Woolly Mammoth - Teacher Materials

Unit 6	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.

Unit 6 Woolly Mammoth Table of Contents

Unit 6 Woolly Mammoth
Ecology and Human Impact

Performance Expectations
HS-LS2-7, HS-LS4-6, HS-LS2-2, HS-LS2-5, HS-LS2-6

Time
27-33 days

What caused the woolly mammoth to go extinct? Should we bring the woolly mammoth back?

How can we develop claims about the extinction of species long ago, based on findings in current ecosystems affected by human actions? Human population growth, globalization, and industrialization are having profound impacts on the long term health and stability of ecosystems, permanently altering the products of billions of years of evolutionary history on planet Earth. After raising questions about the extinction of the woolly mammoth, students investigate how humans have altered ecosystems and what actions may be taken to preserve biodiversity. Students create models throughout the unit and utilize simulations to gain a deeper understanding of large scale geological and biological processes through a set of case studies that highlight the decline of three key species. Finally, students use their learning to evaluate several claims about causes for the extinction of the woolly mammoth, and evaluate a scientific argument about whether we should invest resources in bringing the mammoth back from extinction as a solution to human-caused biodiversity loss.

Unit Opening	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Anchor Phenomenon	→	**5E Lessons connect learning to the performance task**		→	**Performance Task**
What is the story of woolly mammoth extinction? What types of information do we need to know in order to evaluate the cause of a species' extinction?	*Why are there more tuskless elephants now than in the past?*	*How can we understand the causes and potential impacts of climate change?*	*How do all of the components of an ecosystem interact to provide resiliency against a disturbance?*	*How can we evaluate solutions to human-caused biodiversity loss?*	*How can we evaluate the argument that bringing back the woolly mammoth from extinction is a viable solution to biodiversity loss?*

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.

Evaluating solutions to real-word problems is an essential 21st century skill, and through this unit students deepen their understanding of the importance of engaging with problems and argumentation in science. This unit builds intentionally on earlier units in terms of problem-solving and arguing from evidence. Students first generated a scientific argument in Unit 2, Humans vs Bacteria, and then designed solutions to complex real-life problems in Unit 3, Evolution of Sick Humans. In Unit 5, Food for All, students are considering different local innovations that may serve as solutions to the lack of healthy and fresh foods in many communities. In this unit, students are evaluating a potential solution to human-caused biodiversity loss through the de-extinction of extinct organisms such as the woolly mammoth.

This unit was also intentionally designed to build on earlier units that engaged students in the development, use, and revision of models. Students are first introduced to the development and use of models in the first unit of this course, Marathon Runner. The use of models is woven throughout every unit of the course, especially in Unit 3, in which students use models to represent why some people are unable to digest dairy products in adulthood.

The common embedded group learning routines and curriculum structures introduced in the first unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to figure out why woolly mammoths went extinct by evaluating claims and evidence, and if we should bring back organisms from extinction in order to address biodiversity loss. In this unit, students are introduced to several case studies of key stone species that are under threat due to human disturbances. Students apply what they learned about endangered organisms, such as elephants, to explaining the possible causes of the extinction of the woolly mammoth and to consider the ecological implications of the reintroduction of extinct megafauna.

As the final unit in the course, students have multiple opportunities to revisit and review important disciplinary core ideas. For example, students are encouraged to apply what they learned about feedback mechanisms and dynamic equilibrium in the human body from Unit 1, Marathon Runner to the complex interactions within an ecosystem to maintain stability. Natural selection from Unit 2 is reviewed in this unit, as students figure out that selective pressure from human hunting has dramatically changed elephant populations. Students make new connections about the use of biotechnology and genetic diversity in this unit based on their understanding of genetics and reproduction in Units 3 and 4. Finally, students use their understanding of photosynthesis from unit 5, Food for All, to generate a model of the carbon cycle as they consider the implications of human-caused climate change.

The embedded group learning routines and formative assessments found in each of the Biology units support teachers in learning about their students, both academically and personally. Whether students had strong science programs prior to high school, or if three-dimensional teaching and learning is brand new to them (or to the teacher!). This unit is designed to reinforce and further build on students' earlier experiences with three-dimensional learning.

Unit Coherence

In Unit 6, the overall question on if we should bring back the charismatic woolly mammoth 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 four coherent learning sequences within Unit 6. Each sequence builds towards figuring out something that contributes to explaining the overall unit-level question about why the mammoths went extinct, and if we should bring them back. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 6.

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	Investigative Phenomena
• One per unit; drives the learning of the unit • Attention-grabbing and relevant • Does not have to be phenomenal	• One per 5E sequence (four in this unit) • Presented in the Engage phase of each 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 and optimizing 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				
Unit Opening	What is the story of woolly mammoth extinction? What types of information do we need to know in order to evaluate the cause of a species' extinction?	**Performance Expectations**	**Anchor Phenomenon** Woolly mammoths once roamed the Earth and now they are extinct.	**Time** 2 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline. • Why don't we see woolly mammoths today? • What role did early humans play in causing the extinction of the woolly mammoth? • How did climate change impact the ecosystem of the woolly mammoth? • What can we learn about the woolly mammoth extinction event that can help us conserve biodiversity today? • Should we consider using biotechnology to bring the woolly mammoth back from extinction as a solution to biodiversity loss?	Students begin the unit by reviewing a series of visual texts and a video about woolly mammoth extinction, then discussing trends in those graphics. Through this discussion, students "tell the story" of this anchor phenomenon and ask questions related to figuring out what happened to cause the woolly mammoth to become extinct and what they might investigate.	*These ideas are revisited throughout the unit storyline.* • Woolly mammoths, relatives of today's elephants, are extinct. • There may be many contributing factors that led to their extinction, including climate change and human exploitation. • We can use ideas surfaced about the extinction of the woolly mammoth to think about why other species are endangered and how we could conserve them. • Some people think it would be a great idea to bring back the woolly mammoth as a solution to reverse human caused climate change and biodiversity loss.

During the Driving Question Board routine, student questions related to humans possibly hunting mammoths to extinction will surface. Once a category related to these questions has been articulated, let students know that over the next sequences of lessons they will be investigating this question to figure out how overhunting may impact organisms and if there is evidence that connects humans to the extinction of the woolly mammoth.

Tuskless Elephants 5E

Tuskless Elephants 5E	Why are there more tuskless elephants now than in the past?	**Performance Expectations** HS-LS4-6, HS-LS2-7	**Investigative Phenomenon** Some elephant populations have more tuskless elephants than has typically been normal.	**Time** 6-8 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • Why are the number of tuskless elephants increasing in some populations? • How do human activities such as hunting impact biodiversity? • How can we use the causes behind environmental concerns and biodiversity loss to develop effective solutions? • What types of solutions to environmental and conservation concerns are possible? • How can we design, test, and evaluate solutions for reducing the impacts of human activities on the environment and biodiversity?	Students begin this instructional sequence by engaging with a graph that represents data on the changes in the percentage of tuskless elephants in Gorongosa National Park in Mozambique. In order to investigate the reasons behind this phenomenon, students did deeper into the data to better understand why there has been an increase in tuskless elephants in some populations. This activity leads to questions about how human activities are impacting biodiversity in general and how we may design solutions to mitigate negative impacts on elephants and other endangered organisms. Finally, students use evidence collected throughout the 5E sequence to evaluate a claim about how humans may have over hunted the woolly mammoths, contributing to their extinction.	*Students figure out these ideas in this 5E sequence.* • Pressure from poaching has contributed to the trait of tusklessness increasing • Elephants play an important role in the ecosystem by engineering the environment for other organisms • Human activities such as habitat destruction and hunting cause negative impacts to biodiversity and ecosystems. • Understanding the root causes of environmental problems and biodiversity loss facilitates the development of solutions. • Many organisms are under threat due to unsustainable harvesting by humans. • There are many types of solutions available--technological, social, political, and individual actions • Solutions to environmental and conservation concerns must consider the scale of impact, social and economic impacts, and tradeoffs

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about the ecosystem, food web, or habitats of the woolly mammoth. Tell students that in the next sequence of lessons, they will investigate the role organisms play in maintaining ecosystem resilience.

Coral Bleaching 5E	How can we understand the causes and potential impacts of climate change?	**Performance Expectations** HS-LS2-5, HS-LS2-2	**Investigative Phenomenon** Coral reefs are ejecting their symbiotic algae, a phenomenon called coral bleaching.	**Time** 7 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • How did climate change impact the woolly mammoths? How did it impact other organisms still alive today? • What is the greenhouse effect and how does it relate to climate change? • How will climate change impact biodiversity? • How do the current changes in climate compare to past changes in Earth's history? • How do human activities, such as habitat destruction, work alongside climate change to accelerate the loss of biodiversity?	Students begin this instructional sequence by considering a case study on coral bleaching. Questions about this phenomenon lead students into exploring how factors such as warming sea temperatures impact keystone species, such as coral. Students explore the enhanced greenhouse effect through a hands-on simulation in order to surface the role of humans in modern climate change. Students use complex texts and peer discussion to better understand how human induced climate change is impacting ecosystems at different scales.	*Students figure out these ideas in this 5E sequence.* • Human activity, including burning fossil fuels, increases the amount of carbon in the atmosphere. • Current climate change is happening at a faster rate than what has been observed in the past, and many organisms may not be able to adapt to deal with these changes in time. • There is evidence that climate change is impacting species in many ways: shifting their ranges, changing behaviors, and placing stress on vulnerable organisms. • Greenhouse gasses, such as carbon dioxide, trap heat in the atmosphere. This is the greenhouse effect. • Increasing atmospheric greenhouse gasses, such as carbon dioxide, trap heat and increases the Earth's temperature -- which in turn changes climate. • Climate change will have many impacts including shifting climate zones, increasing sea level, and destroying habitats -- these impacts will have a negative impact on biodiversity • There are a variety of human activities that are negatively impacting ecosystems and species. These activities usually exacerbate stress ecosystems face due to climate change (e.g. habitat destruction may limit migration to cooler regions).

Have students identify which categories/questions they have not addressed yet. One question category should relate to the role the woolly mammoth played in its environment, if the mammoth went extinct because of change in its ecosystem (e.g. loss of a predator), and how to evaluate impacts to the current environment if we reintroduce the mammoth. Tell students that in the next sequence of lessons, they will investigate the role organisms, like the mammoth, play in the stability of ecosystems.

Kelp Forest 5E

How do all of the components of an ecosystem interact to provide resiliency against a disturbance?

Performance Expectations
HS-LS2-2, HS-LS2-6

Investigative Phenomenon
Kelp forests and urchin barrens are two stable ecosystems that can be found in the same location. How is that possible?

Time
6-7 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • How is the carrying capacity of an ecosystem dependent on the biotic and abiotic factors of that system? • How do keystone species contribute to the overall biodiversity and stability of an ecosystem? • How do all of the components of an ecosystem interact to provide resiliency against disturbance? • How do ecosystems recover from both natural and human-caused disturbances? • How can our knowledge of keystone species, ecosystem functioning and resiliency help us be strategic in conservation decisions and in our questions around the de-extinction of the woolly mammoth?	Students begin this instructional sequence by considering a case study on kelp forests and urchin barren ecosystems. Students engage with a map and data set to generate initial claims about the stability of these two ecosystems. Students then generate a model to further investigate how disturbances (both small and extreme) impact ecosystems. Students use their ecosystem models, and a complex text to better understand the roles of keystone species, biodiversity, and the interactions between biotic and abiotic factors, in maintaining stable and resilient ecosystems. Finally, students evaluate claims, evidence, and reasoning on an argument that one ecosystem is more stable or resilient than another.	*Students figure out these ideas in this 5E sequence.* • Complex interactions within an ecosystem serve to maintain stability in population numbers and types of organisms over time • Stable ecosystems can generally recover from modest biological and physical disturbances • Extreme fluctuations in populations or other disturbances can change an ecosystem • Resilient ecosystems are generally biodiverse, have sufficient resources, complex relationships between organisms and between organisms and the environment. • Ecosystems have many different component systems that are interdependent. • Resilient ecosystems are more likely to fully recover from disturbances.

Have students identify which categories/questions they have not addressed yet. One question category should relate to questions about the use of biotechnology to bring extinct organisms back from extinction, including the ethical and scientific concerns of de-extinction.

Passenger Pigeon 5E	How can we evaluate solutions to human-caused biodiversity loss?	**Performance Expectations** HS-LS2-7, HS-LS2-6	**Investigative Phenomenon** Ecosystem loss and organism extinction are critical problems. An organization argues that bringing the passenger pigeon back from extinction will restore ecosystems. Do they have a valid argument to justify de-extinction?	**Time** 5-6 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • What solutions exist for ecosystem collapse? • Why would scientists and others want to bring back the passenger pigeon? • What role did humans play in the demise of the passenger pigeon? • What role did it play in the ecosystem? How did it interact with other components of the ecosystem? • How would reintroducing it to its habitat impact ecosystem stability and functioning? • How can we evaluate scientific arguments and/or solutions to problems? • How can the story of the passenger pigeon help us better understand if we should bring back the woolly mammoth?	Students begin this instructional sequence by learning about the extinction of the passenger pigeon and its relationship to ecosystem instability. Students engage with historical descriptions of the pigeon in order to generate models that represent the role they played in their ecosystem in order to better understand how a solution of de-extinction could benefit this problem, allowing them to critique an argument on bringing them back. Finally, students consider counterclaims and evidence presented in a counter argument that outlines the perspective of some scientists and conservationists that argue de-extinction is not the best solution to biodiversity loss and human impacts on the environment. **Extension** Students may have questions and/or be very interested in the biotechnology tools that scientists are using or developing (like CRISPR) to bring back extinct organisms like the passenger pigeon and the woolly mammoth. Although genetics are not a part of the Unit 6 Performance Expectations, engaging with the concepts of modern genetic engineering is a great way to review **LS3.A Heredity: Inheritance and Variation of Traits**, from Unit 3 and Unit 4. Provide students with HHMI's activity, Building a Paper Model of CRISPR-Cas9 , or use the diagrams depicting the revival of the passenger pigeon, Passenger Pigeon Project to investigate how scientists plan on using biotechnology bring organisms back from extinction.	*Students figure out these ideas in this 5E sequence.* • Human over-exploitation of the passenger pigeon drove it to extinction over a short time scale • The loss of the passenger pigeon had negative consequences on the environment, biodiversity, and led to the loss of the cultural and inspirational values held by humans • Passenger pigeons had an important role in engineering their environment by maintaining the composition of the forest ecosystem, creating disturbances, and limiting other species through competition • De-extinction could play a role in supporting ecosystem health by restoring ecosystem engineer species

Students have had opportunities to evaluate arguments on the de-extinction of organisms, including examining new evidence and counter-arguments. In the final task, they will apply their learning to revise their woolly mammoth extinction models and create the final argument evaluation.

Unit Closing	How can we evaluate the argument that bringing back the woolly mammoth from extinction is a viable solution to biodiversity loss?	**Performance Expectations** HS-LS2-6, HS-LS2-7	**Anchor Phenomenon** Woolly mammoths once roamed the Earth and now they are extinct.	**Time** 1-3 days

Student Questions	What Students Do	Student Ideas
These questions are addressed in the performance task. • What were the causes behind the extinction of the woolly mammoth? • Should we use resources to bring back the mammoth as a way to address human caused biodiversity loss? • How might the reintroduction of the woolly mammoth address human-caused climate change? • What are some of the challenges, including the possible disruption of ecosystems, in bringing extinct organisms back?	Students revisit and revise their earlier work generating an extinction model and evaluating an argument. **Extension** At the end of the performance task, students can engage in a Socratic Seminar to discuss their critique of the argument on bringing the woolly mammoth back as a solution to biodiversity loss.	*These ideas were developed throughout the unit storyline.* • Complex interactions maintain stable ecosystems • Resilient ecosystems are able to return to their original state after modest biological or human caused disturbances • Extreme fluctuations in populations or major physical disturbances can disrupt ecosystem stability • Humans are causing disruptions to ecosystem stability and biodiversity loss through a variety of actions including habitat destruction and over-hunting • Human caused climate change is a disruption of the carbon cycle due to combustion of fossil fuels and other activities • Humans depend on ecosystem functioning and biodiversity for many reasons including recreational and aesthetics • Solutions to human caused disruptions should evaluated

Based on all of the evidence and scientific reasoning generated in this unit, students generate a model that represents the causes behind the extinction of the woolly mammoth and evaluate the argument that bringing back the woolly mammoth is a viable solution to the human-caused loss of biodiversity.

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-LS2-7 * **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.**
Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.
Assessment Boundary: None

In NYS the following has been added to the clarification statement: Examples of solutions could include simulations, product development, technological innovations, and/or legislation.

HS-LS4-6 * **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.**
Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
Assessment Boundary: None

This PE is not included in the NYSSLS.

HS-LS2-2 **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.**
Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.
Assessment Boundary: Assessment is limited to provided data.

HS-LS2-5 **Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.**
Clarification Statement: Examples of models could include simulations and mathematical models.
Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.

In NYS the PE and clarification statement have been edited as follows: Develop a model to illustrate the role of various processes in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations, diagrams, and mathematical models of the carbon cycle (photosynthesis, respiration, decomposition, and combustion].

HS-LS2-6 **Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.**
Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Examples of changes in ecosystem conditions could include ecological succession, modest biological or physical changes, such as moderate hunting or seasonal floods; and extreme changes, such as volcanic eruption or sea level rise.

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

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 6 focuses primarily on ideas related to ecosystem stability, human impact on the environment, and the carbon cycle as it relates to human-caused climate change. These ideas fall mostly within Core Idea LS2 of the NGSS/NYSSLS Ecosystem Dynamics, Functioning. This unit also reinforces the SEP of Engaging in Argument from Evidence and the SEP of Developing and Using Models. That is not to say that students will not engage in other SEPs throughout the lessons; 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! Similarly, the foregrounded CCC for this unit is Stability and Change, which fits well with our selected DCI. As students deepen their understanding of the content to understand how and why human actions are impacting ecosystems and biodiversity, they learn how to use multiple lines of evidence to make causal claims and evaluate arguments. Scaffolding across the unit supports students' three-dimensional learning and will help shift classrooms to become more NGSS-aligned spaces.

Three Dimensions in Unit 6

This chart is a high-level summary of the standards for Unit 6. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence Developing and Using Models Using Mathematics and Computational Thinking Constructing Explanations and Designing Solutions	ETS1.B Developing Possible Solutions LS2.A Interdependent Relationships in Ecosystems LS2.B Cycles of Matter and Energy Transfer in Ecosystems LS2.C Ecosystem Dynamics, Functioning, and Resilience LS4.C Adaptation LS4.D Biodiversity and Humans	Cause and Effect Scale, Proportion, and Quantity Systems and Systems Models Stability and Change

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 previous experience using and developing models, based on evidence, to illustrate relationships and to make predictions about a phenomena. This unit builds on this practice, providing students with multiple opportunities to use, develop, and revise models based on evidence to represent complex systems and relationships between components of the system or between systems.

Construction Explanations and Designing Solutions

- Students in middle school have previous experience constructing or implementing a solution based on criteria and tradeoffs. This unit builds on this practice prompting students to design, evaluate, and refine a solution to a complex real-world problem.

Engaging in Argument from Evidence

- In middle school, students have previous experience constructing arguments supported by evidence and reasoning, as well as evaluating competing design solutions. This unit builds on the practice of Engaging in Argument from Evidence through evaluating the strengths and weaknesses of a scientific argument. Students have the opportunity to identify and evaluate the claims, evidence, and reasoning of a presented solution.

Disciplinary Core Ideas from Middle School

LS2.C Ecosystem Dynamics, Functioning, and Resilience

- In middle school, students learn that ecosystems are dynamic and that changes in an ecosystem result in changes in populations. In high school, they examine the idea of resilience and how ecosystems can shift and change based on disturbances; becoming a different ecosystem. In this unit, students engage in multiple opportunities to closely examine how ecosystems work, and the conditions that can contribute to resilience, or the ability of an ecosystem to bounce back after a disturbance.

Crosscutting Concepts from Middle School

Stability and Change

This unit builds on the following aspects of Stability and Change in middle school.

- Students in middle school learn that we can examine the forces that change the stability of systems over time. This unit builds on this understanding by engaging students in multiple opportunities to use the concept of stability of change to better understand and explain how ecosystems function.

