Nature + Nurture:
Developing a Mathematical Model of Human Potential

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This curriculum unit is recommended for:
(Biology, Chemistry, Math 2-3; 9-12 Grades)

Keywords: DNA, mitochondria, genotype, phenotype, code, sequence, scale, epigenetics, probability, theoretical probability, expression, variables, function, experimental probability, modeling, biomathematics, Isometry, Metabolism Physiology, Calorie, Input, Output, Domain, Range, Kleiber's law, exponential growth, differentiation, and golden ratio

Teaching Standards: See Appendix I for teaching standards addressed in this unit.

Synopsis: In an article entitled "Trait versus Fate" the following exchange/joke is told. Darwin and Freud walk into a bar. Two alcoholic mice-a mother and her son-sit on two bar stools, lapping gin from two thimbles. The mother mouse looks up and says, "Hey, geniuses, tell me how my son got into this sorry state." "Bad Inheritance," says Darwin. "Bad mothering," says Freud. This exchange exposes two competing views, is it nature/biology or nurture/psychology that shapes individuals and their future offspring or is some type of synthesis of the two that work together. Nature & Nurture will explore the unique way that environment and experiences interact to influence the genetic code of individuals. This interaction between environment and man can be in the form of nutrition, chemicals, and in some cases continued exposure to harmful elements in the environment. This unit will focus on Statistics/Probability, provide examples of the intersection of mathematics and biological processes, such as cell division through exponential functions, and describe a lesson for an AP Calculus class on optimization in a biological context.

I plan to teach this unit during the coming year to 70 students in 10-12 mathematics.

Introduction

Human beings occupy a unique spot in the web of life. From a biological standpoint life is defined as an organism that exhibits the following traits: a capacity for growth, reproduction, functional activity, and continual change preceding death. Life on the physical plane takes many forms, from single cell organism to the complex form of human beings with an estimated 30-40 trillion cells This multitude of cells arise from one single cell at the time of fertilization . It is interesting that a cell in your heart has the same DNA as a cell in your toe because they have the same progenitor: the reason is because they're both produced by the successive doublings of your first cell. Faced with the fact that we all begin life as a fertilized egg, which is not much more than a collection of DNA strands surrounded by cytoplasm and some proteins, it is easy to imagine that DNA is the boss in the executive suite. From this perspective, DNA provides the code that allows for the differentiation of cells and organs. This resulting differentiation of organs and systems allows one to move around the world, eating, drinking, and doing things like having families and building house. Your genetic instructions are embodied in your DNA, the deoxyribonucleic acid that is the biochemical code for life itself. Two strands of DNA, wrapped together in a spiraling double helix, contain the particular sequence of molecules that say who you are-and that tell your cells what to do to keep you alive and well (Lynch 2018, 46). The structure of DNA is a double helix because the nucleotides of one chain line up with the nucleotides of the second chain in a particular way. The two chains are held together by forces of attraction between matched pairs of bases (Kotz 1996, 5). It is interesting to note that at this point DNA has been given shape and location, two concepts that tie into geometry. The common structure of Deoxyribonucleic acid, or DNA for short, is composed of two right-handed 3-D helices **FIGURE 1.** Skinner goes on to highlight the fact the details of the structure are complicated, yet the system has a simple modular pattern. "Like the logarithmic spiral, the geometry can be easily replicated (but better packed), and its facility for self-replication and growth is built into the geometry of the DNA molecule (Skinner 2006, 73).

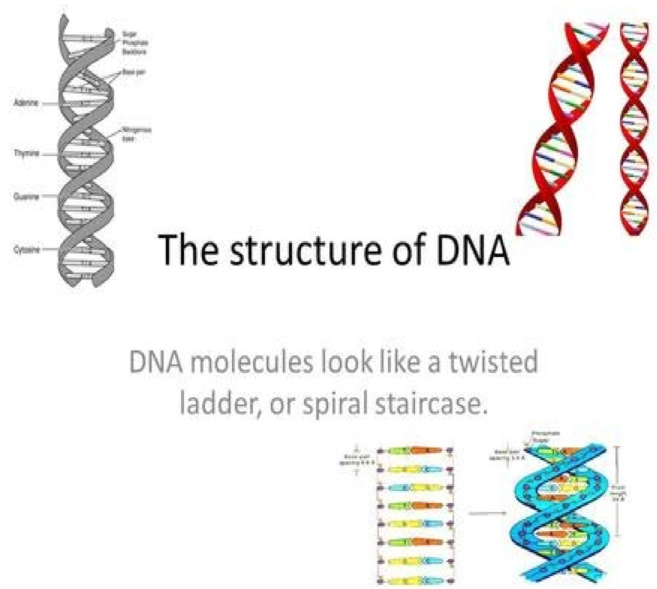

Figure 1. DNA has a particular helical structure due to the chemical bonds between nucleotides.

