

Saving the Mountain Lion - Teacher Materials

Unit 4

Biology



The Curriculum and Instruction Department at New Visions for Public Schools develops free, full-course materials for all areas of high school science, math, ELA, and social studies, for use across our network of 80 New York City schools and beyond.



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Unit 4 Saving the Mountain Lion

Genetics and Variation

Performance Expectations

HS-LS3-2, HS-LS1-8, HS-LS1-4, HS-LS4-3, HS-LS3-3

Time

22-24 days

How can we save the mountain lion?

Students investigate different populations of mountain lions by looking at microsatellite data, and apply concepts of mitosis, meiosis and cause and effect to figure out that the mountain lion in Connecticut came from South Dakota, seeking genetic variation. They apply what they are learning about the mountain lion to the make and defend a claim relating to a solution implemented to increase genetic diversity of the population of mountain lions.

Unit Opening

Mountain Lion Populations 5E

Sexual Reproduction 3E (optional)

Genetic Variation 5E

Engineering Gene Flow 5E

Unit Closing

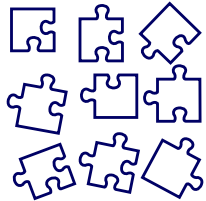
Anchor Phenomenon

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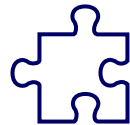
5E Lessons connect learning to the performance task

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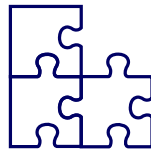
Performance Task



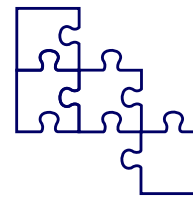
A mountain lion was hit by a car on a highway in Connecticut, right outside NYC. How can we figure out where the mountain lion came from and why it was there?



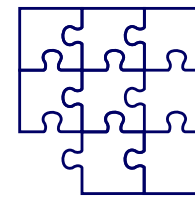
How can we figure out where the Connecticut Cat came from?



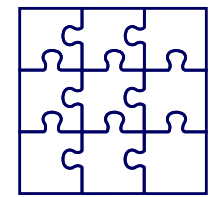
How can we understand the abnormalities seen in the Florida mountain lion population?



Why is it advantageous for a mountain lion to seek variation?



How can humans solve the mountain lion population isolation problem?



What causes a lack of genetic variation in a population?, Why is genetic diversity a problem for some species, and how can we evaluate conservation solutions for isolated populations?

Unit Introduction

How do we make science education meaningful and relevant to our students? High school biology courses are traditionally filled with lectures and cookbook labs, memorizing vocabulary, and an occasional research report. New science education standards (NGSS/NYSSLS) require a more engaging, accessible vision of science teaching and learning to help all students learn about the natural world and become scientifically literate citizens.

The three-dimensional, phenomenon-driven materials in this unit support students in engaging in the authentic practices of science. Students construct meaning about the natural world through modeling, investigations, labs and experiments. As students have opportunities to manipulate the physical tools of science, they also engage in productive struggle that can be resolved through evaluating claims using evidence and engaging in consensus building discussions. The materials support teachers in becoming skillful facilitators of student sense-making and deepen teachers' understanding of how to teach science in an interactive way that is driven by students' questions and ideas.

In Unit 4, students learn about a mountain lion that had walked from South Dakota to Connecticut, got hit by a car on the Merritt Parkway, and died. Why was this mountain lion in Connecticut, where big cats are rare? The backbone of this unit is a data set of genetic variation information of mountain lions. The real-life data was provided through a collaboration with a content expert, Dr. Anthony Caragiulo, a big cat expert from the American Museum of Natural History. Additionally, unit 4 was co-designed with Dr. Dave Randle, an Assistant Director of Curriculum and Instruction, and a faculty member at the Richard Gilder Graduate School, The American Museum of Natural History.

Through an iterative analysis of the genetic data set, students learn about the impact of reduced ranges (due to human-caused habitat destruction) has on mountain lion genetics and overall health. They figure out that variation exists across living things, and that this variation comes from our genes. Students explain that traits are expressed through proteins that are coded for in genes, and that variation can be due to a number of causes including mutations during meiosis, along with environmental influences on gene expression.

Students also figure out that genetic variation is essential for species survival, as a requirement for natural selection and adaptation to changing environments. Finally they use what they have learned about the mountain lion to evaluate the efficacy of a solution designed to increase genetic diversity in mountain lion populations.

Unit Coherence

In Unit 4, the overall question around the causes and benefits of genetic variation is intended to motivate student engagement across the unit. It is our intention that from the students' perspective, there is a clear and explicit unit storyline that guides the sequence of activities. Rather than one long continuous unit, we have chosen to use an instructional model to develop three coherent learning sequences within Unit 4. Each sequence builds towards figuring out something that contributes to explaining the overall unit-level question about what is happening with mountain lion populations, and how to evaluate conservation solutions for megafauna suffering from fragmented populations. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 4.

One additional note - this unit was also designed to support students with a NYSSLS Performance Expectation that addresses human reproduction. This PE is not in the NGSS. The way we have attended to this is to provide an optional "3E" after the first 5E instructional sequence that supports students with that PE. If teachers are ONLY using this unit to meet the NGSS PEs, and if students have already had sufficient NGSS experiences across K-8, this 3E can be skipped, and it will not undermine the coherence of the unit storyline.

Phenomenon-Driven Instruction

Phenomena are a key part of instruction in *A Framework for K-12 Science Education* and the NGSS. As in the work of scientists, students should be encouraged to move from observable phenomena to generalizable explanations of the natural world. Too often, traditional science instruction has started with generalizable principles, sidelining the lived experience and intuitions that all young people bring to school. In this unit (and all New Visions units) there are two kinds of phenomena: anchor phenomena and investigative phenomena.

Anchor Phenomenon

- One per unit; drives the learning of the unit
- Attention-grabbing and relevant
- Does not have to be phenomenal

Investigative Phenomena

- One per 5E sequence (three in this unit *)
- Presented in the Engage phase of each 5E

* NOTE - this unit has an additional “3E” that is optional (only Engage, Explore and Explain), and uses the same investigative phenomena as the 3rd 5E.

Anchor Phenomenon

To support coherence, students are prompted to figure out one overarching, real-world question over the course of the unit. The anchor phenomenon question is revisited across the unit, and this question motivates the investigations conducted in each of the 5E instructional sequences. A good anchor phenomenon should be attention-grabbing and relevant to students but also thought-provoking, comprehensible, and connected to the science learning goals. It needs to be observable to students through firsthand experiences or through someone else’s experiences, such as through a video or secondary data. If a teacher feels the anchor phenomenon will not be familiar or accessible to all students, we suggest relating it to similar, more familiar phenomena. It is important to notice that the phenomenon question anchoring the unit is different from the more generalized and abstracted science question for the unit. This difference is part of what helps make the unit more student-centered, rather than teacher-centered.

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon, typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized, rather than the traditional content questions teachers use as their lesson aims. They present what is being figured out; therefore, the scientific concepts that are in the learning goal cannot be part of the wording of the question!

Solving Problems

One of the major NGSS shifts is integrating engineering into science instruction. Defining problems and developing solutions are critical components of engaging in addressing significant global and social problems within an NGSS-designed high school science course. After being presented with the unit anchor phenomena, students are naturally inclined to want to do something about it - and thus students’ investigations across a unit are also motivated by the desire to solve the related problem. This engineering thread is intertwined with the anchor phenomenon as the science figured out is useful in arguing for a causal explanation of the phenomenon *and* figuring out a solution.

Storyline and Pacing Guide

Unit Opening	A mountain lion was hit by a car on a highway in Connecticut, right outside NYC. How can we figure out where the mountain lion came from and why it was there?	Performance Expectations	Anchor Phenomenon A mountain lion was hit by a car on a highway outside NYC. How did it get there, and what can this tell us about saving mountain lions?	Time 2 days
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Student Questions	What Students Do	Student Ideas
<i>These questions motivate the unit storyline.</i> - Where did the mountain lion come from? - How did it get to Connecticut? - Why would a male mountain lion stray so far from home? - How can we figure out where the mountain lion came from?	Students read a text and watch a video in order to think about why the Connecticut mountain lion was so far away from its home. After telling the story of the mountain lion, students generate a driving question board.	<i>These ideas are revisited throughout the unit storyline.</i> - Mountain lions have historically had a huge range across North America. - Their range has gotten smaller, and this is somehow related to them getting hit by a car.

Students are now curious to know where the Connecticut cat came from and why it was wandering around where there are no other mountain lions! Students will analyze genetic data to figure out where it originated from.

Mountain Lion Populations 5E

How can we figure out where the Connecticut Cat came from?

Performance Expectations
HS-LS3-2

Investigative Phenomenon
A male mountain lion was killed by a car on a parkway in Connecticut. Students need to figure out where it came from, how it got there, and why it would roam so far from its original home.

Time
5 days

Student Questions

These questions motivate this 5E sequence and the unit storyline.

- How did the mountain lion get to Connecticut?
- Why did he come to Connecticut?
- Would other mountain lions be showing up now, too?
- Where are the relatives of this mountain lion?

What Students Do

Students determine where the Connecticut Cat came from using genetic data from five different populations of mountain lions in North America. They then try to determine why a male mountain lion would stray so far. Determining the population that's most closely related to the mountain lion who died requires analysis of genetic data using statistical methods. The same data will also be used to determine the frequency of certain alleles within a population, which leads to calculations of genetic diversity.

Student Ideas

Students figure out these ideas in this 5E sequence.

- The mountain lions in South Dakota are very similar, genetically, to the one found in Connecticut
- The Connecticut Cat must have come all the way from South Dakota

Students apply what they have learned during this investigation to develop a model at different scales, based on evidence, that represents the cause behind the migration of the Connecticut cat.

Have students identify which categories/questions they have not figured out yet. Students should share out these questions, and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

Sexual Reproduction 3E (optional)

How can we understand the abnormalities seen in the Florida mountain lion population?

Performance Expectations
HS-LS1-8

Investigative Phenomenon
Florida panthers, a population of mountain lions, possessed a set of strange traits.

Time
3 days

Student Questions	What Students Do	Student Ideas
<i>These questions motivate this 5E sequence and the unit storyline.</i> - How do mammals (like humans and mountain lions) sexually reproduce? - How do the structures of the reproductive system support internal fertilization and development? - How do abnormal traits impact sexual reproduction and the continuation of the species?	In this 5E students use models of the human reproductive system to closely investigate the structure and function of its parts. Students generate a sequence chart to help them understand how abnormalities in the Florida mountain lion population may negatively impact their ability to reproduce.	<i>Students figure out these ideas in this 5E sequence.</i> - All mammals reproduce sexually with internal fertilization & development - The reproductive structures of the male and female reveal their function in reproduction (including the production of gametes, fertilization, and development of the fetus in the female) - Hormones regulate sexual reproduction in both males and females - Abnormalities in the reproductive system (or in other body systems that interactive with the reproductive system) may reduce the probability of successful fertilization or the growth and development of the fetus
Students apply what they have learned during this investigation to make sense of how abnormalities in structure may impact the functioning of the reproductive system. Have students identify which questions they generated during the Engage phase they have not figured out yet. Questions about whether abnormalities are caused by mutations or another cause. Students should share out these questions, and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.		

Genetic Variation 5E

Why is it advantageous for a mountain lion to seek variation?

Performance Expectations
HS-LS1-4, HS-LS4-3,
HS-LS3-2

Investigative Phenomenon
Florida panthers, a population of mountain lions, possessed a set of strange traits.

Time
6 days

Student Questions	What Students Do	Student Ideas
<i>These questions motivate this 5E sequence and the unit storyline.</i> • Why do the Florida mountain lions have abnormal traits? • How and where do mutations occur? • Why are mutations only expressed in some cells of the body? • Why do mutations increase in frequency in small populations?	Students notice that Florida mountain lions have a high frequency of abnormal traits such as kinked tails and low sperm counts. Students investigate the genetic data on this population to uncover patterns on homozygosity and heterozygosity of allele pairs. Then, students explore more about the origin of the abnormal traits and how they increase in frequency due to inbreeding. Finally, students consider the case of the Chernobyl dogs and how their circumstances contributed to their genetically unique populations..	<i>Students figure out these ideas in this 5E sequence.</i> • Florida mountain lions have a high frequency of homozygous alleles and inbreeding • Mutations are errors during replication; mutations that occur in sex cells can be passed onto offspring • Mutations can happen randomly, and can be caused by mutagens in the environment • After fertilization, mitosis (cell division) occurs as an embryo grows; creating identical cells • Early in embryonic development cells differentiate, so that only some genes are expressed in each cell depending on the type of cell • In small populations inbreeding occurs because there few individuals to mate with • Inbreeding increases the frequency of often deleterious mutations in a population

Students apply what they learned during this investigation to develop a model based on evidence to represent the cause of disadvantageous traits in mountain lions.

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about how to increase diversity in small populations like the Florida mountain lions. Tell students that in the next sequence of lessons, they will investigate these questions.

Engineering Gene Flow 5E

How can humans solve the mountain lion population isolation problem?

Performance Expectations
HS-LS3-2, HS-LS3-3,
HS-LS4-3

Investigative Phenomenon
The introduction of Texas mountain lions into the Florida panther population led to an increase in genetic diversity.

Time
5 days

Student Questions	What Students Do	Student Ideas
<i>These questions motivate this 5E sequence and the unit storyline.</i> - How can humans solve the mountain lion problem of decreasing range sizes and populations? - How does sexual reproduction increase the variation of alleles and traits? - Why is it important to have a variety of individuals to mate with?	Students notice that the genetic diversity in the Florida mountain lions increased after the 1995 introduction of 8 female mountain lions from a population of lions in Texas. Students investigate a model of cellular level processes of sexual reproduction (meiosis) and observe how new genetic combinations in offspring result from sexual reproduction. Then, students model breeding in populations with varying degrees of genetic diversity and use ideas surfaced from the investigations to model what occurred after the introduction of Texas mountain lions to the Florida Panther population and make a claim about whether the intervention increased genetic diversity of the Florida Panthers.	<i>Students figure out these ideas in this 5E sequence.</i> - Exchange of DNA between paired homologous chromosomes (one from each parent) occurs during the first stage of egg and sperm cell development (meiosis). This process results in new combinations of alleles in the gametes (egg or sperm) formed. This is called crossing over. - Half of the new chromosomes randomly move to opposite sides of cells before they split into new cells. This is called random assortment and results in new genetic combinations. - We saw an increase in genetic diversity in the Florida panther population after the Texas mountain lions were introduced because that increased the genetic diversity of the cats mating and that led to more observed heterozygosity in offspring. - Variation is good for offspring: meiosis leads to variation. - During development it's all mitosis, so sexual reproduction is your one shot at variation! - Environmental factors also lead to variation in gene expression.
After students figure out the reason behind the Connecticut Cat's long migration from the genetic, individual, population, and species levels across the unit, they are encouraged in the Unit Closing to apply what they learned to evaluate a solution designed to increase genetic diversity in mountain lion populations.		

Unit Closing

What causes a lack of genetic variation in a population?, Why is genetic diversity a problem for some species, and how can we evaluate conservation solutions for isolated populations?

Performance Expectations
HS-LS4-3, HS-LS3-2

Anchor Phenomenon
A mountain lion was hit by a car on a highway outside NYC. How did it get there, and what can this tell us about saving mountain lions?

Time
1-3 days

Student Questions	What Students Do	Student Ideas
<i>These questions are addressed in the performance task.</i> • What explains why populations of large animals have a problem with genetic diversity? • How does low genetic diversity impact species? • How can we address low genetic diversity in different population's genetic diversity?	Students are introduced to the solution of wildlife corridors to increase mountain lion genetic diversity. Based on the investigations and learning throughout the unit, they analyze the potential impacts of different wildlife corridors in order to generate and defend a claim in support of one corridor.	<i>These ideas were developed throughout the unit storyline.</i> • Mountain lions seek genetic variation to reproduce, and when that variation is limited, will go outside their normal range to find it. • Based on the nature of science, we can predict that other populations of organisms will be governed by the same scientific principles that we observed in the mountain lion populations. • During sexual reproduction a cellular process called meiosis occurs and multiple phases of the process lead to recombination of genes from each parents' gametes. • The more genetic diversity there is within a population, the more likely it is that mating results in new genetic combinations in offspring. • Genetic variation is required for natural selection. • Beneficial traits (including behavioral traits) are adaptations that can increase in a population due to differential survival and reproduction. • Humans can be the cause of the struggle some species are experiencing with limited genetic diversity, and can <i>also</i> provide solutions to help organisms that are struggling with genetic variation.

Based on the investigations and learning throughout the unit, students conduct a statistical analysis of genetic data and in order to make and defend a claim about which wildlife corridor would best address the lack of variation in Mountain Lion populations.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Performance Expectations

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.

In NYS the entire PE has been edited as follows: 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, (3) mutations caused by environmental factors and/or (4) genetic engineering.

[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs including the relevant processes in meiosis and advances in biotechnology.] [Assessment Boundary: Assessment does not include recalling the specific details of the phases of meiosis or the biochemical mechanisms of the specific phases in the process.]

HS-LS1-8 Clarification Statement:

Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Use models to illustrate how human reproduction and development maintains continuity of life. [Clarification Statement: Emphasis is on structures and function of human reproductive systems, interactions with other human body systems, embryonic development, and influences of environmental factors on development.] [Assessment Boundary: Assessment does not include the details of hormonal regulation or stages of embryonic development.]

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

Clarification Statement: None

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

In NYS the entire PE has been edited as follows: Use a model to illustrate cellular division (mitosis) and differentiation. [Clarification Statement: Emphasis should be on the outcomes of mitotic division and cell differentiation on growth and development of complex organisms and possible implications for abnormal cell division (cancer) and stem cell research.] [Assessment Boundary: Assessment does not include specific gene control mechanisms or recalling the specific steps of mitosis.]

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.