Scale, Proportion, and Quantity

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

- Middle school students learn that proportional relationships are helpful in understanding phenomena and that models are useful in representing relationships at different scales. In this unit, students build on these ideas in order to consider how the concept of orders of magnitude can be supportive of understanding how models relate to one another at different scales. Students are developing and using models at different scales (from the individual level, to the ecosystem, to the ocean biome) to make sense of a phenomenon.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 6 targets a bundle of four PEs taken from the second core idea in high school life science (HS-LS), *Ecosystem Dynamics, Functioning, and Resilience*; those standards are HS-LS2-2, HS-LS2-5, HS-LS2-6, and HS-LS2-7. We have also included HS-LS4-6, as it relates to solutions designed to mitigate adverse impacts of human activity. 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 learning goals informed by the bundled PEs for the unit. All other evidence of learning related to the other dimensions/elements in the PEs can be found within the instructional sequences.

There are two primary foregrounded practices for this unit, the SEP of Engaging in Argument from Evidence and the SEP of Developing and Using Models. Providing students with claims to evaluate is a scaffold. Ideally students will generate their own claims for the performance task. Based on students' needs, teachers can move forward with all claims provided, can modify them to better align with student-generated claims, or use entirely student-generated claims, keeping in mind the other instructional goals for the unit. However, as this is the last unit of the course, there are much fewer scaffolds to support student use of the Science and Engineering Practices than found in earlier units.

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:

	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E
Engaging in Argument from Evidence		✓	✓	✓
Developing and Using Models	✓	✓	✓	✓
Using Mathematics and Computational Thinking	✓	✓	✓	
Constructing Explanations and Designing Solutions	✓			
ETS1.B Developing Possible Solutions	✓			✓
LS2.A Interdependent Relationships in Ecosystems			✓	
LS2.B Cycles of Matter and Energy Transfer in Ecosystems		✓		
LS2.C Ecosystem Dynamics, Functioning, and Resilience	✓	✓	✓	✓
LS4.C Adaptation	✓	✓		
LS4.D Biodiversity and Humans	✓	✓		✓
Cause and Effect	✓	✓	✓	
Scale, Proportion, and Quantity		✓	✓	
Systems and Systems Models	✓	✓	✓	
Stability and Change	✓	✓	✓	✓

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 6 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

MP2 Reason abstractly and quantitatively.	Mathematically proficient students make sense of the quantities and their relationships in problem situations. Students bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.
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.
MP4 Model with mathematics.	Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

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.9-10.6 Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.

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.

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.

WHST.9-10.5 Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.

WHST.9-10.9 Draw evidence from informational texts to support analysis, reflection, and research.

Implementing Unit 6

This unit is designed to be the sixth and final 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	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Class Consensus Discussion		1	1	1	1	
Consensus Building Share	1	2		1	1	
Domino Discover		2	3	3	2	
Idea Carousel			1	1		
Read-Generate-Sort-Solve			1		1	
Rumors		1	1			
Think-Talk-Open Exchange				1	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	Tuskless Elephants 5E	Coral Bleaching 5E	Kelp Forest 5E	Passenger Pigeon 5E	Unit Closing
Chunking Text			1		1	
Partner Reading			1			
Text Annotation	1	1			1	

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Tuskless Elephants 5E	Eco Ocean an Overfishing Simulation	https://www.ecoocean.de/play-online/	NA	NA
Coral Bleaching 5E	Annenberg Learner Interactive Carbon Cycle Lab	https://test-learnermedia.pantheonsite.io/wp-content/interactive/envsci/carbon/carbon.html	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	Ice Age 2- Mammoths	https://www.youtube.com/watch?v=vlv5lqFYs1s&t=7s	NA	NA
Unit Opening	Amazing Life Mammoths of The Ice Age Discovery Documentary	https://www.youtube.com/watch?v=Pna2A8tKFfg	NA	NA
Tuskless Elephants 5E	The Great Elephant Census	https://www.biointeractive.org/classroom-resources/great-elephant-census	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Tuskless Elephants 5E	Selection for Tuskless Elephants	https://www.biointeractive.org/classroom-resources/selection-tuskless-elephants	NA	NA
Tuskless Elephants 5E	Appetite for Destruction: Eating Bluefin Tuna Into Extinction	https://www.youtube.com/watch?v=hivvTo6VSS8	NA	NA
Coral Bleaching 5E	Introduction to a Coral Reef (optional stop at 2:30)	https://www.youtube.com/watch?v=J2BKd5e15Jc	NA	NA
Coral Bleaching 5E	Timelapse Video of Coral Bleaching	https://www.youtube.com/watch?v=bFdPmiwZzVE	NA	NA
Coral Bleaching 5E	HHMI BioInteractive: Coral Bleaching Animation	https://www.youtube.com/watch?v=_ZfGIKiSwwQ	NA	NA
Coral Bleaching 5E	Where Does Carbon Dioxide Come From?	https://www.youtube.com/watch?v=bpazvRVh4y0	NA	NA
Coral Bleaching 5E	What Is the Greenhouse Effect?	https://www.youtube.com/watch?v=SN5-DnOHQmE&t=3s	NA	NA
Kelp Forest 5E	Introduction to a Kelp Forest	https://www.youtube.com/watch?v=GcbU4bfkDA4	NA	NA
Kelp Forest 5E	Army of Sea Urchins? (optional)	https://www.youtube.com/watch?v=D3W4OCnHyCs	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Kelp Forest 5E	Some Animals Are More Equal than Others: Keystone Species and Trophic Cascades	https://www.youtube.com/watch?v=hRGg5it5FMI&t=1075s	NA	NA
Passenger Pigeon 5E	Passenger Pigeon Martha 100 Years Later - Cincinnati Zoo	https://www.youtube.com/watch?v=mvjoc8gwwK8&t=192s	NA	NA
Passenger Pigeon 5E	Extinction Is Not Forever: Reviving the Passenger Pigeon with The Long Now Foundation's Ben Novak	https://www.youtube.com/watch?v=xl919RABEbI	NA	NA
Unit Closing	We Can “Bring Back” The Woolly Mammoth. Should We?	https://www.youtube.com/watch?v=W1GAQLKXZj8	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
Tuskless Elephants 5E	Analyzing Data on Tuskless Elephants Investigation Lab minutes: 30 minutes	
Coral Bleaching 5E	Coral Reef Investigation Lab minutes: 30 minutes	
Coral Bleaching 5E	Carbon Cycle Investigation Lab minutes: 45 minutes	
Kelp Forest 5E	Kelp & Barrens Investigation Lab minutes: 45 minutes	

Lesson	Lab	Materials needed (per group)
Passenger Pigeon 5E	Ecology of the Passenger Pigeon Investigation Lab minutes: 45 minutes	

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	- Post-it notes - *Woolly Mammoth Scaffolded Question Set*
Tuskless Elephants 5E	- Tusked Elephant Image (image of a tusked elephant) - Tuskless Elephant Image (image of a tuskless elephant) - Developing an Explanation for Tuskless Elephants Student Handout (student handout) - Analyzing Data on Tuskless Elephants (student handout) - Internet access - Trove of Mammoth Skeletons Excavated Near Mexico City Gives Clues About Hunting - 25,000 Years Later, Javelin Is Still Embedded in Mammoth's Rib
Coral Bleaching 5E	- *Visual Texts* (optional) - NOAA's Data in the classroom: Investigating Coral Bleaching Activity (optional) - Computers with internet access (optional) - HHMI BioInteractive: Coral Reefs and Global Warming resource folder with all student materials - different colored pencils or stickers - Computers with internet access - Chart paper - No safe haven for coral from the combined impacts of warming and ocean acidification (optional text) - Some Good News about Corals and Climate Change (podcast) - What Helps Animals Adapt (or Not) to Climate Change? . Literacy Strategy: Chunking with Turn and Talk (optional) - Driving Question Board from the start of the unit should be available - *Visual Texts* - Interactive Carbon Story (optional)

Lesson	Materials needed
Kelp Forest 5E	*Kelp Forest Visual* printed or displayed in color *Urchin Barren Visual* printed or displayed in color *Kelp Forest & Urchin Barren Map* Sea Urchin Barrens as Alternative Stable States of Collapsed Kelp Ecosystems Map (optional) *Kelp Forest & Urchin Barren Ecosystem Cards* *Kelp Forest & Urchin Barren Ecosystem Fact Sheet* poster paper computers with internet access Status and Trends for the World's Kelp Forests (optional) Driving Question Board from the start of the unit should be available computer access with internet
Passenger Pigeon 5E	Poster paper Building a Paper Model of CRISPR-Cas9 (optional) Passenger Pigeon Project (optional) Passenger Pigeon Project (optional) Bringing extinct species back from the dead could hurt—not help—conservation efforts
Unit Closing	Driving Question Board The Mammoth Project (optional) De-Extinction Debate: Should We Bring Back the Woolly Mammoth? (optional)

Teacher Materials for Unit 6

# Unit Opening	What is the story of woolly mammoth extinction? What types of information do we need to know in order to evaluate the cause of a species' extinction?	**Performance Expectations**	**Anchor Phenomenon** Woolly mammoths once roamed the Earth and now they are extinct.	**Time** 2 days

Human population growth, globalization, and industrialization are having profound impacts on the long term health and stability of ecosystems, permanently altering the products of billions of years of evolutionary history on planet Earth. After raising questions about the extinction of the woolly mammoth, students discuss how humans have altered ecosystems and what actions may be taken to preserve biodiversity.

ANCHOR PHENOMENON	Why don't we see woolly mammoths anymore?	This is a topic that should incite student curiosity and wonder! Many students have been introduced to the woolly mammoth or similar animals in the past and may wonder why they no longer exist. By working with students to surface their prior knowledge of extinct megafauna, it will allow them to engage with the unit and increase student buy-in.
DRIVING QUESTION BOARD	What questions do we have?	**Based on ideas that have surfaced through student discussion, students create a driving question board.**
PERFORMANCE TASK	What caused the woolly mammoth to go extinct? Should we use biotechnology to bring the woolly mammoth back?	Students develop an initial model to explain the cause of the extinction of the woolly mammoth.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

Why don't we see woolly mammoths anymore?

This is a topic that should incite student curiosity and wonder! Many students have been introduced to the woolly mammoth or similar animals in the past and may wonder why they no longer exist. By working with students to surface their prior knowledge of extinct megafauna, it will allow them to engage with the unit and increase student buy-in.

Preparation

Student Grouping	Routines	Literacy Strategies
• Triads	None	• Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
• Visual Texts • Tell the Story	None	• Ice Age 2- Mammoths

Launch

1. Ask students to consider why we do not see woolly mammoths around any longer. It may be helpful to watch a brief video clip, Ice Age 2- Mammoths to provide context on what a mammoth is.
2. Distribute *Visual Texts* and *Tell the Story*
3. Assign each student in a group with a different visual about woolly mammoth extinction.
4. Students read and **annotate** the three texts individually, circling or annotating three details that are the most important to the phenomenon being described.
5. Have students complete the visual text analysis independently, with the guiding question in mind: *Why don't we see woolly mammoths around anymore?*

Access for All Learners

Not all students may be familiar with a woolly mammoth or the idea of extinct megafauna. Many students have seen the movie 'Ice Age', so encourage students to surface what they know about woolly mammoths from that movie or other popular depictions; using additional video clips or visuals as needed.

Telling the Story

1. Students share their ideas in their group, with every individual identifying the details that they thought were important.

Conferring Prompts

Confer with students as they generate 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?

2. As a group, students decide which ideas they think are important, and use those ideas to write out what is happening, or the *story* of the phenomenon.

Example Student Response:

At the beginning. . . .	Mammoths may have lived throughout much of the northern portions of the globe, they were adapted to cold regions. There were several related species of elephant-like animals, including the mammoth and humans were not living in the mammoth's habitat.
After that. . .	Thirty thousand years ago, there were many mammoths living in the northern areas. However, the suitable climate for the mammoths started to shift even more north. Humans started moving north into the mammoths habitat, and may have started hunting them.
By the end. . .	By 6,000 years ago, humans are in all of the mammoth's habitat, and most of their suitable habitat was gone. Most of their previous habitat was becoming less suitable. Humans were living in all of the mammoths territory by 6,000 years ago. The mammoths and the mastodon went extinct, but the three species of elephant are still alive.

Driving Question Board

What questions do we have?

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

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	• Post-it notes • *Woolly Mammoth Scaffolded Question Set* • Amazing Life Mammoths of The Ice Age Discovery Documentary

Generating Questions

1. Prompt students to recall the phenomenon under study for this unit. Clarify for students that we are trying to figure out what happened to the woolly mammoth, *Why don't we see them around anymore?*

2. Watch the first 7 minutes of the Amazing Life Mammoths of The Ice Age Discovery Documentary in order to surface more questions and to introduce the idea that we can use biotechnology to bring the mammoth back from extinction.

3. Let students know that they will be exploring this idea throughout the unit, and will be applying their understanding of the phenomenon to a real life possibility; bringing the woolly mammoth back from extinction so that it can play its' original role in the Arctic ecosystem.

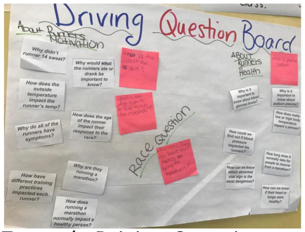
Grouping Questions

1. At this point, students should have a lot of questions! Prompt students to think about what they need to know in order to understand the phenomenon, and what they would need to know in order to decide if we should bring the woolly mammoth back from extinction.

2. Provide students with post-it notes, chart paper, or electronic resources in order to make a DQB.

3. In small groups, prompt students to generate as many questions as possible on post-it notes. Students should share their questions and categorize the questions into 3-5 groups. Students should generate a title or an umbrella question that encompasses all of the smaller sub questions provided on the cards.

4. As a whole class or in small groups, students share and categorize their questions, as they organize the questions on chart paper.



Example Driving Question Board

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?

Differentiation Point

As this is the last unit of the course, students should ideally be successfully generating a Driving Question Board (DQB) in groups. If you are using this unit out of sequence or if students are still struggling with developing or categorizing appropriate questions, provide students with a set of scaffolded questions, *Woolly Mammoth Scaffolded Question Set*. Encourage students to add additional questions to set, and use all of the ideas to support students in categorizing the questions and organizing them into a DQB.

Performance Task

What caused the woolly mammoth to go extinct? Should we use biotechnology to bring the woolly mammoth back?

Students develop an initial model to explain the cause of the extinction of the woolly mammoth.

Preparation

Student Grouping	Routines	Literacy Strategies
• Table Groups	• Consensus Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
• Initial Model	None	

Launching the Performance Task

1. Prompt students to recall the phenomenon under study for this unit.
2. Provide students with the *Initial Model*. Prompt students to read the task.
3. Highlight that students will eventually evaluate a scientific argument on whether or not we should bring the woolly mammoth back from extinction. Ask students to consider why we might want to understand more about why they went extinct in the first place, before we begin to evaluate an argument on bringing them back.

Routine

This is the first time the routine **Consensus Building Share** appears in this unit! Please read the Biology Course Guide for detailed steps about this routine.

Look & Listen For

- If we do not address the cause(s) they may go extinct again
- Maybe the cause(s) are still there and they won't survive at all
- We need to understand more about their habitat or food needs
- We need to understand how they may impact other organisms
- We may learn something that can help us save other organisms from extinction

4. In table groups, allow students to brainstorm different claims on what caused the woolly mammoth to go extinct. Use the group learning routine, **Consensus Building Share**, to create a class-wide list of possible claims that can be investigated throughout the unit.

Example list of causes behind the extinction of the woolly mammoth

1. Humans hunted woolly mammoths too much.
2. An infectious disease killed all of the woolly mammoths.
3. The temperature increased across the region where they lived (or the climate changed and was no longer good for the mammoths)
4. A food source (grass, plants) for woolly mammoths died out.
5. An animal that preys on woolly mammoths died off.
6. There was a new predator introduced to the mammoths habitat

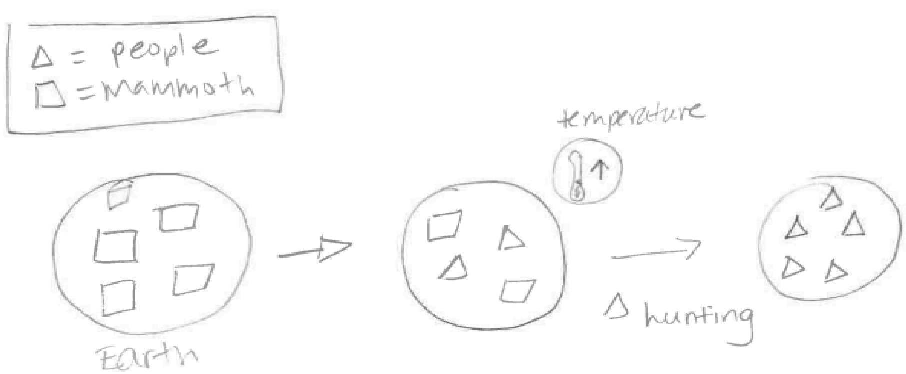
Differentiation Point

All of the listed example claims will be explored throughout the unit, except #2 on infectious disease. Based on student interest and readiness, students can research additional possible causes, beyond those explicitly included in the unit.

5. Students note down the different claims (causes behind extinction) and the empirical evidence they might need to evaluate or support each claim in *Initial Model*.

6. Prompt students to draft their initial extinction model in the space provided in their organizer, incorporating at least two different causes.

Example Student Work: Initial Model



Integrating Three Dimensions

At this point, students have had multiple opportunities throughout the course to develop proficiency in **CCC#2 Cause and Effect**. Students should be able to identify appropriate empirical evidence for each claim (each possible cause behind the extinction of mammoth). If needed, pause and review the concept that empirical evidence is needed to make claims about specific causes and effects, and to differentiate between correlation and causation, first introduced in Unit 2, Humans vs Bacteria.

Differentiation Point

At this point, students have had multiple opportunities throughout the course to develop proficiency in **SEP#2 Developing and Using Models**. If student's initial models do not meet the standard, provide an opportunity for students to surface their ideas on the characteristics of a scientific model and highlight exemplars to support the development of more sophisticated models throughout the unit.

Standards in Unit Opening

Performance Expectations

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)	LS2.C Ecosystem Dynamics, Functioning, and Resilience • Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. LS2.C(2) LS4.D Biodiversity and Humans • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. LS4.D(2)	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

	Anchor Phenomenon	Driving Question Board	Performance Task
Developing and Using Models			*Initial Model*
LS2.C Ecosystem Dynamics, Functioning, and Resilience			*Initial Model*
LS4.D Biodiversity and Humans	*Tell the Story*		*Initial Model*
Cause and Effect			*Initial Model*

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task
Mathematics			
ELA/Literacy	RST.9-10.1 WHST.9-10.2 WHST.9-10.9		WHST.9-10.9 SL.9-10.4

Classroom Resources for Unit Opening

Woolly Mammoth Scaffolded Question Set

Woolly Mammoth Scaffolded Question Set

Cut out these cards.

How could humans cause woolly mammoths to go extinct?	Did illness affect their extinction?	What did mammoths eat?
Did mammoths have predators?	How did they travel? Was it in groups?	Was there a change in food availability that led to extinction?
What caused the environmental changes when the mammoths were living?	What caused the climate change during the time of the mammoths?	What temperature was too cold or too hot for them?

Did climate change impact their food source?	Why did humans hunt the woolly mammoths?	Do we have evidence that humans over hunted the mammoth?
Did mammoths live together in groups or alone?	What specific adaptations did they woolly mammoth have?	Under what conditions did they migrate?
Why were some mammoths able to live on an island, after almost all the others went extinct?	Did they compete with other organisms for resources?	What was their habitat like?

How long did the extinction take?

What characteristics do woolly mammoths have in common with elephants?

What ethical concerns are there in bringing the mammoths back?

Tuskless Elephants 5E

Why are there more tuskless elephants now than in the past?

Performance Expectations
HS-LS4-6, HS-LS2-7

Investigative Phenomenon
Some elephant populations have more tuskless elephants than has typically been normal.

Time
6-8 days

In this 5E instructional sequence, students are investigating the questions about over-hunting or the over exploitation of woolly mammoths by humans surfaced during the Driving Question Board launch: *How did humans impact the woolly mammoths? Did the over-hunting by humans cause the extinction of the woolly mammoths?* Elephants are a close relative of the mammoth. By investigating how humans and elephants currently interact, students gain a deeper understanding of how human activities impact biodiversity and will help students evaluate if hunting may have been an important cause of the extinction of the woolly mammoth.

