Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
2013 Volume IV: Asking Questions in Biology: Discovery versus Knowledge

Cell Biology: From HeLa Cells to the Polio Vaccine

Curriculum Unit 13.04.03
by Lindsey Flanick

Rationale

As a high school science teacher in New Haven it is often challenging to develop units that are engaging and relevant to my students. When I was given the opportunity to join the Yale New Haven Teachers Institute and participate in the "Asking Questions in Biology" seminar I knew that I wanted to develop a unit that involved a case study that was both interesting and relevant to my students. As a result of this seminar, I decided that using *The Immortal Life of Henrietta Lacks* and the discovery of HeLa cells as a focus was the perfect way for me to interest students in cell biology, and to teach them the importance of asking questions in science.

HeLa cells are one of the oldest and most commonly used immortalized cell lines in scientific research. When cervical cancer cells were taken from Henrietta Lacks in 1951, doctors, researchers and scientists had no idea the impact they would have on the understanding of cell biology and treatment of health/disease. HeLa cells have been used to develop vaccines, in cancer and AIDS research, and in countless genetic studies. In this unit students will use the discovery of HeLa cells and their use in biomedical research to study cell biology topics such as: cell growth, cell division, virus-cell interactions and vaccine development.

This unit will be centered on the discovery of HeLa cells by using Rebecca Skloot's, "The Immortal Life of Henrietta Lacks" as an anchor text and backdrop for the content of the unit. With the discovery of HeLa cells as the central focus of the unit, students will learn about the importance of scientific discovery and the impact it has on future research questions and studies. Students will also analyze the Rolling Stone article, "The Double-Edged Helix," which covers the initial challenges of using HeLa cells in research and the impact they had on science. The unit will meet both content and inquiry standards as students learn not only about cell biology, but also about questioning in science and the importance of asking good questions in biology.

The inquiry standards that will be addressed in this unit focus on identifying and developing scientific questions that can be answered through scientific investigation. Students will learn what it means to ask a question and what the criteria are for good questions. As students learn the importance of question-asking in this unit, they will develop their own question for a scientific investigation that they will carry out as a culminating performance task.

The content standards that will be addressed in this unit are related to cell biology. Students will learn about the basic structure of cells and cell division as they read excerpts from "The Immortal Life of Henrietta Lacks" and then will move on to studying the differences between cells and viruses, and the development of vaccines. The use of HeLa cells has been monumental in the development of vaccines, most notably the polio vaccine. Students will see how the accidental discovery of this immortal cell line led scientists to ask more questions and to develop the vaccines and treatments that we use today. Additionally, students will look at how HeLa cells are still being used in research to answer questions related to cancer and AIDS research.

The use of HeLa cells has been a controversial topic in science. During the time when Henrietta Lacks was being treated for cervical cancer it was common practice for doctors to take samples of cells for use in the laboratory. A sample of cells was taken from Henrietta Lacks without her knowledge, and it was these cells that became the first immortalized human cell line. Henrietta and her family were not made aware that her cells were being used all over the country and world and therefore they never received and compensation. The ethics regarding the use of human cells without the consent or knowledge of the individual they were taken from remains an interesting topic to explore. Since it is such an engaging topic, students may also raise questions related to the ethics of using HeLa cells and the impact this discovery had on Henrietta Lacks and her family. Although these questions may not be about biology content, students will be practicing asking questions and using curiosity to develop their own ideas and understanding.

The Inquiry-Based Classroom: The Importance of Asking Questions

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The current trend in science education is to promote inquiry-based learning and student-centered classrooms. These are classrooms where students are asking questions about topics they are interested in and designing investigations to develop new knowledge. This idea of the inquiry-based classroom teaches students to "think" like scientists by having them make observations about the world around them and develop questions that they can answer through research and laboratory investigations [1]. After all, asking questions is how the majority of the scientific discoveries throughout history were made. Although this idea of scientific discovery and inquiry-based learning is a trend in education, current lab exercises in high school and even at the college level provide step-by-step directions with a desired and already known outcome [1]. These lab exercises do not teach students to become scientists, they simply teach them to follow instructions. These laboratory experiments do not even truly teach the scientific process or scientific method because they are carried out with adesired result in mind and a "correct answer." True learning and understanding of science occurs when students are able to develop their own experiments without knowing the results so that they can learn something new. Recent studies show that inquiry-based classrooms also have increased student engagement and students have a greater understanding of content and material [1].

So what does an inquiry-based classroom have to do with asking questions in biology? According to Polacek and Keeling, "asking questions is a critical aspect of thinking about science" [1]. Students are more likely to "think" and learn about science when they are asking questions about how discoveries were made that led to the facts that they are often asked to memorize and recall in class. Students should be asking questions about biology, then carrying out laboratory investigations, and finally reflecting on their data to stimulate their thinking about new questions and new experiments [1]. This is true science in action, an inquiry-based classroom with "question-asking" at its core. In fact, the core of science classrooms should be a laboratory setting to fully engage students in their learning and understanding of science content and to promote scientific thinking. Biology, specifically, is the study of life and the natural phenomena of living things and the course content itself should be thought provoking enough to stimulate students' curiosity and question asking [2]. But in a traditional classroom setting where a teacher lectures, students' curiosity can be stifled and they can fall into the pattern of simply memorizing material without having any interest as to why these natural phenomena occur or how the world works. In classrooms today, the skill of asking questions to discover knowledge must be specifically taught and developed in an inquiry classroom [2].

Not only does asking questions in science have an impact on inquiry-based learning in the laboratory setting, it can also have a significant impact on scientific literacy and understanding. Scientific literacy is the ability to read a scientific article or watch a newscast about a science topic and have an understanding of the material that is being discussed and be able to be skeptical and judge whether it is good science [3]. The root of understanding science and scientific literacy is being able to ask a good question. Once a student asks a question, they are able to make some observations and begin the research process [3]. By asking questions and making observations, students' curiosity about a topic is piqued and it is the beginning of scientific research and understanding.

