

BIOLOGY

Common Ancestry
& Speciation

**What will happen
to Arctic bear
populations as
their environment
changes?**



HIGH SCHOOL SCIENCE



TEACHER EDITION

What will happen to Arctic bear populations as their environment changes?

Common Ancestry & Speciation: Bears

OpenSciEd Unit B.5





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UNIT OVERVIEW

What will happen to Arctic bear populations as their environment changes?

This unit is anchored by the unusual sightings of polar, brown, and black bears in the Wapusk National Park. Students investigate why scientists find this so unusual and consider what this means for the future of the bears as the Arctic warms. Lesson Set 1 (Lessons 1-5) focuses on figuring out how and why the Arctic bears interact in particular ways. Students figure out how past relationships between the species and conditions on Earth over geologic time can help them predict the future. In Lesson Set 2 (Lessons 6-9), students unravel the speed at which extinction and speciation events occurred in the past compared with changes bears living in the modern-day Arctic experience. They figure out that hybridization is a possibility for Arctic bears. Students investigate ways humans have helped protect other species from extinction and debate what role humans should play in protecting Arctic bears and species in danger of extinction. This unit culminates with a Transfer Task where they apply all of their understanding of how to figure out why the bumble bee is threatened with extinction and to evaluate claims about ways to prevent extinction from occurring.

Throughout this unit, students will do the following:

- Develop and revise models to explain and predict the interactions of Arctic bear populations with their environment.
- Construct and evaluate arguments using evidence.
- Evaluate competing solutions to prevent extinction.
- Find patterns in data at different scales that affect the survival of Arctic bears as the climate changes.
- Develop and revise models about the effect of climate change on the long-term survival of Arctic bear populations.
- Make, defend, and evaluate claims about the relationship between thermoregulation and bear behavior.
- Infer mechanisms of bear speciation at scales that cannot be studied directly.
- Construct and revise arguments about how brown and polar bears split from a common ancestor.
- Construct and revise arguments about the causes of mass extinction events on Earth.
- Integrate and evaluate information from multiple sources about ways to prevent the extinction of particular species.
- Evaluate possible solutions for protecting polar bears from extinction.

Building Toward NGSS Performance Expectations

HS-ESS2-7:

Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

HS-LS1-3:

Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

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.

HS-LS2-7:

Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.*

HS-LS4-1:

Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-2:

Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment .

HS-LS4-4:

Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5:

Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

UNIT STORYLINE

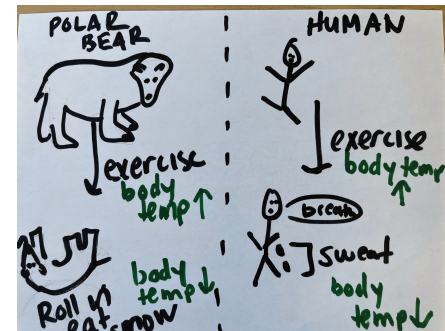
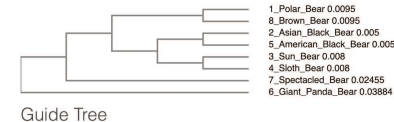
Unit Question: What will happen to Arctic bear populations as their environment changes?

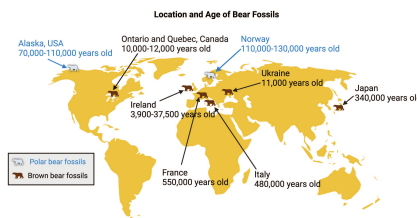
How students will engage with each of the phenomena



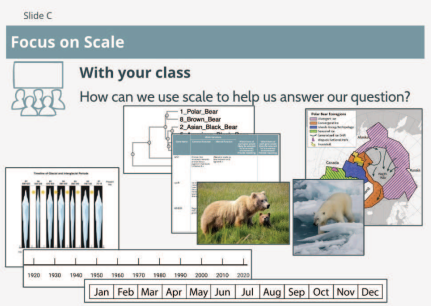
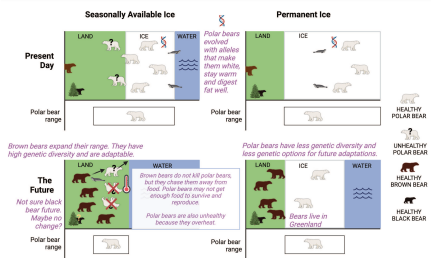
Lesson Set 1: What is happening with Arctic bear populations?			
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 Lesson Set 1 4 days How do changes in climate affect bear species coming together for the first time in the Arctic? Anchoring Phenomenon	<i>The sighting of 3 bear species in one location in Canada for the first time may be related to the effect of climate change.</i>	We investigate changing Arctic environmental conditions and their relationship to Arctic bear populations. We read about polar, brown, and black bears and consider how they may adapt to changing conditions. We investigate the stability of Arctic bear populations in different regions of the Arctic. We develop and share initial models about the future of different polar bear populations. We develop our DQB and figure out: - The coverage and duration of Arctic sea ice is changing, leading to less sea ice habitat for polar bears in areas with seasonally available ice. - Polar bears are adapted to the Arctic ecosystem and rely on Arctic sea ice. - Based on their adaptations, the polar bears are most at risk for population declines as the environment changes. - Based on their adaptations, brown bears may expand their range as the Arctic warms. - Polar and brown bears are likely to interact more as the environment changes.	<i>Illustrations created by OpenSciEd in Biorender.com</i>

↓ Navigation to Next Lesson: We decide to investigate how polar, brown, and black bears interact because changes in climate may make that more likely to occur in the future.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 Lesson Set 1 3 days How and why are bear species interacting and why might brown bears dominate? Investigation 	 Arctic bear population interactions are complex.	We decide to investigate interactions between black, brown, and polar bears. We investigate thermoregulation to figure out why polar bears might run away from brown bears. We construct claims about what will happen in polar and brown bear interactions in the future. We wonder about other similarities and differences between the bears. We figure out: • In interactions with brown bears, polar bears are submissive. • When polar bears exercise, they overheat easily. • Their adaptations, including a variation of the NOS3 gene cause polar bears to get hot. • Other mammals, like humans, can regulate heat through sweating and other mechanisms. • Polar bears can cool off when there is snow, but without it they get too hot and pass out.	
↓ Navigation to Next Lesson: We figure out that polar bears overheat easily, and that can affect their interactions with brown bears. We wonder about other similarities and differences between the bears.			
LESSON 3 Lesson Set 1 2 days How similar/different are the polar, brown, and black bears? Investigation 	 Some bear species are more closely related to each other than others.	We decide to investigate how similar/different the three species of bears are. We investigate similarities and differences in anatomical evidence and realize it is hard to figure out how the bears are related. We decide to use DNA evidence and build a tree of the polar, brown, and black bears with five other bear species. We figure out that polar bears are most similar to brown bears and that they shared a more recent common ancestor than they do with other bears. We figure out: • We have evidence that polar, brown, and black bears have a lot of similarities and differences based on anatomy and behavior. • We can use trees to communicate our hypotheses about relationships among bear species. • Polar bears and brown bears are more genetically similar to each other than they are to any other bear species. • Polar bears and brown bears share a more recent common ancestor than they do with other bears.	 Guide Tree
↓ Navigation to Next Lesson: We figured out that polar bears and brown bears shared a common ancestor and wonder what happened to cause them to split.			

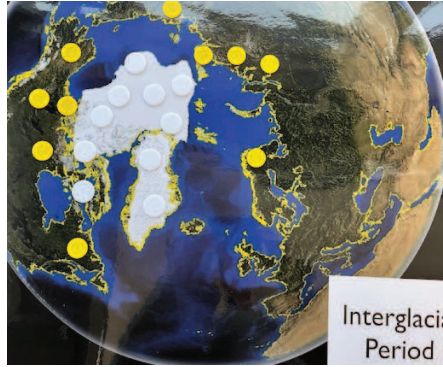
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it								
LESSON 4 Lesson Set 1 3 days How did polar and brown bears become different species? Investigation 	 The Arctic has undergone cycles of glaciation.	We review the mechanism of natural selection and use it to connect evidence at different scales to explain how polar and brown bears split from a common ancestor. We investigate evidence from glacial cycles, fossils, and allele variations. We develop and revise an argument to explain the speciation of polar and brown bears. We decide to use what we know about the impact of glacial cycles on bears in the past to figure out what will happen to Arctic bears in the future. We figure out: - The Arctic has undergone glacial and interglacial periods, creating selective pressures for bears. - Small bear populations may have been isolated in areas that kept ice year round during interglacial periods. - Natural selection acted on genetic variations present in isolated populations of bears over thousands of generations. - Speciation occurred in the common ancestor bear after thousands of generations, leading to polar bears that are adapted to polar environments and brown bears that are adapted to nonpolar environments.	<table><tr><th colspan="2">Claim</th></tr><tr><td colspan="2">Polar bears and brown bears split from a common ancestor between 626,000 and 550,000 years ago because one population of common ancestor bears got trapped in Greenland and reproduced in isolation for thousands of years during an interglacial period while another population remained in Canada. (Note the exact timing and location are not important, but claims should include a complete interglacial period to allow for isolation and enough time for speciation to occur. Greenland is a large island that is an obvious place for isolation, but the scientific community does not currently have evidence that this is where speciation occurred. Students should choose a time period from before 150,000 years ago because there are polar bear fossils that are that old. The oldest brown bear fossil students are presented with is 550,000 years old so the claim above is a likely scenario for a split from a common ancestor. Students could also argue that polar bears evolved from brown bears using the evidence provided.)</td></tr></table> <table><tr><th>Evidence (what data supports your claim?)</th><th>Reasoning (connect each piece of evidence to your claim)</th></tr><tr><td>Evidence Options: Day 1 evidence: -Glacial ice always covers Greenland in the visualization. -There were repeated glacial and interglacial periods of warming and cooling. -Our data: Some bears might get trapped in Greenland or another island in the Arctic during interglacial periods where there would still be ice. Day 2 evidence: -They found 100,000 year old polar bear fossils in Alaska and Norway. -All of the brown bear fossils are found farther to the south than the polar bear fossils. -Brown bear fossils are both younger and older than polar bear fossils. (3,900-550,000 years old)</td><td>Common ancestor bears lived all over the northern hemisphere. During a glacial period, a group of ancestor bears lived in a place that became glaciated. They wandered all over the ice looking for food. Some had better inherited traits for catching food on the ice and survived and reproduced. They passed on those adaptive traits to their offspring so they had them too. Others without adaptive traits died. When the glaciers retreated those bears that stayed on the ice survived. The ones that stayed on the ice and adapted over thousands of generations and became polar bears. Polar bear fossils are only found in areas that would have been glaciated and there were polar bears at least 150,000 years ago so polar bears must have split from a common ancestor before that. It takes thousands of years for speciation to occur, so I chose 426,000 and 380,000 years ago.</td></tr></table>	Claim		Polar bears and brown bears split from a common ancestor between 626,000 and 550,000 years ago because one population of common ancestor bears got trapped in Greenland and reproduced in isolation for thousands of years during an interglacial period while another population remained in Canada. (Note the exact timing and location are not important, but claims should include a complete interglacial period to allow for isolation and enough time for speciation to occur. Greenland is a large island that is an obvious place for isolation, but the scientific community does not currently have evidence that this is where speciation occurred. Students should choose a time period from before 150,000 years ago because there are polar bear fossils that are that old. 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↓ **Navigation to Next Lesson:** Students use their understanding of how bear populations adapted to major changes in climate in the past to help them understand what might happen to Arctic bear populations in the future.

LESSON 5 Lesson Set 1 1 day What will happen to Arctic bear populations as their environment changes? Putting Pieces Together	 <i>Students put the pieces together and revise their model to explain what will happen to Arctic bear populations as their environment changes.</i>	We develop a Gotta-Have-It Checklist and revise our initial consensus model using new evidence. We revisit the DQB and answer questions we have figured out, notice what questions are left unanswered, and add new questions. We figure out: - Polar bear populations will decline in the future because they evolved with adaptations for Arctic environments. When removed from those habitats, they overheat and cannot outcompete brown bears for food. - Arctic brown bear populations will increase in the future as there is less ice and they can use aggression and genetic diversity to find food, survive and reproduce in more areas on land in the Arctic.	 <i>Illustrations created by OpenSciEd in Biorender.com</i>
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↓ **Navigation to Next Lesson:** We wonder how quickly the Arctic climate is warming now compared to other interglacial periods and if polar bears will be able to evolve through natural selection quickly enough to adapt to those changes.

Lesson Set 2: What will happen to Arctic bear populations in the future?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 Lesson Set 2 1 day What will happen to bear species in the Arctic in the future? Investigation 	 <i>Polar and brown bears can mate and produce offspring.</i>	We decide to investigate what will happen to polar bears in the future as the Arctic environment changes. We figure out the climate is likely changing too fast for polar bears to evolve and adapt to environmental changes. We wonder about other possibilities for polar bears and hear about a case where polar bears and brown bears mated and produced hybrid offspring. We use a model to generate evidence to help us predict hybrid fitness in the future. We wonder if polar bears could go extinct. We figure out: - The Arctic climate is likely changing too quickly for polar bears to adapt. - Polar and brown bears may interact and mate with each other. - We can use a model to generate evidence to support predictions. - If polar and brown bears mate, some polar bear genes may not be lost.	

↓ **Navigation to Next Lesson:** We figure out the polar and brown bears will interact in new ways and may produce hybrid offspring. We wonder about the consequences of polar bear extinction.

LESSON 7

Lesson Set 2

2 days

How do past patterns of extinction help us understand possible consequences of extinctions now and in the future?

Investigation





There are notable similarities between the five mass extinction events of the past and current extinctions.

We investigate extinction rates for the whole Earth and wonder how this compares with events in the geologic past. We investigate the five mass extinctions in Earth's history and figure out that in each, a major event precipitated a significant shift in climate. We connect what we learned in the past to what is happening today and update our Progress Trackers. We figure out:

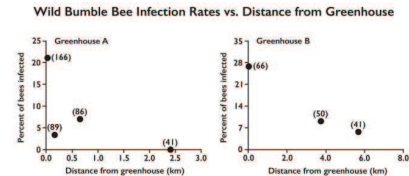
- Five times in Earth's history, significant environmental changes that resulted in major shifts in global climate caused the extinction of at least 75% of all species.
- Extinction is a significant threat to biodiversity, which is necessary for ecosystem resistance.
- There are similarities between environmental conditions that caused the mass extinctions and Earth today.
- Unlike the previous 5 mass extinctions, current extinctions are primarily caused by human activities.

Extinction Event	Cause	Effects (on biosphere and other Earth systems)
Ordovician 444 MYA	Glacial period triggered by eroding mountains, which removed large amounts of CO ₂ from the atmosphere.	Reduced oxygen in ocean Extreme cold 86% species died (trilobites, coral, etc.)
Devonian 359 MYA	Evolution of land plants. Used up carbon dioxide in the atmosphere.	Climate cooled Dead plants ran into oceans and decomposed, caused algae blooms. Oxygen left ocean, killing ocean life 75% species died (armored fish, coral)
Permian 252 MYA	Volcano in Siberia released huge amount of CO ₂ and sulfur dioxide	Acid rain, ocean acidification Global warming 96% species died (insects, coral, amphibians)
Triassic 201 MYA	Underwater volcano CO ₂ levels rose	Global warming, sea level rise Ocean acidification Marine life died from change in ocean chemistry 80% species lost (reptile, coral, amphibians)
Cretaceous 66 MYA	Asteroid fell to earth	Blackened sky, blocked sun Rapid cooling Ocean acidification 76% species died (dinosaurs, plants, mammals)

↓ **Navigation to Next Lesson:** We figured out repeating patterns in the causes for mass extinctions. Many of those causes are happening today and threaten biodiversity. We wonder if we should protect species, like the polar bear, from extinction.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it												
LESSON 8 Lesson Set 2 3 days What are our options for protecting species from extinction and should we implement them? Investigation 	 <i>People approach protection of species at risk from extinction in different ways.</i>	We research and evaluate solutions people have used to protect species from extinction and present what we learn. We discuss if these solutions could work to protect the polar bear and if people should intervene. We write an individual argument with our position on whether we should do something to save polar bears from extinction. We figure out: - Options for protecting endangered species from extinction include habitat conservation, breeding programs, species relocation, long-term storage of genetic material, and others. - Not all species at risk of extinction can be protected in the same way. - Protecting species from extinction requires huge inputs of time, money, resources, and collaboration. - Protecting polar bears from extinction is difficult because they are large, long-lived, reproduce slowly and cannot survive in warm climates.	<table border="1"> <thead> <tr> <th></th><th>Choice 1</th><th>Choice 2</th><th>Choice 3 (optional)</th></tr> </thead> <tbody> <tr> <td>Solution and case study What approach would you use? Which case study introduced it?</td><td>Harvest sperm and eggs to protect habitat and control human behavior.</td><td>Coral reef sperm and eggs and freeze them to create more individuals later.</td><td></td></tr> <tr> <td>Evaluation Why would this solution work for the polar bear? What evidence supports this claim?</td><td>We could pass laws to cut down on greenhouse gases to protect polar bear habitat. This is good for the polar bear because it is the only way to protect the loss of habitat. We have evidence that there is warming in the Arctic and that ice is melting faster than it ever has and we know there cannot be enough generations of polar bears to evolve to warmer temperatures in that time. Polar bears have a gene that makes them overheat. If we do not cool temperatures by reducing greenhouse gases, they will go extinct.</td><td>Polar bears do not have high genetic diversity, we learned that in lesson 4. If we can harvest sperm and eggs from polar bears, we can protect the diversity we do have and help polar bears reproduce in the future. We may be able to screen for genes that do better in this warmer climate and create babies with better adaptations.</td><td></td></tr> </tbody> </table> Above you evaluated solutions that could prevent the extinction of the polar bear. Based on constraints and/or ethical considerations do you think people should put the solution you argued for above in place? Explain your thinking. We should intervene because governments are already passing laws to reduce greenhouse gas emissions and people care about the polar bear so they would be willing to make sacrifices to use cars less and burn less fuels so we can save the species. I think if we collect sperm and eggs and screen them for genetic variations that are adaptive, we will be able to breed polar bears that can survive. We caused this crisis and it is our obligation to protect species from extinction.		Choice 1	Choice 2	Choice 3 (optional)	Solution and case study What approach would you use? Which case study introduced it?	Harvest sperm and eggs to protect habitat and control human behavior.	Coral reef sperm and eggs and freeze them to create more individuals later.		Evaluation Why would this solution work for the polar bear? What evidence supports this claim?	We could pass laws to cut down on greenhouse gases to protect polar bear habitat. This is good for the polar bear because it is the only way to protect the loss of habitat. We have evidence that there is warming in the Arctic and that ice is melting faster than it ever has and we know there cannot be enough generations of polar bears to evolve to warmer temperatures in that time. Polar bears have a gene that makes them overheat. If we do not cool temperatures by reducing greenhouse gases, they will go extinct.	Polar bears do not have high genetic diversity, we learned that in lesson 4. If we can harvest sperm and eggs from polar bears, we can protect the diversity we do have and help polar bears reproduce in the future. We may be able to screen for genes that do better in this warmer climate and create babies with better adaptations.	
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↓ **Navigation to Next Lesson:** We came up with an argument about the future of the polar bear and want to see if we have now answered all of our questions on the DQB. We will apply what we learned to a new phenomenon.

LESSON 9 Lesson Set 2 2 days Can we use everything we have figured out about speciation to explain a new phenomenon? Putting Pieces Together 	 <i>Bumble bees may be at risk of extinction.</i>	We complete a Transfer Task to evaluate claims about ways to protect endangered bumble bees to demonstrate how what we figured out throughout the unit about finding common ancestry, biological evolution, and extinction applies to other systems. We figure out: - Wild bumble bee populations are in danger from pathogens, pesticides, and climate change. - To protect the wild bee population, we need to eliminate the use of pesticides, reduce the number of managed honey bee hives, and maintain genetic diversity of bee populations.	Wild Bumble Bee Infection Rates vs. Distance from Greenhouse  a) Why might the pathogen spread so easily between the bumble bee species in the greenhouses and the wild bumble bees? They are probably closely related and have similar genes. b) Describe the relationship between the level of infection in a wild bumble bee population and the population's distance from greenhouses with commercial hives.
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↓ **Navigation to Next Lesson:** This is the last lesson in the unit.

LESSONS 1-9

21 days total

TEACHER BACKGROUND KNOWLEDGE

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices when conducting hands-on science investigations and demonstrations, whether in an instructional space (traditional laboratory or classroom) or in the field. To this end, teachers must be aware of any school or district safety policies, legal safety standards, and better professional safety practices that are applicable to the activities being undertaken.

Science safety practices in instructional spaces require engineering controls and personal protective equipment (e.g., sanitized safety goggles or safety glasses with side shields as appropriate, non-latex aprons and gloves, eyewash/shower station, fume hood, appropriate ventilation, and fire extinguishers). **Science investigations should always be directly supervised by qualified adults, who should review safety procedures annually and also before initiating any hands-on activities or demonstrations.** Prior to each investigation, students should be reminded of the specific safety procedures they must follow. Each lesson within the OpenSciEd units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as disassembling, disposing of, and storing materials.

Prior to the first investigation of the year, a safety acknowledgement form for students and parents/guardians should be provided and signed. You can access a model safety acknowledgement form for high school activities here: <https://static.nsta.org/pdfs/SafetyAcknowledgmentForm-HighSchool.pdf>

Disclaimer: The safety precautions provided for each activity are based in part on use of the specifically recommended materials and instructions, as well as legal safety standards and better professional safety practices. Be aware that selecting alternative materials or procedures for these activities may affect the activity's level of safety and is therefore at the user's own risk.

Please follow these lab safety recommendations for any science investigation:

1. Wear sanitized safety goggles (specifically, indirectly vented chemical splash goggles) or safety glasses with side shields as appropriate, a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take-down segments of the activity.
 2. Safety goggles are required when working with liquid biological or chemical hazards (e.g., microbes, acids, bases, etc.). Safety glasses with side shields or safety goggles may be used when working with physical hazards (sharp, springs, glass, projectiles, etc.).
 3. Immediately wipe up any spilled liquid (e.g., water) and/or granules on the floor, as this is a slip-and-fall hazard.
 4. Follow your *Teacher Guide* for instructions on disassembling and storing materials and disposing of waste materials.
 5. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
 6. Wash your hands with soap and water immediately after completing the activity.
 7. Never eat any food items used in a lab activity.
 8. Never taste any substance or chemical in the lab.
 9. Use only GFCI-protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
 10. Use caution when working with glassware, which can shatter if dropped and cut skin.
 11. Use caution when using sharp [tools/materials], which can cut or puncture skin.
 12. Never pour chemicals, either used or unused, back into their original containers. Dispose of chemicals according to your teacher's instructions.
 13. If you get a hazardous chemical on your clothing or have a clothing fire, use the emergency shower.
 14. If you get a chemical in your eye, use an eyewash station immediately.
 15. Point the test tubes, beakers, or other vessels away from yourself and other people when the vessels contain reactants or other substances.
 16. When diluting acids or bases, the acid or base should be added to water and not water to the acid or base.
 17. Projective trajectory zones must be well defined and free of any obstacles. No participant is to be in the zone during operation of the projectile..
 18. Make sure the ventilation system meets the needs relative to removal of flammable vapors produced. Also make sure there are no active flames or sparks in the work zone.
- Specific safety precautions are called out within the lesson using this icon and a call-out box.



Where does this unit fall within the OpenSciEd Scope and Sequence?

This unit is the fifth and final in the OpenSciEd High School Biology course sequence.

What is the anchoring phenomenon and why was it chosen?

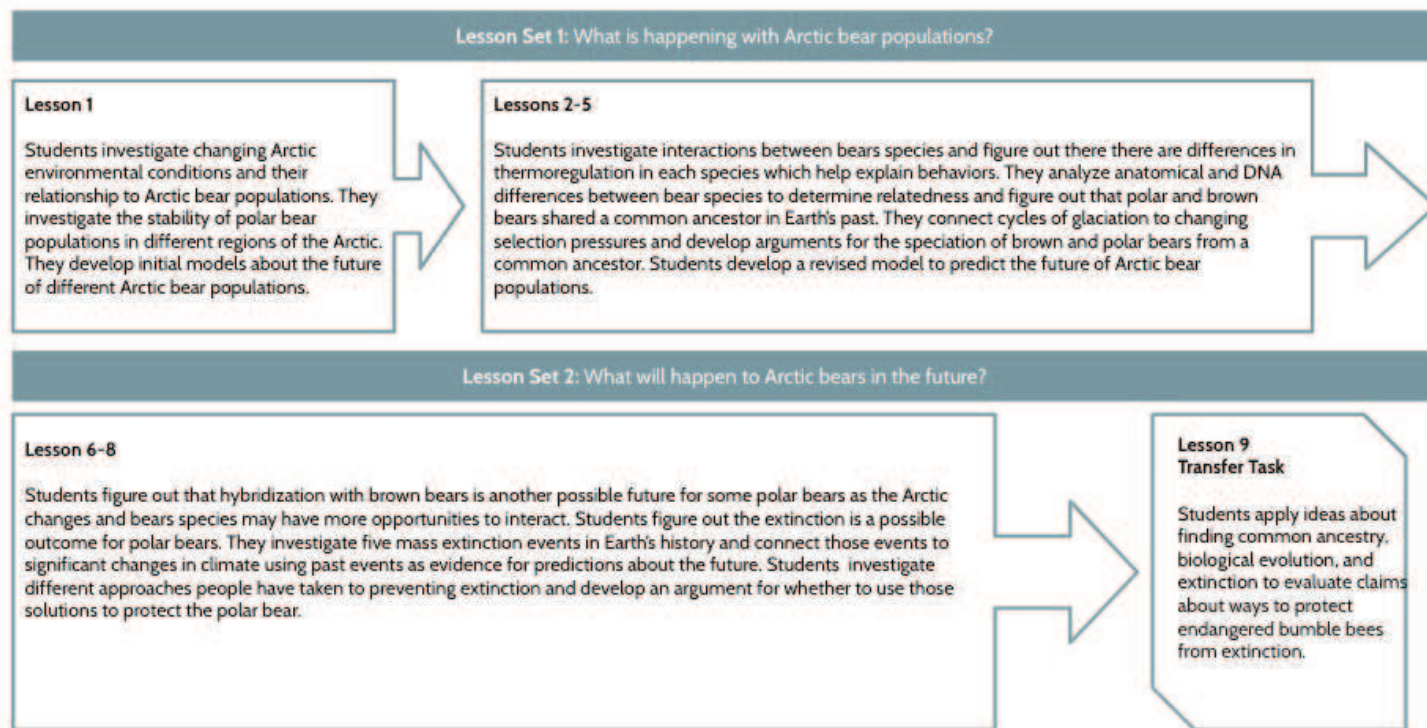
In the anchoring phenomenon, students encounter the sighting of 3 bear species in one location in Canada for the first time, which may be related to the effect of climate change. Students investigate why all three bears may be adapted to the habitats in this area. They conduct a data exploration about changes to Arctic ice and tundra due to climate change and investigate how the 3 bear species could be affected by those changes. Students investigate the relationship between changing Arctic sea ice conditions and the stability of polar bear populations using both Traditional Knowledge and Western scientific sources. They develop initial models to predict how changes in Arctic ice conditions due to a warming climate may affect different polar bear populations in the future. They generate questions that they need to answer to be able to fully explain their models. The phenomenon was chosen because it gives students a real-world context to investigate common ancestry, biological evolution, speciation, and extinction and also provides a way to bring together what they figured out in past OpenSciEd units to consider the gravity of the problem and decide what, if anything, should be done to protect species from extinction. Students understand conservation, the effect of climate change on the Arctic, and connections between habitat fragmentation and evolution from previous units. The fate of the polar bear generated high student interest across racial and gender identities in a national survey.

The bears phenomenon was chosen from a group of phenomena aligned with the target performance expectations based on the results of a survey administered to students from across the country and in consultation with external advisory panels that include teachers, subject matter experts, and state science administrators. The phenomenon was chosen for the following reasons:

- Students showed high interest in questions related to hybrid bears.
- It provides a diverse suite of entry points for students across the unit to make local, cultural, and/or relevant community connections so that students' background knowledge and frames of reference are assets for their sensemaking work.
- Teachers and administrators saw the phenomenon as interesting and on grade band.
- Explaining the phenomenon addresses all the DCIs in the bundle at a high school level.

How is the unit structured?

The unit is organized into two lesson sets. **Lesson Set 1** (Lessons 1-5) focuses on figuring out how and why the Arctic bears interact in particular ways and how speciation occurred between the bears over geologic time. **Lesson Set 2** (Lessons 6-9) helps students begin to unravel the speed at which extinction and speciation events normally occurred compared with changes to bears that live in the modern-day Arctic. They figure out that hybridization is another way forward for Arctic bears and continue to debate what role humans should play in protecting Arctic ecosystems and species in danger of extinction from climate change. This unit culminates with a transfer task where they apply all of their understanding of how to figure out why the bumble bee is threatened with extinction.



What elements of NGSS three dimensions are developed in this unit?

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This unit is designed to introduce students to extinction and speciation and the scale of time over which these processes occur. **Engaging in Argument from Evidence is intentionally developed across this unit**, beginning in Lesson 2, where students develop and revise claims about the effects of internal conditions on bear behavior. In Lessons 3 and 4, students develop and revise arguments for how speciation occurred between polar and brown bears from a common ancestor. In Lesson 7, they develop arguments using patterns of evidence to explain the main cause of mass extinction on Earth. Student arguments use **scale, proportion, and quantity** to find **patterns** and explain the significance of evidence found in the systems they investigate. These concepts are **intentionally developed throughout the unit**.

This unit builds toward these performance expectations:

HS-LS1-3 Plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis.

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.

HS-LS2-7* Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-LS4-1 Communicate scientific information that common ancestry and biological evolution are supported by multiple lines of empirical evidence.

HS-LS4-2* Construct an explanation based on evidence that the process of evolution primarily results from four factors: (1) the potential for a species to increase in number, (2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for limited resources, and (4) the proliferation of those organisms that are better able to survive and reproduce in the environment .

HS-LS4-4* Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

HS-LS4-5* Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

HS-ESS2-7† Construct an argument based on evidence about the simultaneous coevolution of Earth's systems and life on Earth.

*This performance expectation is developed across multiple OpenSciEd Biology units.

†This performance expectation is developed across multiple OpenSciEd courses.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
This unit intentionally develops students' engagement in these practice elements: Engaging in Argument from Evidence - Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. - Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. - Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g., economic, societal, environmental, and/or ethical considerations). Obtaining, Evaluating, and Communicating Information - Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. - Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. - Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (i.e., orally, graphically, textually, mathematically). The following science and engineering practices are also key to the sensemaking in this unit: - Asking Questions and Defining Problems - Developing and Using Models - Obtaining, Evaluating, and Communicating Information	LS1.A. From Molecules to Organisms: Structures and Processes - Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system. (HS-LS1-3) 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. (HS-LS2-2),(HS-LS2-6) - 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. (HS-LS2-7) LS4.A: Evidence of Common Ancestry and Diversity - Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1) LS4.C: Adaptation - Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2) - Changes in the physical environment, whether naturally occurring or human-induced, have thus	This unit intentionally develops students' engagement in these crosscutting concept elements: Patterns - Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. - Empirical evidence is needed to identify patterns. Scale, Proportion, and Quantity - The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs. - Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly. The following crosscutting concepts are also key to the sensemaking in this unit: - Cause and Effect - Stability and Change

	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. (HS-LS4-5),(HS-LS4-6) - Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5) LS4.D Biodiversity and Human - LS4.D.1 Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). (secondary to HS-LS2-7) ESS2.E. Earth's Systems - The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it. (HS-ESS2-7) 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. (HS-ETS1-3)	
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Connections to the Nature of Science (NOS) and Engineering, Technology and Applications of Science (ETS)

Connections to the Nature of Science (NOS)	
Which elements of NOS are developed in the unit?	How are they developed?
Science is a Way of Knowing. Science is a unique way of knowing and there are other ways of knowing.	In Lesson 1, students are introduced to data from Inuvialuit community members whose observations illustrate the ways they know about the natural world their community is a part of. This evidence is used in conjunction with western scientific sources which represent another way of knowing.
Scientific Knowledge Assumes an Order and Consistency in Natural Systems. Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future	Throughout the unit, students draw on their understanding of evolution by natural selection with the assumption that this mechanism will operate in the future as it has in the past. In addition, they use what they figure out about Earth's geologic past, to make predictions about the future.
Science is a Human Endeavor. Individuals and teams from many nations and cultures have contributed to science and to advances in engineering.	Arctic research necessitates collaboration between many nations and cultures. The data utilized in this unit is often from a collaboration between members from many different cultures, communities, nations and traditions.

Science Addresses Questions About the Natural and Material World. Science knowledge indicates what can happen in natural systems—not what should happen. The latter involves ethics, values, and human decisions about the use of knowledge.

In Lesson 8, students use their scientific knowledge about what *could* happen to polar bears in the future to consider what *should* happen using criteria such as ethical consideration.

Connections to Engineering, Technology, and Applications of Science

Which elements of NOS are developed in the unit?

How are they developed?

Influence of Engineering, Technology, and Science on Society and the Natural World. New technologies can have deep impacts on society and the environment, including some that were not anticipated. Analysis of costs and benefits is a critical aspect of decisions about technology.

In Lesson Set 2, students investigate extinction and the ways that systems can be engineered to prevent extinction. They consider criteria and constraints that help them answer questions about not only what could be done, but what should.

How does the unit build three-dimensional progressions across the course and the program?

OpenSciEd units support students in integrated development and use of the three dimensions. No one dimension can be developed in isolation from the others, as reflected in three-dimensional Lesson-Level Performance Expectations (LLPEs), which detail the specific dimensions and elements used and assessed in each lesson. However, some practices and crosscutting concepts are more productive for investigating particular anchoring phenomena, so focal practices and crosscutting concepts are articulated in each unit. All 46 SEP and 29 CCC elements are developed at some point in the high school OpenSciEd program, so all elements of a given SEP or CCC may not be present even in a unit that emphasizes developing that SEP or CCC.

This unit uses and builds upon **disciplinary core ideas (DCIs)** and other science ideas that students should have previously developed in OpenSciEd Middle School or another middle school science program.

- MS-LS4.D: *Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.* LS2.A. Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with non-living factors. (*OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*)
- LS2.A. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (*Palm Oil Unit*)
- LS2.A. Growth of organisms and population increases are limited by access to resources. (*Palm Oil Unit*)
- LS2.A. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and non-living, are shared. (*Palm Oil Unit*)
- LS2.C. Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (*Palm Oil Unit*)
- LS2.C. Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. (*OpenSciEd Unit 7.5: How does changing an ecosystem affect what lives there? (Palm Oil Unit)*)
- LS2.B. Food webs are models that demonstrate how matter and energy is transferred between producers, consumers, and decomposers as the three groups interact within an ecosystem. (*OpenSciEd Unit 7.4: Where does food come from, and where does it go next? (Maple Syrup Unit)*)

This unit uses and builds upon **disciplinary core ideas (DCIs)** and other science ideas that students should have previously developed in OpenSciEd High School Biology.

- LS2.C.1: *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.* *Serengeti Unit*
- LS2.C.2: *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.* *Serengeti Unit*

- LS4.C.2 Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-LS4-4) Natural Selection Unit
- LS4.C.3 Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3) Natural Selection Unit
- LS4.C.4 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.** Natural Selection Unit

This unit uses and builds upon high school level **Science and Engineering Practices (SEPs)** and **Crosscutting Concepts (CCCs)** that students should have previously developed in **OpenSciEd High School Biology** and will continue to build in future units in **OpenSciEd High School Chemistry and Physics**. The progression of these practices and concepts across the program are as follows:

	Questions	Models	Investigations	Data	Math	Explanation	Argument	Obtaining
Biology	Cancer Unit	Serengeti Unit, Fires Unit	Fires Unit, Natural Selection Unit	Natural Selection Unit, Cancer Unit	Serengeti Unit	Fires Unit, Cancer Unit, Natural Selection Unit	Speciation Unit	Cancer Unit, Speciation Unit
Chemistry	Polar Ice Unit, Oysters Unit	Electrostatics Unit, Space Survival Unit	Polar Ice Unit	Fuels Unit	Polar Ice Unit, Oysters Unit	Fuels Unit	Fuels Unit	Electrostatics Unit, Space Survival Unit
Physics	Electricity Unit, Cosmology Unit	Electricity Unit, Microwave Unit	Microwave Unit	Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit, Meteors Unit	Vehicle Collisions Unit, Meteors Unit	Electricity Unit, Earth's Interior Unit, Vehicle Collisions Unit	Vehicle Collisions Unit	Cosmology Unit, Microwave Unit

	Patterns	Cause/Effect	Scale	Systems/Models	Energy/Matter	Structure/Function	Stability/Change
Biology	Natural Selection Unit, Speciation Unit	Cancer Unit, Natural Selection Unit, Speciation Unit, Serengeti Unit	Serengeti Unit	Fires Unit, Cancer Unit, Serengeti Unit	Fires Unit, Serengeti Unit	Cancer Unit	Speciation Unit, Serengeti Unit
Chemistry	Electrostatics Unit, Space Survival Unit	Oysters Unit, Fuels Unit	Electrostatics Unit, Oysters Unit	Polar Ice Unit	Polar Ice Unit, Fuels Unit	Space Survival Unit	Oysters Unit
Physics	Cosmology Unit, Vehicle Collisions Unit, Earth's Interior Unit	Vehicle Collisions Unit, Earth's Interior Unit	Meteors Unit, Earth's Interior Unit	Electricity Unit, Vehicle Collisions Unit, Microwave Unit	Electricity Unit, Earth's Interior Unit	Earth's Interior Unit, Vehicle Collisions Unit	Electricity Unit, Cosmology Unit

What are some common ideas that students might have?

Students will come into the unit with many ideas about conservation and extinction derived from previous classroom experiences, intuitive understandings of the way the world works, everyday experiences with nature, and the conversations they have had with parents, friends, and family members.

- Individuals can evolve during their lifetime.
- An organism can change because it needs to survive.
- Species are fixed.
- Evolution is goal oriented toward improvement.

For more information see: <https://evolution.berkeley.edu/teach-evolution/misconceptions-about-evolution/#a2>

It is valuable to think of ideas like these not as misconceptions that need to be replaced but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board.

How will I need to modify the unit if taught out of sequence?

This is the last unit of the High School Biology Course in the OpenSciEd Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier in the year course. The unit intentionally builds on student understanding built throughout the course, including ideas about ecosystems, inheritance, variation of traits, natural selection, and evolution of populations. Additional support would be needed in all of these areas if this unit were taught out of sequence.

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

The following are example options to shorten or condense parts of the unit without eliminating important sensemaking for students:

- Lesson 1: Consider replacing the fishbowl discussion with a more typical class discussion format.
- Lesson 2: If students have demonstrated proficiency on DCI elements related to cellular respiration, consider modifying this portion of the lesson to condense it.

To extend or enhance the unit, consider the following:

- Lesson 3: Ask students to search for other bear trees and motivate them to figure out why the trees might be different. What type of data was the tree built with? What algorithm was used to build the tree? Students could explore why different types of DNA (coding sequences, non-coding sequences, or mitochondrial DNA) might create different types of trees.
- Lesson 7: This lesson only briefly touches on the causes and effects of the 5 mass extinction events in Earth's histories. Students who show high interest may be encouraged to investigate the causes and effects of these events in more detail.
- Lesson 8: If time allows, let students develop the criteria for their research and develop their own way to organize their notes to record what they figure out.
- Lesson 8: If time and interest allows, students could spend more time researching each case study to better inform the final discussions on day 3.

What mathematics concepts will students engage with in the unit?

This unit requires students to develop mathematical models, use mathematical representations, develop algorithms, and use rates of change. Making mathematical models is a Standard for Mathematical Practice, and specific modeling standards appear throughout the high school standards.

This unit does not assume students are fluent with the mathematical practices listed below, but that students develop these practices as part of the sensemaking. Thus, these standards are not so much prerequisites as co-requisites. If students are simultaneously developing the skills and vocabulary in math class, you can help by making explicit connections to the mathematical standards below.

Talk with the math teacher(s) to identify the strategies students are familiar with for developing algorithms with words or numbers, calculating rates of change, and constructing graphical representations of data.

Category	Code	Domain and Heading	Standard	Lesson
Mathematical Practice	CCSS.MATH.PRACTICE.MP2	Reason abstractly and quantitatively.	Mathematically proficient students make sense of quantities and their relationships in problem situations. They 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.	1
Mathematical Practice	CCSS.MATH.PRACTICE.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.	3, 6

What strategies are available to support equitable science learning in this unit?

OpenSciEd units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies, which are integrated throughout the OpenSciEd routines and are intended to increase relevance and provide access to science learning for all students. OpenSciEd units support these equity goals through several specific strategies such as: 1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and increase accessibility for students to engage in learning experiences; 2) developing and supporting classroom agreements that encourage a safe learning culture; 3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and 4) specific strategies for supporting emerging multilingual students in science classrooms.

Many of these strategies are highlighted in the teacher guides in sidebar callout boxes with the headings of:

- Attending to Equity
- Supporting Emerging Multilingual Learners
- Supporting Universal Design for Learning
- Additional Guidance
- Alternate Activity
- Key Ideas
- Discussion callouts

The example callout below highlights how an activity can be modified to support a wider variety of learners.

*** ATTENDING TO EQUITY- Universal Design for Learning:** If it is something familiar to your students or part of their education plans, consider allowing students to use a digital graphing tool, such as a graphing calculator or spreadsheet software, to help them create their graphs. Students can take the data table and enter it into graphing software. Allowing alternatives for use of tools such as a calculator can remove barriers for students in *expressing* their understanding by keeping the focus on the learning goal. Use of such tools can help provide a match between a student's abilities and the demands of the task.

What are recommended adult-level learning resources for the science concepts in this unit?

