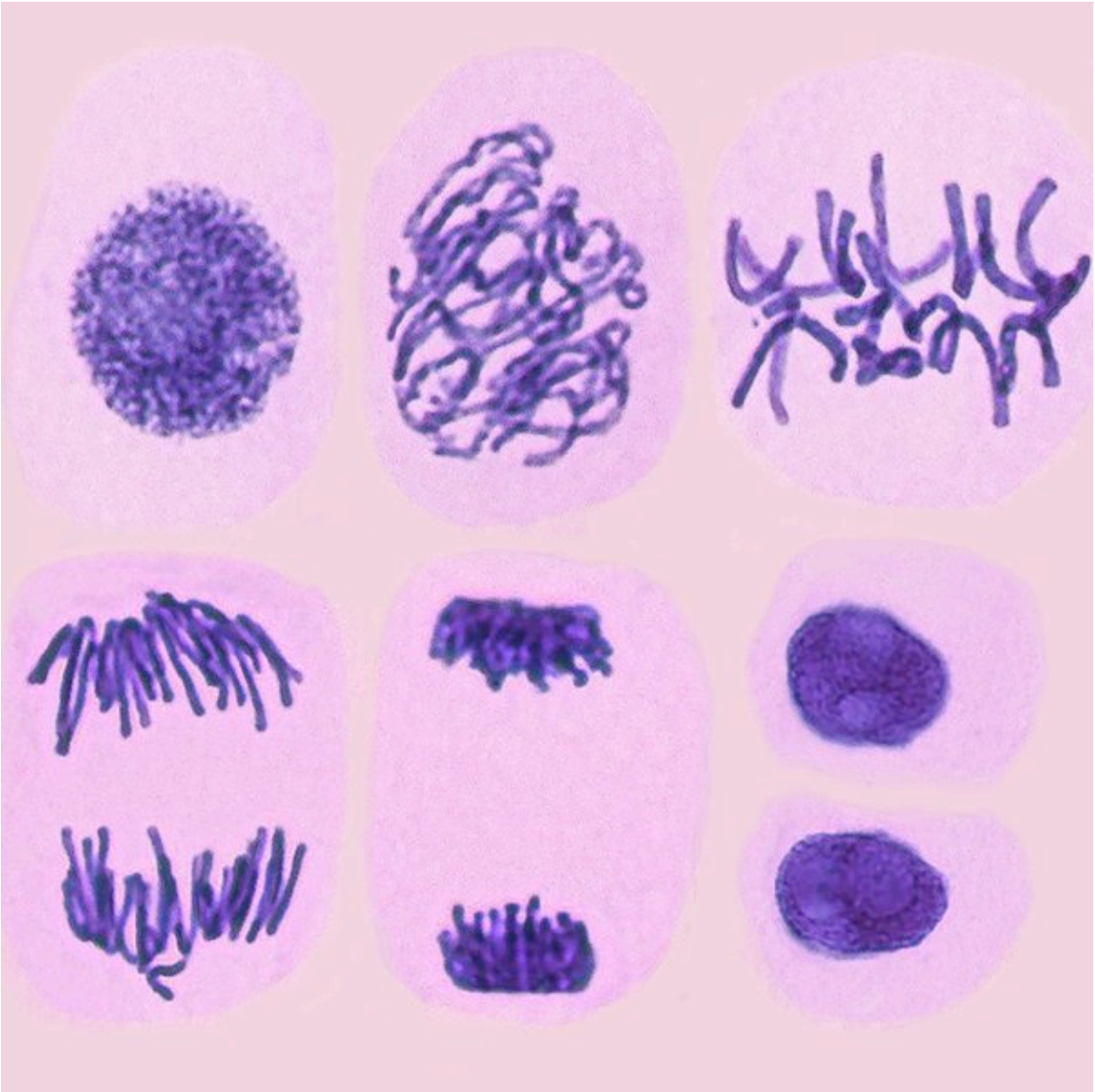
Animation How the Cell Cycle Works
https://www.youtube.com/watch?v=g7iAVCLZWuM

If the students are comfortable with the microscope, they can make slides of onion root tips (or you can purchase the prepared slides from any educational science supply store). Root tips are fast growing parts of a plant, so it is easy to find cells in every phase of mitosis. To make your own, use fresh onion roots. Cut the root tip off the onion and use a razor to shave off a long section, like peeling a carrot. Carefully lay the thin peel on the slide, make a wet mount, then add a stain by putting a drop of stain to one edge of the coverslip and draw it through by wicking the water using a paper towel on the opposite edge. Focus as close to the tip as possible and you should see cells in all the phases of division.