"All of life functions by transforming energy from physical or chemical sources into organic molecules that are metabolized to build, maintain, and reproduce complex highly organized systems. This is accomplished by the operation of two distinct but closely interacting systems: the genetic code, which stores and process the information and "instructions" to build and maintain the organism, and the metabolic system, which acquires, transforms, and allocated energy and materials for maintenance, growth, and reproduction" (West 2017, 79-80) . "Size is a dominating bias in biology. By and large, we are mostly interested in the largest life-forms-the plants, animals, and fungi that we can actually see" (Lane 2005, 151). It has long been held that the complex reasoning skills of man has allowed us to ask the question: Why? In order to spark curiosity, this unit will explore concepts such as if our cells are constantly replicating, why do we age and die, as our cells continue to multiply, why do we achieve a certain height? "Just as growth is an integral part of life, equally so are aging and death" (West 2017, 178). "For nearly a century after the term "epigenetics" first surfaced on the printed page, researchers, physicians, and others poked around in the dark crevices of the gene, trying to untangle the clues that suggested gene function could be altered by more than just changes in the sequence. Today a wide variety of illness, behaviors , and other health indicators already have some level of evidence linking them with epigenetic mechanisms, including cancers of almost allotypes, cognitive dysfunction, and respiratory, cardiovascular, reproductive, autoimmune, and neurobehavioral illness (Weinhold 2006, 1) In addition, in this unit, students will explore and be introduced to the genetic code form a mathematical perspective and explore the probability and the role that mathematical modeling can play in describing and predicting certain traits. This "why?" has been explored in various disciplines with the ultimate question being on the nature of life and what shapes life? It is not surprising that at the search for meaning in the life sciences, mathematics occupies a central spot. As science and technology grows, more why questions will be explored and discovered. Science and technology are increasingly hitting new limits and problems based on traditional disciplines. One avenue of inspiration for developing new and innovative ways of thinking and solving difficulties is biology. From the perspectives of evolutionary theory to creationism the nature of human existence has been explored. In the quest of quantifying and qualifying human existence many disciplines have been consulted. One subject that has unified varying sciences is mathematics. When looking at nature and life from a mathematical perspective, the question can be raised does math model the universe or is the universe a mathematical model that is constantly unveiling new truths to scientists.

> "Does mathematics have an existence that is entirely independent of the human mind? In other words, are we merely *discovering* mathematical verities, just as astronomers discover previously unknown galaxies? Or, is mathematics nothing but a human *invention*? If mathematics indeed exists in some abstract fairyland, what is the relationship between this mystical world and physical reality? How does the human brain, with its known limitations, gain access to such an immutable world, outside space and time? On the other hand, if mathematics is merely a human invention and it has no existence outside our minds, how can we explain the fact that the invention of so many mathematical truths miraculously anticipated questions about the cosmos and human life not even posed until many centuries later" (Livio, 2009).

It is interesting that Livio connected the cosmos to man's quest for awareness. Perhaps instead of searching outer space for the "why's: of human life, the inner space of man should be sought out. In this exploration, the question can be raised is it nature or nurture that makes us who we are or a unique intersection of the two that shapes the affairs and destiny of the human being.

Human beings in general, and scientists as part of their careers conduct experiments to classify and quantify entities. Mathematically, these experiments are represented as desired outcome/possible outcomes; or simply the mathematical probability formula represented by events/number of outcomes. According to probability models, events lie on an axis from 0-1. If an event has a zero chance of happening it is impossible, if the probability is 0.5 there is an equal chance it happen versus not happening (a coin flip), and finally when an event has a numerical value of 1 it is certain to happen. Looking at life from this perspective the chance for conception to occur is from a high end to on a low end. When these numbers are explored in a fractional or decimal form it is apparent that chances of life to occur are close to impossible and highly improbable, whereas death is certain with a 1. The major question of life then is there a predetermined course nature, or is our life shaped by what happens to us and then in turn do these experiences shape our future genetic offspring. Students and educators alike need to realize that the nature of human experience is primarily the nature of experimentation. We all engage in activities with multiple outcomes, with a desired outcome in mind but multiple outcomes can happen do to the unpredictability of life. The goal of this unit is to allow students gain a deeper understanding of mathematics by connecting it to them from a personal perspective as well as for them to see that math is connected to nature and through nature to each individual human being. Students will recognize that from conception to death human beings are a mathematical expression of life. This mathematical expression is readily seen in the genetic structure of the human being. DNA plays an integral part in human growth and development.

School Setting

Rocky River High School is in an urban school district and is situated in a small town called Mint Hill, NC. Rocky River is a new school, built in 2010. The school serves students from grade 9 to grade 12 with a current enrollment of approximately 1479 students: 57% African-American, 28% Hispanic, 7% White, and 3% Multi-Racial, and 3% Asian. The demographics of our student population has not changed over the last five years. Rocky River High School serves students living in east Charlotte. A very small percentage of students reside in the Mint Hill, NC community. As a result, most of the students that attend Rocky River are bused from their east Charlotte neighborhood to the school.

