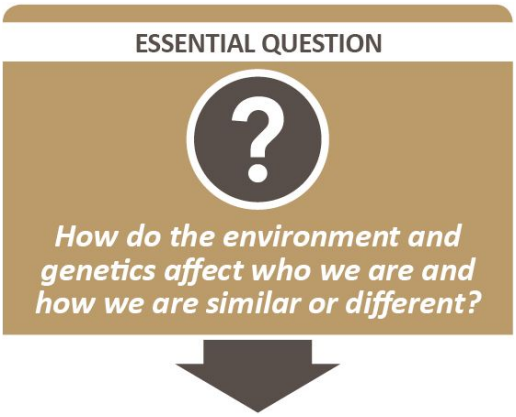
Variation and Heredity Unit Overview



Introduction to Culminating Project and Individual Project Organizer

Lift-Off Task: A Storied Life and Human Traits

Formative Assessment—Individual Project Organizer Lift-Off Task

Task 1: Effects of the Environment on Plant Growth

Formative Assessment—Individual Project Organizer Task 1

Task 2: Traits Leading to Successful Reproduction

Formative Assessment—Individual Project Organizer Task 2

Task 3: Make a Dog Family and Bacteria Family

Formative Assessment—Individual Project Organizer Task 3

Task 4: Variation in Elephants

Formative Assessment—Individual Project Organizer Task 4

Culminating Project: Create a Children's Book

Group and Individual Assessment

Variation and Heredity Objectives

Unit	Content	Science and Engineering Practices	Equity and Groupwork	Language
Lift-Off A Storied Life and Human Traits	• Identify human traits.	• Make an argument from evidence about whether humans are more similar to each other or more different from each other.	• Collaborate with teammates to identify human traits.	• Identify the theme and plot of a story.
Task 1 Effects of the Environment on Plant Growth	• Determine how different environmental conditions affect plant growth rate.	• Plan and conduct an experiment about environmental effects on plant growth. • Use data to construct an explanation about how the environment and genetics influence plant growth.	• Discuss and plan procedures.	• Write a lab report.
Task 2 Traits Leading to Successful Reproduction	• Identify animal behaviors and plant structures that are associated with reproduction.	• Analyze evidence of inherited behavior and characteristics of both plants and animals that increase their ability to survive and reproduce. • Make an argument based on evidence and scientific reasoning that agrees with one of the competing ideas for guppy mating.	• Summarize key points in video clips. • Debate competing ideas with peers.	• Construct an argument based on evidence.
Task 3 Make a Dog Family and Bacteria Family	• Distinguish between sexual and asexual reproduction.	• Develop a model to show how sexual reproduction results in variation of traits and asexual reproduction results in identical traits.	• Collaborate to identify patterns.	• Use language to describe diagrams.
Task 4 Variation in Elephants	• Determine whether variations of living organisms are due to genetics or the environment.	• Construct a scientific explanation about how environmental and genetic factors influence the growth of organisms.	• Share observations with their group.	• Communicate ideas and listen actively.

Unit	Content	Science and Engineering Practices	Equity and Groupwork	Language
Culminating Projects • Group: Create a Children's Book • Individual: Heredity and Variation (genetics simulation with pigeons)	• Genetics and environment affect who we are and how we are different. • Our traits increase the probability that we will survive and reproduce.	• Construct explanations. • Develop and use models.	• Write a children's book together as a group.	• Write a book. • Present a book. • Explain their pigeon offspring.

Connect the Sixth Grade Variation and Heredity Unit with Prior Knowledge

This summary is based on information found in the NGSS Framework.

Disciplinary Core Ideas

LS1 From Molecules to Organisms: Structures and Processes

LS3 Heredity: Inheritance and Variation of Traits

This unit spans two different Disciplinary Core Ideas: LS1, From Molecules to Organisms: Structures and Processes, and LS3, Heredity: Inheritance and Variation of Traits.

In the Cells and Body Systems unit, students began studying LS1, From Molecules to Organisms: Structures and Processes, by formulating an answer to the question "How can we explain the ways cells contribute to the function of living organisms?" Students continue their work on Disciplinary Core Idea LS1 in this Variation and Heredity unit by focusing on the sub-idea LS1B, Growth and Development of Organisms. In the context of this Disciplinary Core Idea, students will achieve the following goals by the end of this unit:

- Construct an explanation about how environmental and genetic factors affect growth of organisms.
- Connect their explanation to the role of animal behaviors in reproduction of animals, as well as the dependence of some plants on animal behaviors for their reproduction.

Meanwhile, the performance expectations in LS3, Heredity: Inheritance and Variation of Traits, help students formulate an answer to the question "How do living organisms pass traits from one generation to the next?" The LS3 Disciplinary Core Idea from the NRC Framework includes two sub-ideas—LS3A, Inheritance of Traits; and LS3B, Variation of Traits—both of which are covered in this unit. By the end of this unit, students will be able to use models to describe the ways gene mutations and sexual reproduction contribute to genetic variation. The crosscutting concept of cause and effect is of paramount importance in this unit.

