Subject: Biology | **Unit:** Inheritance and Variation of Traits
Grade: 10th Grade | **Pacing:** 6 weeks

Overview & Instructional Plan

Essential Question(s)	• How do organisms pass traits from one generation to the next? • How do multicellular organisms go from a one-celled fertilized zygote to a multicellular organism with specialized tissues? • How do multicellular organisms create sex cells that pass their genes onto their offspring? • What is the importance of predicting how often a trait is seen in a population? • What are the implications of altered genetic information? • Why might knowledge of genetics be useful to us and to scientists?
Enduring Understanding/ Big Idea(s) (use student friendly language)	• An organism's traits are determined by its genes, which are inherited from the organism's parent(s). • Mitosis results in new cells that are genetically identical to each other and the original starting cell. • Meiosis results in gametes that contain only half the genes of the original starting cell. • Mutations, which can occur during replication of the DNA in meiosis/mitosis or can be caused by environmental conditions, can result in changes in the traits of an organism. • Genes can be regulated, and this regulation can cause the cells where it occurs to differentiate. • Environmental factors can be used to predict how common specific traits are in a region.
Standards	**Performance Expectations:** Primary: HS-LS3-1, HS-LS1-4, HS-LS3-2, HS-LS3-3 Secondary: HS-ETS1-3 **NGSS Science and Engineering Practices** Constructing Explanations and Designing Solutions; Analyzing and Interpreting Data; Engaging in Argument from Evidence; Developing and Using Models; Asking Questions and Defining Problems **Cross Cutting Concepts:** Systems and System Models; Cause and Effect; Scale, Proportion and Quantity **Essential Skills:** CT, CC, CI, SD
Unit Phenomena & Phenomena Explanation	In Tanzania, having albinism can be dangerous. People born with albinism, commonly to parents without albinism, are seen as sources of witchcraft and sorcery. Many people believe that being born with albinism is a punishment or bad luck, and this bad luck can be contagious. Some also believe that their limbs can be used for creating magical potions. Because of this, they are targets of violence. Albinism is extremely high in Tanzania because of a reduced rate out outbreeding. Recently, the Tanzanian government has taken steps to protect people with albinism, resulting in a reduced rate of violence against people within Tanzanian borders. However, there has been a spike in violence against people with albinism in Malawi, a country adjacent to Tanzania, leading some to believe the problem hasn't disappeared, but rather moved across the border. **Biological concepts behind the phenomenon** • There are many types of albinism, but typically it is a recessively linked trait caused by the inheritance of two recessive alleles, one from each parent, during fertilization. For the purposes of this unit, students will only be dealing with the recessive form of albinism. This means, genotypically, a person needs to be homozygous recessive to phenotypically exhibit albinism. • A heterozygous person is said to be a "carrier" because, while he or she is not phenotypically albino, he or she can pass on the allele to an offspring. If a carrier reproduces with another carrier, the offspring has a 25% chance of having albinism. Thus, two people who phenotypically do not exhibit albinism can very well have an offspring that does exhibit albinism. • If a person with albinism reproduces with another person with albinism, there is a 100% chance their offspring will also have albinism. • In general, 1/15,000 (or more) individuals exhibit albinism, but in some African populations, that number may rise to 1/1,000. • It is unknown why albinism is so high in sub-Saharan Africa, though some believe that the first village with a higher rate of albinism was a place of refuge for some people with albinism, leading to the establishment of a founder population with a higher than normal allele frequency for the recessive albinism allele. Since there is very little gene flow into or out of the gene pool for these sub-Saharan populations, the allele frequency for the recessive albinism gene remained relatively high. A similar situation occurred in Martha's Vineyard regarding deafness. • Albinism, in this instance, is due to a change in the sequence of letters in the gene encoding for the skin pigmentation protein (reference back to unit 1 and Central Dogma). The change in the letters resulted in a differently shaped protein, resulting in a different phenotype. • The difference in the sequence of letters in the skin pigmentation gene originally resulted from a mutation in one individual's DNA, and that mutation was passed onto that person's offspring, who then passed it onto their offspring. This is how new phenotypes appear in any species, thus increasing variation of traits amongst organisms. • Mutations can occur during DNA Replication. When a cell is getting ready to divide through mitosis or meiosis, the DNA needs to be replicated to ensure that the new cells made from the parent cell are made with fidelity. Each new cell receives a double helix of DNA that is half original DNA and half new

	DNA. If the new DNA half is made incorrectly (say, inserting an A where a C should be), the daughter cell has a mutation. This mutation can result in a new phenotype, depending on where in the DNA it occurs (gene versus non-coding DNA). • If a replication error occurs in the gonads, the resulting cell, a gamete, will pass the mutation on to the person's offspring if that gamete is the one used for reproduction. Since a multicellular organism retains all of its genes in every one of its cells from the original zygote, every cell in the multicellular organism that results from that zygote will have the mutation in its nucleus. • Mutations can also be caused by environmental factors such as UV radiation, X-Rays, carcinogenic chemicals (like those in tobacco), etc. Exposure to these stimuli can result in de-novo mutations. Typically, these mutations are not passed to offspring because they occur in body cells, not gonads. • The appearance of the albinism trait necessitates the correct combination of alleles from one's parents, thus indicating the variation of traits that results from different combination of genes. This is also why blue eyes can be seen on children with darkly pigmented skin. If the individual receives the right combination of genes from the parents, and those parents are carriers of a an allele, the unusual variation of traits is possible. • Every cell in a multicellular organism has the same genes and DNA. That is, the genes that were conferred to them from the fertilization of their mother's egg by their father's sperm are located in every cell in their body. At that moment, the genes and DNA for every cell resulting from that zygote was established. • Biolimbs and lab-derived organs have been grown in labs. Basically, an organ can be drained of its cells with detergents, leaving behind a protein scaffold. Then, cells from the transplant receiver are taken (usually bone stem cells), and put into the protein scaffold. The cells take up residence there, go through mitosis, and begin to fill in the gaps left behind by the drained cells. And, since all cells have the entire genome for the human being from which they were taken, the cells can grow into whatever organ the scaffold is for (i.e. the bone stem cells can grow into a heart because they have the heart genes, too. Those genes were just "shut off" in the bone cells.) • Because every cell in a multicellular organism contains the same genes, only some genes need to to be expressed, depending on what type of cell that cell is destined to be. For example, the "digestive enzyme" genes do not need to be expressed in bone cells. Consequently, some genes serve as on-off switches for other genes and therefore prevent the expression of the trait encoded for by that protein. This is what allows genes to be differentially expressed in cells, resulting in differentiation of tissues. • Mutations can be good, bad or neutral. A good mutation results in a change in DNA letters (and thus encoded proteins) by allowing for an advantageous trait or phenotype (like the origin stories in many superheroes). Bad mutations result in disadvantageous traits, such as cancer or a genetic disorder. Neutral mutations occur when a change in the letters in the DNA occurs in a part of a chromosome that doesn't affect a trait. • The environment can determine how common a mutation becomes. As said before, if a mutation is advantageous, the environment might make it easier for individuals with that trait to survive. If the individuals survive more easily, they can reproduce more and spread the trait to new individuals in the next generation. • Conversely, negative traits resulting from mutations become less common because they are selected against by the environment. That is, they become less common because individuals with those traits have a harder time surviving. • For humans, sperm and eggs can be screened for these mutations (if they've been seen before/are known). If a sperm or egg is seen to have a disadvantageous allele (such as albinism), it can be discarded. If it is seen to have an advantageous allele (who's to say what that is?!), it can be selected and used for in vitro fertilization. **insert video link of albinos being attacked** "Malawi's albinos at risk of 'total extinction,' U.N. warns" http://www.thedailybeast.com/articles/2015/02/19/africa-s-albino-island.html https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1584235/
Phenomena Driving Question	How do we stop violence against people with albinism?
Unit Overview/ Storyline/ Staging	**Learning Sequence 1:** *Content covered: structure of DNA/genes/chromosomes; cell division (mitosis); cell differentiation; DNA/gene expression* Learning Sequence 1 Overview: Students will begin by determining which twins in provided pictures are identical and which are fraternal to begin understanding how traits are passed on. They will continue by creating individual and group models of how humans get their eye color which will introduce them to the ideas of mitosis, cellular differentiation and will further the idea that the expression of traits is controlled by an organism's DNA. In the explain phase, they will take the models they previously created and will turn them

into 3D models and they will have to explicitly explain with words (written and recorded on video) what is happening in their models and how DNA controls the expression of traits through the creation of proteins in specialized cells. Students will then apply their new learning to explain how the process of bio-scaffolding works, then using that explanation to create a bio-limb.

Connection to storyline: This learning sequence addresses what causes traits, where we get them from and why they aren't expressed in every cell in a multicellular organism. This will help them to explain why some people get albinism and others do not as well as how similar albino individuals are to non-albino individuals (why albino individuals don't have white blood like they have white skin).

Learning Sequence 2:
Content covered: meiosis; mutations causes and effects

Sequence Overview:
This learning sequence will begin with students creating an explanation for uncommon trait combinations (how can black people end up with blue eyes is the focus but other examples can be used as well). Students will work in groups to develop their explanations and will create a position paper to using evidence to support their explanation. They will then continue this by completing research on different unusual trait combinations to expand their understanding of how meiosis can cause unusual trait combinations in a population. Students will create a model of meiosis with different shapes of pasta and then will use those models to explain the three ways that unusual trait combinations can arise in a population. Students will take that concept one step farther to the variations found in the area of superheros by defending the genetics as to how a superhero attained his/her superpowers or by creating a new superhero with a corresponding backstory on how they gained their superpowers.

Connection to Storyline:
This learning sequence addresses how new traits come about and how they are passed on to future offspring. This will help them to learn how albinism came to be and how an albino individual can come from two non-albino parents.

Learning Sequence 3:
Content Covered: patterns in the distribution of traits and possible causes of them; the process of designer babies

Sequence Overview:
Students will begin this learning sequence by exploring the relationship between the distribution of traits and environmental factors by analyzing data of malaria and sickle cell cases by world region. This will lead them to understand that certain environmental factors can control the expression of traits within a population. The learning sequence continues with students learning about gel electrophoresis technology to understand that genes can be tested for/identified and to further their understanding that trait variation distribution are dictated by environmental factors. Students will then justify their final decisions/arguments from the gel electrophoresis lab in a formal lab report using collected data and researched evidence. After knowing that traits can be identified, students will learn about a specific DNA modification technique (CRISPR) to determine if using that technique to create a designer baby is a viable solution to solving the problem of violence against albino individuals.