ENGAGE	Why do some populations have a high number of tuskless elephants?	Students **analyze a graph** to surface ideas on how **human activities, such as poaching, may impact biodiversity.**
EXPLORE	Why is the trait of tusklessness increasing in some populations of female elephants?	Students **use graphs and data sets** of the tuskless elephant phenomenon to explore how **human activities such as poaching impact biodiversity.**
EXPLAIN	How can we use what we understand about the tuskless elephant phenomenon to design solutions to human impacts on biodiversity?	Students apply their understanding of how **elephant populations and habitats have changed in order to maintain a new stability** after being **impacted by human activities** in order to **design possible solutions** to the elephant decline.
ELABORATE	How can we design and test solutions to human impacts on biodiversity?	Students consider the **role of stakeholders** as they **use and revise a simulation** in order to collect and evaluate **evidence on how a possible solution may cause** a reduction in the **negative actions by humans on biodiversity.**
EVALUATE	How might hunting by humans contributed to the extinction of the woolly mammoth?	Students use **evidence** from the learning sequence to inform the **development of a model** that represents the **causes behind** the **extinction of the woolly mammoth**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why do some populations have a high number of tuskless elephants?

Students **analyze a graph** to surface ideas on how **human activities, such as poaching, may impact biodiversity.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	• Tusked Elephant Image (image of a tusked elephant) • Tuskless Elephant Image (image of a tuskless elephant) • Developing an Explanation for Tuskless Elephants Student Handout (student handout)

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to how humans may have impacted woolly mammoths in the past. Students may have brought up the living relative of woolly mammoths, elephants, as a topic of curiosity or relevance in understanding what happened to the mammoths. If students did not bring up elephants, prompt students to think about ways we could learn about the mammoth, even though it has gone extinct, reminding students of the cladogram of mammoth relative as needed to surface the idea of learning about existing elephants.

2. Use students' ideas to transition to the question, "How are human actions currently impacting elephants?" Students may have examples such as poaching or using them for entertainment like the zoo or circus.

3. Let students know that elephant researchers have recently uncovered a puzzling phenomenon about elephants. Populations of elephants sometimes include a few tuskless elephants, but researchers have found populations with a high number of tuskless elephants.

4. Project an image of a Tusked Elephant Image and a Tuskless Elephant Image so students have a visual. Prompt students to share what they think elephants use their tusks for.

Access for All Learners

All students should have some background knowledge of elephants and their tusks, as they are a charismatic species. Prompt students to think about the last place they saw an elephant (at the zoo, on TV) and to share their experiences and knowledge about elephants.

Surfacing Student Ideas

1. Project or distribute the graph based on researchers in Gorongosa National Park in Mozambique; using only the top portion of the HHMI BioInteractive student handout, Developing an Explanation for Tuskless Elephants Student Handout (only using the introduction and the graph). Allow students time to interpret the graph, noticing the idea that the population of tuskless female elephants in Gorongosa is much higher than in other populations of elephants.

2. Use the group learning routine, **Rumors** to surface student ideas on why so many female elephants are tuskless in this population.

3. After students have shared their ideas through Rumors, categorize student ideas to address during the instructional sequence.

Look & Listen For

Possible student ideas:

- Disease
- Mutation
- More are being killed by people for their tusks (ivory)
- Less habitat or other pressures on the population, such as more people in the area or agriculture
- The environment changed, so they are less advantageous
- Less food available, so many elephants do not grow tusks

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. This is the first time the routine **Rumors** appears in this unit. Please read the Biology Course Guide for detailed steps about this routine.

Explore

Why is the trait of tusklessness increasing in some populations of female elephants?

Students **use graphs and data sets** of the tuskless elephant phenomenon to explore how **human activities such as poaching impact biodiversity.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Consensus Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
• Making Sense of the Analyzing Data on Tuskless Elephants Investigation • Analyzing Data on Tuskless Elephants Investigation Rubric	None	• Analyzing Data on Tuskless Elephants (student handout) • The Great Elephant Census

Launch

1. In the previous Engage phase, students surfaced ideas on why the number of tuskless elephants are increasing. Prompt students to consider how we could investigate this phenomenon in the classroom in order to revise our initial explanation. Provide students time to brainstorm and surface ideas.

Look & Listen For

Students may generate ideas such as:

- Compare elephant population in Gorongosa National Park with other parks to see if it is different
- Learn more about what is happening to elephants in Gorongosa National Park and look for patterns (disease outbreaks, human impacts such as habitat destruction)
- Investigate changes in population data or data on the changes to the number of tuskless elephants

Investigation: Analyzing Data on Tuskless Elephants

1. In table groups, provide students with the HHMI Biointeractive activity handout, Analyzing Data on Tuskless Elephants , pages 1-2 and Page 6 ONLY. Students work in their groups to make sense of the data.

Access for All Learners

Students may be struggling to connect to the idea of elephant populations or to understand how scientists know how many elephants are living in a location. To better understand how elephant populations are counted, watch the video, The Great Elephant Census .

Whole-Class Investigation Summary

1. Provide students with *Making Sense of the Analyzing Data on Tuskless Elephants Investigation* and ask them to independently complete it, noting what they think are the most important observations, ideas and questions based on those observations.
2. After students have completed *Making Sense of the Analyzing Data on Tuskless Elephants Investigation*, prompt table groups to discuss their analysis and decide on their most important observations, ideas and questions from the investigation.
3. Ask groups to come up with one important idea to share with the whole class.
4. Use the group learning routine **Consensus Building Share** to surface ideas and questions.

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. Be sure to look at the Biology Course Guide for the action pattern for this routine.

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?”

Look & Listen For

- The greatest percentage of elephants illegally killed in Gorongosa National Park had tusks and had their tusks taken
- In other parks, the population that experienced the most poaching also had the greatest number of female tuskless elephants (with one exception, North Kafue park)
- Why are the females tuskless and the males are not?
- In Gorongosa, there were 5 elephants that were killed, and neither meat or tusks were taken, why?
- What other ways are humans impacting elephants?

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 *Analyzing Data on Tuskless Elephants 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

How can we use what we understand about the tuskless elephant phenomenon to design solutions to human impacts on biodiversity?

Students apply their understanding of how **elephant populations and habitats have changed in order to maintain a new stability** after being **impacted by human activities** in order to **design possible solutions** to the elephant decline.

Preparation

Student Grouping	Routines	Literacy Strategies
- Table Groups	- Domino Discover - Class Consensus Discussion	- Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
- Tuskless Elephants Note Catcher - Tuskless Elephant Text - Designing a Solution for Elephant Decline - Peer Feedback Guide - Summary Task	None	- Selection for Tuskless Elephants

Using Multimedia to Make Sense of a Phenomenon

1. Use student observations and questions from the Explore phase to transition to using resources to better understand the phenomenon of tusklessness and how we may protect elephants from further decline or negative impacts. Let students know that they will watch a video that might help provide more context on what is happening with the elephants of Gorongosa National Park. Distribute the *Tuskless Elephants Note Catcher*, so that students can note down their ideas as they watch the video, Selection for Tuskless Elephants .

2. Provide students with the *Tuskless Elephant Text*, in order to provide more context on the threats facing elephants in Gorongosa and across the continent of Africa. Students should **annotate** the text, as they look for additional information to add to the note catcher.

Annotation:
- Underline information that is relevant to questions in the note-catcher
- **?** place a question mark next to any points that you have a question about
- **!** place a exclamation point next to any points that are interesting

Access for All Learners

Students have the opportunity to revise their responses from a video, using a text annotation strategy. Providing multiple access points (closed caption video, text, and discussion) and a revision opportunity provides support for **multilingual learners**.

3. In table groups or pairs, prompt students to discuss questions #2 and #6 from *Tuskless Elephants Note Catcher*. Question#2: Explain why an abnormally large proportion of female elephants are tuskless in Gorongosa and Question# 6 Why might we want to develop solutions to the negative impacts humans are causing to elephant populations? Use the group learning routine **Domino Discover** to surface student ideas.

Look & Listen For

Question#2

- Humans are causing disturbances (poaching) that are endangering the elephant population
- Heavy poaching during a war killed off many of the elephants that had tusks and created selective pressure that acted to reduce the number of female tuskless elephants

Question#6

- Moral reasons (humans are causing the problem, we should resolve it)
- Elephants and their habitats are inspirational for some people
- Tourism to see elephants and recreation in their habitat may benefit local communities (and enjoyment for people that visit)
- Elephants are complex organisms that we can learn about and from
- Elephants play an important role in maintaining biodiversity and ecosystems that benefit humans and other organisms

Integrating Three Dimensions

Although many of the elements from the **DCIs** of **LS4D (Natural Selection and Adaptation)** are not a part of the Performance Expectations addressed in this unit, discussing the tuskless elephant phenomenon is a great opportunity to review these concepts from Unit 2 *Humans vs Bacteria*!

Designing Solutions

1. Use student ideas on why it might be desirable to protect elephants or biodiversity in general to transition to designing a possible solution to the decline of African elephants. Use one of the above ideas to encourage students to think about what we could do to address the threats to elephant populations. For example:

"You brainstormed several interesting ideas on why elephants are important. One idea you discussed is that elephants seem to play an especially important role in their ecosystem, that positively impacts a lot of other organisms. Based on what you know already, what are some ways in which we could protect elephants, and therefore many of the other species they impact?"

2. In table groups, provide students with the *Designing a Solution for Elephant Decline*

Differentiation Point

Based on learning goals and student interest, students can research example solutions that are being used to reduce poaching and negative elephant-human interactions and use that information to inform their proposed solutions. One example is building beehive fences to reduce human-elephant conflicts.

3. After designing the proposed solution, each table group switches their solution with another group. Students use the *Peer Feedback Guide* to offer suggestions on optimizing solutions. Students will have an opportunity to revise their solutions after the Elaborate activity.

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 how human activities are impacting biodiversity and what some possible solutions might be, using the elephants of Gorongosa Park as an example."

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.

2. Select two or three group solutions 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 human activities impact biodiversity and possible solutions that mitigate these impacts. The decision about which proposed solutions 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.

3. 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.

4. Proceed through the steps in the Consensus Discussion Steps.

5. 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.

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

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #7 - Stability** and Change explicit for students by elevating ideas related to how observing and asking questions about how things change and how they remain stable helps to make sense of a phenomenon. This is an important element **CCC # 7 - Stability and Change** at the high school level.

Take Time for These Key Points

- Human activities such as poaching, overexploitation, and habitat destruction can disrupt an ecosystem and threaten the survival of some species such as elephants
- Each organism plays a role in ecosystem stability.
- Humans benefit from healthy ecosystems. Sustaining biodiversity also aids humanity by preserving ecosystems of recreational or inspirational value.
- Elephant populations and ecosystems can regain stability after a disruption, such as excessive poaching during a civil war, but may include longer-term changes such as tusklessness in elephants or changes in behavior or habitat use.

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

Integrating Three Dimensions

This Explain phase develops students use of designing solutions from **SEP#6 Constructing Explanations and Designing Solutions**. Many of the components of designing solutions, such as developing criteria, and considering tradeoffs, were first introduced in Unit 3, *The Evolution of Sick Humans*. Review those materials as needed as students navigate designing solutions to human impacts throughout this unit.

Integrating Three Dimensions

The summary task prompts here are designed to get students to consider what they know about using the crosscutting concept of Stability and Change (**CCC #7 - Stability and Change),** then apply it as a tool for asking more questions that build on prior learning about both DCIs and CCCs.

Elaborate

How can we design and test solutions to human impacts on biodiversity?

Students consider the **role of stakeholders** as they **use and revise a simulation** in order to collect and evaluate **evidence on how a possible solution may cause** a reduction in the **negative actions by humans on biodiversity.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Pairs • Table groups	• Consensus Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
• Appetite for Destruction Note Catcher • Overfishing Simulation • Simulation Reminders • Evaluating and Revising A Simulation • Revising Elephant Decline Solution	None	• Internet access • Appetite for Destruction: Eating Bluefin Tuna Into Extinction • Eco Ocean an Overfishing Simulation

Launch

1. In designing their initial solution to the overexploitation of elephants, students may have considered setting limits on the killing of elephants or other ways to protect a 'common' resource, as no one really owns the elephants. Highlight student ideas about that type of solution to transition to investigating the *tragedy of the commons* or the overexploitation of a common resource. Ask students to brainstorm other organisms that might be overexploited.

Look & Listen For

- Forests
- Hunting wildlife
- Fish
- Coral
- Using grasslands or the rainforest to feed cattle

2. To further investigate this idea of overexploitation, introduce students to the case of the BlueFin Tuna, which is being extremely overfished and is also in danger of extinction. Remind students that even though we have been talking about elephants, many species face extinction and overexploitation at the

hands of humans. It might be helpful to think about what is both common and different between the elephants and a different species, like the Bluefin tuna, so we can better understand the concept of overexploitation, or over-hunting so that we can apply that thinking to our unit-level phenomenon of figuring out what happened to the woolly mammoth.

3. Provide students with the *Appetite for Destruction Note Catcher*, and prompt students to watch the video, Appetite for Destruction: Eating Bluefin Tuna Into Extinction while considering the causes behind the decline of the tuna and the different stakeholders involved in the issue
4. Pause the video as needed (the sections are time-stamped on the note catcher) as needed. The entire video is a great resource, but a good introduction to the stakeholders and issues involved can be accessed in the first 15-18 minutes of the video if there is not sufficient instructional time.

Using, Evaluating and Revising a Simulation

1. After students have a better understanding of the stakeholders and the human activities that are behind the decline of the BlueFin Tuna, launch students into engaging with the Eco Ocean an Overfishing Simulation . Distribute the *Overfishing Simulation* and provide students with internet access so they can interact with the simulation in pairs.

Differentiation Point

If students are struggling with the simulation, provide *Simulation Reminders*, which can be used as a quick guide or reminder on how to use the simulation.

2. As students complete *Overfishing Simulation*, highlight that a simulation may be helpful in designing new solutions to this human activity (overexploitation). Provide students with *Evaluating and Revising A Simulation*, so that students can extend their use of the simulation to evaluate and revise a simulation to model and test out solutions to human biodiversity loss (like overfishing).
3. In table groups, prompt students to discuss how what they learned about designing and testing solutions on the BlueFin Tuna decline may help inform or revise their elephant decline solution generated in the Explain phase in *Designing a Solution for Elephant Decline*)
4. Provide students with *Revising Elephant Decline Solution* and time to revise their design for a solution, using peer, self, and teacher feedback from *Peer Feedback Guide*, and new ideas from the use of the simulation to revise their solution.
5. Use the group learning routine **Consensus Building Share** for students to surface ideas about their solution and how their solution to overfishing may inform how they could revise their elephant decline solution. Its important to help students see a commonality between the effects of the overexploitation of both elephants and tuna (even though there are some important differences) so that students can better understand the concepts of human impacts on biodiversity overall, and how we can design solutions many different types of species that are under threat.

Integrating Three Dimensions

The *Evaluating and Revising A Simulation* is designed to partially support students in developing their use of the engineering **DCIs of ETS1.B Developing Possible Solutions.** These DCIs are also partially addressed in Unit 3, *The Evolution of Sick Humans*.

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 Elabotate, 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

Possible Student Ideas:

- Identifying appropriate stakeholders facilitates the design of effective solutions
- Biodiversity is being threatened by the human action of overexploitation (over hunting)
- Hunting or harvesting in a sustainable way may be a solution to overexploitation in some cases
- Trade-offs must be considered when designing solutions to human impacts, as there will always be a consequence or cost of an action
- Solutions to human impacts such as unsustainable fishing or hunting can be complex and multi-faceted; can include laws, technology, incentives, and education campaigns
- Solutions to mitigate human impacts on biodiversity should consider important tradeoffs and strive to minimize the social, cultural, financial, and environmental impacts
- Models, including computer simulations, are useful for a variety of purposes, such as running simulations to test different ways of solving a problem

Evaluate

How might hunting by humans contributed to the extinction of the woolly mammoth?

Students use **evidence** from the learning sequence to inform the **development of a model** that represents the **causes behind** the **extinction of the woolly mammoth**.

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
• Tuskless Elephant 5E - Extinction Model • Tuskless Elephant 5E - Mini Rubric	None	• Trove of Mammoth Skeletons Excavated Near Mexico City Gives Clues About Hunting • 25,000 Years Later, Javelin Is Still Embedded in Mammoth's Rib

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 did hunting by humans impact the Woolly Mammoth?)

Implementation Tip

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

2. Prompt students to review what they figured out in this learning sequence (how over-hunting or overfishing of both elephants and bluefin tuna negatively impacts biodiversity) Ask students to think about how understanding the story of these two organisms may be helpful in understanding what might have happened to the woolly mammoth.
3. Use the group learning routine **Domino Discover** to surface ideas from the class.

Look & Listen For

- Both of these organisms are currently being overexploited by humans, do we see similar evidence with the woolly mammoth for past exploitation?
- Elephants and tuna are endangered by habitat destruction and climate change, do we have evidence of that for the woolly mammoth?
- All three organisms play or played an important role in the ecosystem, thus losing them might have or might have had an impact on the stability of ecosystems and a loss of human benefits
- Solutions to current problems may give us insight into how to protect the mammoth if we bring them back

4. Provide students with the Woolly Mammoth Visuals from the unit launch as a reminder and Trove of Mammoth Skeletons Excavated Near Mexico City Gives Clues About Hunting and 25,000 Years Later, Javelin Is Still Embedded in Mammoth's Rib that outline new evidence of hunting by humans.

5. Students work individually on the *Tuskless Elephant 5E - Extinction Model* in order to review what they have learned during this 5E sequence and consider the new evidence in the on-line texts. Students outline the evidence and scientific reasoning behind the claim that humans caused the extinction of the woolly mammoth through over-exploitation, and represent their ideas in a model.

6. Confer with students while they are working.

7. After completing their response, use the *Tuskless Elephant 5E - 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.

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 these questions and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

3. One question category still unanswered should relate to questions about different components of the woolly mammoth's environment and the possibility of climate change having had a negative impact. Point to student questions and ideas generated about the interaction between elephants and their environment in this learning sequence to transition to the next sequence of lessons, in which they will investigate this set of questions.

Standards in Tuskless Elephants 5E

Performance Expectations

HS-LS2-7 * **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.**
Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.
Assessment Boundary: None

In NYS the following has been added to the clarification statement: Examples of solutions could include simulations, product development, technological innovations, and/or legislation.

HS-LS4-6 * **Create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity.**
Clarification Statement: Emphasis is on designing solutions for a proposed problem related to threatened or endangered species, or to genetic variation of organisms for multiple species.
Assessment Boundary: None

This PE is not included in the NYSSLS.

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

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)

Using Mathematics and Computational Thinking
- Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. SEP5(1)
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(2)

Constructing Explanations and Designing Solutions
- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. SEP6(5)

Disciplinary Core Ideas

ETS1.B Developing Possible Solutions
- When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1)
- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs. ETS1.B(2)

LS2.C Ecosystem Dynamics, Functioning, and Resilience
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. LS2.C(2)

LS4.C Adaptation
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. LS4.C(4)

LS4.D Biodiversity and Humans
- Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). LS4.D(1)
- Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation,

Crosscutting Concepts

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

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)

Stability and Change
- Much of science deals with constructing explanations of how things change and how they remain stable. CCC7(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. LS4.D(2)	

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models			*Designing a Solution for Elephant Decline*	*Appetite for Destruction Note Catcher*	*Tuskless Elephant 5E - Extinction Model* *Tuskless Elephant 5E - Mini Rubric*
Using Mathematics and Computational Thinking		Analyzing Data on Tuskless Elephants *Making Sense of the Analyzing Data on Tuskless Elephants Investigation* Consensus Building Share		*Overfishing Simulation* *Evaluating and Revising A Simulation* *Overfishing Simulation*	
Constructing Explanations and Designing Solutions			*Designing a Solution for Elephant Decline* *Peer Feedback Guide* *Summary Task*	*Revising Elephant Decline Solution*	
ETS1.B Developing Possible Solutions				*Appetite for Destruction Note Catcher* *Overfishing Simulation* *Evaluating and Revising A Simulation* Consensus Building Share *Evaluating and Revising A Simulation* *Revising Elephant Decline Solution* Consensus Building Share	
LS2.C Ecosystem Dynamics, Functioning, and Resilience	Rumors	Analyzing Data on Tuskless Elephants *Making Sense of the Analyzing Data on Tuskless Elephants Investigation* Consensus Building Share	*Tuskless Elephants Note Catcher* *Designing a Solution for Elephant Decline* *Peer Feedback Guide* *Summary Task*		*Tuskless Elephant 5E - Extinction Model* *Tuskless Elephant 5E - Mini Rubric*

	Engage	Explore	Explain	Elaborate	Evaluate
LS4.C Adaptation			*Summary Task*	*Appetite for Destruction Note Catcher* *Overfishing Simulation* Consensus Building Share	
LS4.D Biodiversity and Humans	Rumors	Analyzing Data on Tuskless Elephants *Making Sense of the Analyzing Data on Tuskless Elephants Investigation* Consensus Building Share	*Designing a Solution for Elephant Decline Summary Task* *Tuskless Elephants Note Catcher* *Designing a Solution for Elephant Decline Peer Feedback Guide*	*Appetite for Destruction Note Catcher* *Overfishing Simulation* Consensus Building Share	*Tuskless Elephant 5E - Extinction Model* *Tuskless Elephant 5E - Mini Rubric*
Cause and Effect			*Designing a Solution for Elephant Decline*	*Appetite for Destruction Note Catcher* Consensus Building Share	*Tuskless Elephant 5E - Extinction Model* *Tuskless Elephant 5E - Mini Rubric*
Systems and Systems Models				*Appetite for Destruction Note Catcher* [material: BIO.U6.L1.Elaborate.H2] [material: BIO.U6.L1.Elaborate.H4]	*Tuskless Elephant 5E - Extinction Model* *Tuskless Elephant 5E - Mini Rubric*
Stability and Change			*Tuskless Elephants Note Catcher* *Summary Task*		

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2 MP3	MP2 MP3	MP2	MP2
ELA/Literacy	RST.9-10.7		SL.9-10.4	WHST.9-10.2 SL.9-10.1	

Coral Bleaching 5E	How can we understand the causes and potential impacts of climate change?	**Performance Expectations** HS-LS2-5, HS-LS2-2	**Investigative Phenomenon** Coral reefs are ejecting their symbiotic algae, a phenomenon called coral bleaching.	**Time** 7 days

In this 5E instructional sequence, students are investigating the questions about the climate, and climate fluctuations of the woolly mammoths surfaced during the Driving Question Board launch: How did climate change impact the extinction of the woolly mammoth? In order to apply an understanding of how climate change can impact organisms and their environment, students investigate a case study on coral bleaching. Coral, which are a keystone species, are undergoing a phenomenon of 'bleaching' due primarily to climate change. Students consider the phenomenon of coral bleaching, and other anthropomorphic disturbance to coral reefs in order to evaluate claims about the extinction of the woolly mammoth.