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.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school biology, Unit 4 builds on the ideas developed in Units 2 and 3 related to evolution by natural selection and genetics, and focuses primarily on ideas related to the causes and benefits of genetic variation. These ideas fall mostly within Core Idea LS3 of the NGSS/NYSSL, Heredity: Inheritance and Variation of Traits. Disciplinary Core Ideas within LS1.B: Growth and Development of Organisms, and LS4.B Natural Selection and LS4.C: Adaptation are also addressed in this unit. The use of disciplinary core ideas from LS4.B Natural Selection and LS4.C: Adaptation draw heavily from students' earlier work with these components in Unit 2.

In Unit 4, the second element of LS4.C (Adaptation also means that the distribution of traits in a population can change when conditions change) is **not** assessed, even though it is a part of HS-LS4-3, a performance expectation found in this unit. Evidence for student use of this element is found in Unit 2. Additionally, to address NYS-specific standards, ideas related to sexual reproduction are also part of the Unit 4 storyline.

Similar to Unit 1, this unit draws heavily on the SEP of Developing and Using Models. Students build on their use of modeling to focus on a new SEP, Analyzing and Interpreting Data. That is not to say that students will not engage in other SEPs throughout the lessons, particularly the practice of Engaging In Argument from Evidence; however, it is important to foreground and be explicit about a limited number of practices with enough duration to see how students develop their understanding and ability to use this practice. This is important for both student and teacher learning! The foregrounded CCC for this unit is Patterns, which fits well with our selected SEP. As students deepen their understanding of the content to understand why genetic diversity is important for species survival, they learn how to use multiple lines of evidence to make causal claims based on empirical data at different scales, and strengthen explanatory models. Scaffolding across the unit supports students' three-dimensional learning and will help shift classrooms to become more NGSS-aligned spaces.

Three Dimensions in Unit 4

This chart is a high-level summary of the standards for Unit 4. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models	LS1.A Structure and Function	Patterns
Analyzing and Interpreting Data	LS1.B Growth and Development of Organisms	Cause and Effect
Engaging in Argument from Evidence	LS3.B Variation of Traits	Scale, Proportion, and Quantity
	LS4.B Natural Selection	Systems and Systems Models
	LS4.C Adaptation	

Building on Middle School

High school science teaching necessarily builds on student learning from middle school. It is helpful to consider the middle school standards in order to enact a unit that builds on students' prior experiences. As we are in the middle of a multi-year transition, however, it is also critical to keep in mind that not all students will have experienced an NGSS-designed unit when they come to high school, so the process of building on middle school learning may be particularly complex for years to come. The following sections detail the ways in which this unit builds on middle school standards across the three dimensions.

Science and Engineering Practices from Middle School

Developing and Using Models

- Students in middle school have experience developing models based on evidence, using models to make predictions and evaluating models to evaluate their limitations. The use of modeling in this unit at the high school level builds on these experiences as students have to develop models at different scales and revise their models to show relationships between systems and components of a system.

Analyzing and Interpreting Data

- Students in middle school have previous experience using graphical displays, such as graphs and charts, to identify relationships and to distinguish between causal and correlational relationships. This unit builds on this practice, providing students with multiple opportunities to engage with complex visual representations of data and using concepts of statistics and probability in order to evaluate claims of causal relationships.

Engaging in Argument from Evidence

- In middle school, students have previous experience constructing arguments supported by evidence and reasoning, as well as experience comparing and critiquing each others' arguments; in high school, they develop a deeper understanding of how to evaluate the strength of evidence for different claims, and use evidence to develop and defend claims. This unit builds on the practice of Engaging in Argument from Evidence through scaffolded speaking and writing experiences.

Disciplinary Core Ideas from Middle School

LS4.B Natural Selection

- In middle school, students learn that natural and artificial selection results in the increase in advantageous traits in a population. In high schools, students look at additional ways in which traits increase in a population, including genetic drift and gene flow. In this unit, students engage in multiple opportunities to closely examine genetic diversity in different populations and the processes that may lead to specific traits dominating in a population.

LS3.B Variation in Traits

- Students in middle school learn that 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 and that mutations are a source of genetic variation. In this unit, students learn that meiosis during sexual reproduction generates new combinations of alleles, and that variation can also arise from the variation of the expression traits, based on the environment.

Crosscutting Concepts from Middle School

Patterns

This unit builds on the following aspects of Patterns in middle school.

- Middle school students learn that patterns in data can be identified in graphs and images, and that these patterns can be used to identify cause and effect relationships. Students in middle school also learn that macroscopic patterns observed are related to what is happening at the microscopic level, which will be important in helping them understand and identify causal relationships in this unit.

Cause and Effect

This unit builds on the following aspects of Cause and Effect in middle school.

- Students in middle school learn that relationships may be causal or correlational and that correlation does not always imply causation. This unit builds on this understanding by engaging students in multiple opportunities to evaluate possible causal relationships using empirical evidence. In evaluating claims throughout the unit, students are supported in differentiating between causation and correlation in order to identify the best supported claim.

Scale, Proportion, and Quantity

This unit builds on the following aspects of Scale, Proportion, and Quantity in middle school.

- Students in middle school that scientific relationships can be represented through the use of algebraic expressions and equations. This unit builds on the use of this understanding as students use algebraic thinking to examine and better understand scientific data and concepts; and to predict the impact of changing one variable on another.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 4 targets a bundle of one PE taken from the first core idea in high school life science (HS-LS1), *From Molecules to Organisms: Structures and Processes*; that standard is HS-LS1-4. One PE is taken from the fourth core idea in high school life science (HS-LS4), *Biological Evolution: Unity and Diversity*; that standard is HS-LS4-3. Two PEs are taken from the third core idea in high school life science (HS-LS3), *Heredity: Inheritance and Variation of Traits*; those standards are HS-LS3-2 and HS-LS3-3. Additionally, an optional 3E sequence is used to target the NYSSLS PE, HS-LS1-8, which is not a part of the NGSS. This PE bundle informs the types of three-dimensional tasks in which students engage across the unit. Each sequence of lessons within the unit targets elements from one or more of the performance expectations for the unit, and the teacher has opportunities to collect evidence of student learning around these elements within that learning sequence. The unit-level Performance Task only targets a subset of three-dimensional learnings goals informed by the bundled PEs for the unit. All other evidence of learning related the other dimensions/elements in the PEs can be found within the instructional sequences. It is important to note that Unit 4 does not address the third element of LS4.C Adaption (LS4.C(3)). Evidence for student use of this element is found in Unit 2.

The **Teacher Materials** for each 5E instructional sequence includes a matrix that lists which student artifacts can provide evidence of student learning for each of three-dimensional learning goals from that sequence. Each 5E addresses the integration of the three dimensions across the activities. Please keep in mind that Explore/Explain phases in the matrix should be looked at together, as a continuous experience to assess the foregrounded three-dimensional learning goals across the two phases.

This unit was designed to support teachers in tracking student progress across the three dimensions, not for mastery within individual days of instruction. The targeted disciplinary core ideas (DCIs) listed below will be developed throughout the unit. While all of the science and engineering practices (SEPs) may be utilized across the unit, the target SEPs for the unit are listed below. Similarly, many crosscutting concepts (CCCs) may be useful in making sense of the phenomena in this unit, however the foregrounded, targeted CCCs are listed below.

The following [Science and Engineering Practices](#), [Disciplinary Core Ideas](#), and [Crosscutting Concepts](#) are assessed throughout the unit:

	Mountain Lion Populations 5E	Sexual Reproduction 3E (optional)	Genetic Variation 5E	Engineering Gene Flow 5E
Developing and Using Models	✓	✓	✓	✓
Analyzing and Interpreting Data	✓		✓	✓
Engaging in Argument from Evidence	✓		✓	✓
LS1.A Structure and Function		✓		
LS1.B Growth and Development of Organisms		✓	✓	
LS3.B Variation of Traits	✓		✓	✓
LS4.B Natural Selection	✓		✓	✓
LS4.C Adaptation			✓	✓
Patterns	✓		✓	✓

	Mountain Lion Populations 5E	Sexual Reproduction 3E (optional)	Genetic Variation 5E	Engineering Gene Flow 5E
Cause and Effect	✓		✓	✓
Scale, Proportion, and Quantity				✓
Systems and Systems Models		✓		

At the end of the unit, teachers will have evidence in student work (tasks) related to the elements listed in this table and can therefore make claims at the end of this unit related to student proficiency for all three performance expectations.

To support assessment throughout the unit, rubrics have been included in the **Student Materials** to support the Evaluate phase in every 5E instructional sequence. Teachers should customize these rubrics to support their schools' grading systems. Rubrics address both individual reflection, peer review, and the teacher's feedback. The Unit 4 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit - we have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (Mathematics)

Standards for Mathematical Practice

MP3 Construct viable arguments and critique the reasoning of others.	Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.
MP6 Attend to precision.	Mathematically proficient students try to communicate precisely to others. They try to use clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They are careful about specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. In the elementary grades, students give carefully formulated explanations to each other. By the time they reach high school they have learned to examine claims and make explicit use of definitions.

Common Core State Standards (ELA/Literacy)

Speaking and Listening Standards

- SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9–10 topics, texts, and issues, building on others’ ideas and expressing their own clearly and persuasively.
- SL.9-10.4 Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

Reading Standards for Literacy in Science and Technical Subjects

- RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text’s explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- RST.9-10.7 Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.
- RST.9-10.9 Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects

- WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

Implementing Unit 4

This unit is designed to be the fourth unit of the Biology course. We do not recommend spending more than two months on this unit, as our field testing showed that six to eight weeks is the maximum amount of time students can stay engaged with the unit-level anchor phenomenon.

Within the unit, we also suggest spending no more than two weeks on each 5E instructional sequence. It is important to trust that ideas will build over time. Part of learning to teach NGSS-designed curriculum is getting comfortable with moving on, even if not every student “gets it,” with the knowledge that there are additional opportunities to revisit particular standards. See the Assessment section below for guidance on providing multiple opportunities for assessment throughout the unit.

The first time enacting any unit with students may take longer than anticipated, particularly if the pedagogical approach is significantly different from what a teacher is used to. A teacher may want to skip entire lessons or activities, or revert to more traditional approaches when it seems like time is running out. We often ask teachers to think about the best way to modify recipes. Just like when using a recipe for the first time, it’s a good idea to stay as true to the materials as possible before making modifications or substitutions! As teachers become more familiar and comfortable with the instructional model, the embedded routines, and three-dimensional teaching overall, the desire to skip things will dissipate. Teachers using our curriculum over time have noticed that they are able to move a bit quicker through this and other NGSS-designed units every year!

Routines

The table below summarizes the routines embedded in this unit. The number indicates the number of times a given routine appears in a lesson.

	Unit Opening	Mountain Lion Populations 5E	Sexual Reproduction 3E (optional)	Genetic Variation 5E	Engineering Gene Flow 5E	Unit Closing
Class Consensus Discussion		1		1	1	
Consensus Building Share		1	1			
Domino Discover			1	1	1	
Idea Carousel				1		
Questions Only			1			
Read-Generate-Sort-Solve		1		1	1	
Rumors		1		1	1	
Think-Talk-Open Exchange					1	
Think-Talk-Open Exchange + Buzzwords			1			

Literacy Strategies

The table below summarizes the literacy strategies embedded in this unit. The number indicates the number of times a given strategy appears in a lesson.

	Unit Opening	Mountain Lion Populations 5E	Sexual Reproduction 3E (optional)	Genetic Variation 5E	Engineering Gene Flow 5E	Unit Closing
Concept Mapping				1		
Sequence Chart			1			
Text Annotation	1	1		1	1	

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	Mountain Lions in California	https://www.youtube.com/watch?v=GLvRuSjSYgo	NA	NA
Mountain Lion Populations 5E	Sample Size Explained	https://www.youtube.com/watch?v=Uyd_Fk9cDjA	NA	NA
Mountain Lion Populations 5E	Cheetahs 101 Nat Geo Wild	https://www.youtube.com/watch?v=N7e_IDDojas	NA	NA
Genetic Variation 5E	Mitosis	https://www.youtube.com/watch?v=f-lDPgEfAHI	NA	NA
Engineering Gene Flow 5E	Meiosis	https://www.youtube.com/watch?v=rB_8dTuh73c	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
Mountain Lion Populations 5E	Mountain Lion Genotype Data Investigation Lab minutes: 45 minutes	

Lesson	Lab	Materials needed (per group)
Sexual Reproduction 3E (optional)	Sexual Reproduction 3E Explore Sexual Reproduction Models Investigation Lab minutes: 30 minutes	
Genetic Variation 5E	Mountain Lion Genetic Diversity Investigation Lab minutes: 45 minutes	
Engineering Gene Flow 5E	Increasing Genetic Variation Investigation Lab minutes: 60 minutes	☐ 2 paper bags ☐ 10 colored marbles for each of the following colors: red; blue; yellow; and green

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	☐ Post-it notes ☐ chart paper or digital access
Mountain Lion Populations 5E	☐ Confidence Calculator ☐ Cheetahs: On the Brink of Extinction, Again National Geographic Society
Sexual Reproduction 3E (optional)	☐ <i>Sexual Reproduction Models</i> ☐ <i>Sexual Reproduction Models</i> ☐ <i>Sexual Reproduction Female Sequence Chart Cards</i> ☐ <i>Sexual Reproduction Male Sequence Chart Cards</i>
Genetic Variation 5E	☐ Mountain Lion Genetic Diversity Calculator ☐ Observed and Expected Heterozygosity (optional) ☐ Mutations ☐ Differentiation ☐ CK-12 Reading Causes of Mutations ☐ CK-12 Reading Causes of Mutations Advanced ☐ CK-12 Reading Sources of Genetic Variation Advanced ☐ Are Contaminants Silencing Our Genes? (optional) ☐ computer access

Lesson	Materials needed
Engineering Gene Flow 5E	☐ Post it notes ☐ Mountain Lion Genetic Diversity Calculator ☐ Observed and Expected Heterozygosity (optional) ☐ What causes a sea turtle to be born male or female? ☐ Temperature-Dependent Sex Determination Visual ☐ Temperature-Dependent Sex Determination Unraveled: An Interview with Dr. Alex Lolavar (optional) ☐ Sex Determination: More Complicated Than You Thought
Unit Closing	☐ Driving Question Board

Teacher Materials for Unit 4

Unit Opening

A mountain lion was hit by a car on a highway in Connecticut, right outside NYC. How can we figure out where the mountain lion came from and why it was there?

Performance Expectations

Anchor Phenomenon
A mountain lion was hit by a car on a highway outside NYC. How did it get there, and what can this tell us about saving mountain lions?

Time
2 days

What is the story behind a mountain lion that was found dead on a highway in Connecticut? Students learn about the story of a mountain lion that was killed on a highway in Connecticut and wonder why it was so far from its home. This leads to questions about variation and whether there is something humans can and should do to help preserve diversity of mountain lions in their habitats.

ANCHOR PHENOMENON

A mountain lion was hit by a car on a highway in Connecticut. Why was it there?

This is a topic that should incite student curiosity and wonder! By eliciting what students think about the mountain lion found dead in Connecticut, it is possible to gauge students' interest and prior knowledge in this topic.

DRIVING QUESTION BOARD

Students ask questions about the Connecticut cat.

Based on ideas that have surfaced through student discussion, students create a driving question board.

PERFORMANCE TASK

The performance Task is not introduced during the Unit Opening

Unlike in earlier units, the sensemaking that leads to student understanding of the need for the Performance Task is designed to take place after the completion of all 5Es. After students have reached an understanding of what has happened to the Mountain Lion, students will be introduced to a transfer task that asks them to apply what they've learned about that species to evaluate a solution designed to rehabilitate genetic diversity in those populations.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Anchor Phenomenon

A mountain lion was hit by a car on a highway in Connecticut. Why was it there?

This is a topic that should incite student curiosity and wonder! By eliciting what students think about the mountain lion found dead in Connecticut, it is possible to gauge students' interest and prior knowledge in this topic.

Preparation

Student Grouping

- ☐ Table groups

Routines

None

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ The Connecticut Cat

Lab Supplies

None

Other Resources

- ☐ [Mountain Lions in California](#)

Surfacing Student Ideas

1. Ask students to make a list of any large mammals they have seen in the city where they live. Students may name raccoons, foxes, coyotes, or even deer.
2. Elicit student ideas about whether there are any mammals they would be shocked to see in their city.

Telling the Story

1. Provide students with the handout about the Connecticut Cat, *The Connecticut Cat*. Have students read the text individually and engage using **text annotation** to indicate three important points in the story.
2. Students share their ideas in their group, with every individual identifying the details that they thought were important.
3. As a group, students decide which ideas they think are important, and use those ideas to write out what happened, or the story of the phenomenon.

Access for All Learners



Text annotation supports students who may struggle with the text to focus on the important details and questions they want to bring to their group.

Conferring Prompts



Confer with students as they work in groups to tell the story.

- Why do you think this detail is important?
- Did your group members and you circle the same details?
- How did you agree, as a group, to the overall story?

4. Show the video [Mountain Lions in California](#) to the class to introduce them to some background on mountain lions in California. Be sure only to show the portion from 0:55 to 6:00. Let students know that although this video is shot in California, the same issues apply to all populations of mountain lions throughout their range. After the video, have students revisit and add to their answers to the questions in *The Connecticut Cat*.

Implementation Tip



The launch is designed to generate student curiosity and provide background so they can develop a list of questions that will drive investigation throughout the unit. In this lesson it is important that the teacher does not tell the students that male mountain lions leave their birthplace and travel, sometimes long distances, in order to find unrelated females to mate with. The opening of the video gives background information on mountain lions and introduces some of the issues that wild mountain lion populations face. It does not give away the reason for dispersal in the first six minutes so do not watch past the six minute mark during this lesson.

Driving Question Board

Students ask questions about the Connecticut cat.

Based on ideas that have surfaced through student discussion, students create a driving question board.