Curriculum/Goals

The broad goal of this unit is for students to see how mathematical models can be used across disciplines to illustrate and explain complex phenomena. Particular focus will be placed on Biological Modeling. “Mathematical models and analyses are now routinely used in the study of physiology, from the growth and morphological structure of organisms, to photosynthesis, to the emergence of an ordered patterns during cell division, to the dynamics of the cell cycle and genome expression” (Stewart 2016, 34). This unit will also introduce students to using mathematics as a tool for social justice. Stinson (2012) quotes Gustein by saying that "Teaching Mathematics for social justice has two related pedagogical goals; reading and writing the world with mathematics and developing positive cultural and social identities." In addition to looking at the shared phenotypes that individuals share students will see how choices can positively impact them as impact them negatively. The idea of nature from its Latin roots ate 13c., "restorative powers of the body, bodily processes; powers of growth;" from Old French nature "nature, being, principle of life; character, essence," from Latin natura "course of things; natural character, constitution, quality; the universe," literally "birth," from natus "born," past participle of nasci "to be born," versus nurture which means c. 1300, "breeding, upbringing," from Old French norture, nourreture "food, nourishment; education, training," from Late Latin nutritia "a nursing, suckling," from Latin nutrire "to nourish, suckle. Using these two definitions the unit will explore the concept of are we born with all our qualities or do experiences shape and mold us using the material that we are. The unit will integrate Geometry, Statistics, and Calculus across varying grade levels with remediation/enrichment activities.

The North Carolina Standard Course of Study provides a framework for all goals and objectives. Regretfully this framework does not recognize nor represent the interdisciplinary nature of the sciences, with mathematics as a common thread. "Equations can be thought of as science's similes and metaphors. When physicists, chemists, or biologists use equations to model real processes in nature, they assume that the way an equation unfolds is like the unfolding of the real process that the equation models" (Briggs 2015, pg. 45). Briggs goes on to state that while linear and nonlinear equations both describe a cause and effect relationship, metaphorically they describe relationships in totally different ways. Considering that this unit will be interdisciplinary with mathematics as the linchpin various essential standards will be used.

Bio.3.1 Explain how traits are determined by the structure and function of DNA.
Bio.3.2 Understand how the environment, and/or the interaction of alleles, influences the expression of genetic traits.
Bio.3.3 Understand the application of DNA technology.
Bio.4.1 Understand how biological molecules are essential to the survival of living organisms
Bio 4.2 Analyze the relationships between biochemical processes and energy use in the cell.
Chm.2.2 Analyze chemical reactions in terms of quantities, product formation, and energy.
NC.M2.F-IF.2, NC.M2.F-IF.4, NC.MF-IF.7/Reasoning with equations
S.CP.1, S.CP.3, S.CP.3a, S.CP.3b, S.CP.4, S.CP.5/Simple and compound probability
NC.M3.S-IC.1, NC.M3.S-IC.3, NC.M3.S-IC.4, NC.M3.S-IC.5, NC.MC.S-IC.6/Exponential Functions

Interdisciplinary Background

Science as we know it now for a long part of history was not divided into distinct branches, for a long time, science was more or less a united whole known as natural philosophy. It wasn't until the last century or two did the distinction between physics and even the life sciences become prominent. Later in the 1930's and 1940's, a number of scientists trained as physicists became interested in applying the ideas and techniques of physics to problems in microbiology. As science progress it now seem as if everyone is looking to find a way to unite the sciences, and mathematics may be the key to this lofty goal. They hoped among other things, that studying biological organisms might lead to the discovery of some new unsuspected laws of physics. Alas, this hope has not been realized, but their efforts helped give rise to the field we now call molecular biology and resulted in a drastic increase in our understanding of the genetics and structure of living beings (Giancoli 1991, 4).

"Mathematics also may be viewed as a tool for creating models, or representations of real phenomena….Mathematical models can be as simple as a single equation that predicts how the money in your bank account will grow or as complex as a set of thousands of interrelated equations and parameters used to represent the global climate. By studying models, we gain insight into otherwise unmanageable problems" (Bennett 2011, pg. 8). At one time, one such problem was genetic probability and how to extract desired characteristics through breeding. . It has been noted that Charles Darwin was the 19th Century's greatest biologist, but a terrible geneticist. Since the fundamental nature of science is inquiry, his research paved the way and laid a foundation for continued research even without knowing the mechanisms for how characteristics were inherited. Gregor Mendel, who is styled as the first mathematical biologist, is credited with developing the basic laws of heredity, but Darwin appears to be unaware of his findings. Mendel's statistical analysis is demonstrated in the Punnett Square Based, which was a tremendous first step for a predictive science. Off of this model, and from Mendel's experiments he generated mathematical models that were used to establish heredity. From a biological standpoint, this models the fact that humans carry two copies of most genes. A further explanation and exploration of this concept will occur in later lessons on Genetic probability.