Henrietta Lacks and the Discovery of HeLa Cells

"The Immortal Life of Henrietta Lacks" was written by Rebecca Skloot and chronicles the events that led to the discovery of HeLa cells and the subsequent research in science that eventually led to the development of the polio vaccine, different medicines, gene mapping, cancer research, and many other important scientific discoveries. This accidental, or not-so-accidental, discovery in science is perhaps one of the most important in cell biology.

Henrietta Lacks was a poor 30-year-old black woman who died of cervical cancer at Johns Hopkins Hospital in Baltimore, Maryland on October 4, 1951 [4]. Before her death, a sample of cervical cells was taken from Lacks, which became the immortalized cell line known as HeLa cells [4]. HeLa was the name given to the human tissue cell culture that was able to thrive in a glass-bound container in the laboratory, given the proper nutrients for cell growth [5]. Essentially, tissue cultures have been artfully convinced that the glass walls that surround them are part of the warm body that they came from and they are able to grow and reproduce like normal cells to form a tissue [5]. Today, trillions upon trillions of HeLa cells are used throughout the world for cell biology research and every single HeLa cell today derived from the one original sample taken from Henrietta Lacks nearly 60 years ago [4]. Tissue cell cultures have allowed scientists to observe cellular processes, without having to do tests on actual human beings [5]. Scientists have seen cellular processes in action, looked at bacterial and viral infections, cancer research, and even studied nutrition [5]. In her book, Skloot searches for answers about how Lack's cells were obtained and why her family wasn't informed until years later about the amazing contributions these cells made to science.

When Henrietta was diagnosed with cervical cancer in the 1950's it was standard procedure for doctors to obtain a sample of cells and not even notify the patient. Dr. George Otto Gey at Johns Hopkins was trying to create an immortalized cell line that could be kept alive in the laboratory, at the time that Henrietta came to

Johns Hopkins for treatment. When Gey was given a sample of Lacks' cells, he was amazed to find that they could be kept alive and grown, unlike any human cell that he or other scientists had previously tried to culture [4]. Previous cell samples would die after just a couple of days. Gey was able to isolate one specific cell from Lacks' sample, multiply it, and start the HeLa cell line. This cell line can be grown in the lab and could be used for many experiments. This unexpected discovery was monumental in cell biology and HeLa cells have become the most widely studied cultured cells in science [6].

"The Immortal Life of Henrietta Lacks" would be used in this unit as a hook to interest students in cell biology and eventually to introduce infectious diseases and vaccinations. The story of Henrietta Lacks and the discovery of HeLa cells is a compelling one, with many ethical issues to pique the interest of students. In addition to having students read excerpts from the book, an article in Rolling Stone magazine, "The Double-Edged Helix" would be used in class to discuss the ethical issues regarding the use of HeLa cells.

Cell Structure: An Overview

Prokaryotic Cells

Prokaryotic cells do not house their DNA within a nucleus, and lack certain organelles such as mitochondria. Prokaryotic cells are generally smaller than eukaryotic cells (cells with a nucleus); however, these single cells can perform all of the basic functions associated with living organisms. Even though these cells do not contain a nucleus, they do have genetic material called DNA that floats freely in the cell [7]. This DNA does bundle together in the center of the cell and is called a nucleoid, however it is not compartmentalized in a nucleus like eukaryotic cells. Along with their DNA, these cells contain ribosomes, a cell wall, cell membrane, and cytoplasm. Figure 1 is a drawing of a typical prokaryotic cell with the DNA and other organelles labeled. Bacteria are an example of prokaryotic cells.

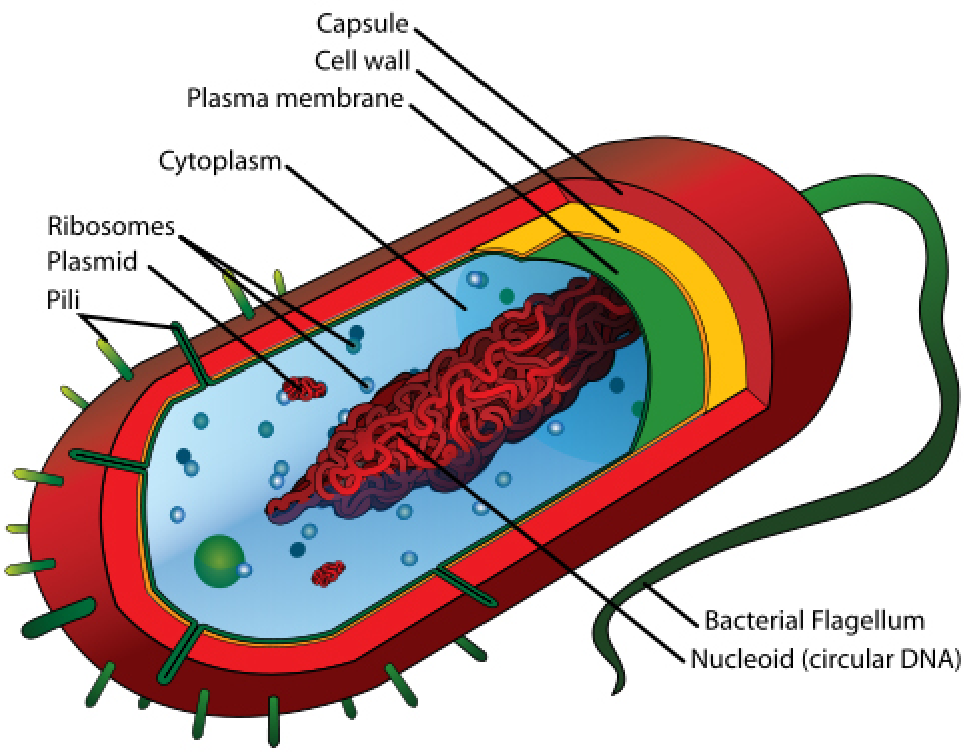

Figure 1. Prokaryotic Cell

http://upload.wikimedia.org/wikipedia/commons/5/5a/Average_prokaryote_cell-_en.svg

Eukaryotic Cells

Eukaryotic cells are usually much larger and more complex than prokaryotic cells. There are two types of eukaryotic cells that are taught in high school biology: plant and animal. Plant and animal cells are very similar and contain many of the same structures, but a few key differences are used to tell them apart, such as the presence of chloroplasts and a cell wall in plant cells. All eukaryotic cells contain DNA enclosed in a nucleus and also have many different organelles to carry out their cellular functions [7]. These cellular organelles are like "little organs" that are specialized for the function that they carry out in the cell and they are all found within the cytoplasm of the cell [7]. The nucleus of the cell holds the DNA, which contains all of the genetic material to direct the cell to make proteins and reproduce. The nucleus is often referred to as the headquarters of the cell because it controls all of the cell's activities.

