YALE NATIONAL INITIATIVE
to strengthen teaching in public schools®

Curriculum Units by Fellows of the National Initiative
2015 Volume VI: Physiological Determinants of Global Health

Genetics and Mechanisms of Disease

Curriculum Unit 15.06.04, published September 2015
by Corryn Nikodemski

“What if you could feel no pain?” I pose this question each year to sixth graders and the responses are always both varied and creative. At first thought, most say that they would enjoy being able to have this characteristic. However, after we read a story about Gabby, a girl that feels no pain, their minds are often changed. Hereditary Sensory Autonomic Neuropathy (HSAN) is an inherited disease, but my attempts to explain this to my students generally only cause confusion since the students do not have sufficient background in genetics. This conundrum was my inspiration for creating this unit. I hope to use the material described in this unit to expose my students to basic genetics concepts and vocabulary so that when they arrive in seventh grade they feel confident in linking the information they learn to the background knowledge from our time together.

Mariner Middle School is a grade six through eight secondary school located in Milton in Sussex County, DE. Our school has separate wings for each grade level and we offer departmentalized teaching environments. I am responsible for teaching general science. The sixth grade curriculum includes units on the Scientific Method, Human Body, Forces That Cause Motion, Electricity, and Earth History. The district is full of middle class families, although there are some areas that house high percentages of low-income students. The surrounding area contains both agricultural and business districts, and, in the summer months, becomes a resort town. My particular school has high number of low-income families so we qualify as a CEP school (Community Eligibility Provision) and offer all students free breakfast and lunch..

The unit is designed to meet both Next Generation Science Standards and Common Core Literacy Standards. The activities are designed for middle-school students, but could be modified to meet the needs of higher learners by adjusting the lexile of the materials. Students at the elementary level could complete the activities, but teachers may need to modify the questioning strategy to be more developmentally appropriate for the age range that is being taught. The unit also meets Delaware State Science Standards in both inquiry and life science. Standard One (Nature and Application of Science) will be met through the activities related to generating questions about the content. Standard Six (Life Processes) states that students should understand that living systems, from the cellular to the organismic level, demonstrate complementary nature of structure and function. This standard will be met through the literacy and reading component of the unit.

Rationale

The students I teach have a wide range of ability levels, but they also have a wide range of background knowledge. My pre-assessment for the Human Body unit is always the same: I give each student a blank sheet of paper with the outline of the human body sketched for them, and ask them to draw what is inside that keeps us alive. The first few years I did this, I was shocked at how many early-adolescent students could put nothing in the graphic organizer. It was as if they thought we were kept alive by fairies and magic. One of my biggest goals is for my students to be scientifically literate when they leave my classroom. I want them to have enough content knowledge, as well as exposure to content area reading materials, so that they can read and understand documents as adults. I also want them to be skeptical of what they read.

The design of the human body curriculum lends itself to teaching mini "units" on each system. When I teach the nervous system, I try to get students to think about what happens when "things go wrong." That is where the lesson on Gabby and HSAN helps focus discussion on our body's defense mechanisms. The kids are intrigued, but also confused, when I try to explain that she can have symptoms of a disease, when neither her parents, nor sister, are affected. While they know that some diseases can be contagious, we are just beginning to address non-communicable diseases. We do a short case study on Pellagra, and the lack of niacin in diets of poor people in the south in the late 1800s. This give the students some background on a non-communicable disease caused by nutrition, but does not address hereditary mechanism for disease. From anecdotal discussions, it seems most students understand that you get a "mix" of "stuff" from your parents, which is why you may resemble them. However, my students are reluctant to offer ideas or explanations of why someone would have a phenotype so different than their parents (for example: presenting with a disease, even though no one else in the family has the disease).

Inevitably, because of this lack of comprehension, I have to do a short "crash course" on genes and inheritance. I would like to learn more about the basics of genetics so that I am able to explain the concepts at a level of understanding appropriate for sixth graders. I am particularly interested in teaching my students about the role of genetics in disease.