Onion Root Tip



Interphase Prophase Metaphase



Anaphase Telophase Cytokinesis

Using Stop Motion Animation to Model Mitosis

Stop motion animation takes advantage of the fact that human visual perception can be fooled when shown a series of pictures in a rapid sequence. By presenting a sequence of still images in quick enough succession, the viewer interprets them as a continuous moving image. The brain tries to make sense of what it is seeing and attributes motion to the pictures. The illusion of movement phenomenon is called persistence of vision.

Persistence of vision works because the human eye and brain can only process 10 to 12 separate images per second, retaining an image for up to a fifteenth of a second. If a subsequent image replaces it in this period of time it will create the illusion of continuity. Movies are shot at 16 frames per second to produce the smooth sense of movement.

There is a lot of stop motion software available, some are very sophisticated and some are simpler and designed to be used by all ages. We use the free software called Monkeyjam.

After opening the Monkeyjam program, you go to File and select New Xps. This is where the sequence of image frames will be stored. The default name is Layer 1. You'll want to give this a unique name for each animation because each picture you take will have a name generated from it: Name0001, Name0002, Name0003, and so forth. If you reuse a base name, you'll get a warning that your new pictures are overwriting existing files.

Next, you click the camera icon. This opens the capture window. There's a camera option here that will let you select which camera you're using. Once selected, the capture window will show what the camera sees, allowing you to position everything.

The capture window also allows you to decide your image hold. This is how many frames an image will be shown for. The default is two.

If a picture is taken by mistake, it can be deleted by going to the list of images, clicking the picture you want deleted, and hitting the delete key. Remember, if your image hold is two, you'll have to delete both copies of the picture from the list.

To preview the animation so far, you click the television icon. You can alter the speed by going to Settings and selecting FPS (Frames Per Second) to a higher or lower number. Slowing down can help if events in the animation are going by too fast to follow, but it'll generally result in a jerky movie as the picture speed falls below the number needed for persistence of vision. The default FPS is 24, which, combined with a default image hold of two, is twelve different images per second.

If there is any writing in the animation, make sure you work out how many images you need for it to be visible long enough to read.

When the animation is complete, the film strip icon lets you save it as a movie file. Remember to keep the file extension, .avi, on the file name when saving.

The students can watch a few animations by other students to get an idea of how it is done.

Mitosis student animation 4
https://www.youtube.com/watch?v=4hPFfj803Us

Student work showcase: a time-lapse video of mitosis
https://www.youtube.com/watch?v=lIabMqF0pUE

Making the Movie: Preparations

Have students plan out their video on a story board. Allow them to explore different materials like Plasticine clay, pipe cleaners, yarn, etc. to decide which materials they want to use to represent the parts of the cell. Alternatively, they can draw their movie on a whiteboard.

Before filming they should practice the stop motion technique using simple objects like erasers. Have them practice making a simple movie of an eraser moving across a table or over a ruler. The movements should be smooth, not too jerky, and there should be no hands visible. They can also try filming words to get the timing right. Words need extra frames so that they stay in view long enough to read them.

After making a storyboard, they should make the labels for their movie. Each cell phase must have a label with a brief explanation of what is happening. They can also label parts like cell membrane, chromosomes, centrioles, etc. They also need a Title and Credits. The title can be written, or made from clay, whatever creative idea they come up with.

Making the Movie: Filming

The movie must depict actual mitosis, it is not a fantasy! They can have fun with the title and credits, but the actual movie is strictly factual.

Students should have practiced with the technique and now have an idea of how careful and patient they must be when moving the components around during filming. They should set up the camera in a way that it will be secure and not get jostled or shifted. The set must also be secure so that everything stays in the camera's field of view. It is also important for the person capturing the images and the person moving the elements to work together in synchrony. The camera person has to wait until the other's hand is no longer in the picture. This is the number one mistake that people make. Stop motion teaches patience and mindfulness!