In this unit, students plan and carry out an investigation to provide evidence of environmental effects on plant growth. They combine their results with other evidence gathered throughout the unit to construct sound explanations about the environmental and genetic influences on the growth of organisms. Students also identify characteristic animal behaviors and plant structures that increase the probability of successful reproduction, and then model the variation that results as a consequence of reproduction.

Note that students have not previously been introduced to much of the basic vocabulary related to genetics, such as ***trait***, ***heredity***, ***gene***, and ***reproduction***. Students may have an experiential understanding of the effects of the environment and genetics on organisms, but they have not yet learned the internal processes and evidence-based thinking in the context of genetics.

The following are the sixth grade Variation and Heredity performance expectations.

MS-LS1-4 **Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

MS-LS1-5 **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [***Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.***]

MS-LS3-2 **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

Prior Knowledge from Prior Grades

In first grade, students begin to think about why certain behaviors in plants and animals exist—for survival. At this stage, students recognize simple patterns between behavior of parents and offspring that aid survival. This understanding sets the foundation for discussions in this Variation and Heredity unit about behaviors that aid not just in survival, but in successful reproduction. This first grade performance expectation does not access the mechanism of heredity, but begins exposing students to concepts that they will later use to form their understanding of heredity. In the first grade, students also make observations of how offspring are similar, but not exactly like, their parents. This understanding introduces students to the concept of variation, but is limited to noticing patterns. It sets the stage for this Variation and Heredity unit, in which students will take these observations and attempt to explain why such variations occur.

The following are the first grade performance expectations.

1-LS1-2 **Read texts and use media to determine patterns in behavior of parents and offspring that help offspring survive.** [Clarification Statement: Examples of patterns of behaviors could include the signals that offspring make (such as crying, cheeping, and other vocalizations) and the responses of the parents (such as feeding, comforting, and protecting the offspring).]

1-LS3-1 **Make observations to construct an evidence-based account that young plants and animals are like, but not exactly like, their parents.** [Clarification Statement: Examples of patterns could include features plants or animals share. Examples of observations could include leaves from the same kind of plant are the same shape but can differ in size; and, a particular breed of dog looks like its parents but is not exactly the same.]

In third grade, students move to more specific references to reproduction and the effects of genetics and environment on the growth of organisms. Students consider the life cycles of living organisms, including birth, growth, reproduction,

and death. Identifying these important events allows students to comfortably explore the events in different contexts in this Variation and Heredity unit, specifically focusing on variation due to reproduction and the effects of genetics and environment on growth. In third grade, students also begin to take an evidence-based approach to variation and inheritance and environmental influence, which sets the stage for students to use the same cognitive skills in combining these two ideas (genetics and environment) in this Variation and Heredity unit.

The following are the third grade performance expectations.

3-LS1-1 **Develop models to describe that organisms have unique and diverse life cycles but all have in common birth, growth, reproduction, and death.** [Clarification Statement: Changes organisms go through during their life form a pattern.]

3-LS3-1 **Analyze and interpret data to provide evidence that plants and animals have traits inherited from parents and that variation of these traits exists in a group of similar organisms.** [Clarification Statement: Patterns are the similarities and differences in traits shared between offspring and their parents, or among siblings. Emphasis is on organisms other than humans.]

3-LS3-2 **Use evidence to support the explanation that traits can be influenced by the environment.** [Clarification Statement: Examples of the environment affecting a trait could include normally tall plants grown with insufficient water are stunted; and, a pet dog that is given too much food and little exercise may become overweight.]

Connect Core Ideas, Scientific Practices, and Crosscutting Concepts from K–6

	First Grade	Third Grade	Sixth Grade
Core Idea LS1.B **Growth and Development of Organisms**	• Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive. (1-LS1-2)	• Reproduction is essential to the continued existence of every kind of organism. Plants and animals have unique and diverse life cycles. (3-LS1-1)	• Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4) • Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4) • Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5) • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)
Core Idea LS3.A **Inheritance of Traits**	• Young animals are very much, but not exactly, like their parents. Plants also are very much, but not exactly, like their parents. (1-LS3-1)	• Many characteristics of organisms are inherited from their parents. (3-LS3-1) • Other characteristics result from individuals' interactions with the environment, which can range from diet to learning. Many characteristics involve both inheritance and environment. (3-LS3-2)	• Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2)
Core Idea LS3.B **Variation of Traits**	• Individuals of the same kind of plant or animal are recognizable as similar but can also vary in many ways. (1-LS3-1)	• Different organisms vary in how they look and function because they have different inherited information. (3-LS3-1) • The environment also affects the traits that an organism develops. (3-LS3-2)	• 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. (MS-LS3-2)
Science and Engineering Practices	• Obtaining, Evaluating, and Communicating Information • Constructing Explanations and Designing Solutions	• Developing and Using Models • Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions	• Constructing Explanations and Designing Solutions • Engaging in Arguments from Evidence
Crosscutting Concepts	• Patterns	• Patterns • Cause and Effect	• Cause and Effect

Standards and Objectives

Variation and Heredity Standards

NGSS Performance Expectations

MS-LS1-4 **Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively.** [Clarification Statement: Examples of behaviors that affect the probability of animal reproduction could include nest building to protect young from cold, herding of animals to protect young from predators, and vocalization of animals and colorful plumage to attract mates for breeding. Examples of animal behaviors that affect the probability of plant reproduction could include transferring pollen or seeds, and creating conditions for seed germination and growth. Examples of plant structures could include bright flowers attracting butterflies that transfer pollen, flower nectar and odors that attract insects that transfer pollen, and hard shells on nuts that squirrels bury.]