ENGAGE	How does human-induced climate change impact other organisms?	Connecting to students' initial questions about how climate change affected the woolly mammoth, students are presented with the phenomenon of the bleaching of coral reefs and use what they already know about **humans' impact on biodiversity** to predict what is **causing** the bleaching and decline of coral.
EXPLORE 1	How can we understand the causes behind the bleaching and decline of coral reefs?	Students **calculate and use mathematical representations** of global heat stress data in order to surface trends on the **relationship between rising sea temperatures and coral bleaching.**
EXPLAIN 1	Constructing an explanation for the cause behind coral bleaching.	Students **develop an initial explanation** on the **effect** of **rising sea temperature on coral bleaching**.
EXPLORE 2	How have human actions caused climate change?	Students collect data from a simulation to **generate a mathematical representation** of the **movement of carbon through the earth as a system** to learn more about **human caused climate change.**
EXPLAIN 2	How are human actions causing rapid climate change?	Students **construct a model** that represents how human induced **climate change is affecting** biodiversity at **different scales**, such as coral reef ecosystems.
ELABORATE	How can organisms adapt to climate change?	Students **use evidence** of the **impact** of **climate change** on different organisms to **explain** the extent to which endangered **organisms can adapt and avoid extinction**.
EVALUATE	How might climate change have contributed to the extinction of the woolly mammoth?	Students revise their initial ideas about what **caused** the extinction of the woolly mammoth and **develop an extinction model** using what they learned about **climate change and human impact.**

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

How does human-induced climate change impact other organisms?

Connecting to students' initial questions about how climate change affected the woolly mammoth, students are presented with the phenomenon of the bleaching of coral reefs and use what they already know about **humans' impact on biodiversity** to predict what is **causing** the bleaching and decline of coral.

Preparation

Student Grouping	Routines	Literacy Strategies
None	• Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
• Coral Reef Coverage Graph	None	• *Visual Texts* (optional) • Introduction to a Coral Reef (optional stop at 2:30) • Timelapse Video of Coral Bleaching

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to the woolly mammoth's climate or environment and how changes in their environment may have led to extinction. Ask students to describe how the mammoths' environment might have changed based on their prior knowledge or review image #3 from *Visual Texts*. Prompt students to think about how we can better understand how changing environments, especially climate can impact organisms. Listen for the idea that we can look at ecosystems that do exist today and how current climate changes are impacting ecosystems and organisms. Remind students that we investigated elephants to better understand how human hunting can impact biodiversity, so it might be helpful to investigate this phenomenon in a living organism.

2. Use the student's ideas to transition to the case study presented in this 5E sequence. Let students know that we will investigate coral reefs to better understand changing environments in order to evaluate if a changing environment might have played a role in the extinction of the woolly mammoth.

3. Ask students to describe what they already know about coral reefs, and chart ideas on the board.

Access for All Learners

Provide students an opportunity to describe their personal experiences or background knowledge of coral reefs, including popular depictions such as Finding Nemo. If students need more support in describing a coral reef habitat, show Introduction to a Coral Reef up until about minute 2:30 to provide a visual reference and introduction to the ecosystem.

Students generate observations based on a graph and visual

1. Introduce the case study by providing students with the *Coral Reef Coverage Graph* and the guiding prompt: "What trend do you see in the coral reef cover (or coral reef population) in the Caribbean between 1977 and 2001?"

2. After students have had a chance to make sense of the graph (that corals are declining in the Caribbean); let students know that one key reason for the decline is the phenomenon of coral bleaching, and that this process is occurring in reefs across the globe. Show students the Timelapse Video of Coral Bleaching and provide time for students to share their observations of the process.

Implementation Tip

The video and graph on coral decline and bleaching is designed to build student investment and background knowledge, not to explain the coral bleaching at this point of the learning cycle. Students may have ideas and prior knowledge about coral decline or bleaching at this point that they can share, but students figure out the details of how and why this phenomenon is occurring over the course of the learning.

3. Ask them to brainstorm the causes behind the changes in the coral reef population in the Caribbean and the phenomenon of coral bleaching. Students should list out all of their ideas, and then start or circle their most important or best idea.

Surfacing Student Ideas

1. Use the Group Learning Routine **Rumors** to elicit student ideas. Categorize student responses.

Look & Listen For

Students may surface ideas around:

- Pollution
- Disease
- Climate change
- Overfishing
- Change in water characteristics (ph, waves, clarity, temperature)
- Invasive species

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.

Explore 1

How can we understand the causes behind the bleaching and decline of coral reefs?

Students **calculate and use mathematical representations** of global heat stress data in order to surface trends on the **relationship between rising sea temperatures and coral bleaching.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Pairs	• Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
• Coral Bleaching Investigation • Making Sense of the Coral Bleaching Investigation • Coral Bleaching Investigation Rubric	None	• NOAA's Data in the classroom: Investigating Coral Bleaching Activity (optional) • Computers with internet access (optional) • HHMI BioInteractive: Coral Reefs and Global Warming resource folder with all student materials • different colored pencils or stickers

Launch

1. Ask students to remind us what we are trying to figure out; (Why some coral reefs are undergoing bleaching (and death) and how understanding their decline may help us figure more out about the decline of the woolly mammoth). Refer to the **Rumors** categories, and highlight questions about water quality. If students did not mention water temperature as an important line of investigation, probe students to generate ideas on what water quality variables we could investigate, surfacing the idea of temperature as a possible factor in the coral bleaching phenomenon.

Differentiation Point

If students require additional interaction with coral reefs to engage with this phenomenon OR if students are interested in identifying healthy versus bleached coral, NOAA's Data in the classroom: Investigating Coral Bleaching Activity . The optional activity includes an underwater exploration using Google maps.

Investigation: Coral Bleaching

1. Provide students with the modified version of the HHMI BioInteractive: Coral Reefs and Global Warming activity, *Coral Bleaching Investigation*.

2. Assign individuals or pairs a different coral reef location to investigate, using the location cards found in the HHMI BioInteractive: Coral Reefs and Global Warming resource folder. There are 28 different locations. If pairing up some students, you may need to assign two locations to pairs, based on the number of students in the class.

3. Provide students with the location data on excel spreadsheets for the 3 years (2002,2010, and 2014) for their location available at HHMI BioInteractive: Coral Reefs and Global Warming resource folder.

4. Students use the data to generate the 3 graphs for their location.

5. Alternatively, provide students with the available graphs, available at HHMI BioInteractive: Coral Reefs and Global Warming resource folder.

6. Using the graphs of sea surface temperature at coral reef locations, students calculate the DHW value (degree heating weeks), which are the weeks that are above the maximum monthly mean (MMM). The DHW value can be used to quantify the amount of heat stress a location has experienced in a given year and the likelihood of coral bleaching events (based on heat stress).

7. In order to better visualize global trends in heat stress, students can create a world map based on the data. Using a predetermined color or symbol, students indicate the risk level at each location for the corresponding years on the world maps, available in the HHMI BioInteractive: Coral Reefs and Global Warming resource folder.

Implementation Tip

Additional guidance on this activity, including implementation variations, answer keys, additional scaffolding, and advanced data analysis tools are available in the HHMI BioInteractive: Coral Reefs and Global Warming educator materials.

Conferring Prompts

Confer with students as they work in collaborative groups as they analyze the data. Suggested conferring questions (these should push students' thinking around establishing relationships, observing patterns, identifying variables, and questioning events):

- How does calculating the DHW values help you understand the relationship between sea temperature and bleaching?
- How do the graphs help you understand the trends in sea temperature over time?
- Why is it important that we focus on sea temperatures that are above the monthly mean?
- What geographic patterns do you notice in the world maps?
- What do you notice about where coral reefs are located?

Whole-Class Investigation Summary

1. Provide students with the *Making Sense of the Coral Bleaching Investigation*.
2. After individually using the See-Think-Wonder graphic organizer to make sense of the data table and world maps, students share their findings with their table group.
3. Ask groups to come up with one important idea to share with the whole class, from their See-Think-Wonder graphic organizer.
4. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' See-Think-Wonder organizers. 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 phenomenon, and what questions that remain.

Look & Listen For

Possible student ideas:

- In 2002, the worst heat stress appeared to be focused on the South Pacific Ocean.
- In 2010, heat stress was slightly lower in the Pacific but higher in the Indian and Atlantic oceans.
- In 2014, heat stress was widespread across all of the locations.
- The equatorial region of the Pacific Ocean (except for the Galápagos Islands) shows significant heat stress in all three years.
- From 2002 to 2014, the heat stress increased for 14 locations, stayed the same for 9 locations, and decreased for 5 locations. Not all places are experiencing the same trends, but overall, the evidence suggests the globe is warming and coral are experiencing heat stress due to warming. Additional empirical evidence could help establish causation.
- Students may wonder why heat stresses out coral (or causes them to bleach) and/ or why the sea is warming.

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 time for students to self and peer assess their investigation using the *Coral Bleaching Investigation Rubric*

Routine

The **Domino Discover routine** 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.

Explain 1

Constructing an explanation for the cause behind coral bleaching.

Students **develop an initial explanation** on the **effect** of **rising sea temperature on coral bleaching**.

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
• Cause & Effect Organizer Coral Bleaching	None	• HHMI BioInteractive: Coral Bleaching Animation

Using an animation to explain a phenomenon

1. Remind students that they are trying to figure out what is causing coral bleaching and the decline of coral reefs. Point to or highlight student ideas and questions surfaced at the end of the Explore 1 investigation, particularly questions about why heat or warm water causes the corals to become bleached. A cause and effect diagram might help them organize their thinking as they connect their observations from the Explore phase to new information about bleaching events.

2. Provide students with the *Cause & Effect Organizer Coral Bleaching*. Display the first 2 minutes of HHMI BioInteractive: Coral Bleaching Animation to orient students to the structure of coral reefs. Stop the video so that students have an opportunity to note down their ideas in the handout.

3. Ask students to fill in the first 1-2 boxes of the cause and effect graphic organizer based on the data from the investigation in Explore 1 on coral bleaching events.

4. Watch the remainder of the video, HHMI BioInteractive: Coral Bleaching Animation and prompt students to listen for more information that responds to the guiding prompt, using the cause and effect organizer to map out the cause of the coral bleaching phenomenon.

Integrating Three Dimensions

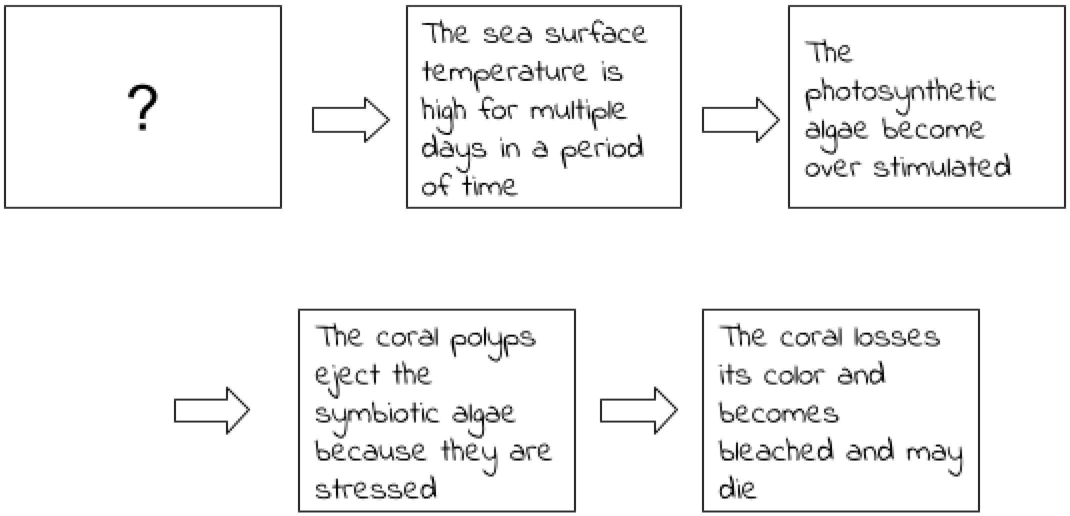
In this portion of the learning cycle, students are using middle school elements of the **SEP#6 Constructing Explanations and Designing Solutions** and **CCC#2 Cause and Effect** in service of figuring out this portion of the phenomenon. Opportunities to assess the claimed high school level elements of **SEP#2 Developing and Using Models** and **CCC#3 Scale, Proportion, and Quantity** and **CCC#4 Systems and Systems Models** are found later in the learning sequence.

Surfacing Student Ideas on Climate Change

1. After students have generated a set of cause and effect relationships, prompt students to share their ideas with their table group. Remind students of the questions generated at the end of the Explore 1 phase. Have they fully answered their questions about the role of increasing temperature on coral bleaching?

2. In table groups, students consider their earlier questions. If students need more support, ask them to reconsider their cause and effect organizer in *Cause & Effect Organizer Coral Bleaching* and to explain what they think would go into a new box on the left. (in other words, what is causing the sea temperature to rise.)

Example student work



3. Use **Domino Discover** to surface student ideas. Highlight ideas and questions about the need to further understand how and why the sea temperature is increasing. Use students' prior knowledge about human caused climate change to plan forward.

Look & Listen For

- Climate change is causing the earth to get warmer
- Organisms get hot and stressed
- Climate change is caused by the release of carbon dioxide
- Climate change is caused by pollution or exhaust from cars

Explore 2

How have human actions caused climate change?

Students collect data from a simulation to **generate a mathematical representation** of the **movement of carbon through the earth as a system** to learn more about **human caused climate change.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
• Carbon Cycle Investigation Part 1 • Carbon Cycle Investigation Part 2 • Making Sense of the Carbon Cycle Investigation • Carbon Cycle Investigation Rubric	None	• Computers with internet access • Where Does Carbon Dioxide Come From? • Annenberg Learner Interactive Carbon Cycle Lab

Launch

1. Begin by asking students to remind us what we are trying to figure out, (such as *How are human actions, such as climate change, impacting coral reefs? How can understanding current human actions that impact biodiversity help us understand what happened to the mammoth?*). In this investigation, students will begin to figure out more about their unanswered questions from the previous Explore and Explain phases.

2. Prompt students to think about the prior knowledge they surfaced at the end of the Explain 1 phase, particularly around the role of carbon dioxide in climate change. If students did not directly mention carbon dioxide, probe students' ideas around pollution, gasses coming from car exhaust, etc. to transition to investigating more about carbon dioxide. Play the Where Does Carbon Dioxide Come From? until minute 1:45 to introduce the source of human-caused carbon dioxide in the atmosphere. Do not play it past 1:45 as it gives too much information that students should figure out themselves.

Implementation Tip

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

Investigation Part 1: The Carbon Cycle

1. In table groups, provide students with the *Carbon Cycle Investigation Part 1* and computers to use the Annenberg Learner Interactive Carbon Cycle Lab simulation.

2. Students use the simulation to collect data on the amount of carbon found throughout the carbon cycle over time when fossil fuel consumption increases at the current rate.

Example Student Data Table

Data Table 1:

Carbon Sink	Year 2010	Year 2060	Year 2110	Year 2160	Year 2300
Atmosphere	720	1031	2254	1669	1003
Biosphere					
Terrestrial Plants	700	758	899	907	780
Soil	2000	2038	2341	2192	2078
Fossil Fuels					
Coal	3500	3170	700	0	0
Oil & Gas	500	66	0	0	0
Ocean					
Ocean Surface	1000	1107	1333	1255	1123
Deep Ocean	38000	38250	48900	40301	41340

Example Data Table

3. After students have had time to collect and analyze data, prompt students to share their most important observations and questions with their table groups. Use **Domino Discover** to highlight the student thinking at this point in the investigation.

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 fossil fuel consumption increases, atmospheric carbon (carbon dioxide) increases - a positive linear relationship. After all fossil fuels have been consumed, carbon dioxide in the atmosphere decreases
- Carbon increases in plants and then decreases after year 2160
- Carbon in soil increases and then decreases after year 2160
- Fossil fuel based carbon decreases until it reaches zero around year 2160
- Carbon in ocean surface increases and then decreases after year 2110
- Carbon in the deep ocean increases between 2010- 2110, decreases between 2110-2160, and then increases again between 2160- 2300

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.

Investigation Part 2: The Carbon Cycle

1. Use student observations and questions to transition to the next part of the investigation, in which students will choose which variables to manipulate in the simulation in order to understand more about the carbon cycle and how it is impacted by fossil fuel emissions.

2. Students brainstorm different variables that they find interesting, and confer with their table group to identify which variable or variables they would like to investigate further. If students have difficulty identifying variables, return to the trends they surfaced at the end of part 1 and probe their ideas.

3. Provide students with *Carbon Cycle Investigation Part 2* in table groups to explore a new variable. Additional variables could include manipulating:
    a. Change in fossil fuel use (emissions) – increase or decrease
    b. Change in deforestation – increase or decrease
    c. Melting Tundra (use the 'melt tundra' setting under Tableau menu)
    d. Manipulate multiple variables to meet the 'goal' (the goal of 550 ppm CO2, which would be twice the amount of atmospheric carbon in comparison to pre-industrial levels).

Access for All Learners

Students may need support in understanding all of the parameters of the simulation. The Annenberg Learner Interactive Carbon Cycle Lab Help Page summarizes each part.

Implementation Tip

Confer with students as they work in table groups to complete the investigation.

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

- Why might deforestation impact the amount of carbon dioxide in the atmosphere?
- How quickly does changing emissions impact the amount of carbon dioxide in the air? Why might that be important?
- How many years of data should you collect? Why?
- How might you analyze and mathematically represent your data to best demonstrate relationships between variables?
- What limitations are you noticing about this simulation?

Whole-Class Investigation Summary

1. Provide students with *Making Sense of the Carbon Cycle Investigation* to individually make sense of the data they have collected.

2. In table groups, prompt students to to discuss summary questions #2 and #5 from *Making Sense of the Carbon Cycle Investigation*.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' ideas. 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 cause and effect relationships between human actions (fossil fuel emissions) and biodiversity (coral bleaching events), and have had the opportunity to clarify what they have figured out about the phenomenon.

Look & Listen For

- The carbon moves through and between different parts of the earth (atmosphere, living things, ocean, fossil fuels) in a cycle
- The carbon may be in different forms in different parts of the cycle
- Some parts of the earth hold onto more (or less) carbon and it leaves or comes in more slowly than in other parts (e.g. the ocean seems to hold a lot of carbon and it moves in and out of the ocean at a slower pace than in and out of the atmosphere)
- Students may still be unclear on the mechanism behind climate change (i.e. how carbon dioxide is causing the temperature of the earth to increase)

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.

Integrating Three Dimensions

This Explore phase supports students in revisiting and building on concepts from **LS2.B: Cycles of Matter and Energy Transfer in Ecosystems** and **PS3.D: Energy in Chemical Processes** Students discussed the role of photosynthesis in Unit 5, *Food For All*, and cellular respiration in Unit 1, *Marathon Runner*. Students will build on these ideas to better understand the carbon cycle.

