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

Access for All Learners

Provide students an opportunity to describe their personal experiences or background knowledge of coral reefs,

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.

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.

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

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.

Biology Course Guide for support with this routine.

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*

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

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

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.

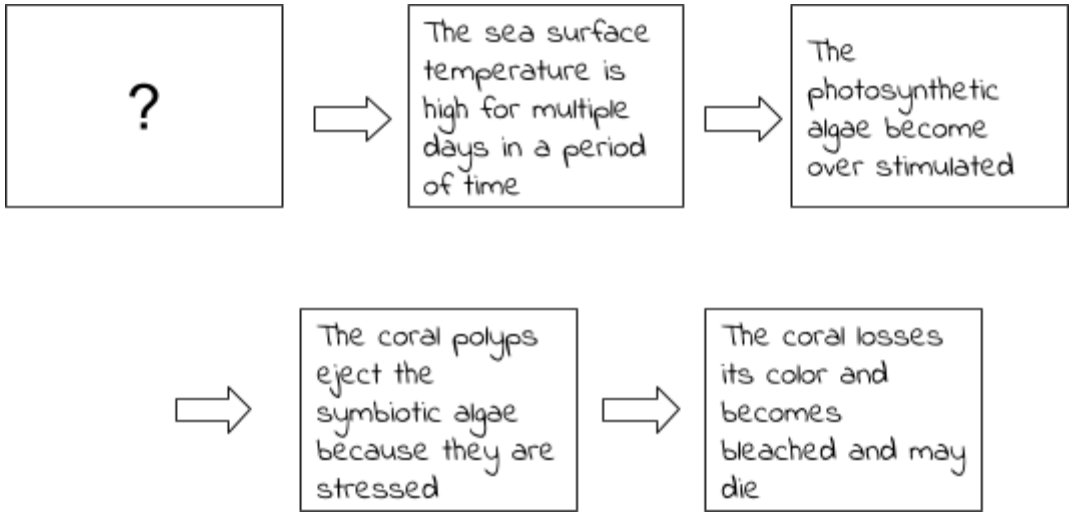
portion of the phenomenon. Opportunities to assess the claimed high school level elements of **SEP#2 Developing and Using Models** and **CCC#3 Scale, Proportion, and Quantity** and **CCC#4 Systems and Systems Models** are found later in the learning sequence.

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

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.

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.

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).

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?

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.

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.

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

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.

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.

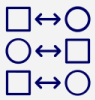
Generating a Model

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.

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.

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 .

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.

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

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.

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.

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?

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*.

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.

Integrating Three Dimensions

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.

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.

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.

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

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)

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. SEP5(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) • 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 decline–and sometimes the extinction–of some species. LS4.C(4) LS4.D Biodiversity and Humans	• 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
	• 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*	*Carbon Cycle Investigation Part 1* *Carbon Cycle Investigation Part 2*		

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
		Making Sense of the Coral Bleaching Investigation Domino Discover	*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*	
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*			*Coral Bleaching 5E - Extinction Model*

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
		Domino Discover *Cause & Effect Organizer Coral Bleaching*			*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		

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
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