MS-LS1-5 **Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.** [Clarification Statement: Examples of local environmental conditions could include availability of food, light, space, and water. Examples of genetic factors could include large breed cattle and species of grass affecting growth of organisms. Examples of evidence could include drought decreasing plant growth, fertilizer increasing plant growth, different varieties of plant seeds growing at different rates in different conditions, and fish growing larger in large ponds than they do in small ponds.] [***Assessment Boundary: Assessment does not include genetic mechanisms, gene regulation, or biochemical processes.***]

MS-LS3-2 **Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.** [Clarification Statement: Emphasis is on using models such as Punnett squares, diagrams, and simulations to describe the cause and effect relationship of gene transmission from parent(s) to offspring and resulting genetic variation.]

Disciplinary Core Ideas

LS1.B: Growth and Development of Organisms

- Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4)
- Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)
- Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5)
- Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)

LS3.A: Inheritance of Traits

- Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2)

LS3.B: Variation of Traits

- 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. (MS-LS3-2)

Science and Engineering Practices

Engaging in Arguments from Evidence

Engaging in arguments from evidence in grades 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

- Use 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. (MS-LS1-4)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in grades 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 knowledge, principles, and theories.

- 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. (MS-LS1-5)

Developing and Using Models

Modeling in grades 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.

- Develop and use a model to describe phenomena. (MS-LS3-2)

Crosscutting Concepts

Cause and Effect

- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (MS-LS1-4, MS-LS1-5)
- Cause and effect relationships may be used to predict phenomena in natural systems. (MS-LS3-2)

Standards by Task

Tasks	Descriptions of Tasks	Performance Expectations	Disciplinary Core Ideas and Crosscutting Concepts	Science and Engineering Practices
Lift-Off Task: A Storied Life and Human Traits	• Students listen to you read a children's book to help them reflect on parts of a book that make it interesting and how a theme runs through a book. • Students are introduced to genetic traits.			
Task 1: Effects of the Environment on Plant Growth	• Students examine variation in plant seeds to see phenotypic variation. • Students design an experiment to identify the effect of environment on plant growth. • Based on their data, students construct an explanation for how the environment and genetics influence plant growth.	Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. (MS-LS1-5)	**LS1.B: Growth and Development of Organisms** • Genetic factors as well as local conditions affect the growth of the adult plant. (MS-LS1-5) **LS3.A: Inheritance of Traits** • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2)	• Planning Investigations • Carrying Out Investigations • Analyzing and Interpreting Data • Constructing Explanations and Designing Solutions
Task 2: Traits Leading to Successful Reproduction	• Students are provided with pictorial and empirical evidence that demonstrates how inherited behaviors and characteristics of both plants and animals can increase their ability to survive and reproduce. • Students analyze competing ideas for guppy mating and make their argument based on evidence and scientific reasoning.	Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants respectively. (MS-LS1-4)	**LS1.B: Growth and Development of Organisms** • Animals engage in characteristic behaviors that increase the odds of reproduction. (MS-LS1-4) • Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction. (MS-LS1-4)	• Engaging in Arguments from Evidence

Tasks	Descriptions of Tasks	Performance Expectations	Disciplinary Core Ideas and Crosscutting Concepts	Science and Engineering Practices
Task 3: Make a Dog Family and Bacteria Family	• Students model sexual reproduction (in dogs) and asexual reproduction (in bacteria) to see the resulting differences in variation. • Students examine how genes from both parents contribute to the genes (and hence appearance) of their offspring.	Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation. (MS-LS3-2)	**LS3.B: Variation of Traits** • 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. (MS-LS3-2) **LS3.A: Inheritance of Traits** • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2) • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2) **LS1.B: Growth and Development of Organisms** • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)	• Developing and Using Models
Task 4: Variation in Elephants	• Students analyze the size of existing species of elephants to determine how they differ based on genetics and environment.	Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms. (MS-LS1-5)	**LS3.A: Inheritance of Traits** • Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (MS-LS3-2) **LS1.B: Growth and Development of Organisms** • Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. (secondary to MS-LS3-2)	• Constructing Explanations and Designing Solutions

Tasks	Group Culminating Project	Individual Culminating Project	Science and Engineering Practices
Culminating Project	**Group Task:** • Students write a children's story based on the theme of how genetics and the environment affect who we are, how we are different, and how our traits increase the probability that we reproduce to make offspring.	**Individual Task:** • Students learn about pigeon traits and pigeon breeding. • They pick two parents with different traits to make their own pigeon. • They explain to a friend how pigeon breeding works. • They design a Q&A Fact Sheet for others who are interested in pigeon breeding.	• Constructing Explanations and Designing Solutions • Developing and Using Models

Misconceptions

Knowing what is wrong is as important as knowing what is right.