My unit will build to a culmination in which students generate high-level questions to ask scientists during a video-conference. I want them to be able to understand the content of what we read and discuss in class, and also to use higher order thinking skills to synthesize and pose new questions. This will require texts that are accessible for students at various reading levels and will also require me to have a deeper understanding of the content that I am asking them to read. I aspire for my students to generate questions that require abstract and complex reasoning as well as investigations or applications to real world work.

Content Objectives

Cells

This unit is designed for sixth grade students. In my district, students are not exposed to cell theory until seventh grade. However, since I am responsible for teaching about organs and their systems, occasionally it is appropriate for me to discuss something that happens at a cellular level. This is a significant motivating factor

since I plan to use this as an enrichment unit during Response to Intervention time and will most likely have students whom are at or above grade level. Therefore, the content begins with background on cells as the basic unit of life.

According to cell theory, all living things are made up of cells (they are the basic unit of life), and all cells are produced from other cells. The production of new cells occurs in a process called cell division and it results in genetic material being passed from parent cell to daughter cell. Cell division occurs my mitosis or meiosis. Mitosis occurs in somatic (body) cells, whereas meiosis occurs in germ-line (reproductive) cells. While my students will not be assessed on their understanding of cell division, it would be helpful for them to know that two types of division take place, and that one type, meiosis, is essential for human reproduction. The cells that result from meiosis are special types of cells called gametes, or what are commonly known as egg and sperm cells.

Multicellular organisms, such as humans, contain different kinds of cells that are specialized at doing jobs to sustain life. For instance, cardiac muscle cells drive the contractions that allow the heart to beat. Red blood cells carry a protein called hemoglobin and are specially shaped like flattened disks. This allows them to efficiently transport oxygen molecules. Special rod and cone cells in your eyes allow you to see colors and give us night vision. Nerve cells connect to muscle cells to allow you to move your fingers to access this unit using your keyboard or mouse.

The cells that make up the human body are classified as eukaryotic cells. Eukaryotes can then be subdivided into plant and animal cells. Distinguishing characteristics between the two include a fixed shape cell wall and the presences of chloroplasts in plant cells. Animal cells are not fixed in shape, but still contain a cell membrane and specialized organelles such as the nucleus, mitochondria, endoplasmic reticulum, Golgi bodies and ribosomes (see Figure 1). Each of these organelles conducts important functions in cell processes, and therefore plays a role in health. The cytoplasm inside the cell contains both the cytosol (fluid-filled space) and the organelles. [1]

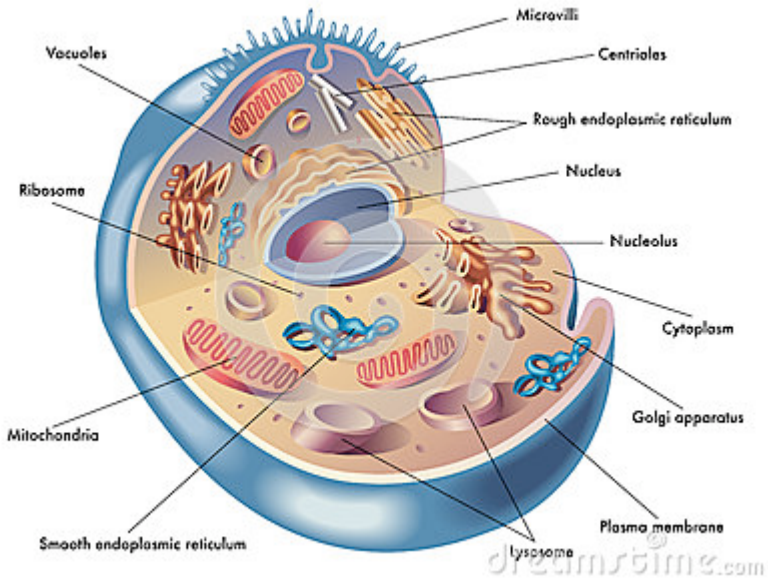

Figure 1

The nucleus of a cell contains all the genetic material to direct functions of the cell. It is often compared to the

brain; its primary function being to give directions for physiological processes that will keep itself alive. In addition to the nucleus, cells also contain ribosomes, which aid in protein synthesis and function within the cytoplasm of the cell. This protein synthesis occurs when DNA is transcribed to mRNA and proteins are created by the translation of mRNA. The ribosomes are attached to the rough endoplasmic reticulum (ER) and are the sites of protein synthesis. ER is mainly acts as a storage facility, but also help with the creation of lipids and steroids.[2] Vesicles are pieces of smooth ER are capable of transporting their contents around the cells. Mitochondria are responsible for cellular respiration and providing energy for the cell to continue life, while Golgi bodies modify, process, and sort newly produced proteins that arrive from the ER.[3]