According to the article "What is DNA?" DNA is a complex molecule made up of chains of four different building blocks called nucleotides (Future Publishing LTD, 2018). The sequence of nucleotides acts like a code, instructing the cell to make certain proteins at certain times. It is interesting to note that the moment the Punnet square was used to produce and predict desirable traits, the concept of race and class crept in with social Darwinism. Despite Darwin's pioneering work with the inheritance of characters that led to the first theory for speciation, it was Gregor Mendel and studies of garden peas to understand the initial basic laws of heredity. His statistical analysis is demonstrated in the Punnett Square Based, which was a tremendous first step for a predictive science. From this model, and from Mendel's experiments he generated mathematical models that were used to establish heredity.

It is interesting to note that whereas Mendel was concerned with finding and breeding desirable traits into plants, his work was taken and used to justify scientific racism. One such individual that took Mendel's work and ran with it in the realm of racial purity was Madison Grant. As discussed in class, and reaffirmed by (Byrd, 2015) Madison Grant remains the darkest and most disturbing figure of the turn-of-the-century American genealogy and eugenics (Byrd, 2015)"., the author goes on to state that the tendency to confuse social conditions with essential traits and then give them a biological explanation looked even more scientific when it was placed in a framework based off of the work of Mendel. For example: Pure + Pure=Normal Chilren, Abnormal + Abnormal: Children Abnormal, Pure + Abnormal= Children Normal but Tainted, some grandchildren abnormal, tainted + Abnormal= Children 0.5 normal but tainted, 0.5 abnormal, tainted + Pure: Children 0.5 pure Normal, 0.5 Normal but tainted, and finally Tainted + Tainted: of every four 1 abnormal, 1 Pure normal, and 2 Tainted. From a historical standpoint, traits and heredity have been viewed as static and that children receive predetermined characteristics from parents and ancestors which in turn are passed down to their descendants which produces a static rigid status quo. This idea was used to form discriminatory policies against those that were genetically unfit. The emerging field of epigenetics offers the view that gene expression is not static and that some traits can be turned on or off based off of environment. With any new discipline or scientific theory there must be those that are poised to form arguments and counter arguments against bias that may creep in.

Rationale

Genetic determinism has been used to classify races and social stratification on the morality throughout America. It can be argued that from the very start of the great experiment, which is America, race and class has played an important part in shaping the cultural and ethnic interactions of many groups. One social group that has perhaps received the gravest of injustice are the 37,144,530 African-Americans. AS a descendant of former slaves it is recognized that North America, as well as South & Central Americans enslaved Black people lived through acute and prolonged suffering for 250 years they were held legally as human chattel and the subsequent 150 years of structured discrimination and exposure to bias. Jackson,2018 states "The descendants of those who survived these conditions are known as Legacy African Americans. Approximately half a million Africans were brought to North America, a small fraction of the 11 million Africans transported over 400 years to the Western Hemisphere. In North America, this period represents approximately 11 generations of legal enslavement and multigenerational bondage".

Legacy African Americans, a term from Jackson, are people who have been robbed of name, culture, religion and history, taken captive and sold like property for 310 years, then faced 100 years of Jim Crow segregation, and still continues to face issues such as poverty, police brutality, and sub-par living conditions. It is important to note that under the current understanding of epigenetics and DNA methylation, stress, adverse living conditions, and poor nutrition are all precursors to activating and sustaining what Lynch calls "dirty genes" (Lynch, 2018) Biology and the theory of race has influenced all aspects of American culture and ideology, even in the sciences.

> Biological determinism and racial essentialism puts forth the position that both the biological extant reality of race alongside the contention that different racial groups possess different traits and characteristics that, in turn result in racially varied social outcomes. These intertwined cultural logics-as two cohesive sets of assumptions, beliefs, and ideologies about the nature and makeup of race and the linkage among racial variation and human actin and order-are now part and parcel of contemporary life. Once thought an ugly component of a bygone era of social Darwinism and race-based eugenics research supported by racially exclusionary and discriminatory laws, overt policies, and hostile attitudes, these modes of thinking have invaded contemporary study of genetics and genomics (Byrd 2015, 9-10).

Working in a school that is for lack of a better description, majority minority population, students must be equipped with an accurate model of historical trends as well as be prepared to apply multidisciplinary learning with the appropriate mathematical modeling when needed. This unit will allow students to be introduced to critical pedagogy. "In general, critical pedagogy supports pedagogical theories and practices that encourage both teachers and students to develop an understanding of the interconnecting relationship among ideology, power, and culture, rejecting any claim to universal foundations for truth and culture…" (Stinson, 2012). *This unit will combine critical pedagogy with applied mathematics to introduce students to how current ideological ideas can influence and shape discourse when it comes to issues of power, through a merger of ideology and accepted science.* For example, Social Darwinism adapted the premise of survival of the fittest and extended that concept to race relations to justify the inherent supremacy of Caucasians over the darker people of the planet. Perhaps the most racially polarized society, America, has held on to these ideas and used raced based arguments to infuse the dialogue of racial equity with scientific jargon.