Preparation

Student Grouping

☐ Table groups

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

- ☐ Post-it notes
- ☐ chart paper or digital access

Developing Questions

1. At this point, students should have a lot of questions! Let them know that they will be investigating why this mountain lion was on a highway and got hit by a car.
2. Individually, students come up with questions they would need to answer in order to figure out the phenomenon. Each question goes on a separate sticky note.
3. As a whole class or in small groups, students share and categorize their questions, as they organize the questions on chart paper.

Conferring Prompts



Confer with students as they create and categorize questions.

- Why do these questions belong together?
- What is the category that connects these?
- Are there other questions within this category?
- Now that you see all of your questions grouped together, do other questions come up?
- For each category, is it possible to develop an umbrella question that encompasses all of the other sub-questions in that category?

Integrating Three Dimensions



In generating a Driving Question Board, students have the opportunity to use **SEP#1 Asking Questions and Defining Problems**, as they are asking questions to clarify and seek additional information about the anchor phenomenon introduced in the unit opening.

Performance Task

The performance Task is not introduced during the Unit Opening

Unlike in earlier units, the sensemaking that leads to student understanding of the need for the Performance Task is designed to take place after the completion of all 5Es. After students have reached an understanding of what has happened to the Mountain Lion, students will be introduced to a transfer task that asks them to apply what they've learned about that species to evaluate a solution designed to rehabilitate genetic diversity in those populations.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Standards in Unit Opening

Performance Expectations

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task
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Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task
Mathematics			
ELA/Literacy	RST.9-10.1 WHST.9-10.2		

Mountain Lion Populations 5E

How can we figure out where the Connecticut Cat came from?

Performance Expectations
HS-LS3-2

Investigative Phenomenon
A male mountain lion was killed by a car on a parkway in Connecticut. Students need to figure out where it came from, how it got there, and why it would roam so far from its original home.

Time
5 days

Mountain lions used to have a large range across North, Central, and South America. As humans have built roads, farmlands, and cities in their range, mountain lions are more restricted to smaller areas. This causes a problem for genetic diversity, since it limits the mates in a reachable area for each animal. Male mountain lions typically roam far from their immediate families in search of mates, but now they may have to travel very far to find a female who is not closely related. Relationships between mountain lions can be determined by looking at genetic data and determining allele frequency.

ENGAGE	How can we figure out where the Connecticut Cat came from?	Connecting to their earlier questions, students develop and share their initial ideas about how they can determine where the mountain lion hit by a car in Connecticut came from. Students develop a table that lists the evidence that would support each of their ideas .
EXPLORE	How can we use genetic data to determine where the Connecticut Cat came from?	Students analyze patterns in genetic variation data from five different populations of North American mountain lions (California, Mexico, South Dakota, Texas, Florida) in order to figure out where the Connecticut cat may have originated.
EXPLAIN	Why would a mountain lion roam so far from his home territory?	Students incorporate descriptions of mountain lion behavior with their analysis of genetic data to make and defend a claim on the cause behind the Connecticut Cat's movements.
ELABORATE	How can we apply what we've learned about mountain lions to another kind of big cat?	Students apply what they learned about mountain lions in North America to analyze data about cheetah populations in Africa, in order to make and defend a claim on the relationship between genetic variability and survival .
EVALUATE	How do changes in populations relate to genetic variation among individuals?	Students develop a model, based on evidence , to represent the cause behind the migration of the Connecticut cat at different scales .

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

How can we figure out where the Connecticut Cat came from?

Connecting to their earlier questions, students develop and share their initial ideas about how they can determine where the mountain lion hit by a car in Connecticut came from. Students develop a table that **lists the evidence** that would support each of **their ideas**.

Preparation

Student Grouping

☐ Pairs

Routines

☐ Rumors

Literacy Strategies

None

Materials

Handouts

- ☐ The Connecticut Cat
- ☐ Investigating Genetic Data

Lab Supplies

None

Other Resources

Surfacing Student Ideas

1. Revisit the story of the Connecticut Cat. Have students look at the range map showing North American mountain lion populations (from *The Connecticut Cat*).
2. Have students list the different hypotheses about where the mountain lion came from.
3. Have students decide what evidence they would need in order to test each hypothesis.
4. Use the group learning routine **Rumors** to share hypotheses and evidence that would be needed.

Implementation Tip



Students may struggle to come up with ideas for figuring out where the mountain lion came from. You may want to ask things like, "How would you figure out if a stray cat has an owner?" Possible hypotheses are in the table "Mountain Lion Hypotheses."

Routine



This is the first time the routine **Rumors** appears in this unit. The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. Please read the Biology Course Guide for detailed steps about this routine.

Mountain Lion Hypotheses

Independent Variable	Dependent Variable
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Escaped from captivity	Microchip, non-wild food in stomach/intestine, other evidence of care
Part of endemic population	Presence of other mountain lions in Connecticut
walked from another place	Sightings, common markings from another population, DNA commonalities with population from another area

Developing a Plan for Investigation

1. Organize student hypotheses and evidence. Explain that no microchip was found, food in the animal's intestine appeared to be deer meat, and there is no evidence of active mountain lion populations in the North East.

Look & Listen For



Students had the opportunity in Units 3 and 4 to consider how individuals and populations differ genetically. Listen for any students' thinking about looking at genetics and genetic similarities as a way to figure out where the mountain lion came from.

2. Let students know that in the next lesson we will look at genetic data to see if it can be used to determine where Connecticut Cat came from.
3. Have students work in pairs to develop a plan for using genetic data to determine the origin of the Connecticut Cat, using *Investigating Genetic Data*.

Explore

How can we use genetic data to determine where the Connecticut Cat came from?

Students **analyze patterns in genetic variation data** from five different populations of North American mountain lions (California, Mexico, South Dakota, Texas, Florida) in order to figure out where the Connecticut cat may have originated.

Preparation

Student Grouping

- ☐ Pairs

Routines

- ☐ Consensus Building Share

Literacy Strategies

None

Materials

Handouts

- ☐ Visualizing Karyotypes
- ☐ Interpreting Microsatellite Data
- ☐ Mountain Lion Genotype Data
- ☐ Mountain Lion Genotype Data Investigation
- ☐ Making Sense of the Mountain Lion Genotype Data Investigation
- ☐ Determining Confidence in Sample Sizes
- ☐ Mountain Lion Genotype Data Investigation Rubric

Lab Supplies

None

Other Resources

- ☐ Confidence Calculator
- ☐ Sample Size Explained

Visualizing Karyotypes

1. Give students the handout *Visualizing Karyotypes*. If students are unfamiliar with the term *karyotype*, explain that a karyotype is an image of a complete set of chromosomes, taken from one cell in an organism and arranged in numerical order.
2. Provide time for students to work in pairs to compare the karyotypes.
3. Invite a few students to share what they noticed, making sure to highlight key ideas about chromosomes.

Integrating Three Dimensions



In discussing Karyotypes, this is a great opportunity to review core ideas from **LS3.A Inheritance of Traits** from Unit 3, and to preview core ideas in **LS4.B Natural Selection** in relation to genetic variation.

Look & Listen For



Some ideas that should come up as students review the karyotypes are the following:

Similarities:

- Chromosomes come in pairs.
- One chromosome comes from the mother, and one comes from the father.
- There is one pair of chromosomes where they aren't always identical. This can be used to know the sex of the animal.

Differences:

- Humans and mountain lions have a different number of total chromosomes.
- Mountain lions have fewer total pairs of chromosomes.

4. Point out to students that while we are able to see the number of chromosomes and their structure through the microscope images, the images do not tell us about the specific genes on these chromosomes. Let students know that they will now have an opportunity to understand how scientists are able to determine specific genes on these chromosomes, using base pair sequences.

Interpreting Microsatellite Data

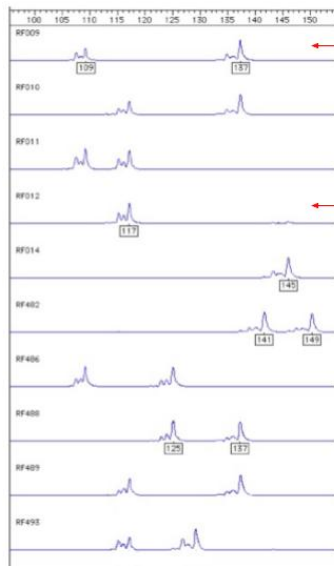
5. Provide students with the handout, *Interpreting Microsatellite Data*. Introduce the idea of microsatellite analysis, using the images in the handout. Explain that in every organism's chromosomes there are repeating sequences of base pairs that occur in different lengths and can be used to identify individuals. The microsatellites show up in sequencing software as little peaks that indicate the location of the repeated segment. Since chromosomes come in pairs, it is possible for one individual to have two different microsatellites (alleles) or two of the same. If there are two of the same alleles that location is homozygous. If the allele is different then it is heterozygous.

Note: The concept of heterozygosity vs homozygosity alleles is introduced here, but are not needed to identify which mountain lion population the Connecticut cat came from. They are introduced here simply to help students interpret the data. During the Engineering Gene Flow 5E, these concepts will need to be applied as they analyze the genetic diversity of various mountain lion populations, including the Florida Panther population before and after 1995 conservation efforts.

Implementation Tip



The microsatellite analysis might be really tricky for students to understand, especially if prior concepts like chromosomes and karyotypes had to be reviewed as well. In Unit 3, we looked at the idea of alleles and inheritance, and here we are looking at genetic data that does not necessarily code for a trait. These sections of DNA are markers, but not linked to phenotypes. Take time to help students unpack this visual if needed, because their ability to make sense of diagrams will affect the subsequent parts of this lesson. Use this visual, if helpful. The peaks on each microsatellite line are a reading from several copies of that allele. If an individual has two peaks they are heterozygous. If they only have one peak then they are homozygous.



Heterozygous. Each allele, from two different parents, is a different length.

Homozygous. Alleles from both parents are the same length.

- Support students to complete the Microsatellite Analysis table. It may be helpful to model determining allele length and zygosity for a few of the examples before having students work in pairs.

Investigation

- Give students the *Mountain Lion Genotype Data*. Let students know that the genetic data comes for scat samples that were collected randomly. In order to prepare students to analyze the complex data set, ask students to independently jot what they notice about the data table, then have students engage in a **Think-Talk-Open Exchange** routine to share initial noticings about the table, and elicit some high-level points from the class.

Look & Listen For



This mountain lion genotype table might be really overwhelming at first! It may be helpful to show students a video of animals in the wild being tagged and tracked, so they understand the idea of data from different individuals in a population.

Make sure to highlight the following ideas from the class:

- Each code in the left column represents a unique, individual mountain lion.
- There are five mountain lions from each location – this is only a sample of the entire population from each location
- There are four different microsatellites we are comparing here: A106, A312, B207, B316.
- For each gene there are lots of different possible alleles!

2. Give students the *Mountain Lion Genotype Data Investigation*. Have students analyze the data in the *Mountain Lion Genotype Data*, in order to identify and list the alleles found in each population. These are *unique alleles*. Then have students identify alleles that are only found in one population. These are *private alleles*.

Whole-Class Investigation Summary

3. Provide students with *Making Sense of the Mountain Lion Genotype Data Investigation*. Ask students to work independently to complete the See-Think-Wonder, then discuss their observations, thoughts, and wonderings as a way to make sense of the investigation.
4. In table groups, have students discuss the guiding prompt: *Where do you think the Connecticut Cat came from? Evaluate the evidence you used to make that conclusion.*
5. Tying into student questions about population and sample sizes (e.g. Why are we only looking at the genetics from 5 individuals?), show students the video [Sample Size Explained](#). Explain to students that different sample sizes, in relation to total population size, result in different “confidence intervals” and “standard errors.” Show them the online tool [Confidence Calculator](#) for calculating these statistical measures.

Tell them that the “confidence interval” means how many percentage points the answer could be between. A confidence interval of 0.05 means that the actual result is within 5% of your answer, while a confidence interval of .25 means that the actual result is within 25% of your answer. For example: if we use sample size 20 in a population of 10,000, the “confidence interval” produced by the calculator will be .225; if we calculate an average using that sample size of 20, that average will be within 22.5% of the true average of the whole population of 10,000.

Standard error refers to the amount that the real answer could vary from your answer. The lower the standard error and confidence intervals, the more confident students can feel in their data. In this case, the lower these two metrics, the more confident students can be that the samples contain all of the alleles in the population.

6. Have students use the tool [Confidence Calculator](#) to complete the final page of *Determining Confidence in Sample Sizes*, *Determining Confidence in Sample Sizes*.
7. Use the group learning routine, **Consensus Building Share**, to share student ideas.

Routine



This is the first time the routine **Consensus-Building Share** appears in this unit. This routine is a way to make sensemaking visible and move towards a class-wide consensus around a new idea. As the whole-class activity for this Explore, it is important to surface as many of the ideas in the Look and Listen For section as possible.

For the first time using this routine, it is appropriate to prompt students with questions such as “Did any group find something similar?” or “Can anyone add to that?” Be sure to look at the Biology Course Guide for the action pattern for this routine.

Look & Listen For



- I think the Connecticut Cat came from the South Dakota mountain lion population.
- The Connecticut Cat genetic data indicates the presence of PcoA106 (length 258), PcoB207 (length 302), PcoB316 (length 272).
- These are private alleles only found in the South Dakota population, so that's the only population from which the Connecticut Cat could have inherited those genes.
- Based on statistical analysis, we can be relatively confident (about 80%) that no region's population, other than South Dakota's, contains the set of alleles found in the CT cat
- Increasing the sample size would improve our confidence in our conclusion
- Students may wonder why a cat from South Dakota would be found in Connecticut

8. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
9. Provide students with *Mountain Lion Genotype Data Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Explain

Why would a mountain lion roam so far from his home territory?

Students incorporate **descriptions of mountain lion behavior** with their **analysis of genetic data** to **make and defend a claim** on the **cause** behind the Connecticut Cat's movements.

Preparation

Student Grouping

- ☐ Table groups

Routines

- ☐ Read-Generate-Sort-Solve
- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Genotype Data Read-Generate-Sort-Solve
- ☐ Summary Task

Lab Supplies

None

Other Resources

Develop and Defend a Claim

1. Review what students figured out in the Explain phase, that based on the genetic evidence, the cat's original population is from South Dakota. Point to or highlight remaining students' questions, such as why the cat would be found so far away from home as a transition.
2. Prompt students to work in small groups on the *Genotype Data Read-Generate-Sort-Solve*, using the data analyzed in the investigation, and the on-line texts. Students respond to the prompt: Using the patterns found in the genetic data, and scientific concepts discussed in the articles: Develop and defend a claim on why the Connecticut Cat roamed so far from its original location. Students can use **text annotation** to pull out important information.
3. At the end of the **Read-Generate-Sort-Solve** routine, each group should have a solid idea to share with the class.

Routine



The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. This is the first time this routine appears in this routine. Be sure to refer to the Biology Course Guide for planning support.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:

"We have a lot of different ideas circulating in the room right now, and they are in the form of different claims along with evidence and reasoning for our claims. It is really important for us to get to some agreement on what happened with this Connecticut Cat, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First I will select a few different groups to share their ideas. Then, we will discuss what we can agree to as a class."

2. You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

3. Select two or three groups' ideas to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how and why animals seek genetic diversity. The decision about which models to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
4. Ask the first group to share their ideas. You can do this by:
 - Projecting using a document camera; OR
 - Copying the idea to be shared and passing them out to the class
5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.
6. Return to student questions from the start of the 5E (Engage), in order to bring up lingering issues not yet resolved, such as:
 - Where did the mountain lion come from?
 - How do we know?

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas.

This is the first time doing such a discussion in this unit, so focus more on the steps and the process. In future parts of this unit, you will use this format to do more in-depth discussions and consensus building. Refer to the Biology Course Guide for support with this routine.

Integrating Three Dimensions



This first lesson sequence is a great opportunity to formatively assess student understanding of the Disciplinary Core Ideas bundled in this unit. In this Explain phase, students can demonstrate their **partial** use of several core ideas from **LS3.B Variation of Traits**, **LS1.B Growth and Development of Organisms**, and **LS4.B Natural Selection**.

Take Time for These Key Points



Pause the discussion and ask for clarification, particularly of the following key points:

- The role of genetic data in explaining where an organism is from.
- Genetic data in a population represents all of the allele variations of that population – as individuals reproduce with other individuals in their population
- Genes/alleles are inherited from parents to offspring
- The patterns in the genetic data demonstrated that some populations had more private alleles than others (some had more genetic variation than others)
- The patterns found in the map demonstrate that the individual cat walked very far without encountering a new population of mountain lions – also it seemed to avoid large cities, etc
- Behavioral traits, such as the dispersion of males from ancestral population, may have contributed to the cat's impulse to move away from his original population – this could be an example of an advantageous behavioral trait acted upon by natural selection
- The majority of the data provided (and reasoning) lends itself to the claim that the Connecticut Cat's impulse to migrate may have been to find a mate (sexual reproduction)

Summary Task

1. . Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to circle back to the ideas in this text, in the coming parts of the 5E lesson.

Summary Task

How did the class discuss discussion #2?

1. One thing that was in the discussion:
2. One thing we can improve the next time we have a discussion:
3. One person who helped me learn today: _____
What did I learn from this person?
4. One idea that contributed to my group or my class:

Explain what you know about the following questions, based on what we discussed today.

1. Evaluate the evidence and reasoning raised in the following claims. The Connecticut cut was originally from populations in South America. It traveled to Connecticut based on the transportation trail of slave shippers. The evidence is that the Connecticut cut was not directly related to him. Its great response, he said to include the evidence that the Connecticut cut was not directly related to him. Its great response, he said to include the evidence that the Connecticut cut was not directly related to him.
2. "Evaluation of the evidence" - what additional evidence would you want to rely on to really be confident about a better cause and effect relationship?
3. "Evaluation of the reasoning" - what additional reasoning would you want to rely on to really be confident about a better cause and effect relationship?

What conclusions or additional critiques can you discuss?

What conclusions or additional critiques can you discuss?

Implementation Tip



This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas.

Elaborate

How can we apply what we've learned about mountain lions to another kind of big cat?