Lift-Off Task: A Storied Life and Human Traits

Misconception	Accurate Concept
Traits are only things you can physically see.	Traits not only refer to physical characteristics, but behaviors as well.
Inheritance means that entire traits are passed down from either your mother or your father.	Your traits are a combination of your mother's and father's genes. Thus, each of your traits comes from both mother and father, not just one or the other.

Task 1: Effects of the Environment on Plant Growth

Misconception	Accurate Concept
Genes determine all of your characteristics, and cloned organisms are exact copies of the original. In other words, "living things are different because they are just born that way."	While genes play a very important role in development, environmental factors also play a role. As stated in the background section, epigenetics shows that gene expression can change from factors such as diet and exposure to toxins, without actually changing the genome itself.
Environmental conditions can change an organism's traits; thus, environment changes the genes of an organism.	The environment does not change the actual genetic makeup, just actual growth of the organism. As stated above, environment can affect gene expression, but not the genes themselves.
If the experimenter changes a variable, any result is definitely caused by that change.	It is also necessary to control all other variables to ensure that logical cause and effect can be attributed to the changed variable.

Task 2: Traits Leading to Successful Reproduction

Misconception	Accurate Concept
Genes and traits are the same thing.	A ***gene*** is a portion of your DNA that codes for a specific trait. A ***trait*** is the physical expression of that gene. For example, if you have a gene that codes for blue eyes, blue eyes are the trait.
Genes and alleles are the same thing.	Genes are units of heredity. Alleles are variants of a gene.
Organisms, like guppies, try to adapt over their lifetime.	Natural selection is a process, not a guiding hand. Individuals cannot try to adapt over their lifetime. Rather, in the case of guppies, they select traits in a mate that will make it more likely for their offspring to survive and reproduce. This results in a more common trait over generations in the population.
Genes only affect physical traits, not behaviors and personality.	Behaviors and personality are traits just like eye color and skin color. These are influenced by genes and the environment.

Organisms only have traits that help them survive.	Variation in traits arises all the time due to mutation and recombination, which do not always benefit the organism's survival. Furthermore, some traits do not help an organism survive, but rather help it reproduce. The case example of this is male guppies with their colorful scales.
Plants do not have reproductive structures or behaviors because they cannot move or think.	Plants have bright flowers to attract pollinators. Plants have different size stamens, pistils, and petals to encourage pollination by way of wind, water, birds, bats, and bees. Plants protect their young in the seed and have evolved seed structures that help disperse seeds to places where there is enough sun, water, and minerals for new plants to grow and survive.
Plants cannot reproduce because there is no male and female.	The pollen is the male reproductive part of the plant and the ovary/egg is the female part of the plant. Together they make a seed, which is equivalent to offspring.

Task 3: Make a Dog Family and Bacteria Family

Misconception	Accurate Concept
There is only one gene for every trait.	Most traits are controlled by many genes.
There are only two different alleles (dominant and recessive) for each gene.	Most traits are controlled by more than two alleles. For example, there are at least six genes that control cat coat color and three different alleles in each gene.
Environmental changes can be inherited (Lamarck view).	Environmental changes, unless they impact actual gene expression (epigenetics), cannot be inherited. For example, an amputated arm is not a trait that is passed on to the offspring.
Breeds and species are the same thing.	Different breeds can mate and produce fertile offspring. Different species cannot.
Offspring inherit alleles from mom or from dad.	Offspring inherit half their alleles from mom and half their alleles from dad when the sperm and egg combine.
Dominant traits are always seen more often.	Dominant traits are not always seen more often. For example, having five digits on your hand is a recessive trait, but is more common.
In dominant traits, there are only dominant alleles. In recessive traits, there are only recessive alleles.	With dominant traits, the genotype can be Tt or TT. In the first genotype example, the dominant allele masks the recessive allele, which is still present.
There are always two parents involved in reproduction.	In asexual reproduction, there is only one parent, which divides into two cells. As a result, the offspring is identical to the parent.

Task 4: Variation in Elephants

Misconception	Accurate Concept
Traits are influenced exclusively by either genetics **or** environment.	Traits are influenced by a combination of genetics and environment. In fact, these two factors often influence each other as well.
Identical twins are exactly the same; that is why they are called "identical."	"Identical" in this context refers to their genes, but if exposed to different environmental factors, twins will most likely not be exactly the same.
Variation in the size of elephants only occurs because of different ages.	Variation in the size of elephants could also arise from genetics, diet, exposure to toxins, stress, exercise, etc.
All types of elephants are similar and can reproduce together.	There are different species of elephants, which means they cannot reproduce together and produce fertile offspring. Different species of elephants are genetically different.
If organisms can mate, then they belong to the same species.	For organisms to be considered the same species they must be able to mate and produce fertile offspring. Donkeys and horses, for example, can mate, but their offspring is not fertile, so they are classified as different species.