Sullivan (2013), in his article, *Epigenetics and the Transgenerational Effects of White Racism*, puts forth the premise that people of color not only have a transgenerational wealth disparity, but also a transgenerational inheritance along biological and or physiological lines. He argues that through the process of methylation, racism has literally gotten under the skin of Black people in America through diet and social experiences to produce generations of individuals that are still physiologically haunted by the transatlantic slave trade and the subsequent 310 years of chattel slavery coupled with 100 years of lynching and Jim Crow segregation. Mathematics which derives from the Greek root mathematikos, which can then be traced to mathesis which literally means mental discipline or learning. Mathematics is typically taught through arithmetic, which from its' root literally means to fit together, in this case the fitting together is the process of using a combination of equations (and their derivation) and the application of these equations into models of particular phenomena. This in turn gives a rise to mathematical models. A mathematical model is a mathematical description (often by means of a function or an equation) of a real world phenomenon, such as the size of a population, the speed of a falling object, the frequency of a particular gene, the concentration of an antibiotic in a patient, or the life expectancy of a person at birth. When constructing models, it is important to note that a faulty model can give rise to false representations of existing realties and pass the knowledge of as scientific fact. In order to convey and give the right information, a model must be as close to existing rules and mirror these rules as accurately as possible. One debate that has been ongoing in the field of genetics is the argument of nature versus nurture. In a simplistic view this can be represented as what Lynch refers to as Dirty Genes. Lynch relates his experience in the following words

> It was just an ordinary day in 2007. I had half an hour to spare and decided to check out a program playing on the PBS show *Nova*, “A Tale of Two Mice.” The Program introduced us to two mice that were genetically identical-but looked completely different. Both were from a strain that had a strong genetic potential for obesity, cardiovascular disease, and cancer. Yet one of the mice was lean and healthy, while the other was massively overweight and vulnerable to disease. Although each had the genetic potential for major illness and excess weight, only one of them was actually unhealthy. As I watched in astonishment, the researcher explained the “x factor”- the mysterious, powerful reason behind our ability to manipulate our genetic inheritance and create health rather than illness. The secret was methylation, a biochemical process that takes place within your body. By methylation certain genes, you can turn off your genetic tendency to obesity and disease. (Lynch, 2018)

As the knowledge grows that individuals can assert a measure of control over their health by DNA methylation, the factors effecting methylation and epigenetics must be studied. It must be understood that if an individual can take it upon themselves to practice selective methylation then governmental and corporate entities can influence the genetic potential of individuals by enacting policies that effect specific communities. Lynch puts forth the premise that some genes are born dirty, which is called genetic polymorphism or genetic variation, whereas some genes just "act dirty" because we are not receiving the right nutrients, living in the wrong environment. "The scientific name for this is genetic expression: the way your genes express themselves in response to your environment, diet, lifestyle, and mindset. Depending on which of your genes are expressed, and how, you can be healthy, energized, and glowing. Alternatively, you might be loaded down with a whole slew of symptoms: obesity, anxiety, depression, acne, headaches, fatigue, achy joints, and poor digestion. If your genes act dirty enough, you might even face such serious conditions as autoimmune disorders, diabetes, heart disease and cancer" (Lynch 2018, 22-23).

Instructional Implementation

Lesson 1: The Coding Function of DNA You are Math

The alphabet of DNA are its' bases A, T, C, and G. These bases are grouped together along the DNA sequences into codons. All codons are the same length (see **FIGURE 2**).

	T	C	A	G
T	TTT, TTC Phe TTA, TTG Leu	TCT, TCC, TCA, TCG Ser	TAT, TAC Tyr TAA, TAG Stop	TGT, TGC Cys TGA Stop TGG Trp
C	CTT, CTC, CTA, CTG Leu	CCT, CCC, CCA, CCG Pro	CAT, CAC His CAA, CAG Gln	CGT, CGC, CGA, CGG Arg
A	ATT, ATC, ATA Ile ATG Met	ACT, ACC, ACA, ACG Thr	AAT, AAC Asn AAA, AAG Lys	AGT, AGC Ser AGA, AGG Arg
G	GTT, GTC, GTA, GTG Val	GCT, GCC, GCA, GCG Ala	GAT, GAC Asp GAA, GAG Glu	GGT, GGC, GGA, GGG Gly

Figure 2. A codon table showing how nucleotides in groups of three code for particular amino acids.

Students will review the concept of probabilities and functions. Students will use characteristics of parent functions such as linear, exponential, quadratic, absolute value, trigonometric, and cubic. Students will identify that basic graph of the function remains the same no matter what types of operations are performed on them and that for every input, there is exactly one output. Students will explore the coding function of DNA and probability through the following problem: *Genome Composition*.