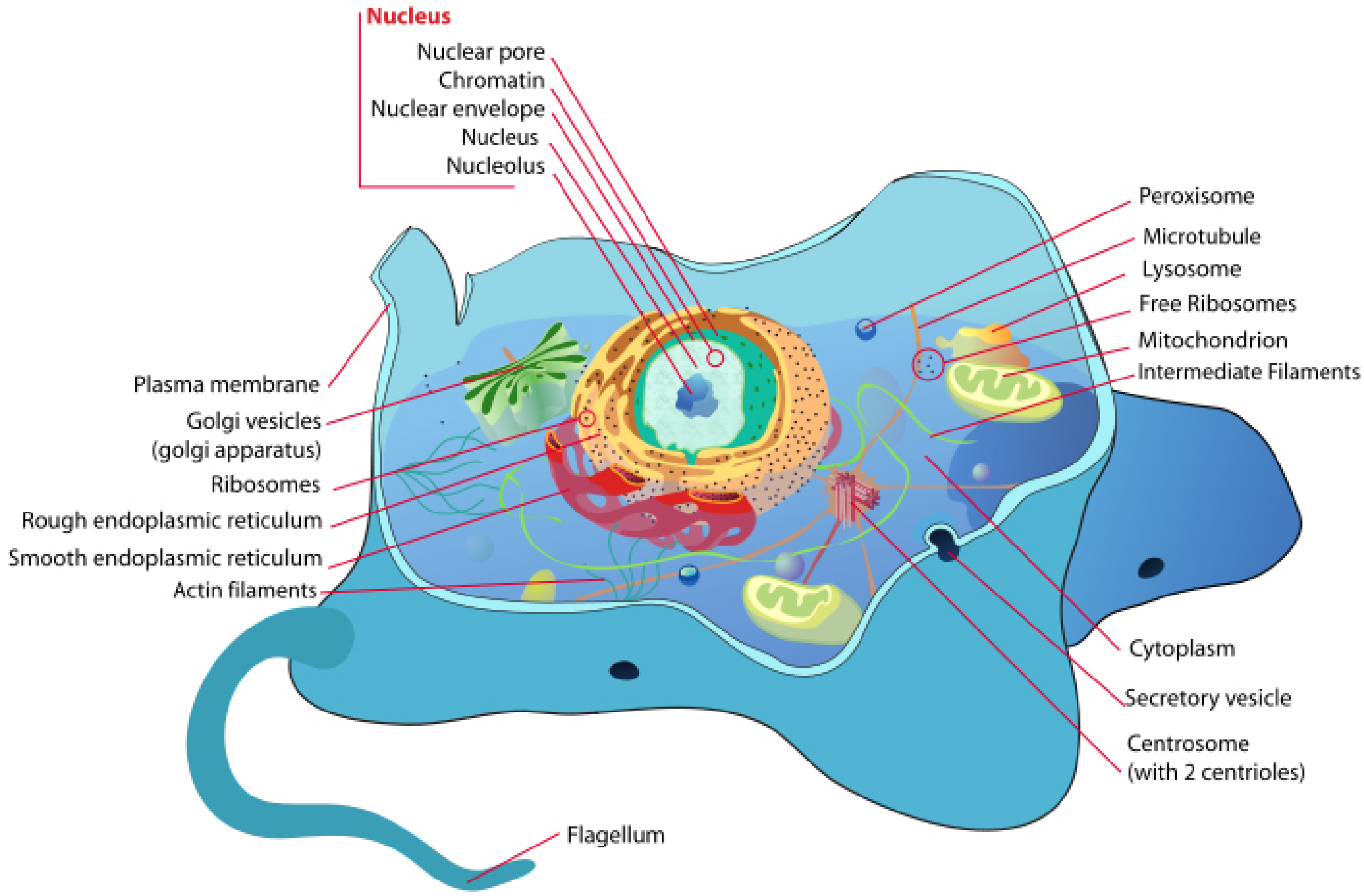

Figure 2. Eukaryotic Animal Cell

http://upload.wikimedia.org/wikipedia/commons/4/48/Animal_cell_structure_en.svg

Outside of the nucleus, the remaining organelles float in the cytoplasm and are surrounded by a cell membrane or plasma membrane. This membrane is made up of a double-layer of phospholipids and is called a lipid bilayer [7] . Some membrane proteins also are in the lipid bilayer and help to move materials in and out of the cell. The lipid bilayer is considered a selectively permeable membrane because only certain materials are allowed to move in and out of the cell, depending on their size, solubility, and charge. All eukaryotic cells have a cell membrane, and some also have a strong cell wall outside of the membrane to support, shape, and protect the cell [7] . The existence of a cell wall is one of the major differences between eukaryotic plant and animal cells; plant cells have a cell wall and animal cells do not.

Within the cytoplasm there are several organelles that are used for storage, clean up and support. Vacuoles are large membrane sacs that store materials such as water, salts, proteins and sugars [7] . Also within the cell are lysosomes, organelles responsible for digesting materials within the cell. These lysosomes contain digestive enzymes that are able to break down lipids, sugars and proteins into smaller molecules that can be used by the cell [7] . Within all eukaryotic cells there is a web of proteins known as the cytoskeleton that gives the cells their shape [7] .