Students apply what they learned about mountain lions in North America to **analyze data** about cheetah populations in Africa, in order to **make and defend a claim** on the **relationship between genetic variability and survival**.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Are Cheetahs Like Mountain Lions?

Lab Supplies

None

Other Resources

- ☐ Cheetahs: On the Brink of Extinction, Again | National Geographic Society
- ☐ Cheetahs 101 | Nat Geo Wild

Comparing with Cheetahs

1. Provide students with *Are Cheetahs Like Mountain Lions?*
2. In this task, students use genetic data on cheetahs, along with readings and text, to surface ways that their learnings about mountain lions are relevant to other big cats. Students then make and defend a claim about the genetic variability of cheetah populations, and their ability to adapt and survive as a species. In addition to the factors affecting mountain lions, students also learn that in addition to current habitat loss, cheetah populations went through two bottlenecks, one about 100,000 years ago when they rapidly expanded their range and another during the last ice age so their genetic diversity was already diminished.
3. Students draw on the following resources for this task:
 - a. Historical and Present Distribution of Cheetahs in Africa in *Are Cheetahs Like Mountain Lions?*
 - b. Cheetah Genetic Diversity Sample in *Are Cheetahs Like Mountain Lions?*
 - c. [Cheetahs 101 | Nat Geo Wild](#)
 - d. [Cheetahs: On the Brink of Extinction, Again | National Geographic Society](#)

Integrating Three Dimensions



This task is a great opportunity to review the disciplinary core ideas **LS4.B Natural Selection** and **LS4.C Adaptation**, that were first introduced in Unit 2 Humans vs Bacteria.

Implementation Tip



The cheetah task introduces the idea of mutations, inbreeding, and the often beneficial nature of genetic variation for survival of a species. These concepts will be further explored and developed as students move through the storyline, so students should not be expected to master these core ideas yet, or have a full picture of how they relate to the migration of the Connecticut cat at this point in the unit.

Evaluate

How do changes in populations relate to genetic variation among individuals?

Students **develop a model, based on evidence**, to represent the **cause behind the migration** of the Connecticut cat at **different scales**.

Preparation

Student Grouping

- ☐ Table groups

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Mountain Lion Populations
- ☐ Mountain Lion Populations Mini Rubric

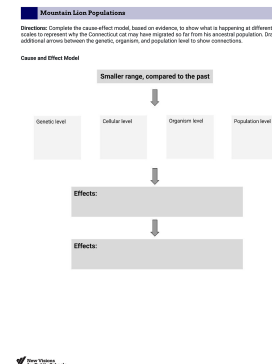
Lab Supplies

None

Other Resources

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence (for example: Why did the mountain lion end up in Connecticut?).
2. Students work individually on *Mountain Lion Populations*, in the Performance Task Organizer. They should make choices on how to represent their ideas using the model they are developing.
3. Confer with students while they are working.



Conferring Prompts



Confer with students as they work to develop their cause-effect models.

Suggested conferring questions:

- How are you using patterns at different scales to figure this out?
- Are there boxes that may be empty at this point in your learning?
- How did the cheetah data and reading inform your model?
- What evidence are you using to develop your model?

4. After completing their response, use the *Mountain Lion Populations Mini Rubric* to generate self, peer, or teacher feedback on their model and scientific reasoning. This feedback will be used to inform further iterations of the performance task throughout the unit.

Implementation Tip



When returning to the **Driving Question Board**, be sure to change these suggested teacher notes so that they match your class' actual questions!

Revisit the Driving Question Board

1. Use the **Driving Question Board** routine to discuss which of their questions have been answered.
2. Have students identify which categories/questions they have not figured out yet. Students should share out these questions, and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

Implementation Tip



Use the **Driving Question Board** unit routine to document students' evolving questions.

Standards in Mountain Lion Populations 5E

Performance Expectations

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.

In NYS the entire PE has been edited as follows: 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, (3) mutations caused by environmental factors and/or (4) genetic engineering. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs including the relevant processes in meiosis and advances in biotechnology.] [Assessment Boundary: Assessment does not include recalling the specific details of the phases of meiosis or the biochemical mechanisms of the specific phases in the process.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Developing and Using Models

- 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. SEP2(3)

Analyzing and Interpreting 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. SEP4(2)

Engaging in Argument from 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. SEP7(5)

Disciplinary Core Ideas

LS3.B Variation of Traits

- 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. LS3.B(1)

LS4.B Natural Selection

- 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. LS4.B(1)

Crosscutting Concepts

Patterns

- 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. CCC1(1)

Cause and Effect

- Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models				Are Cheetahs Like Mountain Lions?	Mountain Lion Populations Mountain Lion Populations Mini Rubric
Analyzing and Interpreting Data		Making Sense of the Mountain Lion Genotype Data Investigation			
Engaging in Argument from Evidence			Class Consensus Discussion Genotype Data Read-Generate-Sort-Solve Summary Task	Are Cheetahs Like Mountain Lions?	Mountain Lion Populations
LS3.B Variation of Traits	Investigating Genetic Data	Making Sense of the Mountain Lion Genotype Data Investigation	Class Consensus Discussion Genotype Data Read-Generate-Sort-Solve Summary Task	Are Cheetahs Like Mountain Lions?	Mountain Lion Populations Mountain Lion Populations Mini Rubric
LS4.B Natural Selection			Summary Task	Are Cheetahs Like Mountain Lions?	Mountain Lion Populations Mountain Lion Populations Mini Rubric
Patterns		Making Sense of the Mountain Lion Genotype Data Investigation			Mountain Lion Populations Mountain Lion Populations Mini Rubric
Cause and Effect			Class Consensus Discussion Genotype Data Read-Generate-Sort-Solve Summary Task	Are Cheetahs Like Mountain Lions?	Mountain Lion Populations Mountain Lion Populations Mini Rubric

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics			MP3		
ELA/Literacy	SL.9-10.1	SL.9-10.1 SL.9-10.4	WHST.9-10.2 SL.9-10.1	RST.9-10.1	

Student Work for Mountain Lion Populations 5E

Example Student Work for the Performance Task

Example 1

Mountain Lion Populations	Directions: Complete the cause-effect model, based on evidence, to show what is happening at different scales to represent why the Connecticut cat may have migrated so far from his ancestral population. Draw additional arrows between the genetic, organism, and population level to show connections.
----------------------------------	---

CAUSE AND EFFECT MODEL			
The mountain Lion has a smaller Range, compared to the past			
Genetic Level	Cellular Level	Organism Level	Population Level
		He decided to leave his pack because he wants to form his own pack and have another territory.	The population is decreasing because people are killing it for doing things that they do by nature.
Effects: But his decision to leave his pack caused his death since he was hit by a truck.			
Effects: This decrease is causing them to fight among themselves over the females in the herd.			

REFLECTION
1. Use your model to explain how patterns at different scales helped you identify causality and to explain what happened to the Connecticut cat.
Our animals are very different and equal at the same time since both of them have to leave their herd to be able to form a family since the largest ones take over the females and this causes them to leave their herd in search of a partner. and that they die by a car or by a predator, making these species increasingly in danger of extinction.

2. Describe the evidence you used to develop your model.

The evidence that I used to realize how each species is becoming extinct, whether due to themselves, pests or humans, was to see the graphs of the class example and the example that I chose since in both graphs we can see how each time they are disappearing. The evidence that I used to realize how each species is becoming extinct, whether due to themselves, pests or humans, was to see the graphs of the class example and the example that I chose since in both graphs we can see how each time they are disappearing.

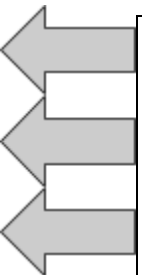
3. Describe the scientific reasoning you used to develop your model

Well, in the species that I chose I could read that there was a plague that killed most of them so these animals not only die because of humans, they also die from natural disasters which shows us another way of how the species of many animals Every day they are becoming more and more extinct since there are thousands of diseases and pests that can cause their death.

CAUSE AND EFFECT MODEL

The mountain Lion has a smaller Range, compared to the past

Genetic Level	Cellular Level	Organism Level	Population Level
Mountain lions must find females to reproduce. The one in Connecticut was looking for a mate to reproduce and pass down its genetic material to a new offspring.	No evidence so far about the cellular level	The mountain lions have to move away from their own group since males must find their own territory with females to mate.	Mountain lion populations are small since males have a big range. They control a large territory with several females. There are less females available in the United States today.



Effects Genetic Level:	Effect Cellular Level:	Effect Organism Level:	Effect Population Level:
Since reproduction is the objective of a male mountain lion, having a smaller amount of females available results in a smaller gene pool (less alleles)	No evidence found yet	Mountain lion males must move from the original group to find a new mate. Having a smaller population of females in the United States results in a bigger area they have to cover and more risk because of humans (hunting) and cities (cars/highways).	This is connected to the organism level. Mountain lions used to have more individuals and more areas available to use to mate. Today the presence of humans and cities reduced their number and area of roaming causing the lion to travel further and reducing the chances to find a mate to reproduce.

REFLECTION



1. Use your model to explain how patterns at different scales helped you identify causality and to explain what happened to the Connecticut cat.

The different scales helped me look at the root cause of the issue. The need for a mate and finding a female is based on the genetic need of each organism to pass down its traits to the next generation. Organisms must reproduce to pass down their DNA. The mountain lion behavior at the organism and population level is linked to the concept of passing down trait: the lion must leave their original population and find a mate in a different area so they do not compete with other males.

2. Describe the evidence you used to develop your model.

*I used the **map** from the unit opening to discuss the mountain lion range. I also used the **alleles data table** to figure out where the lion came from. (South Dakota). I used the **text** to figure out that mountain lions must move far away from their original population to find a female to mate.*

3. Describe the scientific reasoning you used to develop your model

I learned from unit 3 that traits are passed down from parents to offsprings. The purpose of mating is to pass down the genetic information to the offspring and since the text stated that the mountain lion was looking for a mate, he was trying to pass down its DNA and its traits. I also used the text to connect the reason why at the organism and population level the mountain lions have to leave their group to find their territory with females to mate.



Sexual Reproduction 3E (optional)

How can we understand the abnormalities seen in the Florida mountain lion population?

Performance Expectations
HS-LS1-8

Investigative Phenomenon
Florida panthers, a population of mountain lions, possessed a set of strange traits.

Time
3 days

Florida mountain lions possess a set of abnormal traits, many of which impact the reproductive system of male lions. In this 5E students investigate how these abnormalities impact sexual reproduction.

ENGAGE	Why are there a high number of strange traits in a small population of Florida mountain lions?	Students surface their prior knowledge on mutations and sexual reproduction after examining an image and reading a brief text about a small population of Florida mountain lions.
EXPLORE	How do mountain lions sexually reproduce?	Students use models based on evidence to closely examine the structure and function of the reproductive system .
EXPLAIN	How do the abnormalities seen in the Florida mountain lions impact their ability to successfully reproduce?	Students use models based on evidence to understand more about how abnormalities in structure may impact the functioning of the reproductive system .
ELABORATE	This 3E has no Elaborate	
EVALUATE	This 3E has no Evaluate	

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

Why are there a high number of strange traits in a small population of Florida mountain lions?

Students surface their prior knowledge on **mutations** and **sexual reproduction** after examining an image and reading a brief text about a small population of Florida mountain lions.

Preparation

Student Grouping

☐ Pairs

Routines

☐ Questions Only

Literacy Strategies

None

Materials

Handouts

☐ Florida Mountain Lions

Lab Supplies

None

Other Resources

Differentiation Point

- ☐ ↔ ☐ This entire 3E lesson sequence is **optional** and is designed for students that need more support in understanding sexual reproduction. If students have a strong understanding of sexual reproduction from middle school, this 3E sequence can be omitted.
- ☐ ↔ ☐
- ☐ ↔ ☐

Integrating Three Dimensions



This 3E lesson sequence addresses the **New York State Science Learning Standards Performance Expectation HS-LS1-8**, which is not included in the Next Generation Science Standards.

Surfacing Student Ideas

1. Point to students earlier ideas and questions about the dispersal (movement) of the Connecticut cat. Let students know that we are going to look at a specific population of mountain lions to help us understand more about why he strayed so far from his home population.
2. Provide students with *Florida Mountain Lions*. Students individually read the brief text, annotating for new or interesting information about this population of mountain lions that lived in Florida.
3. Use the group learning routine, **Questions Only**, to support students in generating and discussing questions about the Florida mountain lions.

Look & Listen For



- How do the kinked tails impact the mountain lions?
- What is testosterone?
- What is an undescended testis, and how does it impact sexual reproduction?
- Do the females have problems as well?
- How do these problems impact sexual reproduction?
- Are the problems, such as the kinked tail, a result of a mutation?
- Why do these problems occur?

Routine



The **Questions Only** routine offers students an opportunity to generate questions that can guide their investigations about a phenomenon. This is the first time this routine appears in this unit! Please read the Biology Course Guide for detailed steps about this routine.

Explore

How do mountain lions sexually reproduce?

Students **use models based on evidence** to **closely examine the structure and function** of the **reproductive system**.

Preparation

Student Grouping

- ☐ Pairs
- ☐ Table groups

Routines

- ☐ Domino Discover
- ☐ Consensus Building Share

Literacy Strategies

None

Materials

Handouts

- ☐ Sexual Reproduction Models Investigation
- ☐ Making Sense of Sexual Reproduction Models Investigation
- ☐ Sexual Reproduction Models Investigation Rubric

Lab Supplies

None

Other Resources

- ☐ *Sexual Reproduction Models*

Launch

1. Highlight student questions about the reproductive abnormalities seen in the Florida mountain lions, and how those abnormalities may impact sexual reproduction surfaced in the Engage phase. Remind students that we often investigate how something works in one organism, in order to better understand how it works in another organism (especially if the process is similar in both organisms!) This time, we will closely examine sexual reproduction in humans, to better understand sexual reproduction in mountain lions and how the abnormalities may be impacting their reproduction.
2. Prompt students to consider what is similar and different between reproduction in humans and mountain lions. Use the group learning routine, **Domino Discover**, to create a T-chart on the board, comparing and contrasting reproduction in both species.

Investigation

1. Using student ideas from the T-chart, highlight the idea that both humans and animals (all mammals) create babies on the inside of the mother (either internal fertilization and/or internal development). If students did not bring up ideas around commonalities such as both being mammals, prompt students to think back to the lactose persistence reading they did in Unit 3, which outlined the role of milk in the nourishment of all mammals (including humans, cows, etc.) Let students know that we will use this idea as our lens for investigating the reproductive system.

Implementation Tip



This investigation focuses on the functions of each structure, and does not teach meiosis. It may be helpful to your class to mention that the egg and sperm cells are unique in that they are haploid instead of diploid, which allows for a diploid cell to be created during internal fertilization, and that the ovaries and testes have the function to make this type of cell through the process of meiosis. The details of the process of meiosis and its capacity for creating genetic variation are further investigated in a later 5E.

2. In pairs or table groups, provide students with *Sexual Reproduction Models* and their individual *Sexual Reproduction Models Investigation*. Students first work in pairs to make sense of the models and to describe at least one structure and its function in detail.

Whole-Class Investigation Summary

1. Provide students with *Making Sense of Sexual Reproduction Models Investigation*. Ask students to work independently to complete the See-Think-Wonder, then discuss their observations, thoughts, and wonderings as a way to make sense of the investigation.
2. In table groups, have students discuss the guiding prompt: How does closely examining the structures of the reproductive system help us understand the functions of those structures, and how parts of the system interact to produce offspring?
3. Use the group learning routine, **Consensus Building Share**, to share student ideas.

Integrating Three Dimensions



In this phase, students have the opportunity to demonstrate their use of the **CCC#6 Structure and Function**, in service of understanding the structure and function of the human reproductive system. The **CCC#4 Systems and Systems Models**, a part of the performance expectation for this learning cycle is not assessed here, but is used by students in other units, including Unit 6 Woolly Mammoth.

Routine



The **Consensus-Building Share** routine is a way to make sensemaking visible and move towards a class-wide consensus around a new idea. As the whole-class activity for this Explore, it is important to surface as many of the ideas in the Look and Listen For section as possible. Be sure to look at the Biology Course Guide for the action pattern for this routine.

Look & Listen For



- The penis is shaped to deliver sperm inside the vagina
- The sperm has a tail (to swim to meet the egg)
- The penis functions in the reproductive and urinary systems
- The scrotum protects the testes
- The uterus is designed to protect the developing baby
- Fallopian tubes used to transport egg (ova)
- Ova has 'protective' cells
- Placenta has space for blood vessels of mother & baby (but blood doesn't touch) – materials can be exchanged
- Overall - everything is designed for reproduction to occur inside the female's body
- The models of the reproductive system are based on evidence such as imaging of structures, post-mortem observations, and observations of other mammals reproductive system

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
5. Provide students with *Sexual Reproduction Models Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Access for Multilingual Learners



Consensus-Building Share provides receptive language opportunities for students who are **entering and emerging** language learners. For those who are **transitioning and expanding**, this routine provides time to rehearse language with peers, so that students are not responsible for on-the-spot responses before they are ready.

Explain

How do the abnormalities seen in the Florida mountain lions impact their ability to successfully reproduce?

Students **use models based on evidence** to understand more about how abnormalities **in structure may impact the functioning** of the **reproductive system**.