The OpenSciEd instructional model focuses on the teacher being a member of the classroom community, supporting students to figure out scientific ideas motivated by their questions about phenomena. Students iteratively build their understanding of phenomena as the unit unfolds. To match the incremental build of a full scientific explanation across the unit, the science content background necessary for you to teach individual lessons incrementally builds too. Throughout the unit, we provide just-in-time science content background for you that is specific to the Disciplinary Core Ideas (DCIs) that will be figured out in a lesson. Places to look for this guidance include the “Where we are going” and “Where we are not going” sections for each lesson. Also, the expected student responses, keys, and rubrics illustrate important science ideas that should be developed in each lesson. The K-12 Science Framework is another great resource to learn more about the DCIs in this unit (**LS4.A.Evidence of Common Ancestry and Diversity**, **LS2.C: Ecosystem Dynamics, Functioning, and Resilience**, **LS4.B: Natural Selection**, **LS4.C: Adaptation**, **LS4.D: Biodiversity and Humans**, **LS4.D: Biodiversity and Humans**, and **ESS2.E Biogeology**), including what students have learned previously and where they are headed in high school. In addition to the science content background information embedded in the lesson resources, below we provide recommended resources that can help build your understanding of phenomena and Performance Expectations bundle for this unit:

Lynch, Wayne (2021) Bears of the north: A year inside their worlds. Johns Hopkins University Press.

Sea Ice Ecoregions overview (note students see an edited version of this video that does not give away ideas in Lesson 1): <https://www.youtube.com/watch?v=iaT2SssKc2Q>

Tandon, A and Pidcock, R. (December 7, 2022) Polar bears and climate change: What does the science say? Carbon Brief. <https://interactive.carbonbrief.org/polar-bears-climate-change-what-does-science-say/>

Joint Secretariat. 2014. Inuvialuit and Nanuq: A Polar Bear Traditional Knowledge Study. Inuvialuit Settlement Region: Joint Secretariat. p. Xvii

What is the Learning in Places socio-ecological deliberation and decision-making framework?

This unit is informed by the Learning in Places complex socio-ecological systems framework. This framework involves sensemaking across five dimensions (species, kinds, & behaviors; relationships; places, lands, & waters, thinking across scales, and ethical deliberation and decision-making) under an umbrella of power and historicity. These dimensions include making sense of both human and other-than-human values, needs, and behaviors across multiple temporal and spatial scales. The framework guides learners towards designing actions or making decisions for making change in adaptive and resilient ways. Students use these ideas to make sure they are investigating multiple aspects of the Arctic ecosystem from different perspectives.

Socio-ecological decisions are those made by individuals, communities, organizations, and institutions that are informed by and impact the natural world. These decisions are affected by what is called “nature-culture relations” – relationships between humans and the natural world. Nature-culture relations often vary by culture, context, and society and affect which socio-ecological decisions are made and enacted. Understanding the different types of philosophical connections that exist between humans and the natural world is imperative for creating and sustaining socially and environmentally just decisions. These ideas particularly come into play in Lesson 8 when students investigate case studies of different approaches people have taken to preventing species from going extinct. Students will apply what they learn to write an argument for or against using particular solutions to protect the polar bear from extinction. Students will make decisions considering the science, economic, political, and social constraints and/or different ethical considerations stemming from personal or cultural beliefs.

For more about socio-ecological deliberation and decision-making, please visit <http://learninginplaces.org/>. Learning in Places Collaborative. (2022). Framework: Complex Socio-Ecological Systems. Bothell, Seattle, WA & Evanston, IL: Learning in Places.

How do I support students' emotional needs?

In this unit, students explore the challenges associated with climate change and extinction of species. These raise issues concerning climate anxiety, decision-making, and animal welfare. Students may have emotional needs related to two main issues:

- Anxiety about the effects of climate change;
- Strong beliefs about animal well-being.

Before beginning this unit, make sure to reach out to the counselor at your school for student-specific support and strategies that might be needed in regards to the students in your classroom. Consider asking the counselor to join you in the classroom at key moments, such as the discussion about the uncertain future of the polar bear in Lesson 1. Also consider planning follow-up check-ins with the counselor in regard to any students who may need additional emotional support.

Educate yourself on the phenomenon of climate anxiety. More than two-thirds of Americans, including 84% of those aged 16 to 25, are at least moderately worried about climate change. This brief piece from Harvard Medical School provides an excellent starting point: <https://www.health.harvard.edu/blog/is-climate-change-keeping-you-up-at-night-you-may-have-climate-anxiety-202206132761>. Other online resources, such as the Emotional Resilience Toolkit for Climate Work (Version 1.5) <https://static1.squarespace.com/static/5f74c9f17e186b15c051629e/t/5fadc42316947a58febe7782/1605223460375/Copy+of+Copy+of+Emotional-Resilience-Toolkit-for-Climate-Work-v1.5-04Oct19-2.pdf>, also offer other tools to help students manage their emotions when studying climate change (Climate Therapy Alliance - Pacific Northwest, 2019).

Reach out to students' support systems at home before the unit using *Example Home Communication*. This letter is a way to communicate with trusted adults and make them aware of the content of the unit. The letter also provides an opportunity for trusted adults to share important context with you about students' experiences and background that might be relevant.

Be aware that students who are struggling may demonstrate a variety of behaviors including but not limited to: fidgeting, withdrawal, disruption or distraction, rapid breathing, holding their breath, and change in body language or tonation. If you notice a student might be struggling, share what you are observing and ask if they need some help.

Often in science classrooms, we are focused on evidence and data. When addressing a phenomenon or design solution that straddles the nature-cultural divide, like this one, supporting students in using an empathy or socio-emotional lens will also be important. Make space for students to process and validate their feelings and reactions. These opportunities were built in throughout the unit.

Furthermore, an important part of addressing controversial topics is that there is hope. This lesson provides opportunities for Social and Emotional Learning and offers examples where people are successfully working to prevent extinction of endangered species.

Guidance for Developing Your Personal Glossaries

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have co-developed that definition and can add the specific term to a Personal Glossary at the back of their notebooks. These “definitions we co-develop” should be recorded using the students' own words whenever possible. On the other hand, “definitions we encounter” are “given” to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, definitions we encounter are helpful just in that lesson and need not be recorded in students' Personal Glossaries. However, if a word we encounter will be frequently referred to throughout the unit, it should be added.

It is best for students if you create consensus definitions in the moment, using phrases and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the meaning of the word, students “own” the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support. Sometimes defining a word is a challenge. The *Teacher Guide* provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate.

The definitions we co-construct and encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Words with meanings we co-construct	Words with meanings we encounter
L1		Seasonally available ice, permanent ice, species*, adaptation*, population*, convergent, divergent, archipelago
L2	thermoregulation	refute
L3	common ancestry	
L4	speciation	glacial period, interglacial period
L5		

L6		hybrid
L7		family, mass extinction
L8		

*Co-constructed or encountered in a previous OpenSciEd High School unit.

**Co-constructed or encountered in the middle school grade band of NGSS/OpenSciEd Middle School.

HOME COMMUNICATION

Dear Parents, Guardians, and Care-Givers,

Your child's high school biology class is starting a unit called *What will happen to Arctic bear populations as their environment changes?* as part of the OpenSciEd high school science curriculum. Students will explore how new species evolve and the causes of extinction through an investigation of Arctic bear population threats to survival due to climate change. Throughout the unit, students will draw on their own experiences and everyday understandings to help them figure out complex science ideas.

We recognize that climate change and species extinction can cause stress and/or feelings of anxiety. A significant number of young adults (and older adults) are concerned about climate change. If your child has previously experienced climate anxiety, please contact me at _____, if you are comfortable doing so. You can also contact a school counselor, social worker, or other mental health professional at _____. By knowing about these experiences in advance, we can be sensitive to students' needs and provide support for students if they experience any strong emotions during this unit. This support may include providing breathing exercises for students to ground themselves and/or connecting students to a mental health professional, such as a school counselor.

Having conversations about science in our world:

- Encourage your child's curiosity through talking about their own noticings and wonderings.
- Acknowledge any emotions around climate change.
- Ask your child to explain how Arctic environments and bears are affected by climate change and discuss what we can do about it.

Emphasize that we can take action on climate change. Have honest conversations with your child about what they, personally, can do, while taking into consideration the needs of those who would be most affected (people in coastal, Arctic, and desert communities, and in other areas experiencing the greatest effects).

Helping your student make sense of their learning:

- There is no need to teach your child vocabulary before the unit because words often have multiple meanings and are often easier to remember once students have some experience with them.
- Encourage your child to expand and clarify their own thinking by asking your child for examples, saying more about their ideas and repeating what your child said back to them.
- Ask how they might have arrived at a particular conclusion.
- Ask your child to recall what other students have said in class and what parts of their ideas your child agreed or disagreed with.
- Rephrase what your child is saying to check your own understanding. For example, say, "If I hear you right, you are telling me that..."

Best,

(Your name or signature here)

End of day

Estimados padres, tutores y cuidadores:

La clase de biología de la escuela secundaria de su hijo está comenzando una unidad llamada *¿Qué pasará con las poblaciones de osos árticos a medida que cambie su entorno?* como parte del plan de estudios de ciencias de la escuela secundaria OpenSciEd. Los estudiantes explorarán cómo evolucionan las nuevas especies y las causas de la extinción a través de una investigación de las amenazas a la supervivencia de la población de osos árticos debido al cambio climático. A lo largo de la unidad, los estudiantes aprovecharán sus propias experiencias y conocimientos cotidianos para ayudarlos a descubrir ideas científicas complejas.

Reconocemos que el cambio climático y la extinción de especies pueden causar estrés y/o sentimientos de ansiedad. Un número importante de adultos jóvenes (y adultos mayores) están preocupados por el cambio climático. Si su hijo ha experimentado ansiedad climática anteriormente, comuníquese conmigo al _____, si se siente cómodo haciéndolo. También puede comunicarse con un consejero escolar, trabajador social u otro profesional de salud mental al _____. Al conocer estas experiencias de antemano, podemos ser sensibles a las necesidades de los estudiantes y brindarles apoyo si experimentan emociones fuertes durante esta unidad. Este apoyo puede incluir proporcionar ejercicios de respiración para que los estudiantes se relajen y/o conectar a los estudiantes con un profesional de salud mental, como un consejero escolar.

Tener conversaciones sobre ciencia en nuestro mundo:

- Fomente la curiosidad de su hijo hablándole sobre sus propias observaciones y preguntas.
- Reconozca cualquier emoción en torno al cambio climático.
- Pídale a su hijo que le explique cómo el cambio climático afecta los ambientes y los osos del Ártico y analice qué podemos hacer al respecto.

Enfatice que podemos tomar medidas sobre el cambio climático. Tenga conversaciones honestas con su hijo sobre lo que él, personalmente, podemos hacer, teniendo en cuenta al mismo tiempo las necesidades de quienes se verían más afectados (las personas de las comunidades costeras, árticas y desérticas, y de otras zonas que experimentan los mayores efectos).

Ayudar a su estudiante a darle sentido a su aprendizaje:

- No es necesario enseñarle vocabulario a su hijo antes de la unidad porque las palabras suelen tener múltiples significados. y suelen ser más fáciles de recordar una vez que los estudiantes tienen alguna experiencia con ellos.
- Anime a su hijo a ampliar y aclarar su propio pensamiento pidiéndole ejemplos y diciendo más sobre sus ideas. y repitiendo lo que su hijo les dijo.
- Pregúnteles cómo pudieron haber llegado a una conclusión particular.
- Pídale a su hijo que recuerde lo que otros estudiantes han dicho en clase. y con qué partes de sus ideas estuvo de acuerdo o en desacuerdo su hijo.
- Reformule lo que su hijo dice para comprobar su propia comprensión. Por ejemplo, diga: "Si te escuché bien, me estás diciendo que..."

Sinceramente,

(Su nombre o firma aquí)

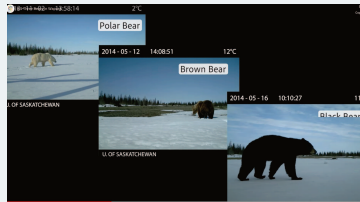
LESSON 1: How do changes in climate affect bear species coming together for the first time in the Arctic?

PREVIOUS LESSON *There is no previous lesson.*

THIS LESSON

ANCHORING PHENOMENON

4 days



Illustrations created by OpenSciEd in BioRender

We hear about a place called Wapusk where brown, black, and polar bears were recently seen together for the first time. We investigate why all three bears may be adapted to the habitats in this area. We conduct a data exploration about changes to Arctic ice and tundra due to climate change and investigate how the 3 bear species could be affected by those changes. We investigate the relationship between changing Arctic sea ice conditions and the stability of polar bear populations from Traditional Knowledge and Western scientific sources. We develop initial models to predict how changes in Arctic ice conditions due to a warming climate may affect different Arctic bear populations in the future. We develop a DQB and decide to further investigate traits that might allow brown bears to dominate over polar and black bears in the future.

NEXT LESSON *We will investigate evidence to help support claims about interactions between polar and brown bears and reason about why brown bears might dominate in the future.*

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

1.A Ask questions that arise about the significance of changes to Arctic ice and habitats observed at multiple scales in terms of the functioning of the ecosystem due to changes in resources and habitat availability. (SEP 1.1; DCI LS2.C.1; CCC: 3.1)

1.B Read and evaluate scientific information from multiple sources to identify patterns in Arctic ice conditions related to stability of polar bear populations. (SEP 8.3; DCI LS2.C.2; CCC: 1.5)

1.C Develop and revise models to predict how Arctic bear populations will expand or decline in response to anticipated changes to their environment. (SEP 2.3; DCI: LS4.C.4; CCC: 2.2)

1.D Ask questions at different scales that lead to investigations about whether Arctic bear populations will expand or decline in response to ongoing changes to polar ice. (SEP 1.1; DCI LS4.C.4; CCC 3.1)

WHAT STUDENTS WILL FIGURE OUT

- The coverage and duration of Arctic sea ice is changing, leading to less sea ice habitat for polar bears in areas with seasonally available ice.
- Polar bears are adapted to the Arctic ecosystem and rely on Arctic sea ice.
- Based on their adaptations, the polar bears are most at risk for population declines as the environment changes.
- Based on their adaptations, brown bears may expand their range as the Arctic warms.
- Polar and brown bears are likely to interact more as the environment changes.

Lesson 1 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Introduce the phenomenon of 3 bears sighted in one location for the first time. Elicit questions about the phenomenon.	A-C	
2	12 min		INVESTIGATE WHAT IS HAPPENING IN WAPUSK Introduce the location and ecosystems of Wapusk National Park in relation to the normal range of the 3 bears and investigate bear sightings at different scales.	D-K	<i>Bear Sightings</i>
3	3 min		MOTIVATE A DATA EXPLORATION Facilitate a brief discussion of the type of data students would like to see to help figure out how climate change is impacting Wapusk.	L	
4	8 min		CONDUCT A DATA EXPLORATION Investigate data related to changing sea ice conditions.	M-O	<i>Scale Organizer</i> , Internet-connected device, Lesson 1 Data Exploration https://docs.google.com/presentation/d/1wHEX1sNfDngbJlbskzARuxWEBtMixvKKF6ImSaKjx6w/edit#slide=id.g25e537d85d9_O_127
5	2 min		INTRODUCE HOME LEARNING Introduce the home learning to about changes communities members experienced due to climate change.	P	
6	13 min		READ ABOUT BEAR DIET, REPRODUCTION, AND BEHAVIOR Read and share information about black, brown, and polar bear diet, reproduction, and behavior. Discuss how these bears are adapted to habitats in Wapusk.	Q-R	<i>Scale Organizer</i> , <i>Bear Diet</i> , <i>Bear Denning and Hibernation</i> , or <i>Bear Reproduction</i> , Laminated Bear Adaptation poster or large printed copy of <i>Bear Adaptation Poster</i> , dry erase marker, <i>Key Bear Adaptation Readings</i>
7	2 min		NAVIGATE Come to consensus about the bear species of most concern. Remind students about the home learning.	S	

End of day 1

Part	Duration		Summary	Slide	Materials
8	5 min		NAVIGATE: SHARE HOME LEARNING Facilitate student sharing of related phenomena about local climate impacts.	T	chart paper, chart paper markers
9	12 min		INVESTIGATE TRADITIONAL KNOWLEDGE ABOUT POLAR BEARS Students share quotes from Inuvialuit people about changing sea ice and the condition of local polar bear populations.	U-X	<i>Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems</i> , Community Agreements, 2 paper lunch bags
10	11 min		ASSESS THE STABILITY OF POLAR BEARS IN 4 ECOREGIONS Watch a video about ice ecoregions and divide into groups to investigate the data about the effect of climate change on polar bears in each ecoregion.	Y-DD	<i>Comparing Polar Bear Populations</i> , Internet-connected device, Convergent Ice Visual Inquiry https://docs.google.com/presentation/d/1SB3MVB3xVx524ewj7LtRHYAFB3-xFn3acf5PrS5kms/edit?usp=drive_link , Divergent ice Visual Inquiry https://docs.google.com/presentation/d/1KSICOYGQd-tS8gDrivcJ4cLxDwEBqSd-iT_ZssdmUNs/edit?usp=drive_link , Islands Group Visual Inquiry https://docs.google.com/presentation/d/1-xwRHzeCv_aCXbP_pLVj6bTzCNNWLE9h6Pug9xN3TA/edit?usp=drive_link , Seasonal Ice Visual Inquiry https://docs.google.com/presentation/d/1X58NGaOQQA5F2_9YBUbq8npjSgpPW8LyWL-CHnRaCn4/edit?usp=drive_link , <i>Key Comparing Polar Bear Populations</i>
11	14 min		FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ON THE STABILITY OF POLAR BEAR POPULATIONS Facilitate the sharing and comparison of the resilience of different populations of polar bears. Discuss the usefulness of data provided for making the comparison. Find consensus about the stability of polar bears living with particular ice conditions.	EE-GG	<i>Comparing Polar Bear Populations</i> , Community Agreements, <i>Key Comparing Polar Bear Populations</i> , <i>Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems</i>
12	3 min		NAVIGATE: STOP AND JOT PREDICTIONS FOR POLAR BEARS Students individually reflect on the fishbowl discussion and record predictions about the future of polar bear populations.	HH	
End of day 2					
13	5 min		NAVIGATE Review the main ideas from the fishbowl discussion.	II	

Part	Duration		Summary	Slide	Materials
14	12 min		DEVELOP INITIAL MODELS Facilitate the development of initial group models.	JJ-LL	chart paper, colored markers
15	8 min		FACILITATE A GALLERY WALK Facilitate a gallery walk to view and compare initial group models.	MM	Initial group models from day 2
16	15 min		DEVELOP A CLASS CONSENSUS MODEL Facilitate the development of the class consensus model.	NN	revised models, chart paper, chart paper markers
17	5 min		NAVIGATE: SOCIAL AND EMOTIONAL LEARNING Facilitate Social and Emotional Learning to express how students feel about the future of Arctic bears.	OO	<i>Feelings Wheel</i>
<i>End of day 3</i>					
18	5 min		NAVIGATE: REVIEW CONSENSUS MODEL Review the consensus model in pairs at the end of the previous class and ask questions raised by the model.	PP	consensus model
19	5 min		DEVELOP QUESTIONS Write questions about the future of the polar bear populations.	QQ	3x3 sticky notes
20	25 min		DEVELOP THE DRIVING QUESTION BOARD Form a Scientists Circle to create a Driving Question Board. If necessary, motivate questions about the past to add to the DQB.	RR-TT	chart paper, chart paper markers
21	5 min		CONSIDER IDEAS FOR INVESTIGATION Help students generate and share investigative ideas for addressing questions about what will happen to Arctic bear populations as their environment changes.	UU	chart paper, chart paper markers

Part	Duration		Summary	Slide	Materials
22	5 min		NAVIGATE Facilitate students deciding what to investigate next.	VV-WW	

End of day 4

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials	- science notebooks <i>Bear Sightings</i> <i>Scale Organizer</i> <i>Bear Diet</i> <i>Bear Denning and Hibernation</i> - or <i>Bear Reproduction</i> <i>Comparing Polar Bear Populations</i> <i>Feelings Wheel</i> 3x3 sticky notes	- Internet-connected device - Lesson 1 Data Exploration https://docs.google.com/presentation/d/1wHEX1sNfDngbJlbskzARuxWEBtMixvKKF6lMsaKjx6w/edit#slide=id.g25e537d85d9_O_127 - Convergent Ice Visual Inquiry https://docs.google.com/presentation/d/1SB3MVB3xVx524ewj7LrHYAFB3-xFn3acf5PrS5kms/edit?usp=drive_link - Divergent ice Visual Inquiry https://docs.google.com/presentation/d/1KSICOYQQd-tS8gDrivcj4cLxDwEBqSd-iT_ZssdmUNs/edit?usp=drive_link - Islands Group Visual Inquiry https://docs.google.com/presentation/d/1-xwRHcueCv_aCXbP_pLVj6bTzCNWLE9h6Pug9xN3TA/edit?usp=drive_link - Seasonal Ice Visual Inquiry https://docs.google.com/presentation/d/1X58NGaOQQA5F2_9YBUbq8npjSgpPW8LyWL-CHnRaCn4/edit?usp=drive_link - chart paper - colored markers - Initial group models from day 2 - revised models	- Laminated Bear Adaptation poster or large printed copy of <i>Bear Adaptation Poster</i> - dry erase marker <i>Key Bear Adaptation Readings</i> - chart paper - chart paper markers <i>Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems</i> - Community Agreements 2 paper lunch bags <i>Key Comparing Polar Bear Populations</i> - consensus model

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Before the unit begins, read through *Trauma-Informed SEL Supports*. Send home *Fires Home Communication* with students to alert families to the unit content around populations at risk due to climate change.

Review the unit overview to see how disciplinary core ideas, crosscutting concepts, and science and engineering practices are developed in this unit.

Make sure the class Community Agreements poster (created in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*) is hung where students can see it. If you are teaching this unit without having developed these agreements, spend at least 15 minutes developing them as described in *Serengeti Unit*. This scaffold is not referenced explicitly here because this unit is the last unit in the Biology course, but it should be available for reference in case students encounter interpersonal conflict or need to be reminded of an agreement that is not being followed.

Three-hole-punch all handouts so they can be added to students' notebooks.

Day 1:

- Gather devices (tablets, chromebooks, etc.) so that each group can access the *Lesson 1 Data Exploration* https://docs.google.com/presentation/d/1wHEX1sNfDngbJlbskzARuxWEBtMixvKKF6lMsaKjx6w/edit#slide=id.g25e537d85d9_O_127, in pairs.
- Divide the class into 6 groups and assign each reading to two groups (2 groups read *Bear Diet*, 2 read *Bear Denning and Hibernation*, 2 read *Bear Reproduction*).
- Gather the laminated Bear Adaptation poster and dry erase markers, or create a poster using *Bear Adaptation Poster*, or draw your own version of the poster.

Day 2:

- Print a copy of *Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems* and cut out each quote. To increase the longevity of the quote strips, laminate them first. Use quotes 1-12 for small classes and add additional quotes based on class size. Gather two small containers, such as small bowls, paper lunch bags, or hats. Put all of the quotes in one container and leave one empty.
- Divide the class into 8 groups and assign two groups to each of the 4 ecoregions.

- Gather devices (tablets, chromebooks, etc.) so that each group can access information about their assigned ecoregion. A non-screen alternative is available for students to access the visual inquiry by printing the slides.
- Gather chart paper and chart paper markers or equivalent to create the Related Phenomena poster.

Day 3:

- Gather chart paper and colored markers or equivalent for groups of 3-4 students to create initial group models.
- Gather chart paper and chart paper markers or equivalent to create the Initial Class Consensus Model.

Day 4:

- Gather chart paper, 3x3 sticky notes, and colored markers for the Driving Question Board and Ideas for Investigation posters.

While you will create many posters throughout the unit, it is helpful to keep the Driving Question Board, Initial Consensus Model, Related Phenomena, and Ideas for Investigation posters easily accessible as you move through the unit to not only keep track of progress on science ideas but also to continually engage students with relevance.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

As the introductory lesson to the culminating unit of the school year, this lesson draws on what students figured out from previous units to predict the future of Arctic bear populations as their environment changes due to warming temperatures. This unit builds on ideas from previous OpenSciEd Biology units, such as natural selection in *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)*; rising temperatures and the effects on Arctic ecosystems in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*; and limiting factors, carrying capacity and interactions, and ecosystem resilience from *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*.

In *Serengeti Unit* students built a partial understanding of LS2.C.1: *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.* This lesson builds toward a complete understanding of the DCI by focusing on *Extreme fluctuations in conditions or the size of any population, however, can challenge the functioning of ecosystems in terms of resources and habitat availability.*

In *Serengeti Unit* students built a partial understanding of LS2.C.2: *Moreover, anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation...can disrupt an ecosystem and threaten the survival of some species.* This lesson builds toward a complete understanding of the DCI by focusing on how **climate change** can disrupt an ecosystem and threaten the survival of some species.

Students developed a partial understanding in *Natural Selection Unit* that *Changes in the physical environment, whether naturally occurring or human-induced, have thus contributed to the expansion of some species. They will continue to develop an understanding in this unit that speciation and extinction...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.* This lesson focuses on how changes to the environment contribute to the possible expansion of the brown bear and decline of the polar bear. Speciation will be discussed beginning in Lesson 3.

In this lesson, students use elements of the science practice *asking questions* and *developing and using models*, which were developed in previous units of OpenSciEd Biology. They intentionally develop a new element of the practice of *obtaining, evaluating, and communicating information* as they encounter, evaluate, and discuss different types of information and data from Western science and Traditional Knowledge and consider the usefulness of each type of evidence in answering their questions.

Students use elements of the crosscutting concepts of *patterns, cause and effect, and scale, proportion, and quantity*, which were developed in previous OpenSciEd Biology units. Data at different scales is a focus in this unit.

Students encounter definitions for *seasonally available ice* and *permanent ice*, which they should add to their Personal Glossaries. If the terms *species, tundra, adaptation, population, convergent, divergent, and archipelago* are new for your students, add them to their Personal Glossaries as well. Words should be defined and recorded AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

This lesson asks students to apply disciplinary core ideas that they developed in *Natural Selection Unit*, in which they developed a model of evolution by natural selection. These concepts are key to the sensemaking in the lesson, including:

- LS4.C.2 *Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not. (HS-LS4-3),(HS-LS4-4)*
- LS4.C.3 *Adaptation also means that the distribution of traits in a population can change when conditions change. (HS-LS4-3)*

Students will be introduced to the phenomena of increasing Arctic temperatures and receding Arctic ice to motivate investigations into the evolutionary history and potential future of polar bear populations. However, the explanations behind these environmental changes, including mechanisms like the Albedo effect or phase-change dynamics, will not be investigated. These mechanisms are the focus of *OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)* that focuses on thermodynamics in Earth's systems.

LEARNING PLAN for LESSON 1

1 · NAVIGATE

5 min

MATERIALS: science notebooks

Introduce the final unit of the year. Celebrate your classroom community's progress throughout the year using science and engineering practices, crosscutting concepts, and science ideas to figure out and explain biological phenomena. Display **slide A**. Introduce students to the phenomenon described on the slide. Photographs from one trail camera in Wapusk National Park captured images of a polar bear, brown bear, and black bear in the same location for the first time ever. Display **slide B** and ask students to set up a Notice and Wonder chart before showing <https://www.youtube.com/watch?v=uUGvqBOTjs8>. Display **slide C** and ask a few students to share their noticings and wonderings.

Listen for students to ask questions such as:

- What were the bears doing in Wapusk National Park?
- Why is this only the first time the three bears have been together here? What is new that caused the change?
- Where do brown bears normally live?
- Where is Wapusk National Park?
- Is there something special about Wapusk?
- What time of year were the photos taken? (note: photographs contain timestamps)
- What would happen if the bears met?
- Why do they think brown bears will dominate?
- Why does climate change matter?
- What is the difference between the bears?

ADDITIONAL GUIDANCE

In this unit, we use **brown bear** (*Ursus arctos*) instead of **grizzly bear** (*Ursus arctos horribilis*) as much as possible. Grizzly bears are a subspecies of brown bears; all grizzlies are brown bears, but not all brown bears are grizzlies. Original source materials included in this unit occasionally use grizzly bear, grizzlies, or grizzly to describe bears. Brown bear is the broadest identifying name for this group of bears, which includes grizzlies, Kodiak bears, and others across Europe and Asia. It is not necessary to correct students who call them grizzly bears. In fact, it may help prompt personal connections to mention that some people call them grizzly bears. If necessary, post a reminder on the wall that the terms will be used interchangeably.

ADDITIONAL GUIDANCE

2 · INVESTIGATE WHAT IS HAPPENING IN WAPUSK

12 min

MATERIALS: *Bear Sightings*

Locate Wapusk on the map. Display **slide D** and ask a few students to describe Wapusk's location. Listen for students to mention it is in Canada, near the North Pole, next to the ocean. Explain to students that the name Wapusk comes from the Cree word for white bear and that Wapusk National Park is on the traditional lands of the Cree and Métis.

Identify the recent historical range of the three bears. Display **slide E**. Ask students to turn and talk about the slide prompt. Listen for students to notice that Wapusk is in the recent historical range for polar and black bears, but not brown. Brown bears are not typically found in Wapusk, although their range is nearby.

* SUPPORTING STUDENTS IN DEVELOPING AND USING SCALE, PROPORTION, AND QUANTITY

Students develop their use of the crosscutting concept *scale, proportion, and quantity* (with a focus on scale) in this unit. As students move between different map

Investigate habitats in Wapusk. Explain that you have some additional information to share with students to help them answer their questions about what is happening in Wapusk. Display **slide F**, which zooms in to show the habitats present in Wapusk National Park. Ask students to share what they may already know about the three habitats present in Wapusk. Display **slide G** to support the discussion and to introduce seasonal changes in the habitats. Explain that tundra habitat has slow-growing, short vegetation, and the ground is frozen most of the year, if not all year. It has a short growing season because of the long winters in the region, when vegetation is covered in ice and snow. Students may wish to add *tundra* to their Personal Glossaries as a word they encounter. If students did not already make the connection between Wapusk and *Fires Unit*, ask what they learned about the habitats present in the Arctic from that unit or what they know from other experiences. This region would also contain peat and permafrost, which are familiar from *Fires Unit*. Students should recall that climate change is affecting the Arctic, with warmer temperatures that melt the permafrost and raise the risk of zombie fires.

ADDITIONAL GUIDANCE

If students have not experienced *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*, provide students with additional information on Arctic habitats. Provide photographs of habitats and a few of the plants and animals that live there. Students should know that the ground in these areas is normally frozen much of the year and there are only a few months of warm temperatures. When students look at changes to Arctic ice later in this lesson, supplement that with information on the link between rising carbon dioxide levels, rising temperatures, and decreases in Arctic ice.

Investigate bear sightings in Wapusk. Display **slide H** and pass out *Bear Sightings* to each student. Explain that they have maps (**slides I and J**) that show where there have been recent reported sightings of the brown, black, and polar bears in both winter and summer. Ask them to turn and talk with a partner about how they think the bears might interact with the three habitats in Wapusk seasonally. After 3-4 minutes, display **slide K** and ask a few students to share their ideas. Display the figures from *Bear Sightings* to support discussion as needed. Listen for students to mention that:

- black and brown bears are not present in winter in Wapusk.
- polar bears go out on the ice in winter.
- black bears are sighted mainly in woodland in summer.
- brown and polar bears are mainly sighted near the coast on land in summer.

Discuss the significance of scale. Discuss the remaining prompts on **slide K**. Listen for students to mention that the maps are different in winter and summer and that the bears are not always in the same location. Say, *It seems to be important for us to discuss not only where the bears are but also when. We need to pay attention to both space and time. The crosscutting concept scale, proportion, and quantity can help us think about this.* Encourage examples from multiple science domains and questions for further investigation. Use the prompts below as a guide. *

Suggested prompt	Sample student response
How is scale important to understanding what is happening with these bears?	Bears use the area differently in summer and winter, so we need to pay attention to time. Bears move and are not always in the same location, so we need to pay attention to where they are.

projections, ask them to reflect on what spatial information becomes significant as they zoom in or out with the different maps. They will also begin to notice how shifts in time scale reveal different information. At first, they will focus on significant times of year for particular bear activities related to the seasons. Later in the lesson, students will notice that as they look at seasonal data over many years, what might be expected to be a predictable pattern of seasonal change slowly shifts over many decades, increasing the significance of that longer-term data for the well-being of bear populations.

Suggested prompt	Sample student response
Can you think of any other times it was important to pay attention to both space and time to understand a phenomenon?	We studied zombie fires, which occurred in peat/permafrost systems at one season, disappeared in winter, and then reemerged nearby in spring.(Fires Unit) We also investigated the relationship between carbon dioxide levels and temperature in a bottle over a few minutes with global atmospheric trends over many years. In middle school, we studied the rates of erosion and plate movement that impacted the elevation of mountains over time. (OpenSciEd Unit 6.4: What causes Earth's surface to change? (Everest Unit)) We studied the timing, intensity, and location of impacts from tsunamis. (OpenSciEd Unit 6.5: Where do natural hazards happen and how do we prepare for them?(Tsunami Unit)).
What else do you want to know about Wapusk?	How do temperatures change in Wapusk over a year? How is climate change impacting Wapusk? Where do black and brown bears go in the winter? Do bears hibernate in winter? Where are the bears in spring and fall? Why do the polar bears go out on the ice? What do the bears eat? Why do only polar bears go out on the ice? Is the type of food available to the bears changing? Do the bears fight when they meet?

3 · MOTIVATE A DATA EXPLORATION

3 min

MATERIALS: None

Frame a data exploration. Display slide L. Say, *Great questions! Some of you mentioned that the permafrost is thawing in the Arctic and that you know the ice is also melting due to climate change.*

Suggested prompt	Sample student response
What type of data would help us understand the effect of climate change in Wapusk?	Temperature data. Sea ice changes. Information about what is growing.
How would the scale of our investigation shift if we want to understand the impact of climate change?	We need to look at data over longer periods of time to see the effects.

4 • CONDUCT A DATA EXPLORATION

8 min

MATERIALS: science notebooks, *Scale Organizer*, Internet-connected device, Lesson 1 Data Exploration https://docs.google.com/presentation/d/1wHEX1sNfDngbjlbskzARuxWEBtMixvKKF6ImSaKjx6w/edit#slide=id.g25e537d85d9_O_127

Introduce a data exploration. Say, *I have data with some of that information.* Distribute *Scale Organizer* to each student. Say, *Because we have been talking about the importance of using space and time, I thought this type of graphic organizer might help us.* Explain that students can use the calendar, timeline, and maps to record their noticings and wonderings from the data exploration.

Conduct a data exploration. Display **slide M**. Organize students into pairs and distribute internet-connected devices with access to the *Lesson 1 Data Exploration*. Give students six minutes to explore and to record their noticings and wonderings on *Scale Organizer* about how climate change is impacting the region.

ALTERNATE ACTIVITY

Keep the students together as a class but display each visual on a large screen to examine and discuss with an elbow partner. They should still write noticings and wonderings on *Scale Organizer* for all visuals before discussing them as a class.



Share noticings and wonderings. Display **slide N**. Bring the class together to debrief noticings and wonderings. Consider having a few pairs share a single noticing or wondering before eliciting volunteers. Display images from the *Lesson 1 Data Exploration* to support discussion.

* ATTENDING TO EQUITY

Social and Emotional Learning: Research on climate change anxiety suggests some young people can have lasting mental health consequences from climate change anxiety. Symptoms associated with climate anxiety include panic attacks, insomnia, and obsessive thinking. If you suspect any of your students are experiencing anxiety, refer them to appropriate student mental health services.

Suggested prompts	Sample student responses	Follow-up questions
<i>What did you notice?</i>	The average temperature in Canada has increased slowly (by more than one degree Celsius) since 1948. Sea ice changes seasonally, and the total amount has been declining over the last 40 years. The ice in the Hudson Bay is breaking up earlier every year (in mid-July in the 1980s; in late June by 2005). The tundra is greening in most parts of the Arctic and browning in a few places. The amount of sea ice in the Arctic goes up and down every year. There is less ice now in the Hudson Bay and over the whole Arctic than there was in 1980.	<i>What pattern do you see on the Arctic sea ice graph?</i> <i>What trend do you see in the data over many years?</i> <i>What trends did you see between the two graphs about sea ice?</i>
<i>How does changing the scale of the data change the trend we notice?</i>	Looking at multiple years allows us to see an overall decline in the amount of ice over time. The temperature and ice data is scattered year to year, but with a longer time scale we see a trend. If we only look at one or two years of ice data, we may see the amount of ice go up, not down. We may see the temperature fall instead of rise. We saw changes to ice extent over the entire Arctic and changes in the Western Hudson Bay near Wapusk. This means the problem is more widespread than just Wapusk. Looking at multiple years allows us to see a change in how green the tundra is. We need multiple years to notice a change.	<i>What different scales did we see in the data (time, space)?</i> <i>How would looking at data at the scale of one year vs. 50 years change what you notice?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What did you wonder about the effects of the trends we noticed on Arctic ecosystems and bears?</i>	How does the sea ice decline affect the polar bears? How does the decline in sea ice affect other animals that live in the Arctic or other components of the ecosystem? If the sea ice in Hudson Bay is breaking up earlier and earlier each year, how does that affect the polar bears who use the sea ice? If the tundra greens, will that cause a change in the food available for the three bears? Are these trends going to continue in the same direction? Is it possible to stop the decline of ice?	<i>How is this related to our questions about the future of bears from the video we watched about bears in Wapusk?</i> <i>Why would Arctic greening matter to the bear species?</i>

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: questions that arise (SEP 1.1) about:

- Whether the trend of declining ice and greening tundra will continue. (CCC: 3.1)
- Long-term implications for resource availability and long-term functioning of the Arctic ecosystem if trends continue. (DCI LS2.C.1; CCC: 3.1)
- Whether trends observed in declining of ice over the Arctic as well as Western Hudson Bay will affect where polar bears hunt or live both in and outside of Wapusk. (DCI LS2.C.1; CCC: 3.1)
- Whether changes to greening of Arctic tundra will also affect the ability of bears in Wapusk to get food. (DCI LS2.C.1; CCC: 3.1)

What to do: Walk around with a clipboard listening for the types of questions students ask during the Data Exploration. Listen for those questions again on day 3 when students build the Driving Question Board.

- Ask students to provide evidence from the visual inquiry to support the trends they observed.
- Ask students if they believe the changes they see in the ice or tundra could cause any changes in the bears.
- Ask students what additional information they need to understand the effects changes to the ice and tundra might have on the bears or the Arctic ecosystem.
- Ask students if the two graphs about ice tell the same story, even though they are at different scales.
- Ask if changes at one scale would impact populations at a larger or smaller scale.

Building towards: 1.A Ask questions that arise about the significance of changes to Arctic ice and habitats observed at multiple scales in terms of functioning of the ecosystem due to changes in resources and habitat availability. (SEP 1.1; DCI LS2.C.1; CCC: 3.1)

Pause for a SEL moment. Display slide O. Say, *We are spending time in this unit looking at the impacts of climate change. These effects are complex and involve human and nonhuman parts of the Earth's systems. We need to respect everyone's lived experiences and thoughts about these issues. As we do this, you may have a variety of feelings that you experience. Here is a tool to help you name or identify those feelings.* Hand out the *Feelings Wheel* at this time as a reference for students to use to identify their feelings throughout the unit. Remind students that all feelings are valid. *

5 · INTRODUCE HOME LEARNING

2 min

MATERIALS: None

Introduce home learning. Say, *The data exploration helped us better understand some of the impacts of climate change on the ice and tundra in the Arctic. Who could we talk to in our community to learn more about how changes in environmental conditions have affected our community? Many times data like temperature trends do not tell us what is actually happening in a particular place. People who live there notice changes to plants and animals and other particular events that do not show up on a graph.* Display **slide P** and ask students to follow the prompts tonight, taking notes in their science notebook about what they learn to bring back for discussion in the next class. *

* ATTENDING TO EQUITY

Framing students' families and communities as legitimate sources of knowledge can serve multiple purposes. It can 1) help students feel like they belong in the science classroom by situating their family/community knowledge as productive for science, 2) engage students' families in conversations about what is happening in the classroom, and 3) help students make connections between the science classroom and their everyday lives.

6 · READ ABOUT BEAR DIET, REPRODUCTION, AND BEHAVIOR

13 min

MATERIALS: *Scale Organizer*, *Bear Diet*, *Bear Denning and Hibernation*, or *Bear Reproduction*, Laminated Bear Adaptation poster or large printed copy of *Bear Adaptation Poster*, dry erase marker, *Key Bear Adaptation Readings*

Investigate the three bears. Display **slide Q**. Say, *You have some insightful questions about the bears and how they will be impacted by the changes we see to the ice and tundra in Wapusk. I have some information about the diet, behavior, and reproduction of all three bears that I think will help us answer some of those questions.* Explain that students will record ideas using the graphic organizer timeline provided on part 2 of *Scale Organizer*. They should focus on questions the class raised about the bears as well as the prompt on the slide as they read. Divide the class into 6 groups and assign each reading to two groups (2 groups read *Bear Diet*, 2 read *Bear Denning and Hibernation*, 2 read *Bear Reproduction*). Each group should prepare points they can share describing how each bear species is adapted to living in Wapusk. *

ADDITIONAL GUIDANCE

If necessary, revisit the definition of adaptation developed in *Natural Selection Unit*: *adaptations are characteristics or traits that increase a population's chance of survival, considering elements of genetics and reproduction.*

Facilitate information sharing about bear adaptations. After 5-7 minutes, bring the class back together again. Display **slide R** and ask each group to take turns sharing one adaptation to life in Wapusk they noted for the bear species. Use the laminated Bear Adaptation poster or a large copy of *Bear Adaptation Poster* to record what students share. Ask groups to continue sharing ideas until all ideas are on the whiteboard. Facilitate a conversation to make connections between the ideas shared from the bear readings to changes they saw happening to the habitats in Wapusk from the *Lesson 1 Data Exploration*. Take a photograph of the final bear adaptation poster to use during Lessons 2 and 3. A sample poster is found on *Key Bear Adaptation Readings*.

* ATTENDING TO EQUITY

Bear Diet, *Bear Denning and Hibernation*, and *Bear Reproduction* are written at similar reading levels. You may wish to allow students to self-select readings based on interest before dividing them into groups. Or, at your discretion, count students into random groups 1-8, or assign them into intentional, mixed-ability reading groups, with the students who need more reading support along with students who do not need the extra support. *Bear Reproduction* is the shortest. *Bear Denning and Hibernation* contains some statistics and percentages and could be a good fit for students who are drawn to math and numeracy. Many students will have some background knowledge relevant to all readings.