Culminating Projects

Essential Question: How do the environment and genetics affect who we are and how we are similar or different?

Introduction

There is extreme diversity in the life that surrounds us. We see all different types of living organisms—for example, plants, animals, mushrooms, seaweed, and bacteria (which we really can't see without a microscope). We see similarities in organisms. Most trees have roots, trunks, branches, leaves, and possibly flowers. If you look closely, there are also differences between the trees—for example, bark color and texture; leaf color, shape, and density; flower color and shape; and tree height. What we don't think about on a regular basis is why are there so many similarities and differences. The similarities are often thought of as being due to similar genes that have been passed down from the parents. But differences are also genetically driven, resulting in differences between parents and offspring, between different individuals in a population, and between different species. There is another factor that may cause similarities and differences between organisms, and that is environmental conditions surrounding the organisms. The amount of food and water an organism has available may determine the final height of an elephant, the number of leaves on a tree, or the color of a bird. In the end, diversity of life is due to both genetic and environmental factors.

In the group Culminating Project, students will write and illustrate a children's storybook to teach the reader about heredity and the interaction between traits and the environment.

In the individual Culminating Project, students will work with a pigeon genetics simulation to learn about pigeon traits and pigeon breeding. Students will pick two pigeon parents with different traits to make their own unique pigeon breed. They will design a model and write a scientific explanation for how traits get passed down and why there are variations between parents and offspring.

Materials

Group Culminating Project

Student Materials

- Blank paper
- Storyboard
- Colored pencils/pens or computer graphics

Individual Culminating Project

Student Materials

- Computer for each student

Group Culminating Project

Instructions

1. Introduce the Culminating Project at the start of the Lift-Off Task.
    - Read over the introduction and instructions found in the Student Edition.
    - The theme of the student's book will be to help a reader understand how genetics and the environment affect who we are, how we are different, and how we increase the probability that we will reproduce to produce offspring.
    - Note that the digital slide presentation for the Lift-Off Task provides information about parts of a story.
2. The plot of the book revolves around writing a story about a character, it's mate, and their offspring. The story should describe the character's adventures as it goes through life, overcomes a problem, has offspring, and is influenced by its environment. The actual plot and characters are up to the imagination of the students.
3. If possible, have some children's story books available for students to look at throughout the unit.
4. Tell students that as they work through the Individual Project Organizer, they may decide to change their story or character(s). This is acceptable and to be expected. Students don't actually do the final writing and illustrating until the end of the unit, so making changes along the way isn't problematic.
5. Make sure students fill out the Individual Project Organizer after each task. The Individual Project Organizer will help students think about different parts of their story along the way and help them apply scientific concepts into their story.
6. The table below summarizes how the Individual Project Organizer guides students through developing different components of their children's book.

Task	Individual Project Organizer	Culminating Project (Children's Book)
Lift-Off Task Read a children's story and identify human traits	• Draw one character for the book. • Identify traits for the character. • Describe the character.	• Main character development • Traits
Task 1 Environmental effects on plants	• Draw a scene in the book. • Draw the character in the environment. • Show and explain in a short narrative how physical traits are affected by the environment.	• Scene • Variation of traits due to environment
Task 2 Behaviors increasing chances of mating and producing offspring	• Decide on and draw traits that will attract a mate. • Draw a mate for the main character. • Decide on and write a short narrative about how traits/behaviors increase the mating or survival of offspring.	• Attracting a mate • Survival of offspring
Task 3 Make a dog family and bacteria family	• Create alleles for the main character and its mate. • Show the alleles in the offspring. • Explain the difference in alleles between the parent and the offspring.	• Inheritance of alleles/traits • Variation in offspring
Task 4 Genetic and environmental effects on elephants	• Create a storyboard of the plot showing how the character goes through life, attracts a mate, has offspring, and is influenced by his/her environment.	• Plot • Option: Recommend that students continue with their storyboard in their science notebook or on a separate sheet of paper.

7. After students have gone through all the learning tasks and filled in all the Individual Project Organizers, students should finish their storyboard and then write and illustrate their children's book. The Individual Project Organizers should be used as reference for students to remind them of all components of their story.
    - Recommend that each group assign individual students to be in charge of parts of the story, like the writing or the illustrating or the coloring of the illustrations.
8. Have students engage in a peer review of other groups' children's books.
    - Ask students to fill out a Peer Feedback for Children's Book form for each book they review. (The form is in the Student Edition.)
    - Have groups trade their children's book with that of another group.
    - Ask that each group designate a reader to read the story out loud to their group. Groups should rotate the reader job for each new book they read.
    - Advise each group to give one positive comment and one constructive comment for each section of the form.