5. Provide students with *Carbon Cycle Investigation Rubric* in order to self and peer assess their work with the investigation.

Explain 2

How are human actions causing rapid climate change?

Students **construct a model** that represents how human induced **climate change is affecting** biodiversity at **different scales**, such as coral reef ecosystems.

Preparation

Student Grouping	Routines	Literacy Strategies
- Table groups	- Idea Carousel - Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
- Carbon Cycle Model - Carbon Cycle Model Peer Rubric - Carbon Cycle Text (optional) - Summary Task	None	- Chart paper - No safe haven for coral from the combined impacts of warming and ocean acidification (optional text) - What Is the Greenhouse Effect?

Launch

1. Draw on student questions from the end of the Explore 2 phase, around how and why increased carbon dioxide in the atmosphere is causing coral reefs to experience heat stress and bleaching events. Prompt students to surface what they already know about carbon and how it moves between different sinks from the simulation they explored in the investigation. Suggest that it might be helpful to visualize how the carbon cycle normally works, so that we better understand how human actions may be impacting the carbon cycle and how that affects organisms such as coral reefs.

Generating a Model

1. Provide students with the *Carbon Cycle Model* and prompt them to individually generate a model that represents the carbon cycle. If needed, students may use their written response to question #2 in *Making Sense of the Carbon Cycle Investigation* from the Explore 2 phase.

2. Once students have generated their individual model, they share their models with a peer in their table group. Students use the *Carbon Cycle Model Peer Rubric* to peer assess their models.

3. Provide table groups with a chart paper. Students use their individual models and peer feedback to develop a group-wide version of the carbon cycle. Ask students to not use the entire chart paper, as they are going to build in new information in the model.

Differentiation Point

Students have learned about photosynthesis and cellular respiration in earlier units, but if they need more support in including these key concepts in their models, provide the *Carbon Cycle Text* as an additional support.

4. Reorient the class to what they are trying to figure out in this sequence, how and why human actions are threatening biodiversity in coral reefs through the phenomenon of coral bleaching. They have been investigating the role of carbon dioxide in this phenomenon, and have figured out how the carbon cycle (and the role of carbon dioxide) works. Revisit the on-going question: How does increasing carbon dioxide in the atmosphere (observed in the investigation) contribute to bleaching events?

5. Students watch a video, What Is the Greenhouse Effect? , and listen for information that addresses the guiding question (How does increasing carbon dioxide in the atmosphere contribute to bleaching events?).

6. Students return to their chart paper with their group wide carbon cycle model. In their table groups, prompt students to add to their model to represent how human activities are impacting the carbon cycle and causing heat stress in corals and other negative impacts on biodiversity (through the enhanced greenhouse effect).

7. Students revise their model using the prompt: How can we use evidence to model our phenomenon of coral bleaching at different scales?

8. Use the routine **Idea Carousel** to share and highlight student thinking.

Differentiation Point

In earlier phases in this sequence, students may have wondered what the impact of increased carbon dioxide diffusing into the ocean has on coral reefs. Based on interest and readiness, prompt students to explore the additional threat of ocean acidification on coral, using No safe haven for coral from the combined impacts of warming and ocean acidification .

Integrating Three Dimensions

This model is designed to support student use of **CCC#3 Scale, Proportion, and Quantity.** Pause and walk students through their learning from this 5E cycle and highlight how the concept of orders of magnitude helps them understand the different relationships between different parts of their model. For example, one car releasing CO2 does not have a significant impact, but a combination of millions of cars does. This then impacts how quickly the temperature changes and impacts ecosystems.

Routine

The **Idea Carousel** 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. This routine, therefore, is great for developing complex understandings of a phenomenon in science. Please read the Biology Course Guide for detailed steps about this routine.

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 a few days ago, to learn about all the thinking in the room and come to some decisions about how the concept of climate change and how different human actions are negatively impacting ecosystems and biodiversity (such as corals). How does the concept of orders of magnitude help us understand how this phenomenon is occurring at different scales?"

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

2. Select two or three groups' models 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 the carbon cycle, climate change, and human impact. The decision about which models / 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.

3. Ask the first group to share their model / response. You can do this by:
    - Projecting using a document camera; OR
    - Copying the chart / response to be shared and passing them out to the class; OR
    - Taking a picture of each and projecting them as slides.

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.

4. 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, so be sure to facilitate the conversation so that key ideas emerge.

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

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC#3 Scale, Proportion, and Quantity** explicit for students by elevating and probing for ideas related to how orders of magnitude helps them understand the different relationships between different parts of their model. This is an important element **CCC#3 Scale, Proportion, and Quantity** at the high school level.

Take Time for These Key Points

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

- Carbon normally cycles through different parts of the earth (geosphere, atmosphere, biosphere, and hydrosphere) at different scales
- Photosynthesis and cellular respiration play an important role in the carbon cycle (moving carbon between the living and nonliving parts of the earth)
- Organisms store carbon in their tissues; fossil fuels contain carbon from organisms that died long ago
- Human actions, specifically burning fossil fuels, disrupts the normal carbon cycle by adding extra carbon dioxide to the atmosphere
- Extra carbon dioxide in the atmosphere leads to the enhanced greenhouse effect, increasing the temperature of the earth
- Increased temperature has a negative impact on some organisms, such as coral as heat stress causes them to eject their symbiotic algae, bleach, and often die (therefore negatively impacting biodiversity and the ecosystem as a whole)
- The models represent what is happening at different scales (individual actions and small individual polyps in corals – to a global phenomenon of climate change and the bleaching of entire coral reef habitats) – understanding orders of magnitude is helpful in understanding how different parts of the model relate to one another and in understanding this entire phenomenon.

Summary

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 engage in sense-making about how human actions are contributing to a disruption of the carbon cycle and climate change, which is in turn, negatively impacting biodiversity.

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: 1) understanding **how they are using the three dimensions**, including the concept of climate change, to make sense of a phenomenon, coral bleaching; 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Integrating Three Dimensions

In the Class Consensus Discussion and Summary Task, students should draw on their previous work with **LS2.A Ecosystems: Interactions, Energy, and Dynamics**; specifically the concept of ecosystem carrying capacity that was fully developed in Unit 5, *Food for All*.

5. Return to student questions that bring up lingering issues not yet resolved, such as:
   - What was the role of climate change (not human caused) in the extinction of the woolly mammoths?
   - What was the role of human caused changes, such as habitat destruction or overexploitation, in the extinction of the woolly mammoth?

Elaborate

How can organisms adapt to climate change?

Students **use evidence** of the **impact** of **climate change** on different organisms to **explain** the extent to which endangered **organisms can adapt and avoid extinction**.

Preparation

Student Grouping	Routines	Literacy Strategies
• Triads	• Read-Generate-Sort-Solve	• Chunking Text • Partner Reading

Materials

Handouts	Lab Supplies	Other Resources
• Read Generate Sort Solve Organizer	None	• Some Good News about Corals and Climate Change (podcast) • What Helps Animals Adapt (or Not) to Climate Change? . Literacy Strategy: Chunking with Turn and Talk (optional)

Text-Based Task

1. Organize students into triads. Highlight for students that in the previous Explore & Explain, they figured out how climate change, and other human actions are impacting ecosystems and biodiversity. Students may have wondered if organisms will be able to adapt to climate change. If students did not consider this during exploring the coral bleaching phenomenon, play the short podcast Some Good News about Corals and Climate Change to introduce the idea, and surface students' questions about organisms, such as coral, ability to adapt to climate change.

2. Use student's questions to transition to create a guiding question, such as "What evidence do we have that organisms are able to adapt and survive climate change? Evaluate the claim that organisms may be able to adapt to impending climate change. What is the evidence and reasoning behind that claim?"

3. Provide students with the *Read Generate Sort Solve Organizer* and the on-line text, What Helps Animals Adapt (or Not) to Climate Change? .

4. Facilitate the group learning routine **Read-Generate-Sort-Solve**, as a way for students to synthesize and extend their thinking.

Integrating Three Dimensions

In this task, students have the opportunity to initially demonstrate their use of the **SEP#7 Engaging in Argument from Evidence,** focusing on identifying and discussing evidence and reasoning for a claim. They will build on this work to fully evaluate an argument as they proceed through the unit.

Differentiation Point

The text, What Helps Animals Adapt (or Not) to Climate Change? is rigorous. If students need support, **chunk the text** up into three sections: 1)Move, Adapt or Die 2) Some Species are Adapting 3) Evolution to the Rescue. Use the Literacy Strategy: Chunking with Turn and Talk to **partner read** the sections.

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.

Evaluate

How might climate change have contributed to the extinction of the woolly mammoth?

Students revise their initial ideas about what **caused** the extinction of the woolly mammoth and **develop an extinction model** using what they learned about **climate change and human impact**.

Preparation

Student Grouping	Routines	Literacy Strategies
- Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
- Coral Bleaching 5E - Extinction Model - Climate Change & Mammoths Text - Coral Bleaching 5E - Mini Rubric	None	- Driving Question Board from the start of the unit should be available - *Visual Texts* - Interactive Carbon Story (optional)

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 did climate change impact the Woolly Mammoth?*)

Implementation Tip

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

2. Prompt students to review what they figured out during this learning sequence (how climate change can negatively impact biodiversity including coral reefs). Ask students to think about how understanding the story of coral bleaching may be helpful in understanding what might have happened to the woolly mammoth.

Look & Listen For

- The increase of temperature of the earth (due to human caused climate change) causes coral reefs to bleach and die (expel their symbiotic algae); perhaps an increase in the earth's temperature at the time of the woolly mammoth had a negative impact
- Coral reefs play an important role in the environment (and are very biodiverse ecosystems) learning about what is happening to them may help us think about how the loss of the mammoth impacted the environment at that time
- Understanding human caused climate change (and the impact on biodiversity) can help us decide if we should bring the mammoth back from extinction
- Solutions to current problems may give us insight into how to protect the mammoth if we bring them back
- Currently, humans are causing an increase in the earth's temperature, however, climate change that occurred in the past (during the time of the mammoths) was a natural fluctuation.

3. Provide students with the *Coral Bleaching 5E - Extinction Model* and the *Climate Change & Mammoths Text*. Students may also find *Visual Texts* from the Unit Opening helpful.
4. Students work individually on the *Coral Bleaching 5E - Extinction Model* in order to review what they have learned during this 5E sequence and consider the new evidence in the *Climate Change & Mammoths Text* . Students outline the evidence and scientific reasoning behind the claim that climate change caused the extinction of the woolly mammoth and represent their ideas in a model.
5. Confer with students while they are working.
6. After completing their response, use the *Coral Bleaching 5E - 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

Students may surface the misconception that early humans caused climate change (through fires, etc.). Although fires and deforestation currently do contribute to increased CO2 in the atmosphere, facilitate a conversation with students about the difference between those activities during the time of early humans and the large scale combustion of fossil fuels occurring today. If students demonstrate readiness and curiosity on this topic, introduce the Interactive Carbon Story for students to engage with.

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 these questions and document new questions that arise based on what they have been learning, which can be added to the Driving Question Board.

3. One question category still unanswered should relate to questions about different components of the woolly mammoths ecosystem and food web. Point to student questions and ideas generated about the interaction between elephants and their environment in the previous learning sequence and the interactions between the coral and their symbiont to transition to the next sequence of lessons, in which they will investigate more about the mammoth's ecosystem.

Standards in Coral Bleaching 5E

Performance Expectations

HS-LS2-2	**Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.** Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data. Assessment Boundary: Assessment is limited to provided data.
HS-LS2-5	**Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.** Clarification Statement: Examples of models could include simulations and mathematical models. Assessment Boundary: Assessment does not include the specific chemical steps of photosynthesis and respiration.

In NYS the PE and clarification statement have been edited as follows: Develop a model to illustrate the role of various processes in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere. [Clarification Statement: Examples of models could include simulations, diagrams, and mathematical models of the carbon cycle (photosynthesis, respiration, decomposition, and combustion].

Aspects of Three-Dimensional Learning

Science and Engineering Practices

Engaging in Argument from Evidence
- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)

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)

Using Mathematics and Computational Thinking
- Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(2)

Disciplinary Core Ideas

LS2.B Cycles of Matter and Energy Transfer in Ecosystems
- Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geologic, and biological processes. LS2.B(3)
- Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes. LS2.B(1)

LS2.C Ecosystem Dynamics, Functioning, and Resilience
- Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. LS2.C(2)
- A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. LS2.C(1)

LS4.C Adaptation
- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the

Crosscutting Concepts

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
- Using the concept of orders of magnitude allows one to understand how a model at one scale relates to a model at another scale. CCC3(4)

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)

Stability and Change
- Much of science deals with constructing explanations of how things change and how they remain stable. CCC7(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	decline–and sometimes the extinction–of some species. LS4.C(4) LS4.D Biodiversity and Humans • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. LS4.D(2)	

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Engaging in Argument from Evidence				*Read Generate Sort Solve Organizer*	
Developing and Using Models			Idea Carousel Class Consensus Discussion *Summary Task* *Carbon Cycle Model* *Carbon Cycle Model Peer Rubric*		*Coral Bleaching 5E - Extinction Model* *Coral Bleaching 5E - Mini Rubric*
Using Mathematics and Computational Thinking		*Coral Bleaching Investigation* *Making Sense of the Coral Bleaching Investigation* Domino Discover	*Carbon Cycle Investigation Part 1* *Carbon Cycle Investigation Part 2* *Making Sense of the Carbon Cycle Investigation*		
LS2.B Cycles of Matter and Energy Transfer in Ecosystems		Domino Discover	*Making Sense of the Carbon Cycle Investigation* Domino Discover Idea Carousel Class Consensus Discussion *Summary Task* *Carbon Cycle Model* *Carbon Cycle Model Peer Rubric*		*Coral Bleaching 5E - Extinction Model* *Coral Bleaching 5E - Mini Rubric*
LS2.C Ecosystem Dynamics, Functioning, and Resilience	Rumors	*Cause & Effect Organizer Coral Bleaching* Domino Discover	Idea Carousel Class Consensus Discussion *Summary Task*		*Coral Bleaching 5E - Extinction Model* *Coral Bleaching 5E - Mini Rubric*
LS4.C Adaptation		*Making Sense of the Coral Bleaching Investigation* Domino Discover		*Read Generate Sort Solve Organizer*	

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
LS4.D Biodiversity and Humans	Rumors	*Making Sense of the Coral Bleaching Investigation* Domino Discover *Cause & Effect Organizer Coral Bleaching*	Idea Carousel Class Consensus Discussion *Summary Task*		*Coral Bleaching 5E - Extinction Model* *Coral Bleaching 5E - Mini Rubric*
Cause and Effect		*Making Sense of the Coral Bleaching Investigation* Domino Discover *Cause & Effect Organizer Coral Bleaching*			*Coral Bleaching 5E - Extinction Model* *Coral Bleaching 5E - Mini Rubric*
Scale, Proportion, and Quantity			*Summary Task* Idea Carousel Class Consensus Discussion		
Systems and Systems Models			*Carbon Cycle Investigation Part 1* *Carbon Cycle Investigation Part 2* *Making Sense of the Carbon Cycle Investigation* Idea Carousel Class Consensus Discussion *Summary Task* *Carbon Cycle Model* *Carbon Cycle Model Peer Rubric*		*Coral Bleaching 5E - Extinction Model* *Coral Bleaching 5E - Mini Rubric*
Stability and Change				*Read Generate Sort Solve Organizer*	

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP2 MP3	MP2 MP3		
ELA/Literacy	SL.9-10.4	RST.9-10.7 WHST.9-10.2 SL.9-10.1 SL.9-10.4	RST.9-10.7 WHST.9-10.2 SL.9-10.1 SL.9-10.4	RST.9-10.1 RST.9-10.7 WHST.9-10.9	RST.9-10.7 WHST.9-10.2 WHST.9-10.5

Kelp Forest 5E	How do all of the components of an ecosystem interact to provide resiliency against a disturbance?	**Performance Expectations** HS-LS2-2, HS-LS2-6	**Investigative Phenomenon** Kelp forests and urchin barrens are two stable ecosystems that can be found in the same location. How is that possible?	**Time** 6-7 days

In this 5E instructional sequence, students are investigating the questions about the habitat, food sources, and ecosystem interactions of the woolly mammoths surfaced during the Driving Question Board launch: How did woolly mammoths fit into a food web and ecosystem? In order to apply an understanding of ecosystem stability and resiliency, students investigate a case study on the Kelp forest. Kelp forests and urchin barren are both stable ecosystems that can exist in the exact same location. Students consider the ecosystem conditions by which a kelp forest can change into an urchin barren (and vice versa) in order to surface how ecosystems can function and remain resilient after disturbances; or why they may not return to their initial state.

ENGAGE	How can two very different ecosystems exist in the same geographic location at different points in time?	Connecting to their earlier questions about mammoths' role in their ecosystems, students are introduced to the case of kelp forests that can be replaced by less diverse urchin barrens under specific conditions. Students consider initial claims on the **stability of the two ecosystems** and **how and why they may change.**
EXPLORE	Why do ecosystems change?	Students **generate mathematical representations** from data in order to support claims on the **stability** of two **ecosystems**.
EXPLAIN	How do components of an ecosystem interact to maintain stability?	Students **develop a model** at **different scales** to better understand the **complex interactions within an ecosystem** that **maintain stability**.
ELABORATE	How can we evaluate arguments on ecosystem stability?	Students engage with text and media in order to **evaluate arguments** on the role biodiversity plays in **maintaining stability** in **ecosystems**.
EVALUATE	How can we use our ideas on how ecosystems function and the role of biodiversity in maintaining stable ecosystems to explain what happened to the woolly mammoths?	Students **use and develop a model to represent** their new understanding of **ecosystem resilience** to revise their initial claims about what caused the extinction of the woolly mammoth.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

How can two very different ecosystems exist in the same geographic location at different points in time?

Connecting to their earlier questions about mammoths' role in their ecosystems, students are introduced to the case of kelp forests that can be replaced by less diverse urchin barrens under specific conditions. Students consider initial claims on the **stability of the two ecosystems** and **how and why they may change.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
• Kelp Forest & Urchin Barren Ecosystem Introduction • Map See-Think-Wonder Graphic Organizer	None	• *Kelp Forest Visual* printed or displayed in color • *Urchin Barren Visual* printed or displayed in color • *Kelp Forest & Urchin Barren Map* • Sea Urchin Barrens as Alternative Stable States of Collapsed Kelp Ecosystems Map (optional) • Introduction to a Kelp Forest

Launch

1. Remind students that during the Driving Question Board launch, one category of questions that emerged was related to the woolly mammoth's habitat and food web (what it ate, what predators it had, etc.) Prompt students to think about how we can understand the mammoth's habitat and how it may have interacted with other organisms, even if it is extinct. Listen for the idea that we can look at ecosystems that do exist today and organisms that may play a similar role in the ecosystem as mammoths once did.

2. Use student's ideas to transition to the case study presented in this 5E sequence. Let students know that we will investigate kelp forests/urchin barrens to better understand how ecosystems work and what makes them healthy (in order to have some ideas about how the ecosystem or ecosystem disruptions may have played a role in the extinction of the woolly mammoth.)

3. Let students know that they are going to consider two possibly stable ecosystems that can both exist in the same location: kelp forests and urchin barrens.

Students generate observations based on visuals

1. Introduce the case study by providing groups of students with the *Kelp Forest Visual* and *Urchin Barren Visual* or project the visuals for students on a screen.

2. Prompt students to first generate observations about each visual. What do they see? How are these two ecosystems different or similar to each other?

3. Let students know that both of these two pictures were taken of the exact same spot (even the same depth), just at a different moment in time (years apart, not the difference between night and day). In other words, both ecosystems (even though they look very different) can exist at different times in the exact same location.

Implementation Tip

Students need to see the images and the map in color. Ideally, print and laminate a class set in color, or project the images in color if that is not possible.

4. Provide students with *Kelp Forest & Urchin Barren Ecosystem Introduction* to support idea generation and context on what these two ecosystems are. Prompt students to share some initial ideas, based on the visuals and the text and to record their ideas in their notebook or on post-it notes.

5. Provide groups of students with the *Kelp Forest & Urchin Barren Map* and/or project the map on the board, available from the original journal article, Sea Urchin Barrens as Alternative Stable States of Collapsed Kelp Ecosystems Map on page 7 and the *Map See-Think-Wonder Graphic Organizer* to support students in generating ideas and questions.

6. Use the group learning routine, **Domino Discover** to highlight and document student ideas and questions about the data represented in the map.