To help students visualize what an Arctic winter looks like for a polar bear with young cubs, watch <https://vimeo.com/groups/832644/videos/156505076>. They can pay attention to how the mother keeps the cubs

Suggested prompt	Sample student response	
<i>What important differences are there between the bear species?</i> <i>How will the changes we saw to ice and greening affect the bears?</i>	Black and brown bears hibernate; the polar bear does not. All bears eat from May–October, but not in the same habitats. Polar bears prefer hunting on sea ice until it melts, brown bears are in tundra and coastal areas, and black bears are in the forest. Polar bears may fast after they come to land in July. Black and brown bears eat regularly during this time and eat even more in fall before they hibernate. Polar bears hunt for food when there is still ice and snow from November to March; the other bears hibernate. Polar bears depend on seals for food, but the other bears eat a wider variety of food, mainly plants. Polar bears hunt on the ice; the others do not. If the ice breaks up earlier, the polar bears may not be able to hunt seals on the ice as long. Polar bears may come to shore earlier where the brown and black bears are. Smaller bears have fewer babies. If polar bears do not have enough to eat, they may have fewer offspring. If the tundra is greening, the black and brown bears may have more food. They may be able to reproduce more. Black and brown bears may not have to hibernate as long if it is warmer. Polar bears may get too hot. Black and brown bears may compete with polar bears for food on land if polar bears have to spend more time on land.	warm, how thin the mother is, and think about the distance the bears may have to travel to get food.
ADDITIONAL GUIDANCE	Students will revisit <i>Bear Diet</i> , <i>Bear Denning and Hibernation</i> , <i>Bear Reproduction</i> , and <i>Scale Organizer</i> in Lesson 2. Make sure materials are safely stored in science notebooks.	

7 · NAVIGATE

2 min

MATERIALS: None

Decide on the bear species of most concern. Display **slide S** and ask students, *Which bear species will be most affected by changes to the habitats in Wapusk?* Ask students to hold up 1, 2, or 3 fingers based on their answer. If time allows, ask a few students with each response to explain the reason for their vote. Most students should choose the polar bear out of concern for loss of ice and access to food.

Remind students to complete the home learning.

End of day 1

8 · NAVIGATE: SHARE HOME LEARNING

5 min

MATERIALS: chart paper, chart paper markers

Discuss home learning. Display **slide T**. Say, *During the last class we talked about the impact of climate change on the Arctic and bears, but we wanted to learn more about some impacts closer to home.* Discuss the prompts on the slide. Listen for students to mention speaking to parents, grandparents, neighbors, other elders. Ideas collected may include droughts, storms, more ticks, plants not flowering, different garden vegetables growing better or worse, invasive species, heat waves, etc. Record these ideas on a poster labeled *Related Phenomena*.

9 · INVESTIGATE TRADITIONAL KNOWLEDGE ABOUT POLAR BEARS

12 min

MATERIALS: *Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems*, Community Agreements, 2 paper lunch bags

Reconnect to questions about polar bears. Say, *Thank you for sharing what you heard from your community. There are so many knowledgeable members of our community with valuable experiences that help us see changes we may not be aware of without their input. Let's think about how we can gain similar insights into what is happening to bears in the Arctic.* Display **slide U** and read the prompts.

Suggested prompts	Sample student responses	Follow-up questions
<i>Which bear species were we most concerned about in Wapusk? Why?</i>	Polar bear. Polar bears had to come off the ice earlier each year in Wapusk and could not hunt seals as long.	<i>What factors might make it difficult or easy for the bears given the changes to the habitats in and around Wapusk?</i>
<i>Who could tell us more about the condition of local bear populations in the Arctic?</i>	Scientists. People who live in the Arctic.	<i>Who has lived in the region the longest and has the most experience?</i> <i>Why are there so few people with long-term knowledge of what is happening to polar bears?</i>

* SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

Throughout this lesson, students are asked to compare, evaluate, and integrate information that comes from multiple sources, including NASA, the Inuvialuit, Canadian government, and peer-reviewed science publications. All sources contribute useful information that provides evidence to explain changes in Arctic ice and the status of polar bear populations, but they provide information at different scales and focus on different aspects of the system with varying degrees of completeness. Facilitate discussions that recognize both the usefulness of each source as well as the gaps or limitations. Putting the pieces together from all sources provides some answers but should raise additional

Share Inuvialuit quotes about polar bears. Explain that you could not find direct information from people who live in Wapusk, but you found a research project that gathered local knowledge about how changes in climate impact polar bear populations from another region of Canada. Display slide V. Say, *The Inuvialuit (In-oo-vee-A-loo-weet), are a group of people who have lived in part of what we now call the Arctic regions of Canada for generations. Many hunt animals on the Arctic sea ice for food and clothing, so they have first hand, generational knowledge of the Arctic habitats, the seasonal changes, as well as the behavior of many of the animals. Traditional Knowledge of the sea ice and the Arctic is passed on from generation to generation in the Inuvialuit community. The Canadian government collaborated with Traditional Knowledge holders to learn more about polar bear populations in the region.* *

Revisit Community Agreements related to a respectful classroom. Display slide W. Explain that you will share quotes from interviews with members of Inuvialuit communities describing changes they have seen in the Arctic. Revisit your Community Agreements regarding respect before distributing the quotes, emphasizing that these are the words of real people whose culture and experiences may be different from our own. Students should be aware of stereotypes they may have of the Inuvialuit and try to avoid assumptions about how they live or speak.

ADDITIONAL GUIDANCE

The quotes come from a study conducted in Canada, and many quotes were translated from the various languages spoken by different Inuvialuit communities. Spelling and grammar were not corrected from the source text. The choice of the term *Traditional Knowledge* honors the choice of the authors. Collaboration between Indigenous communities and Western scientists has been inequitable and contentious in the past. The authors of this study were careful in their use of this knowledge. The authors state that, *"The data documented during the course of the Inuvialuit Polar Bear Traditional Knowledge (PBTk) Study, which are presented in this report, are the intellectual property of the Inuvialuit and are therefore owned by them. In this case, ownership is represented and administered by the Joint Secretariat. The PBTk study, of which this report is a product, recognizes, honours, and respects the intellectual property rights of the Traditional Knowledge Holders, elders, hunters and other Inuvialuit who shared their knowledge concerning polar bears and the world they live in."*

Joint Secretariat. 2014. Inuvialuit and Nanuq: A Polar Bear Traditional Knowledge Study. Inuvialuit Settlement Region: Joint Secretariat. p. Xvii

Share quotes. Display slide X. Fill a lunch bag or other small container with the cut-out quotes from *Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems*. Ask students to stand in a circle. Ask for a volunteer to read the first quote. Hand them the bag, ask them to select a random quote and then pass the bag to the next student, who will select another quote and pass it on. Each student should take a quote and take turns reading them aloud in the circle. Pass a second container to collect quotes after they are read. *Note: The quotes refer to brown bears as grizzly bears, and some students may need clarification to make the connection that they are the same species as the brown bear they read about the previous day.* *

ADDITIONAL GUIDANCE

There are 35 quotes provided in *Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems*. They are organized in order of relevance, starting with the most relevant. The first 12 quotes are appropriate for smaller classes and contain all relevant themes (seasonal changes in ice, changes in ice quality, impact on polar bears, mention of seals and grizzly bears). For larger classes, add quotes from further down the list. To save time, only put the first 12 quotes in the container. Pass the quotes and allow students to volunteer to read instead of requiring all students to read.

Facilitate a class discussion about the content of the quotes. Use the prompts on slide X and below to facilitate a class discussion.

questions and requests for more data to learn what is happening to polar bears in the Arctic.

* ATTENDING TO EQUITY

Universal Design for Learning. The quotes can be selected randomly, but some quotes are longer than others or include more challenging words and could be strategically distributed to provide challenges as appropriate. Students who are not confident reading aloud may benefit from receiving a shorter quote in advance and holding onto it until it is their turn to read. Students who are not verbal could receive their quote in advance and use a device with text to speech capability to take their turn to contribute a quote to the circle.

Suggested prompt	Sample student response
<i>What is happening to polar bear populations in this region?</i>	Some people are not seeing as many polar bears as they used to. Some people see a lot of bears. Bears hang out on the ice, especially big bears. Some think the polar bears are smaller than before. Maybe the large ones are not surviving. Some polar bears look skinnier. They are not eating as well as before. Seals and polar bears depend on certain types of ice to survive. When that ice is not there, they do not survive as well. Brown (grizzly) bears sometimes come in to hunt where you would expect to see polar bears.
<i>What is happening to Arctic ice in this region?</i>	Ice is thinner now. There is less multiyear ice now. The ice that floats around all year is disappearing. The ice is less stable than it used to be and is not safe to be on when they want to go out hunting. The ice forms later in the season now and melts earlier.
<i>How are the ice conditions the same or different from Wapusk?</i>	Like in Wapusk, the sea ice is changing. It is freezing later and melting earlier. Polar bears eat seals in both places. Brown and polar bears are seen together occasionally here as well. The ice seems more dangerous in the Inuvialuit quotes. It piles up or splits up.

Suggested prompt	Sample student response
<i>How is this data useful for understanding the effect of changing environmental conditions on polar bears?</i>	We heard more specifically about how the ice is changing and how changes to ice affect the polar bears. We heard how the size and number of polar bears has changed over time. The Inuvialuit know about different kinds of ice and different ice formations. The data we had in the Data Exploration just talked about ice or no ice. Ice quality impacts the polar bears' ability to hunt. The Inuvialuit provides a personal perspective and speculation on why bears are doing something. The Inuvialuit account is more personal and helps us see connections between people and bears. This helps us think about the whole ecosystem, not just the bears.

10 · ASSESS THE STABILITY OF POLAR BEARS IN 4 ECOREGIONS

11 min

MATERIALS: *Comparing Polar Bear Populations*, Internet-connected device, Convergent Ice Visual Inquiry https://docs.google.com/presentation/d/1SB3MVB3xVx524ewj7LtRHYAFB3-xFn3acf5PrS5kms/edit?usp=drive_link, Divergent Ice Visual Inquiry https://docs.google.com/presentation/d/1KSICOYGQd-tS8gDrvcj4cLxDwEBqSd-iT_ZssdmUNs/edit?usp=drive_link, Islands Group Visual Inquiry https://docs.google.com/presentation/d/1-xwRHZueCv_aCXbP_pLVj6bTzCNNWLE9h6Pug9xN3TA/edit?usp=drive_link, Seasonal Ice Visual Inquiry https://docs.google.com/presentation/d/1X58NGa0QQA5F2_9YBUbq8npJSGpPW8LyWL-CHnRaCn4/edit?usp=drive_link, *Key Comparing Polar Bear Populations*

Consider what we know about the polar bear species as a whole. Display slide Y. Say, *Do we know enough about what is happening with polar bear populations for us to understand how climate change is impacting the entire species?* Listen for students to notice that polar bears live in a much larger part of the Arctic than they have investigated so far. They should also identify that there are gaps in their knowledge about other locations and want more specific data about the number or stability of the polar bears in other places.

Introduce different polar bear populations. Display slide Z and explain that you found additional data from some other studies. Explain that scientists have identified 19 populations of polar bears around the Arctic and revisit the definition for population. Students may want to add this definition to their Personal Glossaries. Say, *Many different groups of scientists investigated the status of the populations as thoroughly as possible given their resources and the remoteness of the locations. They compiled their findings and divided the polar bears into 4 ecoregions.*

Introduce the 4 polar bear ecoregions. Display slide AA. Say, *You all mentioned that the Inuvialuit identified different types of ice and their importance to everyone that lives there. These regions are also identified based on differences in the ice in each of these regions that seems to impact the polar bears.* Explain that they will be divided into groups to evaluate the data from each ecoregion. Distribute *Comparing Polar Bear Populations*. Assign students to 8 small groups of 3-5 students and ask them to fill in which ecoregion they are responsible for on *Comparing Polar Bear Populations*. Display slide BB and watch the embedded video, https://youtu.be/7VFJ4osSY_A, in which Dr. Steven C. Amstrup introduces the 4 ice ecoregions. Students should take notes on their ecoregion in the space provided on *Comparing Polar Bear Populations*.

Briefly discuss the terms *convergent* and *divergent*. The ecoregion names relate to the ice in each area. Suggest students add *convergent* and *divergent* to their Personal Glossaries. Explain that the archipelago ecoregion is called the *Islands Group* on the class materials for simplicity.

ADDITIONAL GUIDANCE

Ask students to think about wildebeest populations from *Serengeti Unit*. There they focused on the carrying capacity of a group of animals from the same species in a particular ecosystem. Compare this earlier definition of population to the one provided on the slide, which focuses on isolated breeding groups.

It may be helpful to break down the prefixes of the glossary terms for students to improve their decoding skills. “Con” means *with* and refers to ice coming together. This term will be familiar to students who speak Spanish. “Di” means *two* and in this case refers to ice splitting and separating. Ask students to think of other words with those prefixes, such as *conference* and *carbon dioxide* (CO₂).

Introduce a visual inquiry. Display slide CC. Prepare students to work in their groups. Explain that they should look at the data they are given and answer the questions on part 1 of the handout and also displayed on slide DD. Make sure each group has access to an internet-connected device and 1 of the 4 visual inquiries. Provide a few minutes for group work. Before the end of that time, they should designate one person from their group to report what they find to help the class figure out if polar bear populations are equally affected by changes to Arctic sea ice. Key *Comparing Polar Bear Populations* provides a guide to information in each ecoregion.

11 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION ON THE STABILITY OF POLAR BEAR POPULATIONS

14 min

MATERIALS: *Comparing Polar Bear Populations*, *Community Agreements*, *Key Comparing Polar Bear Populations*, *Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems*



Facilitate a fishbowl discussion. Display slide EE. Set up two concentric circles of desks. One representative from each group will sit in the inner circle. One-two student volunteers should also join the inner circle representing Traditional Knowledge. Provide them with access to the quotes from *Inuvialuit Observations of Changes in Sea Ice and Arctic Ecosystems*. The remainder of desks should create an outer circle where the majority of students will sit. Use the slide prompts to explain how a fishbowl discussion occurs. Refer to the *Community Agreements* and remind students that the purpose of this discussion is to move their science thinking forward. The goal is to answer the question: *How are polar bear populations in different ecoregions affected by changes to Arctic sea ice?* Students in the inner circle will share information from their ecoregion visual inquiry and discuss the questions on slide FF. Students in the outer circle will listen and complete part 2 of *Comparing Polar Bear Populations*. Students in the outer circle are responsible for deciding if the class has sufficiently answered the discussion questions. As the chosen representatives, only students in the fishbowl may contribute to the conversation. *

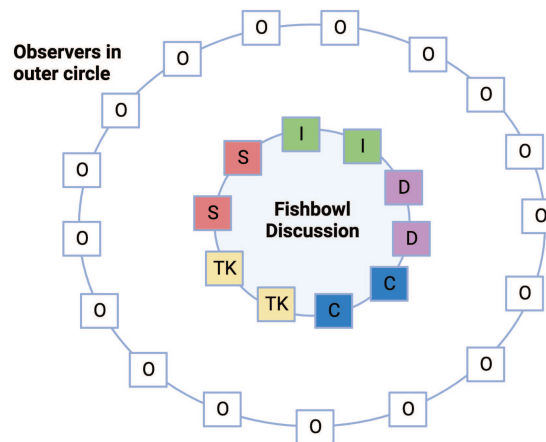
Explain that you, as the teacher, will only jump in to guide the discussion if it gets off track or students are stuck. Explain that if students in the outer circle want to add information or express their opinion, they may “tap in” to the fishbowl. They can tap the shoulder of their group representative and take their place after the person from their group has had a chance to contribute at least once. Once in the inner circle, they are responsible for representing their ecoregion until someone else taps them out, which may or may not occur. If someone from the inner circle is tapped out, they should move to the outer circle, listen, and take notes on the discussion. Explain that you will collect *Comparing Polar Bear Populations* at the end of the discussion but will assess students who participate in the fishbowl based on their discussion contributions, not the handout.

Allow students to self-facilitate the discussion. If there is a lull in the conversation or students begin to move off track, ask the students in the outer circle if all of the discussion questions have been answered.

* ATTENDING TO EQUITY

Universal Design for Learning: The fishbowl discussion provides multiple ways for students to engage in synthesizing the data and putting the pieces together. Some students process better orally and benefit from talking through what they read, whereas others may process more slowly, needing time to listen, absorb information, and take notes. This provides students access by supporting student *action and expression*.

The job of students in the outer circle is also to hold the discussion participants accountable for answering the questions on slide FF. The outer circle may uncover where gaps in knowledge exist as they track the conversation. They may also synthesize the information as they listen and write and come up with ideas that will allow them to tap into the circle to contribute.



Fishbowl discussion inner circle includes 1-2 representatives who read about each ecoregion (seasonal, island ice, divergent, convergent) and 1-2 representatives for Traditional Knowledge (Inuvialuit quotes).

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ADDITIONAL GUIDANCE

It may be helpful to jump in to facilitate a discussion comparing the usefulness of both the Traditional Knowledge and Western science knowledge. The goal is not to value one type of information over another, but rather to understand the benefits and limitations of both. Two important distinctions include:

- The Inuvialuit explain information but from personal experience, memory, or stories told by people they know. Western scientists record similar data using tools and record observations. Both sources of information provide useful details.
- The Inuvialuit do not track precise population counts but recognize patterns from experience. Western scientists include population counts, but the data includes a margin of error because it is not possible to count every animal.
- The data from the Inuvialuit and convergent ice data tell similar stories.

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment: Responses that reference **evidence** from the **visual inquiries, video, and Traditional Knowledge** (SEP 8.3; CCC: 1.5), such as:

- Ice is available for polar bears all year round (islands & convergent) or only in the winter (seasonal ice & divergent).
- When ice is available only in the winter (divergent and seasonal), there is **some evidence of polar bear population decline, declining body condition and reproductive trends.** (DCI LS2.C.2; CCC: 1.5)
- When ice is available all year long (islands & convergent), there is **some evidence of polar bear population stability and/or increase, stable and/or increasing body condition and reproductive trends.** (DCI LS2.C.2; CCC: 1.5)
- **Population trend data** was available for most populations and **was useful in supporting claims.** (SEP 8.3; DCI LS2.C.2)
- For the seasonal ice ecoregion, **body conditions and reproductive trend data** was **useful** because it was complete. For the other ecoregions, it was less useful because there was more uncertainty. (SEP 8.3; DCI LS2.C.2)

What to do: Project the relevant data from visual inquiries as students discuss them and use the following prompts to support student thinking:

- Which ecoregions have polar bear populations that are stable and/or increasing in size? What are the ice conditions like in those regions?
- Which ecoregions have declining polar bear populations? What are the ice conditions like in those regions?
- For students in the outer circle: Have all of the discussion questions been answered?

Keep track of students who participate in the fishbowl, noting when evidence is discussed and using a clipboard with your class roster. Collect *Comparing Polar Bear Populations* at the end of class from other students to assess understanding. Use *Key Comparing Polar Bear Populations* to facilitate the discussion as needed.

Building toward 1.B Read and evaluate scientific information from multiple sources to identify patterns in Arctic ice conditions related to **stability of polar bear populations.** (SEP 8.3; DCI LS2.C.2; CCC: 1.5)

Define key ice conditions. As the fishbowl discussion concludes, display **slide GG**. Say, *I hear you saying that the patterns we uncovered indicate two major ice conditions that seem to determine how stable the polar bear populations are.* Discuss the terms *seasonally available ice* and *permanent ice* with students and add them to their Personal Glossaries.

ADDITIONAL GUIDANCE

Definitions may be similar to the following: *Seasonally available ice* regularly forms in the winter and melts over the course of the summer or becomes unavailable to bears for hunting (divergent and seasonal ice ecoregions). Polar bears that live in ecoregions with seasonal ice must move to land every year. *Permanent ice* does not melt and remains accessible for hunting all year (convergent and islands ice ecoregions). Polar bears living in ecoregions with permanent ice can stay out on the ice all year.

12 · NAVIGATE: STOP AND JOT PREDICTIONS FOR POLAR BEARS

3 min

MATERIALS: None

Individually write a prediction about polar bears. Say, *Wow! That was an interesting discussion. Thank you all for your contributions.* Ask students to stop and jot about the question on **slide HH** in the space provided at the end of *Comparing Polar Bear Populations*. Collect *Comparing Polar Bear Populations*.

End of day 2

13 · NAVIGATE

5 min

MATERIALS: science notebooks

Review the main take-aways from the fishbowl discussion. Display **slide II**. Return *Comparing Polar Bear Populations*. Use the prompts below as a guide to support students in summarizing what they figured out and what questions they have following the fishbowl discussion.

Suggested prompt	Sample student response
<i>What did we figure out from the fishbowl discussion?</i>	There are two kinds of ice environments for polar bears, seasonally available and permanent ice. There was some evidence that the polar bear populations in seasonal ice were declining. There was some evidence that the polar bear populations on permanent ice are stable or increasing. There was a lot of uncertainty in the data.
<i>What new questions do you have?</i>	What will happen to the polar bears in the future? What about all of the other bears (brown and black)?

14 · DEVELOP INITIAL MODELS

12 min

MATERIALS: chart paper, colored markers

Motivate developing initial models. Display **slide JJ**. Say, *We started this unit looking at bears from three species coming together in Wapusk. We became particularly concerned about polar bear populations. We saw some patterns in which polar bear populations are stable, increasing, or declining, depending on whether they have seasonal or permanent ice available. How can we make sense of all of this data, the interactions between bear species, and the future?* Display **slide KK**. Facilitate a think, pair, share. Give students a minute to quietly think about the prompts on the slide and then ask them to share with an elbow partner. Ask a few students to share their ideas. Acknowledge that students have different ideas about what is possible. Ask, *How can we more clearly share our ideas and concerns for what might happen to Arctic bear populations in the future?* Listen for students to suggest that we develop initial models. If this idea does not come up, ask students to recall how we explained or predicted interactions in a system in our past units of study.

Develop initial models. Display **slide LL**. Form groups of 3-4 and distribute a blank piece of chart paper and colored markers to each group. Have students draw a line through the center and give them 10 minutes to develop two models that explain what will happen to the populations of Arctic bears living in habitats with seasonally available vs. permanent ice as their environment changes.

Suggest that groups list components, interactions, and mechanisms they want to include before they begin their models. Encourage the use of pictures, symbols, and/or words in their model to help represent and further explain their ideas. Prompt groups to consider factors related to climate change, habitat change, and interactions with other bears as they develop models. Encourage students to record any questions that emerge for them as they develop their models. They will build a Driving Question Board at the end of the lesson and productive questions will likely arise while modeling. Explain that they will be sharing these models with their peers, so they should make sure ideas are labeled and explained clearly.

15 · FACILITATE A GALLERY WALK

8 min

MATERIALS: Initial group models from day 2

Prepare for a gallery walk. Post the group models around the room where all students can see them. Display **slide MM**. Let students know that they will interact with some of their peers' models through a gallery walk. Ask them to prepare a T-chart in their science notebooks to record similarities and differences between models. They should look for key ideas that could be included in a class consensus model.

Facilitate a gallery walk. Provide a few minutes for students to participate in the gallery walk and record their ideas in their science notebooks.

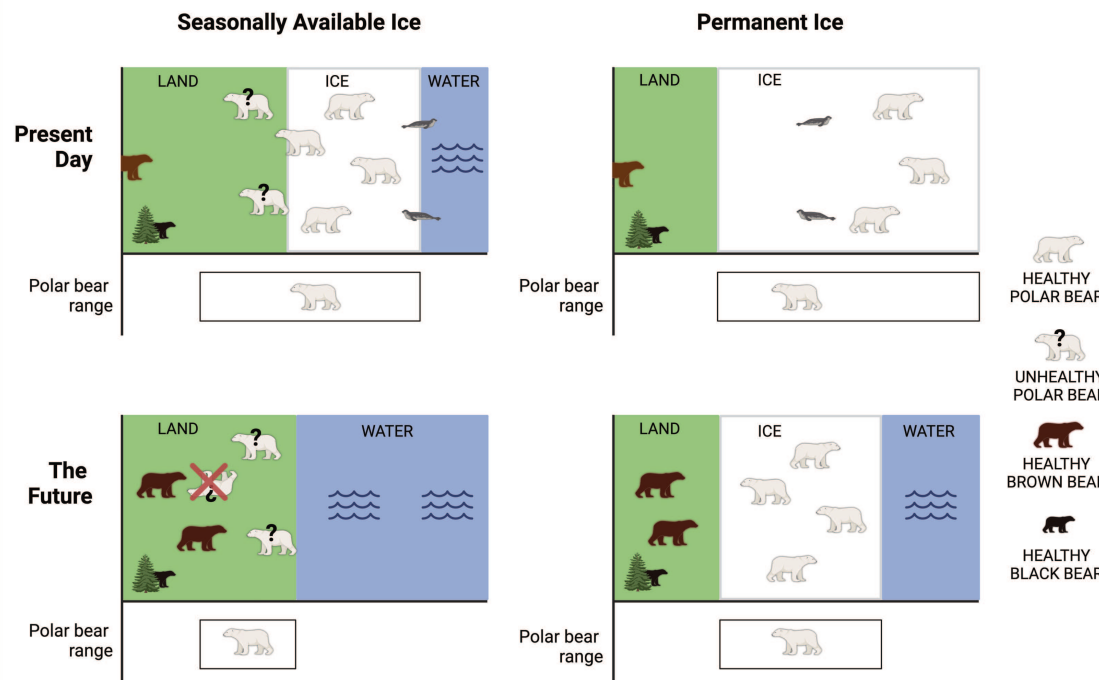
16 · DEVELOP A CLASS CONSENSUS MODEL

15 min

MATERIALS: revised models, chart paper, chart paper markers



Facilitate the development of a class consensus model. Ask students to gather in a Scientists Circle. Display **slide NN**. Use the prompts on the slide to organize your discussion and begin to develop a model. Use a clean sheet of chart paper to create a class consensus model. Ask students to share the key components, interactions, and mechanisms they saw during the gallery walk. If necessary, revisit concepts from *Natural Selection Unit* related to how populations evolve and adapt over time and the effect of fragmentation on genetic diversity in populations. Create a class consensus model of the future of Arctic bear populations living in seasonal and permanent ice. Use the prompts below as a guide. Save this model for use in future lessons. An example of a model is shown below:



Illustrations created by OpenSciEd in Biorender.com

Suggested prompt

What key components do we want in our model?

Sample student response

Seasons: winter/summer.
 Seasonally available and permanent ice.
 Seals.
 Polar bears, brown bears, black bears.
 People.
 Time.
 Tundra.
 Vegetation and berries.

Suggested prompt	Sample student response
<i>What interactions do we want in our model?</i>	Polar bears eating seals. Black and brown bears eating vegetation. Reproduction. People hunting polar bears. Melting ice over time with warming temperatures. Brown bears eating food in tundra and on shore. Shrinking habitat for polar bears. Expanding habitat for brown bears. Brown and polar bears competing for food. Bears competing for resources with other animals.
<i>What are possible outcomes for the polar bear populations if their habitats shrink?</i>	Adapt. Move. Go extinct.
<i>What mechanisms do we know that allow polar bear populations to adapt or change?</i>	Evolution. Natural selection. Random chance can cause populations to lose genetic diversity, especially if populations are small.
<i>What has to happen for a population to evolve and adapt?</i>	Natural selection. There must be genetic variation in the population. Some individuals have variations that allow them to survive and reproduce more than others. They pass on their genes to their offspring.

SCIENTISTS CIRCLE



You will form a Scientists Circle in this lesson. Setting up the Community Agreements and logistics for forming, equitably participating in, and breaking down that space is important. Having students sit in a circle so they can see and face one another can help build a sense of shared mission and a community of learners working together. Returning to this Scientists Circle throughout the course of the unit to take stock of what the class has figured out and where they need to go next will be an important tool in helping the class take on greater agency in steering their learning. You may want to inform students that professional scientists also collaborate with one another to brainstorm, discuss, and review their work.

ADDITIONAL GUIDANCE

Students figured out a mechanism for evolution by natural selection in *Natural Selection Unit*. Review ideas from LS4.C.2 and LS4.C.3, including the idea that heritable variation exists in populations, and differential survival and reproduction based on advantageous heritable traits leads to changes in the proportion of those traits in a population. Distribution of those traits can change when conditions in the environment change. Students should also recall that small, isolated populations randomly lose genetic diversity and therefore contain fewer options for developing adaptations should the environment change.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Students [revise their initial models to develop a class model \(SEP 2.3\)](#) that includes the following:

- [Predictions that climate change will continue to cause a change in Arctic sea ice in some areas and a greening of the tundra. \(DCI: LS4.C.4; CCC: 2.2\)](#)
- [Loss of Arctic sea ice in ecoregions with seasonally available ice, leaving less habitat for polar bears. \(DCI: LS4.C.4; CCC: 2.2\)](#)
- [A decline in the polar bear population in some regions in response to habitat changes. \(DCI: LS4.C.4; CCC: 2.2\)](#)
- [Expansion of ice-free habitat for brown and black bears.](#)
- [An expansion of brown bear populations in response to warming temperatures and greening tundra. \(DCI: LS4.C.4; CCC: 2.2\)](#)

What to do:

- Prompt students to reread *Comparing Polar Bear Populations* to think about varying responses for each ecoregion.
- Review the poster of bear adaptations to think about possible changes to the seasonal timeline.

Building toward 1.C [Develop and revise models to predict how Arctic bear populations will expand or decline in response to anticipated changes to their environment. \(SEP 2.3; DCI: LS4.C.4; CCC: 2.2\)](#)

17 · NAVIGATE: SOCIAL AND EMOTIONAL LEARNING

5 min

MATERIALS: *Feelings Wheel*

Check in with how students are feeling. Display slide OO. Say, *As I mentioned earlier, learning about the impacts of climate change on bear populations may bring up feelings for you. I want to give everyone a chance to do a social and emotional check-in about the predictions we are making with this model.* Encourage students to take time to turn and talk with a trusted peer, write independently in their science notebooks, or think about how they feel about what is happening with the Arctic bears. They can use the feelings wheel from *Feelings Wheel* to help them identify or name an emotion. Encourage them to talk to you or another trusted adult if you notice they have feelings they want to share about what they read.

End of day 3

18 · NAVIGATE: REVIEW CONSENSUS MODEL

5 min

MATERIALS: science notebooks, consensus model

Review the class consensus model. Post the class consensus model in a prominent location in the room. Display **slide PP** and ask students to discuss the prompts with an elbow partner. After a few minutes, ask a few students to share what they are still wondering with the whole class.

19 · DEVELOP QUESTIONS

5 min

MATERIALS: 3x3 sticky notes

Return to the questions students generated earlier and develop new questions. Say, *At many points over the last 3 days, you came up with questions about what is happening to the bear populations in Wapusk and other parts of the Arctic as a result of climate change. Today, we are going to add these and other questions to our Driving Question Board.*



Write initial questions for the Driving Question Board. Display slide QQ. Pass out three sticky notes to each student. Let students know that the DQB will help keep the class organized and keep track of what we want to know and what we figure out throughout the unit. Instruct them to write up to three questions each, one per sticky note, using their science notebook resources as a guide. *

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment: Students use their initial models to ask questions that lead to investigations about (SEP 1.1):

- The ability of polar bears to adapt to new environmental conditions in the future. (DCI LS4.C.4; CCC 3.1)
- The history of polar bears that lived under different environmental conditions than the present. (DCI LS4.C.4; CCC 3.1)
- Genes that may affect the survival of polar or brown bears. (DCI LS4.C.4; CCC 3.1)
- Changes to the ecosystem that may affect the survival of bear populations. (DCI LS4.C.4; CCC 3.1)
- Concern for the large-scale effects of climate change and decreasing amounts of ice on the survival of the entire polar bear population. (DCI LS4.C.4; CCC 3.1)
- Ways to protect polar bear populations from the effects of climate change. (DCI LS4.C.4; CCC 3.1)
- The rate at which Arctic ice conditions may change over time. (DCI LS4.C.4; CCC 3.1)

What to do: Guide students to questions written on initial models, *Scale Organizer* and *Comparing Polar Bear Populations*. Prompt students with the following:

- Can you figure something out by investigating the problem at a different time scale or spatial scale?
- Are all populations equally in danger?
- What questions do you have about the future of polar bears in the Arctic?
- What questions do you have about the future of brown and black bears in the Arctic?
- What questions do you have about how Arctic ice and ecosystems are changing?

Building toward 1.D Ask questions at different scales that lead to investigations about whether Arctic bear populations will expand or decline in response to ongoing changes to polar ice. (SEP 1.1; DCI LS4.C.4; CCC 3.1)

* SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Initial questions about a phenomenon are intended to clarify what information is known and not known, and, as is often the case, there are more questions than answers when scientists begin their investigations. Develop a safe and supportive space for students' uncertainty, and focus on the need to ask and answer questions in order to address the uncertainty that may require the entire unit to resolve.

20 · DEVELOP THE DRIVING QUESTION BOARD

25 min

MATERIALS: chart paper, chart paper markers

Gather in a Scientists Circle. Ask students to form a Scientists Circle, a horseshoe shape oriented toward the DQB, and to bring their sticky notes with them.

Students create a Driving Question Board. Display slide RR. Explain to the class that since this is the last unit of the year, you would like students to take responsibility for creating the DQB. The process for doing so is described on the slide. You might want to choose the first volunteer to begin the process and then step back. Step in when necessary to point students to some of the class Community Agreements that encourage equitable participation. Remind students that all questions are acceptable. The student-facing directions for assembling the DQB include:

1. Choose a volunteer to go first, read their question, and put it on the DQB.
2. Instruct students to raise their hand if they have a question that is related or the same.
3. The first volunteer selects the next student whose hand is raised. The student who is called on reads the related question, says why or how it relates, and then places it onto the DQB next to the original question.
4. That student selects the next student, who will read another related sticky note, move it, and then call on the next student.
5. Continue until the class agrees that all the related questions have been placed. Continue until everyone has shared at least one question.

Suggested prompt	Sample student response
<i>What questions do we have about the future of different polar bear populations?</i>	Will the different polar bear populations be affected the same by the loss of ice? Why are brown bears more likely to dominate if they interact with polar bears? What is happening to seals? Is someone going to research the “uncertain” areas? What do polar bears eat when they go to land? If polar bears eat less seal blubber, will they be less fat? Can polar bears adapt to life on land? If polar bears need cold, is Wapusk too warm? Will polar bears learn to eat things other than seals? Can we save polar bears? What can we do to protect polar bears? Will polar bears overheat with climate change? Will polar bears change in ways similar to the animals we studied in Unit 4? How will brown bears and polar bears interact? Can brown and polar bears mate? Are brown bears an invasive species now? What is the carrying capacity of the polar bear? Is the carrying capacity decreasing? Are polar bears a keystone species? If there is no ice, can polar bears still survive? Can polar bears recover if the environment gets colder again?

Suggested prompt	Sample student response
What questions about the past?	Will there be enough seals to feed the bears? Things have gone extinct before. Do we really need to save the polar bears? Has this happened to other animals or plants? How many generations until polar bears go extinct? Are the polar bears going to go extinct? How long have polar bears been around? Where did all three bear species come from? Have polar bear populations always looked the way they do today or did they look different in the past? Have polar bears had to deal with other bears before? Have polar bears always just eaten ring seals or has their diet changed? The Earth heats and cools. What happened to the polar bear when that happened before? Has it always been cold in the Arctic? Was it ever too cold for polar bears? Have polar bears had to deal with too little ice in the past? Have polar bears always been white? What were the ranges of the bears before? Can we look at bear fossils? How far back do we have information about polar bears and brown bears? Did polar bears adapt to what they are now so they could get more food when there was less ice?

Cluster the questions. After all students have shared their questions, you will have several different clusters of questions on the DQB. As a class, decide on “umbrella” questions or topics for the clusters of questions and then label them. Similar to the initial development of the DQB, consider having students lead this process, especially since this is the last unit of the year. Then if you have not already done so, post an overarching unit question at the top of the DQB similar to: *What will happen to Arctic bear populations as their environment changes?*

Motivate questions about the past. Compliment students on the interesting set of questions they have on the DQB. If they have not asked any questions about the past, display **slide SS**. Say, *I notice we have a lot of questions about the future of bears but we do not have any way of investigating the future. What kind of information do scientists use to make predictions about the future?* Listen for students to mention they investigate the past to find patterns. *What questions could we ask about the past that might help us improve our predictions of what will happen to the bear populations in the future?* Optionally, display **slide TT** to remind students what they figured out in *Fires Unit* about historical changes in temperature that occurred in the Arctic region when the Earth's tilt changed. Peat accumulated during a time period when higher rates of photosynthesis and plant growth occurred because there was more direct sunlight on that region of the Earth. Ask, *What additional questions does that raise about the bear populations?* Allow time to add additional questions to the DQB.

21 • CONSIDER IDEAS FOR INVESTIGATION

5 min

MATERIALS: science notebooks, chart paper, chart paper markers

Generate ideas for investigation. Congratulate students on generating a productive board full of great questions. Let them know that the next step is to brainstorm ideas that will help us figure out how to answer those questions. Display **slide UU**. They should focus on one question at a time and generate ideas for how they could go about answering each question. Their first instinct may be to “do research.” Prompt them to be more specific and answer questions about what specific data they would need to answer each question. Consider modeling an example to get them started.

Give students two minutes to generate ideas for investigation in their science notebooks. Ask students to share their ideas and record them on a list on a whiteboard or chart paper titled “Ideas for Investigation.”

Suggested prompt	Sample student response
<i>What kind of investigations could we do?</i>	We could watch documentaries or videos. We could read some scientific articles. Find out how long polar bears and other bears have been around. Research other foods polar bears eat. Learn more about how polar bear and brown bear ranges have changed. Talk to people who have seen the 3 bear species interact. Observe polar, brown, and black bears interacting. Find out if polar bears were different when the Arctic was warmer when peat was forming. Learn about bear adaptations to different temperatures. Analyze the genetic diversity in polar bears to see how much variation is in the population so we know if they have enough to adapt. Find out what the brown bears are doing in Wapusk. Do they live there or are they passing through?

Suggested prompt	Sample student response
<i>What additional sources of information would we need to help us answer our questions?</i>	Find fossils of bears. Get DNA from different bear populations. More information about the polar bear populations from the ecoregions that had incomplete information. More stories from people who live in other parts of the Arctic.

22 • NAVIGATE

5 min

MATERIALS: None

Students prioritize what question(s) to answer next. Display slide **VV**. Say, *We have a lot of questions that we want to try and find the answers to during our last unit. We also have a great list of ideas for how to investigate those questions.* Remind the class of the unit question, *What will happen to Arctic bear populations as their environment changes?*

Ask students to review the DQB and their initial ideas for investigation with the unit question in mind. After a minute, ask students to share what question they think the class should investigate next. As students identify specific questions or groups of questions, keep a record of which questions the class thinks should be answered next. Prompt students to consider what aspects of their models are the most incomplete and increasingly motivated to understand the mechanisms better. They might think about which types of data or information would be more readily available to begin. Push students to justify their choices with reasoning for why answering that question first would be best. Encourage students to connect their reasoning to the broader unit question.

Ask students to complete an exit ticket. Display slide **WW**. Ask students to tear out a half sheet of loose-leaf paper and, based on the DQB and ideas for investigation everyone just shared, write down their ideas for what the class should investigate next and why conducting that investigation would help the class make progress on the unit question.

Additional Lesson 1 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

Students read evidence from multiple texts and data sources to analyze the resilience of polar bear populations and predict the future stability of those populations.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

MP.2 Reason abstractly and quantitatively.

Students interpret graphs on temperature and extent of sea ice over time to make predictions about how these changes may affect polar bear populations. They use timelines and maps to build a picture of how different components in the ecosystem interact spatially and over time.

LESSON 2: How and why are bear species interacting and why might brown bears dominate?

PREVIOUS LESSON

We heard about a place called Wapusk where brown, black, and polar bears were recently seen together for the first time. We investigated why all three bears may be adapted to the habitats in this area. We conducted a data exploration about changes to Arctic ice and tundra due to climate change and investigated how the 3 bear species could be affected by those changes. We investigated the relationship between changing Arctic sea ice conditions and the stability of polar bear populations from Traditional Knowledge and Western scientific sources. We developed initial models to predict how changes in Arctic ice conditions due to a warming climate may affect different Arctic bear populations in the future. We developed a DQB and decided to further investigate traits that might allow brown bears to dominate over polar and black bears in the future.

THIS LESSON

INVESTIGATION

3 days



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We decide to investigate interactions between black, brown, and polar bears. We look at evidence from scientific studies and see that brown and polar bears are the most likely to interact and that polar bears are likely to run away. We investigate thermoregulation in our own bodies and use that evidence along with evidence about genetic differences in polar bears to make sense of overheating. We construct claims about what will happen in polar and brown bear interactions in the future. We wonder about other similarities and differences between the bears.

NEXT LESSON

We will investigate how similar/different the three species of bears are with anatomical and DNA evidence to build a tree to see that polar bears are most similar to brown bears and that they shared a recent common ancestor.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

2.A Make and defend claims about effects of internal conditions on bear behavior. (SEP 7.5; DCI LS1.A.4; CCC 2.4)

2.B Evaluate a claim to determine the merit of thermoregulation as a cause to explain polar and brown bear interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4)

WHAT STUDENTS WILL FIGURE OUT

- In interactions with brown bears around food, polar bears run away.
- When polar bears exercise, they overheat easily.
- Polar bear adaptations, including a variation of the NOS3 gene, cause polar bears to get hot.
- Other mammals, like humans, can regulate heat through sweating and other mechanisms.
- Polar bears can cool off when there is snow, but without it they get too hot and pass out.
- Genetic differences in thermoregulation may lead to brown bears dominating over polar bears in a warming Arctic.