Individual Culminating Project

Time Needed

- 1.5 days for the pigeon breeding simulation
- 1.5 days for creating a unique pigeon

Instructions

1. Refer students to the Introduction of the Individual Culminating Project instructions in their Student Edition. Review the first page with students to introduce the project.
2. Refer students to the Day 1 section of the project in their Student Edition. It is recommended that you go through the task before students attempt the simulations so that questions about process can be addressed quickly. The simulation is easy once it has been played for a short amount of time. Students will play games 1–7 as shown below.
    - Games 1–2: Students will do a breeding simulation focusing on one trait (two alleles), the male and female alleles. Note that bird alleles for gender are different and backward as compared to human or dog alleles. Bird females are ZW and human females are XX. Bird males are ZZ and human males are XY. (This may not be an issue for students who have not internalized information about human sex alleles.)
    - Games 3–6: Students will do a breeding simulation focusing on two traits: crest and gender or slippers and gender.
        - The slippers simulation introduces the situation in which two alleles can equal an in-between trait. This situation is called ***incomplete dominance***, but you do not need to introduce this term.
    - Game 7: Students will do a breeding simulation focusing on three traits: slippers, crest, and gender.
    - There are actually 26 simulation games that focus on multiple genetic situations (incomplete dominance, sex linked, multiple genes). Interested students can do other simulations.
3. Review the chart of game controls in the Student Edition before students use the simulation so that they are comfortable with the controls and can move on at their own pace.
4. Help students to access the Pigeonetics simulation.
5. Have students move through Games 1–7. After each game they should either diagram (model) what they did or check off a box to indicate that they played the game.
6. After the simulation, refer students to Day 2 of the project in their Student Edition. Have them follow the instructions to make their own pigeon breed.
7. Students can move through Day 2 at their own pace. Students will be assessed on their work in Day 2.

Assess the Individual Culminating Project

The Individual Culminating Project will be assessed using:

- The Science and Engineering Practices Rubric
    - "Constructing Explanations and Designing Solutions" row
    - "Developing and Using Models" row
- The Science Content Rubric

Science Content Rubric

Assess Using Individual Culminating Project Script

SCIENCE CONTENT RUBRIC				
THE STUDENT DEMONSTRATES THEIR SCIENTIFIC KNOWLEDGE OF THE FOLLOWING CONTENT STANDARD	EMERGING	DEVELOPING	PROFICIENT	ADVANCED
In sexually reproducing organisms, each parent contributes (at random) half of the genes acquired 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. (LS3.B)	The concept of how one allele moves from each parent to the pigeon offspring is modeled and/or explained **inappropriately and/or incorrectly**.	The concept of how one allele moves from each parent to the pigeon offspring is modeled and/or explained **correctly but incompletely**.	The concept of how one allele moves from each parent to the pigeon offspring is modeled and/or explained **correctly and completely**.	The concept of how one allele moves from each parent to the pigeon offspring is modeled and/or explained **in detail, correctly and completely**.
Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited. (LS3.A)	The concept that variation between the parent and pigeon offspring is a result of different genes on chromosomes is modeled and/or explained **inappropriately and/or incorrectly**.	The concept that variation between the parent and pigeon offspring is a result of different genes on chromosomes is modeled and/or explained **correctly but incompletely**.	The concept that variation between the parent and pigeon offspring is a result of different genes on chromosomes is modeled and/or explained **correctly and completely**.	The concept that variation between the parent and pigeon offspring is a result of different genes on chromosomes is modeled and/or explained **in detail, correctly and completely**.
Genetic factors as well as local conditions affect the growth of an adult organism. (LS1.B) *DCI has been expanded from plant to organism to align with PE	The concept that the environment as well as genetics affects the growth of pigeons is explained **inappropriately and/or incorrectly.**	The concept that the environment as well as genetics affects the growth of pigeons is explained **correctly but incompletely**.	The concept that the environment as well as genetics affects the growth of pigeons is explained **correctly and completely**.	The concept that the environment as well as genetics affects the growth of pigeons is explained **in detail, correctly and completely**.

Science and Engineering Practices Rubric

The Variation and Heredity Unit will be assessed using the highlighted rows.