DNA and the Nucleus

The genomic DNA, or set of DNA instructions within a cell, is contained with the nucleus. DNA is made up of a series of nucleotides. DNA in the nucleus is arranged as a double helix (Figure 2). Nucleotides contain a sugar, a phosphate, and a nitrogenous base. These are put together like a puzzle to form DNA molecules. During the life of a cell, the instructions encoded in genes on DNA are first transcribed into mRNA, and then translated into proteins. Thus, the instructions embedded in DNA within the cell nucleus are used throughout the life of a cell to generate new proteins.

Human DNA is a long molecule in which the instructions for making proteins are written in a language consisting of four acid bases (adenine, guanine, cytosine, and thymine). The linear sequence written by the four chemical characters make up what is referred to as your genotype. The order of the paired bases specifies the codes for genes, which are translated into proteins, which dictate your phenotype, or how you look and behave. The combination of these organic bases reads like a code, but even with all the genetic variations around us, over 99% of our DNA is exactly the same among individuals. This means our genotypes are 99% similar. The human genome contains over three billion base pairs, so less that one percent of them are different in each human. However, that one percent is enough to account for all of the phenotypic diversity in the human population. [4]

These base pairs are arranged on the DNA molecule into a specific structure called the double helix. At the molecular level, these bases pair with each other (A and T, C and G), and are bonded with sugar and phosphate molecules. These base pairs are bundled, called genes, and packaged into groups called chromosomes. On each chromosome, there is a “discrete” location for each gene. Chromosomes are what determine whether someone is a male or a female. As stated in *Biology: Exploring Life*:

> The existence of chromosomes as pairs of homologs explains why each body cell has two copies of each allele. The separation of homologous chromosomes during meiosis accounts for the presence of only one pair of alleles in a gamete.[5]

When genes are passed from parent to offspring, all the genetic information from each of the two parent cells is “inherited” to the daughter cell. In the nucleus of a fertilized human egg cell, there are twenty-three pairs of structures called chromosomes. When fertilization occurs, each gamete, carrying half of this information (half in the egg and half in the sperm), come together to form the new cell. The mixing of the genetic information, during meiosis, from each parent cell is what allows for variation to keep the population sustained. This variation allows for some individual to have a survival advantage over others in the same population, thus driving evolution. These patterns of inheritance are described by scientists in graphical models such as the

pedigree and Punnett square.

Special chromosomes called sex chromosomes determine gender in most animals. Females generally have two X chromosomes and males have an X and a Y chromosome (XY). Therefore, some diseases that are considered linked to the X chromosome are expressed when a male receives a recessive X allele on his X chromosome.