Connection to Storyline:
This learning sequence addresses why some traits are more common than others in certain populations (why albinism is more common in Tanzania) and if designer babies could be a solution to the problem of violence against albino individuals.

Learning Sequence 1 *	Learning Sequence 2 *	Learning Sequence 3 *
Performance Expectations	Performance Expectations	Performance Expectations
HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. **HS-LS1-4.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.	**HS-LS3-2.** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.	**HS-LS3-3.** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. **HS-ETS1-3.** Evaluate a solution to a complex real world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics as well as possible social, cultural, and environmental impacts.
Question 1	Question 2	Question 3

Subject: Biology **Unit:** Inheritance and Variation of Traits

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What causes traits?

Learning Targets

- *I can create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing the instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits.*
- *I can create a second model to illustrate how multicellular organisms use mitosis to grow from a single-celled zygote after fertilization to a complex, multicellular organism.*
- *I can adjust the second model to demonstrate mitosis by showing that one parent cell (including the zygote) starts the cell division and that two daughter cells are created at the end.*
- *I can use the second model to demonstrate that all cells within an organism contain the same genes and chromosomes found in the original zygote.*
- *I can use the second model to show that each cell in complex organisms contains two copies of each chromosome.*
- *I can use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization.*
- *I can use the second model to demonstrate how chromosomes are replicated within the parent cell before mitosis completes.*
- *I can use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote).*
- *I can use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote).*
- *I can use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs.*
- *I can use the second model to illustrate that multicellular organisms use mitosis to replace dead cells.*
- *I can connect model number one to model number two to illustrate that trait differences between different differentiated cell types is due to different expression of the genes in the cell, not differences in the genes that are there.*
- *I can adjust and refine my model to demonstrate that genes can be regulated to prevent or allow the instructions to be used to make proteins.*
- *I can adjust and refine my model to show how some regions of DNA within a chromosome regulate the genes expressed in other regions of the chromosome by acting as an on-off switch and therefore do not code for proteins directly.*
- *I can analyze the accuracy of my model compared to what actually happens during mitosis.*
- *I can ask questions about the phenomenon that can be scientifically tested.*

Anchor Activity 1

Bio-limb construction (utilizing principles researched from twin opening engagement)

Formative Assessment 1

3D model and narrative from Explain phase answering driving question for sequence 1.

Suggested Resources 1

https://www.youtube.com/watch?v=I-ldPgEfAHI

http://www.pbs.org/wgbh/nova/body/repla

How do new traits come about?

Learning Targets

- *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from new genetic combinations through meiosis.*
- *I can make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.*
- *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from mutations caused by environmental factors.*
- *I can use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.*
- *I can identify the strengths and weaknesses of the types and numbers of sources for the evidence used to support the claim.*
- *I can identify the strengths and weaknesses of the success of the evidence in defending the claim.*
- *I can identify the strengths and weaknesses of the evidence of the relationships that cause the claim and of those that only correlate (relate) to the claim.*
- *I can identify the strengths and weaknesses of the validity and reliability of the evidence to support the claim.*
- *I can use reasoning to describe the link between the evidence and the claim that genetic mutations produce genetic variations between cells or organisms.*
- *I can use reasoning to describe the link between the evidence and the claim that genetic variations produced by mutation and meiosis can be inherited.*
- *I can use reasoning and valid evidence to describe that new combinations of DNA can come from several sources including meiosis, errors during replication, and mutations caused by environmental factors.*
- *I can defend a claim against counter-claims by evaluating the connection between the relevant and appropriate evidence of the counterclaim.*
- *I can defend a claim against counter-claims by evaluating which claim is the strongest.*

Anchor Activity 2

Superhuman backstory construction (utilizing principles researched from unusual trait variation engagement)

Formative Assessment 2

Product created (video, paper, comic) from Elaborate phase detailing the scientifically accurate origin of a superhero

Suggested Resources 2

http://afrotonal.com/black-people-with-blue-eyes/
http://www.arequndade.com/can-black-people-have-blue-eyes-are-there-green-eyed-black-people-afr

Can we control or change traits?

Learning Targets

- *I can organize the given data by the frequency of the expressed traits in the population.*
- *I can organize the given data by the distribution of the expressed traits in the population.*
- *I can organize the given data by the variation of the expressed traits in the population.*
- *I can perform and use probability measures of the given data to determine the relationship between a trait's occurrence within a population and the environmental factors impacting the population.*
- *I can recognize and use patterns to predict the changes in trait distribution within a population if environmental variables change as a way to analyze and interpret data used to explain the distribution of expressed traits.*
- *I can describe the expression of a chosen trait (and its variations) as being caused by or as being correlated (just related) to some environmental factor based on reliable evidence.*
- *I can generate a list of three or more realistic criteria and two or more constraints (including cost, safety, reliability and how the solution looks) for an acceptable solution to a complex real-world problem.*
- *I can assign priorities for each criterion and constraint to allow me to logically and systematically evaluate alternative solution proposals.*
- *I can analyze and describe the strengths and weaknesses of the solution with using the criteria and constraints, the environmental impacts, as well as how well the solution would be socially and culturally accepted.*
- *I can describe possible barriers to using each solution thinking about the cultural, economic (financial), or other sources of resistance for each possible solution.*
- *I can provide an evidence-based decision of which solution is best, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution as well as the barriers to be overcome.*
- *I can describe which parts of the complex real-world problem might remain even if the proposed/selected solution is implemented.*

Anchor Activity 3

Gel electrophoresis for albinism gene, but in reality, food coloring (utilizing principles researched from sickle-cell anemia distribution charts)

Formative Assessment 3

Lab report for gel electrophoresis from Explain phase depicting discovery of trend of albinism as it relates to geographical location.

Suggested Resources 3

http://www.motherjones.com/politics/2016/02/genome-embryo-crispr-designer-babies
https://www.davidson.edu/news/news-stories/160318

Subject: Biology **Unit:** Inheritance and Variation of Traits

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cing-body-parts.html	can-americans-with-blue-green-and-hazel-eyes.html http://news.nationalgeographic.com/news/2007/04/070418-chernobyl-birds.html	-designer-babies-and-education
Key Vocabulary 1	**Key Vocabulary 2**	**Key Vocabulary 3**
Gene, Chromosome, Mitosis, Zygote, Daughter Cell, Parent Cell, DNA Replication, Differentiation, Gene Regulation, Expression, Trait, Scaffold, Bio-limb	Meiosis, Sex Cell, Gamete, Inheritance, Mutation, Variation, Environmental factor, Allele	Frequency, Distribution, Population, Gel Electrophoresis, Restriction Enzyme (possibly), CRISPR, Genetic testing, Designer baby

*** Model 5E Lessons provided for this Learning Sequence**

Summative Assessment

Summative Performance Task	
Standards:	Each Learning Sequence contains an assessment task to assess the Performance Expectations for that Learning Sequence which are considered the summative assessments for that Learning Sequence. The summative assessment options for this unit include: Learning Sequence 1 Assessment Task Learning Sequence 2 Assessment Task Learning Sequence 3 Assessment Task
HS-LS3-1, HS-LS1-4, HS-LS3-2, HS-LS3-3	
Essential Skills:	

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

Stage 1: Desired Results

Learning Sequence 1 450 Minutes	Learning Sequence 2 450 Minutes	Learning Sequence 3 450 Minutes
PERFORMANCE EXPECTATIONS		
Performance Expectation HS-LS3-1 & HS-LS1-4 **HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring. ***Assessment Boundary:*** **Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process** **HS-LS1-4.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms. ***Assessment Boundary:*** **Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis**	Performance Expectation HS-LS3-2 **HS-LS3-2.** Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors. ***Clarification Statement:*** **Emphasis is on using data to support arguments for the way variation occurs.** ***Assessment Boundary:*** **Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process**	Performance Expectation HS-LS3-3 & HS-ETS1-3 **HS-LS3-3.** Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population. ***Clarification Statement:*** **Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits** ***Assessment Boundary:*** **Assessment does not include Hardy-Weinberg calculations** **HS-ETS1-3.** Evaluate a solution to a complex real world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics as well as possible social, cultural, and environmental impacts.
	Performance Expectation HS-LS4-2 *HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment.* *Clarification Statement:* I Emphasis is on using evidence to explain the influence each of the four factors has on the number of organisms, behaviors, morphology, or physiology in terms of ability to compete for limited resources and subsequent survival of individuals and adaptation of species. Examples of evidence could include mathematical models such as simple distribution graphs and proportional reasoning. *Assessment Boundary:* Assessment does not include other mechanisms of evolution, such as genetic drift, gene flow through migration, and co-evolution	Performance Expectation HS-LS4-3 *HS-LS4-3. Apply concepts of statistics and probability to support explanations that organisms with an advantageous heritable trait tend to increase in proportion to organisms lacking this trait.* *Clarification Statement:* Emphasis is on analyzing shifts in numerical distribution of traits and using these shifts as evidence to support explanations. *Assessment Boundary:* Assessment is limited to basic statistical and graphical analysis. Assessment does not include allele frequency calculations Performance Expectation HS-LS4-5 *HS-LS4-5. Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.* *Clarification Statement:* Emphasis is on determining cause and effect relationships for how changes to the environment such as deforestation, fishing, application of fertilizers, drought, flood, and the rate of change of the environment affect distribution or disappearance of traits in species
DISCIPLINARY CORE IDEAS		
Structure and Function ***LS1.A: All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)*** Inheritance of Traits ***LS3.A: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function*** Growth and Development of Organisms ***LS1.B: In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.***	Variation of Traits ***LS3.B: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.***	Variation of Traits ***LS3.B: Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.*** Developing Possible Solutions ***ETS1.B: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.***
	Natural Selection *LS4.B: Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information —*	Natural Selection *LS4.B: Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information — that is, trait variation — that leads*