SCIENCE AND ENGINEERING PRACTICES RUBRIC				
SCORING DOMAIN	**EMERGING**	**DEVELOPING**	**PROFICIENT**	**ADVANCED**
ASKING QUESTIONS AND DEFINING PROBLEMS	Asks general questions that cannot be investigated.	Asks specific questions that can be investigated but do not require empirical evidence.	Asks questions that require empirical evidence to answer.	Asks questions that require empirical evidence to answer and evaluates the testability of the questions.
❑ No Evidence*	Writes a problem or design statement but it does not match the intent of the problem or the need of the client.	Writes a problem or design statement that matches the intent of the problem or the need of the client with minor errors.	Writes a problem or design statement that accurately matches the intent of the problem or the needs of the client.	Writes a problem or design statement that accurately and completely matches the intent of the problem or the need of the client.
DEVELOPING AND USING MODELS	Makes models (drawings, diagrams, or other) with major errors.	Makes models (drawings, diagrams, or other) to represent the process or system to be investigated with minor errors.	Makes accurate and labeled models (drawings, diagrams, or other) to represent the process or system to be investigated.	Makes accurate and labeled models (drawings, diagrams, or other) to represent the process or system to be investigated and explains the model.
❑ No Evidence*	Explains the limitations of the model with major errors.	Explains the limitations of the model with minor errors.	Explains the limitations of the model as a representation of the system or process.	Explains the limitations of the model as a representation of the system or process and discusses how the model might be improved.
PLANNING INVESTIGATIONS	Plans an investigation that will not produce relevant data to answer the empirical question(s).	Plans an investigation that will produce some relevant data to answer the empirical question(s).	Plans an investigation that will produce relevant data to answer the empirical question(s) and identifies the dependent and independent variables when applicable.	Plans an investigation that will completely produce relevant and adequate amounts of data to answer the empirical question(s) and identifies the dependent and independent variables when applicable.
❑ No Evidence*	Plans a design that does not match the criteria, constraints, and intent of the problem.	Plans a design and writes an explanation that partially matches the criteria, constraints, and intent of the problem.	Plans a design and writes an explanation that accurately and adequately matches the criteria, constraints, and intent of the problem.	Plans a design and writes a detailed explanation that accurately and completely matches the criteria, constraints, and intent of the problem.
CARRYING OUT INVESTIGATIONS	Writes procedures that lack detail so the procedures cannot be duplicated by another person.	Writes procedures with enough detail that another person can duplicate (replicable) but does not conduct a sufficient number of trials.	Writes detailed replicable procedures with descriptions of the measurements, tools, or instruments and conducts adequate number of trials.	Writes detailed replicable procedures with descriptions of the measurements, tools, or instruments and conducts adequate number of trials with an explanation for the proposed data collection.
❑ No Evidence*				

* If there is no student response then check the "No Evidence" box.

The Variation and Heredity Unit will be assessed using the highlighted rows.

SCIENCE AND ENGINEERING PRACTICES RUBRIC				
SCORING DOMAIN	**EMERGING**	**DEVELOPING**	**PROFICIENT**	**ADVANCED**
ANALYZING AND INTERPRETING DATA ***"Accurately labeled" means inclusion of title, column titles, description of units, proper intervals.*** ❑ No Evidence*	Makes spreadsheets, data tables, charts, or graphs that are not accurately labeled or do not display all the data. Uses inappropriate methods or makes major errors analyzing the data.	Makes accurate and labeled spreadsheets, data tables, charts, or graphs to summarize and display data but does not arrange the data to examine the relationships between variables. Uses appropriate methods but makes minor errors analyzing the data.	Makes accurate and labeled spreadsheets, data tables, charts, and/or graphs to summarize and display data and arranges the data to examine relationships between variables. Uses appropriate methods to accurately and carefully identify patterns **or** explains possible error or limitations of analyzing the data.	Makes accurate and labeled spreadsheets, data tables, charts, and/or graphs and uses more than one of these methods to summarize and display data; arranges the data to examine relationships between variables. Uses appropriate methods to accurately and carefully identify patterns **and** explains possible error or limitations of analyzing the data.
CONSTRUCTING EXPLANATIONS AND DESIGNING SOLUTIONS ❑ No Evidence*	Constructs an explanation that includes an inappropriate claim, inaccurate evidence, and/or unclear reasoning. Uses no data to evaluate how well the design answers the problem and the redesign of the original model or prototype is inappropriate or incomplete.	Constructs or evaluates an explanation consisting of minimal claim(s), limited sources of accurate evidence, and/or minimal reasoning. Uses minimal data to evaluate how well the design answers the problem and describes an appropriate redesign of the original model or prototype with minor errors.	Constructs or evaluates an explanation that includes a claim, multiple sources of accurate evidence, and reasoning using accurate and adequate scientific ideas or principles. Uses adequate data to evaluate how well the design answers the problem and accurately explains an appropriate redesign of the original model or prototype.	Constructs, evaluates, or revises an explanation that includes a claim, multiple sources of accurate evidence, and reasoning using accurate and adequate scientific ideas or principles. Uses adequate data to evaluate how well the design answers the problem and accurately provides a detailed rationale for the appropriate redesign of the original model or prototype.
ENGAGING IN ARGUMENTS FROM EVIDENCE ❑ No Evidence*	Constructs an argument that includes an inappropriate claim, inaccurate evidence, and/or unclear reasoning.	Constructs or evaluates an argument consisting of minimal claim(s), limited sources of evidence, **or** minimal reasoning.	Constructs and/or evaluates an argument consisting of appropriate claim(s), multiple sources of evidence, and reasoning using accurate and adequate scientific ideas or principles.	Constructs, evaluates, or revises an argument consisting of appropriate claim(s), multiple sources of evidence, and reasoning using accurate and adequate scientific ideas or principles.
OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION ❑ No Evidence*	Communicates information that is inaccurate and/or inconsistent with the evidence.	Communicates accurate but minimal information consistent with the evidence but does not explain the implications **or** limitations of the investigation or design.	Communicates accurate, clear, and adequate information consistent with the evidence and explains the implications and/or limitations of the investigation or design.	Communicates accurate, clear, and complete information consistent with the evidence and provides a rationale for the implications and limitations of the investigation or design.