Preparation

Student Grouping

- ☐ Pairs
- ☐ Table groups

Routines

- ☐ Think-Talk-Open Exchange + Buzzwords

Literacy Strategies

- ☐ Sequence Chart

Materials

Handouts

- ☐ Florida Mountain Lion Reproduction TTOE
- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ *Sexual Reproduction Models*
- ☐ *Sexual Reproduction Female Sequence Chart Cards*
- ☐ *Sexual Reproduction Male Sequence Chart Cards*

Using Models to Understand Sexual Reproduction

1. Remind students that at the end of the Engage phase, they had questions about some of the abnormalities found in the Florida population, like low sperm count and low testosterone and how those traits may impact their ability to reproduce. Highlight student ideas discussed at the end of the Explore phase that point to the male reproductive system in particular, as that is where many of the abnormalities were found. Use these ideas to transition to needing to understand more about how the reproductive system works so we can explain why the abnormalities may be a problem.
2. Provide table groups of students with the *Sexual Reproduction Models*, *Sexual Reproduction Female Sequence Chart Cards* and *Sexual Reproduction Male Sequence Chart Cards*. Students use the card sets (and the models) to develop a sequence of key events in the process of sexual reproduction. Note that there is no wrong way to start the sequence (male or female processes are occurring at the same time), but should follow a logical sequence of events. Be sure to mix the cards up before providing them to students (keeping male and female cards separate).
3. Once student table groups have a sequence that makes sense, provide them with *Florida Mountain Lion Reproduction TTOE*. Allow students time to look through and discuss both sequences as a group. Then, individually, students respond to the original prompt on their handout: Using the models and your understanding of the structure and function of the reproductive system, discuss why the abnormalities

Routine



During the **Think-Talk-Open Exchange** routine, students share with others and gain feedback on their ideas by finding similarities and differences, piecing together disparate bits of information, or reconciling different interpretations. This is a variation called **Think-Talk-Open Exchange + Buzzwords** which needs a little additional introduction. Refer to the Biology Course Guide for support with this routine.

found in the Florida population may be disadvantageous for them. Encourage students to use the included buzzwords.

4. Use the group learning routine, **Think-Talk-Open Exchange + Buzzwords**, to surface student ideas on the phenomenon under study (the reproductive abnormalities in the FI mountain lion population).

Take Time for These Key Points



- Low testosterone may limit the amount (or health) of the sperm, so fewer chances the sperm will successfully travel through the cervix and into the fallopian tube in order to reach the egg for internal fertilization
- Low sperm count so fewer chances the sperm will successfully travel through the cervix and into the fallopian tube in order to reach the egg for internal fertilization
- Undescended testes may limit the amount (or health) of the sperm because it may be unprotected from high temperatures (or other issues), so fewer chances the sperm will successfully travel through the cervix and into the fallopian tube in order to reach the egg for internal fertilization
- Holes in the heart may limit blood flow, limiting blood circulation for both males and females. In females it may limit her ability to provide sufficient oxygen and nutrients to the developing fetus through the placenta. In males it may limit his ability to find mates, or the engage in sexual intercourse
- Same idea as above with high infection rate and parasite load for both males and females

5. Provide students with the *Summary Task* to complete individually.

Elaborate

This 3E has no Elaborate

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

Evaluate

This 3E has no Evaluate

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

Standards in Sexual Reproduction 3E (optional)

Performance Expectations

HS-LS1-8

Clarification Statement:

Assessment Boundary:

This PE, added by NYS, is not in the NGSS: Use models to illustrate how human reproduction and development maintains continuity of life. [Clarification Statement: Emphasis is on structures and function of human reproductive systems, interactions with other human body systems, embryonic development, and influences of environmental factors on development.] [Assessment Boundary: Assessment does not include the details of hormonal regulation or stages of embryonic development.]

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Developing and Using Models

- 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. SEP2(3)

Disciplinary Core Ideas

LS1.A Structure and Function

- The structures and functions of the human female reproductive system produce gametes in ovaries, allow for internal fertilization, support the internal development of the embryo and fetus in the uterus, and provide essential materials through the placenta, and nutrition through milk for the newborn. The structures and functions of the human male reproductive system produce gametes in testes and make possible the delivery of these gametes for fertilization LS1.A(5)NYS

LS1.B Growth and Development of Organisms

- The continuity of life is sustained through reproduction and development. Human development, birth, and aging should be viewed as a predictable pattern of events influenced by factors such as gene expression, hormones, and the environment. LS1.B(2)NYS

Crosscutting Concepts

Systems and Systems 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. CCC4(3)
-

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models		<i>Sexual Reproduction Models Investigation</i> <i>Making Sense of Sexual Reproduction Models Investigation</i> Consensus Building Share	<i>Florida Mountain Lion Reproduction TTOE Summary Task</i> TTOE Discussion		
LS1.A Structure and Function	Questions Only Discussion	<i>Sexual Reproduction Models Investigation</i> <i>Making Sense of Sexual Reproduction Models Investigation</i> Consensus Building Share	<i>Florida Mountain Lion Reproduction TTOE Summary Task</i> TTOE Discussion		
LS1.B Growth and Development of Organisms		<i>Making Sense of Sexual Reproduction Models Investigation</i>	<i>Florida Mountain Lion Reproduction TTOE</i> TTOE Discussion		
Systems and Systems Models		<i>Sexual Reproduction Models Investigation</i> <i>Making Sense of Sexual Reproduction Models Investigation</i> Consensus Building Share			

Common Core State Standards Connections

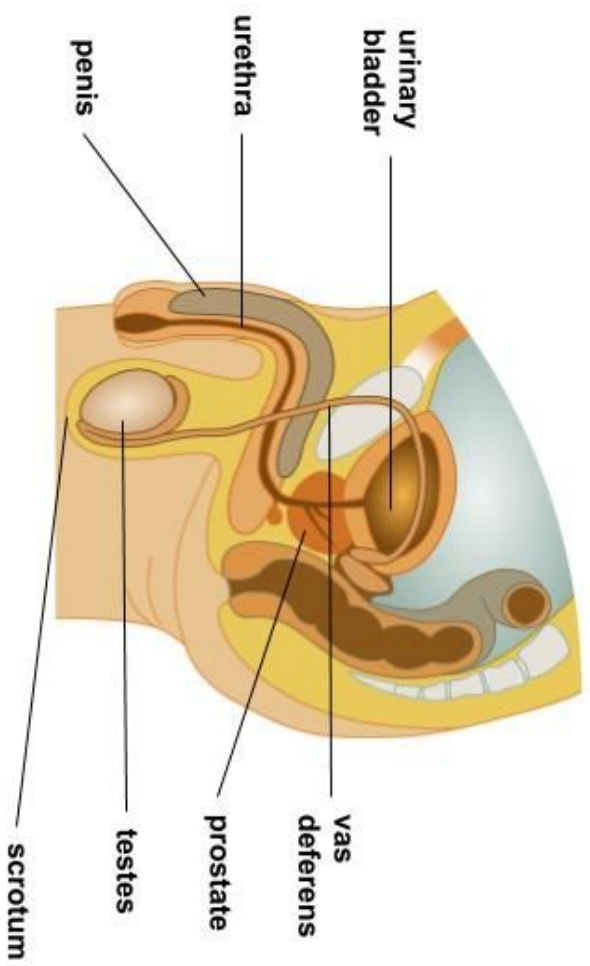
	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP6			
ELA/Literacy	SL.9-10.1		WHST.9-10.2 SL.9-10.1		

Classroom Resources for Sexual Reproduction 3E (optional)

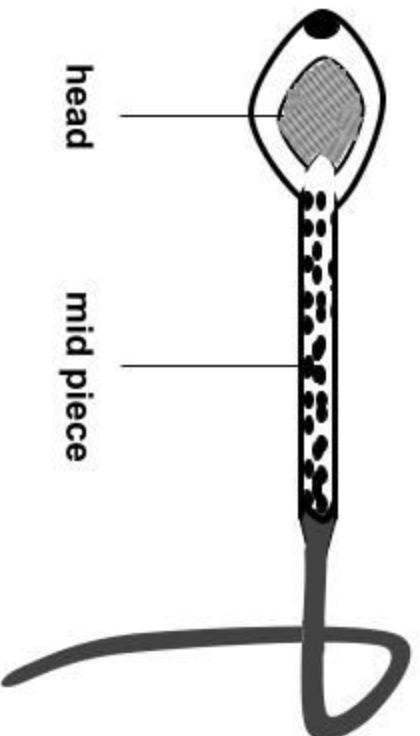
Sexual Reproduction Models

Sexual Reproduction Female Sequence Chart Cards

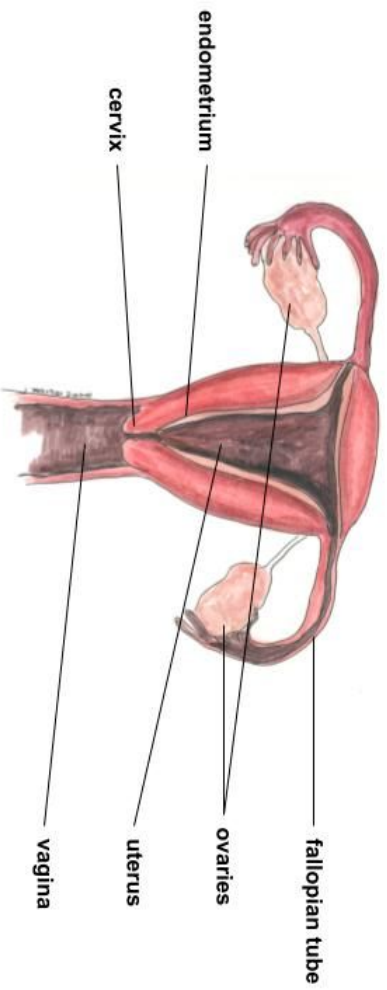
Sexual Reproduction Male Sequence Chart Cards



Male reproductive System



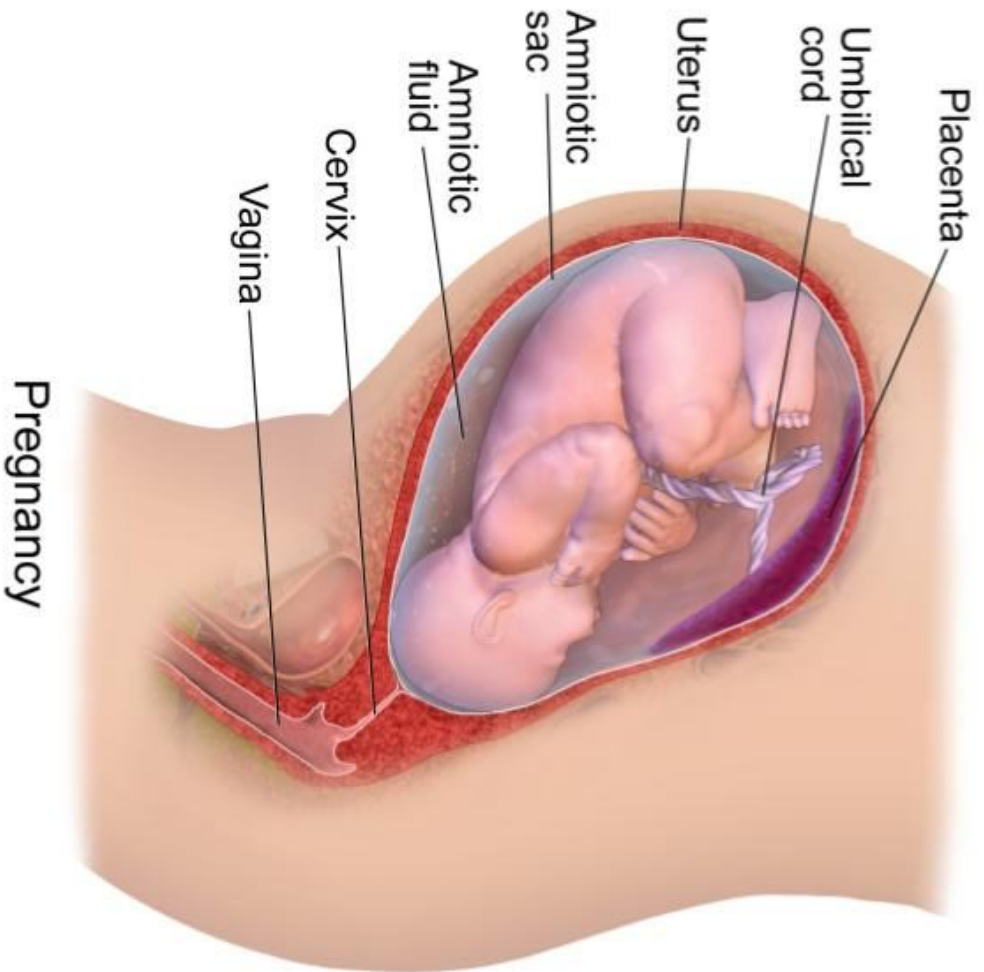
Male Sex Cell (Gamete)



Female Reproductive System



Female Sex Cell (Gamete)



Developing Fetus in The Female

Pregnancy

Sexual Reproduction Female Sequence Chart Cards

Use this master to create cards for the card sequence activity.



Estrogen, a hormone, stimulates the production of ova (an egg) in the ovaries. The ova is the female gamete.	Once mature, the ova is released from the ovaries and travels down the fallopian tube towards the vagina.	During sexual intercourse, the penis enters the female's vagina and deposits semen (which contains sperm) inside of the vagina.
If the sperm and ova meet in the fallopian tube, fertilization can occur. Fertilization is the joining of sperm and ova, which creates a single-celled zygote.	The zygote travels down the fallopian tube and settles into the lining of the uterus. The lining of the uterus is thick and rich in blood. This lining is maintained by the hormone progesterone.	The zygote grows through cell division (mitosis) and becomes an embryo. Once the embryo has reached a certain size it is called a fetus.

The sperm can travel (using its tail and sugar & nutrients found in semen) up through the narrow **cervix** to reach the fallopian tube.

As the fetus grows, the **placenta** develops. Small blood vessels of both the mother and fetus are found in the placenta, nutrients and wastes diffuse across the placenta to pass between the mother and the growing fetus.

Once the fetus is fully developed, hormones regulate the birth of the fetus (baby). The cervix expands, and the baby is pushed out through the vagina, from strong muscle contractions of the uterus.



Sexual Reproduction Male Sequence Chart Cards



Use this master to create cards for the card sequence activity.

Testosterone, a hormone, stimulates the production of sperm	Sperm, the male sex cell (or gamete) is made and stored in the testes of the male.	Sperm travels through a system of tubes called the vas deferens.
As the sperm travels through the vas deferens, fluids and nutrients are produced in the prostate and added to the sperm, creating semen.	When a male ejaculates, the semen moves into the urethra of the penis, and out of the opening of the penis. The urethra is also a structure of the urinary system.	During sexual intercourse, the semen leaves the penis and enters the vagina of the female



Sperm are sensitive to high body temperatures. Therefore, the testes are found outside of the body, protected inside of sac-like structure called the **scrotum**.



Genetic Variation 5E

Why is it advantageous for a mountain lion to seek variation?

Performance Expectations
HS-LS1-4, HS-LS4-3,
HS-LS3-2

Investigative Phenomenon
Florida panthers, a population of mountain lions, possessed a set of strange traits.

Time
6 days

In this 5E, students investigate how mutations in sex cells can lead to disadvantageous traits in a small population of mountain lions.

ENGAGE	Why are there a high number of strange traits in a small population of Florida mountain lions?	Students surface their prior knowledge on mutations and sexual reproduction after examining an image and reading a brief text about a small population of Florida mountain lions.
EXPLORE	How can we determine the genetic diversity of a population?	Students analyze and interpret genetic data in order to better understand the genetic diversity of a population.
EXPLAIN	How do abnormal traits increase in a population?	Students make and defend a claim on the cause behind the abnormalities seen in a small population of Florida mountain lions.
ELABORATE	Did toxins or other environmental factors cause the mutations leading to unique combinations of genes in the Chernobyl dogs?	Students engage with a text to consider the claim that the environment caused the unique genes seen in populations of dogs living in the Chernobyl Exclusion Zone. .
EVALUATE	How do changes in populations relate to genetic variation among individuals?	Students develop a model at different scales, based on evidence , to represent the cause of disadvantageous traits in mountain lions .

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

Why are there a high number of strange traits in a small population of Florida mountain lions?

Students surface their prior knowledge on **mutations** and **sexual reproduction** after examining an image and reading a brief text about a small population of Florida mountain lions.

Preparation

Student Grouping

☐ Pairs

Routines

☐ Rumors

Literacy Strategies

None

Materials

Handouts

☐ Florida Mountain Lions

Lab Supplies

None

Other Resources

Surfacing Student Ideas

1. Point to students earlier ideas and questions about the dispersal (movement) of the Connecticut cat. Let students know that we are going to look at a specific population of mountain lions to help us understand more about why he strayed so far from his home population.
2. Provide students with *Florida Mountain Lions*. Students individually read the brief text, annotating for new or interesting information about this population of mountain lions that lived in Florida. Have students check in with an elbow partner, what is happening with the Florida mountain lions?
3. In pairs, ask students to brainstorm how each of the abnormalities (kinked tails, heart problems, low sperm count, etc.) may impact an individual's ability to survive and reproduce. Chart their ideas.

Look & Listen For



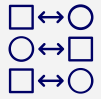
- Kinked tails may hinder communication or be painful
- Heart problems mean cardiovascular and blood flow issues, can't run or find food
- Low testosterone, low sperm count, undescended testes all may lead to reproduction problems (can't make babies to maintain the population)
- High parasite load may weaken individuals

Routine



The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. Please read the Biology Course Guide for detailed steps about this routine.

Differentiation Point



If students require additional background information on sexual reproduction, implement the optional Sexual Reproduction 3E plan.

4. Prompt students to brainstorm the cause behind these new and strange traits.
5. Use the group learning routine **Rumors** to surface student ideas behind the cause of these traits (kinked tails, reproductive problems).
6. Categorize student ideas

Look & Listen For



- Toxins in the environment
- Poor or lack of food or other resources like water
- Mutations or birth defects
- Stress

Explore

How can we determine the genetic diversity of a population?

Students **analyze and interpret genetic data** in order to better understand the **genetic diversity** of a population.

Preparation

Student Grouping

- ☐ Table groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Mountain Lion Genetic Diversity Investigation
- ☐ Making Sense of the Mountain Lion Genetic Diversity Investigation
- ☐ Mountain Lion Genetic Diversity Investigation Rubric

Lab Supplies

None

Other Resources

- ☐ [Mountain Lion Genetic Diversity Calculator](#)
- ☐ [Observed and Expected Heterozygosity \(optional\)](#)

Launch

1. Remind students that they were interested in understanding why the small population of mountain lions in Florida have strange traits such as kinked tails. Point to or elevate student ideas surfaced in the Engage phase about possible genetic issues or mutations to transition to the investigation.
2. Let students know that they are going to go back to the data they explored before, *Mountain Lion Genotype Data*, to learn more about the differences in alleles between different mountain lion populations in order to figure out what might be happening with the Florida population.