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

	that is, trait variation — that leads to differences in performance among individuals. Adaptation *LS4.C: Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and*	*to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.* Adaptation *LS4.C: Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change.* Adaptation LS4.C: Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline — and sometimes the extinction — of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.
SCIENCE AND ENGINEERING PRACTICES		
Asking Questions and Defining Problems **Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining and evaluating empirically testable questions and design problems using models and simulations. Ask questions that arise from examining models or a theory to clarify relationships.** Developing and Using Models **Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Use a model based on evidence to illustrate the relationships between systems or between components of a system.**	Engaging in Argument from Evidence **Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence.**	Analyzing and Interpreting Data **Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using** Constructing Explanations and Designing Solutions **Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.**
	Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories. Construct an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.	Analyzing and Interpreting Data Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. Engaging in Argument from Evidence Engaging in argument from evidence in 9- 12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current or historical episodes in science. Evaluate the evidence behind currently accepted explanations or solutions to determine the merits of arguments.
CROSS CUTTING CONCEPTS		
Cause and Effect **Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.** Systems and System Models **Systems and System Models Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions — including energy, matter, and information flows — within and between systems at different scales.**	Cause and Effect **Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.**	Scale, Proportion and Quantity **Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).**
	Cause and Effect	Patterns

	Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.	Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. Cause and Effect Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.
CONNECTIONS to NATURE of SCIENCE or ENGINEERING, TECHNOLOGY, and APPLICATIONS of SCIENCE		
		Science is a Human Endeavor • Technological advances have influenced the progress of science and science has influenced advances in technology. (HS-LS3-3) • Science and engineering are influenced by society and society is influenced by science and engineering. (HS-LS3-3) **Connections to Engineering, Technology and Applications of Science** • Influence of Science, Engineering, and Technology on Society and the Natural World New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.
Integrated Standards and Essential Skills		
CCSS ELA Reading and Writing	**CCSS ELA Reading and Writing**	**CCSS ELA Reading and Writing**
CCSS Mathematics Practices	**CCSS Mathematics Practices**	**CCSS Mathematics Practices**
CREC Essential Skills (CT) Critical Thinking and Problem Solving (CC) Communication and Collaboration (CI) Creativity and Innovation (SD) Self-Direction and Resourcefulness	**CREC Essential Skills** (CT) Critical Thinking and Problem Solving (CC) Communication and Collaboration (CI) Creativity and Innovation (SD) Self-Direction and Resourcefulness	**CREC Essential Skills** (CT) Critical Thinking and Problem Solving (CC) Communication and Collaboration (CI) Creativity and Innovation (SD) Self-Direction and Resourcefulness

Learning Targets

Learning Sequence 1:

- *I can create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing the instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits.*
- *I can create a second model to illustrate how multicellular organisms use mitosis to grow from a single-celled zygote after fertilization to a complex, multicellular organism.*
- *I can adjust the second model to demonstrate mitosis by showing that one parent cell (including the zygote) starts the cell division and that two daughter cells are created at the end.*
- *I can use the second model to demonstrate that all cells within an organism contain the same genes and chromosomes found in the original zygote.*
- *I can use the second model to show that each cell in complex organisms contains two copies of each chromosome.*
- *I can use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization.*
- *I can use the second model to demonstrate how chromosomes are replicated within the parent cell before mitosis completes.*
- *I can use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote).*
- *I can use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote).*
- *I can use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs.*
- *I can use the second model to illustrate that multicellular organisms use mitosis to replace dead cells.*
- *I can connect model number one to model number two to illustrate that trait differences between different differentiated cell types is due to different expression of the genes in the cell, not differences in the genes that are there.*
- *I can adjust and refine my model to demonstrate that genes can be regulated to prevent or allow the instructions to be used to make proteins.*
- *I can adjust and refine my model to show how some regions of DNA within a chromosome regulate the genes expressed in other regions of the chromosome by acting as an on-off switch and therefore do not code for proteins directly.*
- *I can analyze the accuracy of my model compared to what actually happens during mitosis.*
- *I can ask questions about the phenomenon that can be scientifically tested.*

Learning Sequence 2:

- *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from new genetic combinations through meiosis.*
- *I can make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.*

- *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from mutations caused by environmental factors.*
- *I can use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.*
- *I can identify the strengths and weaknesses of the types and numbers of sources for the evidence used to support the claim.*
- *I can identify the strengths and weaknesses of the success of the evidence in defending the claim.*
- *I can identify the strengths and weaknesses of the evidence of the relationships that cause the claim and of those that only correlate (relate) to the claim.*
- *I can identify the strengths and weaknesses of the validity and reliability of the evidence to support the claim.*
- *I can use reasoning to describe the link between the evidence and the claim that genetic mutations produce genetic variations between cells or organisms.*
- *I can use reasoning to describe the link between the evidence and the claim that genetic variations produced by mutation and meiosis can be inherited.*
- *I can use reasoning and valid evidence to describe that new combinations of DNA can come from several sources including meiosis, errors during replication, and mutations caused by environmental factors.*
- *I can defend a claim against counter-claims by evaluating the connection between the relevant and appropriate evidence of the counterclaim.*
- *I can defend a claim against counter-claims by evaluating which claim is the strongest.*

Learning Sequence 3:

- *I can organize the given data by the frequency of the expressed traits in the population.*
- *I can organize the given data by the distribution of the expressed traits in the population.*
- *I can organize the given data by the variation of the expressed traits in the population.*
- *I can perform and use probability measures of the given data to determine the relationship between a trait's occurrence within a population and the environmental factors impacting the population.*
- *I can recognize and use patterns to predict the changes in trait distribution within a population if environmental variables change as a way to analyze and interpret data used to explain the distribution of expressed traits.*
- *I can describe the expression of a chosen trait (and its variations) as being caused by or as being correlated (just related) to some environmental factor based on reliable evidence.*
- *I can generate a list of three or more realistic criteria and two or more constraints (including cost, safety, reliability and how the solution looks) for an acceptable solution to a complex real-world problem.*
- *I can assign priorities for each criterion and constraint to allow me to logically and systematically evaluate alternative solution proposals.*
- *I can analyze and describe the strengths and weaknesses of the solution with using the criteria and constraints, the environmental impacts, as well as how well the solution would be socially and culturally accepted.*
- *I can describe possible barriers to using each solution thinking about the cultural, economic (financial), or other sources of resistance for each possible solution.*
- *I can provide an evidence-based decision of which solution is best, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution as well as the barriers to be overcome.*
- *I can describe which parts of the complex real-world problem might remain even if the proposed/selected solution is implemented.*

Vocabulary

Learning Sequence 1: Gene, Chromosome, Mitosis, Zygote, Daughter Cell, Parent Cell, DNA Replication, Differentiation, Gene Regulation, Expression, Trait, Scaffold, Bio-limb

Learning Sequence 2: Meiosis, Sex Cell, Gamete, Inheritance, Mutation, Variation, Environmental factor, Allele

Learning Sequence 3: Frequency, Distribution, Population, Gel Electrophoresis, Restriction Enzyme (possibly), CRISPR, Genetic testing, Designer baby

Subject: Biology | **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade | **Pacing:** 6 weeks

Stage 2: Assessment Evidence

Summative Assessments	
Performance Task	
Standards: *What Standards are addressed? Codes only.* Essential Skills: *What Essential Skills are addressed? Codes only.*	•Is there alignment to the identified standards? •Does the task address the big idea? •Is the task appropriately challenging?
Unit Assessment	
Standards: Essential Skills:	Are priority standards addressed in a way that gives you multiple points of evidence on a particular standard?

Formative Assessments	
Formative Assessment 1	
Standards: HS-LS3-1, HS-LS1-4 Essential Skills:	3D model and narrative from Explain phase answering driving question for sequence 1
Formative Assessment 2	
Standards: HS-LS3-2 Essential Skills:	Product created (video, paper, comic) from Elaborate phase detailing the scientifically accurate origin of a superhero
Formative Assessment 3	
Standards: HS-LS3-3, HS-ETS1-3 Essential Skills:	Lab report for gel electrophoresis from Explain phase depicting discovery of trend of albinism as it relates to geographical location

CREC Curriculum

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

Stage 3: Anchor Activities & Resources

Anchor Activities		
Standards: HS-LS3-1, HS-LS1-4	**Anchor Activity 1**	**Scaffolding:**
Essential Skills:	Bio-limb construction (utilizing principles researched from twin opening engagement)	**Enrichment:**
Standards: HS-LS3-2	**Anchor Activity 2**	**Scaffolding:**
Essential Skills:	Superhuman backstory construction (utilizing principles researched from unusual trait variation engagement)	**Enrichment:**
Standards: HS-LS3-3, HS-ETS1-3	**Anchor Activity 3**	**Scaffolding:**
Essential Skills:	Gel electrophoresis for albinism gene, but in reality, food coloring (utilizing principles researched from sickle-cell anemia distribution charts)	**Enrichment:**

Additional Resources
Learning Sequence 1 Resources
Learning Sequence 2 Resources
Learning Sequence 3 Resources

Essential Skills:	**(CT) Critical Thinking and Problem Solving** **(CC) Communication and Collaboration** **(CI) Creativity and Innovation** **(SD) Self-Direction and Resourcefulness**

CREC NGSS Science Learning Sequence Detailed Plan

Learning Sequence 1 of 3

UNIT Phenomenon: People in Africa born with albinism are targeted for violence. **Phenomenon Driving Question:** How do we stop the violence against people with albinism?
Learning Sequence 1 Main Question: What causes traits?

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

Possible Student Questions: Why doesn't his skin have color? How do my genes affect my skin color? Are his/her parents albino? Is it just his skin that has no color or is it his eyes and hair, too? What gives skin its color? Can I get albinism? Does albinism go away? Does DNA have to do with albinism? How do I get my genes? Where are genes located? Can I give my kids albinism? Why do fraternal twins look similar? Am I a 50/50 mix of my parents? Can you be a little albino? Can being albino be good in any way?

How does Learning Sequence 1 support students in figuring out or solving the phenomenon?

By the end of Learning Sequence 1, students will be able to correctly identify DNA as the ultimate controller of an organism's traits because DNA contains the instructions for building proteins, which ultimately determine the organism's traits. Since organisms receive their DNA from their parents, an organism's traits are often reflective of that organism's parents' traits. However, students will also discover the idea that genes, although universally present within every cell within an organism's body, can be regulated. Essentially, they can be turned on and off, which results in different cells within an organism expressing different proteins. And, since proteins determine traits, different proteins ultimately results in different traits within cells of the same organism. Consequently, cells begin to express different traits, giving them different functions, leading to the process of differentiation. As a zygote undergoes mitosis to create a multicellular organism, it is the differentiation of the cells by regulating their genetic expression that causes the organism to develop into the complex system of tissues and organs that it has.