* If there is no student response then check the "No Evidence" box.

Materials

Lift-Off: A Storied Life and Human Traits

Teacher Materials

- "A Storied Life and Human Traits" digital slide presentation
- Children's book; recommendations:
  - ***Elmer the Patchwork Elephant*** by David McKee (addresses the idea that being different is okay)
  - ***The Day Jimmy's Boa Ate the Wash*** by Trinka Hakes Noble
  - ***If You Give a Mouse a Cookie*** (or any of the others in this series) by Laura Numeroff
  - ***Because I Stubbed My Toe*** by Shawn Byous
  - ***The Lorax*** by Dr. Seuss (long version)
  - ***Where Once There Was a Wood*** by Denise Fleming
  - ***Cleaning Day*** by D. H. Figueredo
  - ***First Day in Grapes*** by L. King Perez

Task 1: Effects of the Environment on Plant Growth

Student Materials

Part I:

- Bag of mixed beans
- Metric ruler

Part II:

- Kidney beans (approximately 6 per group—3 for the experimental group and 3 for the control group)
- Paper towels (used to make "growth chambers")
- Plastic plates (to put growth chambers on) or plastic bags (to store growth chambers in)
- Permanent pens (to label growth chambers)
- Possible environmental factors:
  - Vinegar (This a weak acid.)
  - Detergents/soaps (These are bases.)
  - Fertilizer (This adds minerals.)
  - Heat (Use a heat lamp, but cover beans up so light is not a factor.)
  - Cold (Put beans in a refrigerator.)
  - Dark (Put beans in a paper towel.)
  - Light (Don't cover beans in a paper towel, but make sure there is lots of water under under the bean for germination. Perhaps put beans in a container with a half inch of water.)
  - Wind (Use a fan.)
- Small cups or beakers (to measure the amount of water the beans are given every day)
- Ruler (to measure bean growth; have both metric and English standard rulers available, since students will decide what units they want to use)
- Graph paper
- Large poster paper (to draw and display each group's graph of data)

Task 2: Traits Leading to Successful Reproduction

Student Materials

per group

- Computer to play videos
- Video clips (These videos were selected because they specifically show how different animal behaviors and plant structures help animals and plants reproduce, which is the focus of this task's performance expectation.)
    - Pronghorn bucks battle for dominance: https://youtu.be/qJ9s6WF68LQ
    - Peacock mating dance display: https://youtu.be/jTBHiZtnCsA
    - Matriarch Elephants Protect Baby Elephant from Crocodile Attack: https://youtu.be/BGY0BHmjEtg
    - Amazing Animal Babies: Emperor Penguin Chicks: https://youtu.be/lf26jtJfL30
    - Flower Reproduction: https://youtu.be/YqM6rgB_l_o
    - Pollination Rock: https://youtu.be/V5yya4elRLw
    - Seed Dispersal: https://youtu.be/j1hRxuy1ezQ
    - Biggest flower in the world: https://youtu.be/FHaWu2rcP94
    - Butterfly pollination: https://youtu.be/gLJIcKpzH5E
    - Pine pollen blown by the wind: https://youtu.be/V_9palHvAIc
    - Guppy mating dance!: https://youtu.be/1tKOIc0qReQ
- Red and green markers

Task 3: Make a Dog Family and Bacteria Family

Student Materials

per student

Part II

- Dog Family Picture Frame handout (see Handout: VARHER_Task3_Handouts)

Part V

- Bacteria Family Picture Frame (see Handout: VARHER_Task3_Handouts)

per group

Part I

- Domestic Dog Pictures Resource Card (see Handout: VARHER_Task3_Handouts)
- Animal and Plant Reproduction Resource Card (see Handout: VARHER_Task3_Handouts)

Parts II and III

- Domestic Dog Pictures Resource Card (see Handout: VARHER_Task3_Handouts)
- Dog Traits and Alleles Resource Card (see Handout: VARHER_Task3_Handouts)
- 7 pennies with alleles attached to them (using paper and tape or stickers)
    - 2 pennies with a capital letter on each side of the coin
    - 2 pennies with a capital letter on one side and a small letter on the other side of the coin
    - 2 pennies with a small letter on each side of the coin
    - 1 penny with no letters (alleles) on it for flipping to identify (TT) or (Tt)

Part IV

- Bacteria Resource Card (See Handout: VARHER_Task3_Handouts)

Parts V and IV

- Bacteria Resource Card (See Handout: VARHER_Task3_Handouts)
- Bacteria Traits Resource Card (See Handout: VARHER_Task3_Handouts)
- Optional: A few pennies with only capital letters on each side and/or lowercase letters on each side of the coin

Teacher Materials

- "Variations and Heredity Task 3" digital slide presentation

Task 4: Variations in Elephants

- none