Lesson 2 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Ask the class to recall what they figured out about each of the three bears in the previous lesson.	A	
2	5 min		INTRODUCE BEAR INTERACTIONS AND MAKE CLAIMS Support students in making claims to predict bear interactions.	B	<i>Bear Interaction Claims</i> , laminated Bear Adaptation poster from Lesson 1
3	10 min		INVESTIGATE BEAR INTERACTIONS Investigate data from bear interaction studies to identify evidence to support and refute claims.	C-G	<i>Bear Interaction Claims</i>
4	7 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT INTERACTION CLAIMS Facilitate a Building Understandings Discussion about student claims and reasoning.	H	<i>Bear Interaction Claims</i>
5	7 min		INITIAL IDEAS DISCUSSION AND EVALUATE A CLAIM ABOUT OVERHEATING Generate ideas from student experience about overheating and apply that to the polar bear.	I-K	<i>Bear Interaction Claims</i>
6	10 min		INTRODUCE NEW POLAR BEAR DATA Facilitate pairs of students in making sense of new polar bear data.	L-N	<i>Polar Bear Treadmill Data</i>
7	3 min		NAVIGATE Re-evaluate the claim about overheating.	O	
<i>End of day 1</i>					
8	3 min		NAVIGATE Review the claim students evaluated during the previous class.	P	
9	17 min		PLAN AND CARRY OUT A THERMOREGULATION INVESTIGATION Introduce an investigation and support students in deciding on additional variables to measure and carry out the investigation.	Q-U	<i>Human Thermoregulation Investigation</i> , infrared thermometer(s), timer
10	12 min		SMALL-GROUP SENSEMAKING Support small groups in making sense of their data.	V	<i>Human Thermoregulation Investigation</i>
11	8 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE THERMOREGULATION INVESTIGATION Facilitate a Building Understandings Discussion about the Human Thermoregulation Investigation.	W-Y	

Part	Duration		Summary	Slide	Materials
12	5 min		NAVIGATE: REVISIT CLAIM Facilitate an individual evaluation of the claim about overheating.	Z	<i>Human Thermoregulation Investigation</i>
<i>End of day 2</i>					
13	5 min		NAVIGATE Review feedback on claims with a partner.	AA	<i>Human Thermoregulation Investigation</i>
14	10 min		INVESTIGATE ADDITIONAL DATA Share additional evidence with students from a video and reading.	BB-DD	<i>Thermoregulation</i>
15	10 min		SMALL-GROUP CARD SORT Support small-group sensemaking with matter and energy cards.	EE	<i>Thermoregulation, Human Thermoregulation Investigation, dry erase marker, 3x3 sticky notes, Matter Energy Cards</i>
16	10 min		CONSENSUS DISCUSSION ABOUT OVERHEATING AS THE POSSIBLE CAUSE FOR POLAR BROWN BEAR INTERACTIONS Facilitate a Consensus Discussion about the role of overheating in bear interactions and what it might mean for the future.	FF	
17	10 min		NAVIGATE: INTRODUCE PROGRESS TRACKERS Introduce Progress Trackers and support students as they complete an entry for Lesson 2.	GG	<i>Progress Tracker</i>
<i>End of day 3</i>					

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Bear Interaction Claims</i> <i>Polar Bear Treadmill Data</i> <i>Human Thermoregulation Investigation</i> <i>Thermoregulation</i> <i>Progress Tracker</i>	- infrared thermometer(s) - timer - dry erase marker 3x3 sticky notes <i>Matter Energy Cards</i>	laminated Bear Adaptation poster from Lesson 1

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

For day 3, if you do not have access to a unit kit, print color copies, laminate, and cut cards from *Matter Energy Cards* for each group. These cards were also used in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

Day 2: Human Thermoregulation Investigation

- **Group size:** 3-5 students
- **Setup:** Gather enough infrared thermometers and timers for each group to have one of each.
- **Notes for during the investigation:** Make sure that students are respectful of one another and their different abilities when it comes to physical activity.
- **Safety:** Students will be engaging in exercise.
 - The activity zones must be well defined and free of any obstacles.
 - Only one participant is to be in each activity zone during the physical exercise.
 - Make sure there are no trip/fall or slip fall hazards in the activity zone.
 - Make sure there is someone monitoring the participant's movements while performing the activity.
 - Make sure the participant is not getting overheated or stressed while performing the physical exercise.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students investigate homeostasis in the context of the role it plays in interactions between polar and brown bears.

Students build on their middle school understanding of LS1.D: *Each sense receptor responds to different input (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain, resulting in immediate behaviors or memories.*

The lesson addresses the high school disciplinary core ideas: LS1.A.4 *Feedback mechanisms maintain a living system's internal conditions within certain limits and mediate behaviors, allowing it to remain alive and functional even as external conditions change within some range. Feedback mechanisms can encourage (through positive feedback) or discourage (negative feedback) what is going on inside the living system.*

Students also revisit the DCI LS1.C.4: *As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment.* (HS-LS1-7) Students worked with these ideas in OpenSciEd Unit B.2: *What causes fires in ecosystems to burn and how should we manage them? (Fires Unit).*

The science and engineering practice of *engaging in argument with evidence* is intentionally developed in this lesson as students use scaffolds on day 1 to support them in constructing claims supported by evidence.

Students use the crosscutting concept of *cause and effect* in similar ways as they have in previous OpenSciEd Biology units.

In this lesson, students will co-construct a definition for: *homeostasis, thermoregulation, positive and negative feedback*. Students encounter the term *refute*. Words should be defined and recorded in Personal Glossaries AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

In the context of homeostasis, this lesson focuses on temperature regulation and does not investigate other metabolic activities that contribute to homeostasis.

LEARNING PLAN for LESSON 2

1 · NAVIGATE

3 min

MATERIALS: science notebook

Navigate. Display *slide A*. Say, *We started this unit looking at three bear species that were seen by scientists in the same location for the first time. Ask students to share their ideas with an elbow partner as they discuss the questions on the slide. Note that in the camera images on the slide, the bears look bigger or smaller depending on how far they are from the camera. A scale drawing is included to help students think about the average size of bears of each species (from left to right, it shows polar, brown, and black bear). After a few minutes, have a few pairs share with the class.*

Suggested prompts	Sample student responses
What have we figured out about polar, brown, and black bears?	Some polar bear populations are declining in places where there is seasonally available ice. Brown bears are expanding their range as the tundra greens. We heard in the video that brown bears dominate when interacting with other bears. Black bears wander into the area from time to time, but they tend to live in areas where there are trees.
What questions do we still have about each of the bears?	What do interactions between each of the bears look like? When do these interactions happen? What does it mean that brown bears dominate?

2 · INTRODUCE BEAR INTERACTIONS AND MAKE CLAIMS

5 min

MATERIALS: science notebook, *Bear Interaction Claims*, laminated Bear Adaptation poster from Lesson 1

Make claims about possible bear interactions. Display *slide B*. Say, *We know that brown, black, and polar bears are more likely to interact as the Arctic warms, especially in areas with seasonally available ice. Distribute Bear Interaction Claims. Ask students to work with a partner and construct a claim * about how and why they think the different combinations of bear species will interact. Reference the laminated Bear Adaptation poster from Lesson 1 to remind students of what they figured out already about the three species of bears. Encourage them to utilize readings and handouts in their science notebooks from Lesson 1 to support them. Call on a few pairs to share their predictions. At this point, predictions will vary widely.*

*** SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE**

Students make a claim based on evidence that reflects scientific knowledge, including technical and scientific information adapted for classroom use. The scaffolds provided in *Bear Interaction Claims* support students as they learn to identify both evidence that supports and refutes their claim and to use that evidence to provide reasoning.

3 · INVESTIGATE BEAR INTERACTIONS

10 min

MATERIALS: science notebook, *Bear Interaction Claims*

Use bear interaction data to cite evidence to support claims. Say, *You all have a lot of interesting ideas about how the bear species might interact. Where can we look for evidence to support your claims?* Listen for students to say that we can observe bears on webcams or look at data scientists have collected. Introduce the brown and black bear interaction data on **slide C**. Pause to give students time to add evidence to their handouts. They should include both evidence that supports and refutes their claim. If students have not previously encountered the definition for *refute*, pause to add a definition similar to *show to be false or contradict* to their Personal Glossaries.

 Display **slide D**. Prompt students to consider what they might infer based on the lack of data about polar and black bear interactions. Continue to **slide E**. Before sharing the data on the following slides with students, pause to ask them to consider the prompt on the slide. Use the sample responses below as a guide.

Suggested prompts	Sample student responses
Why did scientists study polar and brown bear interactions in a location with seasonally available ice in September?	Polar and brown bears will be together on land. The polar bears are on land with the brown bears because they are waiting for the ice to freeze.
What do we know about polar and brown bear behavior in September?	Brown bears are eating a lot and getting ready to hibernate. Polar bears are waiting for the seasonally available ice, may have been fasting, and are likely quite hungry.

Introduce the polar/brown bear interaction study. Introduce the study location on **slide F** and share the data on **slide G**. Pause again for students to record any evidence that supports or refutes their claim in *Bear Interaction Claims*.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See *Bear Data Analysis* for sample student responses.

What to do: Listen in on small-group conversations to make sure students use relevant evidence to support their claims from the scientific studies. The polar bear-brown bear interaction is the most complex. Prompt students with the following:

- Which evidence supports and which refutes your claim?
- At what time of the year is the interaction between polar and brown bears happening?
- What are the bears doing at this time?
- What is going on inside the bear that might cause polar bears to overheat?

Building toward 2.A Make and defend claims about effects of internal conditions on bear behavior. (SEP 7.5; DCI LSI.A.4; CCC 2.4)

4 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT INTERACTION CLAIMS

7 min

MATERIALS: science notebook, *Bear Interaction Claims*

Building Understandings Discussion about claims and reasoning. * Display **slide H** and invite groups to share their claims and reasoning. As one group shares, record their claim and reasoning on the whiteboard or other public space. Ask other groups to add additional reasoning to support each claim.

*** STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION**

Suggested prompts	Sample student responses	Follow-up questions
<i>Who can share a revised claim supported by reasoning for the brown and black bear interactions?</i>	Black and brown bears will live in the same areas as more brown bears move into the Arctic, but black bears will avoid brown by keeping to the trees and being active at different times of day because black bears are smaller and are at risk of being killed by brown bears.	<i>What kinds of habitats do brown bears and black bears spend most of their time in?</i> <i>Why might black bears avoid brown bears?</i> <i>What evidence did scientists find of black bears avoiding brown bears?</i>
<i>Who can share a revised claim supported by reasoning for the polar and black bear interactions?</i>	Black bears will avoid polar bears in space (and maybe time) because they have really different habitats and diets. If black bears are at risk for being killed by brown bears, they might also be killed by polar bears because black bears are much smaller.	<i>Why might there be a lack of evidence of polar and black bear interactions?</i> <i>How are the habitats, diets, behaviors of black and polar bears different from each other?</i> <i>How could those differences keep them from interacting?</i>
<i>Who can share a revised claim supported by reasoning for the polar and brown bear interactions?</i>	Polar bears will come into more contact with brown bears on seasonally available ice, especially in the fall, as the Arctic warms but will avoid/run away from brown bears because they are weak (low body mass and fat) and overheat easily.	<i>The polar and brown bear interaction data was collected in September, what are the brown and polar bears doing in September?</i> <i>What kind of physical shape will polar and brown bears be in?</i> <i>How hungry will these bears be?</i> <i>Which bear is typically larger?</i>
<i>What evidence is hard to reason with or does not support your claim?</i>	The polar bear is really big and really hungry and gets scared away from the whale by the brown bear. Why does the polar bear run away from the brown bear and the food?	<i>Some of you thought the polar bear would scare away the brown bear. What evidence supports that claim?</i> <i>What evidence refutes that claim?</i> <i>Do we have enough evidence to reason about why this happens?</i>

A Building Understandings discussion is a useful kind of discussion following an investigation because the purpose is to focus students on writing claims based on evidence. Your role during the discussion is to invite students to share claims and push them to support them with evidence. Students can disagree with each other and the class does not need to reach consensus on all ideas shared. Areas of disagreement can motivate future investigations. Helpful prompts during these kind of discussions include:

- What can we conclude?
- How did you arrive at that conclusion?
- What's your evidence?
- Does any group have additional evidence to support A's claim?
- What data do we have that challenges B's claim?

5 · INITIAL IDEAS DISCUSSION AND EVALUATE A CLAIM ABOUT OVERHEATING

7 min

MATERIALS: science notebook, *Bear Interaction Claims*

Summarize what we have figured out so far. Say, *I heard some interesting ideas and some disagreement about the reasons that the polar bear might run away from food when they encounter brown bears even if they are very hungry. In my own research, I found an interesting claim made by scientists about polar bear behavior that might help us move forward.* Display **slide 1** and read the claim to students.

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

Initial Ideas Discussion about overheating. Say, *Before we make sense of the claim, let's make sure we have a common understanding of what overheating means.* Display **slide J** and ask students to turn and talk to a partner about what happens when an animal overheats, using their own personal experiences. Use the prompts below as a guide to a whole-class discussion.*

Suggested prompt	Sample student response
What causes overheating?	It being hot outside. Doing something physically challenging, like exercising hard (running, playing sports). When you cannot cool your body down.
How do you keep yourself cool so you do not overheat?	Drink water, stop moving, go inside in the air conditioning. Remove some clothes or take a cold shower.
What happens when you or other animals overheat?	You sweat, turn red. Pant. Shed fur. You pass out, faint, throw up, fall down and maybe go unconscious.
How could overheating help explain the interactions we saw between brown and polar bears?	If the polar bears are trying to avoid overheating, they might avoid conflict. Fighting over food with the brown bears might make the polar bears overheat.

The discussion is an opportunity to elicit and build on students' own experiences with overheating. The ideas students generate from their own lived experiences are useful building blocks for understanding thermoregulation, homeostasis, and feedback. Eliciting these ideas provides an entry point for all students to participate meaningfully as the class works together to move their science thinking forward.

KEY IDEAS

Purpose of this discussion: To elicit initial ideas about overheating based on student experience.

Listen for these ideas:

- Exercise and ambient temperature may cause overheating.
- The human body has some ways to cool itself off (e.g., sweating).
- Other animals may have different ways to cool off.
- Overheating might affect interactions.

Turn and talk about the claim. Display **slide K**. Ask students to turn and talk about the questions on the slide and record their ideas in their science notebooks. Call on a few students to share their thinking. Listen for students to suggest that they need evidence that polar bears actually overheat and/or evidence about how the polar bear heats and cools its body in order to support the claim.

6 · INTRODUCE NEW POLAR BEAR DATA

10 min

MATERIALS: science notebook, *Polar Bear Treadmill Data*

Introduce a polar bear video. Say, *I found a video of polar bears at the Portland, Oregon Zoo that I thought might help us think about polar bears and overheating.* Display **slide L** and ask students to set up a Notice and Wonder chart in their science notebooks. Then, play <https://www.youtube.com/watch?v=lf3Sca8g9M&t=17s> and ask them to jot down their ideas as they watch. Call on a few students to share their ideas,

especially those related to overheating.

Introduce new polar bear data. Say, *You all noticed the polar bear walking on the treadmill! I have some data that scientists collected to understand more about what is happening inside the polar bears on the treadmill.* Display **slide M** and distribute *Polar Bear Treadmill Data* to each student. Ask students to turn and talk to a partner about what the treadmill data can tell us. Then, call on a few pairs to share their thinking, using the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>Who can summarize the data?</i>	The faster the treadmill goes, the more and longer breaks they take. As their walking speed increased, their body temperature increased. The polar bear body temperature increased to almost 104 degrees F.	<i>How hot did the polar bears get on the treadmill?</i>
<i>What does this tell us about polar bears and overheating?</i>	When the bears have more movement, they get too hot and have to stop and cool off. Polar bears get really hot when they exercise.	<i>Do you think your temperature goes up to 104 degrees F when you exercise?</i> <i>How do polar bears avoid overheating?</i>
<i>How does this help explain the interactions like those we saw between polar and brown bears in September on seasonally available ice?</i>	The polar bears might run/walk away because they want to avoid overheating that might occur if they got aggressive with a brown bear. There is not any ice or snow in September, so if they get really hot from fighting over food, they might not be able to cool off.	<i>When you have a temperature of 104 degrees F, how do you feel?</i> <i>How would a polar bear cool off on land in the late summer?</i> <i>What would happen to a polar bear who overheated in Alaska in September when there is no snow or ice?</i>

Update Personal Glossaries. Say, *As you all have described the polar bear getting hot and finding ways to cool down, you have described what scientists call thermoregulation.* Display **slide N**. Pause to give students a moment to add this definition to their Personal Glossaries. Definitions may look like: *how the body maintains a constant temperature.*

7 · NAVIGATE

3 min

MATERIALS: science notebook

Re-evaluate the claim about overheating. Display **slide O**. Ask students to respond to the prompts on the slide in their science notebooks and be prepared to share at the beginning of the next class.

End of day 1

8 · NAVIGATE

3 min

MATERIALS: science notebook

Revisit the claim students evaluated on day 1. Display **slide P**. Ask to review the claim evaluated in their science notebooks. Call on a few students to share their ideas using the prompts below as a guide.

Suggested prompts

How did the new evidence from the treadmill data help you decide whether the claim has merit?

The data we investigated was about a single polar bear, and we do not have access to additional data. How can we learn more about overheating? What else do we need to know?

Sample student responses

We saw that when the polar bear exercised, its body temperature went up.

When it exercised for a long time and its body temperature went up, it got off the treadmill more to roll in and eat snow.

We can study ourselves.

We could study something similar to a polar bear.

9 · PLAN AND CARRY OUT A THERMOREGULATION INVESTIGATION

17 min

MATERIALS: science notebook, *Human Thermoregulation Investigation*, infrared thermometer(s), timer

Introduce a thermoregulation investigation. Say, *Those are great ideas. We cannot exactly replicate the polar bear treadmill study in our classroom, but I have some ideas for how we can adapt it.* Display **slide Q** and explain to students that you have some infrared thermometers and that they can exercise in class and collect temperature data that will help answer the class's questions. Distribute *Human Thermoregulation Investigation* to each student. *

Decide on additional variables. Say, *Temperature is one variable that can give us information about thermoregulation. What other variables would help us understand how we regulate body temperature so we can understand more about thermoregulation?* Display **slide R** and ask students to turn and talk with a partner. Ask pairs to share their ideas and come to a consensus on variables that class would like to measure. Examples include pulse, breathing rate, perspiration rate, and sweat level. Make sure the class determines how they will collect data while the participants are doing jumping jacks.



Carry out investigation and collect data. Display **slide S** and **slide T** and review safety protocols with students. Then organize students into small groups of 3-5, distribute thermometers and timers, and instruct them to begin their investigations. Display **slide U**. Make sure students in each group feel comfortable volunteering for or passing on being the study participant and that each group knows who is collecting which data and how. * While students collect data, make a class data table (see example below) on the whiteboard or other public space and ask a representative from each group to fill in their data. *

Time (min)	Group 1 Temperature	Group 2 Temperature	Group 3 Temperature	Group 4 Temperature	Group 5 Temperature	Group 6 Temperature	Class Average
0							
2							
4							

* ATTENDING TO EQUITY

For students with different abilities related to mobility, consider alternate movements, such as wheelchair sprints or vigorous arm movements. Varying the activity type can support meaningful participation for students with different needs.

* ATTENDING TO EQUITY

Universal Design for Learning: This is an important opportunity to emphasize that each individual has a contribution to make to the classroom community. Here, students have an opportunity to choose how they participate by carrying out the exercise portion of the investigation, serving as a control case, or by collecting data. Allow students to participate in ways they feel good about and encourage all students to recognize everyone's contribution even when it looks different from their own.

6							
8							

ADDITIONAL GUIDANCE

In this investigation, students will use infrared thermometers to measure the body temperature of their classmates as they exercise. In the polar bear treadmill study, a probe was implanted in the bears to measure core body temperature. Ask students to consider the differences they might observe between core body temperature and skin temperature. Additional information about infrared thermometers can be found at: <http://www.fda.gov/medical-devices/general-hospital-devices-and-supplies/non-contact-infrared-thermometers> <https://www.fda.gov/medical-devices/general-hospital-devices-and-supplies/non-contact-infrared-thermometers>.

* SUPPORTING STUDENTS IN ENGAGING IN PLANNING AND CARRYING OUT INVESTIGATIONS

Students use elements of this practice as they plan their investigation by choosing additional variables and determining how they will be measured. They may want to establish a control case and measure a student that is not exercising to compare temperature and other variables over time in classmates that are exercising vs. not.

10 · SMALL-GROUP SENSEMAKING

12 min

MATERIALS: *Human Thermoregulation Investigation*



Complete Making Sense questions in small groups. Display slide V. As students finish collecting data, remind them to return their supplies to the designated locations and direct them to the Making Sense questions on *Human Thermoregulation Investigation*.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Evidence about thermoregulation that supports claims that explain interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4)
 - Polar bear temperature rises during exercise.
 - To cool off, polar bears use snow.
 - Our body temperature did not rise that much during exercise.
 - We had a lot of ways to cool off (sweating, breathing hard, etc.)

What to do: Circulate around the room and support small-group discussion. Use *Thermoregulation Investigation Key Collect Human Thermoregulation Investigation* from each student at the end of class to evaluate student responses. Provide feedback on student claims to support revision and ask students to resubmit.

Building toward 2.B.1 Evaluate a claim to determine the merit of thermoregulation as a cause to explain polar and brown bear interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4)

11 · BUILDING UNDERSTANDINGS DISCUSSION ABOUT THE THERMOREGULATION INVESTIGATION

8 min

MATERIALS: science notebook

Display slide W. Guide students in a Building Understandings Discussion using the prompts below.*

Suggested prompts	Sample student responses
What does the class data tell us about how human body temperature changes during exercise?	Human body temperature stays relatively constant during exercise.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

As students share their ideas, encourage them to provide specific evidence to justify how the evidence from their own investigation supports their ideas about thermoregulation in polar bears.

Suggested prompts	Sample student responses
How is it similar or different to what we saw in the polar bear treadmill study?	Polar bear temperature went way up during exercise where ours stayed more constant.
When we got hot, we did not stop and roll in or eat snow. What evidence do we have about how we cooled off?	We sweated, breathed harder, our faces turned red. We lost heat through our sweat, and our blood moved more to our skin to transfer heat.
Where did the heat come from when we exercised and where did it go when we cooled off?	The heat came from our muscles moving. It went to the air when our sweat evaporated. Our blood brought it to our skin, which is why we turned red. We were breathing heavily to get rid of more carbon dioxide.
What explains the difference between humans and polar bears?	Polar bears have adaptations like thick fur and fat that keep them from losing heat, and they are not good at sweating. Polar bears keep their heat in and can overheat if they do not rest or cool off.
KEY IDEAS	Purpose of this discussion: To use students' own experiences to build understanding about thermoregulation in polar bears. Listen for these ideas: - Humans thermoregulate by sweating and breathing hard when exercising to get rid of some of the heat from the muscles. - Polar bears are not as good at thermoregulating, so they keep more of the heat in. Update Personal Glossaries. Display slide X. Let students know that they have just described ideas that scientists refer to as <i>negative feedback</i> and <i>positive feedback</i>. Describe how each type of feedback works and give students an opportunity to come to consensus on definitions to add to their Personal Glossaries. Negative feedback may be similar to: <i>when the body gets hot and goes above our normal range and cooling mechanisms kick in to bring our body temperature back down to a set point, which in humans is approximately 98.6 degrees F</i> and <i>positive feedback is where the body temperature moves farther away from the set point and ends with overheating</i>. Let students know that negative and positive feedback are part of what scientists call <i>homeostasis, the ability to maintain a steady internal state as external conditions change</i>. They will encounter this definition again on day 3. Display slide Y after students have discussed feedback and talk through the image to help students with their entries.
ADDITIONAL GUIDANCE	Students will likely be familiar with feedback from <i>OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)</i> . Remind them they worked with this idea in the context of carbon dioxide and temperature in Earth's atmosphere. They can update the definition in their Personal Glossaries or make new entries.

12 · NAVIGATE: REVISIT CLAIM

5 min

MATERIALS: *Human Thermoregulation Investigation*

 **Revisit claim.** Display **slide Z**. Ask students to revise their response to the final question on *Human Thermoregulation Investigation* and turn in before they leave class.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Evidence about **thermoregulation** that supports **claims** that explain **interactions**. (SEP 7.2; DCI LS1.A.4; CCC 2.4)
 - Polar bear temperature rises during exercise.
 - To cool off, polar bears use snow.
 - Our body temperature did not rise that much during exercise.
 - We had a lot of ways to cool off (sweating, breathing hard, etc.)

What to do: Collect *Human Thermoregulation Investigation* from each student. Provide feedback on student claims using *Thermoregulation Investigation Key* and return to students at the beginning of day 3.

Building toward 2.B.2 Evaluate a claim to determine the merit of **thermoregulation** as a **cause** to explain polar and brown bear **interactions**. (SEP 7.2; DCI LS1.A.4; CCC 2.4)

End of day 2

13 · NAVIGATE

5 min

MATERIALS: science notebook, *Human Thermoregulation Investigation*

Review evidence for claims. Return *Human Thermoregulation Investigation* with your feedback to each student. Display **slide AA**. Organize students into pairs and ask them to review the feedback and discuss the prompts on the slide. Call on a few student pairs to share their ideas for additional evidence.

Listen for the following ideas:

- Does the polar bear get so hot because of its fur?
- Is overheating something that is inherited?
- Do all polar bears have this?
- Do brown bears overheat?
- If there is no snow, will the polar bears have no way to cool down?

14 · INVESTIGATE ADDITIONAL DATA

10 min

MATERIALS: *Thermoregulation*, science notebook

Watch a video about polar bear adaptations. Say, *I have a video that gives an overview of polar bear traits*. Display **slide BB**. Ask students to set up a Notice and Wonder chart in their science notebooks. Play the video <https://www.youtube.com/watch?v=n3ahSPfZfqU> and give students time to record their ideas in their science notebooks. Call on a few students to share their ideas. Listen for students to notice that polar bears have thick fur that might make it hard for them to cool off.

* ATTENDING TO EQUITY

To encourage equitable participation in small groups, use a **discussion diamond** routine to support students as they make sense of the

Introduce a reading. Say, *You noticed some traits that could affect thermoregulation. I found one more data source for us to investigate.* Display slide CC. Distribute *Thermoregulation* to each student and give them time to read and annotate using whatever literacy strategy is in place in your classroom.

Small-group discussion. Display slide DD. Organize students into small groups of 3-4 students and have them discuss and record their responses to the questions in their science notebooks. Circulate around the room and support student small-group discussion.

NOS3 gene and how it affects thermoregulation in bears. Students can make a diamond on a piece of notebook paper and place it in the center of the table. Each student writes their own ideas on their triangle/corner. Every group member shares. The group decides on which ideas are best supported by evidence and writes this in the middle of the diamond.

15 · SMALL-GROUP CARD SORT

10 min

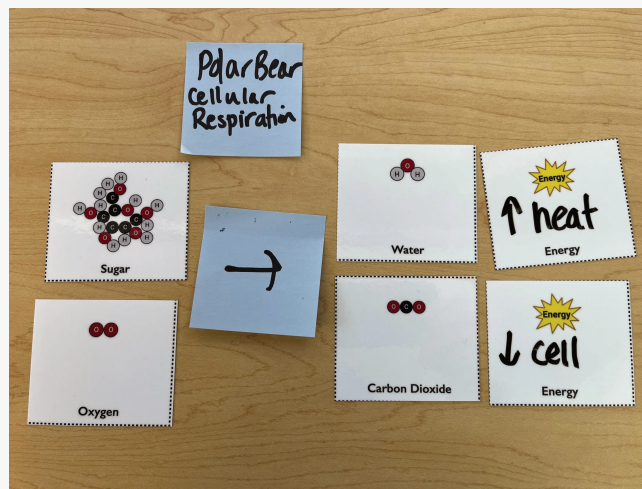
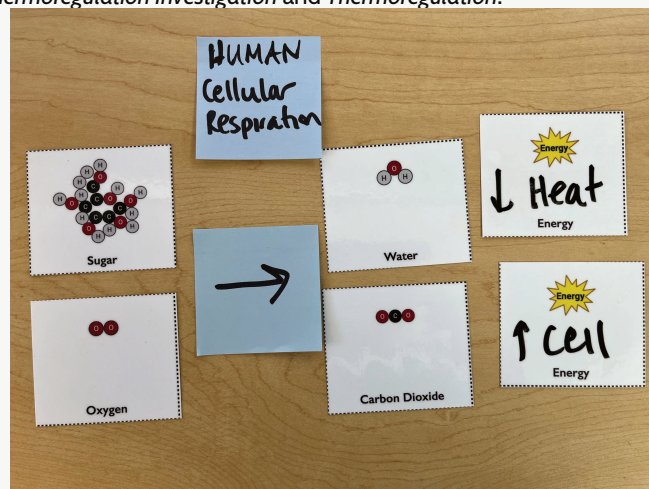
MATERIALS: *Thermoregulation*, *Human Thermoregulation Investigation*, dry erase marker, 3x3 sticky notes, *Matter Energy Cards*

Review cellular respiration. Display slide EE. Remind students that in *Decomposition Investigation Data and Sensemaking* they figured out ideas about cellular respiration. Say, *Let's take a minute to revisit cellular respiration and make sense of it in this new context.* Ask students to turn and talk about what they remember about cellular respiration from *Fires Unit*.

Listen for students to share:

- Yeast “ate” sugar and turned it into carbon dioxide, water, and energy.
- The yeast used the energy to grow and carry out their functions.

 **Small-group card sort.** Organize students into small groups of 3-5 students. Distribute a set of matter and energy cards to each group. Ask students to use the cards to explain thermoregulation in both polar bears and humans. Encourage students to use *Human Thermoregulation Investigation* and *Thermoregulation*.



ADDITIONAL GUIDANCE

In the *Fires Unit*, students figured out ideas related to HS-LS1.C *As a result of these chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases the energy needed to maintain body temperature despite ongoing energy transfer to the surrounding environment when making sense of decomposition in the Arctic. Here, they add new ideas about how cellular respiration in muscles during exercise can generate both cellular energy and heat.*

16 · CONSENSUS DISCUSSION ABOUT OVERHEATING AS THE POSSIBLE CAUSE FOR POLAR BROWN BEAR INTERACTIONS

10 min

MATERIALS: science notebook

 Display **slide FF** and facilitate a Consensus Discussion * about whether or not we have enough evidence to say that the claim that overheating causes polar bears to run away from brown bears in interaction has merit in explaining why brown bears might dominate.

* STRATEGIES FOR THIS CONSENSUS DISCUSSION

The Consensus Discussion is an important opportunity to support students in building a common class-level understanding about interactions between bear species and whether the claim about overheating being a cause for the brown bears might dominate in the future is supported by enough evidence to have merit. Your role is to help them identify where they agree and disagree and resolve conflict whenever possible.

Suggested prompts	Sample student responses	Follow-up questions
<i>What evidence do we have to support the claim that polar bears overheat?</i>	Polar bears do get really hot (more than us) when they exercise. Polar bears turn more energy into heat than we (or other bears) do because of the NOS3 gene . Polar bears hold a lot of heat through their fur. Polar bears do not have any easy time cooling off by sweating.	<i>What evidence do we have about polar bears overheating?</i>
<i>We saw polar bears interacting with brown bears around food on land in September. How does our evidence explain why they ran away?</i>	Since polar bears are likely to overheat and it is hot at that time of year, they avoid conflict.	<i>Why do polar bears avoid conflict in September?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>How could this lead to brown bears dominating in the future?</i>	If the Arctic gets warmer, polar and brown bears will interact more. Polar bears will be trapped on land for longer waiting for ice and will not be able to compete for food with brown bears. If the polar bears only have the NOS3 allele, they will keep overheating as it gets hotter. Brown bears have more variation in the NOS3 gene, so they will be better able to deal with the heat.	<i>Will polar and brown bears interact more or less often in the future? Why?</i> <i>What evidence do we have that brown bears would dominate?</i>
<i>In terms of evaluating our claim, is the claim well enough supported by evidence and reasoning to have merit?</i>	Yes, there is a good deal of evidence, and the reasoning makes sense.	<i>Have we included all of the evidence we learned about in this lesson?</i>

KEY IDEAS

Purpose of this discussion: To build consensus about whether the claim that brown bears will dominate due to polar bears overheating is supported by enough evidence to have merit.

Listen for these ideas:

- We have evidence that polar bears are likely to overheat.
- In the future, there will be more opportunities for polar and brown bears to interact.
- The temperature will get warmer, and polar bears have a gene that makes it harder for them to manage heat/maintain homeostasis.
- The claim is supported by evidence and has merit.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Evidence about thermoregulation that supports claims that explain interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4)
 - Polar bears have a difficult time cooling off due to the NOS3 gene variant they have.
 - It will be hotter and there will be less snow, so it will be even harder to cool off.
 - Brown bears have variation in the NOS3 gene, so they will be better able to deal with heat than polar bears.

What to do: If students need additional support with the mechanism of overheating the the NOS3 gene, organize them in pairs and ask them to work again with the Matter and Energy cards and *Thermoregulation* and explain to each other thermoregulation in a warming Arctic.

Building toward 2.B.3 Evaluate a claim to determine the merit of thermoregulation as a cause to explain polar and brown bear interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4)

MATERIALS: *Progress Tracker*

Propose starting a Progress Tracker to keep track of ideas. Display slide **GG**. Say, *We have figured out a lot about polar bear thermoregulation and how that affects bear interaction. Let's capture what we have figured out in this lesson.* Distribute *Progress Tracker* to each student and have students complete a row for Lesson 2.

	What we figured out (WWFO)	How does WWFO help us make progress on figuring out the future of Arctic bear populations?	How does WWFO connect to me or my community or have a larger-scale impact?	What questions do I have now?
Lesson 2: How and why are bears interacting?	-Brown and polar bears will continue to interact as the Arctic warms where there is seasonal ice. -Brown bears may dominate because the polar bear overheats and runs away from brown bears around food.	-If the brown bears scare the polar bears away from food and the ice stays away for longer, the polar bears may not have enough to eat while they wait for the ice, and the population may decline.	We also behaviorally change if our body temperature is too high or too low.	How did the bears get this NOS3 gene variant? Why do brown and black bears not have this variant? What other genes do bears have in common/different?

Additional Lesson 2 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

Students read different polar bear studies and draw information from each case study to explain the fluctuations in their body temperature.

LESSON 3: How similar/different are the polar, brown, and black bears?

PREVIOUS LESSON

We decided to investigate interactions between black, brown, and polar bears. We looked at evidence from scientific studies and saw that brown and polar bears were the most likely to interact and that polar bears were likely to run away. We investigated thermoregulation in our own bodies and used that evidence along with evidence about genetic differences in polar bears to make sense of overheating. We constructed claims about what will happen in polar and brown bear interactions in the future. We wondered about other similarities and differences between the bears.

THIS LESSON

INVESTIGATION

2 days



We decide to investigate how similar/different the three species of bears are. We investigate similarities and differences in anatomical evidence and realize it is hard to figure out how the bears are related. We decide to use DNA evidence and build a tree of the polar, brown, and black bears with five other bear species. We figure out that polar bears are most similar to brown bears and that they shared a more recent common ancestor than they do with other bears. We want to figure out more about what was happening when polar and brown bears split from a common ancestor.

NEXT LESSON

We will look at evidence from glacial and interglacial periods, fossils, and genetics to construct an argument to explain why polar bears and brown bears split from their common ancestor.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

3.A Integrate empirical evidence, including anatomical and genetic information, to infer evolutionary relationships in bear species. (SEP 8.2; DCI: LS4.A.1; CCC 1.5)

WHAT STUDENTS WILL FIGURE OUT

- We have evidence that polar, brown, and black bears have a lot of similarities and differences based on anatomy and behavior.
- We can use trees to communicate our hypotheses about relationships among bear species.
- Polar bears and brown bears are more genetically similar to each other than they are to any other bear species.
- Polar bears and brown bears share a more recent common ancestor than they do with other bears

Lesson 3 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Ask students to share what they figured out from the previous class.	A	
2	10 min		INITIAL IDEAS DISCUSSION ABOUT SIMILARITIES AND DIFFERENCES BETWEEN BEAR SPECIES Elicit initial ideas around similarity/differences between bear species.	B	<i>Bear Traits Organizer</i> , Bear Adaptation Poster from Lesson 1
3	19 min		INVESTIGATION INTO SIMILARITIES AND DIFFERENCES BETWEEN BEAR SPECIES Introduce and organize a station investigation.	C	<i>Bear Traits Organizer</i> , Station Investigation Cards (https://docs.google.com/presentation/d/1RRZxTWCTuGrqSeBOuQGURdylo-gZyx9SCLbREmDI3m4/edit#slide=id.p), 2 sets of bear claws, 4 metric rulers
4	10 min		MAKE SENSE OF SIMILARITIES AND DIFFERENCES Support small groups in making sense of their evidence.	D	<i>Bear Traits Organizer</i>
5	3 min		NAVIGATE: UPDATE PROGRESS TRACKER Support students in updating their Progress Trackers.	E	<i>Progress Tracker</i>
End of day 1					
6	5 min		NAVIGATE Facilitate a Turn and Talk about what the class figured out and questions that remain.	F	<i>Bear Traits Organizer</i>
7	12 min		INVESTIGATE RELATEDNESS USING DNA Introduce students to DNA data to identify relationships.	G-L	
8	15 min		BUILD A BEAR TREE USING DNA Introduce students to a computer program that can analyze differences in DNA between species.	M-P	<i>Bear DNA Tree</i> , <i>Bear DNA Sequences</i>
9	12 min		NAVIGATE: ELECTRONIC EXIT TICKET Ask students to complete an Electronic Exit Ticket.	Q	https://docs.google.com/forms/d/1Ln6ypozASssLBwCpFn_YlQFg59ezXcusRvyHzZZin28/copy
End of day 2					

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Bear Traits Organizer</i> <i>Progress Tracker</i> <i>Bear DNA Tree</i> https://docs.google.com/forms/d/1Ln6ypozASssLBwCpFn_YlQFg59ezXcusRvyHzZZin28/copy	<i>Bear DNA Sequence</i>s	- Bear Adaptation Poster from Lesson 1 - Station Investigation Cards (https://docs.google.com/presentation/d/1RRZxTWCTuGrqSeBOuQGURdylo-gZyx9SCLbREmDI3m4/edit#slide=id.p) 2 sets of bear claws 4 metric rulers

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

For day 1, set up the stations around the room so there are 2 locations for each of the 4 stations and each station has a full set of slides. If a kit is not available, slide decks can be printed and laminated from <https://docs.google.com/presentation/d/1RRZxTWCTuGrqSeBOuQGURdylo-gZyx9SCLbREmDI3m4/edit#slide=id.p>. Each of the two locations for station 4 should have a black, brown and polar bear claw as well as 2 metric rulers. Bear claws can be found in the unit kit or sourced from Bone Clones (item #s: KO-049, KO-047, and KO-048).

Make sure each small group has access to an internet-connected device that can run <https://docs.google.com/presentation/d/1RRZxTWCTuGrqSeBOuQGURdylo-gZyx9SCLbREmDI3m4/edit#slide=id.p>.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

The lesson addresses the high school disciplinary core idea LS4.A: Evidence of Common Ancestry and Diversity:

- Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

Students use elements of the science practice *Obtaining, Evaluating, and Communicating Information* to extract information from scientific data to build trees (phylogenies) and explain them to their peers.

Students will co-construct the definition for common ancestry.

Where We Are NOT Going

This lesson uses a nuclear intron sequence to build a phylogenetic tree. It does not discuss the differences between trees developed with maternal, paternal, or somatic DNA, as those concepts are beyond the scope of this unit.

Students will see a number of terms used in determining evolutionary relationships on the computer program. Many of these are beyond the scope of the lesson but can be added to Personal Glossaries as encountered. These include cladograms, phylograms, and phylogenetic trees.

LEARNING PLAN for LESSON 3

1 · NAVIGATE

3 min

MATERIALS: science notebook

Review what we figured out in our last lesson. Display **slide A**. Ask students to review their science notebooks and share their ideas about the displayed prompts, first with a partner and then with the class.

Suggested prompts	Sample student responses
What did we figure out in our last class?	Polar bears are adapted to life at cold temperatures, but these adaptations might be costly because they could overheat with a lot of activity or maybe in warm temperatures or when they have to compete with brown bears for food. Polar bears have a version of the NOS3 gene that the other bears do not have, so they make more heat.
What new questions did we have?	How did the bears get this NOS3 gene variant/allele? Why do brown and black bears not have this variant? Are there other traits that we can look at that might be important?

2 · INITIAL IDEAS DISCUSSION ABOUT SIMILARITIES AND DIFFERENCES BETWEEN BEAR SPECIES

10 min

MATERIALS: science notebook, *Bear Traits Organizer*, Bear Adaptation Poster from Lesson 1

Orient students to similarities and differences between bear species. Say, *Brown and black bears are similar in the variation they have in the NOS3 gene, and polar bears are different. We know a lot about other traits that the bears have. Let's take a few moments to organize what we already know.*

Small-group work to organize similarities and differences. Display **slide B**. Distribute *Bear Traits Organizer* to each student. Organize students into small groups of 3-5 students and ask them to work with their group to visually organize the similarities and differences between the three bear species. Encourage them to reference other materials from earlier lessons in their science notebooks, such as the readings and Bear Adaptation Poster from Lesson 1.

Initial Ideas Discussion about similarities and differences. Facilitate a class discussion by asking each group to share what they came up with about the similarities and differences they identified. *

* STRATEGIES FOR THIS INITIAL IDEAS DISCUSSION

The purpose of this discussion is to get student initial ideas on the table. Students should draw on resources from Lessons 1 and 2 as they consider what they already know about the three bear species. The small-group work before the discussion gives students an opportunity to first share their ideas with peers before they share with the whole class.

KEY IDEAS

Purpose of this discussion: To elicit what students already understand about similarities and differences in bear species.

Listen for these ideas:

- The polar and brown bears are similar in size; the black bear is smaller.
- The brown and black bears both hibernate; the polar bear does not.
- Brown bears are the most aggressive. Black and polar bears avoid conflict.
- Brown and black bears have more overlap in fur color; the polar bear is more different.
- Polar bears have the NOS3 gene allele that makes them overheat; brown and black bears have more variation.
- Black and brown bears eat a lot of plants; polar bears mainly eat meat.

3 · INVESTIGATION INTO SIMILARITIES AND DIFFERENCES BETWEEN BEAR SPECIES

19 min

MATERIALS: *Bear Traits Organizer*, Station Investigation Cards (<https://docs.google.com/presentation/d/1RRZxTWCTuGrqSeBOuQGURdylo-gZyx9SCLbREmDI3m4/edit#slide=id.p>), 2 sets of bear claws, 4 metric rulers

Introduce an investigation. Say, *We already have a lot of information to organize about the bear similarities and differences. What other traits might help us understand what will happen to bear species in the future?* Listen for students to suggest traits related to food and survival. Let them know that you have some additional information about each of the three bear species that might help. Display **slide C**. Review the additional resources that you have organized into the station investigation. Let students know that with their group, they will visit each of the 4 stations, 1) General Information, 2) Skulls, 3) Teeth, and 4) Claws, and record similarities and differences they find on *Bear Traits Organizer*.

Organize a station investigation. Organize students into groups of 3-5 students. Ask them to travel to each of the 4 stations and follow the prompts at the station. Consider setting a timer that goes off every 3-5 minutes to indicate they should move on to another station. They should add new information to *Bear Traits Organizer* about similarities and differences between each of the bear species.