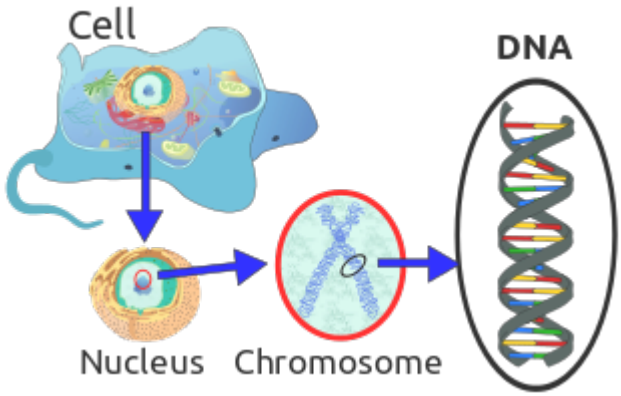

Figure 2: An Inside Look of a Cell

Chromosomes, Heredity, and Mendelian Genetics

Chromosomes are the "suitcases" of DNA. They contain DNA and "unpack" it during cellular reproduction. A disease is considered "inherited" when it occurs because of the pattern of inheritance during reproductive processes. When an egg is fertilized, it receives an allele for each gene from each parent, and depending on the combination received, the new human is afflicted with the disease, a carrier for the disease, or may receive no genetic information related to the disease. In a given family situation for a recessive autosomal disease like HSAN, if both parents are heterozygous for a disease (meaning they carry a dominant and a recessive allele), a child will be born with the disease if the gametes that fertilize both happen to have the recessive allele. A child can be a carrier of the disease, but not affected, if he or she receives one dominant and one normal allele. [6]

People have known diseases can be "passed" from parents to offspring for a long time, but they weren't sure how. In early Judaism, if two sisters lose a son as the result of the excessive bleeding after circumcision, they are not required to have subsequent sons circumcised. This exemption to a religious regulation demonstrates an earlier acknowledgement of hemophilia as an inheritable disease.[7]

While all diseases that present at birth are called congenital diseases, not all are considered inherited. For instance, if a baby is born with a ventricular septum defect (commonly called a "hole in the heart), it could be due something that occurred during somatic cell division during gestation. Other examples of congenital defects include spina bifida, club foot, and gastroschisis (when intestines present outside the abdomen). Adults that displayed these conditions as children can produce offspring with no chance of having the defect since it was not inherited.

The graphical models of the patterns displayed through the passing of genes are most commonly known as Punnett squares. Created in 1900 by Gregor Mendel, Punnett squares are some of the most familiar organizers used to discuss inheritance trends. Using controlled experiments, Mendel provided evidence that certain phenotypes could be created through careful mating of parent organisms.

Mendel's conclusions were drawn from experiments he conducted with pea plants. He chose to examine seven traits including height, seed color, flower color, and others. In order to begin, he had to be sure the plants were self-fertilized and would not produce plants that had characteristics different than the parent plant.[8] To start, he completed mono-hybrid crosses of plants that would only cross one type of characteristic (example: seed color). The data analysis of these monohybrid crosses led to the generation of new vocabulary such as dominant/recessive trait, P generation, and F1 generation. Dominant trait refers to the characteristic that was displayed, while recessive trait refers to the characteristic that seemingly disappeared when plants with two different characteristics were mated (example: yellow is dominant to green for seed color.) A "P generation" is the original parental generation, and the "F1 generation" is the first round of offspring (F1= first filial).

When he crossed the plants for a second time (the F2 generation), he found that the recessive traits that had disappeared showed up again in a special ratio of 3:1. This ratio was found in each of the seven traits he studied. This reappearance conflicted with the theories on inheritance that were current at that time, which stated that genetic characteristics were a true "blending" of fluids. Mendel eventually hypothesized that the traits in plants were governed by factors that were derived from each parent. The term allele is now used to describe this factor. Additionally, while the traits may not show up in the individual, they can show up in later generations.[9]

In a monohybrid cross, during which on a single trait is crossed, hereditary patterns follow specific patterns as shown in Figure 3. This shows a homozygous recessive trait (small y, green) being crossed with a heterozygous dominant trait (capital Y, yellow).

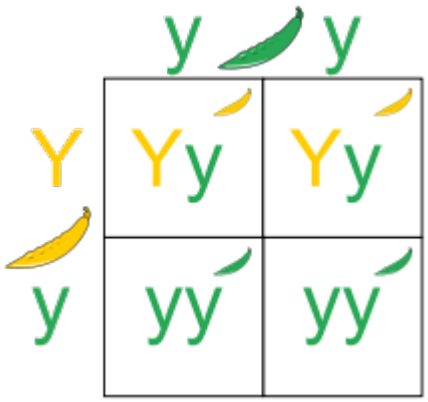

Figure 3: A Monohyrbid Cross Punnett Square

In a dihybrid cross, organisms with two specific traits are crossed. These produce more complex Punnett squares as shown in Figure 4. A dihybrid cross also illustrates the law of Independent Assortment as discussed below.