The information coded in DNA consists of a sequence letters, each of which can be A, C, G, or T. These letters each represent one of four biomolecules called nucleotides: adenine, guanine are called purines; cytosine and thymine are called purines. Suppose a nucleotide is chosen at random from the following DNA sequence ATCGATTGAGCTCTAGCGFind the probability of the given event: A thymine is chosen. A purine is chosen. Students will recognize that codons express exactly one amino acid. Students will be introduced to sequences through mathematical sequences such as an arithmetic sequence and a geometric sequence. Students will then be led in a whole group discussion on what does a sequence of DNA look like. Students will understand that Sequencing DNA means determining the order of the four chemical building blocks - called "bases" - that make up the DNA molecule. The sequence tells scientists the kind of genetic information that is carried in a particular DNA segment. For example, scientists can use sequence information to determine which stretches of DNA contain genes and which stretches carry regulatory instructions, turning genes on or off. In addition, and importantly, sequence data can highlight changes in a gene that may cause disease. Particular focus will be placed on factors that can turn gene expression on or off. At this point students will be introduced to methylation and environmental factors such as nutrition, parental behavior, and past traumas that can turn genetic expression on or off. Students will then be introduced to the unit and told that in class work will focus on mathematical modeling of biological principles such as traits, simple and compound probability and applying Euclidean geometry to represent certain cellular functions.

Lesson 2: The Possibility of Life the Certainty of Death/Describing Events

Lesson Objectives: S.CP.1, S.CP.3, S.CP.3a, S.CP.3b, S.CP.4, S.CP.5 Bio.3.1, 3.2

Lesson Description: From this lesson, students will be able to answer the following questions: (1) how can you describe events? (2) How can you determine whether two events are independent?

Vocabulary: Theoretical Probability, Complement, equally likely outcomes, independent events, sample space, meiosis, inheritance, dominance, codominance, allele

Activating Strategy/Lesson Hook Students will be presented with the statement that it is said that the probability of an individual existing is$1 : 10^{2,685,000}$. Students will then determine where this number falls on the probability spectrum. After successfully identifying that the odds of being born and who they are, students will then be asked to identify some of the events that had to take place for them to be born, such as their parents meeting, etc… form this discussion students will be introduced to sample space and probability.

Female Chromosome	**X**	**X**
Male Chromosome	**X**	**Y**

Based on the following table students will be introduced to the probability of likelihood form of $0 \leq p \leq 1$, where 0 represents impossible, and 1 represents certainty. Based off of the following table, students will be introduced to the concept of equally likely events through analyzing sample space. Students will recognize that the sample space for a female sex chromosome is {X, X}. From the likelihood model, students will identify that because a female lacks the Y chromosome, it is the Male that determines the sex of a child. Students will identify that sample space as {X, Y}. From this sample space students will be introduced to the following equation which describes the probability of an event occurring; $P(E) = \frac{n(E)}{n(\Omega)}$ where the numerator represents desired outcome and the denominator represents possible outcomes. Based off of this model students will deal with the female chromosome first by modeling $P(X) = \frac{1}{1}$ and$P(Y) = \frac{0}{1}$. As a check for understanding students will then develop a probability model for male chromosome sex selection. Based off of the chart and prior knowledge students should recognize that the probability of having a female is .5 and having a male is .5. Once this has been determined students will working small groups to determine other traits parents can pass on to their children besides gender. At this point students will be transitioned into dealing with

Punnett squares and Mendelian genetics. Students will be introduced to the fact that many genetic traits are controlled by two alleles, one dominant and the other recessive. Students will conduct independent research and find the definitions of the terms homozygous and heterozygous. Students will be provided with the following example for brown and blue eyes. Bb, Bb:

Male	B	b
Female	**B**	**b**

Students will be asked to identify all possible outcomes from the sample space. Once this has been accomplished. Students will then explore the likelihood of the parents having a boy that is Homozygous (AA or aa) or a girl that is heterozygous Bb or bB. Students will then look at if both parents are Homozygous BB for Brown eyes, or bb for blue eyes and answer the question is it possible for them to give birth to a child that has Brown eyes if both parents have Blue eyes or is it possible for both parents to give birth to a Blue eyed child if they both have brown eyes? As an enrichment exercise students will research phenotypes of their family lineage and develop various mathematical models.

Day 2; Lesson Two: Out of One Many

Lesson Objectives: This lesson will introduce the students to the concept of exponential growth and how populations change over time. The emphasis will be on viewing the human body as a collection of 40 trillion cells. Students will recognize basic cell structure, identify how growth is a major part of defining life and recognize that cells are continually dividing and replacing themselves in a cell cycle.

Students will begin the lesson with the following problem: The following chart represents the growth of a hypothetical bacteria. Is this growth an arithmetic progression or geometric progression? Suppose this pattern was to continue unhindered, how many bacteria would be present in 10 minutes, 20 minutes, and so on? Students will then work in small groups to derive a mathematical model (equation) to predict how many bacteria will be present at any time.

Minutes	0	1	2	3
Bacteria	1	2	4	8

Students will then be introduced to biological term zygote, a fertilized egg. Students will then work collaboratively to produce a KWL chart on single celled organisms versus multicellular organisms (**FIGURE 3**).