4 · MAKE SENSE OF SIMILARITIES AND DIFFERENCES

10 min

MATERIALS: science notebook, *Bear Traits Organizer*

Small-group discussion about bear species similarities and differences. Display **slide D**. Ask students to discuss the prompts on the slide, record their responses in their science notebooks, and be ready to share their ideas with the whole class.



Whole-class discussion about similarities and differences. Lead a whole-class discussion about similarities and differences using the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
What did you figure out about similarities and differences between the bears?	The black and brown bears have the most in common; the polar bears are more different. The skulls all seem really similar; I am not sure.	Why do the black and brown bears have more in common? Why are they all so similar?

Suggested prompts	Sample student responses	Follow-up questions
<i>How can the similarities and differences help us predict what will happen to the bear populations as the Arctic changes?</i>	The black and brown bears can eat a diet of plants and animals, and not being specialized will help them. If the black and brown bears are more closely related, they probably have more traits in common.	<i>How can relatedness help us predict the future for the bear populations?</i> <i>If they are all really similar, why do we think the polar bears are in trouble?</i>

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- **Anatomical evidence** from **skulls, claws, and teeth** suggests the bear species are **closely related**. (SEP 8.2; DCI: LS4.A.1; CCC 1.5)
- **Evidence** raises questions about which bears are more **closely related**. (SEP 8.2; DCI: LS4.A.1)

What to do: Encourage students to share evidence that supports their ideas about relatedness here. At this stage, the class does not need to come to consensus. Disagreement about which species are most closely related is productive.

Building toward 3.A.1 Integrate empirical evidence, including **anatomical and genetic information**, to infer **evolutionary relationships** in bear species. (SEP 8.2; DCI: LS4.A.1; CCC 1.5)

5 · NAVIGATE: UPDATE PROGRESS TRACKER

3 min

MATERIALS: Progress Tracker

Update Progress Trackers. Display **slide E** and give students a few minutes to record their ideas about what they figured out today and what questions they still have in a new row for Lesson 3.

	What we figured out (WWFO)	How does WWFO help us make progress on figuring out the future of Arctic bear populations?	How does WWFO connect to me or my community or have a larger-scale impact?	What questions do I have now?
Lesson 3: How similar/different are the polar, brown, and black bears?	-Brown and black bears have some behaviors like hibernating in common and have the NOS3 gene it common -Black and polar bears both run from brown bears	-If brown and black bears are more similar, maybe they will do better in the changing Arctic and polar bears will not do as well.	-Species that have things in common might be hurt by the same kind of things (pollution) and helped by the same kinds of things (clean water).	-What does it mean that the polar bears are related? -Which bears are more closely related?

End of day 1

6 · NAVIGATE

5 min

MATERIALS: science notebook, *Bear Traits Organizer*

Turn and Talk. Display **slide F**. Ask students to turn and talk with a partner about what they figured out in the previous class and what questions they still have. Call on a few pairs to share their thinking. Encourage students to use their Progress Trackers to help them.

Suggested prompts	Sample student responses
<i>What did we figure out in our last class?</i>	We figured out that polar, black, and brown bears have a lot of similarities but some unique traits as well. It was difficult to sort out the traits.
<i>What questions do we still have?</i>	We want to know more about how the species are related.

7 · INVESTIGATE RELATEDNESS USING DNA

12 min

MATERIALS: None

Turn and talk about relatedness. Say, *You all have some ideas about the similarities and differences between the bears and how it might tell us something about relatedness, but we are not really sure what it all means. Besides anatomy, what else can we use to figure out relatedness?* Ask students to turn and talk about the prompts on **slide G**. Call on a few pairs to share their thinking. Listen for students to suggest we look at genes and or DNA.

Partners discuss DNA similarities and differences. Say, *You already mentioned that they had the same gene, NOS3, but different versions/alleles of the gene. We already know a lot about genetics. Let's see if we can use our understanding of genetics to get some ideas about what is happening.* Display **slide H**. Let students know that you have three hypothetical DNA strands from the three different species. Ask students to discuss the prompts on the slide with a partner.

Whole-class discussion about genetics and relatedness. Facilitate a whole-class discussion using the prompts below as a guide.

Suggested prompts	Sample student responses
<i>What do you notice about this data?</i>	There is only one strand of DNA per species. The sequences are mostly similar, but there are differences.
<i>How do you think we can use this data to look at relatedness between the bear species?</i>	We can look at the number of differences between sequences in polar, brown, and black bears. If there are fewer differences, then they are more closely related.

Identify relationships using DNA. Say, *OK, let's try this out! See if you can identify which species are most closely related.* Display **slide I**. Distribute *DNA Sequences* and *Comparing DNA sequences* to pairs of students to complete. Ask students to share their findings with the class. *

Suggested prompts	Sample student responses
Which species had the most similar DNA sequences?	The species 1 and species 2 had two differences. They had a percent difference of 13%.
Which species had the most different DNA?	Species 3 had three differences when compared with species 1 and three differences when compared with species 2. They were both 20%.
How did you use this information to model relationships? (Share completed table on slide J.)	We decided to draw the three species as overlapping circles. The more overlap they have the more related they are. We did a graph. The higher the bars, the more related the species are. We did a branching diagram (like we saw in middle school).

ADDITIONAL GUIDANCE

Ideas for scaffolding:

- For question 1, compare species 1 and 2 as a class, then ask students to complete comparisons for species 1 and 3 and 2 and 3 with their partner.
- For question 1, explain: *There are 15 bases. Species 1 and 2 have 2 differences, so divide 2 by 15, then multiply by 100 and get 13%.*
- Divide the class into groups and have each group complete one comparison.

Introduce a tree as a model to show relationships. Display slide K. Say, *There seem to be different ways we can model relationships. One way is to use a structure like this. Scientists call it a tree because its structure looks like one. They even refer to it like a tree: there are branches and leaves. What do you notice about this tree?* Elevate ideas that branches come together at a point (or node), then meets up with another branch at a point (or node).

Display slide L. Ask students to return to question 3 on *Comparing DNA sequences* and follow the prompts to 1) draw a tree similar to the one on the slide, 2) label the leaves “Species 1,” “Species 2,” “Species 3” based on their calculations in the handout, and 3) explain their choices to their partner. Ask students to share with the class how the pattern seen in this tree reflects what they saw in the data.

8 • BUILD A BEAR TREE USING DNA

15 min

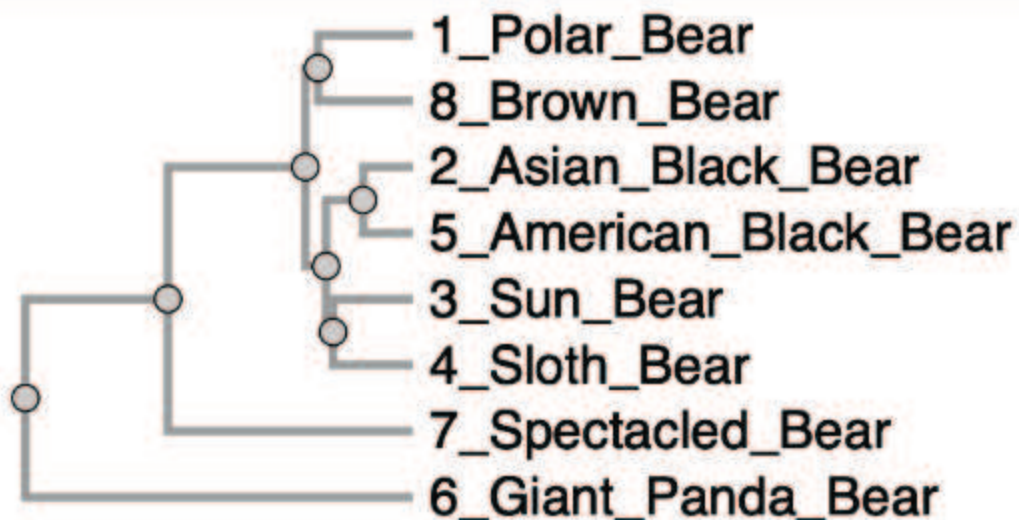
MATERIALS: science notebook, *Bear DNA Tree*, *Bear DNA Sequences*

Examine bear DNA sequences. Display slide M. Say, *It sounds like we have an idea of how to compare DNA sequences and show it as a tree. Let's look at some bear DNA collected by scientists.* Organize students into small groups of 3-5. Distribute *Bear DNA Sequences* either in print or digitally. When providing a digital copy, make sure students do not have edit access to the file. Ask students to share their noticings with the class.

Suggested prompts	Sample student responses	Follow-up questions
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Suggested prompts	Sample student responses	Follow-up questions
<i>What did you notice?</i>	There are eight sequences, one for each different type of bear. It includes the polar, black, and brown bears, and bears that we are not looking at. All sequences are written the same way, like they have the same format: a line saying their name and then the next line has the sequence. The sequences are long. It is hard to compare them when you cannot see everything at once.	<i>Why do you think the data set contains sequences from eight different species of bears (more data)? Accept all answers.</i> <i>How do you think the tree will look with eight species of bears? We think there will be eight leaves/tips and these branches connect to points which connect via branches to another point.</i>
<i>Earlier, we compared DNA sequences to figure out how similar and different they were. How easy or hard would it be to do that here?</i>	It would be really hard to compare them and really easy to lose track of how many bases they have in common. There are more bases and more species, so it would take a really long time.	<i>What would you have to update on Comparing DNA sequences to work with this data?</i>
<i>What are some techniques we have used in the past when we had more data than was practical for us to analyze by hand?</i>	We can use a computer!	<i>How did we analyze the data about the wildebeest in the Serengeti?</i>

Build a bear DNA tree. Say, *Scientists have special software that can help them align and compare sequences similar to what you did by hand. Let's try using one version of this software and see how it can help us build trees with these sequences.* Let students know that in addition to the three bear species the class has been investigating, there are five other bear species in the bear family and the computer program can analyze the DNA for all of the bears in this group. Display **slide N**. Distribute *Bear DNA Tree* and an electronic copy of *Bear DNA Sequences* to each student. Organize students into pairs and provide each pair with an internet-connected device that can run <https://www.ebi.ac.uk/jdispatcher/msa/mafft>. Ask students to follow the instructions to create a computer-generated tree with a partner. The tree should look like



Created by OpenSciEd using Search and sequence analysis tools services from EMBL-EBI in 2022

ADDITIONAL GUIDANCE

This lesson uses intron (non-coding) sequences from a nuclear gene, transthyretin. Inputting different segments of DNA can produce different trees. Many of the trees students could find through an internet search of a bear DNA tree or phylogeny will be built using more DNA than provided in this lesson and with more complex analytical techniques. While trees using different data will vary, most trees will show similar relationships, including close relationships between polar and brown bears and a close relationship between Asian and American black bears. Most trees will also show giant pandas as the outgroup, or the group least related to the other species. We have the students use the guide tree because it has a similar topology to what would be seen if one had rooted the tree under the phylogenetic tree tab.

The numbers displayed on the scale are a quantification of the amount of genetic change from the last branch point (node) to present. This mathematical representation is beyond the scope of the lesson, but students may be interested in understanding more about what the numbers represent. If this is the case, you can ask students to consider how they think the mathematical representation could correspond to time.

As an extension, ask students to search for other bear trees and motivate them to figure out why the trees might be different. What type of data was the tree built with? What algorithm was used to build the tree? Students could explore why different types of DNA (coding sequences, non-coding sequences, or mitochondrial DNA) might create different types of trees.

Stop and Jot to interpret bear DNA tree. Display slide O. Say, *You just used the same tools that researchers who study the relationships among organisms use. Biologists with many different skills collaborate to collect, read, and analyze these DNA sequences. Computer science, computation, and mathematics are increasingly important parts of genetics research. There are many different ways to be a biologist. Ask students to record their answers to the questions on the slide and then call on a few students to share what they figured out about bear relationships.*

Suggested prompts

Sample student responses

Follow-up questions

Suggested prompts	Sample student responses	Follow-up questions
<i>What did you figure out about polar, brown, and black bears using DNA?</i>	Brown bears and polar bears grouped together. They had very similar DNA. Asian black bears and American black bears grouped together. They had very similar DNA. The group with American black bears eventually came to a point with brown and polar bears before connecting with the spectacled bears and panda bears. The polar, brown, and black bears had DNA in common with the other bears. Eventually all the bear DNA met in a single point	
<i>Why do polar and brown bears share more DNA with each other than they do with other bears?</i>	We think they are related. We think they shared an ancestor. Somehow they split into two species from one?	<i>Where do you think this ancestor is on the tree?</i> <i>What do you think it means that their two lines branch out from the same point?</i> <i>What do you think the other branching points mean?</i> <i>If we are talking about ancestors, how do you think time is represented on this tree?</i>
<i>Why was it helpful to look at all the bear species in the bear family?</i>	The other bears help us see how closely related the polar and brown bears are in comparison.	<i>What do all the additional branches help you understand about polar, brown, and black bears?</i>
<i>How did what you figured out from the DNA sequences compare to what you figured out from looking at anatomical and behavioral traits?</i>	It confirmed some of our ideas that brown and polar bears are more closely related. It clarified where we were uncertain about which bear was more closely related. It contradicted some of our ideas that brown and black bears were the most closely related.	
Update Personal Glossaries. Say, <i>You all figured out an important idea, that two species, the polar and brown bears, split from a common ancestor. Let's take a moment to co-construct a definition and add it to our Personal Glossaries.</i> Display slide P and ask students to share their ideas for what should be included in a definition of <i>common ancestor</i>. When the class comes to consensus, pause to give students a moment to update their Personal Glossaries.		

ADDITIONAL GUIDANCE

As students work together to make sense of their trees, they will explain how polar and brown bear species branch out from a common point. Some students may mention the idea of a common ancestor. If not, let them know that what they have just figured out is what scientists call a **common ancestor**. Work together to come up with a common definition such as *a species that lived in the past that they both are related to*.

Once students come to consensus on a definition, encourage them to use pictures, symbols, and/or words as they add this definition to their Personal Glossaries.

9 · NAVIGATE: ELECTRONIC EXIT TICKET

12 min

MATERIALS: science notebook, https://docs.google.com/forms/d/1Ln6ypozASsLBwCpFn_YlQFg59ezXcusRvyHzZZin28/copy



Complete an exit ticket. Display slide Q. Guide students to complete https://docs.google.com/forms/d/1Ln6ypozASsLBwCpFn_YlQFg59ezXcusRvyHzZZin28/copy

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Use *L3 Electronic Exit Ticket* for guidance.

What to do: Use *L3 Electronic Exit Ticket* for guidance.

Building toward 3.A.3 Integrate empirical evidence, including genetic sequences, to infer evolutionary relationships in bear species. (SEP 8.2; DCI: LS4.A.1; CCC 1.5)

Additional Lesson 3 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflections, and research.

Students use evidence from textual evidence in Station Investigation Cards to support their analysis of relationships between bear species.

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH

MP.4 Model with mathematics.

Students calculate percent difference in DNA sequences and use the results to create a tree model to describe relatedness. They use a computer model that uses a similar process to analyze and model larger sequences.

LESSON 4: How did polar and brown bears become different species?

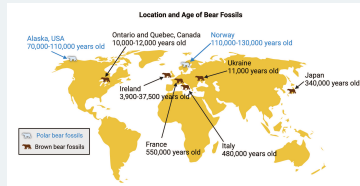
PREVIOUS LESSON

We decided to investigate how similar/different the three species of bears are. We investigated similarities and differences in anatomical evidence and realized it is hard to figure out how the bears are related. We decided to use DNA evidence and built a tree of the polar, brown, and black bears with five other bear species. We figured out that polar bears are most similar to brown bears and that they shared a more recent common ancestor than they do with other bears. We wanted to figure out more about what was happening when polar and brown bears split from a common ancestor.

THIS LESSON

INVESTIGATION

3 days



Illustrations created by OpenSciEd in BioRender; Data sources: Cahill, et al. (2018); Harington et al. (2014); Marciszak et al. (2015); Segawa et al. (2021); Villalba de Alvarado et al. (2022); Wang et al. (2022)

We review the mechanism of evolution by natural selection, which motivates us to learn more about selection pressures caused by glacial and interglacial periods that may have caused polar bears and brown bears to split from their common ancestor. We connect these geologic events with fossil evidence of bears and genetic variations found in polar and brown bears. We construct and revise arguments about what could have caused polar and brown bears to become distinct species as we look at each type of evidence. We decide to leverage what we have figured out about bear speciation in the past to figure out what will happen to polar bears in the future.

NEXT LESSON

We will create a class consensus model to put together the pieces we figured out so far in the unit and revisit the Driving Question Board to check on our progress.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

- 4.A Construct an argument based on data and evidence to explain how and why speciation of polar and brown bears occurred over geologic time due to environmental changes caused by glaciation. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)
- 4.B Construct an argument based on the mechanism of evolution by natural selection to explain how and why speciation of polar and brown bears occurred over geologic time. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)

WHAT STUDENTS WILL FIGURE OUT

- The Arctic has undergone glacial and interglacial periods, creating selective pressures for bears.
- Small bear populations may have been isolated in areas that kept ice year round during interglacial periods.
- Natural selection acted on genetic variations present in isolated populations of bears over thousands of generations.
- Speciation occurred in the common ancestor bear after thousands of generations, leading to polar bears that are adapted to polar environments and brown bears that are adapted to nonpolar environments.

Lesson 4 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Ask students to share what they figured out about the relationships between polar bears and brown bears and the rest of the bear family.	A	
2	5 min		REVIEW NATURAL SELECTION Discuss what students mean by species splitting. Facilitate a review of how populations change through the process of evolution by natural selection.	B-D	B.4 class consensus model
3	9 min		INITIAL IDEAS DISCUSSION ABOUT HOW POLAR AND BROWN BEARS SPLIT Support students in generating ideas about what happened between the common ancestor in the past and polar and brown bears in the present.	E-G	
4	11 min		CONDUCT A DATA EXPLORATION ABOUT EARTH CONDITIONS IN THE PAST Provide students with data about glaciation in the past to use as evidence.	H-L	<i>Glacial and Interglacial Periods, Scale Organizer</i> , https://youtu.be/QOKgdNk--iU
5	12 min		DEVELOP A CASE FOR ISOLATION Support students as they investigate possible interactions between glacial and interglacial periods and bear populations.	M-N	calculator, Laminated glacial/interglacial map or <i>Connecting Evidence For Speciation</i> , set of white 1-inch chips, <i>Bears and Glacial Cycles Key</i>
6	5 min		NAVIGATE: EXIT TICKET Students write an initial claim for when, where, and how polar and brown bears split from a common ancestor.	O	
<i>End of day 1</i>					
7	5 min		NAVIGATE: SHARE CLAIMS Students share and compare their claims about how bears split from a common ancestor with another student.	P	Exit ticket from last class
8	15 min		FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION Scaffold the construction of an initial argument to connect glacial cycles to students' initial ideas about selection pressures on bears.	Q-S	Exit ticket from last class, <i>Developing an Argument</i> , <i>Developing an Argument Key</i>
9	8 min		WRITE INITIAL ARGUMENTS Students individually fill in the graphic organizer on <i>Developing an Argument</i> to develop an argument for why polar and brown bears split from a common ancestor based on evidence from day 1. They reflect on additional evidence needed to strengthen the arguments for the split.	T-U	
10	5 min		DISCUSS QUESTIONS THAT REMAIN ABOUT INITIAL ARGUMENTS Facilitate a sharing of what additional evidence is needed to strengthen their arguments.	V	<i>Developing an Argument</i> , <i>Self-Assessment on Constructing an Argument</i>

Part	Duration		Summary	Slide	Materials
11	12 min		EXPLORE FOSSIL EVIDENCE Students investigate the location and age of polar bear and brown bear fossils from around the world. They discuss how this new evidence refutes or supports their initial arguments.	W	<i>Developing an Argument, Bear Fossils Map</i>
12	5 min		NAVIGATE: UPDATE EVIDENCE NEEDED FOR ARGUMENTS Students update <i>Developing an Argument</i> with fossil evidence.	X	<i>Developing an Argument</i>
<i>End of day 2</i>					
13	5 min		NAVIGATE Students reread the changes they made to their arguments after adding fossil data and discuss additional evidence they need to support their arguments.	Y	<i>Developing an Argument</i>
14	15 min		EXPLORE GENETIC DATA Students investigate allele variations and differences in genetic diversity found in polar and brown bear populations and add what they figure out as genetic evidence to their arguments.	Z-CC	<i>Genetic Bear Data, Developing an Argument, Bear Gene Data Key</i>
15	8 min		CONNECT GENETIC INFORMATION TO GLACIATION MAPS Students work in small groups using maps and chips representing genetic variations in bears to make sense of all the evidence they collected before revising their argument for why bears split from a common ancestor. Students add the term <i>speciation</i> to their Personal Glossaries.	DD-EE	<i>Genetic Bear Data, Connecting Evidence For Speciation, 48 1-inch chips with Trait Stickers, Bear Trait Key</i>
16	10 min		REVISE ARGUMENTS FOR SPECIATION Students individually revise their written arguments.	FF	<i>Developing an Argument</i>
17	4 min		COMPLETE A SELF-ASSESSMENT Students complete a self-reflection on their ability to construct and revise an argument.	GG	<i>Self-Assessment on Constructing an Argument</i>
18	3 min		NAVIGATE Motivate a return to the unit question by leveraging students' arguments about the past to figure out what could happen to Arctic bear populations in the future.	HH	
<i>End of day 3</i>					

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Glacial and Interglacial Periods</i> <i>Scale Organizer</i> - calculator - Exit ticket from last class <i>Developing an Argument</i> <i>Self-Assessment on Constructing an Argument</i> <i>Bear Fossils Map</i> <i>Genetic Bear Data</i>	- Laminated glacial/interglacial map or <i>Connecting Evidence For Speciation</i> - set of white 1-inch chips <i>Connecting Evidence For Speciation</i> 48 1-inch chips with Trait Stickers <i>Bear Trait Key</i>	- B.4 class consensus model https://youtu.be/QOKgdNk--iU <i>Bears and Glacial Cycles Key</i> <i>Developing an Argument Key</i> <i>Bear Gene Data Key</i>

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Review the unit overview to see how disciplinary core ideas, crosscutting concepts, and science and engineering practices are developed in this unit.

Make sure the class Community Agreements poster (created in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*) is hung where students can see it. This scaffold is not referenced explicitly here because this unit is the last unit in the Biology course, but it should be available for reference in case students encounter interpersonal conflict or need to be reminded of an agreement that is not being followed.

Three-hole-punch all handouts so they can be added to students' notebooks.

Day 1:

- If a kit is not available, print enlarged versions (24" x 22") of the two images from *Connecting Evidence For Speciation* for groups of 3-5 students. Laminate if possible to facilitate reuse.
- Prepare groups of 3-5 students. Gather a set of approximately 50 white 1-inch chips for each group.

Day 3:

- Add *Trait Stickers* to 1-inch chips.
- Gather *Connecting Evidence For Speciation*, a random set of approximately 48 1-inch chips with *Trait Stickers*, and *Bear Trait Key* for each group

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students develop an argument supported by evidence for the speciation of brown and polar bears from a common ancestor. The initial claims of their argument are developed on day 1, when they rely primarily on evidence related to selection pressures from changing climate during glacial and interglacial periods. On day 2, students revise their argument to include evidence from fossil location and age; and on day 3, they add in genetic evidence for inherited traits that allow the polar bears in particular to adapt to Arctic environments, where they rely on seals with high fat content as their main food source.

The lesson develops ESS2.E.1 on both days as students consider how life on Earth coevolved with cycles of glaciation. Days 1 and 2 focus on changes to the physical environment that cause speciation (LS4.C.4), whereas day 3 brings in evidence for genetic changes in species, allowing students to refine arguments using all of the steps of evolution by natural selection learned in *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)* to provide a mechanism to support their argument (LS4.C.1).

- ESS2.E.1 The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual coevolution of Earth's surface and the life that exists on it.
- LS4.C.4. 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.1 Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

LS4.C.4 was partially developed in Lesson 1, when students were introduced to the decline of the polar bear and possibility of extinction. This topic will be revisited in Lesson 5. ESS2.E.1 will continue to be developed in Lesson 7.

In this lesson, students continue to develop elements of the science practice of *engaging in argument from evidence* from Lesson 2 as they construct and revise an argument based on data and evidence to explain the speciation of polar and brown bears. Lesson 2 supported students in their ability to articulate simple claims and support them with evidence and reasoning. This lesson scaffolds the development of a more complex argument with a greater variety of possible responses. They will continue to develop this practice with less support in Lessons 7 and 8.

This lesson continues to develop this unit's focus on the crosscutting concept *scale, proportion, and quantity*. Students develop elements of this concept by using indirect evidence to develop an argument explaining the speciation of polar and brown bears, a process that occurred over thousands of years in the past.

Students will encounter the definitions for *glacial period*, *interglacial period*, and *speciation*. Words should be defined and recorded in students' Personal Glossaries AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

Although changing sea levels accompany glacial and interglacial periods and may have been part of the speciation story for polar and brown bears, the emphasis here is on areas with and without ice.

Also note that although there is strong evidence to support claims for population isolation as a mechanism of speciation for the bears, scientists do not yet have a complete picture of what occurred and continue to debate the timing, location, and mechanism of speciation. Because there is still debate in the research literature, there is no "right answer" to the question posed in this lesson. Help students to create strong arguments based on the evidence they have and provide reasoning that explains how the evidence supports their claim.

LEARNING PLAN for LESSON 4

1 · NAVIGATE

3 min

MATERIALS: science notebook

Navigate from the previous lesson. Display **slide A** and ask for a few volunteers to share with the class.

Suggested prompts	Sample student responses
<i>What did we figure out about the history of the bear family?</i>	There are many different species of bears around the world that share genetic similarities and a common ancestor. We drew trees that showed the evolutionary relationships between the different bear species.
<i>What were we wondering at the end of the last lesson?</i>	What happened to cause polar and brown bears to split?

2 · REVIEW NATURAL SELECTION

5 min

MATERIALS: science notebook, B.4 class consensus model

Motivate a review of natural selection. Display **slide B** and briefly discuss the prompts on the slide. Listen for students to suggest that splitting means one species turns into two, or two new species evolve. Students may suggest that the common ancestor bears either went extinct, or evolved into a polar bear or brown bear.

Review natural selection. Say, *We are trying to figure out how a common ancestor bear population split into the two separate species they are today. We know that polar and brown bears have different adaptations to their environment. If they had a common ancestor, something must have happened to cause the common bear populations to change. What do we already know about what can cause populations to change over time?* Display **slide C**. Provide time for students to discuss the prompts with an elbow partner. If you have the class consensus model from *Natural Selection Unit*, display it in a prominent place in the classroom to aid in discussion. Encourage students to review the Progress Tracker and other materials in their science notebook from *Natural Selection Unit* to remember the specific components of evolution by natural selection. Bring the class back together and display **slide D**. Facilitate a review of the model of evolution by natural selection.

Suggested prompts	Sample student responses	Follow-up questions
<i>What mechanism causes populations to change and develop adaptations?</i>	Evolution Natural selection	<i>In the last unit, what caused the hawksbeard/rat/junco populations to change over time?</i>
<i>What must be present in a population for evolution to occur?</i>	Genetic variation within the population. Not all individuals in a population have the same gene variations.	<i>Can evolution happen if all of the members of a population are genetically identical?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What must be present in the environment for evolution to occur?</i>	Selection pressures. Environmental factors that make it more difficult/easy for some individuals to survive over others.	<i>Will populations change over time in all environments?</i>
<i>How do populations evolve through natural selection?</i>	Members of a population compete for a limited amount of resources, and some get more. Some individuals outcompete others based on genetic variations they have and survive to reproduce and produce more offspring. Over time, the proportion of individuals with favorable genetic traits in the population increases.	<i>What happens to individuals with different genetic variations when they encounter selection pressures?</i>

3 · INITIAL IDEAS DISCUSSION ABOUT HOW POLAR AND BROWN BEARS SPLIT

9 min

MATERIALS: science notebook

Brainstorm ideas about bear evolution. Say, *I heard you say that natural selection may have occurred between the common ancestor in the past and the polar and brown bears in the present. In order for that to happen, you identified genetic variation and selection pressures as necessary components.* Display **slide E**. Encourage students to turn and talk with an elbow partner about the prompts. Suggest students look at the DQB for ideas as well.

After a few minutes, display **slide F** and lead a discussion using the sample prompts below.

Suggested prompts	Sample student responses	Follow-up questions
<i>What kinds of genetic variations might have been present in the common ancestor?</i>	Differences in fur color, claws, and teeth. Differences in how they dealt with temperature/ thermoregulation/ homeostasis.	<i>What do we know about the adaptations polar and brown bears have now?</i>
<i>What kinds of selection pressures may have caused the traits we see today to be selected for?</i>	Some bears were in a really cold place. Ice, cold, snow. Only seals available for some bears.	<i>Would all of the bears in the common ancestor population have been exposed to the same selection pressures?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What evidence do we need to help figure out what happened?</i>	The genetics of the bears and/or some information about what they looked like in the past (e.g., fossils). When did this happen, and what was going on in the environment (e.g., climate, food sources, predators)? Where the common ancestor bears lived.	<i>What would help us figure out what adaptations the bears had in the past and how they are linked to genes?</i> <i>What would help us figure out what the selection pressures were that gave some bears in the population an advantage?</i>

Discuss limitations to gathering sufficient data. Display slide G and discuss the prompts on the slide.

Suggested prompts	Sample student responses	Follow-up questions
<i>How does the crosscutting concept of scale apply to our question about the split of the bears?</i>	Bears live over a very large range, making them hard to study. We are investigating something that occurred in the past that we cannot observe, so we have to study it indirectly. Natural selection is too slow for us to see.	<i>When did the phenomenon we are studying occur?</i> <i>Where did it occur?</i> <i>How long did it take?</i>
<i>Why could it be challenging to find data?</i>	We do not have a time machine to observe the past. It is hard to gather data about enough bears to know what happened. The bears are dangerous and live in remote places. We need to find fossils, which can be hard to find. We cannot directly study climate in the past; we have to infer it from other sources of information.	<i>Why is it difficult to find fossils in the Arctic?</i> <i>Why is it difficult to study polar and brown bears?</i> <i>How do we study climate in the past?</i>

4 · CONDUCT A DATA EXPLORATION ABOUT EARTH CONDITIONS IN THE PAST

11 min

MATERIALS: science notebook, *Glacial and Interglacial Periods*, Scale Organizer, <https://youtu.be/QOKgdNk--iU>

Introduce geologic Arctic climate data. Say, *You all wanted to know more about selection pressures and what might have been going on in the bears' environment. I have some data about ways the Arctic environment changed over geologic time that may help us figure this out.* Review the map on on **slide H** as a class. Give students a few minutes to consider the questions on the slide, then call on a few students to share their ideas using the prompts below as a guide.

Listen for students to mention:

- Polar bears live on the Arctic circle with ice and snow much of the year.
- Brown bears overlap in some areas but live on land, to the south of polar bears that have warmer temperatures, with open tundra.
- There might have been ice ages or other big geological differences in Earth's past.

Read about cycles of glaciation. Say, *It sounds like we have some questions about what happened in Earth's past. I have some information that can help us.* Display **slide I** and distribute *Glacial and Interglacial Periods* to each student. Provide time for them to read *Glacial and Interglacial Periods* using whatever literacy strategy is in place in your classroom. Then ask them to work with a partner, discuss the prompts on the slide, and record their responses in their science notebooks.

Discuss cycles of glaciation. After a few minutes, display **slide J** and bring the class together to share what students noticed and wondered about *Glacial and Interglacial Periods*. Use the diagram of glacial and interglacial periods to support discussion.

Suggested prompts	Sample student responses	Follow-up questions
<i>What were the major environmental changes over the last 700,000 years?</i>	There were a series of glacial and interglacial periods. It got really cold for 15-55,000 years, then warmer for 50-60,000 years, then really cold, and then warm. Land got covered in ice, and then it melted. The sea level rose and fell.	<i>How would the environment change during a(n) (inter)glacial period?</i> <i>How long did the glacial and interglacial periods last?</i>
<i>How do these environmental changes relate to selection pressures for bear populations?</i>	The ice and cold could have made it harder for some bears to survive if they did not have traits that kept them warm. When it was glacial/ interglacial, the kinds of foods available may have changed, and some bears could have eaten more than others.	<i>How could environmental conditions make it so some bears in the population survived and reproduced more than others?</i>

* ATTENDING TO EQUITY

Universal Design for Learning: Throughout this lesson, students engage in activities through multiple formats to provide additional *representations*. This can help support them as they process the evidence and piece together information from multiple domains and different time and spatial scales. Providing multiple formats for presenting the information provides more access for the diverse learners in your classroom.

Suggested prompts	Sample student responses	Follow-up questions
<i>What do you wonder about this information?</i>	What does glaciation look like? Does all the ice disappear in an interglacial period? How does this affect the bears? Where would bears go if there was ice everywhere?	<i>Do we know what glaciation looks like?</i> <i>How is this information relevant to the split from the common ancestor?</i>

Add glacial and interglacial periods to Personal Glossaries. As it is relevant during the discussion of the data exploration, display **slide K** and provide time for students to add the definitions they encountered for glacial and interglacial periods to their Personal Glossaries based on *Glacial and Interglacial Periods*.

Visualize the geographic effect of glacial and interglacial periods. Say, *It sounds like some of us are still trying to figure out what it really means to have a glacial or interglacial period so we can think about how it might affect the population of bears living at that time. Let's look at this visualization I have that shows what scientists think part of one of these glacial cycles may have looked like. This one I found shows the minimum amount of ice each summer from 18,000 years ago to today. It pieces together images of the summer ice over that time.* Ask students to use *Glacial and Interglacial Periods* to identify if 18,000 years ago was a glacial or interglacial period. They should see that G1 ended 15,000 years ago, so the visualization begins at the end of a glacial period. Display **slide L** and play the video <https://youtu.be/QOKgdNk--iU> 2-3 times, helping students orient themselves using the Northern Hemisphere map on *Scale Organizer*. Ask students to share what they notice and wonder as they watch. Remind students that the visualization shows summer ice, so there would be seasonal ice in many of these areas in the winter. Even in interglacial time periods, there is still ice in winter, but less of it and farther north. The visualization would show more ice if the snapshots were from the winter. *

Suggested prompts	Sample student responses
<i>What did you notice?</i>	When it started, I could not tell what countries were below it. The ice covered everything over the North Pole. As the ice melted, I could see Canada, Alaska, Wapusk, Europe, Russia, and Greenland. When ice melts, (Greenland, or other location) almost becomes an island of ice.
<i>What did you wonder?</i>	What was happening to the bears at that time? Did the bears get covered in ice? Could the bears move south fast enough to get away from the glaciers?

5 · DEVELOP A CASE FOR ISOLATION

12 min

MATERIALS: calculator, Laminated glacial/interglacial map or *Connecting Evidence For Speciation*, set of white 1-inch chips, *Bears and Glacial Cycles Key*

Make a case for isolation. Remind students that they just saw the transition from G1 to the present, but this transition happened at the end of each glacial period and likely reversed as the Earth cooled as each glacial cycle began. Ask students to visualize what it would look like if the changes in ice from the last 18,000 years happened over and over again with each glacial and interglacial period that they saw on *Glacial and Interglacial Periods*. Display **slide M** and give students at least 30 seconds to consider the prompt on their own. Say, *We specifically noticed that (Greenland) was one place that almost became an island during the interglacial period, and we wondered what happened to the bears as the climate changed from a glacial to an interglacial period. Let's take some time to talk in small groups about what the possibilities could be and why the bears may have split into two species.* *

ALTERNATE ACTIVITY

If students struggle to visualize multiple cycles of glaciation, show this second visualization, which shows ice grow and retreat multiple times over the last 400,000 years: <https://youtu.be/8lt3uhToMCI> Note that this visualization only shows glacial ice on land and does not show any sea ice, which is slightly deceptive.

Small-group work. Distribute *Bears and Glacial Cycles* to each student. Display **slide N**. Explain that you will give students two freeze-frame images of a glacial and interglacial period showing the extremes of ice extent. Students should decide which consecutive interglacial and glacial periods from *Glacial and Interglacial Periods* this represents, for example from G5 through the beginning of G4 (470 to 380,000 years ago). You will also give them a set of approximately 50 chips that represent a population of common ancestor bears. Demonstrate how they should randomly scatter the bear chips on the glacial map (like spreading cheese on a pizza) to represent the common ancestor population living during one of the glacial periods, such as G5. Groups will use *Connecting Evidence For Speciation* and bear chips to answer the questions on *Bears and Glacial Cycles*. Distribute *Connecting Evidence For Speciation* and a set of chips to groups of 3-5 students and provide time to complete the activity. Walk around and ask probing questions of groups such as:

- What options do bears have in each location when the amount of ice changes?
- How would bears living in Greenland experience the changes differently from bears living in Wapusk/Canada/Europe?
- What selection pressures existed during that time in that location?
- How quickly did the climate change?

Bears and Glacial Cycles Key provides examples of discussions you may hear during small-group work.

ADDITIONAL GUIDANCE

At this point, support students with whatever glacial and interglacial time period is logical to them. There will likely be uncertainty as to which time period is correct, and some groups may choose a period at random. Use this uncertainty to call for additional evidence that may help clarify when the split happened more specifically in the next step.

ADDITIONAL GUIDANCE

As students argue that bears may have been isolated on islands that retained their ice during interglacial periods, they may ask about their ability to swim to other locations. Polar bears, in particular, are strong swimmers. In one study conducted over 6 years, researchers tracked the movement of 52 bears. On 50 occasions, they recorded the bears swimming distances greater than 30 miles (50 km). Longer recorded distances included 66 miles (106 km), 122 miles (196 km), and 188 miles (303 km). A few swims took a day and some as long as 9 days. The longest recorded swim was 427 miles (687 km). Lynch, Wayne. (2021). *Bears of the north: A year inside their worlds*. Johns Hopkins University Press.

* SUPPORTING STUDENTS IN THREE-DIMENSIONAL LEARNING

Students construct and revise a supported argument (SEP: 7.4) to explain how climate change could have caused the speciation of polar and brown bears from a common ancestor throughout the lesson. The emphasis on day 1 and 2 is on the role of the changing environment on speciation (DCI LS4.C.4), whereas the emphasis on day 3 is on genetic variation and differential reproduction of bears with adaptive variations (LS4.C.1). Students will consider coevolution of Earth and living things on both days. (DCI ESS2.E.1). Because of the large time scale of bear evolution and the large amount of missing data from fossil or DNA evidence, students must infer that the process of speciation occurred from the mechanism of evolution of natural selection (CCC: 3.2). Support students to move between time scales to connect selection pressures that act on bears over a few years to speciation, which takes thousands of years.

6 · NAVIGATE: EXIT TICKET

5 min

MATERIALS: science notebook



Develop an initial claim about the split. Say, *We have some idea of what selection pressures the common ancestor bears might have experienced in different locations during the cycles of glaciation. Let's take some time to individually come up with a claim about what caused brown and polar bears to split from their common ancestor during this time period.* Display **slide O** and ask students to turn in a claim following the prompts on the slide. Refer to *Developing an Argument Key* for a sample claim.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: As students write a claim about the **split of polar and brown bears from a common ancestor**, look for arguments that include: (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4):

- Evidence of glacial and interglacial periods creating a changing environment for bear populations. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)
- Separation of different populations of bears in different climates, one with Arctic ice year round and one without. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)
- Isolation of bears on ice where natural selection favored traits with variations adapted to cold climates. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)
- Natural selection acted over many many generations (over glacial and interglacial periods) to cause a new species to form. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)

What to do: Collect student exit tickets. Add questions for students to consider as they develop their arguments on day 2, including:

- During what time period did that occur?
- Where in the world did that happen?
- Were all bears living in the same location? What about bears in (Greenland/Canada)?
- What was the selection pressure that caused the change?
- How many generations of bears were there over that period of time?
- What evidence do you have that this occurred?

Building toward 4.A.1 Construct an argument based on data and evidence to explain how and why speciation of polar and brown bears occurred over geologic time due to environmental changes caused by glaciation. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)

End of day 1

7 · NAVIGATE: SHARE CLAIMS

5 min

MATERIALS: Exit ticket from last class

Reread claims. Distribute the exit tickets students wrote at the end of the previous class. Display **slide P** and provide time for students to share and compare the claims they wrote.

8 · FACILITATE A BUILDING UNDERSTANDINGS DISCUSSION

15 min

MATERIALS: Exit ticket from last class, *Developing an Argument*, science notebook, *Developing an Argument Key*

Facilitate a Building Understandings Discussion. Arrange the class in a Scientists Circle and display **slide Q**. Ask a few students to share their claims and discuss how they are similar or different from their partner's. Write at least one student claim on the board to use during the discussion to demonstrate how to support and turn it into an argument during the discussion. Discuss the prompt on the slide. Listen for students to mention they need evidence and reasoning to support their claims to turn them into arguments. If necessary, ask what they need to prove or convince someone that their claim makes sense.

KEY IDEAS

Purpose of this discussion: This Building Understandings Discussion is an opportunity to scaffold students as they begin to construct an argument supported with evidence and reasoning for how polar bears and brown bears split from a common ancestor and for students to identify gaps in evidence to support those arguments. Be explicit with students about how your and their roles will be different than in other discussion types. *

Listen for these ideas:

- Common ancestor bears experienced repeated cycles of glaciation.
- At some point, a small population of bears was isolated in an Arctic environment during an interglacial period for thousands of years and thousands of generations.
- The isolated populations evolved generalized adaptations to survive and reproduce in an Arctic environment.
- Uncertainty over when and where isolation occurred.
- Uncertainty as to what genetic traits evolved during this time.

Construct an initial argument. Display slide R and distribute *Developing an Argument* to each student. Facilitate a discussion about how to build an initial argument using the graphic organizer on *Developing an Argument*. Students can add their claim to Part 1 of *Developing an Argument*. Discuss the evidence students have to support the sample claim written on the board. Demonstrate how to add that information to the evidence column on *Developing an Argument*. Students may need to refer to other handouts in their science notebooks for evidence. Discuss how to add reasoning to the graphic organizer on *Developing an Argument* for each piece of evidence. Refer to the prompts below or *Developing an Argument Key* for sample entries using day 1 evidence.

Suggested prompts	Sample student responses	Follow-up questions
What evidence do we have to support our claims?	Glacial ice always covers the island (of Greenland) in interglacial and glacial periods. There were repeated glacial and interglacial periods of warming and cooling. From the maps and bear chips: Some bears might get trapped in Greenland or another island in the Arctic during interglacial periods where there would still be ice.	What additional evidence do we have? Does the ice completely disappear in all locations?

*** STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION**

A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on developing arguments based on evidence. Your role during the discussion is to invite students to share claims and push them to support their claims with evidence and reasoning. Students can disagree with each other, and the class does not need to reach consensus on all ideas shared. Areas of disagreement can motivate future investigations. Helpful prompts during these kind of discussions include:

- What can we claim?
- How did you arrive at that idea?
- What's your evidence?
- How does the evidence support the claim?
- Does anyone have evidence to support A's claim?
- What data do we have that challenges B's claim?

Suggested prompts	Sample student responses	Follow-up questions
<i>What is our reasoning? (What science idea connects the evidence to our claim?)</i>	Cold weather may be a selection pressure for bears. They need to be able to withstand cold temperatures to survive and reproduce in the cold. Ice may be a selection pressure for the bears. They need to be able to hunt and find food to survive and reproduce on the ice. A population of bears may have been trapped on an icy island (like Greenland) during an interglacial period and would have thousands of years where they could only mate with other bears that had adaptations to survive the ice and cold. Bears that were not adapted to cold weather and hunting on ice may have moved to the south during glacial periods and reproduced separately from bears that stayed on the ice.	<i>What was the selection pressure for these bears?</i> <i>Which bears survived to reproduce?</i> <i>During what time period did that occur?</i> <i>How many generations of bears were there over that period of time?</i> <i>Where in the world did that happen?</i> <i>Were all bears living in the same location? What about bears in (Greenland/Canada)?</i> <i>Who could bears choose as mates?</i>

Review the possible consequences of isolation. Optionally, If students are struggling to connect isolation to what they learned about natural selection from *Natural Selection Unit*, display **slide S**. Say, *You mentioned that bears may have gotten stuck in Greenland*. Review what students remember about how evolution by natural selection may work in populations that are fragmented and isolated from the rest of the population.

Suggested prompts	Sample student responses	Follow-up questions
<i>What do you know about what happens to a small population that becomes isolated for many generations from the rest of the population?</i>	Isolated/fragmented populations may experience different selection pressures from other populations. They can only mate with animals within their own population. It can be harder for smaller populations to adapt because they may have less genetic diversity. Random alleles are lost when populations are isolated. Populations can still adapt if they have the right alleles (gene choices) in the populations to survive.	<i>What happened to hawksbeard populations in urban vs. nonurban environments?</i> <i>What happened to the genetic diversity of the panther populations when they were fragmented?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>How could isolation affect the common ancestor bear population during cycles of glaciation?</i>	Bears in Canada and Greenland would experience different selection pressures. Each population might evolve differently with those pressures to have different adaptations. Bears in Greenland could be isolated and not be able to mate with any bears on the mainland for thousands of years during an interglacial period.	<i>Would bears in Canada and bears in Greenland experience the same selection pressures during interglacial periods?</i> <i>Can the bears that are stuck in Greenland mate with bears in Canada?</i>
<i>How long could bears in Greenland be isolated from other bears during glacial cycles?</i>	45-75,000 years 3,913-6,522 generations of bears	<i>How long are the interglacial periods?</i> <i>How many generations of bears might occur over that time (assume one generation is 11.35 years)?</i>

9 • WRITE INITIAL ARGUMENTS

8 min

MATERIALS: None



Draft initial arguments. Display **slide T** and provide students with a time to add evidence and reasoning for the claim they wrote on the exit ticket to Part 2 of *Developing an Argument*.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: As students participate in the Building Understandings Discussion about the split of polar and brown bears from a common ancestor and fill in *Developing an Argument*, look and listen for an argument that includes: (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4):

- Evidence of glacial and interglacial periods creating a changing environment for bear populations. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)
- Separation of different populations of bears in different climates, one with Arctic ice and one without. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)
- Isolation of bears on ice where natural selection favored traits with variations adapted to cold climates. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)
- Natural selection acted over many many generations (over glacial and interglacial periods) to cause a new species to form. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)
- Questions about evidence for which genetic traits caused evolution by natural selection. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4)
- Questions about additional fossil data to provide evidence for where bears were located during glacial and interglacial periods when new species could have evolved. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)

What to do: If students struggle to construct individual arguments after the Building Understandings Discussion, collect *Developing an Argument* at the end of class to provide individual feedback.

- Ask students to imagine two populations of common ancestor bears are isolated in two locations during glacial and interglacial periods, one in Greenland and one in Canada. Prompt them to think about how environmental conditions would change, how bears could respond to those changes, and what traits might help them to survive those conditions.
- Ask students to articulate the reasons why they are having trouble supporting a claim with evidence. Have them write down the type of data or evidence they want to see but do not have in Part 3 of *Developing an Argument*.

Building toward 4.A.2 Construct an argument based on data and evidence to explain how and why speciation of polar and brown bears occurred over geologic time due to environmental changes caused by glaciation. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2)

Individually reflect on initial arguments. Commend students on making their first drafts of their arguments explaining what happened between a common ancestor in the past and brown and polar bears in the present. Display slide U. Ask them to complete Part 3 at the bottom of *Developing an Argument*, describing additional evidence they need to better support their argument.

10 · DISCUSS QUESTIONS THAT REMAIN ABOUT INITIAL ARGUMENTS

5 min

MATERIALS: *Developing an Argument*, *Self-Assessment on Constructing an Argument*

Discuss additional evidence needed. Say, *So we have some plausible claims but still have some holes in our arguments.* Display slide V and discuss the prompts on the slide.

Suggested prompts	Sample student responses
<i>Which parts of your claim do not feel well supported?</i>	We do not know when polar bears and brown bears split. We do not know where the split happened. We do not know what the bears looked like in the past. We do not understand what genes were important for bears to adapt to the cold.
<i>What evidence are we missing?</i>	Fossil data to tell us when and where isolation occurred. Genetic information to explain what traits were important to different bear populations.

11 • EXPLORE FOSSIL EVIDENCE

12 min

MATERIALS: *Developing an Argument, Bear Fossils Map*

Discuss fossil evidence. Say, *We are interested in knowing where researchers found bear fossils to figure out when and where a population of common ancestor bears may have been isolated on the ice. Unfortunately, scientists have not discovered very many fossils showing where the bears were during the glacial and interglacial periods in the Arctic. Why do you think that is?* Listen for students to mention that conditions were not good to create fossils: Polar bears live on ice so if they die, they may fall into the ocean, where we cannot find their bones. Explain that you did find a few examples to share, however. Display **slide W** and distribute *Bear Fossils Map* to each student. Ask students to turn and talk about the data with an elbow partner using the prompt on the slide. Encourage them to compare the dates to *Glacial and Interglacial Periods*. After 5–7 minutes working in pairs, facilitate a class discussion of what students noticed.

Suggested prompts	Sample student responses	Follow-up questions
<i>What did you notice about the fossils?</i>	Polar bear fossils are around 110,000 years old. Polar bear fossils are both in the far north. Brown bear fossils range in age from 10,000 years old to 550,000 years old. Brown bear fossils are found in many parts of the Northern Hemisphere, south of the polar bear fossils.	<i>What did you notice about the locations of polar bear vs. brown bear fossils?</i> <i>What did you notice about the ages of polar bear vs. brown bear fossils?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>Does the new evidence support or refute your argument?</i>	The polar bear fossils support my argument because they are located in the far north and polar bears are adapted to ice, and they fit in the timeline. Polar bears must be older than 130,000 years old, so the time frame I chose was correct/incorrect. Brown bears must be older than 550,000 years old, so the time frame I chose was correct/incorrect. The brown bear fossils support my argument because they are in locations farther to the south than the polar bear fossils, where it was warmer during glacial and interglacial periods. If the youngest brown bear fossils occurred during the last interglacial period, that could support my reasoning that some bears migrated north after the glaciers retreated.	<i>How does that support your argument?</i> <i>What is another possible explanation if it refutes your argument?</i> <i>How does that shift the time frame for when the split happened?</i>
<i>What questions do you have?</i>	Why are brown bear fossils so much older than polar bear fossils? Why is there such a large range in ages for brown bear fossils compared with polar bear fossils? Is it possible that polar bears were around as long as the brown bears but we just cannot find fossils? What did these fossil bears look like? What traits did they have?	<i>What additional evidence would you like to have?</i> <i>What is required for fossils to form?</i>

12 · NAVIGATE: UPDATE EVIDENCE NEEDED FOR ARGUMENTS

5 min

MATERIALS: *Developing an Argument*

Update evidence lists. Display **slide X**. Say, *So it sounds like the fossil evidence was useful for supporting some of our arguments for why bears split and maybe gave some of us some ideas of how we might need to revise our arguments. Let's take a few minutes to revise Developing an Argument.*

End of day 2

13 · NAVIGATE

5 min

MATERIALS: *Developing an Argument*

Reread *Developing an Argument*. Display slide Y and give students a minute to reread the changes they made to *Developing an Argument*.

Motivate the need to look at genetic data. Discuss the prompt on the slide. Listen for students to mention they need to know about bear genetics.

14 · EXPLORE GENETIC DATA

15 min

MATERIALS: *Genetic Bear Data*, *Developing an Argument*, *Bear Gene Data Key*

Introduce genetic data. Say, *You want to know more about the genes and genetic variations that make polar bears and brown bears different. In Lesson 2, we learned about one genetic difference in the NOS3 gene related to how bears generate heat. In Lesson 3, when we used DNA to figure out how closely related brown and polar bears are, we saw that the codes were slightly different, but we did not actually know what the differences meant for the bears. We still do not know if the differences might be related to traits selected for during natural selection to help populations adapt to their environment.* Display slide Z and distribute *Genetic Bear Data*. Read through the introduction together. Put students in pairs and provide time for them to discuss the selective advantage of each variation to bears based on the environmental conditions where they live. Use *Bear Gene Data Key* to see possible student responses. As students work, circulate and encourage students to consider how this new information supports or refutes their arguments about bear speciation.

Discuss genetic data. Display slide AA and discuss the prompts on the slide.

Suggested prompt	Sample student response
How does this new information support or refute your argument for bear speciation?	Polar bears have the altered LYST allele to help them camouflage and hunt better to survive in the Arctic environment. Whiter bears would outcompete darker-colored bears and eat more. Polar bears have the altered apoB to help them survive with a high fat diet from seals in the Arctic. Without the gene, they might die from heart disease. Polar bears have the altered ARID58 alleles to help them survive extremely cold temperatures. Brown bears would not have an advantage from altered apoB and ARID58 alleles but could carry them without being harmed. Brown bears would probably have the common LYST allele to blend into their surroundings better. This would help them hunt better in the tundra or forest and outcompete lighter-colored bears.

ADDITIONAL GUIDANCE

apoB is associated with the production of low-density lipoproteins, or LDL. LDL cholesterol is a known risk factor for heart disease in humans. Scientists do not understand the exact mechanism of the gene variant in polar bears, but they do recognize its role in helping them cope with high levels of fat in their diet and extremely elevated levels of cholesterol in their blood due to the consumption of seals as their main energy source. Some students may have personal connections to individuals with high cholesterol and heart disease. This may make the fatty diet of polar bears more relevant to them.

Source: Liu, S., Lorenzen, E. D., Fumagalli, M., Li, B., Harris, K., Xiong, Z., Zhou, L., Korneliussen, T. S., Somel, M., Babbitt, C., Wray, G., Li, J., He, W., Wang, Z., Fu, W., Xiang, X., Morgan, C. C., Doherty, A., O'Connell, M. J., Wang, J. (2014). Population genomics reveal recent speciation and rapid evolutionary adaptation in polar bears. *Cell*, 157(4).

Update *Developing an Argument*. At the end of the discussion, display **slide BB** and encourage students to add relevant new evidence to *Developing an Argument*.

Review quote about genetic diversity. Say, *I found one other study about bear genetics that might provide useful evidence.* Display **slide CC**, which shows a quote from one of the researchers who was working on the same question. Ask a student volunteer to read the quote aloud. Discuss the prompts on the slide. As you discuss, encourage students to add relevant new evidence to *Developing an Argument*.

Suggested prompts	Sample student responses	Follow-up questions
<i>Why might brown bears be more genetically diverse than polar bears?</i>	Brown bears live in a wider range of locations and may be more genetically diverse to adapt to more locations. They may have experienced many different kinds of selection pressures. Maybe a small population of polar bears was fragmented and randomly lost genetic diversity. They may also have had fewer mates to choose from with less genetic diversity. If polar bears only ever lived in places with lots of ice, they would have evolved very specific adaptations to survive the harsh conditions. Brown bears eat a wider variety of foods than polar bears and therefore perhaps are more genetically diverse to help them do that.	<i>Which environments have more deadly selection pressures?</i> <i>Can mutations remain in a population if they do not experience a selection pressure?</i> <i>How would a larger range be connected to greater genetic diversity?</i> <i>How would a smaller range be connected to less genetic diversity?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>Does this statement support or refute your argument for bear speciation?</i>	If polar bears evolved from a population of bears that were isolated from others, they might be less genetically diverse due to random chance or because selection pressures caused very specific adaptations to evolve. If brown bears evolved from common ancestor bears that went south during glaciation, they may have encountered a wide range of habitats.	<i>Some of you thought that polar bears were isolated on an island/ Greenland during an interglacial period. How might that affect their genetic diversity?</i>

15 · CONNECT GENETIC INFORMATION TO GLACIATION MAPS

8 min

MATERIALS: science notebook, *Genetic Bear Data*, *Connecting Evidence For Speciation*, 48 1-inch chips with Trait Stickers, *Bear Trait Key*

Connect genetic information to glaciation maps. Say, *Yesterday you developed initial arguments supporting a claim for what could have happened between a common ancestor in the past and polar and brown bears in the present. However, we noticed that we were missing some evidence that we needed to support our arguments. What additional evidence do we have now?* Listen for students to mention fossil evidence and genetic evidence. Say, *We have talked a little bit about how each of these pieces of evidence supports or refutes our arguments individually. Let's see if we can put all of the pieces we have together before we revise our arguments.* Acknowledge the challenge of bringing together evidence from different spatial and temporal scales to create a coherent argument. Explain that the students will use the same maps of glacial and interglacial periods that they used in the previous class, but this time you have added the traits from the genetic variations to the bear chips. Distribute a copy of *Connecting Evidence For Speciation*, a set of approximately 48 chips with *Trait Stickers*, and *Bear Trait Key* to groups of 3–5 students and display **slide DD**. Explain that the chips with symbols represent bears with random combinations of the common and altered forms of the 3 genes they just investigated plus the NOS3 gene from Lesson 2. Suggest they have *Genetic Bear Data* available to remind them about the function of those variations. Allow them to annotate *Bear Trait Key* if it is helpful. All “altered” forms of the genes are ones they determined were advantageous in polar bears. Demonstrate how students should randomly scatter their bear chips on the glacial period map to represent the common ancestor population. They should then discuss which bears would survive based on the traits they have, removing any bears that would not survive from the map. Groups should then discuss how bear populations may evolve as the climate changes toward the interglacial map. Walk around to groups and use the following prompts to promote discussion:

- Which traits would survive better in this environment? Why?
- Would it help a bear survive if it had at least one or two of the traits?
- Which bears would be more likely to reproduce?
- What traits do their potential mates have?
- How many generations would it take for the change to happen?
- Which glacial/interglacial period are you representing here?

Add speciation to Personal Glossaries. Bring students back together after 6–7 minutes. Display **slide EE**. Say, *We have been discussing how over very long periods of time, selection pressures act on genetic variations in bear populations living in different environments, causing them to evolve to become very different from one another, so different that we call them another species. Scientists call this process speciation.* Provide time for students to add this term to their Personal Glossaries.

16 · REVISE ARGUMENTS FOR SPECIATION

10 min

MATERIALS: *Developing an Argument*



Revise written arguments. Display slide FF. Provide quiet time for students to revise their initial arguments individually on *Developing an Argument* or on a clean piece of paper. Collect their responses.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: As students talk through and revise their arguments on *Developing an Argument*, use *Developing an Argument Key* to evaluate their responses.

What to do: Provide feedback using *Developing an Argument Key* as guidance.

Building toward 4.B Construct an argument based on the mechanism of evolution by natural selection to explain how and why speciation of polar and brown bears occurred over geologic time. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)

17 · COMPLETE A SELF-ASSESSMENT

4 min

MATERIALS: *Self-Assessment on Constructing an Argument*

Students complete a self-assessment. Display slide GG and distribute *Self-Assessment on Constructing an Argument* to each student. Provide time for students to complete the self-assessment. Collect *Self-Assessment on Constructing an Argument* and make note of what students learned from the process and where they struggled. Bring these ideas to Lessons 7 and 8, when students will be asked to construct and defend arguments again.

18 · NAVIGATE

3 min

MATERIALS: None

Motivate a return to the unit question. Display slide x. Celebrate students' accomplishment of writing and supporting a complex argument. Say, *When we started this lesson, we said we needed to learn about the past to figure out the future for Arctic bears. Do we have enough information to do that now? Let's investigate this in the next class.*

Additional Lesson 4 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST9.12.1 Write arguments focused on discipline-specific content.

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

Students develop arguments based on evidence from informational texts adapted from scientific literature.

LESSON 5: What will happen to Arctic bear populations as their environment changes?

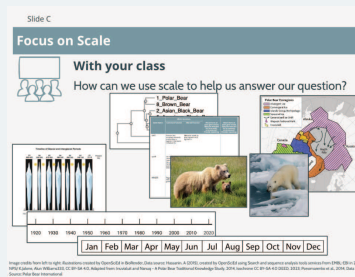
PREVIOUS LESSON

We reviewed the mechanism of evolution by natural selection and learned about selection pressures caused by glacial and interglacial periods that may have caused polar bears and brown bears to split from their common ancestor. We connected these geologic events with fossil evidence of bears and genetic variations found in polar and brown bears. We constructed and revised arguments about what could have caused polar and brown bears to become distinct species as we look at each type of evidence. We decided to leverage what we figured out about bear speciation in the past to figure out what will happen to polar bears in the future.

THIS LESSON

PUTTING PIECES TOGETHER

1 day



We develop a Gotta-Have-It Checklist and revise our class consensus model, putting together what we figured out from Lessons 2-4. We revisit our Driving Question Board and evaluate our progress in answering those questions. We decide to figure out more about how the polar bear population will respond to changes in climate in the future.

NEXT LESSON

We will investigate data and use a model to predict what will happen to polar bears as the climate changes and polar and brown bears interact in new ways..

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

5.A Revise a model based on evidence to explain and predict what will happen to Arctic bear populations as their environment changes. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4; CCC: 3.1)

WHAT STUDENTS WILL FIGURE OUT

- Polar bear populations will decline in the future because they evolved with adaptations for Arctic environments. When removed from those habitats, they overheat and cannot outcompete brown bears for food.
- Arctic brown bear populations will increase in the future, as there is less ice and they can use aggression and genetic diversity to find food, survive, and reproduce in more areas on land in the Arctic.

Lesson 5 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Lead a short discussion to navigate into the day's work.	A-B	copy of class consensus model from Lesson 1
2	3 min		FOCUS ON SCALE Facilitate a brief discussion of how focusing on scale may help answer the unit question.	C	
3	7 min		BUILD GOTTA-HAVE-IT CHECKLISTS Introduce the Gotta-Have-It Checklist, then pair students with a partner to draft their checklists.	D	copy of class consensus model from Lesson 1
4	8 min		BUILD A CONSENSUS GOTTA-HAVE-IT CHECKLIST Lead students in compiling their Gotta-Have-It Checklists into a class consensus checklist.	E	chart paper, chart paper markers
5	10 min		REVISE CLASS CONSENSUS MODEL Support the class in revising the consensus model.	F-G	copy of class consensus model from Lesson 1, chart markers
6	10 min		TAKE STOCK OF WHAT WE HAVE FIGURED OUT Ask students to individually identify questions from the DQB that the class has figured out. Facilitate a class discussion to determine which questions have been answered on the Driving Question Board.	H-I	<i>DQB Questions</i>
7	4 min		NAVIGATE Students add questions to the DQB.	J	Driving Question Board, tape (optional), 3x3 sticky notes

End of day 1

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • <i>DQB Questions</i>		• copy of class consensus model from Lesson 1 • chart paper • chart paper markers • chart markers • Driving Question Board • tape (optional) • 3x3 sticky notes

Materials preparation (minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure the class Community Agreements poster (created in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*) is hung where students can see it. It should be available for reference in case students encounter interpersonal conflict or need to be reminded of an agreement that is not being followed.

- Three-hole-punch all handouts so they can be added to students' notebooks.
- Gather the class consensus model from Lesson 1 and the Driving Question Board.
- Gather chart paper and chart paper markers to create the class consensus Gotta-Have-It Checklist.
- Add questions from the class DQB into *DQB Questions* before copying for students.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

During this culminating lesson of Lesson Set 1, students put the pieces together to model and predict what will happen to Arctic bear populations as the environment changes. Students use the evidence collected in Lesson Set 1 to support their explanations. The DCI elements that students put together in this lesson include:

- LS2.C.2 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. (HS-LS2-7)
- LS4.C.4 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. (HS-LS4-5),(HS-LS4-6)

Students continue to use elements of *developing and using models* intentionally developed in previous other OpenSciEd units, including *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)*.

Students continue to develop elements from the focal crosscutting concept *scale, proportion, and quantity*. As they prepare to revise their models, they are prompted to consider spatial and time scales (from Lessons 1 and 4), as well as consider the levels of biological organization (from genetics to ecosystems from Lessons 1-4) involved in answering the unit question.

Where We Are NOT Going

Students may ask questions about how glacial cycles interact with human-caused climate change. The relative speed of increasing temperatures due to human-caused climate change is relevant to their predictions and will be explored in Lesson 6. However, the mechanisms for understanding these differences are beyond the scope of the unit. Understanding feedback effects from fossil fuel emissions and the geologic time scale of cycling carbon will be further developed in *OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)* and *OpenSciEd Unit C.4: Why are oysters dying, and how can we use chemistry to protect them? (Oysters Unit)*.

LEARNING PLAN for LESSON 5

1 · NAVIGATE

3 min

MATERIALS: copy of class consensus model from Lesson 1

Recall what we figured out last time. Display **slide A**. Have students turn and talk with a neighbor about the question on the slide. Invite a few students to share with the whole class. Sample student responses include:

- There were cycles of glaciation, and a population of bears became isolated on an island that was always covered in ice.
- Over thousands of generations, the isolated bear population adapted to cold and ice through evolution by natural selection.
- Allele variations helped them blend in with the ice, become fat, and survive with a very fatty diet spread throughout the isolated bear population.
- Eventually, after thousands of years, the isolated bear population became so different from the other bears that they were a new species, the polar bear.
- Brown bears were more like the common ancestor bear, were very diverse, and lived in a very large habitat south of the ice.

Navigate to today's work. Direct student attention to the class consensus model. Say, *We have figured out a lot since we first created our class consensus model in Lesson 1. Display slide B and discuss progress the class has made so far in answering the unit question, What will happen to Arctic bear populations as their environment changes? Use the following prompts as a guide.*

Suggested prompt	Sample student response
<i>What does our current model explain?</i>	The ice is melting, the tundra is greening, and some brown bears are moving north to places they haven't been before. Some polar bears, especially those with seasonally available ice, are stuck on land for longer periods of time. They are less healthy than those on permanent ice.
<i>What new ideas might we need to add to our model?</i>	When the brown and polar bears interact, brown bears dominate. Polar bears overheat easily and are not adapted to life on the land, so they are unlikely to do well. Polar bears and brown bears are closely related and share a lot of DNA. Polar bears and brown bears have a common ancestor. It takes thousands of generations and thousands of years for bear populations to adapt to changes in climate. Polar bears have genetic variations that make them well adapted to ice and snow. Polar bears are not as genetically diverse as brown bears. Brown bears are genetically diverse and live over a huge range.

2 · FOCUS ON SCALE

3 min

MATERIALS: None

Facilitate a discussion about scale. Display slide C and discuss the prompts on the slide.

Suggested prompts	Sample student responses	Follow-up questions
<i>How can we use the concept of scale to answer our question?</i>	We need to consider multiple scales at one time. We need to think about where the environment is changing and over what time period. We need to understand how bears are adapted to their habitats and seasonal changes that normally occur. We need to think about genetics and how it allows individuals to survive, but that adaptations can only evolve if there is genetic variation within the population. We need to think about how long it takes for populations to evolve if the environment changes.	<i>What time scale is important? (Are we concerned about seasonal change, human-caused climate change, or geologic cycles?)</i> <i>Are we concerned about individual bears, populations, or whole species? (Are we interested in genetics, behaviors, evolution, or speciation?)</i> <i>What spatial scale is important? (Are we concerned about resource availability and adaptations in one habitat, an ecoregion, or all of the Arctic?)</i>

3 · BUILD GOTTA-HAVE-IT CHECKLISTS

7 min

MATERIALS: science notebook, copy of class consensus model from Lesson 1

Prepare to develop the Gotta-Have-It Checklist. Display slide D. Say, *Throughout our school year, we talked about how important modeling is to scientists like us. How have models helped us make sense of what we have figured out?* Listen for students to mention how they used models to develop an explanation of evolution by natural selection, how zombie fires burn under ice, and other examples from previous units.

Ask students to recall how we have figured out what to put into our models. Listen for students to recall that they developed Gotta-Have-It Checklists. Suggest to students that we do the same here today.

ADDITIONAL GUIDANCE

Students have created Gotta-Have-It Checklists on many occasions throughout the year. If students are unsure how to create the three-column chart of components, interactions, and mechanisms, they should look through their science notebooks for examples from *Natural Selection Unit*, *Serengeti Unit*, or other units.

Define the task. Remind students to look back through their science notebooks, posters the class has co-created (see Materials Preparation section), readings, Progress Trackers, and other handouts to pick out the most important ideas for a model to answer the question, *What will happen to Arctic bear populations as their environment changes?*

Provide work time with partners. Pair off students and provide time to compose their Gotta-Have-It Checklists.

4 · BUILD A CONSENSUS GOTTA-HAVE-IT CHECKLIST

8 min

MATERIALS: chart paper, chart paper markers

Build a consensus Gotta-Have-It Checklist. Display **slide E** and use prompts to facilitate a consensus discussion* to build toward a checklist for the whole class. Record students' suggestions on chart paper and encourage them to revise their own lists to include ideas that the class decides are appropriate. Students may leave additional items on their own checklists if they are supported by evidence the class has collected.

KEY IDEAS

Purpose of this discussion: This Consensus Discussion is an opportunity for students to come to agreement about the most important ideas to include in their models. Be explicit with students about how your and their roles will be different than in other discussion types.

Listen for these ideas: See the sample Gotta-Have-It Checklist below. The list focuses on new components, interactions, and mechanisms that were not present in the Lesson 1 consensus model.

* STRATEGIES FOR THIS CONSENSUS DISCUSSION

A consensus discussion is different from other kinds of discussions because its purpose is to converge on one or more ideas that the whole class agrees on. During this work, the class resolves disagreements where possible. Your role is to help students see where they agree and where they still disagree. Helpful prompts include:

- What ideas are we in agreement about?
- Would anyone have put this point a different way?
- Who feels like their idea is not quite represented here?
- Are there still places where we disagree? Can we clarify these?

What will happen to Arctic bear populations as their environment changes?

Components	Interactions	Mechanisms
Unhealthy polar bears, brown bears, warmer temperatures	Climate change makes polar bears overheat; interacting with brown bears makes polar bears overheat.	Too much fat insulates polar bears' bodies so they have to slow down. They cannot eat as much if they slow down and become unhealthy.
Allele variations (like white fur) and ice	White polar bears are on land more, where being white does not help them hunt. White polar bears on ice hunt seals using camouflage.	Polar bears on seasonal ice might not get enough food to survive and reproduce, and the population might get smaller. Polar bears on permanent ice are well adapted to hunt and eat seals. They survive and reproduce.
Highly diverse brown bear populations and more tundra	Brown bears expand into new ranges as ice melts.	Brown bears have a variety of alleles that allow them to adapt to different environments. They survive and reproduce, and their population grows.
Greenland or other islands of permanent ice and polar bears	Only polar bears are only found living on these islands.	Only polar bears have evolved adaptations to survive year round in Arctic conditions in these locations.
Brown bear, polar bear, whale carcasses	Polar and brown bears interact at whale carcasses in the fall. Brown bears are aggressive; polar bears are submissive.	Brown bears learn to be aggressive from their parents. Polar bears overheat, so they avoid conflict. Polar bears are also often tired and skinny in the fall when they cannot hunt on ice.

Brown bear, polar bear

Bears interact more in places where their ranges overlap or are near each other.

Bears are closely related and share a lot of traits; therefore they may interact in similar environments.

5 • REVISE CLASS CONSENSUS MODEL

10 min

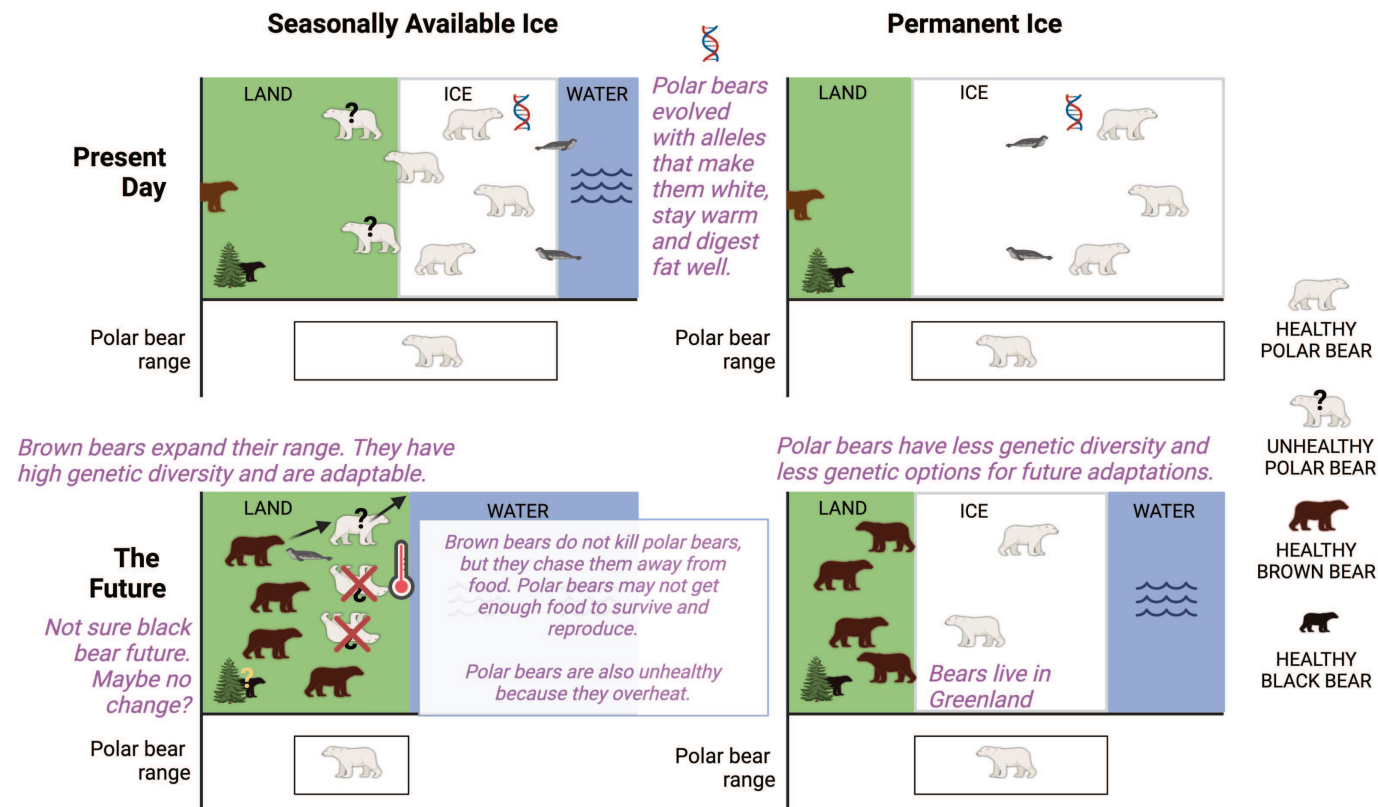
MATERIALS: science notebook, copy of class consensus model from Lesson 1, chart markers



Revise the class consensus model. Display **slide F**. Explain that now we can use our Gotta-Have-It Checklists to revise our class consensus model. Provide a minute for students to quietly consider how they would revise the model before you begin as a class.* Then display **slide G** and facilitate the revision of the initial consensus model that includes the items on the Gotta-Have-It Checklist. One sample of a revised consensus model is shown below.

* ATTENDING TO EQUITY

Providing a minute for quiet thought before revising the class consensus model provides additional time for all students to process the consensus Gotta-Have-It Checklist and consider how to apply new ideas for the model. This should allow more students to formulate ideas to contribute to the full-class discussion. The extra processing time is particularly important for multilingual learners.



Illustrations created by OpenSciEd in Biorender.com

As students propose revisions, remind them to note areas of uncertainty in their model and record the questions they have in their science notebooks, as we will continue pursuing answers to those questions. Some of students' lingering questions may include:

- How quickly will changes to Arctic ice occur?
- Will polar bears on permanent ice recover again if another glacial period comes?
- Is there any way to protect polar bears from the effects of climate change?
- Do polar bears still have genes from their common ancestor that might protect them from climate change?
- Will black bear populations change if there are more brown bears? Will there be more trees?

ASSESSMENT OPPORTUNITY

What to look/listen for in the moment: As the class revises the initial consensus model (SEP: 2.3), look/listen for:

- Brown bear populations will expand because climate change melts the ice earlier than before, increasing their available range and making more food available to them. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4)
- Polar bear populations on seasonally available ice will decline because:
 - They will overheat on land.
 - They will interact more often with brown bears at food sources and lose. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4; CCC: 3.1)
- Polar bear populations on permanent ice will decline because they will have less ice habitat every year into the future.
- Uncertainty about whether ice will melt more quickly in the future due to human-induced climate change compared to past glacial cycles. (DCI: LS2.C.2; LS4.C.4; CCC: 3.1)
- Uncertainty about the ability of polar bear species to evolve fast enough to adjust to climate change. (DCI: LS2.C.2; LS4.C.4; CCC: 3.1)
- Uncertainty about what will happen to the black bear populations. (DCI: LS2.C.2; LS4.C.4; CCC: 3.1)

What to do: As groups revise their models, ask:

- What evidence do we have to support that idea?
- Will polar bear populations decline in all ecoregions? What accounts for the difference?
- What other problems will polar bears encounter if they come to land more often?
- How do small-scale changes influence changes on a larger scale?
- Do these large-scale changes allow time for smaller-scale changes to occur?

Building toward 5.A Revise a model based on evidence to explain and predict what will happen to Arctic bear populations as their environment changes. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4; CCC: 3.1)

ALTERNATE ACTIVITY

If time allows, have students revise the initial model in small groups or individually before working on the class consensus model. This will allow participation from more students and provide an additional assessment moment to collect and evaluate.

6 · TAKE STOCK OF WHAT WE HAVE FIGURED OUT

10 min

MATERIALS: DQB Questions

Revisit the Driving Question Board. Say, *It is important to take time to check in on our Driving Question Board questions so we can see the progress we have made toward answering them and use them to direct where we are going next in the unit.* Display slide H and distribute *DQB Questions* to all students. Provide a few minutes for students to evaluate the DQB questions individually by marking them on *DQB Questions* using the key on the handout *, replicated here:

- We did not answer this question or any parts of it yet: ○
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓

* ATTENDING TO EQUITY

Building classroom culture: Students benefit personally and intellectually from feeling like they belong in and contribute to the science classroom community. The return to the

- Our class answered this question, or Using the ideas we developed, I could now answer this question: ✓+

Direct students to answer one of the questions they marked with a ✓ or ✓+.

Answer questions on the DQB. Display slide I. Invite students to share questions they think the class has answered, along with a brief explanation of the answer as time allows. If the class agrees that the question was fully answered, move that sticky note to a new poster near the DQB titled “Questions We Have Answered.” Optionally: Have a student jot the answer on a sticky note and attach it to the question. If the question was partially answered, put a check mark on the question to keep track of questions we are making progress toward but leave it on the DQB.

DQB is an opportunity for students to recognize how much growth they have had both individually and as a collective.

7 · NAVIGATE

4 min

MATERIALS: Driving Question Board, tape (optional), 3x3 sticky notes

Add any new questions to the DQB. Display slide K. Say, *Impressive! We have answered many of our questions. As we revised our consensus models, you were prompted to record any new questions that may have come up for you. Let's take a moment to add those to our DQB.* If students have new questions, ask them to write them in marker on sticky notes and post them on the DQB now. Listen for questions such as:

- How quickly is the Arctic climate warming now compared to other interglacial periods?
- How long will the ice last?
- Will polar bears be able to evolve through natural selection to adapt to the warming conditions?
- Will polar bears keep interacting with the brown bears?
- Will polar bears go extinct?
- What will happen to the black bears going forward?

Summarize new DQB questions. Say, *It sounds like we are still concerned about the future of the polar bears and want to know more about their ability to adapt and survive in the future. Let's look into that next time.*

LESSON 6: What will happen to bear species in the Arctic in the future?

PREVIOUS LESSON We revised our class consensus model, putting together what we figured out from Lessons 2-4. We revisited our Driving Question Board and evaluated our progress answering those questions. We decided to figure out more about how the polar bear population will respond to changes in climate in the future.

THIS LESSON

INVESTIGATION

1 day



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We decide to investigate what will happen to polar bears in the future as the Arctic environment changes. We figure out the climate is likely changing too fast for polar bears to evolve and adapt to environmental changes. We wonder about other possibilities for polar bears and hear about a case where polar bears and brown bears mated and produced hybrid offspring. We use a model to generate evidence to help us predict hybrid fitness in the future. We wonder if polar bears could go extinct.

NEXT LESSON We wonder if polar bears could go extinct and will review how the changes to one species cascades through an ecosystem. We will investigate current extinction rates for the whole Earth and wonder how this compares with events in the geologic past. We will investigate the five mass extinctions in Earth's history, look for patterns in the evidence for the cause of those extinctions, and connect those ideas to what is happening today.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

6.A Use a model to generate new evidence to support claims about the survival of polar bears in the changing Arctic. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2)

WHAT STUDENTS WILL FIGURE OUT

- The Arctic climate is likely changing too quickly for polar bears to adapt.
- Polar and brown bears may interact and mate with each other.
- We can use a model to generate evidence to support predictions.
- If polar and brown bears mate, some polar bear genes may not be lost.

Lesson 6 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	3 min		NAVIGATE Guide a brief discussion about what students figured out in the previous class and what questions they still have.	A	
2	13 min		INVESTIGATE HOW POLAR BEARS COULD ADAPT TO THE WARMING CLIMATE Investigate how polar bears might adapt to a warming climate.	B-E	<i>Future Predictions</i>
3	8 min		INTRODUCE EVIDENCE OF MATING INTERACTIONS BETWEEN POLAR AND BROWN BEARS Introduce and support sensemaking of hybridization data.	F-I	<i>Mating Between Bear Species, Making Sense of Matings</i>
4	10 min		USE A MODEL OF HYBRIDIZATION BETWEEN POLAR AND BROWN BEARS Introduce a model of brown and polar bear hybridization.	J-M	Polar and Brown Bear Hybridization
5	8 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT HYBRIDIZATION Lead a Building Understandings Discussion about hybridization.	N	
6	3 min		NAVIGATE Administer an Electronic Exit Ticket.	O	internet-connected device, copy of https://docs.google.com/forms/d/1YvuP5uOT8Mo_Em-mBb3wuWzrqHVklOdiO_xSps8m8Cl/copy

End of day 1

Lesson 6 • Materials List

	per student	per group	per class
Polar and Brown Bear Hybridization materials	1 coin <i>Hybridization Model Traits</i>	- interglacial map from Lesson 4 - set of white chips - set of brown chips <i>Hybridization Model</i>	
Lesson materials	- science notebook <i>Future Predictions</i> <i>Mating Between Bear Species</i> <i>Making Sense of Matings</i> - internet-connected device - copy of https://docs.google.com/forms/d/1YvuP5uOT8Mo_Em-mBb3wuWzrqHVklOdiO_xSps8m8CI/copy		

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

Day 1: Polar and Brown Bear Hybridization

- Group size:** 3-5 students
- Setup:** For each group, gather 1 interglacial map from Lesson 4, set of 10 white chips, set of 10 brown chips (or any other color), 1 coin per person

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students explore future possibilities for the Arctic bear species as their environment changes.

The lesson addresses the high school disciplinary core ideas:

- *LS4.C.5 Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.*

Students use the science practice *developing and using models* to generate evidence to predict future outcomes. Students have used this element in similar ways in previous OpenSciEd Biology units.

Students use the crosscutting concept *cause and effect* to consider the effect of allele recombination on hybrid offspring. Students have used this element in similar ways in previous OpenSciEd Biology units.

In this lesson, students encounter the definition for hybrid. Words should be defined and recorded in Personal Glossaries AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

While students investigate how polar and brown bears can produce hybrid offspring, they do not investigate ideas such as hybrid vigor or hybrid sterility. These ideas are beyond the scope of the standards and may serve as an extension for high-interest students.

LEARNING PLAN for LESSON 6

1 · NAVIGATE

3 min

MATERIALS: science notebook

Review progress to date. Display **slide A**. Facilitate discussion to review what the class figured out in Lesson Set 1 and what questions remain using the prompts below as a guide.

Suggested prompts	Sample student responses
<i>What did we figure out?</i>	Brown bear populations will expand. Polar bear populations on seasonally available ice and permanent ice will decline. Polar and brown bears will interact more on land. Polar bears and brown bears are closely related. The climate is getting warmer. Polar bears have adapted to changes in climate in the past.
<i>What questions do we still have?</i>	How quickly is the Arctic climate warming now compared to other interglacial periods? How long will the ice last? Will polar bears be able to evolve through natural selection to adapt to the warming conditions? Will polar bears keep interacting with the brown bears? Will polar bears go extinct? What will happen to the black bears going forward?