	RA	**Ra**	**rA**	**Ra**
RA	RRAA	RRAa	RrAA	RrAa
Ra	RRAa	RRaa	RrAa	Rraa
rA	RrAA	RrAa	rrAA	rrAa
Ra	RrAa	Rraa	rrAa	Rraa

Figure 4: A Dihybrid Cross Punnett Square

Both of these squares illustrate two of Mendel's Laws. The first Law of Segregation refers to the fact that pairs of chromosomes separate from the two members, and one member determines the genetic make-up of each gamete. [10] When there are two alleles for a trait, the fertilized cell will be either homologous or heterozygous for that specific trait. If an allele is dominant, that means that it will be expressed over an allele that is recessive: therefore, in heterozygous cells, the dominant trait will be expressed. Mendel's second Law of Independent Assortment states that the pairs of chromosomes that are inherited are done so independent of one another, so that different traits have an equal opportunity of occurring together.[11]

Mutation

The complications that arise with genetic inheritance in humans create many more questions that new frontiers of biomedical research are trying to answer. Some of these complications are called mutations. These occur when extra copies of genes are present, when copies of genes are missing, or when the sequence within a gene gets altered in some way. In fact, mutations account for all biological evolution. New alleles form either randomly or in response to the environment. New mutations lead to offspring that are born with a new trait and thus the gene pool is diversified.

While some new traits can be devastating, as is the case with HSAN, other mutant traits can also allow for adaptations and survival. One of the best-known examples of a mutant trait offering a favorable outcome occurs in the peppered moth. During the Industrial Revolution, as the air became polluted with dark soot, a dark form of peppered moth began to flourish. Scientists believe this resulted because predatory birds could not see it against the soot-covered surfaces. Using a linkage map, scientists are hoping to find the exact mechanism for the mutation.[12]

Other mutations create outcomes that are not favorable. In humans. single gene defects can cause diseases such as sickle-cell anemia and phenylketonuria (PKU), both of which can be fatal. If detected early, during a newborn screening test, infants with PKU can be given a special diet. The gene mutation linked to PKU is caused by a defect in the gene that helps create the enzyme needed to break down phenylalanine. When a person with this defect eats a diet high in protein, a dangerous build up of amino acids can put them at a high risk of issues like intellectual disabilities, neurological problems, and poor bone strength among others.[13]

Disease

After I teach my students the basics of DNA, chromosomes, and genetics, I will have them apply the information by reading medical texts on genetic diseases (cystic fibrosis and HSAN) and their impact on various body systems.

Cystic Fibrosis occurs when a person inherits a defective gene on chromosome seven called CFTR (cystic fibrosis transmembrane conductance regulator). The disease is recessive, which means both parents must have the defective gene for their children to get the disease. It primarily affects Caucasians, for reasons still unknown, but occurs because both the father and the mother have a recessive allele on one copy of chromosome seven. If only one has the gene, the child may become a carrier. One of many mutations that cause cystic fibrosis is a three base deletion. This means that a certain amino acid is not present within the protein produced in cells.[14]

The gene that is affected in CF is responsible for chloride transport in and out of cells. When chloride transport is impaired, mucus builds up outside the cells in the airway of the lung, and other places. While I originally

believed cystic fibrosis only affected the lungs, it can also cause mucus build up in the digestive tract. This build up can affect enzymes ability to break down food, which in turns causes issues with nutrition absorption. Therefore, people affected with cystic fibrosis not only have a compromised respiratory system, but also have digestive system that does not function properly.[15]

The other genetic disease that I found interesting is the one that was mentioned at the start of this unit. HSAN is a class of diseases that affect the sensory and autonomic nervous systems. There are multiple classes of the disease, but the class that we discuss is autosomal recessive. The protein that helps nerve cells create myelin produces in an abnormal manner. This causes defects in the development of the nerve cells that detect pain and temperature. This is generally diagnosed in infants when self-destructive behaviors occur and the baby does not respond in a typical manner. For instance, the baby may bite his or her tongue or fingers, but does not cry.[16]

Classroom Strategies

I plan to combine literacy and reading strategies with hands-on labs in order to capture and sustain attention during the unit. My students struggle to find relevance in topics, and while they may find something interesting, it is difficult for them to make connections with personal background knowledge. This results in a struggle to make global connections to the implications of science on their lives. Understanding the advancements biomedical engineering has made over time may be motivation for them to remain interested in the class discussions.