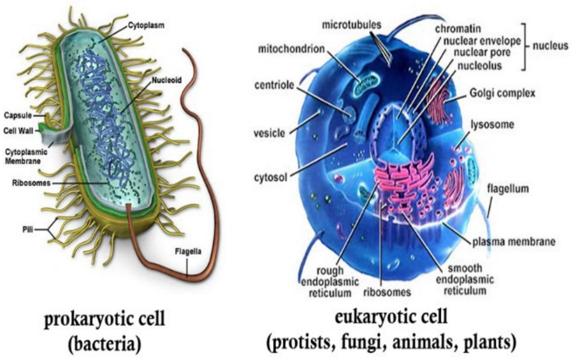

Figure 3. Prokaryotic versus Eukaryotic cells.

Students will then be introduced to cell specialization and differentiation. Particular focus will be focused on the skin. Students will be asked to be asked a series of probing questions on the different organs and asked if all cells come from a single source, how does differentiation occur?

Students then will be presented with the following table:

Time	0	1	2	3
Cells	35,000,000,000			

During this section, students will review scientific notation and the rules of exponents and be introduced to the fact that it is estimated that the human body loses approximately 40,000 skin cells every minute.

Day 3, Lesson 3 Form and Function: Is Bigger Better?

Sometimes bigger is better—tall basketball players, more closet space, and savings accounts may come to mind. What about cells? Does having big cells make an organism bigger or better? Would having larger cells be an advantage to an organism? If so, why do cells divide rather than continue growing? Maybe there is an advantage to being small.

Lesson Description: Students will explore cellular differentiation such as size and shape and equate them to function. Students will represent mathematically the doubling pattern of cells. Students in addition will design a model of the cell and explore question such as why cells undergo meiosis when they grow but do not gain size.

Students will begin the daily activity by reviewing a diagram of an animal cell structure (see **FIGURE 4**).

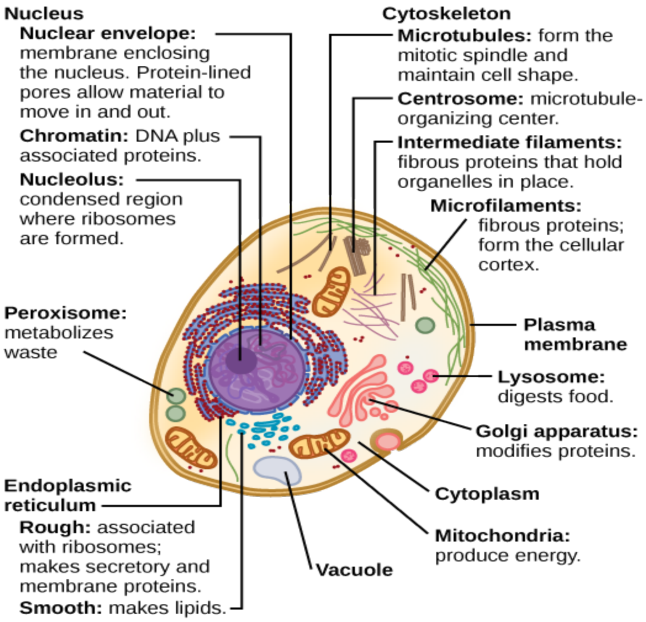

Figure 4. Eukaryotic cell with the principal components and structures labeled.

From the model, students will recognize that outside the atom, on the molecular level, the cell is the basic unit of physical anatomy. Cells vary in shape depending on function and students will be introduced to the different functions of cells and the structure and function. The following activity will be introduced to address the question: if cells are constantly doubling, why do they remain small and organisms grow larger?

Guided Practice: Students will reimagine a cell as a cube instead of a circular spherical shape. Students will then research the plasma membrane and the role it plays in eliminating waste material and gaining energy.

Students will be provided the following equations: Surface Area = $6 \cdot s^2$

Volume = S^3

CUBE SIZE	SURFACE AREA CM^2	Volume CM^3	Surface Area to Volume Ratio	Distance Traveled
1^3	6 cm^2	1 cm^3	6:1	
2^3				
3^3				

Investigative question: If a cell was a perfect circle and the nucleus was located at the exact center of the cell what would happen to efficiency as the cell became larger without splitting? Students will explore the following formulas,$A = \pi r^2$,$A = 4\pi r^2$, V=$\frac{4}{3}\pi r^3$. Students will recognize that radius is the distance from the center of a circle to any point on the outside of a circle. Students will use coordinate geometry to describe the relationship of the nucleus of a cell to the center of a circle/sphere. Students will use the guided practice table to model aspects of increasing the radius for cellular efficiency.

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APPENDIX I: Implementing Teaching Standards

Bio.3.1 Explain how traits are determined by the structure and function of DNA.