2 · INVESTIGATE HOW POLAR BEARS COULD ADAPT TO THE WARMING CLIMATE

13 min

MATERIALS: science notebook, *Future Predictions*

Introduce an investigation into whether polar bears can adapt to a warming climate. Say, *One of the questions I heard you ask was about natural selection and if polar bears can adapt to the warming Arctic. Let's investigate that.* Display **slide B**. Ask students to turn and talk about the questions on the slide. Call on a few pairs to share their ideas using the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>What conditions need to be present for natural selection to take place?</i>	Selection pressure from the environment. Genetic variation in a population. Differential survival and reproduction of those with favorable traits.	<i>What steps did we review in Lesson 4?</i>
<i>What do we already know about these conditions for polar bears?</i>	The environment is changing. They will compete for resources. There is not a lot of genetic variation. They do not produce a lot of offspring or reproduce very quickly.	<i>What did we learn in previous lessons about...?</i>
<i>When we investigate speciation of brown and polar bears from a common ancestor, how long did that take?</i>	Thousands of years.	<i>How many generations of bears were there in that many years?</i>
<i>What do we still need to know?</i>	What is going to happen to the ice in the Arctic? How fast will the ice in the Arctic melt?	<i>What do we want to know about the future?</i>

Review new data. Display **slide C**. Introduce the graph on the slide with students. Explain that based on all of the data collected by NASA and the National Snow and Ice Data Center, scientists have modeled predictions about what could happen to Arctic ice under different greenhouse gas emissions levels. Give students a few moments to review the data and ask questions.

ADDITIONAL GUIDANCE

Students will likely need support with making sense of the figure on slide C. The black line represents the actual observations of the sea ice area each September (representing the minimum amount of ice) since 1980. Each of the other lines are projects using a model of what could happen to ice under different climate scenarios. The blue line represents a model with the lowest level of greenhouse gas emission, and the red line represents the highest level of greenhouse gas emission.

Small-group investigation. Display **slide D**. Organize students into small groups, distribute a copy of *Future Predictions* to each student, and ask students to discuss and record their responses on the handout.

Whole-class discussion. Display **slide E**. Once students have had time to discuss and record their responses, discuss as a whole class using *Future Predictions Key* and the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>How did you describe the take-away from Figure 1?</i>	It predicts that in all but the low emissions scenario, the Arctic will be ice-free in September by about 2080.	<i>What do each of the lines show?</i> <i>Why are there so many different lines?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>Based on scientists' predictions of future ice conditions in the Arctic, how likely is it that polar bears will adapt to their changing environment? Please explain.</i>	It is unlikely that polar bears will adapt via natural selection because they have low genetic diversity and the change is happening really fast. Even under the most conservative conditions, they only have about 5 generations to adapt, and that is not a lot based on what we saw in the past.	<i>How many years/generations did it take for polar bears to evolve when the environment changed in the past?</i>
<i>If it is not likely that polar bears will adapt via natural selection. What are the other possibilities for their future?</i>	They might go extinct. They might mate with brown bears.	<i>How does the past compare to the present/future?</i> <i>We know polar bears interact with brown bears around food. How else might they interact?</i>

3 · INTRODUCE EVIDENCE OF MATING INTERACTIONS BETWEEN POLAR AND BROWN BEARS

8 min

MATERIALS: *Mating Between Bear Species, Making Sense of Matings*

Introduce new data from the Inuvialuit community. Say, *I know some of you are concerned about polar bears and extinction and others wonder if the polar bears and brown bears might interact and mate. I found some very interesting data about instances where polar and brown bears have interacted in the wild.* Display **slide F** and explain to students that the first piece of data comes from members of the Inuvialuit (In-oo-vee-A-loo-weet) that we heard from in Lesson 1. Read the quote to students. Then ask students to turn and talk to a partner to interpret the quote. Call on a few pairs to share their ideas about what the quote tells them, such as:

- People have seen polar and brown bears mating before.
- They have also seen half breeds, half polar half brown bears and can recognize them.

Introduce a study of polar and brown bears that mated and produced offspring. Let students know that you have some additional data from a study published by scientists that you have summarized. Display **slide G**. Distribute *Mating Between Bear Species* to each student. Ask students to read on their own using whatever literacy strategy is in place in your classroom.

ADDITIONAL GUIDANCE

Students will encounter the definition for *hybrid* in their reading. Encourage them to add a definition similar to *offspring of two individuals of different species* to their Personal Glossaries.

Partner work to make sense of data. Display **slide H**. Organize students into pairs and distribute *Making Sense of Matings* to each student. Ask students to discuss and record their responses to the Making Sense questions on the handout.

Whole-class discussion about the hybrid data. Display **slide I** and use the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>Why might polar and brown bears interact on Banks and Victoria Islands? What kind of ecoregions would they be in?</i>	They are islands near Canada and probably have seasonally available ice where polar bears and brown bears will come into contact. The Inuvialuit have seen polar and brown bears mating..	<i>Where else have we seen polar and brown bears interacting?</i>

Suggested prompts	Sample student responses	Follow-up questions
How did the interaction data help explain why female polar bears might mate with male brown bears and not the other way around?	Female polar bears were more aggressive with male brown bears and less likely to be scared away.	Which polar bears were most/least aggressive?
If brown bears and polar bears were to mate and produce offspring more frequently, how well adapted for the environment do you think the hybrids would be? Explain.	Hybrid bears might be more fit because they would have traits from both bears. They might have some more variation from the brown bears that would make the bears better at dealing with changing conditions and eating different foods.	What traits have we investigated that brown and polar bears have?

4 · USE A MODEL OF HYBRIDIZATION BETWEEN POLAR AND BROWN BEARS

10 min

MATERIALS: Polar and Brown Bear Hybridization, science notebook

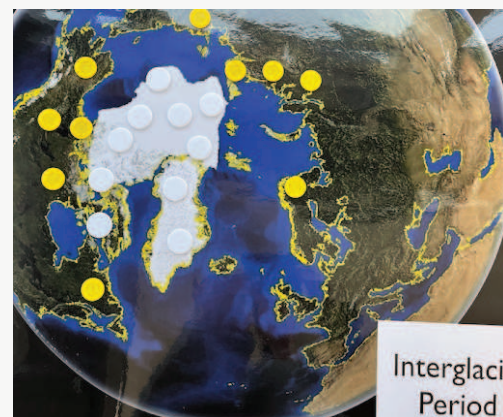
Introduce the polar and brown bear hybridization model. Say, *You all have some great ideas about hybrid bears and how well suited they might be to the environment. I have a model we can use that will help us explore your ideas about their traits and how well suited they might be for the warming Arctic with less ice.* Display **slide J**. Explain to students that using the interglacial map and the traits they investigated in Lesson 4, they will develop a model of hybridization.

Review the model set-up. Explain that each group will have one map and 10 chips of each color, 10 for polar bears, 10 for brown bears, and one coin per person.

Introduce the alleles. Display **slide K**. Explain to students that although each species has many traits, they will be investigating the role of traits they are already familiar with in their hybridization models. Distribute *Hybridization Model Traits* to each student.

Review the model instructions. Display **slide L**. Let students know you will organize them into small groups. With their group, they will put the brown and polar bear chips where they think they would be on the map as shown in the example here.

Then they will pair up one brown bear with one polar bear. For each mating, they will flip a coin for each trait to determine which allele they have. They should notice that while they need to flip the coin for the brown bear, the polar bear has no variation for these traits. Since there is only one possibility, they do not need to flip the coin for the polar bear. In *Hybridization Model*, students will record the outcome for each mating by circling the allele they get for each brown bear. Then they should describe how they think the offspring will express the trait. For example, if they have two copies of the same allele (homozygous), they will express the trait as written. If they have two different alleles (heterozygous), they will express an intermediate phenotype.



ADDITIONAL GUIDANCE

The brown and polar bear have close to 20,000 coding genes. Here we are looking at a sample of just four genes whose expression may have meaningful interactions with the bear's environment. Prompt students to consider the limitations of the model they use due to the number of genes they are investigating.

Student groups model hybridization. Distribute *Hybridization Model* to each group. As students use their model, circulate around the room to support them.



Students make claims supported by evidence. Display slide M. When they have completed all 10 matings, groups should review the entire population of hybrids and make a claim in their science notebooks on loose-leaf paper that they can turn in about how well suited they think the hybrid population will be to the warming Arctic.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Claims using evidence from student models to predict the fitness of hybrids in the changing Arctic such as:

- Roughly half of the hybrids will be well adapted to changing Arctic conditions. Those that gain alleles for less fat that do not overheat will be able to survive and reproduce as it gets warmer. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2)
- Some of the hybrids will be well adapted to changing Arctic conditions, but some will not. Those that have darker fur and do not overheat will be able to hunt well and will be able to fight over food to survive and reproduce. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2)

What to do: Direct students back to *Hybridization Model* and ask how many hybrids would do well and why. Ask which traits seem most important for survival.

Building toward 6.A Use a model to generate new evidence to support claims about the survival of polar bears in the changing Arctic. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2)

5 • BUILDING UNDERSTANDINGS DISCUSSION ABOUT HYBRIDIZATION

8 min

MATERIALS: science notebook

Facilitate a Building Understandings Discussion. * Display slide N and use the prompts below as a guide.

Suggested prompts	Sample student responses	Follow-up questions
<i>What happened when polar and brown bears mated?</i>	Some of the offspring were well suited for the environment, but others were not.	
<i>What do you think would happen to the hybrids after the first generation?</i>	The ones with traits well suited to the environment might mate with each other and make more hybrids. The hybrids might mate with polar or brown bears. The hybrids might not be well suited and might not survive to reproduce.	<i>Who could the hybrids mate with?</i> <i>Which hybrids might survive and reproduce?</i>

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

As students share, encourage them to use evidence from their group's model to support their ideas. It is not necessary for the class to reach consensus during this discussion. Some groups may have a hybrid population that is more or less well suited to the warming Arctic with less ice.

Suggested prompts	Sample student responses	Follow-up questions
<i>If the polar bear mates with the brown bear, could the hybrid bear become a new species?</i>	It is possible that they could.	<i>How do we know if it is a new species?</i> <i>This does not fit our definition of speciation. What do we do with this information?</i>

KEY IDEAS

Purpose of this discussion: To explain that although it is not the main mechanism, hybridization could lead to speciation in a changing environment.

Listen for these ideas:

- Polar and brown bears have hybridized.
- The hybrids may or may not be well suited for the environment.
- Hybrids may mate with brown, polar, or other hybrid bears.
- It is possible that hybridization could lead to speciation.

6 • NAVIGATE

3 min

MATERIALS: science notebook, internet-connected device, copy of https://docs.google.com/forms/d/1YvuP5uOT8Mo_Em-mBb3wuWzrqHVklOdiO_xSps8m8Cl/copy



Students complete an Electronic Exit Ticket. Ask students to complete the Electronic Exit Ticket found at https://docs.google.com/forms/d/1YvuP5uOT8Mo_Em-mBb3wuWzrqHVklOdiO_xSps8m8Cl/copy.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See *L6 Electronic Exit Ticket Key* for guidance.

What to do: See *L6 Electronic Exit Ticket Key* for guidance.

Additional Lesson 6 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

Students use a graph and informational text as evidence about the future of polar bears.

LESSON 7: How do past patterns of extinction help us understand possible consequences of extinctions now and in the future?

PREVIOUS LESSON

We decided to investigate what will happen to polar bears in the future as the Arctic environment changes. We figured out the climate is likely changing too fast for polar bears to evolve and adapt to environmental changes. We wondered about other possibilities for polar bears and heard about a case where polar bears and brown bears mated and produced hybrid offspring. We used a model to generate evidence to help us predict hybrid fitness in the future. We wondered if polar bears could go extinct.

THIS LESSON

INVESTIGATION

2 days



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We are concerned about the extinction of the polar bear and remember that the changes to one species can cascade through an ecosystem. We investigate current extinction rates for the whole Earth and wonder how this compares with events in the geologic past. We investigate the five mass extinctions in Earth's history and figure out that in each, a major event precipitated a significant shift in climate, which led to the loss of at least 75% of species. We connect what we learned in the past to what is happening today and wonder if we should protect species, like the polar bear, from extinction.

NEXT LESSON

We will research and evaluate different solutions people have used to protect species from extinction and present what we learn to our peers. We will discuss if these solutions could work to protect the polar bear and if people should intervene to protect the polar bear.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

7.A. Construct an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)

7.B. Revise an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth and its effect on biodiversity. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)

WHAT STUDENTS WILL FIGURE OUT

- Five times in Earth's history, significant environmental changes that resulted in major shifts in global climate caused the extinction of at least 75% of all species at the time.
- Extinction is a significant threat to biodiversity, which is necessary for ecosystem resistance.
- There are similarities between environmental conditions that caused the mass extinctions and what Earth is like today.
- Unlike the previous 5 mass extinctions, current extinctions are primarily caused by human activities.

Lesson 7 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review ideas about different strategies available to polar bear populations in response to environmental changes.	A-D	
2	9 min		EXPLORE CURRENT EXTINCTION DATA Explore current extinction data beyond the Arctic to figure out the full extent of the threat.	F-I	
3	3 min		SOCIAL AND EMOTIONAL LEARNING CHECK-IN Create space for students to reflect on their feelings about extinction data.	J	
4	5 min		MOTIVATE AN INVESTIGATION OF PAST MASS EXTINCTIONS Investigate past mass extinction events in a visual inquiry.	K-M	<i>Extinctions Graphic Organizer</i> , internet-connected device, https://docs.google.com/presentation/d/1hXQ_nYegNKQ2bOjWMfm1A7QbYxxNqNMQEKJYjpCjMTO/edit?usp=drive_link
5	13 min		VISUAL INQUIRY: MASS EXTINCTION EVENTS Students conduct a visual inquiry to investigate the five mass extinction events in Earth's history, looking for patterns in the evidence that link causes to the effects of mass extinctions.	M	<i>Extinctions Graphic Organizer</i> , printed images from the Mass Extinction Visual Inquiry
6	8 min		WRITE INITIAL ARGUMENTS Students work in groups to write an argument that explains the main cause of mass extinctions on Earth.	N	<i>Extinctions Graphic Organizer</i>
7	2 min		NAVIGATE: REQUEST FURTHER EVIDENCE Students share information they need to revise their initial arguments.	O	<i>Extinctions Graphic Organizer</i>
End of day 1					
8	8 min		NAVIGATE: PEER REVIEW INITIAL ARGUMENTS Students share and compare their initial arguments about the cause of mass extinctions with a partner.	P-R	<i>Extinctions Graphic Organizer</i> , <i>Peer Feedback Protocol</i>
9	12 min		BUILDING UNDERSTANDINGS DISCUSSION ABOUT MASS EXTINCTIONS Facilitate a Building Understandings Discussion about the main causes of mass extinctions and effects on biodiversity.	S-T	<i>Extinctions Graphic Organizer</i> , <i>Key Extinctions Graphic Organizer</i>
10	5 min		CONNECT EXTINCTIONS TO CHANGES IN BIODIVERSITY Facilitate a brief discussion of the connection between mass extinctions and fluctuations in biodiversity. Discuss how speciation allows biodiversity to increase after a mass extinction.	U-V	

Part	Duration		Summary	Slide	Materials
11	10 min		REVISE INITIAL ARGUMENTS Students individually revise their arguments to explain the main cause of mass extinctions and how it impacts biodiversity.	W	<i>Key Extinctions Graphic Organizer</i>
12	5 min		CONNECT HUMAN ACTIONS TODAY TO PAST MASS EXTINCTIONS Facilitate a brief discussion to connect the causes of mass extinction in the past to events happening today.	X	
13	5 min		NAVIGATE: UPDATE PROGRESS TRACKERS Students update their Progress Trackers to update progress on the lesson and unit question. Students share questions they have and wonder if they should take action to prevent extinctions.	Y-Z	

End of day 2

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials	- science notebook <i>Extinctions Graphic Organizer</i> <i>Peer Feedback Protocol</i>	- internet-connected device https://docs.google.com/presentation/d/1hXQ_nYegNKQ2bOjWMfm1A7QbYxxNqNMQEKJYjpCjMTO/edit?usp=drive_link	- printed images from the Mass Extinction Visual Inquiry <i>Key Extinctions Graphic Organizer</i>

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to student notebooks.

Day 1:

- If you do not have the kit, print each page from https://docs.google.com/presentation/d/1hXQ_nYegNKQ2bOjWMfm1A7QbYxxNqNMQEKJYjpCjMTO/edit?usp=drive_link to create mass extinction stations.
- Tape images from the 5 mass extinction events on the wall in 5 separate areas of the room.
- Divide the students into groups of 3-4 to find patterns in evidence from the *Mass Extinction Visual Inquiry*.

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students connect the causes of current extinctions to patterns of evidence from the 5 mass extinctions in Earth's history. Students figure out that previous mass extinctions resulted from major events that caused global climate changes. Climate change today similarly threatens many species with extinction, but this and other threats in the modern age are due to the cumulative effects of human activities.

In *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*, students discovered that biodiversity is necessary for ecosystem resilience. In this lesson, students connect this knowledge to what they figured out about natural selection and speciation earlier in the unit. They figure out causes of mass extinction with mechanisms for recovery of biodiversity. Students note that biodiversity recovered after previous mass extinctions, but this took millions of years. Students discuss how current rates of extinction also threaten the survival of humans as part of the biosphere and wonder if we should protect species from extinction to prevent greater losses.

Students build on their middle school understanding of how life responds to biodiversity loss from MS-LS4.D: *Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.*

The lesson addresses the high school disciplinary core ideas:

- LS4.D.1 *Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction).* (HS-LS4.D.1)
- ESS2.E.1 *The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.* (HS-ESS2-7)

Students build off their knowledge of speciation built in Lesson 4 and again look for patterns in Earth's geologic past for evidence to understand how extinction and speciation are connected to major geologic and biologic events.

Students continue to develop the science and engineering practice of *engaging in argument with evidence* to construct and revise arguments about the relationship between climate change, mass extinction, and biodiversity. In Lessons 2 and 4, students received scaffolds to construct arguments by writing claims and directly connecting them with evidence and reasoning. In this lesson, formal scaffolds for writing arguments are removed. However, students have the support of peers to write their initial arguments. After a whole-class Building Understandings Discussion, students have an opportunity to revise their arguments individually.

Students develop the use of the crosscutting concepts *patterns* by connecting evidence from all 5 mass extinction events to find the cause for the global drop in biodiversity.

Students encounter the term *family and mass extinction* and may add it to their Personal Glossaries. Words should be defined and recorded AFTER your class has developed a shared understanding of their meaning.

Where We Are NOT Going

This lesson only briefly touches on the causes and effects of the 5 mass extinction events in Earth's histories. Students who show high interest may be encouraged to investigate the causes and effects of these events in more detail. Although ocean acidification connected to climate change is discussed as a cause of some mass extinction events, students will not investigate this mechanism until *OpenSciEd Unit C.1: How can we slow the flow of energy on Earth to protect vulnerable coastal communities? (Polar Ice Unit)*.

LEARNING PLAN for LESSON 7

1 · NAVIGATE

5 min

MATERIALS: science notebook

Turn and Talk to review ideas from previous lessons. Display **slide A**. Ask students to share with their shoulder partners what they figured out in the previous lesson and to gather ideas of what still needs to be figured out. Call on volunteers to share.

Suggested prompt	Sample student response
<i>What new ideas did we figure out in the last lesson about our question: What will happen to Arctic bear populations as their environment changes?</i>	We determined there is not enough time for polar bears to evolve to adapt to human-caused climate change. We saw evidence that polar bears and brown bears sometimes hybridize.
<i>What questions did we have?</i>	If polar bears cannot evolve fast enough to adapt to climate change, will they go extinct?

Introduce the phenomena. Say, *So I hear a lot of concern about the uncertain future of the polar bear. What would the consequences be if they disappeared?* Display **slide B**. Direct students to set up their notebooks with a Notice and Wonder chart. Display **slide C** and provide 2 minutes for students to fill out their noticings and wonderings in their notebook. Then display **slide D** and facilitate a discussion of what they recorded. Listen for ideas such as:

- Ringed seal populations would increase.
- Indigenous populations that rely on polar bears would not be able to hunt bears.
- Killer whales may benefit from the additional ringed seals in the area.
- Tourism would decrease because people visit the Arctic to see the polar bears.
- Questions about the resulting change in population size of other organisms in the ecosystem.
- Questions about other ways climate change might disrupt the Arctic ecosystem.

ADDITIONAL GUIDANCE

If students bring up Arctic organisms that are not on the model, celebrate their contributions and explain that this is a simplified version of the Arctic ecosystem. Additionally, as the Earth changes, other species could be in their model as they move into the area, just like the brown bear did.

Review the importance of biodiversity to ecosystem resilience. Display **slide E** and discuss the slide prompts. Listen for students to mention that an ecosystem with higher biodiversity can adjust and recover more easily from disturbances in the environment, like changes in rainfall patterns or small fires. Without the polar bear, the ecosystem will be less resilient and there could be harm to unexpected parts of the ecosystem in the future. Humans are part of these ecosystems. If students do not recall the word *resilience*, instruct them to look at the Personal Glossaries from *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects?* (Urbanization Unit).

2 · EXPLORE CURRENT EXTINCTION DATA

9 min

MATERIALS: None

Activate student knowledge about extinctions. Ask students if they know of any species that have gone extinct. Listen for students to mention dinosaurs, mammoths, and other species. After students share what they know, display **slide F**, which shows some pictures of animals that have gone extinct.

Explore current extinction data with a partner. Say, *So we know some species that have gone extinct in the past. Let's look into what species other than polar bears are in danger or are at risk of extinction. Let's find out more about other species.* Explain that you found some data related to this question. Display **slide G** and read through the bullets together. Display **slide H** and give students a few minutes to discuss the prompts with their elbow partner. Bring the class back together and ask a few groups to share highlights of their discussion with the class.

Suggested prompt	Sample student response
<i>How does this data relate to what you have heard about extinction from other sources?</i>	I heard that coral reefs are in trouble; this confirms it. Maybe these losses are related to burning of carbon sinks or habitat loss. I heard frogs can be endangered by chemicals in the environment that pass through their skin. I know panthers are endangered.
<i>What do you want to know about the data on the slide?</i>	Why are plants most endangered? Without plants, what will most consumers eat? What is causing all of these extinctions? Are extinction rates getting worse?

Compare extinction rates. Display **slide I**. Say, *It sounds like we want to know more about causes of extinction and if they are happening faster now than in the past. I found some information on how rates of extinction have changed over time.* Review what is meant by rate in this situation (see the guidance call-out below). Give students a minute to look over the graph quietly and then call on a few volunteers to describe what they see. Explain that background rates of extinction are like a control rate. Some extinctions always occur even without huge changes to the environment.

Suggested prompt	Sample student response
<i>What do you notice?</i>	Extinction rates are much higher after the industrial revolution than before it. Amphibians have extremely high rates of extinction compared to birds and mammals.
<i>Why would extinction rates increase after the industrial revolution?</i>	People created pollution from industry that killed plants and animals. Burning coal and fossil fuels increased carbon dioxide levels, causing climate change, leading to more fires. People's standard of living increased, more urbanization occurred, and they destroyed more habitats.

ADDITIONAL GUIDANCE

Rates of extinction are the number of species that die out over a certain amount of time.

The rates on the graph are measured in extinctions per million species-years (E/MSY). If the E/MSY=1, that means if we had one million species, one species would go extinct every year. If there was one species, it would go extinct in one million years. Emphasize the relative rates in the discussion rather than determining the number of species that have gone extinct.

After the Industrial Revolution, ecological degradation, habitat fragmentation, overexploitation, the introduction of non-native species, and pollution multiplied as humans relied more on industry, machines, and the burning of fossil fuels, and population explosions caused cities to swell worldwide and scaled up the mechanisms for climate change. There have been so many permanent changes to the Earth due to human activity that some scientists call this period *The Anthropocene* or The Age of Man.

3 · SOCIAL AND EMOTIONAL LEARNING CHECK-IN

3 min

MATERIALS: science notebook

Facilitate a social and emotional learning reflection. Display slide J. Provide time for students to reflect on their feelings about extinction using the feelings wheel from Lesson 1. They may choose between talking to a trusted peer, silent reflection in their science notebook, or thinking about how they feel about the extinction data. Encourage students to use the feelings wheel to help articulate their feelings or give them the language they need to process them. If they need further support, suggest they share with a trusted adult.

4 · MOTIVATE AN INVESTIGATION OF PAST MASS EXTINCTIONS

5 min

MATERIALS: *Extinctions Graphic Organizer*, internet-connected device, https://docs.google.com/presentation/d/1hXQ_nYegNKQ2b0jWMfm1A7QbYxxNqNMQEJYjpCjMTO/edit?usp=drive_link

Motivate investigation into past extinction events. Say, *We have seen evidence that extinction rates are higher now than before the Industrial Revolution, and some of us are worried about what the future holds. We know that extinctions have happened way in the Earth's past with the dinosaurs. Since looking at the past helped us think about the future before, let's take some time to look into Earth's past again to see what happened with extinction rates well before the Industrial Revolution.*

Prepare for a visual inquiry of Earth's five mass extinction events. Display slide K and distribute a copy of *Extinctions Graphic Organizer* to each student so they can examine the graph on the slide more closely. Ask what students notice. Listen for them to mention that there are 5 spikes in extinction rate in Earth's past. Say, *Let's do some investigation to find out what happened during these mass extinction events and see if we can better predict the future.* Ask students to turn and talk with an elbow partner about the discussion prompts on the slide.

ADDITIONAL GUIDANCE

If necessary, clarify the difference in scale of extinction rates shown on slides I and K. Slide I is measured in species and slide K is measured in families. Use slide L, hidden in the deck, to explain the relationship between species and families. Families and species are nested within categories of relatedness often based on common characteristics. For example, students investigated 8 bear species in the bear family (Ursidae) in Lesson 3, but not all had the same genus name. Discuss how it is often difficult to identify a species using only fossil evidence, so measurements of extinction over geologic time are usually less specific.

As an example, consider on the graph if almost 20 families/million years went extinct during the Ordovician, that would mean that 20 whole categories of living things would be lost every million years, such as all 8 bear species, all 50 species in the duck and goose family (Anatidae), or over 30,000 species of daisies, sunflowers and dandelions in the Aster family. The graph shows the Ordovician extinction happening over millions of years, so the number of lost species would be significant if nearly 20 families were lost every million years during that extinction event.

5 • VISUAL INQUIRY: MASS EXTINCTION EVENTS

13 min

MATERIALS: *Extinctions Graphic Organizer*, printed images from the Mass Extinction Visual Inquiry

Conduct a visual inquiry of the mass extinction events. Display slide M. Explain that you have put information around the room about each of the 5 mass extinction events. Review the instructions for Parts A and B on *Extinctions Graphic Organizer*. Divide students into groups of 3-5. Assign 1-2 groups to start each event, depending on the size of your class. Students should work with group members to complete the row in part A of *Extinctions Graphic Organizer* for their extinction event. Every 2 minutes, direct students to rotate to the next station until they have visited all 5 extinction events and completed the table in Part A of *Extinctions Graphic Organizer*.

ALTERNATE ACTIVITY

Provide https://docs.google.com/presentation/d/1hXQ_nYegNKQ2b0jWMfm1A7QbYxxNqNMQEKjYjpCjMTO/edit?usp=drive_link on a computer to groups of students or print a set of one-sided color copies for each group and allow them to conduct the *Mass Extinction Visual Inquiry* while seated.

Look for patterns in the evidence. Once groups have visited all 5 stations of the *Mass Extinction Visual Inquiry*, ask them to sit together to complete part B of *Extinctions Graphic Organizer*. Encourage them to revisit stations if they need more information. Use *Key Extinctions Graphic Organizer* to support groups as they discuss patterns of evidence.

6 • WRITE INITIAL ARGUMENTS

8 min

MATERIALS: *Extinctions Graphic Organizer*



Write initial arguments. Display slide N and provide time for students to individually write their initial arguments on Part C of *Extinctions Graphic Organizer*. Encourage students to support the people in their group during this process.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Arguments supported by evidence (SEP 7.4) that include:

- Mass extinctions were caused by patterns of significant biological and geological events that caused drastic swings in Earth's temperatures and changes to ocean chemistry. (DCI LS.4.D.1+ESS2.E; CCC 1.1)
- Most of the significant biological and geological events had evidence of major increases or decreases in atmospheric carbon dioxide levels, which caused drastic swings in Earth's temperatures and ocean chemistry. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)
- Requests for evidence related to the effect of extinctions of biodiversity.

What to do: Remind students of the self-assessment they did on *Self-Assessment on Constructing an Argument* and to reread how they wanted to improve their arguments. Prompt students to review *Bear Interaction Claims* and *Bear DNA Tree* to remember how to write arguments supported with evidence and reasoning. Use *Key Extinctions Graphic Organizer* to support groups as they develop arguments. Collect *Extinctions Graphic Organizer* at the end of class from students who struggle with writing arguments to provide additional assistance. Ask probing questions such as:

- What happened to carbon dioxide levels in each mass extinction event?
- How did rising/falling carbon dioxide levels affect Earth's temperature?
- How did that change ocean chemistry?
- How did that change cause extinction?
- What evidence do you have to show that pattern?

Building toward 7.A Construct an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)

7 · NAVIGATE: REQUEST FURTHER EVIDENCE

2 min

MATERIALS: *Extinctions Graphic Organizer*

Share additional information needed to support arguments. Congratulate students on writing an initial argument without your assistance. Explain that they will have a chance to share arguments and revise them next class. Display **slide O** and discuss the prompt.

End of day 1

8 · NAVIGATE: PEER REVIEW INITIAL ARGUMENTS

8 min

MATERIALS: *Extinctions Graphic Organizer*, *Peer Feedback Protocol*

Review initial arguments individually. Display **slide P**. Provide a minute for students to reread the argument they wrote during the last class on *Extinctions Graphic Organizer* and to think about the prompt on the slide.

Review Community Agreements. Explain that the class will spend some time sharing arguments with someone who was not in their group during the last class and provide feedback to strengthen the arguments they wrote. Display **slide Q**. Discuss how the class has used these agreements to move their science thinking forward in the past when they conducted peer reviews.

Review the peer feedback document. Display **slide R**. Distribute *Peer Feedback Protocol* to each student. Say, *Use Peer Feedback Protocol to help you give and receive feedback from your peers*. Talk through a few examples on the *Peer Feedback Protocol* and encourage students to use these sentence starters when they provide feedback to their partner. *

* ATTENDING TO EQUITY

Building classroom culture: It is important to organize activities in ways that create opportunities for students to engage in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to multilingual students.

Facilitate a peer review of initial arguments. Distribute *Peer Feedback Rubric* to each student. Pair students up with another student who was not in their group when they visited the mass extinction stations to share their initial argument and complete *Peer Feedback Rubric*. Provide time for students to read one another's arguments, write feedback, and discuss the feedback with one another.

9 • BUILDING UNDERSTANDINGS DISCUSSION ABOUT MASS EXTINCTIONS

12 min

MATERIALS: science notebook, *Extinctions Graphic Organizer*, *Key Extinctions Graphic Organizer*

Facilitate a Building Understandings Discussion about the cause of the mass extinction events. Arrange the class in a Scientists Circle and display **slide S**. Facilitate a discussion of the arguments students wrote and help the class come to some agreement on the main causes of extinction. Use the prompts below and the answers from *Key Extinctions Graphic Organizer* to facilitate the discussion. *

KEY IDEAS

Purpose of this discussion: 1) To share the patterns of evidence students saw in the mass extinction data. 2) To develop a shared understanding of the main cause of mass extinctions.

Listen for these ideas:

Areas of agreement

- Earth's temperature warmed or cooled significantly with each mass extinction.
- Increases or decreases in atmospheric carbon dioxide levels contributed to the warming or cooling in most of the mass extinction events.
- Most mass extinctions affected marine life.

Possible areas of disagreement

- Some students may argue that changes to ocean chemistry were the primary cause of extinction. There were numerous changes to ocean chemistry from multiple sources mentioned in the evidence. Many of these mechanisms will not be explained until *Oysters Unit*, so they may struggle with reasoning.

* STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Asking students to restate what another student has said helps students listen carefully to each other so that they can work with others' ideas. This move can feel odd to students at first, so it will help if you let them know ahead of time that you will be asking this.

Post the following question prompts to increase student to student discussion.

- What is your evidence?
- How did you arrive at that conclusion?
- Could there be another explanation for that?
- How does that idea fit with ____'s claim?
- Can you clarify _____ aspect of your reasoning?
- So let me see if I understand this aspect of your reasoning here. Are you saying...?

Suggested prompt

Sample student response

What was your claim?

Mass extinctions were caused by rapid cooling or heating of Earth's atmosphere.

Mass extinctions were caused by changes to ocean chemistry.

What pattern did you see in the evidence to support that claim?

At least 75% of species went extinct during each mass extinction event.

In each event, something happened that caused rapid heating or cooling of the atmosphere.

In 4 of 5 cases, changes to carbon dioxide levels from volcanic activity, photosynthesis, or erosion were responsible for the change in temperature.

Each cause (volcanic activity, photosynthesis, asteroid, or erosion) also changed the chemistry of the ocean, which killed marine life.

Suggested prompt	Sample student response
How would that cause extinction?	Carbon dioxide is a greenhouse gas that warms the atmosphere. Increasing/decreasing the amount of carbon dioxide changes the temperature. Plants may have died when it got too cold or too hot, which could cause the food web to collapse. Chemicals from volcanic eruptions are poisonous and kill living things. Without oxygen in the ocean, no cellular respiration happens and many species die. Plants die if there is no sunlight hitting the Earth. Changes to ocean chemistry could poison ocean life.
What questions do we still have?	Did the mass extinction events kill everything directly or did food webs collapse? How do they know all of these species died? How does the Earth change when 75% of species die? Are we headed for a mass extinction right now?
Update Personal Glossaries. As students explain the pattern of species lost during mass extinctions, display slide T and add the term <i>mass extinctions</i> to their Personal Glossaries.	
ADDITIONAL GUIDANCE	A possible class definition could include <i>when at least 75% of species around the world go extinct in a short amount of geologic time.</i>

10 · CONNECT EXTINCTIONS TO CHANGES IN BIODIVERSITY

5 min

MATERIALS: None

Connect mass extinctions to changes in biodiversity. Say, *So we seem to agree on the main causes of mass extinction in Earth's past and recognize that many of the mass extinctions greatly affected life in the oceans. I found one more graph of information about what happened in the oceans over this entire time period.* Display **slide U** and discuss the slide prompt.

Suggested prompts	Sample student responses	Follow-up questions
What pattern do you notice?	Biodiversity falls during each mass extinction event. Biodiversity rises after each mass extinction event. After the first two mass extinctions, biodiversity returned to the level where it was before the mass extinction event. But then biodiversity kept climbing after the more recent extinction events.	What happens to biodiversity during each mass extinction? What happens to biodiversity after each mass extinction?
What mechanisms might explain that pattern?	Biodiversity falls if extinction happens. The ocean chemistry is different after a mass extinction, so there are new environments and new selection pressures, so evolution by natural selection occurs in the remaining species. Speciation happens over many many generations.	How did the environment change with each mass extinction? Which species were more likely to survive those changes? What happens to the amount of competition for resources immediately following a mass extinction? What mechanism did we figure out that can create new species?

Remind students that they saw images of marine life in each of these time periods when they looked at the *Mass Extinction Visual Inquiry*. Display **slide V**. Ask students what they notice about how life forms change after each extinction and discuss possible mechanisms for those differences. Listen for students to mention that there are different kinds of organisms after each extinction that look different. Listen for them to explain that depending on which species survive an extinction, there is different genetic information available for evolution to work with. If entire families disappear, some life forms may be gone forever. Selection pressures from changed ocean environments may also cause species to evolve with different adaptations (change size, different ways of eating, etc.). Say, *So we know that biodiversity returns after a mass extinction, but it does not always look the same.*

11 • REVISE INITIAL ARGUMENTS

10 min

MATERIALS: Key Extinctions Graphic Organizer



Revise initial arguments. Say, *I think we now have a better understanding of what caused mass extinctions in the past and the consequences for biodiversity. Let's spend some time revising our arguments.* Display **slide W** and provide time for students to revise arguments based on the prompt. Point out the subtle change in the argument writing prompt and that they should make sure they are explaining how extinctions affect biodiversity and supporting this idea with additional evidence if necessary.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Arguments supported by evidence (SEP 7.4) that include:

- Mass extinctions were caused by patterns of significant biological and geological events that caused drastic swings in Earth's temperatures and changes to ocean chemistry. (DCI LS.4.D.1+ESS2.E; CCC 1.1)
- Most of the significant biological and geological events had evidence of major increases or decreases in atmospheric carbon dioxide levels, which caused drastic swings in Earth's temperatures and ocean chemistry. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)
- Patterns of mass extinctions causing decreases in biodiversity followed by an increase in biodiversity over millions of years.
- Reasoning that increases in biodiversity occurred because of natural selection and speciation over long periods of time.

What to do: Use *Key Extinctions Graphic Organizer* to support students as they develop arguments. Collect *Extinctions Graphic Organizer* at the end of class. Ask probing questions such as:

- How are extinction and biodiversity related?
- Why did biodiversity levels increase after each mass extinction event?
- What evidence do you have to show that pattern?

Building toward 7.B Revise an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth and its effect on biodiversity. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)

12 · CONNECT HUMAN ACTIONS TODAY TO PAST MASS EXTINCTIONS

5 min

MATERIALS: None

Connect patterns from past mass extinctions to human-caused problems occurring today. Display slide X. Say, *We decided to investigate the causes and consequences of extinctions in the past to figure out what could happen in our future if species, like the polar bear and others, go extinct.* Facilitate a discussion of the prompt. Write student ideas on the board as they come up with ideas. Use the prompts below to facilitate discussion.

Suggested prompts	Sample student responses	Follow-up questions
<i>What similarities do you see between the causes of mass extinctions in the past and events happening today?</i>	Carbon dioxide levels in the atmosphere are rising. Temperatures are rising, ice is melting, and sea levels are rising. Fertilizers get in the ocean and cause dead zones where there is no oxygen, so fish die. People pollute the oceans with garbage and chemicals that can kill ocean life. Many species are going extinct today because their habitat was destroyed.	<i>What do we know about climate changes happening today?</i> <i>What changes do we know about in ocean chemistry?</i> <i>What did we learn about causes of changing oxygen levels in the water in the past (final transfer task from Fires Unit).</i> <i>Why else are species in danger of extinction today?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What differences are there?</i>	The past mass extinctions were caused by huge geologic events, like volcanoes or mountains eroding or a giant asteroid. The ones today are caused by lots of small things people do. People have control over the reasons for extinction now.	<i>What caused the events in the past compared to now?</i>
<i>What consequences might be expected in the future if nothing changes?</i>	We could see more extinctions. Ecosystems could become unstable if key species become extinct. Humans could become extinct.	<i>How would extinctions affect ecosystem resilience?</i> <i>How could this impact us?</i>

13 · NAVIGATE: UPDATE PROGRESS TRACKERS

5 min

MATERIALS: None

Update Progress Trackers. Display slide Y. Say, *We have figured out a lot about patterns of past extinctions and discussed a bit about how this could impact our future. Let's capture what we have figured out in this lesson. Be sure to write down the questions our last discussion raises for you.* Provide time for students to update *Progress Tracker*.

	What we figured out (WWFO)	How does WWFO help us make progress on figuring out the future of Arctic bear populations?	How does WWFO connect to me or my community or have a larger-scale impact?	What questions do I have now?
Lesson 7: How do past patterns of extinction help us understand possible consequences of extinctions now and in the future?	Mass extinctions have happened in the past when massive climate change events occurred. Current climate change from human activities could cause the same to happen.	If big changes to climate caused mass extinctions in the past, this could happen again with Arctic bears.	Many other species around the world could go extinct with human-caused climate change as well as other ways humans harm the environment, like pollution or fragmentation and habitat loss. Humans could also go extinct, and then life in the future may evolve to look completely different.	Are we headed for another mass extinction? Should we try to protect the polar bear and other key species from extinction? How can we prevent the extinction of the polar bear and other species?

Share questions and motivate a discussion about taking action to prevent extinction. Display slide Z. Ask a few students to share the questions they wrote in their Progress Trackers to help the class consider what to study next. Motivate the students to discuss whether action should be taken to prevent extinctions.

Additional Lesson 7 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST9.12.1 Write arguments focused on discipline-specific content.

Students develop a scientific argument to explain the main cause of mass extinctions.

LESSON 8: What are our options for protecting species from extinction and should we implement them?

PREVIOUS LESSON

We reviewed ecosystem resilience and remembered that the changes to one species can cascade through an ecosystem. We investigated current extinction rates for the whole Earth and wondered how this compares with events in the geologic past. We investigated the five mass extinctions in Earth's history and figured out that in each, a major event precipitated a significant shift in climate, which led to the loss of at least 75% of species. We connected what we learned in the past to what is happening today and wondered if we should protect species, like the polar bear, from extinction.

THIS LESSON

INVESTIGATION

3 days



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We research and evaluate different solutions people have used to protect species from extinction and present what we learn to our peers. We discuss if these solutions could work to protect the polar bear. We discuss if people should intervene to protect the polar bear. We write an individual argument with our position on whether we should do something to save polar bears from extinction.

NEXT LESSON

We will complete a Transfer Task to evaluate claims about ways to protect endangered bumble bees to demonstrate how what we figured out throughout the unit about finding common ancestry, biological evolution, and extinction applies to other systems.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

8.A Integrate and evaluate information from multiple sources to explain how well a solution designed to prevent extinction reaches its goal, taking into account a range of constraints. (SEP 8.2; DCI: ETS.1B.1, LS4.C.5; CCC 7.1)

8.B Communicate information in multiple formats to explain how well a solution designed to prevent extinction reaches its goal, taking into account a range of constraints. (SEP 8.5; DCI: ETS.1B.1, LS4.C.5; CCC 7.1)

8.C Evaluate proposed solutions to protect polar bears from extinction, taking into account a range of constraints. (SEP 7.6; DCI: ETS.1B.1, LS4.C.5; CCC 2.3)

WHAT STUDENTS WILL FIGURE OUT

- Options for protecting endangered species from extinction include habitat conservation, breeding programs, species relocation, long-term storage of genetic material, and others.
- Not all species at risk of extinction can be protected in the same way.
- Protecting species from extinction requires huge inputs of time, money, resources, and collaboration from people with different interests.
- Protecting polar bears from extinction is difficult because they are large, long-lived animals that reproduce slowly and cannot survive in warm climates.