Biomedical engineers are responsible for, essentially, keeping the human population alive longer than previous generations by development of new tools or techniques for disease diagnosis or treatment. This is accomplished through research in areas such as medical technologies (x-rays, prosthetic limbs), creation of vaccines, and gene therapies, in addition to diagnostic tools and health care computer applications. The breadth of this field is wide, such that we only know that the needs and opportunities will be increasing with certainty.[17] Exposing students to biographies of biomedical engineers through reading assignments would be useful to help them make connections and engage with content.

Lab Based Activities

My goal is to use hands on activities, like the DNA extraction method, to hook students and to preview key vocabulary like DNA, genes, and chromosomes. I will also use this method as a way to link back to the scientific method discussion we have at the start of the year, especially concerning controlling variables and posing new questions. While it would not be inquiry based since students are supplied with a procedure, the strawberry DNA extraction method will raise questions since it is so different than the normal content I teach. I hope the activity raises their intrinsic motivation, and especially for my low readers, gives them an experience that will help them to stay engaged with subsequent readings.

Student Generated Questions

Offering students strategies for posing new questions is an area in which I feel I lack as an instructor. I tend to get caught up in teaching science content, but unfortunately, it doesn’t leave much time for their curiosity to

come through. Therefore, a major rationale behind choosing to create an enrichment unit is to get kids to not only understand material, but also to be able to start posing their own high-level questions. I want them to have that sensation of wonder and awe. I also want to understand how the innovations in the world around us are available because of the asking and answering of questions.

Literacy Activities

I feel a strong connection to the literacy aspect of science education. I want to use strategies in my classroom that allow students to become independent readers of science materials, those who have the confidence to deal with complex texts, and the confidence to know where to find answers when they have questions. Therefore, after the demonstration portion, but before the conference portion, the majority of the activities will include literacy strategies. It will be essential that my students be able to understand material in order to ask the higher-level questions that are the goal of my unit.

The students will be able to apply the knowledge they learn about genetic diseases to our discussions on the body systems and how they function to keep us alive. When we get to our discussion on alveoli and their basic function (to increase surface area in the lungs for more gas exchange), I will now be able to ask higher level application questions about how cystic fibrosis may affect the structure of the alveoli and what possible outcomes that could have on lung function. Students would understand that cystic fibrosis can causes a build up of mucus, thereby blocking the alveoli and making gas exchange more difficult.

Classroom Activities

Activity One: Strawberry Lab and DNA Puzzle

Essential Question: What about our cells make me different than you?

The introduction to the unit will be a hands-on activity to help gain momentum with student motivation and engagement. The purpose of the first activity is to provide students with a common experience that will help them when they need to work cooperatively in subsequent parts of the unit.

To prepare for the DNA extraction activity, students will view a short video on cells. The video will be a very basic introduction to the cell as the basic unit of life. A diagram of a cell will be given to students and very general overview of organelles will be discussed. The main focus will be on the structure and function of the nucleus.

The Strawberry DNA extraction activity requires students to follow a procedure to chemically breakdown and separate the DNA molecules in a frozen strawberry. Students are given frozen strawberries, baggies, and salt, water, and dish detergent. The contents are mashed together and eventually strained through a coffee filter. One strained, rubbing alcohol is added to the mixture and the DNA will “settle out” on top. Students can use a fork or a bamboo stick to pull the DNA out in globs.

I am choosing not to do this as an inquiry based activity, since my students would not have enough background knowledge to make hypothesis and create a procedure, however, students with a strong background in chemistry or biology could be challenged by being given a bin of materials and asked to come

up with a procedure. I will link the DNA extraction activity to the scientific method by bringing up a discussion on controlled variables, sample size, and data collection. My students have sufficient background to discuss these topics, but other grade levels may need to modify as needed.