There are also a group of organelles within eukaryotic cells with the specific job to build proteins. Ribosomes are organelles in cells that are composed of RNA and their job is to build proteins [7] . Protein construction is aided by be endoplasmic reticulum and golgi apparatus which help to transport, modify and sort proteins so that they can travel to different parts of the cells where they are needed [7].

There are also organelles in cells that capture and release energy. All eukaryotic cells have mitochondria, which perform cellular respiration to convert the chemical energy from food into usable energy in the form of ATP [7]. In eukaryotic plant cells there is also an organelle known as a chloroplast. Chloroplasts use energy from the sun, water, and carbon dioxide to produce energy in the form of sugar; this process is known as photosynthesis [7]. Figures 2 and 3 are diagrams of plant and animal eukaryotic cells with their cellular organelles labeled. In the figures you can note the two major differences between these cells: the presence of a cell wall and chloroplasts in the plant cell.

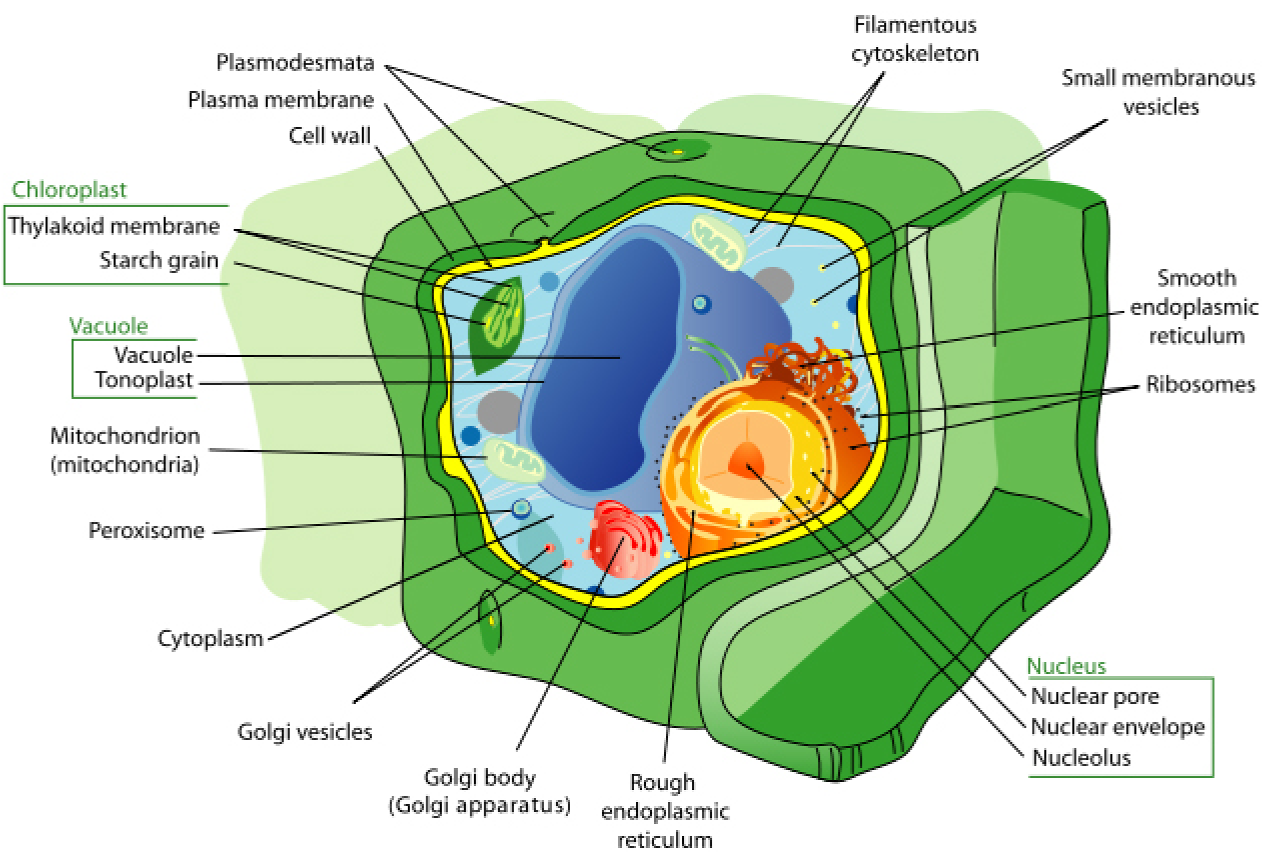

Figure 3. Eukaryotic Plant Cell

http://upload.wikimedia.org/wikipedia/commons/a/ae/Plant_cell_structure_svg.svg

Cell Division

One of the most important functions of living organisms is the ability to reproduce. Cells reproduce by dividing and passing their genetic information on to their daughter cells that are produced. DNA in cells is packed tightly into chromosomes to make it easy to separate the DNA precisely during cell division [7]. The cell cycle and prokaryotic cell division is called binary fission. Prior to cell division, chromosomes are replicated and the two DNA molecules attach to different parts of the cell membrane and the cell membrane cleaves and is pinched to divide into two cells [7]. The result is two identical daughter cells with the same DNA.

The eukaryotic cell cycle is relatively more complex and has four major phases: G1, S, G2, and M phase [7]. Figure 4 gives an overview of the eukaryotic cell cycle and cell division. A eukaryotic cell spends most of its "life" in interphase, which is composed of G1, S and G2. G1 and G2 are the growth phases where the cell grows and prepares for cell division. The "S" phase is the synthesis phase, where DNA is being replicated for cell division. After the cell goes through interphase, it enters the mitotic phase, which is composed of mitosis and cytokinesis. Mitosis can be broken down into a series of events that lead to cell division: prophase, metaphase, anaphase and telophase [7]. During prophase the cell "prepares" for cell division as DNA condenses into chromosomes and the nuclear envelope dissolves to allow the chromosomes to migrate throughout the cell [7]. The next step, metaphase, is where chromosomes migrate to the "middle" of the cell and spindle fibers that have formed attach to the centromere at the center of the chromosomes and to opposite ends of the cells. During anaphase the spindle fibers begin to pull the replicated chromosomes "apart" and towards opposite ends so that a complete set of chromosomes is on each side [7]. The last step in mitosis is telophase. This is where chromosomes spread back out and a nuclear envelope reforms around the two identical sets of DNA at opposite ends of the cell. At this point mitosis is complete, but cell division has not yet occurred [7]. The actual process of cell division is called cytokinesis. During cytokinesis the cell membrane begins to cleave in the center and eventually the cytoplasm is pulled into two parts. The result is two identical daughter cells with the same DNA. The cell cycle occurs in both eukaryotic plant and animal cells to promote cell growth.