Look & Listen For

Observations & Inferences (See/Think Column)

- Most of the range shifts back and forth between kelp and barrens (or vice versa)
- Some areas have clustered changes (many occurrences of shifting back in forth) such as NE section of North America and SE Australia
- There are some locations (e.g. Western side of Australia) that are just kelp with no changes
- Many locations (approximately 18) are barrens in the kelp range
- Some locations have a single change, some locations have multiple changes back and forth

Questions

- Why are some areas free from changes?
- Why do some areas have a lot of changes?
- What is the normal or original ecosystem?
  - Is kelp the normal ecosystem, since there are areas with kelp and no changes?
  - Or are the barrens the normal ecosystem because it seems to shift to that?
  - Or are both normal?
- What causes the change from kelp to barrens or barrens to kelp?

Differentiation Point

If students are struggling to visualize a kelp forest, show the Introduction to a Kelp Forest that briefly introduces the ecosystem found in the resources above.

Explore

Why do ecosystems change?

Students **generate mathematical representations** from data in order to support claims on the **stability** of two **ecosystems**.

Preparation

Student Grouping	Routines	Literacy Strategies
Table groups	Consensus Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
Kelp & Barrens Investigation Making Sense of the Kelp & Barrens Investigation Kelp & Barrens Investigation Rubric	None	

Launch

1. Ask students to remind us what we are trying to figure out (how can a kelp forest and an urchin barren exist in the same location?). Highlight or point to charted student ideas and questions related to the map presented in the Engage phase.

2. Introduce the idea (or remind students of earlier conversations) that it is difficult to study phenomena that happen in far away places and at different scales. Highlight ideas around using secondary data sets collected by scientists in the field, maps, and other visualizations and how these tools can be useful to get a better understanding of a phenomenon.

Analyzing Data to Investigate Kelp Forest and Urchin Barrens Ecosystems

1. In table groups, provide students with *Kelp & Barrens Investigation*. The data table including this investigation is connected to the map provided in the Engage phase (but has been edited for clarity and brevity). Each location (number in a colored circle) corresponds to a row in the data table. It may be helpful to project or provide color copies of *Kelp Forest & Urchin Barren Map* so that students can orient themselves to the location of each data point.

2. Students should be encouraged to make choices around how to analyze and visualize the data in the table. Creating a graph that represents the average time an ecosystem type persisted in a given location would be helpful in evaluating the claims on which (or both) ecosystem is stable or more stable than the other. Students could also calculate the number or type of phase shifts (ecosystem changes), as well as categorize or connect phase shifts, or length of stability with drivers of change (disturbances).

Differentiation Point

The data table presented in the investigation has been edited for brevity, with most data excluded, and additional data added for context. Based on student readiness, provide the original article, Sea Urchin Barrens as Alternative Stable States of Collapsed Kelp Ecosystems Map and encourage students to use the original data table found on pgs 8-9.

Integrating Three Dimensions

Students have had multiple opportunities throughout the course to engage with **SEP#5 Using Mathematics and Computational Thinking.** As the last unit in the course, students should be comfortable making decisions on what data from the map and text is helpful (and how to best analyze and visualize it) in supporting a particular claim or explanation on the stability of each ecosystem. The conferring prompts found below may be helpful if students need additional support.

Making Sense of the Kelp & Urchin Barrens Investigation

1. Provide students with *Making Sense of the Kelp & Barrens Investigation* so they can consider the trends and generate additional questions in order to make sense of the data.

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):

- Why did you choose to graph ….. ?
- What are you noticing about the average length of time each location remains stable in each ecosystem?
- What are you noticing about the disturbances?
- How does the data support/not support a particular claim?

2. Students can discuss their responses as a group, and share ideas with the class, during a **Consensus Building Share**.

3. Ask groups to come up with one important idea to share with the whole class, from their *Making Sense of the Kelp & Barrens Investigation*.

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.

4. Use the group learning routine **Consensus Building Share** to surface important trends, inferences, and questions. 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 phenomenon.

Look & Listen For

Possible student ideas:

- There is not a large difference between the average time each ecosystem is stable, but kelp forest tends (on average) to exist a little longer than urchin barrens
    - This may be considered evidence that the kelp forest is more stable, or both are equally stable as there is not a large difference – but more information is necessary to support any claim
- There are several disturbances that cause an ecosystem shift: Otter population changes, urchin population changes, storms, overgrazing of kelp, current changes, La Nina events, lobster population changes
- Students may wonder why and how these changes (disturbances) cause a shift to a new ecosystem.
- Students may wonder why either ecosystem may stay stable for any given period of time
- Students may wonder what additional evidence they may need to understand or explain this phenomenon
- Students may wonder if there are any reasons why humans might want to maintain one of these ecosystems over another?

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 *Kelp & Barrens Investigation Rubric* to self and peer assess their work in the investigation.

Explain

How do components of an ecosystem interact to maintain stability?

Students **develop a model** at **different scales** to better understand the **complex interactions within an ecosystem** that **maintain stability**.

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover • Idea Carousel • Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
• Summary Task	None	• *Kelp Forest & Urchin Barren Ecosystem Cards* • *Kelp Forest & Urchin Barren Ecosystem Fact Sheet* • poster paper • computers with internet access • Status and Trends for the World's Kelp Forests (optional) • Army of Sea Urchins? (optional)

Investigating Ecosystems

1. Remind students that we are trying to figure out how these two ecosystems work, so that we can understand why there can be two different ecosystems in the same location. Review or point to students' questions from the end of the Explore phase. For example, they may wonder why and how these changes (disturbances) cause a shift to a new ecosystem type or why would either ecosystem be stable for any given period of time.

2. Introduce the idea that a model may be helpful in helping students understand these two ecosystems. In pairs, prompt students to think in groups about what evidence they already have to help generate a model, and what additional evidence they would need.

3. Use **Domino Discover** to share ideas from pairs of students.

Differentiation Point

Students should have some background knowledge from middle school, as well as earlier experience in this unit and in unit 2 on ecosystems, food chains, and food webs. Pause and prompt students to remember these concepts as they are important for developing a model of these ecosystem(s).

Look & Listen For

Possible student ideas

- What do different organisms eat? What are their predators?
- Role of important organisms (otter, lobster, urchins)
- How can we represent environmental or human disturbances (storms, La Nino, fishing)
- How can we represent interactions between different parts of the system?

Generating Models

1. Remind students that they are generating models to better understand the stability of each ecosystem including why and how one can switch to the other, In table groups, allow students to choose exactly what they want to model: a stable kelp forest, a stable urchin barrens, how a disturbance causes one to change to another, etc. Students should have access to their earlier work from the learning cycle, specifically *Kelp Forest & Urchin Barren Map* and the data table in *Kelp & Barrens Investigation*.

2. Provide table groups with *Kelp Forest & Urchin Barren Ecosystem Cards*, *Kelp Forest & Urchin Barren Ecosystem Fact Sheet*, poster paper, and at least one computer with internet access. Students may need to find additional information to model their understanding of the phenomenon, including how ocean currents or a La Niña event can impact kelp/urchin barren ecosystems.

Conferring Prompts

Confer with students as they work in collaborative groups to generate their models.

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

- How are populations normally kept in check? (not allowed to grow exponentially)
- Which organisms seem to play a key role?
- How do disturbances play a role in changing these ecosystems?
- What conditions lead to stability? Instability?
- What would happen if you removed just a few otter/urchins/kelp?
- How are you representing changes in your model? How are you representing stability in your model?
- How are you using the concept of orders of magnitude to represent how different components of the model or other models are related?

Integrating Three Dimensions

This Explain is designed to support students in using **CCC #7 - Stability and Change** to do this sensemaking. Be sure to make **CCC #7 - Stability and Change** explicit for students by elevating and probing for ideas related to how observing and asking questions about how things change and how they remain stable helps to make sense of a phenomenon.

Access for All Learners

If students need more support, or demonstrate interest, use Army of Sea Urchins? to provide more context on the urchin barren ecosystem.

Implementation Tip

Interactions in ecosystems that maintain stability (such as predator-prey interactions) build off of the work students have done in Unit 5 on carrying capacity. It may be helpful to point to students' earlier work or to review this concept. Additionally, help students make connections between their understanding of dynamic equilibrium (including feedback mechanisms) from Unit 1 in human body systems and dynamic equilibrium in ecosystems by highlighting earlier student work from Unit 1.

Using Models to Explain a Phenomenon

1. After groups have generated their model, use the Group Learning Routine, **Idea Carousel** to share and build on their models

1. Post chart papers around the room, or in the hallway if needed. You need to provide enough space that students can talk and circulate.
2. Launch the group learning routine Idea Carousel, to engage students in sharing then discussing their sequence charts. Groups come to consensus at the end of the routine when they return to their own work and read the annotations provided from other groups.
3. At the end of the routine, each group revises and finalizes their model. If necessary, they can use new chart papers to do this.

Routine

The **Idea Carousel** 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. This routine, therefore, is great for developing complex understandings of a phenomenon in science. Please read the Biology Course Guide for detailed steps about this routine.

Differentiation Point

Based on student interest and readiness, provide Status and Trends for the World's Kelp Forests to push students' thinking on the complexity of kelp forest ecosystems and how ecologists can manage and protect these areas in the future.

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 why ecosystems change and what affects the stability and resiliency of an ecosystem, 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 responses, and discuss what we can agree to as a class."

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.

2. 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 the factors that maintain ecosystem stability, and the crosscutting concepts of **Stability and Change** and **Scale, Proportion & Quantity**. 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.

3. 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.

4. 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.

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

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #7 - Stability** and Change explicit for students by elevating ideas related to how observing and asking questions about how things change and how they remain stable helps to make sense of a phenomenon. This is an important element **CCC # 7 - Stability and Change** at the high school level.

Take Time for These Key Points

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

- Many factors work together to keep an ecosystem stable, such as predators keeping herbivore populations in check so that they do not eat all of the producers – these are feedback mechanisms and similar to what happens in the body to maintain homeostasis!
- Stable means that populations stay relatively constant over long periods of time – and the ecosystem is able to ‘bounce back’ after small disturbances
- Major disturbances, such as the removal of a top predator (the over-hunting of otters) can cause an ecosystem to change into a different ecosystem
- If the disturbance is removed (e.g. stopping otter hunting) the ecosystem may return to the original state
- The concept of orders of magnitude is helpful for understanding our ecosystem models – changes occurring in just one population or food chain (otters) has exponential impacts on a food web, an entire ecosystem and even on many other food webs and systems within the ocean

Access for Multilingual Learners

Rather than assigning a list of vocabulary words—a technique that rarely works for learning new vocabulary—this activity allows language learners to learn vocabulary from context, which may be particularly helpful for **transitioning** language learners, who already have some mastery of language.

Summary

1. Students individually complete *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 engage in sense-making about how interactions between organisms, and between organisms and their environment regulate ecosystem stability.

Integrating Three Dimensions

The summary task prompts here are designed to get students to consider what they know about using the crosscutting concept of Stability and Change (**CCC #7 - Stability and Change),** then apply it as a tool for asking more questions that build on prior learning about both DCIs and CCCs.

Elaborate

How can we evaluate arguments on ecosystem stability?

Students engage with text and media in order to **evaluate arguments** on the role biodiversity plays in **maintaining stability** in **ecosystems**.

Preparation

Student Grouping	Routines	Literacy Strategies
• Triads	• Think-Talk-Open Exchange	None

Materials

Handouts	Lab Supplies	Other Resources
• Think-Talk-Open Exchange Notetaker • Ecosystem Resiliency Text	None	• Some Animals Are More Equal than Others: Keystone Species and Trophic Cascades

Text-Based Task

1. Begin by asking students to remind us what we have already figured out, some of factors that support ecosystem stability, and factors (disturbances) that can drive an ecosystem to change from one ecosystem to another. Remind students that at the beginning of this learning cycle, we looked at evidence for different claims on the stability of kelp forests and urchin barrens. We are going to return to those claims to evaluate an argument on which ecosystem is more stable.

2. Let students know that they are going to look at different resources in order to evaluate different arguments on which ecosystem is more stable, or if they are equally stable.

3. Provide the guiding prompt: We have discussed that under certain circumstances, kelp forests can shift to urchin barrens, and urchin barrens can shift to kelp forests. One could argue that both are stable, resilient ecosystems – or that one or the other is more resilient. Choose one argument to evaluate. Support your analysis by discussing the available evidence and reasoning. What additional evidence would be relevant to your argument?

4. Provide students with *Think-Talk-Open Exchange Notetaker*, *Ecosystem Resiliency Text*, and a computer to watch, Some Animals Are More Equal than Others: Keystone Species and Trophic Cascades . Allow time for students to individually craft their response.

5. In triads, use the group learning routine, **Think-Talk-Open Exchange** for students to share their ideas. Students should revise their ideas after sharing ideas with their peers.

Integrating Three Dimensions

In considering the claims and evidence on ecosystem stability, students are engaging with the **Nature of Science Practice, Scientific Knowledge is Open to Revision in Light of New Evidence**.

Look & Listen For

The kelp/urchin barrens ecosystems are very complex, and there are a variety of claims that could be supported. What is important in this discussion is to listen to student talk and highlight their understanding of ecosystem stability and change; and how to evaluate an explanation/ argument.

- Complex interactions maintain stability in an ecosystem
- Keystone species, and overall biodiversity in an ecosystem may contribute to resilience
- Disturbances, if powerful enough, may shift an ecosystem to a new ecosystem disrupting stability
- Modeling the complex interactions (including food webs, environmental variables such as sunlight, nutrients, etc.) helps us understand ecosystem stability
- Evidence over the long term is helpful (including changing population numbers, types of organisms), and monitoring how outside influences such as storms and human interactions

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. Overall, the routine allows students to clarify or generate ideas collaboratively. Please consult the Biology Course Guide for detailed steps about this routine.

Integrating Three Dimensions

In this 5E sequence, students are building proficiency with **SEP#7 Engaging in Argument from Evidence**, specifically the element that asks students to evaluate explanations and solutions. Students will have the opportunity to fully develop this element in the final learning sequence, *The Passenger Pigeon,* and again in the final performance task.

Evaluate

How can we use our ideas on how ecosystems function and the role of biodiversity in maintaining stable ecosystems to explain what happened to the woolly mammoths?

Students **use and develop a model to represent** their new understanding of **ecosystem resilience** to revise their initial claims about what caused the extinction of the woolly mammoth.

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
• Woolly Mammoth Ecosystem • Kelp Forest 5E - Extinction Model • Kelp Forest 5E - Mini Rubric	None	• Driving Question Board from the start of the unit should be available • computer access with internet

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 did the woolly mammoth interact with its environment?*)

2. Prompt students to review what they figured out during this learning sequence . Ask students to think about how understanding the story of kelp forests and urchin barrens may be helpful in understanding what might have happened to the woolly mammoth.

Look & Listen For

- A disturbance may have caused their habitat to change, and it could not recover negatively impacting the mammoth
- A predator of the mammoth (or another important species) may have been removed causing a trophic cascade
- A keystone species may have died out OR the woolly mammoth could be a keystone species which is important to consider not only in their extinction but if we should bring them back
- A lack of biodiversity in the mammoths habitat could have lead to instability or other negative impacts on the mammoth or the food it relied on

3. Provide students with *Kelp Forest 5E - Extinction Model*, *Woolly Mammoth Ecosystem*, and computer access so they can consider the additional evidence discussed in Trophic cascades' of disruption may include loss of woolly mammoth, saber-toothed cat . Students use all of the evidence and scientific reasoning developed over the course of this learning cycle to consider the claim that the cause behind the woolly mammoth extinction was related to ecosystem stability or disruption.

4. Confer with students while they are working.

5. After considering ecosystem stability, students should generate their final extinction model based on all of the evidence and scientific reasoning developed over the course of the unit.

6. After completing their response, use the *Kelp Forest 5E - 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.

Revisit the Driving Question Board

1. Use the **Revisit 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, including questions around how to bring the mammoth back, and impacts it may have on current ecosystem. 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 Kelp Forest 5E

Performance Expectations

HS-LS2-2 **Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.**
Clarification Statement: Examples of mathematical representations include finding the average, determining trends, and using graphical comparisons of multiple sets of data.
Assessment Boundary: Assessment is limited to provided data.

HS-LS2-6 **Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.**
Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Examples of changes in ecosystem conditions could include ecological succession, modest biological or physical changes, such as moderate hunting or seasonal floods; and extreme changes, such as volcanic eruption or sea level rise.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking • Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2) 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)	LS2.A Interdependent Relationships in Ecosystems • Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem. LS2.A(1) LS2.C Ecosystem Dynamics, Functioning, and Resilience • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. LS2.C(1) • Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. LS2.C(2)	Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1) 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) Stability and Change • Much of science deals with constructing explanations of how things change and how they remain stable. CCC7(1)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Using Mathematics and Computational Thinking		*Kelp & Barrens Investigation* *Making Sense of the Kelp & Barrens Investigation*			
Engaging in Argument from Evidence		*Making Sense of the Kelp & Barrens Investigation*		*Think-Talk-Open Exchange Notetaker*	
Developing and Using Models			Ecosystem models Class Consensus Discussion		*Kelp Forest 5E - Extinction Model* *Kelp Forest 5E - Mini Rubric*
LS2.A Interdependent Relationships in Ecosystems			Ecosystem models Class Consensus Discussion *Summary Task*		
LS2.C Ecosystem Dynamics, Functioning, and Resilience	Domino Discover	*Making Sense of the Kelp & Barrens Investigation*	Ecosystem models Class Consensus Discussion *Summary Task*	*Think-Talk-Open Exchange Notetaker*	*Kelp Forest 5E - Extinction Model* *Kelp Forest 5E - Mini Rubric*
Cause and Effect		*Making Sense of the Kelp & Barrens Investigation*	*Summary Task*		*Kelp Forest 5E - Extinction Model* *Kelp Forest 5E - Mini Rubric*
Systems and Systems Models			*Summary Task*		*Kelp Forest 5E - Extinction Model* *Kelp Forest 5E - Mini Rubric*
Stability and Change	Domino Discover	*Making Sense of the Kelp & Barrens Investigation*	Ecosystem models Class Consensus Discussion *Summary Task*	*Think-Talk-Open Exchange Notetaker*	*Kelp Forest 5E - Extinction Model* *Kelp Forest 5E - Mini Rubric*

Common Core State Standards Connections

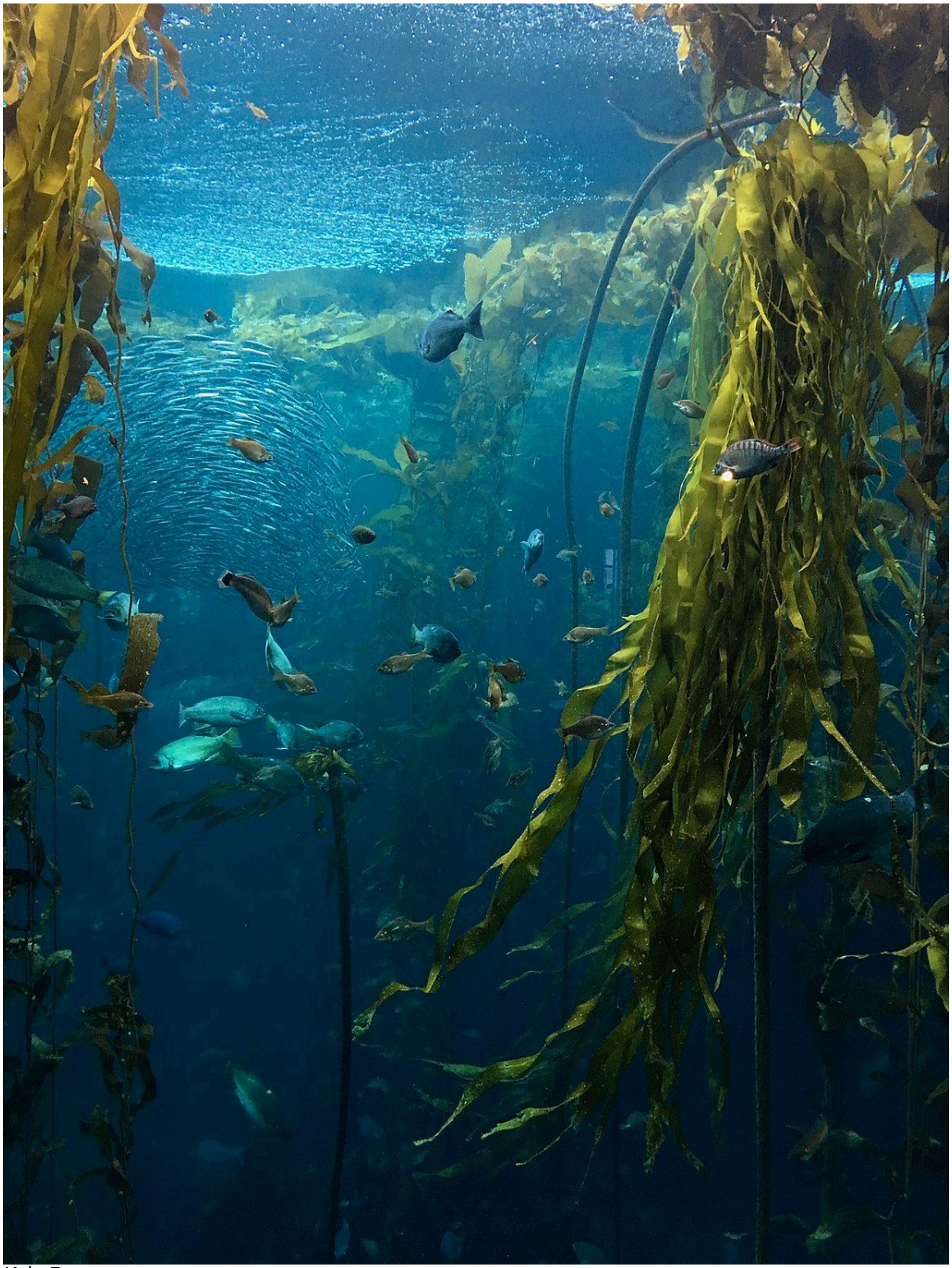
	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2 MP3	MP3 MP4	MP 2 HSS-ID.C.5	MP2
ELA/Literacy	SL.9-10.1		SL.9-10.1 SL.9-10.4		