What part of the storyline does this learning sequence address?
This addresses what causes traits, where we get them from and why they aren't expressed in every cell in a multicellular organism

Performance Expectations for Learning Sequence 1

Performance Expectation HS-LS3-1 & HS-LS1-4

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Assessment Boundary: **Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process**

HS-LS1-4. Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.

Assessment Boundary: **Assessment does not include specific gene control mechanisms or rote memorization of the steps of mitosis**

Science and Engineering Practices	Disciplinary Core Ideas	Cross Cutting Concepts
Asking Questions and Defining Problems **Asking questions and defining problems in 9-12 builds on K-8 experiences and progresses to formulating, refining and evaluating empirically testable questions and design problems using models and simulations. Ask questions that arise from examining models or a theory to clarify relationships.** **Developing and Using Models** **Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds. Use a model based on evidence to illustrate the relationships between systems or between components of a system.**	Structure and Function ***LS1.A: All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins. (secondary) (Note: This Disciplinary Core Idea is also addressed by HS-LS1-1.)*** Inheritance of Traits ***LS3.A: Each chromosome consists of a single very long DNA molecule, and each gene on the chromosome is a particular segment of that DNA. The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways. Not all DNA codes for a protein; some segments of DNA are involved in regulatory or structural functions, and some have no as-yet known function*** Growth and Development of Organisms ***LS1.B: In multicellular organisms individual cells grow and then divide via a process called mitosis, thereby allowing the organism to grow. The organism begins as a single cell (fertilized egg) that divides successively to produce many cells, with each parent cell passing identical genetic material (two variants of each chromosome pair) to both daughter cells. Cellular division and differentiation produce and maintain a complex organism, composed of systems of tissues and organs that work together to meet the needs of the whole organism.***	Cause and Effect **Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.**

Student Learning Targets for Learning Sequence 1

I can:

- *create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing the instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits.*
- *create a second model to illustrate how multicellular organisms use mitosis to grow from a single-celled zygote after fertilization to a complex, multicellular organism.*
- *adjust the second model to demonstrate mitosis by showing that one parent cell (including the zygote) starts the cell division and that two daughter cells are created at the end.*
- *use the second model to demonstrate that all cells within an organism contain the same genes and chromosomes found in the original zygote.*
- *use the second model to show that each cell in complex organisms contains two copies of each chromosome.*
- *use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization.*
- *use the second model to demonstrate how chromosomes are replicated within the parent cell before mitosis completes.*
- *use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote).*
- *use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote).*
- *use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs.*
- *use the second model to illustrate that multicellular organisms use mitosis to replace dead cells.*
- *connect model number one to model number two to illustrate that trait differences between different differentiated cell types is due to different expression of the genes in the cell, not differences in the genes that are there.*
- *adjust and refine my model to demonstrate that genes can be regulated to prevent or allow the instructions to be used to make proteins.*
- *adjust and refine my model to show how some regions of DNA within a chromosome regulate the genes expressed in other regions of the chromosome by acting as an on-off switch and therefore do not code for proteins directly.*
- *analyze the accuracy of my model compared to what actually happens during mitosis.*
- *ask questions about the phenomenon that can be scientifically tested.*

Progression of Student Learning in this Learning Sequence Across the 3 Dimensions

	Prior Learning	Future Learning
Science & Engineering Practices	By the end of grade 8:	End of grade band descriptions

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

	Asking Questions and Defining Problems: *Asking questions and defining problems in 6-8 builds on K-5 experiences and progresses to specifying relationships between variables and clarifying arguments and models.* • *Ask questions:* ○ *that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.* ○ *to identify and/or clarify evidence and/or the premise(s) of an argument.* ○ *to determine relationships between independent and dependent variables and relationships in models.* ○ *to clarify and/or refine a model, an explanation, or an engineering problem.* ○ *that require sufficient and appropriate empirical evidence to answer* ○ *that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.* ○ *that challenge the premise(s) of an argument or the interpretation of a data set* • *Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.* Developing and Using Models: *Modeling in 6-8 builds on K-5 experiences and progresses to developing, using, and revising models to describe, test and predict more abstract phenomena and design systems.* • *Evaluate limitations of a model for a proposed object or tool.* • *Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed.* • *Use and/or develop a model of simple systems with uncertain and less predictable factors.* • *Develop and/or revise a model to show the relationships among variables, including those that are not observable but predict observable phenomena.* • *Develop and/or use a model to predict and/or describe phenomena.* • *Develop a model to describe unobservable mechanisms.* • *Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.*	Asking Questions and Defining Problems: *Asking questions and defining problems in 9–12 builds on K–8 experiences and progresses to formulating, refining, and evaluating empirically testable questions and design problems using models and simulations.* • *Ask questions:* ○ *that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.* ○ *that arise from examining models or a theory, to clarify and/or seek additional information and relationships.* ○ *to determine relationships, including quantitative relationships, between independent and dependent variables.* ○ *to clarify and refine a model, an explanation, or an engineering problem.* • *Evaluate a question to determine if it is testable and relevant.* • *Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.* • *Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design.* • *Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.* Developing and Using Models: *Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed worlds.* • *Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.* • *Design a test of a model to ascertain its reliability.* • *Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.* • *Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations.* • *Develop a complex model that allows for manipulation and testing of a proposed process or system.* • *Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.*
Disciplinary Core Ideas	By the end of grade 8: LS1.A: *All living things are made up of cells, which is the smallest unit that can be said to be alive. An organism may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live.* LS1.B: *Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. Plant growth can continue throughout the plant's life through production of plant matter in photosynthesis. Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range. (Boundary: Reproduction is not treated in any detail here; for more specifics about grade level, see LS3.A.)* LS3.A: *Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of a specific protein, which in turn affects the traits of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations. (Boundary: The stress here is on the impact of gene transmission in reproduction, not the mechanism.)*	End of grade band descriptions LS1.A: *Systems of specialized cells within organisms help them perform the essential functions of life. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.* LS1.A: *Multicellular organisms have a hierarchical structural organization, in which any one system is made up of numerous parts and is itself a component of the next level.* LS1.A: *Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.*
Cross Cutting Concepts	By the end of grade 8: Cause and Effect: *students classify relationships as causal or correlational, and recognize that correlation does not necessarily imply causation. They can use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*	End of grade band descriptions Cause and Effect: *students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale*

	Systems and System Models: *students understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions - such as inputs, processes, and outputs - and neregy, matter and information flows within systems. They also learn that models are limited in that they only represent certain aspects of the system under study.*	*mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.* Systems and System Models: *students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models. They can also design systems to do specific tasks.*

Connecticut Core Connections Reading Writing Mathematics	*Essential Skills Connections*

5E Lessons for Learning Sequence 1

ENGAGE Activity: Identical and Fraternal Twin Comparisons Time: 30 minutes Materials Needed: Pictures of sets of twins (laminated) Description: Students will determine whether each set of twins is fraternal or identical based on the evidence presented in each picture (traits).	
Teacher Actions: • Have pictures ready. Each placard has a picture of twins (can be celebrity or not). • Ask students to view different cards, and for each card, determine if the twins are identical or fraternal. Inform students to indicate evidence that informed their decision. • Ask students to explain how their justification using evidence • Ask students to draw a preliminary model demonstrating how a single baby gets his or her traits • Have students ask questions about traits to drive the next portions of the learning sequence	Student Actions: • Working in pairs/groups discussing pictures to determine groupings • Determining criteria to judge pictures on • Justifying groupings (identical or fraternal) to group members/teacher using evidence • Individually draw a model to show how twins get their traits (if "traits" vocab is not present, teacher can guide students to what it means and/or use "characteristics") • Write questions they have about twins on post-its to add to parking lot *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: This begins the discussion of how traits are determined by one's genes (DNA), and that the individuals in each picture received their genes from their parents. Students, in all likelihood, will know from previous knowledge that identical twins receive identical genes from their parents, whereas fraternal twins receive different genes from their parents.	
Student Learning Targets (underlined portions indicate areas that might not be completely addressed at this stage): • I can create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing <u>the instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits</u>. • I can use the second model to show that <u>each member of this pair of chromosomes</u> came from each of of the organism's parents when the parents' sex cells joined together during fertilization.	
Formative Assessment: student's initial models	

EXPLORE Activity: Eye Color Modeling Time: 150 minutes Materials Needed: craft supplies (paper, coloring utensils, scissors, glue/glue sticks), Fruit Fly picture/video, Description: Students will collaborate to create a hand-drawn model showing how a human baby gets its eye color.	
Teacher Actions: • Have students share models with each other and hand draw a new, group model demonstrating their understanding of how a baby gets its eye color (this will open up the exploration to the topics of mitosis from a single-celled zygote and differentiation) • Facilitate discussion focusing on groups' preliminary models demonstrating how a baby gets its eye color. Do the models correctly and adequately explain the entire process? • Have students ask testable questions that would help them determine whether their models are complete or not. • Be ready to use discussion on fruit fly eyes to discuss the idea of a regulatory switch to control differentiation. Genes can be turned on and off, which causes fruit fly cells to differentiate without eyes or with cells that have eye genes expressed when they shouldn't. • Have resources available for students failing to identify the cause and effect connection between DNA and proteins and traits (videos, articles, text)	Student Actions: • Students will discuss their individual drawings with their group members • Students will view, read, and discuss teacher supplied information, pictures, and videos to help build their understanding of the topic • Ultimately, they will then draw a new group model showing how a baby gets its eye color • Students will need to include a description explaining their model to their classmates • Students will participate in a gallery walk of their classmates models, leaving feedback and getting feedback on the accuracy/completeness of their model • Groups will identify problems with their hand-drawn models to reflect the feedback they have gotten and search for new evidence to better inform their next model *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: This will show students how traits are passed down to offspring from parents. It will also allow students to grasp and model the concept of mitosis. Within this model, students should start to incorporate depictions and explanations of development with a focus on cell differentiation. Ultimately, the students may start to connect back the idea that the traits expressed in an organism (even within a differentiating cell) are controlled by the genes in one's DNA.	
Student Learning Targets (underlined portions indicate areas that might not be completely addressed at this stage): • *I can create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing the <u>instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits</u>.* • *I can create a second model to illustrate how multicellular organisms use mitosis to grow from a single-celled zygote after fertilization to a complex, multicellular organism.* • *I can adjust the second model to demonstrate mitosis by showing that one parent cell (including the zygote) starts the cell division and that two daughter cells are created at the end.* • *I can use the second model to show that each cell in complex organisms contains two copies of each chromosome.* • *I can use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization.* • *I can use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote).* • *I can use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote).*	
Formative Assessment: Group hand-drawn model	