Bio.3.2 Understand how the environment, and/or the interaction of alleles, influences the expression of genetic traits.
Bio.3.3 Understand the application of DNA technology.
Bio.4.1 Understand how biological molecules are essential to the survival of living organisms
Bio 4.2 Analyze the relationships between biochemical processes and energy use in the cell.
Chm.2.2 Analyze chemical reactions in terms of quantities, product formation, and energy.
Experiment with transformations in the plane
NC.M1.G-CO.2
NC.M1.G-CO.3
NC.M1.G-CO.4
NC.M1.G-CO.5
Conditional probability and, the rules for probability. Understand independence and conditional probability and use them to interpret data.
NC.M1.S-CP.1
NC.M1.S-CP.3a
NC.M1.S-CP.3b
NC.M1.S-CP.4
NC.M1.S-CP.5
NC.M2.F-IF.2
Making Inference and Justifying Conclusions
Understand and evaluate random processes underlying statistical experiments.
NC.M3.S-IC1 Understand the process of making inferences about a population based on a random sample from that population.
Making Inference and Justifying Conclusions
Make inferences and justify conclusions from sample surveys, experiments, and observational studies.
NC.M3.S-IC.3 Recognize the purposes of and differences between sample surveys, experiments, and observational studies and understand how randomization should be used in each.

Eight Mathematical Practices:

1. Make sense of problems and persevere in solving them
2. Construct viable arguments and critique the reasoning of others
3. Reason abstractly and quantitatively
4. Model with mathematics
5. Attend to precision
6. Use appropriate tools strategically
7. Look for and make use of structure
8. Look for and express regularity in repeated reasoning

APPENDIX II: STUDENT RESOURCES

Laptops

Calculators

Internet Access

Google Classroom

Is DNA Destiny

How do our lives shape our genes? Factors like nutrition and environmental stressors affect the'epigenomic software' (above or in addition the gene) rather than the 'genomic hardware' of our bodies, with huge potential for better health. Images and explanation by researcher. Learn more in plain language with slides from Dana Dolinoy, Ph.D., Searle Assistant Professorship in Public Health at University of Michigan School of Public Health. Teachers will use this as an activating hook to introduce students to the concept of epigenetics.

Assessment of student prior knowledge of DNA:

http://www.pbs.org/inthebalance/archives/ourgenes/what_do_you_know.html

https://www.sciencealert.com/what-is-the-likelihood-that-you-exist

https://learn.genetics.utah.edu/

https://www.ck12.org/biology/probability-in-biology/

https://www.yourgenome.org/stories/of-mice-and-men introduction to observational and experimental studies

https://learn.genetics.utah.edu/content/math/ :Provides a mathematical model of scale

APPENDIX III: Teacher Resources

Future Publishing Limited. 2018. "What is DNA?" How it Works Book of Amazing Science, April 25: 028. Provides a brief description and integrative approach of various scientific disciplines.

Journal of Clinical Epigenetics Online resource for research and peer reviewed articles

Khan Academy: Provides videos for key concepts for a flipped classroom

Assessment of student's prior knowledge provides teacher with an opportunity to see where they can improve their functional knowledge.http://www.pbs.org/inthebalance/archives/ourgenes/what_do_you_know.html

Introduction to probability in human birth and genetics, Simple and compound events, https://www.sciencealert.com/what-is-the-likelihood-that-you-exist

https://learn.genetics.utah.edu/

Student/Teacher resource for flipped lesson: https://www.ck12.org/biology/probability-in-biology/

https://www.yourgenome.org/stories/of-mice-and-men Introduction video for observational versus experimental studies

https://learn.genetics.utah.edu/content/math/ Connects Mathematics to genetics with a focus on size/scale factor

Annotated Bibliography

Bennett, Jeffrey & Briggs William. 2011. *Using and Understanding Mathematics A Quantatative Reasoning Approach.* Boston: Pearson.

Briggs, John. 2015. *Fractals The Patterns Of Chaos.* Brattleboro: Echo Point Books & Media.

Byrd, Carson W. & Hughey, Matthew W. 2015. "Biological Determinism and Racial Essentialism: The Ideological Double Helix of Racial Inequality." *The ANNALS of the American Academy of Political and Social Science* 661 (1): 8-22.

Giancoli, Douglas C. 1991. *Physics.* New Jersey: Prentice Hall.

Kotz, John C. & Treichel, Paul Jr. 1996. *Chemistry & Chemical Reactivity.* Orlando: Saunders College Publishing.

Lane, Nick. 2005. *Power, Sex, Suicide Mitochondria and the Meaning of Life.* New York: Oxford University.

Livio, Mario. 2009. *is GOD a MATHAMATICIAN.* New York: Simon & Schuster.

Lynch, Ben. 2018. *Dirty Genes A Breakthrough Program to Treat the Root Cause of Illness and Optimize Your Health.* New York: Harper Collins.

Moore, David S. 2015. *The Developing Genome An Introduction to Behavioral Epigentics.* Oxford: Oxford University Press.

Skinner, Stephen. 2006. *Sacred Geometry Deciphering the Code.* New York: Sterling.

Stinson, David, Bidwell, Carla R. & Powell, Ginny C. 2012. "Critical Pedagogy and Teaching Mathematics for Social Justice." *International Journal of Critical Pedagogy* 4 (1): 76-94.

Tegmark, Max. 2014. *Our Mathematical Universe My Quest for the Ultimate Nature of Reality.* New York: Random House.

West, Geoffrey. 2017. *Scale The Universal Laws of Growth, Innovation, Sustaninability, and the Pace of Life in Organisms, Cities, Economies< and Companies.* New York: Penguin Press.