Classroom Resources for Kelp Forest 5E

Kelp Forest Visual
Urchin Barren Visual
Kelp Forest & Urchin Barren Map
Kelp Forest & Urchin Barren Ecosystem Cards
Kelp Forest & Urchin Barren Ecosystem Fact Sheet

Kelp Forest Visual

Visual 1



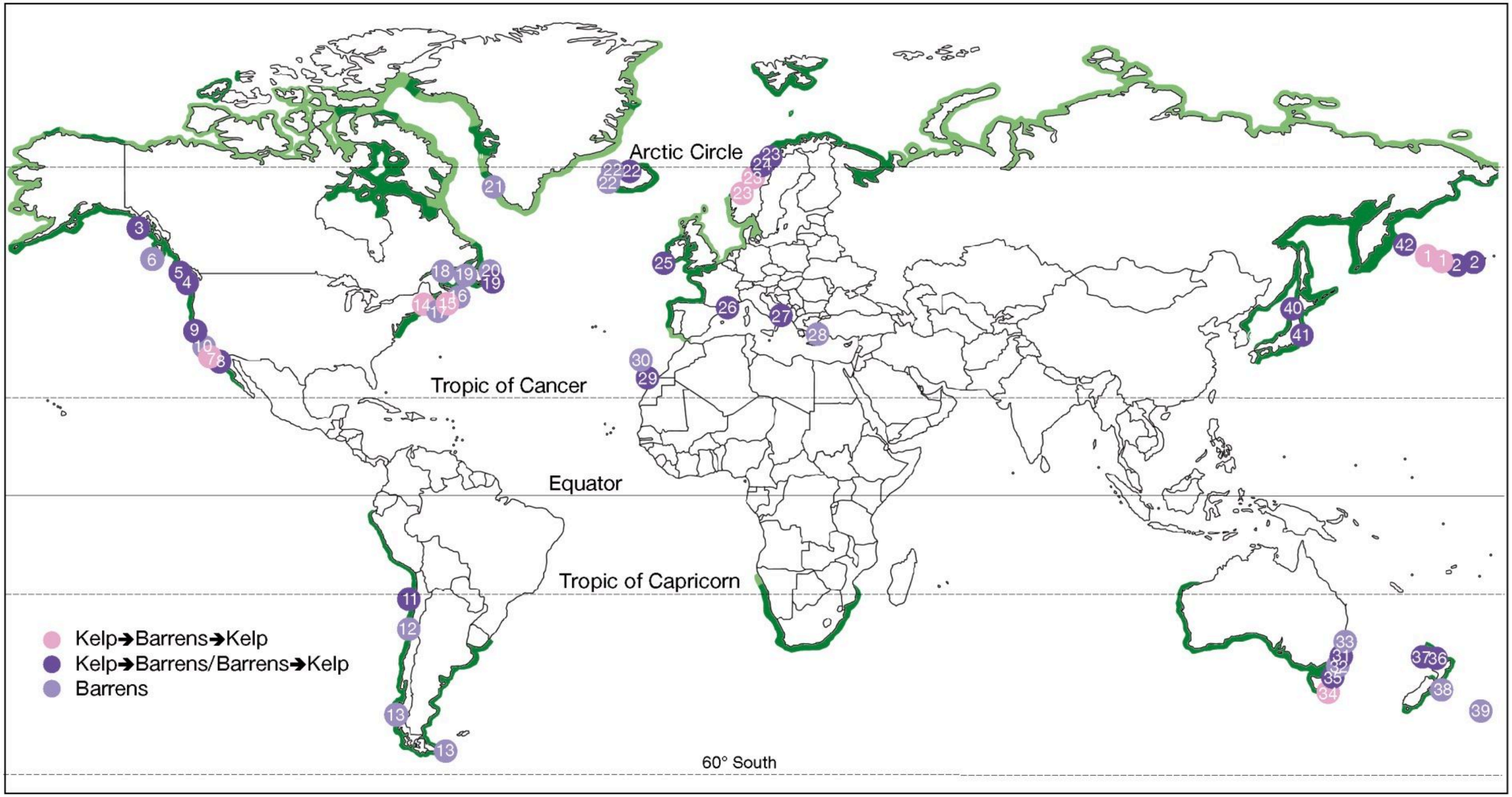
Kelp Forest

Urchin Barren Visual

Visual 2

Urchin Barren

Kelp Forest & Urchin Barren Map

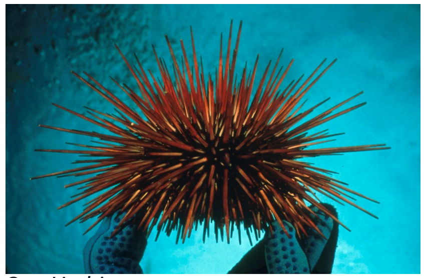
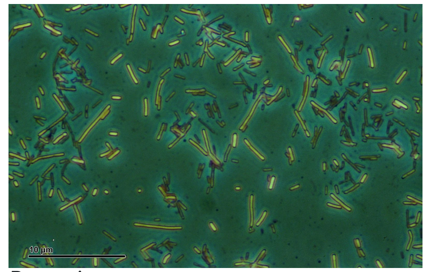
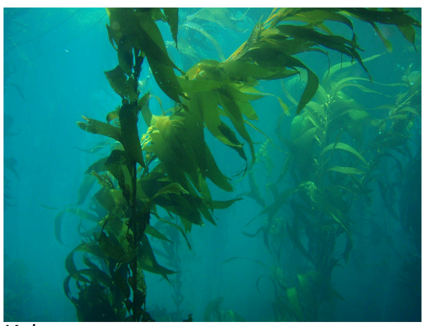
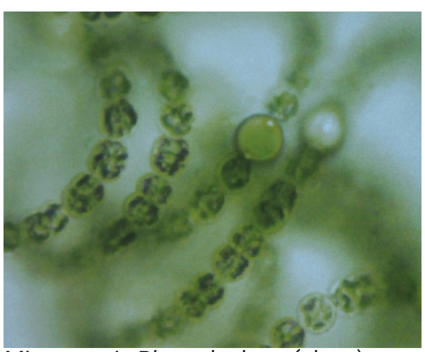
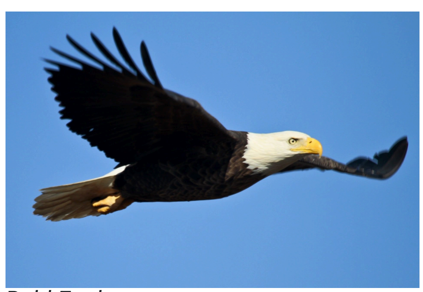
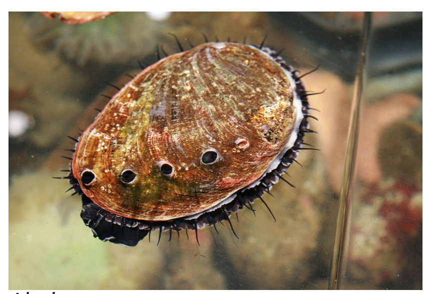


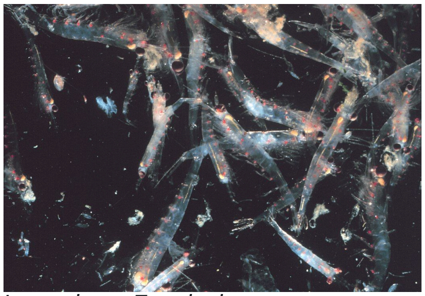
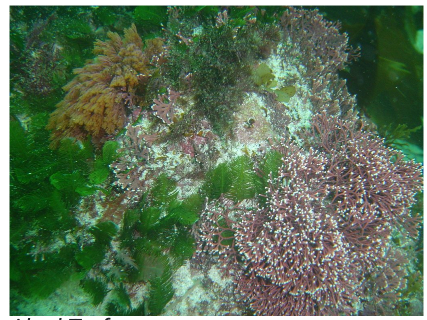
Global occurance of sea urchin barrens documented throughout the range of kelp

- Numbered locations (colored circles) indicate areas where urchin barrens have been documented (throughout the range of kelp forests)
- The numbers inside of the circles correspond to a data table that has additional information
- Pink circles indicate areas that have experienced multiple changes back and forth between kelp and urchin barrens
- Dark purple circles indicate areas that have experienced a single change between either kelp forest to a barren or a barren to a kelp forest
- Light purple circles indicate areas that have urchin barrens (in the possible range of kelp), but a change has not been observed or documented
- Dark green shading indicates the observed range of kelp (the areas kelp forests have been documented)
- Light green shading indicates the possible range of kelp based on light and temperature, but kelp may not have been documented in these areas or other organisms similar to kelp may be present

Kelp Forest & Urchin Barren Ecosystem Cards

Cut out these cards.

Sea Otter  *Sea Otter*	Sea Urchin  *Sea Urchin*	Bacteria  *Bacteria*
Kelp  *Kelp*	Starfish  *Starfish*	Isopod  *Isopod*
Microscopic Phytoplankton (algae)  *Microscopic Phytoplankton (algae)*	Bald Eagle  *Bald Eagle*	Abalone  *Abalone*

Invertebrate Zooplankton  *Invertebrate Zooplankton*	Herring (Alosa)  *Herring (Alosa)*	Atka Mackerel  *Atka Mackerel*
Kelp Crab  *Kelp Crab*	Drift Algae  *Drifing Algae*	Algal Turf  *Algal Turf*

Kelp Forest & Urchin Barren Ecosystem Fact Sheet

Organism	Description

Sea Otter	Otters are carnivorous marine mammals that eat shellfish and other invertebrates (especially sea urchins, and abalone) and are a top predator in the kelp forest. Otters have very thick fur that insulates them against the cold. Otters were extensively hunted for their fur between the 1700's and the early 1900's.
Sea Urchin	Herbivores that eat kelp, other algae, and some small invertebrates. When lacking predators, sea urchin populations explode and eat all of the available kelp and other producers in the ecosystem. Sea urchins will often eat through the root-like structure that holds kelp to the sea floor. This process of overconsumption of the kelp, can lead to areas with little to no kelp but a lot of urchins. These ecosystems are called urchin barrens.
Bacteria	A variety of different types of bacteria live in the kelp forest and in the urchin barrens ecosystem. The largest number of bacteria would be found on the seafloor among the decaying organic matter, but can be found universally throughout the ecosystem. Bacteria are very small, and decompose dead or decaying organic matter, helping to cycle nutrients and matter throughout the ecosystem.
Kelp	Large marine algae that serve as the primary producer in kelp forests. Many species of kelp are long lived, and may grow up to 150 feet tall. Kelp are anchored to the sea floor through root-like structures, and act as habitat engineers, creating a vertical habitat that supports many other species. Kelp superficially look like plants or trees, with structures that resemble roots, stems, and leaves.
Sea Star (Starfish)	Marine invertebrate that is a predator of sea urchins and other animals that live on the floor of the kelp forest, such as isopods, and abalones. Sometimes sea stars will scavenge and eat dead animals and pieces of algae that are drifting in the water.
Isopod	There are many different species of isopods that live in the kelp forest. They are a marine invertebrate that eats smaller organisms, algae on the ocean floor, and is often a detritivore. Isopods are related to insects. They are often absent or few in number in urchin barrens
Microscopic Plankton Algae	Phytoplankton are very small photosynthesizing organisms that inhabit the upper sunlit layer of almost all oceans. Plankton float along with ocean currents and are common in both kelp forests and urchin barrens.
Bald Eagle	Bald eagles are large, predatory birds that have a wide range, but often live and search for food near bodies of water. Bald eagles are carnivores. In the kelp forest, bald eagles eat medium to large sized fish near the surface of the water, such as herring and mackerel.
Abalone	Abalone are marine snails. The abalone shell is very strong and made out of calcium carbonate. Abalone eat algae, either algae drifting along in the water, or they will use their special zipper-like tongue to scrape algae off of rocks or the sea floor. They compete with urchins for algae

Zooplankton	Zooplankton are a diverse group of small invertebrate organisms and the juvenile phases of larger organisms that float throughout the water column. Zooplankton eat phytoplankton and sometimes smaller zooplankton and are common in both kelp forests and urchin barrens.
Herring (Alosa)	Herring are small fish that lay their eggs among the kelp. They eat phytoplankton, zooplankton, and the young of larger fish. There are fewer in urchin barrens than in kelp forests because urchins often eat clams and other small invertebrates that serve as their food in a kelp forest
Atka Mackerel	Atta Mackerel are small to medium sized fish that primarily feed on zooplankton and small invertebrates such as isopods. There are few or absent in urchin barrens
Kelp Crab	Kelp crabs are herbivores that primarily eat kelp and drifting algae. The crabs hide in the kelp beds to avoid predators, and will sometimes attach pieces of kelp to their shell to better camouflage themselves (and to save to eat later). They are few or absent in urchin barrens
Drift Algae	Drift algae is not a separate organism, but are pieces of kelp that have broken off from the main structure and float in the ocean currents.
Algal Turf	A set of algae species that grow, and live on the ocean floor, beneath the kelp. These algae must compete for light in order to photosynthesize.

Passenger Pigeon 5E

Passenger Pigeon 5E	How can we evaluate solutions to human-caused biodiversity loss?	**Performance Expectations** HS-LS2-7, HS-LS2-6	**Investigative Phenomenon** Ecosystem loss and organism extinction are critical problems. An organization argues that bringing the passenger pigeon back from extinction will restore ecosystems. Do they have a valid argument to justify de-extinction?	**Time** 5-6 days

In this 5E instructional sequence, students are investigating the questions about if, why, and how we should bring species like the woolly mammoth back from extinction surfaced during the Driving Question Board launch. Students start by considering the problem of organism extinction and its impacts on ecosystems, focusing on the case of the passenger pigeon that went extinct over 100 years ago. After analyzing the role of passenger pigeons in stabilizing their ecosystem, students consider the argument of an organization that is currently working to bring the passenger pigeon back from extinction. Students investigate the ecosystem and environmental implications of bringing this species back, as well as the ethical, cultural, technological, and financial costs associated with de-extinction as a solution for biodiversity loss.

ENGAGE	Why did the passenger pigeon go extinct?	Students read a historical description to **ask questions** and surface ideas about **the role humans played in the extinction** of the passenger pigeon.
EXPLORE	What role did the passenger pigeon play in its habitat?	Students use historical descriptions to **generate models** representing how the passenger pigeon played an important role in **maintaining its environment** in order to better understand the impact from the **human caused extinction event.**
EXPLAIN	How can we evaluate an argument on the de-extinction of the passenger pigeon?	Students **evaluate an argument** presented to invest resources into bringing the passenger pigeon back from extinction **as a solution** to **human-caused biodiversity loss** and **ecosystem disruption.**
ELABORATE	How can understanding counterclaims help us evaluate an argument?	Students engage with an on-line text in order to **evaluate a counter argument** on using de-extinction **as a solution to human-caused biodiversity loss.**
EVALUATE	How can we evaluate an argument on bringing back the woolly mammoth as a solution to modern biodiversity loss and climate change?	Students **evaluate an argument** on the de-extinction of the woolly mammoth by considering the mammoth's unique role in **maintaining its prehistoric ecosystem** and its possible contributions to **reducing human-caused climate change and biodiversity loss.**

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Why did the passenger pigeon go extinct?

Students read a historical description to **ask questions** and surface ideas about **the role humans played in the extinction** of the passenger pigeon.

Preparation

Student Grouping	Routines	Literacy Strategies
• Pairs	• Consensus Building Share	• Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
• Introduction to the Passenger Pigeon	None	• Passenger Pigeon Martha 100 Years Later - Cincinnati Zoo

Launch

1. Remind students that during the Driving Question Board launch, categories of questions that emerged were related to how, why, and if scientists should bring the woolly mammoth back from extinction. Prompt students to think about what goal de-extinction would serve, given the likely high cost of doing so and other concerns they may have about it.

2. Use student's ideas to transition to the problem of extinction and ecosystem collapse occurring today. Tell students that we will consider another extinct organism, whose extinction came as a surprise and resulted in other negative effects.

3. To introduce the extinction of the passenger pigeon, project or print out the description of the wild passenger pigeon flocks, as described by a Potawatomi tribal leader named Simon Pokagon in 1850. As a class read the passage and prompt students to note down questions they have about the description or what happened to the passenger pigeon:

In the Spring of 1850, a young Potawatomi tribal leader named Simon Pokagon was camping at the headwaters of Michigan's Manistee River. He was startled by an approaching loud sound. He described the sound like, "an army of horses laden with sleigh bells was advancing through the deep forests towards me," He went on to explain, "As I listened more intently, I concluded that instead of the tramping of horses it was distant thunder; and yet the morning was clear, calm, and beautiful." The mysterious sound came "nearer and nearer," until Pokagon deduced its source: "While I gazed in wonder and astonishment, I beheld moving toward me in an unbroken front of millions of pigeons, the first I had seen that season."

Access for All Learners

If students do not have any background knowledge of the passenger pigeon, or need more support in visualizing what occurred, watch Passenger Pigeon Martha 100 Years Later - Cincinnati Zoo up to about 2:55 to introduce the story. Also, most students have experience with the common, extant pigeon found in cities. Prompt students to imagine seeing so many of these pigeons, as described by Simon Pokagon!

Tell students that these animals were so numerous that their extinction came as a shock. Ask students if they could imagine rats or other extremely common animals disappearing.

4. In pairs, provide students with *Introduction to the Passenger Pigeon*. In pairs, students record their questions, based on the passage and quotes by Simon Pokagon; they partner read, **annotating** the text for more information on their questions.

5. Highlight student questions about how the pigeon became extinct, how their extinction produced other problems, and what solutions to ecosystem loss they can think of. Use the Group Learning Routine, **Consensus Building Share** to surface student ideas and remaining questions.

Look & Listen For

- Passenger pigeons lived in extremely large, communal flocks; this unique trait made them vulnerable to extinction, as humans were able to hunt them easily until they were reduced to very small populations
- Once they were in small flocks, they were not able to function in their unique ecological role – further making them vulnerable to extinction
- Expansion of the railroad allowed for the commercial over exploitation of the pigeons
- At the same time as passenger pigeons went extinct, large parts of the forest suffered
- One potential solution for correcting this type of ecosystem collapse is to bring back the passenger pigeon from extinction, in order to stabilize the ecosystem

Integrating Three Dimensions

Although not a Science and Engineering Practice assessed in this unit, students are drawing upon **SEP#1 Asking Questions and Defining Problems** to seek additional information or clarity on the extinction of the passenger pigeon.

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.

Explore

What role did the passenger pigeon play in its habitat?

Students use historical descriptions to **generate models** representing how the passenger pigeon played an important role in **maintaining its environment** in order to better understand the impact from the **human caused extinction event.**

Preparation

Student Grouping	Routines	Literacy Strategies
- Table groups	- Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
- Ecology of the Passenger Pigeon Investigation - Making Sense of the Ecology of the Passenger Pigeon Investigation	None	- Poster paper - Building a Paper Model of CRISPR-Cas9 (optional) - Passenger Pigeon Project (optional)

Launch

1. Ask students to remind us what we are trying to figure out (if bringing the passenger pigeon back from extinction would support ecosystem health). Highlight or point to charted student ideas and questions related to the text presented in the Engage phase, especially around the role of the pigeon in the ecosystem or its' adaptation to living in large flocks.