EXPLAIN Activity: 3D Meiosis Model Time: 90 Materials Needed: Whatever (craft supplies if desired by students)

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

Description: During this step, students will be revising their model to include new information and evidence gathered from the exploration portion of the learning sequence. They will be creating a 3D version of their model at this stage. As a result of the exploration, students can construct an understandable narrative that connects inheritance of genes, DNA expression into protein, and differentiation of cells after mitosis due to gene regulation.	
Teacher Actions: • Facilitate student construction of their 3D models. • Remind them to include all aspects of the inheritance, genetic expression, and differentiation concepts. • Remind students to record and upload their understanding as it pertains to their model	Student Actions: • Groups will consider all previous revisions and revision choices to plan and create a 3D model • Students will create a written narrative to explain what is happening within their 3D model • Record and upload a video of their group explaining what is happening within their 3D model *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: This will connect all the final missing aspects of mitosis, cell differentiation and how traits are passed from parent to offspring.	
Student Learning Targets: • *I can connect model number one to model number two to illustrate that trait differences between different differentiated cell types is due to different expression of the genes in the cell, not differences in the genes that are there.* • *I can adjust and refine my model to demonstrate that genes can be regulated to prevent or allow the instructions to be used to make proteins.* • *I can adjust and refine my model to show how some regions of DNA within a chromosome regulate the genes expressed in other regions of the chromosome by acting as an on-off switch and therefore do not code for proteins directly.* • *I can analyze the accuracy of my model compared to what actually happens during mitosis.* • *I can use the second model to demonstrate that all cells within an organism contain the same genes and chromosomes found in the original zygote.* • *I can use the second model to show that each cell in complex organisms contains two copies of each chromosome.* • *I can use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization.* • *I can use the second model to demonstrate how chromosomes are replicated within the parent cell before mitosis completes.* • *I can use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote).* • *I can use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote).* • *I can use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs.*	
Formative Assessment: 3D model and narrative in video	

ELABORATE Activity: Bio-limb - Where's my arm?! (File in folder) Time: 150 Materials Needed: Articles/Videos, Body Part Candy Molds, Agar, Yeast, Petri Dish Description: During this stage, students will be applying their new understanding of inheritance, mitosis, and differentiation to the technology of bio-limb growth. Students will be exposed to the new medical process of using bio-scaffolds to construct human limbs by implanting the scaffold with cells, which then undergo mitosis to fill the scaffold, creating a fully functional, host-derived organ.	
Teacher Actions: • Introduce the concept of bio-limb construction • Allow students to construct explanation for how bio-limb construction works based on their models depicting genetic expression, regulation, differentiation, and mitosis • Provide students with the basic steps for building a bio-limb, reminding them that they will need to explain how it's possible to construct a bio-limb utilizing only a few seed donor cells from the person receiving the bio-limb.	Student Actions: • Understand the concept of bio-limb construction • Create their own miniature bio-limb by following teacher procedure • Explain how bio-limbs are made using model created during Explain phase *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: Students will be applying their new understanding of mitosis, inheritance, genetic regulation, and differentiation to this concept of bio-limb generation.	
Student Learning Targets: • *I can use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs.* • *I can use the second model to illustrate that multicellular organisms use mitosis to replace dead cells.*	
Formative Assessment: Explanation of how bio-limbs are created using model	

EVALUATE Activity: Time: Materials Needed: Description: Mother and Father used IVF, do not believe baby is biologically theirs.	
Teacher Actions:	Student Actions:
Connection to Driving Question:	

Rubrics:

Note: Indicate the Anchor Activities, Formative Assessment(s), Performance Task(s), and Summative Assessment, where applicable.

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

CREC NGSS Science Learning Sequence Detailed Plan   Learning Sequence 2 of 3

UNIT Phenomenon: People in Africa born with albinism are targeted for violence.
Phenomenon Driving Question: How do we stop the violence against people with albinism?

Learning Sequence 2 Main Question: How do *new* traits come about?

Possible Student Questions: Where did albinism start? Who was the first albino person? Why is there albinism? What causes albinism? Is albinism a mutation? How can non-albino parents have albino children? Why are there different versions of the same trait?

How does Learning Sequence 2 support students in figuring out or solving the phenomenon? (from Unit Overview)

By the end of Learning Sequence 2, students will understand the process of meiosis and how that contributes to genetic variability. They will know that meiosis creates sperm and egg cells and that a part of the process of meiosis includes the mixing of their parent's genes to create unique gametes, helping to explain why the same parents don't have identical children (unless they're identical twins). Because meiosis creates gametes, they will understand why it is important for meiosis to cut the number of chromosomes in a cell in half before contributing it to their children. Students will understand the main processes that cause mutations and which types of mutations are passed on and which are not. Lastly, they will learn that mutations cause new traits.

What part of the storyline does this learning sequence address?
This addresses how new traits come about and how they are passed on to future offspring.

Performance Expectations for Learning Sequence 2

Performance Expectation HS-LS3-2

HS-LS3-2. Make and defend a claim based on evidence that inheritable genetic variations may result from: (1) new genetic combinations through meiosis, (2) viable errors occurring during replication, and/or (3) mutations caused by environmental factors.

Clarification Statement: **Emphasis is on using data to support arguments for the way variation occurs.**

Assessment Boundary: **Assessment does not include the phases of meiosis or the biochemical mechanism of specific steps in the process**

Science and Engineering Practices	Disciplinary Core Ideas	Cross Cutting Concepts
Engaging in Argument from Evidence **Engaging in argument from evidence in 9-12 builds on K-8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science. Make and defend a claim based on evidence about the natural world that reflects scientific knowledge and student-generated evidence**	**Variation of Traits** ***LS3.B: In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors***	**Cause and Effect** **Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects**

Student Learning Targets for Learning Sequence 2

I can:

- *make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from new genetic combinations through meiosis.*
- *make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.*
- *make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from mutations caused by environmental factors.*
- *use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.*
- *identify the strengths and weaknesses of the types and numbers of sources for the evidence used to support the claim.*
- *identify the strengths and weaknesses of the success of the evidence in defending the claim.*
- *identify the strengths and weaknesses of the evidence of the relationships that cause the claim and of those that only correlate (relate) to the claim.*
- *identify the strengths and weaknesses of the validity and reliability of the evidence to support the claim.*
- *use reasoning to describe the link between the evidence and the claim that genetic mutations produce genetic variations between cells or organisms.*
- *use reasoning to describe the link between the evidence and the claim that genetic variations produced by mutation and meiosis can be inherited.*
- *use reasoning and valid evidence to describe that new combinations of DNA can come from several sources including meiosis, errors during replication, and mutations caused by environmental factors.*
- *defend a claim against counter-claims by evaluating the connection between the relevant and appropriate evidence of the counterclaim.*
- *defend a claim against counter-claims by evaluating which claim is the strongest.*

Progression of Student Learning in this Learning Sequence Across the 3 Dimensions

	Prior Learning	Future Learning
Science & Engineering Practices	By the end of grade 8: Engaging in Argument from Evidence: *Asking questions and defining problems in 6-8 builds on K-5 experiences and progresses to specifying relationships between variables and clarifying arguments and models.* • *Compare and critique two arguments on the same topic and analyze whether they emphasize similar or different evidence and/or interpretations of facts.* • *Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.* • *Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.* • *Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on*	By the end of grade 12: Engaging in Argument from Evidence *Engaging in argument from evidence in 9–12 builds on K–8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science.* • *Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.* • *Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.* • *Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.*

	empirical evidence concerning whether or not the technology meets relevant criteria and constraints.	• *Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.* • *Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.* • *Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations).*
Disciplinary Core Ideas	By the end of grade 8: LS3.B: *In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.*	End of grade band descriptions LS4.A: *Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.* LS4.B: *Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.* LS4.C: *Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change. Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.* LS4.D: *Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.*
Cross Cutting Concepts	By the end of grade 8: Cause and Effect: *students classify relationships as causal or correlational, and recognize that correlation does not necessarily imply causation. They can use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability.*	End of grade band descriptions: Cause and Effect: *students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.*

Connecticut Core Connections	*Essential Skills Connections*
Reading Writing Mathematics	

5E Lessons for Learning Sequence 2

ENGAGE Activity: **Dark-skinned people with blue eyes**	
Time: 30 mins Materials Needed: pictures of dark-skinned people with blue eyes Description: Students hypothesize how these people ended up with their uncommon trait combinations based on the information they learned during the first learning sequence.	
Teacher Actions: • Expose students to picture of individuals with dark skin and blue eyes, a rare combination that many students will not have been exposed to. • Ask students to develop a defendable explanation for the cause behind the uncommon combination of traits. • Share ideas, list the possibilities on the board • After sharing ideas, assign areas of room to each explanation • Have students sort themselves into part of room that corresponds to their understanding	Student Actions: • Analyze pictures given to them • Individually hypothesize how the dark-skinned individuals have the uncommon trait of blue eyes (when generally dark-skinned individuals have brown eyes) • Contribute to group discussion of possibilities • Within group, work to provide data/evidence to support your hypothesis • Create a "position paper" describing your individual stance and the evidence that support it.