After students answer lab based questions about the DNA extraction, we will take guided Cornell Notes. As an AVID school (Advancement Via Individual Determination), we are required to model this type of note-taking and scaffold students into reflecting and asking questions about the notes. The notes will be basic information on DNA, genes, and chromosomes and how they relate to the nucleus. I will use distributed summarizing and focused note-taking strategies to help students begin to make connections. My goal for this activity is for students to work in pairs and be able to come up with at least one Depth of Knowledge (DOK) level three or four question. These questions require students to use strategic thinking to explain their understanding of concepts. DOK three or four questions may yield more than one answer and require a student to justify his or her reasoning.

Activity Two: DNA Puzzle and Small Group Reading

Essential Question: What makes a disease hereditary?

The hands on portion of the second activity reviews information about the cell and nucleus, but also previews the terms mutation and hereditary. To begin, students will view a short video on DNA. Then, they would work together in partners or groups of three to complete the DNA puzzle activity. The DNA puzzle pieces will be colored and students will create a key for showing what the colors represent (A, C, T, G, etc). After the puzzle is completed, I will refer back to the Cornell notes to discuss from where the pieces of the DNA originated (that is, we receive half from our mothers and half from our fathers). A graphic organizer, such as a frayer model, would be used to help me organize information from the class discussion. The graphic organizer would include sections for definitions, examples, non-examples, and a picture representation. I would like the class to come up with a definition of heredity on their own, but will be prepared to scaffold if necessary. This part of the lesson could be modified up to allow older students to work by themselves or in partners. It may be more appropriate to give younger students a definition.

On the smart board (or using magnetic pieces on the whiteboard), I would show a completed DNA molecule with one piece shaded black. This would help me introduce the idea of a mutation, or change, in DNA. While there are many ways these mutations can occur, sixth graders will only be responsible for understanding that an overall change has occurred.

Students would be given the reading “Genetics” from KidsHealth.Org and complete a close read of the text. The text paragraphs and lines would be pre-numbered to make it easier to students to reference information for the second part of the lesson. The first close read would be for them to code the text for new and important words. The second read would be for them to identify the main ideas of the text and use a highlighter to notate this. Finally, students would be responsible for creating text-dependent questions. An exit ticket would be used as a formative assessment to gather information on what students feel they strongly understand and in what areas they need additional support.

Activity Three

Essential Question: What happens when signals in a cell “get crossed” and don’t function properly?

The final activity will be a pair-share activity. Students will be assigned either CF or HSAN and will be

responsible for reading articles relating to each disease. Using graphic organizers and note-taking strategies discussed earlier in the unit, students will become experts on the disease they have researched. The texts will include news articles as well as readings from kid-friendly health websites. After students have had some time to read and take notes on their own, I will ask them to share what they have learned. We will start our discussion of ideas by just generating information in list format. Then, students will sort and categorize the statements. They will need to give each category a heading and be prepared to explain their thoughts. For this activity, students will work by themselves initially, but will work in partners and then as groups of four to finalize the organization of the statements. The groups will put their final thoughts on poster paper and we will share out as a class to see common thoughts.

Notes

1. New World Encyclopedia, Cytoplasm, accessed July 7, 2015
2. Cell Structure, Biology4Kids, accessed July 11, 2015
3. Gil, Karp, & McKane, *Biology: Exploring Life*, 98-99
4. "What is DNA?" Genetics Home Reference
5. Gil, Karp, & McKane, *Biology: Exploring Life*
6. Gil, Karp, & McKane, *Biology: Exploring Life*, 343
7. Pasternak, *Introduction to Human Molecular Genetics*, 3-4
8. Gil, Karp, & McKane, *Biology: Exploring Life*, 232-240
9. O'Neill, Mendel's Genetics
10. McClean, Mendelian Genetics
11. Gil, Karp, & McKane, *Biology: Exploring Life*, 24
12. Zakaib, Gwyneth Dickey, *Peppered Moth,* Nature
13. Mayo Clinic, Phenylketonuria
14. Cystic Fibrosis Foundation
15. Genetic Science Learning Center, Cystic Fibrosis
16. Indo, Congenital Insensitivity to Pain with Anhidrosis
17. Mark Saltzman, Biomedical Engineering, 1-28

Bibliography

Andrew Rader Studios. "Cell Structure." Biology4kids.com. http://www.biology4kids.com/files/cell_er.html (accessed July 11, 2015)

Brum, Gil, Gerald Karp, and Larry McKane. *Biology: Exploring Life*. 2nd ed. New York, NY: Wiley, 1993.