Investigation

1. Provide students with *Mountain Lion Genetic Diversity Investigation* and the same data set that they engaged with in the first 5E cycle, *Mountain Lion Genotype Data*, and access to the Google Sheet [Mountain Lion Genetic Diversity Calculator](#) (students will be prompted to make a copy).
2. Students follow the procedure in *Mountain Lion Genetic Diversity Investigation* to analyze the data.

Implementation Tip



This investigation requires students to pay close attention to a large data set, and to go back and forth between the data and their data tables with multiple populations. It may be helpful to have individual work time, and then allow students to confer in table groups to generate a group wide data set to minimize errors OR to assign pairs (or groups) different populations to work with and then create a set of class-wide data tables.

3. Provide students with the *Making Sense of the Mountain Lion Genetic Diversity Investigation* and prompt students to use the See-Think-Wonder graphic organizer to make sense of the data.
4. After students have had time to individually complete *Making Sense of the Mountain Lion Genetic Diversity Investigation*, pause and use the group learning routine, **Domino Discover**, to surface what students are seeing in the data and what questions they now have.

Look & Listen For



- Location PcoB207 has the most private alleles
- The S. Dakota population has the most private alleles
- All of the populations except Florida have a similar frequency of heterozygosity (average across all 4 chromosome locations)
- CA, Mexico, and S. Dakota all have a negative inbreeding coefficient
- FL and Texas have a positive inbreeding coefficient, with FL having the highest across all of the populations
- Patterns at the individual mountain lion, and at the population level were used to provide evidence for causality (what caused the abnormalities)
- What is inbreeding and what causes it?
- Why does the Florida population have the most positive inbreeding coefficient?
- How is inbreeding connected to the physical abnormalities displayed in the FL population?

5. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
6. Provide students with *Mountain Lion Genetic Diversity Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Integrating Three Dimensions



Keep in mind that students need to go beyond determining the genetic diversity in mountain lion populations; this investigation is designed to support them in engaging and understanding approaches to **SEP #4 Analyzing and Interpreting Data**, specifically the application of concepts of probability to scientific questions, using digital tools when feasible. Be sure to make **SEP #4 Analyzing and Interpreting Data** explicit for students by supporting them in understanding that an inbreeding coefficient is a comparison of the observed heterozygosity in a population to the expected heterozygosity which is based on probability, a good indication of the degree of inbreeding in a population.

Routine



Domino Discover is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Biology Course Guide for support with this routine.

Implementation Tip



If students do not know what inbreeding is, it is ok to define it for them at this point in the sequence. Inbreeding is defined as the probability of two alleles in an individual being identical by descent (from the parents), and is normally the result of mating related individuals. **Do not tell them the consequences** of inbreeding, as they will learn more about that later in the sequence (even though they may have ideas about it being a disadvantageous thing at this point from the cheetah discussion).

Differentiation Point



If students ask questions or show curiosity related to how expected heterozygosity is calculated, provide them with the video, [Observed and Expected Heterozygosity](#). This is a great opportunity for students to further develop facility with applying concepts of probability to scientific questions, an important element of **SEP #4 Analyzing and Interpreting Data** at the high school level.

Access for Multilingual Learners



Domino Discover provides receptive language opportunities for students who are **entering and emerging** language learners. For those who are **transitioning and expanding**, this routine provides time to rehearse language with peers, so that students are not responsible for on-the-spot responses before they are ready.

Explain

How do abnormal traits increase in a population?

Students **make and defend a claim** on the **cause** behind the **abnormalities** seen in a small population of Florida mountain lions.

Preparation

Student Grouping

- ☐ Triads
- ☐ Table groups

Routines

- ☐ Idea Carousel
- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation
- ☐ Concept Mapping

Materials

Handouts

- ☐ Abnormal Traits Note-taker
- ☐ Inbreeding Text
- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ [Mutations](#)
- ☐ [Differentiation](#)
- ☐ [Mitosis](#)

Accessing Multimedia to Explain a Phenomenon

1. Review unanswered questions from the Explore and Engage phases. Highlight that students still do not have a clear understanding of the causal mechanisms behind the physical abnormalities found in the Florida population. Let students know that they are going to explore some biological processes that may help us understand more about how all of these abnormalities occurred in the Florida mountain lion population.
2. In groups of three, assign each student one of three biological process to learn more about:
 - a. Mitosis
 - b. Differentiation
 - c. Mutations
3. As students access their resource set, they should use the note-taker, *Abnormal Traits Note-taker* to record patterns, information that may help them understand the cause behind the abnormalities, and questions they have about their assigned process.

Differentiation Point

- ☐ ↔ ☐ Create expert groups for students if they need additional time and support in accessing the resources and understanding their assigned process.
- ☐ ↔ ☐
- ☐ ↔ ☐

Routine



This is the first time the routine **Idea Carousel** appears in this unit! This routine supports groups of students in thinking through a set of related problems, tasks, or visuals, in order to develop a larger insight or discovery. Therefore, it's great for developing complex understandings of a phenomenon in science. For the first implementation, focus on having students learn the steps. Please read the Biology Course Guide for detailed steps about this routine.

4. After students have completed their individual note-taker, in groups, students should collaborate to respond to the guiding prompt:

Make and defend a claim, based on evidence and scientific reasoning, that explains the cause behind the abnormalities found in the Florida population.

5. Provide students with *Inbreeding Text*. Students should **annotate** the text, looking for additional information on the guiding prompt.
6. In table groups, students generate a **concept map** that represents their thinking on the guiding prompt. Prompt students to color-code their work to include the following:
 - a. The evidence for their claim (yellow)
 - b. How each of the three biological processes they investigated connects to their claim
 - i. Mitosis (blue)
 - ii. Mutation (orange)
 - iii. Differentiation (green)
7. Students use the group learning routine, **Idea Carousel**, to share their ideas with the whole class.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a **Class Consensus Discussion**. You may say something like this:
 - “We are going to use a class consensus discussion, just like we did in the last unit, to learn about all the thinking in the room and come to some decisions about why the Florida mountain lions have a high frequency of abnormalities and why this might be disadvantageous for the survival of the population.”
2. You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Refer to the Biology Course Guide for support with this routine.

3. Select one or two group posters to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of inbreeding, mutations, and how the lack of genetic diversity may lead to the inability of a species to adapt and survive. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
4. Ask the first student or group to share their explanation. You can do this by:
 - Projecting using a document camera; OR
 - Copying the written explanation to be shared and passing them out to the class; OR
 - Taking a picture of each explanation and projecting them as slides.
5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get “buried” in student talk.

Take Time for These Key Points



- The Florida population is small, which has led to inbreeding (the mating of closely related individuals)
- Inbreeding has caused low genetic variation in this population
- Random mutations occur in sex cells (sometimes they are detrimental mutations, but not always) → these mutations end up in every cell, but are only expressed in certain places in the body (based on which gene was mutated)
- Because the number of individuals is small in the Florida mountain lions, this has caused a build-up of mutations (changes in DNA) in the population that cause abnormalities (such as kinked tails, etc.)
- This has led to the increase in frequency of abnormal traits, like kinked tails, and less successful reproduction and survival overall, further decreasing the population.

6. Provide students with *Summary Task* to complete individually.

Elaborate

Did toxins or other environmental factors cause the mutations leading to unique combinations of genes in the Chernobyl dogs?

Students engage with a text to **consider the claim** that the environment **caused** the **unique genes** seen in populations of dogs living in the Chernobyl Exclusion Zone. .

Preparation

Student Grouping

☐ Triads

Routines

☐ Read-Generate-Sort-Solve

Literacy Strategies

None

Materials

Handouts

- ☐ Read-Generate-Sort-Solve Graphic Organizer
- ☐ Chernobyl Dogs

Lab Supplies

None

Other Resources

- ☐ CK-12 Reading Causes of Mutations
- ☐ CK-12 Reading Causes of Mutations Advanced
- ☐ CK-12 Reading Sources of Genetic Variation Advanced
- ☐ Are Contaminants Silencing Our Genes? (optional)
- ☐ computer access

Defending a Claim

1. Remind students of answered questions from the Engage phase, such as “did environmental toxins cause the abnormalities in the Florida mountain lions?” or a similar question. Ask students if they have answered this question, and how they know. Point out that although we read in the text that scientists could not find evidence of environmental toxins (or other mutagens that could have caused the abnormalities) in the Florida population, other organisms may be impacted by this.
2. Tell students that they will now look at a different example of animals living in isolated populations to determine if environmental toxins might be causing the changes observed in those groups.
3. Provide students with *Read-Generate-Sort-Solve Graphic Organizer* and *Chernobyl Dogs*, and a computer with internet to access on-line texts, [CK-12 Reading Causes of Mutations](#) , [CK-12 Reading Causes of Mutations Advanced](#) (advanced), [CK-12 Reading Sources of Genetic Variation Advanced](#) (advanced). Jigsaw the texts in triads.
4. Students use the routine **Read-Generate-Sort-Solve**, looking for information in the text that helps them defend the claim that environmental toxins caused the genetically unique populations of dogs in

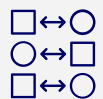
Routine



The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. Refer to the Biology Course Guide for planning support.

Chernobyl.

Differentiation Point



Jigsaw the texts based on readiness and interest. Additionally, based on readiness, provide students with [Are Contaminants Silencing Our Genes?](#), which draws on their understanding of non-coding DNA from Unit 3 and discusses the idea that certain chemicals may cause mutations that silence genes and cause chronic illnesses such as diabetes and cancer.

Evaluate

How do changes in populations relate to genetic variation among individuals?

Students **develop a model** at **different scales**, **based on evidence**, to represent the **cause** of **disadvantageous traits in mountain lions**.

Preparation

Student Grouping

- ☐ Table groups

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Genetic Variation
- ☐ Genetic Variation Mini Rubric

Lab Supplies

None

Other Resources

Revist the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence (for example: How are reduced ranges impacting mountain lions?).
2. Students work individually on *Genetic Variation*, in the Performance Task Organizer. They should make choices on how to represent their ideas using the model they are developing.
3. Confer with students while they are working.

Conferring Prompts



Confer with students as they work to develop their cause-effect models.

Suggested conferring questions:

- How are you using patterns at different scales to figure this out?
- Are there boxes that may be empty at this point in your learning?
- How did the Florida panther data and readings (inbreeding text and mutation texts) inform your model?
- What evidence are you using to develop your model?

4. After completing their response, use the *Genetic Variation Mini Rubric* to generate self, peer, or teacher feedback on their model and scientific reasoning. This feedback will be used to inform further iterations of the performance task throughout the unit.

Implementation Tip



When returning to the **Driving Question Board**, be sure to change these suggested teacher notes so that they match your class' actual questions!

Revisiting the Driving Question Board

1. Use the **Driving Question Board** routine to discuss which of their questions have been answered.
2. Have students identify which categories/questions they have not figured out yet. Students should share out these questions, and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

Standards in Genetic Variation 5E

Performance Expectations

HS-LS1-4

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

Clarification Statement: None

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

In NYS the entire PE has been edited as follows: Use a model to illustrate cellular division (mitosis) and differentiation. [Clarification Statement: Emphasis should be on the outcomes of mitotic division and cell differentiation on growth and development of complex organisms and possible implications for abnormal cell division (cancer) and stem cell research.] [Assessment Boundary: Assessment does not include specific gene control mechanisms or recalling the specific steps of mitosis.]

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.

In NYS the entire PE has been edited as follows: 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, (3) mutations caused by environmental factors and/or (4) genetic engineering. [Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs including the relevant processes in meiosis and advances in biotechnology.] [Assessment Boundary: Assessment does not include recalling the specific details of the phases of meiosis or the biochemical mechanisms of the specific phases in the process.]

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.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models - 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. SEP2(3) Analyzing and Interpreting 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. SEP4(2) Engaging in Argument from 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. SEP7(5)	LS1.B Growth and Development of Organisms - 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. LS1.B(1) LS3.B Variation of Traits - 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. LS3.B(1) - 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. LS3.B(2) - Environmental factors can cause mutations in genes. Only mutations in sex cells can be inherited. LS3.B(3)NYS LS4.B Natural Selection - 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	Patterns - 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. CCC1(1) - Classifications or explanations used at one scale may fail or need revision when information from smaller or larger scales is introduced; thus requiring improved investigations and experiments. CCC1(2) Cause and Effect - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

leads to differences in performance among individuals. LS4.B(1)

- The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2)

LS4.C Adaptation

- 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. LS4.C(2)
-

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models			Summary Task		Genetic Variation Genetic Variation Mini Rubric
Analyzing and Interpreting Data		Mountain Lion Genetic Diversity Investigation Making Sense of the Mountain Lion Genetic Diversity Investigation Domino Discover			
Engaging in Argument from Evidence			Abnormal Traits Note-taker Class Consensus Discussion	Read-Generate-Sort-Solve Graphic Organizer	Genetic Variation Genetic Variation Mini Rubric
LS1.B Growth and Development of Organisms			Abnormal Traits Note-taker Summary Task Class Consensus Discussion		Genetic Variation Genetic Variation Mini Rubric
LS3.B Variation of Traits	Rumors categories	Making Sense of the Mountain Lion Genetic Diversity Investigation Domino Discover	Abnormal Traits Note-taker Summary Task Class Consensus Discussion Summary Task	Read-Generate-Sort-Solve Graphic Organizer	Genetic Variation Genetic Variation Mini Rubric
LS4.B Natural Selection			Abnormal Traits Note-taker Summary Task Class Consensus Discussion Summary Task		Genetic Variation Genetic Variation Mini Rubric
LS4.C Adaptation			Abnormal Traits Note-taker		Genetic Variation Genetic Variation Mini Rubric
Patterns		Making Sense of the Mountain Lion Genetic Diversity Investigation Domino Discover	Abnormal Traits Note-taker Summary Task		Genetic Variation Genetic Variation Mini Rubric

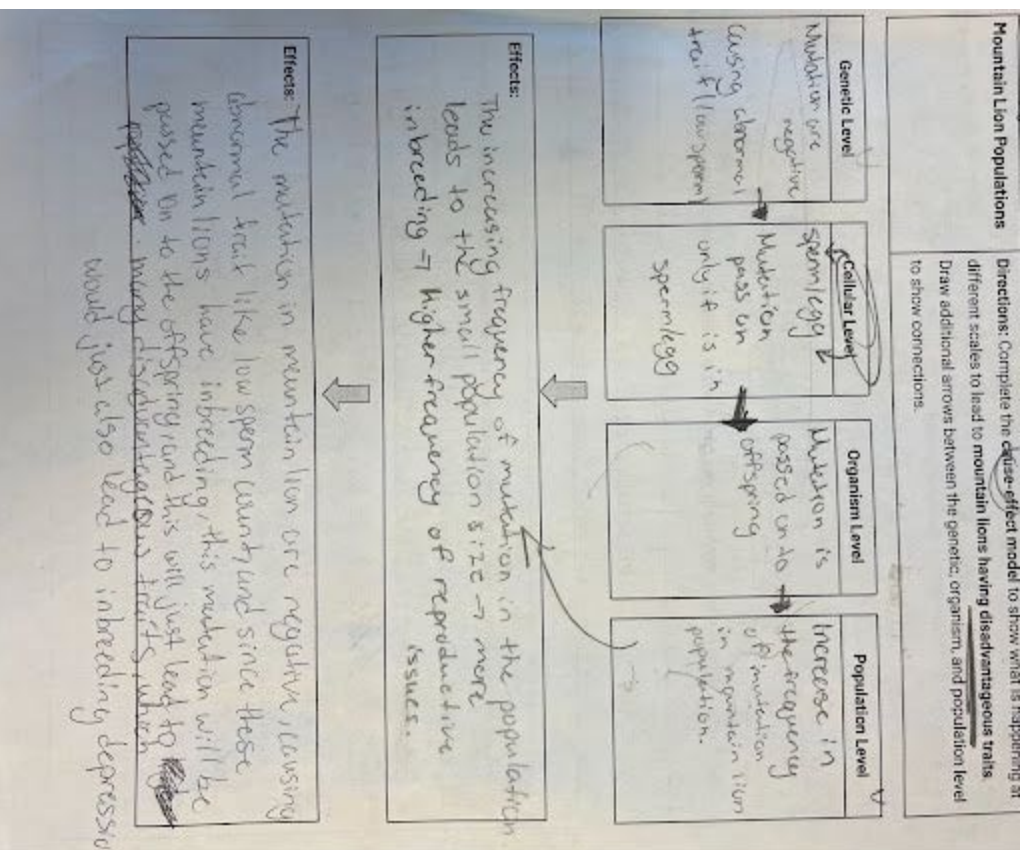
	Engage	Explore	Explain	Elaborate	Evaluate
Cause and Effect			Abnormal Traits Note-taker	Read-Generate-Sort-Solve Graphic Organizer	

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		HSS-ID.C.5	MP3		
ELA/Literacy	RST.9-10.7 RST.9-10.2	RST.9-10.7	SL.9-10.1	RST.9-10.9	