• Resume conversation; ensure students can defend their beliefs and remind them to point out the causes of the effect (blue eyes in dark-skinned individuals)	*Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: After this portion of the learning sequence, students should be able to formulate initial understandings and possible causes for the uncommon combination of traits. Using their prior knowledge and their experiences from learning sequence one, we expect many of the options for the cause to revolve around genetic inheritance, regulation of expression, and/or mutations (depending on the ability to meet the PE's for the 8th grade band).	
Student Learning Targets: • *I can make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.* • *I can use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.* • *I can use reasoning to describe the link between the evidence and the claim that genetic mutations produce genetic variations between cells or organisms.*	
Formative Assessment: position paper	

EXPLORE Activity: What is meiosis? Time: 150 minutes Materials Needed: Sources to help them understand meiosis (animations, teacher support, textbook); various types of pasta (at least 5 types); more examples of interesting trait variations, some caused by replication errors during meiosis (BRCA), some caused by interesting combinations during meiosis (labrador retriever puppy litter coat colors), and some caused by straight-up environmental mutations (frogs with 6 legs) Description: Exploration will have two stages: a mechanisms of meiosis stage and a causes of variation stage. Students will first learn about the process of meiosis and will create a pasta model showing the correct way that meiosis occurs. They will then be exposed to other uncommon combinations of traits and will determine the cause of the interesting trait variation.	
Teacher Actions: • Teacher will ask students to model how they think sperm cells and egg cells are created using pasta (Each chromosome is represented by a different shaped pasta). This will establish the classroom rules of how meiosis works, thus allowing them to all work from the same starting point when discussing how variations come about. To help students establish rules governing meiosis, teacher can provide videos and texts. Make sure students receive connection to crossing over (name not important, idea that chromosome portions can swap is) (60 mins) • Teacher, after facilitating acquisition of meiosis concepts, facilitates the modeling of meiosis using pasta. • For the rest of the time, teachers will direct students to explore different provided variations and research causes of the variations. Teacher will provide students with vetted resources for each variation (breast cancer and BRCA, lab litter coat color, and frogs with six legs, for example). Each option provides a different avenue for how new variations are passed to offspring after meiosis is completed.	Student Actions: • Use provided resources to learn the mechanisms of meiosis and the resulting variation it causes • Using pasta, create a model of the process of meiosis using the established classroom rules • Students will then be provided with different examples of trait variations and will determine their cause (gene recombinations during meiosis, mutation caused by replication errors during meiosis or environmental factors that have caused a mutation. *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: After this portion of the sequence, students will begin to assume the understanding that variations in traits within a population are due to errors during meiosis, new combinations through meiosis, and inherited errors caused by environmental factors.	
Student Learning Targets: • *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from new genetic combinations through meiosis.* • *I can make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.* • *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from mutations caused by environmental factors.* • *I can use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.* • *I can use reasoning and valid evidence to describe that new combinations of DNA can come from several sources including meiosis, errors during replication, and mutations caused by environmental factors.*	
Formative Assessment: Meiosis pasta model	

EXPLAIN Activity: "Pasta-bilities" Time: 90 minutes Materials Needed: More pasta Description: Students will create pasta models showing the three ways that new traits come about in a population. They will then create a video recording of their models and the explanations of how their models exemplify the three ways that new traits can arise. Last they will contribute to an online discussion commenting on the accuracy and completion of their models.	
Teacher Actions: • Direct students to incorporate causes of variation into their pasta models so that their final pasta models have the process of meiosis (restricted to replication and separation into reduced chromosome number) and resulting sources of variation. • Facilitate the creation of video reports allowing students to explain how meiosis works and how it can result in variation (the three main ways described above) • Create discussion board allowing students to engage in argument about whether each other's video is accurate or not	Student Actions: • Create new/update their previously created pasta models to show how the three ways that new traits arise. • Create and upload a video (or three videos) explaining how they created their models and how their models work • Students will participate in an online discussion comparing the videos uploaded evaluating how accurately each model portrayed the three ways that new traits can come about *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: At this point, students will have acquired the knowledge that allows them to answer the question, "How do new traits come about?" Students will understand that new traits/variations are created as a result of meiotically-derived chromosomal combinations, meiotic errors as a result of mistaken replication, or environmentally caused mutations to DNA in a gene. Each of these results in new traits being observed in a population.	
Student Learning Targets: • *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from new genetic combinations through meiosis.* • *I can make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.* • *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from mutations caused by environmental factors.* • *I can use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.* • *I can identify the strengths and weaknesses of the types and numbers of sources for the evidence used to support the claim.* • *I can identify the strengths and weaknesses of the success of the evidence in defending the claim.* • *I can use reasoning to describe the link between the evidence and the claim that genetic variations produced by mutation and meiosis can be inherited.* • *I can use reasoning and valid evidence to describe that new combinations of DNA can come from several sources including meiosis, errors during replication, and mutations caused by environmental factors.* • *I can defend a claim against counter-claims by evaluating the connection between the relevant and appropriate evidence of the counterclaim.* • *I can defend a claim against counter-claims by evaluating which claim is the strongest.*	
Formative Assessment: Creation of video(s) and analysis of others' videos	

ELABORATE Activity: Superheros or just genetics? Time: 150 Materials Needed: signs with superhero background stories, craft supplies Description: To elaborate their understanding, students will apply their newfound understandings of sources of variation to the area of superheroes. Students will be exposed to actual "superhumans" and apply their understanding of inheritance of traits to one of two possible courses of action: (1) create a new superhero with a biologically (genetically) sound backstory explaining how that individual received his or her superpower or (2) pick a current superhero and argue that that superhero is theoretically possible by giving a genetic lens to his or her origin story.	
Teacher Actions:	Student Actions:

Subject: Biology | **Unit:** Inheritance and Variation of Traits
Grade: 10th Grade | **Pacing:** 6 weeks

• Introduce the topic of superhumans by showing them a clip of actual superhumans
• Ask students to pick one of two options:
  o Create a new superhero
  o Pick an existing superhero
• Students can then create a product explaining how the superhero became super with a scientifically sound origin story; students should be encouraged to think of the three possible venues of variation; they can write a paper, make a comic book, make a video
• Teacher must make a rubric for assessing the product
	• Create a new superhero and corresponding backstory that explains how the individual gained their superpowers OR defend genetically how they gained those superpowers
	• After designing their story, they will have three options to "present" their product.
	  o Create a new comic book/story including the biologic explanation of how they attained their superpowers
	  o Write a paper about their character and the biologic explanation of how they attained their superpowers
	  o Create a video about their character and the biologic explanation of how they attained their superpowers
	
	Note: Include scaffolding and enrichment learning opportunities for this activity.

Connection to Driving Question: Students will finally know that new traits are developed in one of three ways: mutations during meiotic replication, mutations from environmental factors, and new and unique combinations due to the meiotic process. Students will be able to argue their understanding based off the evidence they collected during the exploration stage.	
Student Learning Targets: • *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from new genetic combinations through meiosis.* • *I can make a claim and identify and describe evidence to support the idea that genetic variations may result from errors occurring during replication.* • *I can make a claim and identify and describe evidence to support the idea that inheritable genetic variations may result from mutations caused by environmental factors.* • *I can use scientific knowledge, literature, student-generated data, simulations and/or other sources as my evidence to support the claim.* • *I can use reasoning to describe the link between the evidence and the claim that genetic mutations produce genetic variations between cells or organisms.* • *I can use reasoning to describe the link between the evidence and the claim that genetic variations produced by mutation and meiosis can be inherited.* • *I can use reasoning and valid evidence to describe that new combinations of DNA can come from several sources including meiosis, errors during replication, and mutations caused by environmental factors.*	
Formative Assessment: product created (video, paper or comic)	

EVALUATE Activity: Unit 2 Summative Assessment	
Time: 30min Materials Needed: Assessment Description: Students will complete a 26 point, three scenario assessment consisting of eleven open ended responses to assess their understanding of the performance expectations for this learning sequence.	
Teacher Actions: • Proctor the assessment	Student Actions: • Take the assessment
Connection to Driving Question: This will assess that students understand how new traits come about and how they are passed on to future offspring.	

Rubrics:

Note: Indicate the Anchor Activities, Formative Assessment(s), Performance Task(s), and Summative Assessment, where applicable.

Subject: Biology **Unit:** Inheritance and Variation of Traits

Grade: 10th Grade **Pacing:** 6 weeks

CREC NGSS Science Learning Sequence Detailed Plan

Learning Sequence 3 of 3

UNIT Phenomenon: People in Africa born with albinism are targeted for violence.
Phenomenon Driving Question: How do we stop the violence against people with albinism?

Learning Sequence 3 Main Question: Can we change or control traits?

Possible Student Questions: Can we prevent or reverse albinism? Is albinism treatable? If parents have albinism, is there any way to make sure their children don't? Can we test for albinism? Why are there more people with albinism in Africa? Is there a way to save people with albinism?

How does Learning Sequence 3 support students in figuring out or solving the phenomenon? (from Unit Overview)

Students will learn and understand a population's traits will only reflect the genes present within the individuals of those populations. Additionally, they will begin to see that environmental factors often correlate with a higher/lower distribution of specific traits than is typical elsewhere. During this learning sequence, students will explore the idea of genetic testing and counseling with the end goal of evaluating the concept of designer babies. Students will research ways to test genetics, and thus learn about how it is possible to choose and select the traits that will result in one's offspring by seeking specific genes.

What part of the storyline does this learning sequence address?
This addresses why some traits are more common than others in certain populations and if designer babies is a viable solution for undesirable traits.

Performance Expectations for Learning Sequence 3

Performance Expectation HS-LS3-3 & HS-ETS1-3

HS-LS3-3. Apply concepts of statistics and probability to explain the variation and distribution of expressed traits in a population.

Clarification Statement: **Emphasis is on the use of mathematics to describe the probability of traits as it relates to genetic and environmental factors in the expression of traits**

Assessment Boundary: **Assessment does not include Hardy-Weinberg calculations**

HS-ETS1-3. Evaluate a solution to a complex real world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability and aesthetics as well as possible social, cultural, and environmental impacts

Science and Engineering Practices	Disciplinary Core Ideas	Cross Cutting Concepts
Analyzing and Interpreting Data **Analyzing data in 9-12 builds on K-8 experiences and progresses to introducing more detailed statistical analysis, the comparison of data sets for consistency, and the use of models to generate and analyze data. Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using** Constructing Explanations and Designing Solutions **Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles and theories. Evaluate a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.**	Variation of Traits ***LS3.B: Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus, the variation and distribution of traits observed depends on both genetic and environmental factors.*** Developing Possible Solutions ***ETS1.B: When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts.***	Scale, Proportion and Quantity **Algebraic thinking is used to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).**

Student Learning Targets for Learning Sequence 3

I can:

- *organize the given data by the frequency of the expressed traits in the population.*
- *organize the given data by the distribution of the expressed traits in the population.*
- *organize the given data by the variation of the expressed traits in the population.*
- *perform and use probability measures of the given data to determine the relationship between a trait's occurrence within a population and the environmental factors impacting the population.*
- *recognize and use patterns to predict the changes in trait distribution within a population if environmental variables change as a way to analyze and interpret data used to explain the distribution of expressed traits.*
- *describe the expression of a chosen trait (and its variations) as being caused by or as being correlated (just related) to some environmental factor based on reliable evidence.*
- *generate a list of three or more realistic criteria and two or more constraints (including cost, safety, reliability and how the solution looks) for an acceptable solution to a complex real-world problem.*
- *assign priorities for each criterion and constraint to allow me to logically and systematically evaluate alternative solution proposals.*
- *analyze and describe the strengths and weaknesses of the solution with using the criteria and constraints, the environmental impacts, as well as how well the solution would be socially and culturally accepted.*
- *describe possible barriers to using each solution thinking about the cultural, economic (financial), or other sources of resistance for each possible solution.*
- *provide an evidence-based decision of which solution is best, based on prioritized criteria, analysis of the strengths and weaknesses (costs and benefits) of each solution as well as the barriers to be overcome.*
- *describe which parts of the complex real-world problem might remain even if the proposed/selected solution is implemented.*

Progression of Student Learning in this Learning Sequence Across the 3 Dimensions

	Prior Learning	Future Learning
Science & Engineering Practices	By the end of grade 8: Analyzing and Interpreting Data: *Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to*	By the end of Grade 12: Analyzing and Interpreting Data: *Analyzing data in 9–12 builds on K–8 experiences and progresses to introducing more detailed statistical analysis,*

	investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • *Construct, analyze, and/or interpret graphical displays of data and/or large data sets to identify linear and nonlinear relationships.* • *Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.* • *Distinguish between causal and correlational relationships in data.* • *Analyze and interpret data to provide evidence for phenomena.* • *Apply concepts of statistics and probability (including mean, median, mode, and variability) to analyze and characterize data, using digital tools when feasible.* • *Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).* • *Analyze and interpret data to determine similarities and differences in findings.* • *Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.* Constructing Explanations and Designing Solutions: *Constructing explanations and designing solutions in 6-8 builds on K-5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles and theories.* • *Construct an explanation that includes qualitative or quantitative relationships between variables that predict(s) and/or describe(s) phenomena.* • *Construct an explanation using models or representations.* • *Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.* • *Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.* • *Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.*	*the comparison of data sets for consistency, and the use of models to generate and analyze data.* • *Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.* • *Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible.* • *Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.* • *Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.* • *Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.* • *Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success.* Constructing Explanations and Designing Solutions *Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.* • *Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.* • *Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.* • *Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.* • *Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.* • *Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.*
Disciplinary Core Ideas	By the end of grade 8: LS3.B: *In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.* *ETS1.B: Developing Possible Solutions There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.* *ETS1.C: Optimizing the Design Solution Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.*	By the end of Grade 12: LS4.A: *Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.* LS4.B: *Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population.* LS4.C: *Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. Adaptation also means that the distribution of traits in a population can change when conditions change. Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.* LS4.D: *Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value.* *ETS1.B: Developing Possible Solutions Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to*

		test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.
Cross Cutting Concepts	By the end of grade 8: Scale, Proportion and Quantity: *students observe time, space, and energy phenomena at various scales using models to study systems that are too large or too small. They understand phenomena observed at one scale may not e observable at another scale and that the function of natural and designed systems may change with scale. They use proportional relationships to gather information about the magnitude of properties and processes. They represent scientific relationships through the use of algebraic expressions and equations.* Influence on Engineering, Technology, and Science on Society and the Natural World: *All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Technology use varies over time and from region to region.*	By the end of Grade 12: Scale, Proportion and Quantity: *students understand the significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. They recognize patterns observable at one scale may not be observable or exist at other scales, and some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. Students use orders of magnitude to understand how a model at one scale relates to a model at another scale. They use algebraic thinking to examine scientific data and predict the effect of a change in one variable on another (e.g., linear growth vs. exponential growth).* Influence on Engineering, Technology, and Science on Society and the Natural World: *Scientific knowledge is a result of human endeavor, imagination, and creativity. Individuals and teams from many nations and cultures have contributed to science and to advances in engineering. Scientists' backgrounds, theoretical commitments, and fields of endeavor influence the nature of their findings. Technological advances have influenced the progress of science and science has influenced advances in technology. Science and engineering are influenced by society and society is influenced by science and engineering.*

Connecticut Core Connections	*Essential Skills Connections*
Reading Writing Mathematics	

5E Lessons for Learning Sequence 3

ENGAGE Activity: Geographical Distribution of Sickle Cell Anemia

Time: 50 minutes
Materials Needed: Data for sickle-cell anemia trends, colorable maps of the world
Description: In this stage of the learning sequence, students will be initially exposed to the idea that geographical characteristics and environmental factors can determine how common a specific trait is in a population. Students will explore the relationship between distribution of traits, specifically sickle-cell anemia, and environmental factors, in this case the commonality of malaria in areas around the equator.

Teacher Actions:	Student Actions:
• Disseminate data for distribution of sickle-cell anemia by world region • Ask students to utilize data to color in maps based on rates of sickle-cell anemia • Have students create understanding of trends; uncover correlation between location and rates of malaria • Present hypothetical situation where new strains of malaria are discovered to survive in temperate climates of northern US; facilitate discussion explaining what would happen • Direct students to construct graphs that represent what they perceive to be the change in distribution in sickle-cell traits in the US after the environment changes	• Students will analyze given data and will sort it based on a variety of factors, location of cases, severity of cases and by how many cases are in a given location to analyze whether there is a relationship between the geographic location/factors and the expression of the sickle cell trait • Color world maps to show the distribution of sickle cell across the world • Predict the outcome of the proposed hypothetical scenario, taking into account prior learning from previous learning sequences • Create a graphical representation depicting their prediction of the distribution of sickle cell in the US reflective of the the new environmental condition justifying their rationale with a narrative *Note: Include scaffolding and enrichment learning opportunities for this activity.*

Connection to Driving Question: As a result of this portion of the learning sequence, students will come to understand that the environment has an effect on how commonly a specific trait (and thus gene) appears in a population. Therefore, they will realize that although genes encode for and determine traits, they can be controlled by the environment with regards to whether or not that trait is present in the population.

Student Learning Targets:

- *I can organize the given data by the frequency of the expressed traits in the population.*
- *I can organize the given data by the distribution of the expressed traits in the population.*
- *I can organize the given data by the variation of the expressed traits in the population.*
- *I can perform and use probability measures of the given data to determine the relationship between a trait's occurrence within a population and the environmental factors impacting the population.*
- *I can recognize and use patterns to predict the changes in trait distribution within a population if environmental variables change as a way to analyze and interpret data used to explain the distribution of expressed traits.*
- *I can describe the expression of a chosen trait (and its variations) as being caused by or as being correlated (just related) to some environmental factor based on reliable evidence.*

Formative Assessment: graphical representation and narrative

EXPLORE Activity: Gel Electrophoresis

Time: 180 minutes
Materials Needed: Electrophoresis materials (chamber, tray, power supply, pipettes)
Description: For exploration, the students will be introduced to the concept of genetic testing to identify individuals with a specific gene. Specifically, students are going to learn about the process of electrophoresis. After that, students will (as a class) investigate the DNA of two groups of individuals. One set of samples will be from American citizens and one set of samples will be Tanzanian individuals. Students will use this task to find an association between trait variation distribution and environmental factors.

Teacher Actions:	Student Actions:
• Teacher will prepare exploration activity utilizing paper fragments to simulate gel electrophoresis. Teacher will need to facilitate activity by helping students to discover that smaller genes travel faster in a gel electrophoresis that larger fragments. • Teacher will introduce genetic testing task by explaining to students the difference in length of the albinism gene (it's shorter due to deletion, at least for the version of albinism we're focusing on) • Teacher gives each student a representative sample of DNA (in reality, tubes will contain blue food coloring to indicate DNA indicator, red dye to indicate albinism gene, and yellow dye to indicate normal pigmentation dye) • Teacher facilitates electrophoresis activity; red dye travels faster, thus indicating individuals with albinism	• Students will complete a paper gel electrophoresis activity (files in folder) to understand the basics of how electrophoresis works (emphasis on the size of DNA segments and how far different sized segments travel) • Students will be given DNA samples to analyze through real gel electrophoresis techniques • Students will share individual data with their classmates to determine the number of individuals from each country that have albinism • They will then determine which country would have more cases of albinism and why and will justify their reasoning during the explain phase *Note: Include scaffolding and enrichment learning opportunities for this activity.*

• Teacher then formulates discussion where students determine that Tanzanian individuals have a higher rate of albinism and that those with the albinism gene can be identified by using electrophoresis • Teacher will disseminate similar data pictures of electrophoresis gels to students to analyze (these gels will be reflective of the before and after genetic tests of individuals in the hypothetical malaria case from ENGAGE)	
Connection to Driving Question: This will show how to identify the genes that control the traits in question so that trait can potentially be changed or controlled. It also furthers the understanding that geographical location dictates the distribution of traits by affecting the genetics of the population there.	
Student Learning Targets: • *I can perform and use probability measures of the given data to determine the relationship between a trait's occurrence within a population and the environmental factors impacting the population.* • *I can recognize and use patterns to predict the changes in trait distribution within a population if environmental variables change as a way to analyze and interpret data used to explain the distribution of expressed traits.*	
Formative Assessment: Analysis of different gels that represent the before and after of the hypothetical US malaria situation from the Engage phase of this sequence (to show if they can connect the idea of what a gel shows to the frequency of a trait in a population).	