Cystic Fibrosis Foundation. *Frequently Asked Questions.* www.cff.org. (accessed July 15, 2015)

Genetic Science Learning Center, "Cystic Fibrosis," Learn.Genetics, 22 June 2014, (12 July 2015)

Indo Y. Congenital Insensitivity to Pain with Anhidrosis. 2008 Aug 5 [Updated 2014 Apr 17]. In: Pagon RA, Adam MP, Ardinger HH, et

al., editors. GeneReviews® [Internet]. Seattle (WA): University of Washington, Seattle; 1993-2015. Available from: http://www.ncbi.nlm.nih.gov/books/NBK1769/ (accessed July 15, 2015)

Mayo Clinic. “Phenylketonuria.” http://www.mayoclinic.org/diseases-conditions/phenylketonuria/basics/symptoms/con-20026275 (accessed July 10, 2015).

Meader, Derrick. “Depth of Knowledge.” Teaching.About.com http://teaching.about.com/od/A-ITeachingGlossary/g/Depth-Of-Knowledge.htm (accessed July 8, 2015).

"Mendelian Genetics." Mendelian Genetics. Accessed July 12, 2015. https://www.ndsu.edu/pubweb/~mcclean/plsc431/mendel/mendel1.htm.

New World Encyclopedia. “Cytoplasm.” http://www.newworldencyclopedia.org/entry/Cytoplasm (accessed July 7, 2015)

O’Neill, Dennis. “Mendel’s Genetics.” http://anthro.palomar.edu/mendel/mendel_1.htm (accessed July 8, 2015)

Pasternak, Jack J. *An Introduction to Human Molecular Genetics Mechanisms of Inherited Diseases*. 2nd ed. Hoboken, N.J.: Wiley-Liss, 2005.

Saltzman, W. Mark. "Introduction: What Is Biomedical Engineering?" In *Biomedical Engineering: Bridging Medicine and Technology*. Second ed. Cambridge Press, 2015.

"What Is DNA?" Genetics Home Reference. Accessed July 12, 2015. http://ghr.nlm.nih.gov/handbook/basics/dna.

Zakaib, Gwyneth Dickey. "The Peppered Moth's Dark Genetic past Revealed." *Nature*, 2011. http://www.nature.com/news/2011/110414/full/news.2011.238.html. (Accessed August 4, 2015).

Appendix

Common Core Literacy Standards:

CCSS.ELA-Literacy.RI.6.2

Determine a central idea of a text and how it is conveyed through particular details; provide a summary of the text distinct from personal opinions or judgments.

CCSS.ELA-Literacy.RI.6.7

Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.

CCSS.ELA-Literacy.RI.6.8

Trace and evaluate the argument and specific claims in a text, distinguishing claims that are supported by reasons and evidence from claims that are not.

Delaware State Science Standards:

DE.1. Nature and Application of Science and Technology

1.1. Enduring Understandings: Scientific inquiry involves asking scientifically-oriented questions, collecting evidence, forming explanations, connecting explanations to scientific knowledge and theory, and communicating and justifying the explanation.

1.2. Enduring Understandings: The development of technology and advancement in science influence each other and drive each other forward.

DE.6. Life Processes

6.1. Enduring Understandings: Living systems demonstrate the complementary nature of structure and function.

DE.7. Diversity and Continuity of Living Things

7.1. Enduring Understandings: Organisms reproduce, develop, have predictable life cycles, and pass on heritable traits to their offspring.

Next Generation Science Standards:

Growth, Development, and Reproduction

MS.LS3.1 Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.

Structure, Function, and Information Processing

MS.LS1.3 Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.