The cell cycle is closely controlled by regulatory proteins. There are both internal regulators and external regulators. External regulators are proteins that respond to events outside of the cell [7]. Examples of external regulators are growth factors, which are proteins that control the cell cycle when you have an injury or during the development of an embryo [7]. Internal regulators are proteins that respond to events inside of the cell and make sure that the cell cycle is controlled and that the timing of mitosis is regulated [7]. When cell growth becomes uncontrolled it results in cancer. Cancer develops when a cell becomes aberrant and ignores checks on its own growth [7]. In the case of Henrietta Lacks, cervical cells were growing without regulation and a tumor formed in her cervix. A tumor is a mass of cancer cells that grows and divides rapidly [7]. As the cancer cells grow and divide they use nutrients from nearby healthy cells and can prevent organs and tissues from functioning normally. Cancer is caused by a mutation in the DNA that regulates cell growth and division [7].

Once students are introduced to the basic cell structure of prokaryotic and eukaryotic cells it their division process, this unit moves towards infectious diseases and how HeLa cells were used to develop vaccines for prevention. It is important for students to have a basic understanding of both bacteria and viruses before learning about infectious diseases and how they affect the human body.

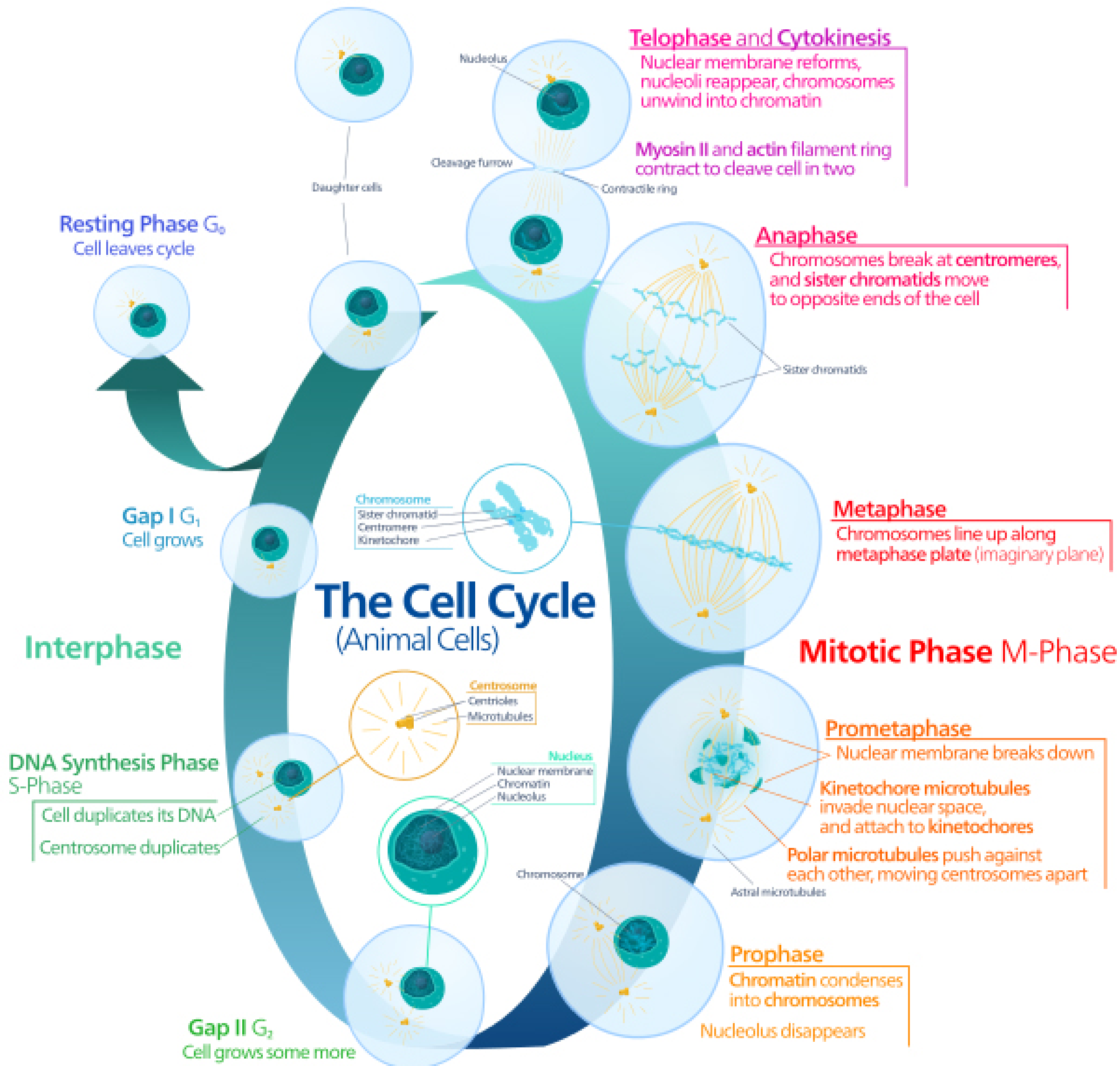

Figure 4. The Eukaryotic Cell Cycle

http://upload.wikimedia.org/wikipedia/commons/7/7e/Animal_cell_cycle.svg

Understanding Microbes: What is the Smallest Living Thing?