EXPLAIN Activity: Gel Electrophoresis Lab Report	
Time: 40 minutes Materials Needed: computer access, lab report rubric, previously attained lab data and researched evidence Description: Students will create a lab report for their gel electrophoresis labs. In this report they will explain their data, explain the analysis of their data, and justify their final decisions (about which country each group of individuals are from) with data collected, new learning from this and the previous learning sequence and any researched evidence acquired.	
Teacher Actions: • Teacher monitors and assists students writing their reports • Teacher will create in advance and review lab report rubric	Student Actions: • Students will finish collecting all necessary data/evidence and will write their lab reports. *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: This will again further enforce that geographical location dictates the distribution of traits affecting the genetic expression of traits in the population.	
Student Learning Targets: • *I can perform and use probability measures of the given data to determine the relationship between a trait's occurrence within a population and the environmental factors impacting the population.* • *I can recognize and use patterns to predict the changes in trait distribution within a population if environmental variables change as a way to analyze and interpret data used to explain the distribution of expressed traits.* • *I can describe the expression of a chosen trait (and its variations) as being caused by or as being correlated (just related) to some environmental factor based on reliable evidence.*	
Formative Assessment: Lab report	

ELABORATE Activity: CRISPR/Designer Babies	
Time: 150 minutes Materials Needed: Description: Students will determine whether the CRISPR techniques applied to the bigger concept of designer babies is a possible solution for the changing and/or controlling of less desirable traits within a population.	
Teacher Actions: • Teacher begins group discussion about lab reports and what students discovered and explained from the electrophoresis activity and gently directs conversation at the question of "What's the point? Why do we care that we can test for genes in individuals considered to be "at risk" for unfavorable traits? • Teacher introduces topic of CRISPR by giving students a resource with information on the gene splicing technology • Discuss what uses this technology might be used for, with a gentle nudging towards the concept of a designer baby (students will remember that every cell in a multicellular organism has the same DNA... using CRISPR to delete every copy of an unfavorable gene in every cell is not oftentimes feasible) • Have students research the CRISPR and formulate an opinion to answer the question: should we be able to use CRISPR to search for specific genes and then cut them out so that our babies don't have sickle-cell anemia, albinism, blue eyes, whatever people might not want? • Inform students that the next class will be devoted to a class debate of pro vs. con: should people be able to design their babies? • Facilitate debate; remind students of classroom expectations and that data must be used to back up their stances	Student Actions: • Participate in group discussion about the importance/purpose of genetic testing and identifying individuals with specific traits/genes • Learn about CRISPR and participate in discussion on what it could be used for and begin learning about designer babies • Research the CRISPR and formulate an opinion to answer the question: should we be able to use CRISPR to search for specific genes and then cut them out so that our babies don't have sickle-cell anemia, albinism, blue eyes, whatever people might not want? • Prepare for next class which will be devoted to a class debate of pro vs. con: should people be able to design their babies? *Note: Include scaffolding and enrichment learning opportunities for this activity.*
Connection to Driving Question: Finally, students can discuss and debate the cultural, social, cost, environmental, reliability and safety of designer babies. Students should be able to correctly state that trait distribution often correlates to environmental factors, and that those traits (or rather, the genes that encode for them) can be tested for. Because of their work with CRISPR, they will be able to discuss the possibility of controlling a gene, both good and bad.	
Student Learning Targets: • *I can describe the expression of a chosen trait (and its variations) as being caused by or as being correlated (just related) to some environmental factor based on reliable evidence.* • *I can generate a list of three or more realistic criteria and two or more constraints (including cost, safety, reliability and how the solution looks) for an acceptable solution to a complex real-world problem.* • *I can assign priorities for each criterion and constraint to allow me to logically and systematically evaluate alternative solution*	
Formative Assessment: Participation/preparation for the debate	

EVALUATE Activity: WHO Debate on Utilizing Designer Babies to Prevent Atrocities Against People With Albinism	
Time: 30 minutes Materials Needed: Description:	
Teacher Actions:	Student Actions:
Connection to Driving Question:	

Subject: Biology | Unit: Inheritance and Variation of Traits
Grade: 10th Grade | Pacing: 6 weeks

Rubrics:

Note: Indicate the Anchor Activities, Formative Assessment(s), Performance Task(s), and Summative Assessment, where applicable.

CREC NGSS Assessment Tracking & Summary

Course: Biology
Unit: Inheritance and Variation
Learning Sequence: 1

NGSS Performance Expectations Assessed:

- **HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- **HS-LS1-4.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
- Practices: Asking Questions and Defining Problems, Developing and Using Models
- Crosscutting Concepts: Cause and Effect

Learning Targets:

1. *create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing the instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits.*
2. *create a second model to illustrate how multicellular organisms use mitosis to grow from a single-celled zygote after fertilization to a complex, multicellular organism.*
3. *adjust the second model to demonstrate mitosis by showing that one parent cell (including the zygote) starts the cell division and that two daughter cells are created at the end.*
4. *use the second model to demonstrate that all cells within an organism contain the same genes and chromosomes found in the original zygote.*
5. *use the second model to show that each cell in complex organisms contains two copies of each chromosome.*
6. *use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization.*
7. *use the second model to demonstrate how chromosomes are replicated within the parent cell before mitosis completes.*
8. *use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote).*
9. *use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote).*
10. *use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs.*
11. *use the second model to illustrate that multicellular organisms use mitosis to replace dead cells.*
12. *connect model number one to model number two to illustrate that trait differences between different differentiated cell types is due to different expression of the genes in the cell, not differences in the genes that are there.*
13. *adjust and refine my model to demonstrate that genes can be regulated to prevent or allow the instructions to be used to make proteins.*
14. *adjust and refine my model to show how some regions of DNA within a chromosome regulate the genes expressed in other regions of the chromosome by acting as an on-off switch and therefore do not code for proteins directly.*
15. *analyze the accuracy of my model compared to what actually happens during mitosis.*
16. *ask questions about the phenomenon that can be scientifically tested.*

Video Portion	Question Text	PE	Learning Target(s)	Expected Response	Point Value
1	An explanation of what a trait is, how it is determined, and the source from which organisms get their traits Depiction of the process of fertilization and how it affects inheritance of traits Appropriate analysis of the number of chromosomes, and thus genes, a sexually reproduced offspring, such as a human child, receives	HS-LS3-1	1, 5, 6		

2					

Learning Sequence 1 Assessment Task

Target Performance Expectations, Practices and Crosscutting Concepts

- **HS-LS3-1.** Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.
- **HS-LS1-4.** Use a model to illustrate the role of cellular division (mitosis) and differentiation in producing and maintaining complex organisms.
- Practices: Asking Questions and Defining Problems, Developing and Using Models
- Crosscutting Concepts: Cause and Effect

Learning Targets for Sequence:

- *create a model to show the cause and effect relationship where DNA/genes cause traits to appear in organisms by containing the instructions ("recipe") for how to build proteins and that the proteins affect the organism's traits. (I)*
- *create a second model to illustrate how multicellular organisms use mitosis to grow from a single-celled zygote after fertilization to a complex, multicellular organism. (M)*
- *adjust the second model to demonstrate mitosis by showing that one parent cell (including the zygote) starts the cell division and that two daughter cells are created at the end. (M)*
- *use the second model to demonstrate that all cells within an organism contain the same genes and chromosomes found in the original zygote. (M)*
- *use the second model to show that each cell in complex organisms contains two copies of each chromosome. (I)*
- *use the second model to show that each member of this pair of chromosomes came from each of of the organism's parents when the parents' sex cells joined together during fertilization. (I)*
- *use the second model to demonstrate how chromosomes are replicated within the parent cell before mitosis completes. (M)*
- *use the second model to connect how the daughter cells receive their genes and chromosomes from the parent cell (which is sometimes the zygote). (M)*
- *use the second model to connect that the daughter cells created after mitosis are genetically identical to each other and the parent cell (which is sometimes the zygote). (M)*
- *use the second model to demonstrate differentiation as the process in which cells become specialized in their roles as a multicellular organism develops from a zygote through mitosis, which leads to different tissues and organs. (D)*
- *use the second model to illustrate that multicellular organisms use mitosis to replace dead cells. (D)*
- *connect model number one to model number two to illustrate that trait differences between different differentiated cell types is due to different expression of the genes in the cell, not differences in the genes that are there. (D)*
- *adjust and refine my model to demonstrate that genes can be regulated to prevent or allow the instructions to be used to make proteins. (D)*
- *adjust and refine my model to show how some regions of DNA within a chromosome regulate the genes expressed in other regions of the chromosome by acting as an on-off switch and therefore do not code for proteins directly. (D)*
- *analyze the accuracy of my model compared to what actually happens during mitosis.*
- *ask questions about the phenomenon that can be scientifically tested.*

Scenario: Students at the local middle school have welcomed a new member into their eighth grade classroom. The new student has a trait where he has six fingers on one hand instead of five, as seen in the picture below:

The students are extremely interested in how the student obtained his sixth finger and why it only appears on one hand and not both. The teacher of the eighth grade science class at the middle school, knowing you have worked on genetics and inheritance for the last few weeks, asks you to create a video that she can show her classes to demonstrate to them where their classmate got this six-finger traits. You will do this with a stop motion video, and it will be done in three parts.

Portion 1 - Model of Fertilization and Inheritance

Create a stop motion video that demonstrates the concept of inheritance as you have come to understand it through your activities during this unit. Your video must include the following:

- An explanation of what a trait is, how it is determined, and the source from which organisms get their traits
- Depiction of the process of fertilization and how it affects inheritance of traits
- Appropriate analysis of the number of chromosomes, and thus genes, a sexually reproduced offspring, such as a human child, receives

Your video for this portion will be assessed utilizing this rubric:

Area of Rubric	4 - Exemplary	3 - Proficient	2 - Developing	1 - Needs Further Work
I - Inheritance	Stop motion film superbly addresses all those standards marked with an (I) with a high level of understanding and rigorous model explanation	Stop motion adequately addresses all those standards marked with an (I) with an appropriate level of understanding fitting of a high school student	Stop motion partially addresses those standards marked with an (I), failing to address one	Stop motion partially addresses those standards marked with an (I), failing to address two or more

Portion 2 - Model of Mitosis

Now that you have created a stop motion video that demonstrates the concept of inheritance as you have come to understand it through your activities during this unit, create a second video that demonstrates how the newly formed zygote exhibits that trait as it develops into a fully grown human baby. Your video must contain:

- An explanation of the process of mitosis, including what it starts with, what it ends with, and how the products compare to each other
- Depiction of the development of a multicellular organism from a zygote and how the genetics of the individual are affected

Your video for this portion will be assessed utilizing this rubric:

Area of Rubric	4 - Exemplary	3 - Proficient	2 - Developing	1 - Needs Further Work
M - Mitosis	Stop motion film superbly addresses all those standards marked with an (M) with a high level of understanding and rigorous model explanation	Stop motion adequately addresses all those standards marked with an (M) with an appropriate level of understanding fitting of a high school student	Stop motion partially addresses those standards marked with an (M), failing to address one or two	Stop motion partially addresses those standards marked with an (M), failing to address three or more

Part 3 - Model of Differentiation

Now that you have created a second video that demonstrates how the newly formed zygote exhibits that trait as it develops into a fully grown human baby, you must create a third video that explains to the students why the six-finger trait doesn't appear on both hands. Your video must contain:

- An explanation of how cells start to specialize during the development of the embryo
- A depiction of what causes different types of cell to develop during the growth of an organism
- Demonstration of how some genes can act as switches for others, leading to different gene expressions in different parts of the body