2. Let students know that we are going to investigate these questions further by looking at historical descriptions and secondary research done to better understand the role pigeons played in North American forests before they were extinct.

Modeling the Passenger Pigeon's Role in the Ecosystem

1. Ask students how modeling the kelp/urchin ecosystem(s) helped them understand ecosystem stability and why an ecosystem may (or may not) change. Build off these ideas to transition to modeling the pigeon in its habitat. Students will use historical data and descriptions to model pigeons in their original habitat. In table groups provide students with *Ecology of the Passenger Pigeon Investigation* and poster paper. Let students know that the goal is to represent the complex interactions between the pigeon and the physical and living parts of the ecosystem – not to simply generate a food web.

Whole-Class Investigation Summary

1. Once table groups have completed their model, have table groups switch papers with another group. Using their peers' model, students complete a *Making Sense of the Ecology of the Passenger Pigeon Investigation*. Confer with students as they are working.

Conferring Prompts

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

- What are the different ways that the forest ecosystem food web was impacted by the extinction of the passenger pigeon?
- Do you think the disturbances made by the passenger pigeon were extreme enough to cause a change to a new ecosystem (like the kelp/urchin case?) Why or why not?
- Based on the model, do you think the passenger pigeon was a keystone species? Why or why not?
- How did the passenger pigeon impact the nonliving parts of the ecosystem?
- How are you using your model to represent relationships between different parts of the system?
- How is your partner groups' model different and similar to your group's model? How does looking at their model help you better understand the complexity of the pigeon's ecosystem and what happened when they were removed from it?

2. Provide time for students to discuss their ideas and questions in their groups. Use the Group Learning Routine, **Domino DIscover** to share out with the class.

Look & Listen For

- The extinction of the passenger pigeon, through the over exploitation by humans, caused significant changes in the forest ecosystem:
  - Shift in dominant tree species
  - Increase in population of the mouse (and maybe an increase in lyme disease)
  - Lack of small disturbances that served to increase biodiversity
  - Lack of nutrients (from feces) in roosting sites
  - Decrease in prey items for predators
- There is a lot of redundancy in terms of the food web – other organisms feed on nuts and other prey items (in lieu of pigeons) for predators
- Humans lost an important food item and an organism that held important cultural value to Native American peoples
- Passenger pigeons have been gone for over a 100 years, has the forest ecosystem settled into a new dynamic equilibrium? Would bringing it back cause a positive disturbance, or a harmful one?

3. 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.

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.

4. Provide students with *Ecology of the Passenger Pigeon 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

Students may have questions and/or be very interested in the biotechnology tools that scientists are using or developing (like CRISPR) to bring back extinct organisms like the passenger pigeon and the woolly mammoth. Although genetics are not a part of the Unit 6 Performance Expectations, engaging with the concepts of modern genetic engineering is a great way to review **LS3.A Heredity: Inheritance and Variation of Traits**, from Unit 3 and Unit 4. Provide students with HHMI's activity, Building a Paper Model of CRISPR-Cas9 , or use the diagrams depicting the revival of the passenger pigeon, Passenger Pigeon Project to investigate how scientists plan on using biotechnology bring organisms back from extinction.

Explain

How can we evaluate an argument on the de-extinction of the passenger pigeon?

Students **evaluate an argument** presented to invest resources into bringing the passenger pigeon back from extinction **as a solution** to **human-caused biodiversity loss** and **ecosystem disruption.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Pairs • Triads	• Think-Talk-Open Exchange • Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
• Evaluating an Argument • Summary Task	None	• Passenger Pigeon Project (optional) • Extinction Is Not Forever: Reviving the Passenger Pigeon with The Long Now Foundation's Ben Novak

Launch

1. Prompt students to review what we have figured out about the passenger pigeon story. Ask students what they think at this point about if scientists should bring it back from extinction.

2. Tell students that there is a group of scientists who believe that bringing the passenger pigeon back from extinction would benefit the ecosystem overall, and are actively working on its de-extinction. Evaluating their argument (in bringing back the passenger pigeon) may help us figure out if we should, in turn, support the revival of the woolly mammoth.

Evaluating an Argument

1. In pairs, provide students with computer access to view Extinction Is Not Forever: Reviving the Passenger Pigeon with The Long Now Foundation's Ben Novak . Let students know they will watch a video in which Ben Novak, a scientist leading the project to revive the passenger pigeon, presents his argument. Prompt students to use their passenger pigeon ecosystem models as a lens for evaluating his argument: the claims, evidence, and reasoning behind his solution to the extinction/biodiversity crisis. Provide students with *Evaluating an Argument* so that they can record their ideas as they watch the video.

Differentiation Point

In addition to the video provided above, many of Ben Novak's points are available in text format in, Passenger Pigeon Project . It may be helpful for some students to have access to both the video and text version as they critique his argument.

2. In triads, use the Group Learning Routine **Think-Talk-Open Exchange** to discuss their evaluation. Students respond to the prompt: Using the analysis you completed with your partner, discuss the strengths and weaknesses of Ben Novak's proposed solution.

3. Provide students time to revise their ideas, based on discussion with their peers.

type	Routine
text	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. Overall, the routine allows students to clarify or generate ideas collaboratively. Please consult the Biology Course Guide for detailed steps about this routine.

Integrating Three Dimensions

In this Explain phase, students are primarily using **SEP#7 Engaging in Argument from Evidence**, but they are drawing on their earlier work with **SEP#6 Constructing Explanations and Designing Solutions** in the *Tuskless Elephant 5E*, in which they designed, evaluated, and refined a solution. In *Evaluating an Argument*, you can find evidence of students' ability to evaluate a solution.

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 the strength of the argument that we should use resources to bring extinct animals back to address the current biodiversity crisis 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 responses, and discuss what we can agree to as a class."

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.

2. 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 the strengths and weaknesses of de-extinction as a solution. 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.

3. 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.

4. 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.

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

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #7 - Stability** and Change explicit for students by elevating ideas related to how observing and asking questions about how things change and how they remain stable helps to make sense of a phenomenon. This is an important element **CCC # 7 - Stability and Change** at the high school level.

Take Time for These Key Points

- The extinction of the passenger pigeon due to human overexploitation has caused negative impacts including: biodiversity loss, changes to ecosystem make-up, functioning and productivity, and a loss of the cultural and inspirational value of the pigeon for humans
- Bringing the pigeon back may restore the above losses
- Return of the passenger pigeon may be impactful because of its keystone / ecosystem engineer role
- It was suggested that bringing species back will re-energize the conservation movement
- Little empirical evidence was provided that de extinction will adequately address biodiversity loss overall and/or that it is a viable option
- Many questions remain on the viability of the de-extinction process for pigeons (and all species) including the biotechnology, and the continuation of the social/behavioral aspects of the species

Implementation Tip

Passenger pigeons displayed a unique level of social interaction and communal behaviors that must have been advantageous to their survival. Trying to recreate those conditions with an initial small population will be challenging. This may be a great place to review and make connections to **LS2.D Social Interactions and Group Behavior**, from Unit 2 - Humans vs Bacteria.

Summary

1. Students individually complete *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 engage in sense-making about how interactions between organisms, and between organisms and their environment regulate ecosystem stability.

Integrating Three Dimensions

The summary task prompts here are designed to get students to consider what they know about using the crosscutting concept of Stability and Change (**CCC #7 - Stability and Change),** then apply it as a tool for asking more questions that build on prior learning about both DCIs and CCCs.

Elaborate

How can understanding counterclaims help us evaluate an argument?

Students engage with an on-line text in order to **evaluate a counter argument** on using de-extinction **as a solution to human-caused biodiversity loss.**

Preparation

Student Grouping	Routines	Literacy Strategies
• Table groups	• Domino Discover • Read-Generate-Sort-Solve	• Chunking Text

Materials

Handouts	Lab Supplies	Other Resources
• Read-Generate-Sort-Solve Graphic Organizer	None	• Bringing extinct species back from the dead could hurt—not help—conservation efforts

Text-Based Task

1. Students have been evaluating the argument made by some that de-extinction is a viable solution to human-cased biodiversity loss. They have been introduced to some of the counter-claims and issues of concern to this solution (in the video) and may have some ideas on why some people disagree with this solution. In pairs, prompt students to brainstorm concerns and counterclaims.
2. Use the Group Learning Routine, **Domino Discover** to share their ideas.

Integrating Three Dimensions

Students are engaging with parts of **SEP#6 Constructing Explanations and Designing Solutions,** as they are evaluating a solution to a complex real-world problem. Student use of this element is assessed in Learning Cycle #1, *Tuskless Elephants*.

Look & Listen For

- Ecosystems have settled into a new stable state over long periods of time, re-introducing these organisms could be disturbance that leads to instability or even a new ecosystem
- The organisms we have been discussing (pigeons, woolly mammoths) are most likely keystone species, therefore bringing them back may have extreme impacts on the ecosystem
- Using technology such as CRISPR to bring back a ‘passenger pigeon-like’ bird may create additional challenges
- Passenger pigeons were very social and communal – it may be impossible to replicate that part of their behavior and ecological role

3. Use student's ideas and questions to transition to thinking about additional counter-claims and points to consider in the de-extinction process. Many of their ideas should be based on ecological concerns, as that is what they have been investigating in this unit. However, there are additional ideas to consider and use as a lens for critiquing an argument for de-extinction. Let students know that they will read a counter-argument that represents the thinking of some scientists. Introduce the prompt: 'What are scientists and conservationists concerned about in terms of the de-extinction of organisms such as the passenger pigeon and woolly mammoth?'

4. Provide students with the *Read-Generate-Sort-Solve Graphic Organizer* and access to the on-line article, Bringing extinct species back from the dead could hurt—not help—conservation efforts .

5. Facilitate the group learning routine **Read-Generate-Sort-Solve**, as a way for students to synthesize and extend their thinking.

Access for All Learners

Encourage students to discuss their thoughts on the moral or ethical considerations in bringing back extinct organisms, as this is a relevant and interesting topic! However, in critiquing a scientific argument we want to emphasize the quality of evidence and the use of sound scientific reasoning.

Access for All Learners

The on-line article, Bringing extinct species back from the dead could hurt—not help—conservation efforts may be challenging for some students. Use the literacy routine, **chunking text**, as a way to make the text more accessible to all students. Additionally, the article could be printed and jigsawed so that individual students only work with a portion of the text.

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.

Evaluate

How can we evaluate an argument on bringing back the woolly mammoth as a solution to modern biodiversity loss and climate change?

Students **evaluate an argument** on the de-extinction of the woolly mammoth by considering the mammoth's unique role in **maintaining its prehistoric ecosystem** and its possible contributions to **reducing human-caused climate change and biodiversity loss.**

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
• Woolly Mammoth Argument • Passenger Pigeon 5E - Argument Evaluation • Passenger Pigeon 5E - Mini Rubric	None	

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, *Should we bring the woolly mammoth back from extinction?)*

2. Prompt students to review what they figured out during this learning sequence . Ask students to think about how understanding the story of the passenger pigeon may be helpful in evaluating if we should bring the woolly mammoth back.

3. Provide students with *Passenger Pigeon 5E - Argument Evaluation* and *Woolly Mammoth Argument*. Students use the text and all of the evidence and scientific reasoning developed over the course of this learning cycle to evaluate the argument that de-extinction is a good solution to the human-caused biodiversity loss.

4. Confer with students while they are working.

5. After completing their response, use the *Passenger Pigeon 5E - Mini Rubric* to generate self, peer, or teacher feedback on their initial evaluation. This feedback will be used to inform their final performance task response.

Performance Expectations

HS-LS2-6 **Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.**
Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Examples of changes in ecosystem conditions could include ecological succession, modest biological or physical changes, such as moderate hunting or seasonal floods; and extreme changes, such as volcanic eruption or sea level rise.

HS-LS2-7 * **Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.**
Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species.
Assessment Boundary: None

In NYS the following has been added to the clarification statement: Examples of solutions could include simulations, product development, technological innovations, and/or legislation.

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2) 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)	ETS1.B Developing Possible Solutions • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1) LS2.C Ecosystem Dynamics, Functioning, and Resilience • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. LS2.C(1) • Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. LS2.C(2) LS4.D Biodiversity and Humans • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). LS4.D(1) • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining	Stability and Change • Much of science deals with constructing explanations of how things change and how they remain stable. CCC7(1)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. LS4.D(2)	

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Engaging in Argument from Evidence			*Evaluating an Argument* Class Consensus Discussion *Summary Task*	*Read-Generate-Sort-Solve Graphic Organizer* Domino Discover	*Passenger Pigeon 5E - Argument Evaluation* *Passenger Pigeon 5E - Mini Rubric*
Developing and Using Models		Ecosystem models *Making Sense of the Ecology of the Passenger Pigeon Investigation* Domino Discover	*Summary Task*		
ETS1.B Developing Possible Solutions			*Evaluating an Argument* Class Consensus Discussion	*Read-Generate-Sort-Solve Graphic Organizer* Domino Discover	*Passenger Pigeon 5E - Argument Evaluation* *Passenger Pigeon 5E - Mini Rubric*
LS2.C Ecosystem Dynamics, Functioning, and Resilience	Consensus Building Share Discussion	Ecosystem models *Making Sense of the Ecology of the Passenger Pigeon Investigation* Domino Discover Domino Discover	*Evaluating an Argument* Class Consensus Discussion *Summary Task*	*Read-Generate-Sort-Solve Graphic Organizer*	*Passenger Pigeon 5E - Argument Evaluation* *Passenger Pigeon 5E - Mini Rubric*
LS4.D Biodiversity and Humans	Consensus Building Share Discussion	Domino Discover Ecosystem models *Making Sense of the Ecology of the Passenger Pigeon Investigation* Domino Discover	*Evaluating an Argument* Class Consensus Discussion *Summary Task*	*Read-Generate-Sort-Solve Graphic Organizer* Domino Discover	*Passenger Pigeon 5E - Argument Evaluation* *Passenger Pigeon 5E - Mini Rubric*
Stability and Change		Ecosystem models *Making Sense of the Ecology of the Passenger Pigeon Investigation* Domino Discover	Class Consensus Discussion *Summary Task*	*Read-Generate-Sort-Solve Graphic Organizer*	*Passenger Pigeon 5E - Argument Evaluation* *Passenger Pigeon 5E - Mini Rubric*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics					
ELA/Literacy	RST.9-10.1		RST.9-10.6 SL.9-10.1	RST.9-10.6	RST.9-10.6 SL.9-10.1

Unit Closing	How can we evaluate the argument that bringing back the woolly mammoth from extinction is a viable solution to biodiversity loss?	**Performance Expectations** HS-LS2-6, HS-LS2-7	**Anchor Phenomenon** Woolly mammoths once roamed the Earth and now they are extinct.	**Time** 1-3 days

Based on the investigations and learning throughout the unit, students generate a final model that represents the causes behind the extinction of the woolly mammoth, and then evaluate an argument on bringing it back from extinction as a solution to reducing biodiversity loss.

ANCHOR PHENOMENON	Why did the woolly mammoths go extinct? Should we bring them back from extinction?	Students generate additional ideas on the extinction of the woolly mammoth
DRIVING QUESTION BOARD	What questions about the woolly mammoth extinction have been answered? What questions 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 use models to represent what caused the extinction of the woolly mammoth and evaluate arguments on bringing them back?	Based on the investigations and learning throughout the unit, students develop a final extinction model and argument evaluation.
UNIT REFLECTION		Students reflect on what they learned in this unit, and in the entire Biology course.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

Why did the woolly mammoths go extinct? Should we bring them back from extinction?

Students generate additional ideas on the extinction of the woolly mammoth

Preparation

Student Grouping	Routines	Literacy Strategies
- Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	

Generating Ideas about Anchor Phenomenon

1. Students return to the anchor phenomenon and generate ideas on why the woolly mammoth may have gone extinct, and if we should try to bring it back from extinction.

Driving Question Board

What questions about the woolly mammoth extinction have been answered? What questions 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	Routines	Literacy Strategies
• Table groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	• 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 might be interested in investigating in the future?

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 use models to represent what caused the extinction of the woolly mammoth and evaluate arguments on bringing them back?

Based on the investigations and learning throughout the unit, students develop a final extinction model and argument evaluation.

Preparation

Student Grouping	Routines	Literacy Strategies
Individual	None	None

Materials

Handouts	Lab Supplies	Other Resources
Final Task Final Model Rubric Final Argument Evaluation Rubric	None	The Mammoth Project (optional) De-Extinction Debate: Should We Bring Back the Woolly Mammoth? (optional) We Can "Bring Back" The Woolly Mammoth. Should We?

Returning to the Performance Task

1. Reorient students to the argument under consideration by watching, We Can "Bring Back" The Woolly Mammoth. Should We? .

2. Students will return to their earlier work on the extinction model and argument evaluation, including all of the feedback provided by their peers and teachers using the mini-rubrics. Encourage students to do additional research on finding additional evidence for their extinction model or to be used in the evaluation of the argument.

Differentiation Point

Students may struggle finding appropriate resources as additional evidence and ideas for their performance task. The on-line texts, The Mammoth Project , and De-Extinction Debate: Should We Bring Back the Woolly Mammoth? are good starting points.

3. Provide students with *Final Task* to work on individually.

4. Use the *Final Model Rubric* and *Final Argument Evaluation Rubric* provide feedback as students are working.

Unit Reflection

Students reflect on what they learned in this unit, and in the entire Biology course.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
Biology Course Student Reflection	None	

Course Learning Reflection

1. As the final unit in the course, provide students with the opportunity to reflect on their own learning. It may be helpful to prompt students to look at their work over the course of the year (performance tasks, notebook, portfolios, etc) so that they can observe their own growth across all three dimensions, and as science-knowers.

2. Provide students with *Biology Course Student Reflection*. Students should choose a few prompts to respond to, and should be encouraged to express their reflections in any format that they choose (written, drawings, cartoons, video, etc.).

Standards in Unit Closing

Performance Expectations

HS-LS2-6	**Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.** Clarification Statement: Examples of changes in ecosystem conditions could include modest biological or physical changes, such as moderate hunting or a seasonal flood; and extreme changes, such as volcanic eruption or sea level rise. Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Examples of changes in ecosystem conditions could include ecological succession, modest biological or physical changes, such as moderate hunting or seasonal floods; and extreme changes, such as volcanic eruption or sea level rise.

HS-LS2-7 *	**Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.** Clarification Statement: Examples of human activities can include urbanization, building dams, and dissemination of invasive species. Assessment Boundary: None

In NYS the following has been added to the clarification statement: Examples of solutions could include simulations, product development, technological innovations, and/or legislation.

The performance expectations marked with an asterisk (*) integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2) 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)	LS2.C Ecosystem Dynamics, Functioning, and Resilience • A complex set of interactions within an ecosystem can keep its numbers and types of organisms relatively constant over long periods of time under stable conditions. If a modest biological or physical disturbance to an ecosystem occurs, it may return to its more or less original status (i.e., the ecosystem is resilient), as opposed to becoming a very different ecosystem. Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability. LS2.C(1) • Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species. LS2.C(2) ETS1.B Developing Possible Solutions • When evaluating solutions it is important to take into account a range of constraints including cost, safety, reliability, and aesthetics and to consider social, cultural, and environmental impacts. ETS1.B(1) LS4.D Biodiversity and Humans • Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). LS4.D(1) • Humans depend on the living world for the resources and other benefits provided by biodiversity. But human activity is also having adverse impacts on biodiversity through overpopulation, overexploitation, habitat destruction, pollution, introduction of invasive species, and climate change. Thus, sustaining biodiversity so that ecosystem functioning and productivity are maintained is essential to supporting and enhancing life on Earth. Sustaining	Stability and Change • Much of science deals with constructing explanations of how things change and how they remain stable. CCC7(1) 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)

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	biodiversity also aids humanity by preserving landscapes of recreational or inspirational value. LS4.D(2) LS4.C Adaptation • Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species. LS4.C(4)	

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Engaging in Argument from Evidence			*Final Task*	
Developing and Using Models			*Final Task*	
LS2.C Ecosystem Dynamics, Functioning, and Resilience	Student generated ideas		*Final Task*	
ETS1.B Developing Possible Solutions			*Final Task*	
LS4.D Biodiversity and Humans	Student generated ideas		*Final Task*	
LS4.C Adaptation	Student generated ideas			
Stability and Change			*Final Task*	
Systems and Systems Models			*Final Task*	

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics				
ELA/Literacy				