Microbes are tiny organisms that are too small to be seen without a microscope. They fall into four major categories: bacteria, fungi, protozoa, and viruses [8]. These microbes often get a bad reputation when they are referred to as "germs" or "bugs," but while some microbes cause infectious diseases in humans, others are necessary for a healthy life [8]. Scientists have uncovered evidence that microbes have been infecting plants and animals with infectious diseases since ancient times by observing prehistoric material such as human skeletons and mummified remains [8].

Bacteria

The group of microbes known as bacteria is single-celled organisms that fall into the category of life known as the prokaryotes. Prokaryotic cells do not contain a nucleus, but bacterial cells do contain DNA as their genetic material. Like other prokaryotic cells, bacteria often have a rough cell wall, plasma membrane, and ribosomes suspended in their cytoplasm. Many bacteria require oxygen and need food for energy [8]. Bacteria are among the oldest living things on Earth, with scientists having found fossilized remains that date back more than 3.5 billion years [8]. Bacteria can also survive in the most extreme conditions, from extremely cold to extremely hot areas. There are thousands of species of bacteria but a majority of bacteria fall into three basic shapes: rod-shaped bacilli, ball-shaped cocci, and spiral-shaped [8]. Of the thousands of species of bacteria, less than one percent causes diseases in humans [8].

Viruses

It is often debated whether or not a virus is considered a living thing. Most notably, these functions include metabolism and reproduction. While viruses do contain their own genetic material (DNA or RNA), a virus is not made up of cells and cannot perform the basic functions of living things without hijacking a cell and taking control of its metabolism to reproduce [8]. So is it alive? Or is a virus this strange particle that straddles a thin line between a living and nonliving thing? The question continues to be asked by scientists today. Viruses are basically small bundles of genetic material, either DNA or RNA, covered in a protein coat called a capsid [8]. They can be rod-shaped, sphere-shaped, or icosahedral [8]. Like other microbes, viruses can be found almost everywhere on Earth. They are the smallest microbe, and are basically found anywhere that there is a cell to infect; from bacterial cells to human cells. There are different viruses, each one behaving differently and very particular about what type of cell it hijacks and infects [8]. When they attack, viruses attach to the outside of a cell, enter the cell or inject their genetic material, and then take over the metabolism of the cell and direct it to make more copies of the viruses that are released to infect other cells [8].

Infectious Diseases

Tiny microbes, such as viruses, bacteria, fungi and protozoa, can cause infectious diseases in humans. While many microbes do not harm us and some even help us, the disease-causing microbes that we refer to as "germs" can make us sick and can even be deadly [9]. Microbes are spread through food, water, the air, the environment, or physical contact between two people or sometimes contact with animals [9].

The Immune Response and Germ Theory

When our bodies are infected with a microbe our immune system recognizes the foreign invader and launches an immune response [10]. The main defense we have against foreign substances such as bacteria or viruses are our white blood cells. White blood cells are produced in the bone marrow and we make about a billion of them each day [10]. White blood cells, called macrophages, will detect and destroy bacteria when they see them. When a viral infection begins our T and B-lymphocytes will work to fight off the infection [10]. B-cells are important in producing antibodies, which bind to viruses to stop them from replicating and tag them so that other cells can recognize them. Once an infection is cleared, some specialized B and T-cells stay in our bodies and act as memory cells that will easily recognize a virus if we come in contact with it again [10]. Scientists have been able to use this idea of acquired immunity and resistance with memory cells to create vaccines, which will be discussed later in this section.

Before the discovery of these disease-causing microbes, people blamed sickness on evil spirits or "bad blood" [9]. It wasn't until the invention of the microscope that scientists were able to see microbes and began to study bacteria, viruses, protozoa and fungi. Louis Pasteur was the first scientist to establish the presence of germs by linking them to illnesses. Pasteur proved that fungi and bacteria were present in the air and that they caused sickness in humans [9]. He was able to show that germs caused diseases and began to pioneer a way to get rid of them with a process called pasteurization; eventually he was able to develop vaccines for chicken pox, cholera, diphtheria, anthrax and rabies [9]. Pasteurization is the process of heating and then cooling a liquid food to remove microbes that may spoil that food (beer, wine, milk, etc.). Pasteur began by studying alcohol fermentation and observed that wine would go sour and turned to vinegar unexpectedly [11]. Using a microscope, Pasteur was able to see that small, rod-like microbes were present during fermentation and cause the contaminating the wine [11]. Pasteur was able to identify microbes that were responsible for contaminating beer, wine and milk and found that if he heated the liquids to a high temperature and then cooled them down he could kill the microbes and sterilize the liquids [11]. This process became known as pasteurization, and was coined to honor Louis Pasteur and his discovery. The identification of microbes that "spoiled" beer and wine led scientists to the understanding that diseases are caused by microorganisms that entered the body; similar to how microbes could contaminate the liquids Pasteur studied [11]. Today, scientists are still researching causes of various human diseases and ways to prevent or cure them.

Treatment and Prevention

Two of the most important tools for curing or preventing diseases are antibiotics and vaccines. Antibiotics are a class of drugs that kill bacteria in the human body [9]. Antibiotics are targeted at bacterial infections and come in the form of pills, liquids, injections, lotions, or creams; each type is used to attack a specific bacterial pathogen [9].

Vaccines are another way to fight infectious diseases, but unlike antibiotics that are used to treat an infection, vaccines are used to prevent disease. Vaccines stimulate the immune system by creating antibodies to fight specific infections. A vaccine usually contains a killed or weakened form of a microbe that causes a disease and your body is able to produce antibodies to kill that germ without getting sick [9]. When a person who has been given a vaccine is later exposed to the illness, their body is already prepared to fight the infection because of the antibodies that are already created. Edward Jenner developed the first real vaccine when he inoculated a young boy with the cowpox virus in 1796 [9]. Jenner found that people exposed to the cowpox virus did not contract smallpox, a disease that was killing thousands of people. Edward Jenner began by observing patients who had contracted cowpox while working on the farm. These patients had mild discomfort, aching, pustules and swelling but the disease did not lead to death like smallpox [12]. Jenner noted that the individuals who were infected with cowpox did not become infected with smallpox when they were exposed to this. Jenner hypothesized that this was because the individuals who were infected with cowpox had antibodies that made them immune to the smallpox virus. Jenner tested his hypothesis on an 8-year old boy, James Phipps, by vaccinating him with a fluid from pustules of cowpox-infected patients and then exposing him to the smallpox virus [12]. When he came in contact with the disease Phipps did not contract smallpox, a result of the immunity he obtained from the cowpox injection. Jenner had successfully created the smallpox vaccination by triggering the immune system to create antibodies for a pathogen that was closely related to smallpox to fight the infection when exposed to it. This discovery would lead to the development of many other vaccines throughout history.