Student Work for Genetic Variation 5E

Student 1 Example of Performance Task



Performance Task Student Work Page 1

REFLECTION

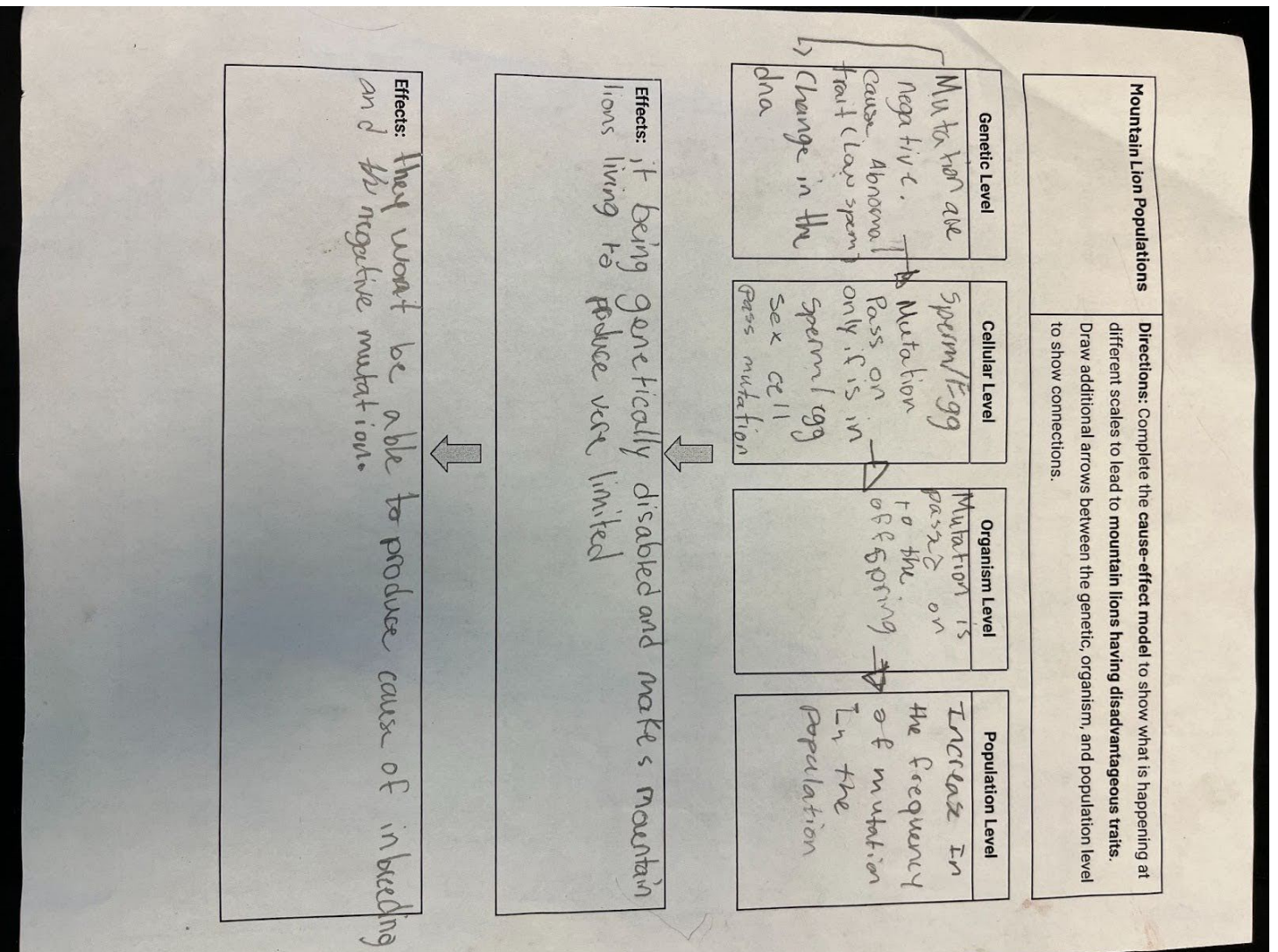
1. In the past, the mountain lion population was vast and covered most of the US. We not see smaller populations such as the florida population. Use your model to explain how such changes at the population level can result in changes to the traits in an individual organism.

If a population had low population level, this may lead to inbreeding, and in the genes of the mountain lion, the mutation is negative causing low sperm count and this mutation can pass on only if it is in the sperm/egg. Therefore the mutation is passed onto the offspring, and this will increase the frequency of the

2. Use the space below to clarify anything in your model, add in additional scientific reasoning, or ideas.

Too much inbreeding in mountain lion population will result in inbreeding depression which will negatively affect the mountain lion's survival rate.

Student 2 Example of Performance Task



Performance Task Student Work Page 3

REFLECTION

1. In the past, the mountain lion population was vast and covered most of the US. We not see smaller populations such as the Florida population. Use your model to **explain how such changes at the population level can result in changes to the traits in an individual organism.**

The population change due low population and the Florida mountain lions are in breeding which gave them having defects from negative mutation such low sperm and etc which they can't produce so the population can't thrive

2. Use the space below to **clarify anything in your model, add in additional scientific reasoning, or ideas.**

Mutation can be be positive, neutral, and negative and the mountain lions are having negative and it causing a issue cause they can't produce offspring

Mountain Lion Populations

Directions: Complete the **cause-effect model** to show what is happening at different scales to lead to **mountain lions having disadvantageous traits**. Draw additional arrows between the genetic, organism, and population level to show connections.

Genetic Level	Cellular Level	Organism Level	Population Level
Mutations can be beneficial, negative, or neutral. Florida panther has abnormal traits caused by negative mutations that are passed on from one generation to another.	These negative mutations are happening in the sex cells (sperm and egg), this is why they are passed on from one generation to another. Mutations in body cells cannot pass from one generation to another.	When an individual has a mutation in the sex cells, they can pass it to their offspring. Inbreeding (mating with a close relative that might also have the mutations) is causing the increase in the frequency of mutations in the offspring.	If in the population there is low genetic diversity and most individuals possess the negative mutation, the mutations build up over time leading to disadvantageous traits seen in the Florida population.



Effect	Effect
If a mutation (genetic level) is negative and happens in the sex cells (cell level), the effect is noticed in the offspring.	If there is more inbreeding, there are higher chances a mutation is passed on and shared among individuals. If more individuals have the same mutation and they mate between teacher, the frequency of that mutation increases and it stays in the population over time causing all the problems seen in the Florida panther (undescended testes, kinked tails, heart holes..)

Engineering Gene Flow 5E

How can humans solve the mountain lion population isolation problem?

Performance Expectations
HS-LS3-2, HS-LS3-3,
HS-LS4-3

Investigative Phenomenon
The introduction of Texas mountain lions into the Florida panther population led to an increase in genetic diversity.

Time
5 days

In this 5E, students investigate how cellular level processes of sexual reproduction lead to new genetic combinations in offspring and how higher diversity in parents' genetics increases the probability of new genetic combinations in individual offspring and in a population. Genetic variation allows for a variation of traits, the material needed for natural selection and adaptation during changing environmental conditions.

ENGAGE	How do you increase genetic diversity in small isolated populations?	Connecting to their questions about how the genetic diversity of the Florida panther population can be increased, students generate solutions for how this can be addressed.
EXPLORE	What happened when additional individuals from an outside population were brought into the Florida mountain population?	Students analyze genetic data and engage with a simulation to surface how sexual reproduction between individuals can increase genetic variation at the population level .
EXPLAIN	Did the introduction of mountain lions from Texas improve the likelihood that the Florida population will survive and reproduce in the future? Was it an effective solution?	Students make and defend a claim , if bringing in the Texas individuals was an effective solution to increase genetic variation so that the Florida population survives and reproduces into the near future .
ELABORATE	What other factors affect variation in gene expression?	Students make and defend a claim on how the environment can cause variation in traits in turtles.
EVALUATE	Would the same solution that was used for addressing the low genetic diversity of the Florida panther population be effective in addressing low genetic diversity within other populations?	Students develop a model, based on evidence , to represent the cause behind the migration of the Connecticut cat at different scales .

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Engage

How do you increase genetic diversity in small isolated populations?

Connecting to their questions about how the genetic diversity of the Florida panther population can be increased, students **generate solutions** for how this can be addressed.

Preparation

Student Grouping

None

Routines

☐ Rumors

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

☐ Post it notes

Surfacing Student Ideas

1. Remind students that in the previous 5E learning sequence they figured out that the Florida mountain lion population suffered from abnormal physical traits due to a lack of genetic variation in their very small and isolated population. Ask students to brainstorm all the ideas/solutions they have about ways that genetic diversity could be increased in this population so that Florida mountain lions could improve their health and ability to reproduce and survive.
2. Use the group learning routine **Rumors** to share their ideas.

Look & Listen For



- Clone the healthy mountain lions.
- Monitor breeding in captivity to ensure biodiversity.
- We could increase gene flow through genetic engineering of the sex cells.
- Bring in mountain lions from other populations.

Explore

What happened when additional individuals from an outside population were brought into the Florida mountain population?

Students **analyze genetic data** and engage with a simulation to surface how **sexual reproduction between individuals can increase genetic variation at the population level**.

Preparation

Student Grouping

- ☐ Table groups

Routines

- ☐ Domino Discover

Literacy Strategies

None

Materials

Handouts

- ☐ Increasing Genetic Variation Investigation Part 1
- ☐ Increasing Genetic Variation Investigation Part 2
- ☐ Making Sense of Increasing Genetic Variation Investigation
- ☐ Increasing Genetic Variation Investigation Rubric

Lab Supplies

- ☐ 2 paper bags
- ☐ 10 colored marbles for each of the following colors: red; blue; yellow; and green

Other Resources

- ☐ [Mountain Lion Genetic Diversity Calculator](#)
- ☐ [Observed and Expected Heterozygosity \(optional\)](#)

Launch the Investigation

1. In the Engage phase, It's likely that one idea that many students generated was to bring mountain lions from another region to breed with the Florida population, or something similar. Let students know that scientists did exactly that! In 1995, 8 females from Texas were introduced to Florida mountain lion habitat. Prompt students to predict what the impact of the introduction was.
2. Let students know that scientists collected genetic data (from scat) on the post 1995 Florida population, and they will now have an opportunity to investigate that data to start to figure out the impact was.

Integrating Three Dimensions



Keep in mind that students need to go beyond determining the genetic diversity in mountain lion populations; this investigation is designed to support them in engaging and understanding approaches to **SEP #4 Analyzing and Interpreting Data**, specifically the application of concepts of probability to scientific questions, using digital tools when feasible. Be sure to make **SEP #4 Analyzing and Interpreting Data** explicit for students by supporting them in understanding that an inbreeding coefficient is a comparison of the observed heterozygosity in a population to the expected heterozygosity which is based on probability, a good indication of the degree of inbreeding in a population.

Analyzing Genetic Data

1. Provide students the handout *Increasing Genetic Variation Investigation Part 1* and have them analyze data from post 1995 to compare heterozygosity to the pre-introduction population in Florida, using the See-Think-Wonder table.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Conferring Prompts



Confer with students as they work in collaborative groups to collect data and complete the See-Think-Wonder chart.

Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- What do you notice about the number of private alleles in the post 1995 Florida panther population compared to the pre-1995 Florida panther population and other populations?
- What do you think the number of private alleles tells us about the degree of isolation for each population?
- What do you notice about the frequency of heterozygotes in the post 1995 Florida panther population compared to the pre-1995 Florida panther population and other populations?
- What do you think the frequency of heterozygotes tells us about the degree of inbreeding in each population?
- What do you notice about the inbreeding coefficient in the post 1995 Florida panther population compared to the pre-1995 Florida panther population and other populations?

2. Facilitate a whole class share of what students noticed in the analysis using the Group Learning Routine, **Domino Discover**.

Look & Listen For



- The private alleles in the post 1995 Florida mountain lion population is lower compared to the pre-1995 Florida mountain lion population.
- The private alleles in the post 1995 Florida mountain lion population is closer to the number of private alleles in other more genetically diverse populations.
- The frequency of heterozygotes in the post 1995 Florida mountain lion population is higher compared to the pre-1995 population.
- The frequency of heterozygotes in the post 1995 Florida panther is comparable to other larger and more diverse populations.
- The inbreeding coefficient in the post 1995 Florida panther population is lower (negative) than the pre-1995 Florida panther population and closer to other populations.
- This evidence suggests that introducing the Texas mountain lions was effective in increasing the genetic variation in the Florida population – this may lead to fewer disadvantageous mutations building up in the population
- What exactly happens during the sexual reproduction process that leads to an increase in genetic variation?
- Why did they only choose to introduce 8 mountain lions from Texas?
- Why were all the lions from Texas introduced from Texas females?
- Will they need to introduce more mountain lions from Texas or one of the more diverse populations in the future?

Modeling a Genetic Process

1. Highlight student questions around why bringing in only 8 females would increase the genetic variation in the entire population. Let students know that we are going to model a process that occurs during

sexual reproduction that may help us visualize and start to understand what is happening at the genetic/cellular level when the 8 females were introduced and mated with the Florida population males.

2. Provide students with *Increasing Genetic Variation Investigation Part 2* and take the opportunity to clarify what students are simulating this investigation. The paper bags, one labeled male and another labeled female represent sexually reproducing parents. In this simulation, the marbles represent alleles that are passed on to the offspring, and the number of marbles indicates population size. Students run the trials as described in the procedure and record their results. Students then use the See-Think-Wonder graphic organizer to record observations, ideas, and questions.

Conferring Prompts



- What do you notice about the observed heterozygosity as you add more different colored marbles?
- How do you think this relates to what we observed in the Florida panther population when Texas mountain lions were introduced?
- Why do you think we saw a change in the genetic diversity of the Florida mountain lion population after the Texas mountain lions were introduced?

Whole-Class Investigation Summary

1. Provide students with *Making Sense of Increasing Genetic Variation Investigation*. Ask students to work independently to complete the See-Think-Wonder for *Increasing Genetic Variation Investigation Part 2* and the Summary Questions in *Making Sense of Increasing Genetic Variation Investigation*, then use these completed pages to discuss the findings from the investigation.
2. Ask groups to come up with one important idea to share with the whole class, from their discussion.
3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' responses. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon.

Routine



The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Biology Course Guide for support with this routine.

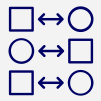
Look & Listen For



- As we added more different colored marbles (genetic variation) to the population, sexual reproduction led to more observed heterozygosity in offspring.
- Trial 1 and maybe 2 modeled what the Florida panther population was like before the Texas mountain lions were introduced and the other trials with more colors were modeling what happened after the Texas mountain lions were introduced.
- The process is happening in the sex cells of the parents (or somewhere in their reproductive system)
- The genetic variation changed when the females were brought in as they had different combinations of alleles to introduce to the population through sexual reproduction

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.
5. Provide students with *Increasing Genetic Variation Investigation Rubric*. Ask students to use the investigation rubric to self and peer assess their progress on engaging with the investigation individually and as a group.

Differentiation Point



If students ask questions or show curiosity related to how expected heterozygosity is calculated, provide them with the video, [Observed and Expected Heterozygosity](#). This is a great opportunity for students to further develop facility with applying concepts of probability to scientific questions, an important element of **SEP #4 Analyzing and Interpreting Data** at the high school level.

Explain

Did the introduction of mountain lions from Texas improve the likelihood that the Florida population will survive and reproduce in the future? Was it an effective solution?

Students **make and defend a claim**, if bringing in the Texas individuals was an effective solution to **increase genetic variation** so that the Florida population survives and reproduces **into the near future**.

Preparation

Student Grouping

- ☐ Triads

Routines

- ☐ Think-Talk-Open Exchange
- ☐ Class Consensus Discussion

Literacy Strategies

- ☐ Text Annotation

Materials

Handouts

- ☐ Florida Mountain Lion Solution
- ☐ Solution for the Florida Mountain Lions Text
- ☐ Summary Task

Lab Supplies

None

Other Resources

- ☐ [Meiosis](#)

Making and Defending a Claim

1. Revisit student questions from the end of the Engage and Explore phases. Highlight questions about why sexual reproduction with the introduced females resulted in increased genetic variation, and if introducing the Texas individuals is a viable long-term solution to protecting the Florida population that was on the brink of extinction. Let students know that we are going to take a closer look at the genetic/sexual process they simulated with the marbles, so we can better assess the solution used for the Florida mountain lions.
2. Give students the handout *Florida Mountain Lion Solution* and internet access to watch the video [Meiosis](#) so they can find out more information about the process they simulated and how it relates to increasing genetic variation. Once students have had a chance to watch the video and record their ideas in the handout, provide them with *Solution for the Florida Mountain Lions Text*. Students **annotate** the text, looking for additional information – recording their new ideas in *Florida Mountain Lion Solution*.
3. Provide students time to discuss their ideas in triads, using the Group Learning Routine, **Think-Talk-Open Exchange**.

Class Consensus Discussion

1. Orient the class to the purpose and the format of the group learning routine **Class Consensus Discussion**. You may say something like this:
 - “We have a lot of different ideas circulating in the room right now. It is really important for us to get to some agreement on how we evaluate the introduction of Texas mountain lions to the Florida population as an effective solution for the long term health and success of the population, so that we have a shared understanding to build upon as we move ahead. In order to do this we are going to do something called a **Class Consensus Discussion**. First I will select a few different groups to share their ideas. Then, we will let each group share their response, and discuss what we can agree to as a class.”
2. You may decide to walk students through the entire poster, or take them through the steps as you facilitate it.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

3. Select two or three groups' responses to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of why the introduction of Texas mountain lions to the Florida panther population was effective in increasing biodiversity. The decision about which ideas or responses to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.
4. Ask the first group to share their most important ideas. You can do this by:
 - Projecting using a document camera; OR
 - Copying the responses to be shared and passing them out; OR
 - Writing key points on the board or on poster paper.
5. Proceed through the steps in the Consensus Discussion Steps. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion.

Routine



Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Refer to the Biology Course Guide for support with this routine.

Integrating Three Dimensions



Keep in mind that students need to go beyond arguing the effectiveness of the Texas mountain lion Introduction; this Explain is designed to support them in using a crosscutting concept to do this sensemaking. Be sure to make **CCC #3 - Scale, Proportion, and Quantity** explicit for students by elevating and probing for ideas related to the concept of how we can predict the change in one variable on another using algebraic thinking.

6. Sometimes, important points get buried in student talk; use the guidelines below to ensure the class focuses on ideas that will drive the lesson and unit forward.