Vaccine Development: A Focus on Polio

Polio is a disease caused by a virus that attacks the central nervous system and causes paralysis [13]. The poliovirus is spread by direct person-to-person contact by contact with infected mucus or feces and leads to the disease, poliomyelitis [13]. Like all viruses, the poliovirus works by infecting human cells. The poliovirus enters the body through the mouth and nose where it travels through the digestive system and multiplies [13]. Once it reaches the intestinal tract, the virus is absorbed into the blood stream and spread to the lymphatic system [13]. While polio has been largely eradicated, lack of immunization and exposure to the poliovirus will cause a person to contract the disease. The people that are most likely to be infected by the poliovirus are children, pregnant women, and the elderly [13].

Polio was a worldwide epidemic between 1840 and 1950, before the polio vaccine was developed. The development of the vaccine was aided largely by the discovery of HeLa cells and the incidence of the disease has been greatly reduced [13]. In fact, the disease has been completely eradicated in some countries. In 1948, Dr. Jonas Salk began researching the poliovirus at a virology lab at the University of Michigan [14]. HeLa cells were easily infected by the poliovirus and therefore were perfect for vaccine testing and development. Since HeLa cells were easily grown and cultured in the laboratory, Salk was able to infect large amounts of HeLa cells and develop a vaccine that was viable for human use. In 1950 he began working to create an inactivated poliovirus vaccine, and by 1952 Dr. Salk had created what he considered a safe and effective vaccine against the poliovirus [14].

Teaching Strategies

The Cell City

Teaching students to memorize all of the organelles in prokaryotic cells and eukaryotic plant and animal cells can be a tedious job. Instead, have students complete a project where they are asked to create an analogy between a cell and a city. The cell can be thought of as its own miniature city: each organelle represents a part of a city that carries out a specific job or function so that the cell can survive. For example, the nucleus would be like the town hall of a small city. The nucleus is in charge of controlling all of the actions of the cell, just as the town hall is responsible for controlling the activities. Additionally, the mitochondria can be compared to the power company in a town. The mitochondria are responsible for powering the cell through cellular respiration and the formation of ATP. Similarly, the power company produces energy for the city. Students should be asked to come up with a comparison for all major cellular organelles to develop a complete cell city analogy. The final project would consist of a poster presentation or 3D model of the city that is labeled with both the cell and city parts. A written summary explaining the analogy should also be included. Also, this activity can be extended by using the "cell city" as an example and then asking students to come up with their own analogy such as a classroom, school bus, car, kitchen, house, etc.

Infectious Disease Case Studies

In this activity students are given the opportunity to be the doctor and diagnose patients that are presenting with various infectious diseases. Provide the students with a list of patients and a brief summary of their symptoms. The goal of the activity is to have students correctly diagnose the patients using the Internet and their understanding of pathogens. Students should use websites such as Web MD and Mayo Clinic to assess the symptoms of their patients. In addition to correctly diagnose their patients, students should determine what type of pathogen caused the infectious disease (virus, bacteria, protist or fungus) and should develop a plan for treatment. Some diseases that can be used are: athlete's foot (fungus), HIV/AIDS (virus), strep throat (bacteria), tetanus (bacteria), amebic dysentery (bacteria), and malaria (protist).

Spread of Disease Laboratory

A great way to demonstrate the transmission of disease is to have students complete the spread of disease laboratory experiment. In this lab, students are each given a cup with a clear, colorless solution and a disposable pipette. All students in the class, except for one, are given a cup with just water in it. One student in class is the "index patient" and their cup has a few drops of sodium hydroxide in it. None of the students know who the index patient is at the start of the lab. Students are instructed to "come in contact" with 3 other people in the class by exchanging a pipette full of solution with each person. This should be completed in rounds and signaled by the instructor. Students should keep track of with whom they have come in contact with in their data table. At the end of the third round a drop of phenolphthalein should be added to each students' cup. Students who were infected by the disease will end up with a pink solution in their cup. As a class, students should create a tree to determine how the disease was transmitted and to determine who the index patient was. This activity promotes collaboration between all students in the classroom and demonstrates how quickly a disease can be spread throughout a population. Additionally, this activity can be repeated with more than one index patient to make the determination of transmission more difficult for the class to solve.

Pathogen Jigsaw

In this unit is important to understand that there are several pathogens that cause disease in humans: bacteria, fungi, protists, and viruses. An interactive way to get students involved in their learning and promote reading is to have students participate in a pathogen jigsaw. Students should be divided into groups of four for this activity. Each member in a group will be assigned a different pathogen that they are responsible for learning about. Students are given short articles with information about the pathogens and they are given time to read the information and look for key points and facts. Students are instructed to become an "expert" on their specific pathogen. Then, each expert will teach the other three members in their group about the pathogen they read about. Students can be given a graphic organizer to take notes about each pathogen so that at the end of the activity they have information about viruses, bacteria, fungi and protists.

Microscope Investigations

The use of light microscopes is essential for this unit. Students should be given several opportunities throughout the unit to observe life at the cellular level using a microscope. There are many different ways to incorporate microscopes into this unit, such as: the use of prepared slides to observe microscopic bacteria, fungi and protists, the use of the plant Elodea to observe chloroplasts, and the use of potato or cork to observe plant cell walls.