Take Time for These Key Points



- Based on the evidence, bringing in new females to the population was a positive step – as the heterozygosity of the population increased – but there is not enough evidence that it is enough variation to ensure health and survival over the long term (e.g. if the population remains isolated, over time inbreeding may occur again)
- Sexual reproduction, including meiosis produces genetic variations
- Crossing-over during meiosis creates new combinations of alleles
- Increasing the number of individuals in a population increases the possible genetic variations during sexual reproduction
- Mutations are a source of novel variation (can be neutral, maladaptive, or adaptive) but can only be inherited if found in the sex cells of an individual
- Natural selection requires genetic variation, and variations in traits so that there can be differences in performance, survival, and reproduction so the beneficial traits can be passed onto offspring

7. Have students complete the *Summary Task* individually.

Elaborate

What other factors affect variation in gene expression?

Students **make and defend a claim** on how the environment can **cause variation in traits** in turtles.

Preparation

Student Grouping

- ☐ Table groups

Routines

- ☐ Read-Generate-Sort-Solve

Literacy Strategies

None

Materials

Handouts

- ☐ Environmental Factors and Gene Expression R-G-S-S

Lab Supplies

None

Other Resources

- ☐ What causes a sea turtle to be born male or female?
- ☐ Temperature-Dependent Sex Determination Visual
- ☐ Temperature-Dependent Sex Determination Unraveled: An Interview with Dr. Alex Lolavar (optional)
- ☐ Sex Determination: More Complicated Than You Thought

The Role of Environment in Genetic Variation

1. Remind students of their earlier questions about what caused the abnormalities in the Florida mountain lions, and they had wondered if the environment had played a role. We learned earlier that mutations in genes can be caused by environmental factors such as U.V. radiation – but there is a different way that the environment can impact variation in traits.
2. Ask students what they already know about how biological sex is determined in humans. They may already know that there are different chromosomes involved for male and female sex, or have heard that “the dad determines the sex.” Tell students that in mammals, biological sex is determined by if offspring receive two X chromosomes, or one X and one Y, and that these combinations of chromosomes are caused by assortment during meiosis. However, not all organisms determine sex in the same way.
3. Show students [Sex Determination: More Complicated Than You Thought](#) . Note: the video will talk about human babies and other organisms being “boys” or “girls.” Remind students that we are talking about the determination of biological sex, not gender, despite the language being used by the video.

Routine



The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. Refer to the Biology Course Guide for planning support.

4. Project (or print in color) [Temperature-Dependent Sex Determination Visual](#) . Let students know that sea turtles lay their eggs in the sand on beaches. What do they notice happening? Prompt students to discuss their observations based on the image. In this task, students will read about turtles and a special case of how the environment can impact the expression of a very important trait!
5. Provide each student with the handout, *Environmental Factors and Gene Expression R-G-S-S* and the text, [What causes a sea turtle to be born male or female?](#) . After students have had the opportunity to read the text, have students work together to develop a claim for how an environmental factor determines if a turtle is born male or female by facilitating the Group Learning Routine, **Read-Generate-Sort-Solve**.

Differentiation Point

- ☐ ↔ ☐ Based on student interest and readiness, they can explore temperature-dependent sex determination (TDS) more, using [Temperature-Dependent Sex Determination Unraveled: An Interview with Dr. Alex Lolavar](#) .
- ☐ ↔ ☐
- ☐ ↔ ☐

Evaluate

Would the same solution that was used for addressing the low genetic diversity of the Florida panther population be effective in addressing low genetic diversity within other populations?

Students **develop a model, based on evidence**, to represent the **cause behind the migration** of the Connecticut cat at **different scales**.

Preparation

Student Grouping

- ☐ Table groups

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Engineering Gene Flow
- ☐ Engineering Gene Flow Mini Rubric

Lab Supplies

None

Other Resources

Revisit the Performance Task

1. Prompt students to consider where they currently stand on the question category from the Driving Question Board that they have been investigating throughout this 5E instructional sequence (for example: *How are reduced ranges impacting mountain lions? Why did the Connecticut Cat range so far?*).
2. Students work individually on *Engineering Gene Flow*, in the Performance Task Organizer to generate their final model. They should make choices on how to represent their ideas using the model they are developing.
3. Confer with students while they are working.

Conferring Prompts



Confer with students as they work to develop their cause-effect models.

Suggested conferring questions:

- How are you using patterns at different scales to figure this out?
- Are there boxes that may be empty at this point in your learning?
- How did the Florida panther data (after the introduction of the Texas females) and readings (meiosis video, genetic variation text) inform your model?
- What evidence are you using to develop your model?

4. After completing their response, use the *Engineering Gene Flow Mini Rubric* to generate self, peer, or teacher feedback on their model and scientific reasoning.

Revisiting the Driving Question Board

1. Use the **Driving Question Board** routine to discuss which of their questions have been answered.
2. Have students identify which categories/questions they have not figured out yet. Students should share out these questions, and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

Standards in Engineering Gene Flow 5E

Performance Expectations

- 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.
- In NYS the entire PE has been edited as follows: 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, (3) mutations caused by environmental factors and/or (4) genetic engineering.
[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs including the relevant processes in meiosis and advances in biotechnology.] [Assessment Boundary: Assessment does not include recalling the specific details of the phases of meiosis or the biochemical mechanisms of the specific phases in the process.]
- 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-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.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models - 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. SEP2(3) Analyzing and Interpreting 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. SEP4(2) Engaging in Argument from 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. SEP7(5)	LS3.B Variation of Traits - 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. LS3.B(1) - 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. LS3.B(2) LS4.B Natural Selection - 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. LS4.B(1) - The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2) LS4.C Adaptation - 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. LS4.C(1)	Patterns - 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. CCC1(1) Cause and Effect - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1) 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). CCC3(5)

- 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. LS4.C(2)
-

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models					<i>Engineering Gene Flow Engineering Gene Flow Mini Rubric</i>
Analyzing and Interpreting Data		<i>Increasing Genetic Variation Investigation Part 1 Making Sense of Increasing Genetic Variation Investigation</i>	<i>Summary Task</i>		
Engaging in Argument from Evidence			<i>Florida Mountain Lion Solution Summary Task Class Consensus Discussion</i>	<i>Environmental Factors and Gene Expression R-G-S-S</i>	
LS3.B Variation of Traits	Rumors	<i>Increasing Genetic Variation Investigation Part 2 Making Sense of Increasing Genetic Variation Investigation Domino Discover</i>	<i>Florida Mountain Lion Solution Summary Task Class Consensus Discussion</i>	<i>Environmental Factors and Gene Expression R-G-S-S</i>	<i>Engineering Gene Flow Engineering Gene Flow Mini Rubric</i>
LS4.B Natural Selection			<i>Florida Mountain Lion Solution Class Consensus Discussion Summary Task</i>		<i>Engineering Gene Flow Engineering Gene Flow Mini Rubric</i>
LS4.C Adaptation			<i>Summary Task</i>		<i>Engineering Gene Flow Engineering Gene Flow Mini Rubric</i>
Patterns		<i>Increasing Genetic Variation Investigation Part 2 Making Sense of Increasing Genetic Variation Investigation Domino Discover</i>	<i>Summary Task</i>		<i>Engineering Gene Flow Engineering Gene Flow Mini Rubric</i>

	Engage	Explore	Explain	Elaborate	Evaluate
Cause and Effect		<i>Making Sense of Increasing Genetic Variation Investigation</i>	<i>Florida Mountain Lion Solution</i>	<i>Environmental Factors and Gene Expression R-G-S-S</i>	
Scale, Proportion, and Quantity			<i>Florida Mountain Lion Solution Summary Task Class Consensus Discussion</i>		

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics	S-ID.C.5		MP3		
ELA/Literacy	RST.9-10.2 SL.9-10.1	SL.9-10.1	SL.9-10.4		WHST.9-10.2

Student Work for Engineering Gene Flow 5E

Student Work Example

Mountain Lion Populations				
Directions: Complete the cause-effect model to show what is <u>happening</u> at different scales to lead to greater gene flow in mountain lions. Draw additional arrows between the genetic, organism, and population level to show connections.				
Genetic Level	Cellular Level	Organism Level	Population Level	
Introduction of new alleles	There was new combination of cells to create different kinds of cells <u>Gamete</u>	The brought & mountain lions from Texas to Florida	There were more diversity in the population	
↓				
Effects: The rate of the <u>reduction of the population</u> was reduced <u>more detail?</u>				
↓				
Effects:				

Performance Task Student Work Page 1

REFLECTION

1. Use your model to explain how changes at the genetic level can change a population overall.

So since new alleles were introduced the disease causing the mountain lion's population to reduce will stop because new alleles means more diversity so the population will increase over time.

Performance Task Student Work Page 2



Mountain Lion Populations

Directions: Complete the cause-effect model to show what is happening at different scales to lead to greater gene flow in mountain lions. Draw additional arrows between the genetic, organism, and population level to show connections.

Genetic Level	Cellular Level	Organism Level	Population Level
Before 1995 the frequency of heterozygosity was low and the inbreeding coefficient was high. After 1995, the frequency of heterozygosity went up and the inbreeding coefficient went down. More alleles were introduced in the population	During meiosis, the random assortment of genes, alleles, and crossing over produces genetically diverse sperm and egg cells. During fertilization a random	The introduction of 8 new females from Texas introduced a new combination of alleles to the Florida population.	After 1995, the Florida population increased its allele pool.



Effects:

Genetic Level: new alleles (256 - 282 - 310 - 258) were present after 1995 because of the introduction of the 8 Texas females. These alleles doubled the frequency of heterozygosity (from 0.35 before 1995 to 0.7 after 1995) and decreased inbreeding coefficient (from +0.34 to -0.30).

Cellular Level: meiotic cell division increased genetic diversity introduced by the 8 Texas females. Males were able to reproduce and fertilize eggs that were genetically different from the Florida female population.

Organism level: 8 new females from Texas increased the options for Florida males to mate with a different organism that was not related to the Florida panther, reducing the chances of inbreeding.

Population level: the overall result is a decreased number of individuals who carry a genetic mutation causing abnormal traits by increasing the gen flow from one population from Texas to the population in Florida.

REFLECTION



1. Use your model to explain how **changes** at the **genetic level** can **change** a **population overall**.

As discussed in the model, the genetic and cellular level changes introduced by the 8 Texas females lions introduced new alleles that became widespread in the Florida population. Genes were “flowing” from the Texas Mountain Lion population to the Florida population, increasing the genetic diversity and heterozygosity in the Florida population.

2. Use the space below to clarify your model or add additional information.

The reason why females were introduced is also related to the male Mountain lion behavior. While males are territorial and move around a lot, females stay in the area allowing mating. Introducing the females from Texas allowed a targeted impact on the Florida population (the one who experiencing lower gene flow).

Unit Closing

What causes a lack of genetic variation in a population?, Why is genetic diversity a problem for some species, and how can we evaluate conservation solutions for isolated populations?

Performance Expectations
HS-LS4-3, HS-LS3-2

Anchor Phenomenon
A mountain lion was hit by a car on a highway outside NYC. How did it get there, and what can this tell us about saving mountain lions?

Time
1-3 days

Students make and defend a claim based on evidence in support of a solution that was designed to increase the genetic diversity of mountain lion populations.

ANCHOR PHENOMENON	A mountain lion was hit by a car on a highway outside NYC. How did it get there, and what can this tell us about saving mountain lions?	Based on the investigations and learning throughout the unit, students share their ideas about why a mountain lion would go outside their normal range to find genetic variation.
DRIVING QUESTION BOARD	What questions have been answered? What have we not answered yet?	Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.
PERFORMANCE TASK	How can we evaluate another solution designed to address population decline and a lack of genetic diversity in Mountain Lions?	Based on the investigations and learning throughout the unit, students analyze genetic data to make and defend a claim about a solution that was designed to address low genetic diversity in Mountain Lion populations.
UNIT REFLECTION	How can we evaluate our progress on modeling to represent a phenomenon at different scales?	Students reflect on their learning and use of modeling and patterns throughout the unit.

Science & Engineering Practices

Disciplinary Core Ideas

Crosscutting Concepts

Anchor Phenomenon

A mountain lion was hit by a car on a highway outside NYC. How did it get there, and what can this tell us about saving mountain lions?

Based on the investigations and learning throughout the unit, students share their ideas about why a mountain lion would go outside their normal range to find genetic variation.

Preparation

Student Grouping

☐ Table groups

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

Reviewing Explanations about the Anchor Phenomenon

1. Students return to the anchor phenomenon about the Connecticut Cat, and review their explanations for what happened, what it had to do with genetic variation, and why this might be a problem we need to address for mountain lions and other species.

Driving Question Board

What questions have been answered? What have we not answered yet?

Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.

Preparation

Student Grouping

☐ Small groups

Routines

None

Literacy Strategies

None

Materials

Handouts

None

Lab Supplies

None

Other Resources

☐ Driving Question Board

Revisit the Driving Question Board

1. Students return to the questions generated throughout the unit and reflect. What questions have been answered? Are there questions that we still need to investigate?
2. Note that not all of the students' questions will be answered at the end of the unit, and students may have generated entirely new questions. Depending on student interest and instructional time, prompt students to explore some of the unanswered questions independently.

Performance Task

How can we evaluate another solution designed to address population decline and a lack of genetic diversity in Mountain Lions?

Based on the investigations and learning throughout the unit, students analyze genetic data to make and defend a claim about a solution that was designed to address low genetic diversity in Mountain Lion populations.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

- ☐ Mountain Lion Final Task
- ☐ Table of Unique Alleles
- ☐ Performance Task Rubric

Lab Supplies

None

Other Resources

Introducing a Novel Solution for Genetic Variation

1. Prompt students to review what they have learned about mountain lion genetic diversity and its importance to the continuation of the species. Then, ask students to brainstorm what other solutions might be possible in order to increase mountain lion genetic diversity.

Integrating Three Dimensions



In evaluating a solution to a complex, real-world problem students are engaging with design elements from **SEP#6 Constructing Explanations and Designing Solutions** and dimensions from the high school Engineering Design PEs. Opportunities to assess students on their use of engineering and designing solutions are found in Unit 3, The Evolution of Sick Humans.

Revisit the Performance Task

1. Provide students with the *Mountain Lion Final Task* and *Table of Unique Alleles*.
2. Students individually read the *Wildlife Corridors* solution and evaluate the solution that was described. Students use the genetic data provided to conduct a statistical analysis of population similarities, using shared alleles between populations. They then use that analysis to make a claim regarding which corridor would be most successful in improving the long-term survival of the mountain lions.

Differentiation Point

- ☐ ↔ ☐ Students have already interacted with the Table of Unique Alleles, the completed version of which is reproduced and provided here to reduce the need for students to flip back to that document from the first 5E. In this task, they are looking for genetic similarity between populations by doing pairwise analyses of shared unique alleles. To do so, they will be looking for unique alleles shared between pairs of populations, listed in their data table. Populations with higher levels of overlap have more genetic similarity, and populations with fewer shared alleles have less genetic similarity.

3. Use *Performance Task Rubric* for students to peer and self reflect on their work.

Integrating Three Dimensions



Throughout this unit, students have begun to develop their understanding of many of the concepts described in LS4.C Adaptation; including how human induced changes to the environment may cause the extinction of or the reduction of populations of organisms. These DCIs are further explored in Unit 6.

Unit Reflection

How can we evaluate our progress on modeling to represent a phenomenon at different scales?

Students reflect on their learning and use of modeling and patterns throughout the unit.

Preparation

Student Grouping

None

Routines

None

Literacy Strategies

None

Materials

Handouts

☐ Self Reflection

Lab Supplies

None

Other Resources

Reflecting on the Unit

1. Remind students that they started the unit by generating an initial set of ideas around what caused the Connecticut Cat to wander away so far from home, and if solutions such as bringing in additional individuals could help the Florida mountain lions.
2. Prompt students to identify how their thinking has changed on using models to represent cause and effect relationships – and how it may inform a solution to societal problems (such as human-caused isolation of populations due to habitat destruction).
3. Provide students with the *Self Reflection* to complete individually.

Standards in Unit Closing

Performance Expectations

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.

In NYS the entire PE has been edited as follows: 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, (3) mutations caused by environmental factors and/or (4) genetic engineering.

[Clarification Statement: Emphasis is on using data to support arguments for the way variation occurs including the relevant processes in meiosis and advances in biotechnology.] [Assessment Boundary: Assessment does not include recalling the specific details of the phases of meiosis or the biochemical mechanisms of the specific phases in the process.]

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.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models - 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. SEP2(3) Analyzing and Interpreting 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. SEP4(2) Engaging in Argument from 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. SEP7(5)	LS1.A Structure and Function - The structures and functions of the human female reproductive system produce gametes in ovaries, allow for internal fertilization, support the internal development of the embryo and fetus in the uterus, and provide essential materials through the placenta, and nutrition through milk for the newborn. The structures and functions of the human male reproductive system produce gametes in testes and make possible the delivery of these gametes for fertilization LS1.A(5)NYS LS1.B Growth and Development of Organisms - 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. LS1.B(1) - The continuity of life is sustained through reproduction and development. Human development, birth, and aging should be viewed as a predictable pattern of events influenced by factors such as gene expression, hormones, and the environment. LS1.B(2)NYS LS3.B Variation of Traits - 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	Patterns - 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. CCC1(1) Cause and Effect - Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1) 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). CCC3(5)

of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited. LS3.B(1)

LS4.B Natural Selection

- 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. LS4.B(1)
 - The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. LS4.B(2)
-

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Developing and Using Models				Self Reflection
Analyzing and Interpreting Data			Mountain Lion Final Task	
Engaging in Argument from Evidence			Mountain Lion Final Task	
LS1.A Structure and Function			Mountain Lion Final Task	
LS1.B Growth and Development of Organisms			Mountain Lion Final Task	
LS3.B Variation of Traits			Mountain Lion Final Task	
LS4.B Natural Selection			Mountain Lion Final Task	
Patterns				Self Reflection
Cause and Effect			Mountain Lion Final Task	
Scale, Proportion, and Quantity			Mountain Lion Final Task	

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics				
ELA/Literacy				WHST.9-10.2