HeLa Cells and Chromosome Spreads

CellServ produces a kit that will allow students to use HeLa cells in the lab to observe cells and chromosomes under the microscope. Students are given microtubules containing HeLa cells that have been fixed in solution prior to metaphase in mitosis. Students use pipettes to drop the cell solution onto clean microscope slides and then stain the slides with stain that is included in the kit. Once the slides have dried, students are able to look for cells under the microscope. Using the oil immersion lens on a light microscope students should be able to see chromosomes inside of the cells.

iPad Applications

There are several applications that are available on the iPad that give students a look at cellular life and the spread of disease. A list of a few of these applications and a short summary are below.

Powers of Minus Ten – Cells and Genetics: This application allows students to virtually zoom in through a human hand to observe skin and blood cells. The application can be used to show students different phases of mitosis, differentiate between different types of cells, and identify cell parts.

Plague Inc.: This application is a simulation about how a virus can spread throughout the globe rapidly. A virus rapidly reproduces and mutates as students try to stop it by creating vaccines and ways to prevent the spread or cure the disease.

3D Cell Simulation and Stain Tool: This application allows students to virtually look at 3D plant and animal cells. The application has information about cellular organelles and students can stain the cell to focus on one or more organelles at a time.

Appendix A: Standards

DINQ.1 Identify questions that can be answered through scientific investigation

DINQ. 2 Read, interpret and examine the credibility and validity of scientific claims in different sources of information

DINQ. 4 Design and conduct appropriate types of scientific investigations to answer different questions

D.31 Describe the similarities and differences between bacteria and viruses

D.30 Explain the role of the cell membrane in supporting cell functions

D.27 Describe significant similarities and differences in the basic structure of plant and animal cells

Appendix B: Materials for Students

National Institute of Allergy and Infectious Disease. "Understanding Microbes: in Sickness and in Health." *NIH Publication* , no. 09-4914 (2009).This is a publication of the NIAID and covers basics about microbes such as: how microbes make us sick, immunity, types of microbes, infectious diseases, treatment, and prevention.

Rogers, Michael. "The Double-Edged Helix." *Rolling Stone Magazine* . March 23, 1976.This is one of the first articles published about HeLa cells and the controversy over the use of Henrietta Lacks' cells in science without the consent of her family.

"Smallest Thing." American Association for the Advancement of Science. Last modified 2013. http://sciencenetlinks.com/science-news/science-updates/smallest-thing/. This website has lesson plans that talk about microbes, specifically viruses and the question of whether they can be considered living things. The website includes articles, questions and lesson ideas.

Skloot, Rebecca. *The Immortal Life of Henrietta Lacks.* New York: Broadway Paperbacks, 2010.This book is used as the backdrop for this unit. Skloot details the life of Henrietta Lacks and the contributions her cells have made to science, as well as the controversy her family has become a part of with the use of her cells without their knowledge.

Appendix C: Bibliography

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[2] Zion, Michal and Sadeh, "Curiosity and Open Inquiry Learning." *Journal of Biological Education* 41, no. 4 (2007): 162-168. This research article talks about inquiry learning in the science classroom.

[3] Brewer, Carol. *Scientific Literacy in the Classroom* .By ActionBioscience.org. AIBS Annual Meeting, 2007.This resource is an interview by Carol Brewer about the use of scientific literacy to empower students in the classroom and improve their inquiry and critical thinking skills.

[4] Claiborne, Ron and Wright, Sidney. "How One Woman's Cells Changed Medicine." *ABC World News* , January 31, 2010. http://abcnews.go.com/WN/henrietta-lacks-woman-cells-polio-cancer-flu-research-medicine/story?id=9712579#.UaQiLpV3cwE. This article gives a general overview of HeLa cells and their use in the development of the polio vaccine and medicine.

[5] Rogers, Michael. "The Double-Edged Helix." *Rolling Stone Magazine* . March 23, 1976. This is one of the first articles published about HeLa cells and the controversy over the use of Henrietta Lacks' cells in science without the consent of her family.

[6] Brumback, Roger A. "Book Reviews: The Immortal Life of Henrietta Lacks." *Journal of Evidence-Based Complementary & Alternative Medicine* 16, no. 3 (2011).This resource is a book review of the Immortal Life of Henrietta Lacks by Rebecca Skloot.

[7] Miller, Kenneth R., and Levine, Joseph S. *Biology: Foundation Edition* . New Jersey: Pearson Education, Inc., 2010. A high school textbook with general information related to cell biology and infectious diseases. A great student resource as well.

[8] National Institute of Allergy and Infectious Disease. "Understanding Microbes: in Sickness and in Health." *NIH Publication* , no. 09-4914 (2009).This is a publication of the NIAID and covers basics about microbes such as: how microbes make us sick, immunity, types of microbes, infectious diseases, treatment, and prevention.

[9] "Part 2: So, What's Changed." American Association for the Advancement of Science. Last modified 2013. http://sciencenetlinks.com/media/filer/2012/02/17/yourhealth9-21.pdf. An article by the AAAS about microbes and infectious disease.

[10] "How Does the Body Fight Off a Virus?" BBC. Last modified 2013. http://www.bbc.co.uk/science/0/22028517. This resource is an article by BBC Science: Knowledge and Learning Beta. It reviews the immune response to a viral infection and the role macrophages, T-cells and B-cells play in immunity.

[11] Cohn, Ph.D. David V. "Louis Pasteur." October 2004. http://pyramid.spd.louisville.edu/~eri/fos/interest1.html. This resource gives some background information about Louis Pasteur and the development of the pasteurization process for elimination microbes. It also briefly describes how Pasteur contributed to the germ theory for the spread of disease.

[12] Cohn, Ph.D. David V. "Edward Jenner." October 2004. http://pyramid.spd.louisville.edu/~eri/fos/jenner.html. This resource gives some background information about Edward Jenner and the development of the smallpox vaccine.

[13] *The University of Maryland: First Year Book Program.* 2013. http://fyb.umd.edu/2011/henrietta-lacks.html.This website by the University of Maryland covers some background information about HeLa cells, Rebecca Skloot's book and the development of the polio vaccine at the Salk Institute.

[14] *The Salk Institute for Biological Studies.* 2013. http://www.salk.edu/index.php.This resource gives a timeline for the development of the polio vaccine from the Salk Institute.