Lesson 8 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		NAVIGATE Review what students wrote in their Progress Trackers at the end of the last lesson. Raise questions about whether we should prevent the extinction of polar bears.	A	
2	5 min		EXPLAIN ENDANGERED SPECIES DESIGNATIONS Briefly explain how people at local, national, and international levels decide which species are at risk of extinction.	B-D	
3	10 min		INTRODUCE CASE STUDIES Explain the structure for taking notes on case studies and provide time for students to read the overview of their topic.	E-G	<i>Research Notes Organizer</i> , Copies of reading for each student <i>Manatee Case Study</i> , <i>Saguaro Case Study</i> , <i>Coral Reefs Case Study</i> , <i>African Wild Dogs Case Study</i> , <i>California Condor Case Study</i> , <i>Axolotl Case Study</i> , <i>American Bison Case Study</i> , <i>Seed Bank Case Study</i>
4	8 min		DISCUSS HOW TO EVALUATE ONLINE RESOURCES Facilitate a discussion of how to find and evaluate online information about each case study.	H-I	<i>Research Notes Organizer</i> , <i>Evaluating Information Checklist</i>
5	14 min		CONDUCT RESEARCH IN GROUPS ON CASE STUDY SPECIES Students work in groups to research additional information on the case study species at risk of extinction to learn more about how people are working to protect it.	J	
6	3 min		NAVIGATE: SOCIAL AND EMOTIONAL LEARNING CHECK-IN Create space for students to reflect on their feelings about the program to protect a species from extinction.	K	<i>Feelings Wheel</i>
<i>End of day 1</i>					
7	5 min		NAVIGATE: SHARE RESEARCH WITH GROUP Students share what they learned about their case study species with other members of their group.	L	
8	20 min		DEVELOP POSTERS TO COMMUNICATE WHAT THEY FIGURED OUT ABOUT EACH CASE STUDY Motivate the sharing of what students figured out and provide time to develop a poster to share with other students in the class.	M-N	<i>Research Notes Organizer</i> , <i>Evaluating Information Checklist</i> , chart paper, colored markers
9	15 min		TWO STAY, OTHERS STRAY GALLERY WALK Facilitate a gallery walk to learn about other case studies.	O	<i>Extinction Prevention Organizer</i> , Posters from each group

Part	Duration	Summary	Slide	Materials
10	5 min	NAVIGATE: APPLY NEW IDEAS TO THE PROTECTION OF THE POLAR BEAR Students write about how the techniques they learned about may or may not help protect the polar bear from extinction.	P	<i>Extinction Prevention Organizer</i>
<i>End of day 2</i>				
11	5 min	NAVIGATE: REFLECT ON BEST SOLUTION Students individually write about whether people should protect polar bears from extinction given the science they understand and their personal values.	Q-R	<i>Extinction Prevention Organizer, Case study posters, Community Agreements</i>
12	13 min	SHARE POLAR BEAR CASE STUDIES AND DISCUSS IF THEY SHOULD BE PROTECTED FROM EXTINCTION IN GROUPS Students share their evaluations of the case studies they saw in the last class in small groups. They discuss if people should intervene to save the polar bear from extinction.	S	<i>Extinction Prevention Organizer, case study posters</i>
13	15 min	EVALUATE OPTIONS FOR THE POLAR BEAR AS A CLASS Facilitate a discussion to evaluate the proposed solutions for saving or not saving the polar bear from extinction.	T	<i>Extinction Prevention Organizer</i>
14	12 min	COMPLETE AN EXIT TICKET ABOUT SAVING THE POLAR BEAR FROM EXTINCTION Students write an argument supported with evidence and reasoning to answer the question: <i>Do you think people should make an effort to protect the polar bear from extinction?</i>	U	<i>Extinction Prevention Argument</i>
<i>End of day 3</i>				

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials	• <i>Research Notes Organizer</i> • <i>Evaluating Information Checklist</i> • science notebook • <i>Extinction Prevention Organizer</i> • <i>Extinction Prevention Argument</i>	• Copies of reading for each student <i>Manatee Case Study</i> • <i>Saguaro Case Study</i> • <i>Coral Reefs Case Study</i> • <i>African Wild Dogs Case Study</i> • <i>California Condor Case Study</i> • <i>Axolotl Case Study</i> • <i>American Bison Case Study</i> • <i>Seed Bank Case Study</i> • chart paper • colored markers	• <i>Feelings Wheel</i> • Posters from each group • Case study posters • Community Agreements • case study posters

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure the class Community Agreements poster (created in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)*) is hung where students can see it. It should be available for reference in case students encounter interpersonal conflict or need to be reminded of an agreement that is not being followed.

- Three-hole-punch all handouts so they can be added to students' notebooks.
- On day 1, print copies of each case study *Manatee Case Study*, *Saguaro Case Study*, *Coral Reefs Case Study*, *African Wild Dogs Case Study*, *California Condor Case Study*, *Axolotl Case Study*, *American Bison Case Study*, *Seed Bank Case Study* for students to read. Each student will only need a copy of one case study.
- Provide an internet-connected device for each student to conduct research on day 1. Provide an internet-connected device to each group if needed to finish research on day 2.
- Gather chart paper and colored markers for students to communicate what they figure out from their extinction research.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

During this culminating lesson of the unit and the entire course, students bring together what they have learned about speciation and extinction, together with what they learned about conservation, climate change, genetics, and natural selection to evaluate solutions for protecting species from extinction. Students will combine their understanding of scientific mechanisms with consideration for social, economic, and cultural constraints to debate if and how humans should intervene to protect the polar bear and other species at risk of extinction.

The DCI elements that students put together in this lesson include:

- ETS.1B.1 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. (HS-ETS1-3)
- LS4.C.5 Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5)

ETS.1B.1 was developed in *OpenSciEd Unit B.1: How do ecosystems work, and how can understanding them help us protect them? (Serengeti Unit)* and *OpenSciEd Unit B.4: How does urbanization affect nonhuman populations, and how can we minimize harmful effects? (Urbanization Unit)*. LS4.C.5 builds on what was developed in Lesson 6 in regard to the polar bear and asks students to apply what they learned to evaluate if another species has lost its ability to evolve and is in danger of extinction.

Students continue to use elements of *engaging in argument from evidence* developed in *Natural Selection Unit*, which were developed in Lessons 2, 4, and 7. They also continue to develop the element of *obtaining, evaluating, and communicating information*, which was started in Lessons 3 and 6, as well as all previous OpenSciEd units. As students are doing open-ended online research, which was not previously developed, scaffolds are provided for evaluating sources and integrating information from each source using a graphic organizer. These techniques will be used again in future OpenSciEd courses.

Students continue to use elements from the focal crosscutting concepts *cause and effect*, developed in *OpenSciEd Unit B.2: What causes fires in ecosystems to burn and how should we manage them? (Fires Unit)* and *Natural Selection Unit*. They also use elements of *stability and change*, developed in *Serengeti Unit* and *Natural Selection Unit*.

Where We Are NOT Going

There is insufficient time to fully investigate the status of the species in each case study. The purpose of the investigations is to learn about different techniques used to protect species from extinction, become aware of the significant costs in time and energy that are made to implement these techniques, and evaluate differing perspectives on what, if anything, should be done. If time and interest allows, students could spend more time researching each case study to better inform the final discussions on day 3.

LEARNING PLAN for LESSON 8

1 · NAVIGATE

5 min

MATERIALS: None

Review what we figured out in the last lesson. Display slide A. Discuss the slide prompts.	
Suggested prompt	Sample student response
<i>What did we figure out in the last lesson?</i>	Mass extinctions have happened in the past when massive climate change events occurred. Current climate change from human activities could cause another mass extinction.
<i>How does WWFO help us make progress on figuring out the future of Arctic bear populations?</i>	If big changes to climate caused mass extinctions in the past, this could happen again with Arctic bears.
<i>How does WWFO connect to me or my community or have a larger-scale impact?</i>	Many other species around the world could go extinct with human-caused climate change. Humans could also go extinct and then life in the future may evolve to look completely different.
<i>What questions do you have now?</i>	Are we headed for another mass extinction? Should we try to protect the polar bear and other species from extinction? How can we prevent the extinction of the polar bear and other species?

2 · EXPLAIN ENDANGERED SPECIES DESIGNATIONS

5 min

MATERIALS: None

Discuss how scientists designate at risk species. Say, *It sounds like we are starting to consider whether it makes sense to protect the polar bear and other species from extinction. To do that, we may need to have a better understanding of your other question about HOW people are doing this work already. Let's look at how people decide which species are at risk.* Display **slide B-D** and explain how scientists and governments currently designate species as at risk for extinction. This will help us figure out which species to investigate.

ALTERNATE ACTIVITY

Assessing Extinction Risk contains the same information presented on slides B-D. Print this out for students to read and spend more time figuring out the criteria for designating a species as at risk for extinction.

3 · INTRODUCE CASE STUDIES

10 min

MATERIALS: *Research Notes Organizer*, Copies of reading for each student *Manatee Case Study*, *Saguaro Case Study*, *Coral Reefs Case Study*, *African Wild Dogs Case Study*, *California Condor Case Study*, *Axolotl Case Study*, *American Bison Case Study*, *Seed Bank Case Study*

Introduce the investigation. Display **slide E**. Explain that you found some case studies of species that are at risk of extinction and have an overview of what is happening with each one. Distribute *Research Notes Organizer* and discuss how students will use this graphic organizer to integrate information from multiple sources. You will provide each group with the first reading, but they will be responsible for finding others to understand what is happening to prevent its extinction. *

- Display **slide F** with the case study choices. Organize the class into groups of 3-5 students and allow them to choose one of the case studies. Encourage students to pick a species not chosen by another group so that the class as a whole will learn about a variety of approaches to protecting endangered species from extinction. Coral reef protection introduces the widest variety of options and may be appropriate for more than one group to investigate.
- Distribute the chosen case study reading to each student based on their choice: *Manatee Case Study*, *Saguaro Case Study*, *Coral Reefs Case Study*, *African Wild Dogs Case Study*, *California Condor Case Study*, *Axolotl Case Study*, *American Bison Case Study*, or *Seed Bank Case Study*.

Read extinction prevention case studies. Display **slide G**. Explain to students that they will have about 7 minutes in their groups to read the overview and begin to fill in information. As they read, students can use the literacy strategies in place in your district/school, or they can apply the Coherent Reading Protocol found in the *OpenSciEd Teacher Handbook: High School Science*. Working together, students should complete *Research Notes Organizer* to make sense of the information in their case study. Students should support one another in understanding the reading and begin developing questions for further research.*

ALTERNATE ACTIVITY

If there is another case study you believe would generate higher interest for your students, exchange it for an existing case study. If you make a change, make sure you include the following ideas:

- An introduction to the species.
- A brief overview of the threat.
- Data on the current and historical population size (including status as threatened/endangered/etc.).
- Information about genetic diversity within the species.
- Overview of interest holders involved in protecting/opposing species protection.
- Ongoing concerns and a teaser for further research.
- References that suggest organizations, individuals, or resources to investigate.

* ATTENDING TO EQUITY

Universal Design for Learning: You may wish to allow students to self-select case studies based on interest before dividing them into groups. See *UDL for Case Studies* for differentiation guidance. Students may choose which text to read based on reading level, familiarity with the species, text features, or the option to access companion videos.

ALTERNATE ACTIVITY

If time allows, instead of using *Research Notes Organizer* and *Evaluating Information Checklist* (in the next step), let students develop the criteria for their research and develop their own way to organize their notes to record what they figure out. If your school teaches particular techniques for conducting research projects, vetting materials and note-taking, use the process that is most familiar to your students.

4 • DISCUSS HOW TO EVALUATE ONLINE RESOURCES

8 min

MATERIALS: *Research Notes Organizer*, *Evaluating Information Checklist*

Introduce the *Evaluating Information Checklist*. Say, *At this point, all of you have started figuring out what is happening to the species in your case study and why it is at risk for extinction. I also heard you raise good questions in your small groups about things you want to understand better. Let's take some time to discuss the most effective way to go about researching the answers to those questions.* Display **slide H** and discuss what students already know about ways to find quality resources online. Listen for ideas such as:

- Use the references on our case study to look for names of organizations or people to research.
- Make sure it is from a reliable source.
- Look for something written by a scientist, the government, or a university.
- Double-check other sources to see if they have the same information.

Display **slide I**. Discuss how to use *Evaluating Information Checklist*. Students can work in pairs or individually within their group to conduct research. Before they start adding information to *Research Notes Organizer*, however, they should use *Evaluating Information Checklist* to evaluate if the website or resource is one they should use. Discuss the explanations of each category at the bottom of the page and discuss examples of (un)reliable sources (e.g., sites created by a governmental science group, like NOAA, vs. bloggers). Explain that some websites may not meet criteria for every item on the checklist but may still be reliable. If students determine that the resource is reliable, they should write down the source citation on the next open row of *Evaluating Information Checklist*. Then they can return to *Research Notes Organizer* and fill in what they learn from that resource on the appropriate row, adding the number of that source to column 2.

5 • CONDUCT RESEARCH IN GROUPS ON CASE STUDY SPECIES

14 min

MATERIALS: None



Provide time to conduct research. Display **slide J**. Send students back to their groups to continue their research.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: As students conduct research on their case study, look and listen for them to **integrate and evaluate information from multiple sources** on *Research Notes Organizer* and *Evaluating Information Checklist* (SEP: 8.2) to **explain** (CCC 7.1):

- **How well a solution to prevent extinction reaches its goal.** (DCI: ETS.1B.1, LS4.C.5 ; CCC 7.1)
- **Constraints on the system.** (DCI: ETS.1B.1)
- **Whether evolution of the species can continue.** (DCI: ETS.1B.1, LS4.C.5)
- **Acceptance or rejection of sources as (un)reliable for addressing the problem.** (SEP: 8.2, DCI: ETS.1B.1, LS4.C.5)

What to do: Circulate around the room to formatively assess student progress. Bring your class roster and mark off when you hear a student correctly evaluate a source or accurately integrate new information onto *Research Notes Organizer*. Use the prompts on *Evaluating Information Checklist* to assist students as they evaluate websites. Use the prompts on *Research Notes Organizer* to spark directions for additional research. Use these additional prompts with groups:

- Do the references on your case study provide additional ideas for websites to investigate or keywords to search?
- What evidence do you have that this project is providing an opportunity for the species to continue to evolve?
- How does that technique protect genetic diversity?
- What constraints are they running into with this project?

Building toward 8.A **Integrate and evaluate information from multiple sources to explain how well a solution designed to prevent extinction reaches its goal, taking into account a range of constraints.** (SEP 8.2; DCI: ETS.1B.1, LS4.C.5; CCC 7.1)

6 · NAVIGATE: SOCIAL AND EMOTIONAL LEARNING CHECK-IN

3 min

MATERIALS: science notebook, *Feelings Wheel*

Facilitate a social and emotional learning reflection. Display **slide K**. Provide time for students to reflect on their feelings about their case study using the feelings wheel from Lesson 1. They may choose between talking to a trusted peer, silent reflection in their science notebook, or thinking about how they feel about the extinction data. Encourage students to use the feelings wheel to help articulate their feelings or give them the language they need to process them. If they need further support, suggest they share with a trusted adult.

End of day 1

7 · NAVIGATE: SHARE RESEARCH WITH GROUP

5 min

MATERIALS: None

Share research findings. Display **slide L**. Direct students to sit with their groups from the last class and share what they figured out from their research. Refer to the Community Agreements and remind them it is important to hear from all group members to move their science thinking forward.

8 · DEVELOP POSTERS TO COMMUNICATE WHAT THEY FIGURED OUT ABOUT EACH CASE STUDY

20 min

MATERIALS: *Research Notes Organizer, Evaluating Information Checklist*, chart paper, colored markers

Motivate students to develop an organized way to share what they figured out. Display **slide M**. Say, *Each group has uncovered some interesting information about how people are trying to protect each of the species in their case studies from extinction, which might give us some ideas about what could be done to protect polar bears from extinction. How could we share what we figured out?* Listen for students to suggest making posters, doing a gallery walk, making presentations. Display **slide N**, which outlines the basic information each group should synthesize and communicate on a poster to share in a gallery walk. Explain that students will have about 19 minutes to put this together and that all group members should be prepared to share some of what they figured out. Their poster should include evidence to support their statements when possible.

Distribute chart paper and colored markers to students and provide time for each group to work.

9 · TWO STAY, OTHERS STRAY GALLERY WALK

15 min

MATERIALS: *Extinction Prevention Organizer*, Posters from each group



Facilitate a gallery walk. Thank students for putting together their posters so quickly. Display **slide O**. Remind students that the purpose of this gallery walk is to learn about the status of other species at risk of extinction and what approaches are being taken to protect them. We want to hear about different approaches to help us think about possible futures for the polar bear. Distribute *Extinction Prevention Organizer* to each student. Explain that students will visit 2-3 posters from other groups and record the ideas their classmates share on this handout. Each group should choose two individuals who “stay” to talk visitors through their case study for the first half of the gallery walk. The other members of each group will “stray” to listen to explanations from different groups. Halfway through, students will switch roles so everyone has a chance to both explain their poster and hear other ideas. The second group should visit case studies that the first two students did not to expand the number of case studies the group sees in total. Provide time for each student who strays to observe two or three other posters.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: As students **communicate information on their posters** during the gallery walk (**SEP: 8.5**), look and listen for them **to explain** (**CCC 7.1**):

- **How well a solution to prevent extinction reaches its goal.** (DCI: ETS.1B.1, LS4.C.5 ; CCC 7.1)
- **Constraints on the system.** (DCI: ETS.1B.1)
- **Whether evolution of the species can continue.** (DCI: ETS.1B.1, LS4.C.5)
- **Information about the method for protecting the species from extinction presented in multiple formats** (writing, visuals, data). (SEP: 8.2, DCI: ETS.1B.1, LS4.C.5)

What to do: Listen as students present their poster. Bring your class roster and mark off when you hear a student explain how well the solution they researched reached its goal. Collect posters at the end of the day to assess. During presentations, ask questions such as:

- What evidence do you have that the species is doing better/worse now than before?
- What evidence do you have that they maintained/lost genetic diversity in the population?
- What makes this technique challenging to implement?

Building toward 8.B **Communicate information in multiple formats to explain how well a solution designed to prevent extinction reaches its goal, taking into account a range of constraints.** (SEP 8.5; DCI ETS.1B.1, LS4.C.5 ; CCC 7.1)

10 · NAVIGATE: APPLY NEW IDEAS TO THE PROTECTION OF THE POLAR BEAR

5 min

MATERIALS: *Extinction Prevention Organizer*

Reflect individually about the application of new ideas. Display **slide P** and provide time for students to answer the question on the bottom of *Extinction Prevention Organizer*.

End of day 2

11 · NAVIGATE: REFLECT ON BEST SOLUTION

5 min

MATERIALS: *Extinction Prevention Organizer*, science notebook, Case study posters, Community Agreements

Reflect individually on the future of the polar bear. Display **slide Q**. Display the case study posters where students can see them. Provide a minute for students to review their evaluations of the case studies they saw in the last class on *Extinction Prevention Organizer*, then ask them to stop and jot in their notebooks about the prompts on the slide. Emphasize that in the last class, we talked about what we **COULD** do and how we could do it, but today we are focussing about what we **SHOULD** do.

Facilitate social emotional learning. Display **slide R**. Prepare students for potentially difficult ethical discussions by reminding them of the Community Agreements and asking them to stay aware of their own emotional reactions, if any. Remind students that there is no one right answer to the topics being discussed and the idea is to stay respectful, listen to what others figured out, and learn from hearing different arguments and reasoning so we can move our science thinking forward.

12 · SHARE POLAR BEAR CASE STUDIES AND DISCUSS IF THEY SHOULD BE PROTECTED FROM EXTINCTION IN GROUPS

13 min

MATERIALS: *Extinction Prevention Organizer*, science notebook, case study posters

Evaluate options for the polar bear in groups. Say, *We are still forming our arguments for if we should save the polar bear from extinction, and we did not have a chance to look at all of the options from the case studies yesterday.* Display **slide S**. Explain that students will return to the same groups they worked with to create their poster. First they will share with the other half of their group what they figured out from the extinction prevention case studies. Students should be open to listening to what the other half of their group saw yesterday as it may sway the argument they wrote in the opening navigation. Once they finish sharing what they learned from the case studies, they can take turns sharing their arguments and then respectfully discuss if people should intervene to save the polar bear. As groups discuss, prompt students as needed with questions such as *:

- Do the new solutions you heard about change your argument about what should be done?
- What evidence do you have that this would help/hurt the polar bears?
- What evidence do you have that this could maintain genetic diversity in the population?
- What makes this technique challenging to implement?
- Who would need to be involved to make this successful?
- Do your ethical concerns fit with the science ideas we have figured out?

* SUPPORTING STUDENTS IN ENGAGING IN ARGUMENT FROM EVIDENCE

Throughout the second and third days of this lesson, students evaluate different options for protecting species from extinction in order to develop a logical argument for whether people should intervene to protect polar bears from extinction. Explain that while there is no right answer to this question, students should still challenge one another to use scientific evidence to support their statements. They should also be encouraged to ask about relevant factors that may make it difficult to implement solutions, such as cost, space, time, technological capability, and ethical considerations. Remind students that in previous units, such as *Fires Unit* and *Natural Selection Unit*, they also made these types of decisions based on who was involved in decision-making and how challenging it is to meet the needs of all interest holders.

13 · EVALUATE OPTIONS FOR THE POLAR BEAR AS A CLASS

15 min

MATERIALS: *Extinction Prevention Organizer*, science notebook

Evaluate possible solutions to prevent extinction. Invite students to sit in a Scientists Circle. Display **slide T**. Say, *I heard some thoughtful discussions in your small groups. Let's bring your ideas to the large group and talk about whether we think people should intervene to save the polar bear from extinction.* Begin by making a list of possible solutions on the board and clarify that students understand the basic idea behind how those solutions could work. Discuss the possible outcomes students want for the polar bear and how they would measure that they achieved that outcome. Discuss who should be involved in the solution and what constraints are involved. If students do not believe people should intervene to protect polar bears, they should justify those choices. Use the prompts below to guide your discussion.

Suggested prompts

Sample student responses

Follow-up questions

Suggested prompts	Sample student responses	Follow-up questions
<i>What solutions are we considering?</i>	Putting bears in zoos and breeding them. Freezing sperm and eggs to save for later. Creating hybrid polar-brown bears. Reducing greenhouse gas emissions. Doing nothing.	<i>What solution did they use for species x?</i> <i>Did you all agree that people should intervene to save the polar bear?</i>
<i>How would that protect the bear from extinction?</i>	This protects individuals from dying in the wild because we can provide them all the food, shelter, and correct temperature they need. That would protect genetic diversity of many bears to use into the future. It would allow bears to live in the wild because they would get genes that allow them to adapt to warming temperatures. It would reduce the threat that is causing ice to melt. It would not.	<i>How does that technique allow evolution to continue?</i> <i>How long would it protect the bear? How many generations?</i>
<i>What are the consequences of that decision?</i>	Bears would no longer be found in the wild. We would depend on future technology, people, and money to keep the bears alive into the future. We might not have true polar bears anymore. It would reduce climate change and have many positive effects on species beyond the Arctic. Polar bears would go extinct.	<i>Where would we find polar bears in the future?</i> <i>Who would be in charge of implementing this solution in the future?</i> <i>How certain are we that this will work?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What outcomes do we want for the bears?</i>	We want a big population of bears that reproduce and evolve naturally. We want to maintain genetic diversity. We want to protect the whole ecosystem. We want to prevent climate change to protect the ecosystem. We want to let nature run its course, which could mean the bears go extinct.	<i>How do we measure success?</i> <i>For how long do we want that outcome?</i> <i>Who/what are we helping?</i> <i>What evidence do we have that this would happen?</i>
<i>Who should be involved in making this decision?</i>	Scientists. Inuvialuit communities and other local people. Government where bears live or where they will go. Organization raising the money. All people agreeing to reduce their use of fossil fuels. Zoos.	<i>Who does the decision impact?</i>

Suggested prompts	Sample student responses	Follow-up questions
<i>What constraints should we consider?</i>	Cost. Safety/cost to move bears. It is expensive to keep the bears cold if they live outside of the Arctic. Technology needed to freeze and preserve samples Ethical considerations of making a decision for another species/ecosystem Space needed for a large population of bears. Limits to how much genetic diversity we can add to the system. Polar bears reproduce slowly. They cannot adapt quickly. Difficulty of creating an international agreement on bears that live in multiple countries.	<i>What else makes this difficult to achieve?</i> <i>What equipment is needed for this?</i> <i>Do we have the technology to do that?</i> <i>Where would that happen?</i> <i>Who would be in charge of that?</i> <i>How can we maintain that for decades?</i> <i>Do your ethical concerns fit with the science we have learned?</i>

14 · COMPLETE AN EXIT TICKET ABOUT SAVING THE POLAR BEAR FROM EXTINCTION

12 min

MATERIALS: *Extinction Prevention Argument*

Complete an exit ticket. Display slide U and distribute *Extinction Prevention Argument* to each student. Provide time for students to complete the exit ticket. *

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: On *Extinction Prevention Argument*, as students **argue for whether to protect polar bears from extinction** (SEP 7.6; DCI ETS.1B.1, LS4.C.5), look and listen for:

- **Evaluation of the benefits of proposed solutions.** (SEP 7.6; DCI ETS.1B.1, LS4.C.5 ; CCC 2.3)
- **Consider a range of social, economic, cultural, and/or environmental constraints for the proposed solutions.** (SEP 7.6; DCI ETS.1B.1, LS4.C.5; CCC 2.3)
- **Consideration of evidence if a solution could maintain genetic diversity in the polar bear population over the long term.** (SEP 7.6; DCI ETS.1B.1, LS4.C.5; CCC 2.3)

What to do: Prompt students to include evidence and reasoning that explains how a solution could protect the polar bear from extinction. Prompt students who do not want to protect the polar bear to provide evidence and reasoning for why this is not feasible. Look at *Extinction Prevention Argument Key* to see sample responses.

Building toward 8.C Evaluate proposed solutions to protect polar bears from extinction, taking into account a range of constraints. (SEP 7.6; DCI: ETS.1B.1, LS4.C.5; CCC 2.3)

* ATTENDING TO EQUITY

Universal Design for Learning: Allowing students to express their ideas using multiple modalities, such as recording their responses on video or audio. This will be most useful for students who struggle with writing but have strengths expressing themselves verbally to demonstrate their understanding in the task.

Additional Lesson 8 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

WHST.9-10.7

Conduct short ~~as well as more sustained~~ research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Students conduct a short research project using multiple sources to learn about how people protected a particular species or group of species from extinction.

CCSS.ELA-LITERACY.SL.9-10.4 Present information, findings, and supporting evidence clearly, concisely, and logically so that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

Students create a poster about a case study where people worked to protect a species or groups of species from extinction and present it to their peers in a short amount of time.

LESSON 9: Can we use everything we have figured out about speciation to explain a new phenomenon?

PREVIOUS LESSON

We researched and evaluated different solutions people have used to protect species from extinction and presented what we learned to our peers. We discussed if these solutions could work to protect the polar bear and if people should intervene to protect the polar bear. We wrote an individual argument with our position on whether we should do something to save polar bears from extinction.

THIS LESSON

PUTTING PIECES TOGETHER

2 days



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We complete a Transfer Task to evaluate claims about ways to protect endangered bumble bees to demonstrate how what we figured out throughout the unit about finding common ancestry, biological evolution, and extinction applies to other systems.

NEXT LESSON

There is no next lesson.

BUILDING TOWARD NGSS

HS-LS1-3, HS-LS2-6, HS-LS2-7,
HS-LS4-1, HS-LS4-2, HS-LS4-4,
HS-LS4-5, HS-ESS2-7



WHAT STUDENTS WILL DO

9.A. Evaluate claims and evidence about the future of bumble bee species on a global scale. (SEP: 7.2; DCI: LS4.C.5; CCC: 3.1)

WHAT STUDENTS WILL FIGURE OUT

- Wild bumble bee populations are in danger from pathogens, pesticides, and climate change.
- To protect the wild bee population, we need to eliminate the use of pesticides, reduce the number of managed honey bee hives, and maintain genetic diversity of bee populations.

Lesson 9 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	10 min		NAVIGATE: Update Progress Trackers Review ideas from the unit and update Progress Trackers.	A	<i>Progress Tracker</i>
2	20 min		CLOSE THE DRIVING QUESTION BOARD Revisit the DQB with the class to take stock of all of the questions we have now answered.	B-C	<i>DQB Questions, Driving Question Board</i>
3	13 min		ORGANIZE MATERIALS FOR A TRANSFER TASK Support students in organizing their materials to complete a Transfer Task.	D	<i>Progress Tracker</i>
4	2 min		NAVIGATE Help students get organized in preparation for the Transfer Task.	E	<i>Progress Tracker</i>
<i>End of day 1</i>					
5	5 min		NAVIGATE Help students get organized in preparation for the Transfer Task.	F	<i>Progress Tracker</i>
6	38 min		COMPLETE A TRANSFER TASK Orient students to the Transfer Task and administer.	G	<i>Bumble bee Transfer Task, Progress Tracker</i>
7	2 min		NAVIGATE Celebrate student accomplishments.	H	
<i>End of day 2</i>					

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials	• <i>Progress Tracker</i> • science notebook • <i>DQB Questions</i> • <i>Bumble bee Transfer Task</i>		• Driving Question Board

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Lesson 9 • Where We Are Going and NOT Going

This final lesson concludes the unit. Students apply ideas, practices, and crosscutting concepts, especially about engaging in argument from evidence, speciation, extinction, and scale. They use this knowledge for a Transfer Task related to endangered bumble bees.

This lesson is designed to coherently build ideas related to the following disciplinary core ideas:

- LS4.C.5: Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to the change that is too fast or drastic, the opportunity for the species' evolution is lost.

This builds on what students figured out about extinction in Lessons 6 and 7, as well as related concepts about the way species evolve to adapt to their environment from Lessons 4 and 5.

Students use the science practice *engaging in argument from evidence* to evaluate claims made by scientists. Students have constructed and revised arguments multiple times prior to this lesson (Lessons 2, 4 and 7), figuring out how to use reasoning to connect evidence to their claims and deciding what additional evidence was needed to strengthen claims. They provided feedback to peers on the strength of their arguments in Lesson 7. In this lesson, they use that experience to evaluate claims based on the evidence scientists gathered from their study and provide reasoning for how the evidence supports or refutes each claim.

Students also use elements of the crosscutting concept *scale*, which was developed in Lessons 1, 4, and 5, to evaluate the significance of each threat to bumble bee populations.

LEARNING PLAN for LESSON 9

1 · NAVIGATE: Update Progress Trackers

10 min

MATERIALS: *Progress Tracker*, science notebook

Revisit Progress Trackers. Say, *We figured out some new ideas in our last lesson.* Display **slide A** and direct students to complete the four columns in this lesson row on *Progress Tracker*. An example Progress Tracker entry is provided below.

	What we figured out (WWFO)	How does WWFO help us make progress on figuring out the future of Arctic bear populations?	How does WWFO connect to me or my community or have a larger-scale impact?	What questions do I have now?
Lesson 8:	There are many ways to protect species from extinction, including putting animals in zoos and breeding them, freezing sperm and eggs to save for later, and reducing greenhouse gas emissions. But many of these can be expensive and require a lot of technology and are not guaranteed to protect genetic diversity over many generations.	Polar bears could be saved from extinction by saving the sperm and eggs of many bears and then keeping bears in captivity. We could breed them with diverse sperm and eggs to protect the species long enough until we can cool the planet enough that they can survive again in the Arctic.	I'm worried about climate change killing the bears. Ethically I think we have an obligation to protect animals from extinction and should do whatever we can to save them.	Is anyone actually going to implement our ideas? What could I do to help protect polar bears from extinction?

2 · CLOSE THE DRIVING QUESTION BOARD

20 min

MATERIALS: *DQB Questions*, science notebook, Driving Question Board

Return to the Driving Question Board. Say, *Now that we have had a chance to think about speciation and protecting a species from extinction, let's look back at our Driving Question Board. We have actually figured out a lot of things that we were wondering at the start of the unit that can help answer our unit question, What causes fires in ecosystems to burn and how should we manage them?*

* ATTENDING TO EQUITY

Revisiting the Driving Question Board is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed,

Evaluate which questions from the Driving Question Board were answered.* Display **slide B**. Have students take out *DQB Questions* from Lesson 5 and provide them with an updated version if you made one. Have students work in pairs for 5 to 10 minutes to mark questions they think the class has answered using the symbols on the handout, replicated here. Additionally, have students choose three questions to answer with evidence from their science notebooks.

this helps students see the hard work that they have done to answer many of their own questions.

- We did not answer this question or any parts of it yet: o
- Our class answered some parts of this question, or the ideas we developed help me see how I could now answer some parts of this question: ✓
- Our class answered this question, or using the ideas we developed, I could now answer this question: ✓+

Annotate the DQB. Display **slide C**. Ask individual students to come to the DQB and mark questions that the class has answered in whole or in part through our investigations. Have as many students as possible participate until all the questions that the class has answered have been marked. If there is time, ask students to share evidence that we have answered the questions as each one is checked off. At the end, you may ask them to summarize which groups of questions have and have not been answered. Thank students again for all their hard work on this unit and celebrate just how much we have figured out through our efforts.

ALTERNATE ACTIVITY

If you have time, have students choose one question from the DQB that has sticker dots for either categories ✓ or ✓+ to answer individually and then share their answer during the discussion.

Point to the questions that are still unanswered on the DQB. Remind students of some of these questions they were interested in answering and encourage them to explore those questions on their own.

3 · ORGANIZE MATERIALS FOR A TRANSFER TASK

13 min

MATERIALS: *Progress Tracker*, science notebook

Organize materials for a Transfer Task. Display **slide D**. Ask students to work with a partner. Review their Progress Trackers alongside all the materials that are in their science notebooks. Encourage students to share resources. If one student missed class and needs help filling in any gaps, provide time for that now.

4 · NAVIGATE

2 min

MATERIALS: *Progress Tracker*, science notebook

Orient to the Transfer Task. Display **slide E**. Remind students that in the next class they will complete a Transfer Task and they will need all of the materials they just organized. Ask students to jot down any questions they have related to their Progress Trackers on a half sheet of paper. Review these questions and use them as you navigate into day 2.

End of day 1

5 · NAVIGATE

5 min

MATERIALS: *Progress Tracker*, science notebook

Organize materials in preparation for the Transfer Task. Display **slide F**. Ask students to take out their Progress Trackers and any other materials you think may help them as they complete the Transfer Task. Provide students with an opportunity to ask any clarifying questions that they may have. If questions came up at the end of the previous class, pause to answer them.

6 · COMPLETE A TRANSFER TASK

38 min

MATERIALS: *Bumble bee Transfer Task*, *Progress Tracker*, science notebook

Orient students to the Transfer Task. Display [slide G](#). Distribute *Bumble bee Transfer Task* and give students a few minutes to read over the scenario and ask clarifying questions. Consider allowing your students to use their completed Progress Trackers to support them as they complete the Transfer Task.



Administer the task. Give students the rest of the class period to complete the task, then collect assessments before students leave.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: After students complete *Bumble bee Transfer Task*, use *Bumble bee Transfer Task Key* to evaluate their responses.

What to do: Provide feedback using *Bumble bee Transfer Task Key* as guidance.

Building toward 8.A. Evaluate claims and evidence about the future of bumble bee species on a global scale (SEP: 7.2; DCI: LS4.C.5; CCC: 3.1)

7 · NAVIGATE

2 min

MATERIALS: None

Close the unit. Display [slide H](#). Congratulate students on all that they have figured out about ways to find common ancestors and explain biological evolution!



Unit B.5 Teacher Reference Materials



ASSESSMENT SYSTEM OVERVIEW

Each OpenSciEd unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial Models Driving Question Board	Pre-Assessment The student work in Lesson 1 should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Hearing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit. The initial model developed on day 3 of Lesson 1 is a good opportunity to pre-assess student understanding of how students define and identify the important changes to components and interactions of the seasonally available and permanent ice regions now and into the future for Arctic bears. The Driving Question Board on day 4 is another opportunity for pre-assessment. Reinforce that students should generate open-ended questions, such as how and why questions, and post them to the board. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions when they relate to the investigations underway.
Lesson 2	<i>Bear Interaction Claims</i> <i>Bear Data Analysis</i> <i>Human Thermoregulation Investigation</i> <i>Thermoregulation Investigation Key</i>	Formative On day 1, students write and revise claims about bear interactions based on evidence and reasoning from multiple investigations. On day 2, students conduct an investigation about human thermoregulation and use what they figure out to support a claim about polar bear thermoregulation.
Lesson 3	<i>Lesson 3 Exit Ticket</i> <i>L3 Electronic Exit Ticket</i>	Formative This Electronic Exit Ticket addresses 3-D elements associated with the lesson-level performance expectations (LLPEs) for Lesson 3. The first Electronic Exit Ticket allows relatively quick individual assessment of students on a key LLPE. Teachers can quickly check students' understanding of how to integrate genetic information to infer evolutionary relationships for two species of bees. Additionally, students have an opportunity here to reflect on how understanding the situation with honey bees connects to their own lives, how they used science and engineering practices and crosscutting concepts in sensemaking, and the value of the classroom Community Agreements in supporting their learning.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 4	<i>Bears and Glacial Cycles</i> <i>Bears and Glacial Cycles Key</i> <i>Developing an Argument</i> <i>Developing an Argument Key</i> <i>Genetic Bear Data</i> <i>Bear Gene Data Key</i> <i>Self-Assessment on Constructing an Argument</i>	Formative On day 1, students investigate the relationship between cycles of glaciation and changes to selection pressures on the common ancestor of brown and polar bears. They consider the role of both geographic and time scale on these processes. On day 1, students construct an initial argument about the speciation of brown and polar bears on an exit ticket. On day 3, they revise their arguments. On day 2, students look at genetic differences between brown and polar bears and discuss the selective advantages of the variations. Self-Assessment Students reflect on their ability to construct and revise arguments on day 2.
Lesson 5	Science notebook Class consensus model	Formative Students develop a Gotta-Have-It Checklist and revise the class consensus model about the future of Arctic bears based on evidence.
Lesson 6	<i>Future Predictions</i> <i>Future Predictions Key</i> <i>Making Sense of Matings</i> <i>Making Sense of Matings</i> <i>Hybridization Model</i> <i>Hybridization Model Key</i> <i>Lesson 6 Exit Ticket</i> <i>L6 Electronic Exit Ticket Key</i>	Formative On day 1, students look at predictive models of sea ice and apply them to what they know about rates of natural selection and adaptation. They analyze data about bear interactions that could lead to matings. They work in groups to model how genetic variation could be passed on to polar bear-brown bear hybrids. This Electronic Exit Ticket addresses 3-D elements associated with the lesson-level performance expectations (LLPEs) for Lesson 6. This Electronic Exit Ticket allows relatively quick individual assessment of students on a key LLPE. Teachers can quickly check students' understanding of the predictive models of sea ice levels in the future as well as hybridization of bears, how they used science and engineering practices and crosscutting concepts in sensemaking, and connections to classroom climate.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 7	<i>Key Extinctions Graphic Organizer</i>	Formative On day 1, students construct an initial argument about the main cause of mass extinction based on patterns of evidence. On day 2, they revise their arguments to include the effect on biodiversity based on class discussion and additional evidence they receive.
Lesson 8	<i>Extinction Prevention Argument Key</i>	Formative Students complete an argument about the best way to protect the polar bear as well as an argument for if we should.
Lesson 9	<i>Bumble bee Transfer Task</i> <i>Bumble bee Transfer Task Key</i>	Summative End-of-Unit Transfer Task Students will have the opportunity to demonstrate their competence with a Transfer Task, where they will apply what they know about finding common ancestry and biological evolution to claims about the threats to wild bumble bees and ways to protect them from extinction. This task is robust and will take approximately 30-45 minutes. The ideas, crosscutting concepts, and practices students engage with as part of completing this assessment can be found at the top of the Scoring Guidance (key). Please use scoring that works for your class and your requirements. We strongly recommend that you encourage students to use their notebooks as a resource for completing all assessments.
Embedded in each lesson	Lesson-by-Lesson Assessment Opportunities (below)	Formative Assessment Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in several lessons	<i>Progress Tracker</i> <i>Progress Tracker Key</i>	Formative and Self-Assessment The Progress Trackers are thinking tools designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Trackers reflects their own thinking at that particular moment in time. In this way, the Progress Trackers can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Trackers are meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative “grade” other than for completion. In addition to this flexible resource, Progress Trackers have been written directly in the unit in Lessons 2, 3, 7.
Occurs in several lessons	Student Self-Assessment Rubrics	Self-Assessment Student self-assessment rubrics for giving and receiving feedback can be used throughout the unit. Opportunities include after a discussion or at the end of a class period. The rubric helps students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As they gain practice and proficiency with discussions, ask for their ideas about how the whole-class and small-group discussions can be more productive. Additional support can be found in the <i>OpenSciEd Teacher Handbook: High School Science</i> . In addition to this flexible resource, self-assessment has been written directly in the unit in Lessons 3, 4, and 6.

When	Assessment and Scoring Guidance	Purpose of Assessment
Occurs in several lessons	Routines and Tools to Support Peer Assessment	Peer Assessment There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback. We suggest that peer feedback happen at least two times per unit. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good opportunities to use a peer feedback protocol. They do not need to be final pieces of student work; rather, peer feedback will be more valuable to students if they have time to revise after receiving it. This should be a formative rather than summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities in which they can use these experiences as evidence for the feedback they give. Additional support can be found in the <i>OpenSciEd Teacher Handbook: High School Science</i>. In addition to this flexible resource, peer feedback has been written directly in the unit in Lesson 7.

For more information about the OpenSciEd approach to assessment and general program rubrics, visit the OpenSciEd Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every OpenSciEd lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to [Science and Engineering Practice\(s\)](#), alignment to [Cross-Cutting Concept\(s\)](#), and alignment to the [Disciplinary Core Ideas](#).

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	1.A Ask questions that arise about the significance of changes to Arctic ice and habitats observed at multiple scales in terms of the functioning of the ecosystem due to changes in resources and habitat availability. (SEP 1.1; DCI LS2.C.1; CCC: 3.1) 1.B Read and evaluate scientific information from multiple sources to identify patterns in Arctic ice conditions related to stability of polar bear populations. (SEP 8.3; DCI LS2.C.2; CCC: 1.5)	1.A When to check for understanding: On day 1, when students work in pairs to record noticing and wonderings about the <i>Lesson 1 Data Exploration</i> and when the class shares these ideas. What to look for/listen for in the moment: Questions that arise (SEP 1.1) about: - Whether the trend of declining ice and greening tundra will continue. (CCC: 3.1) - Long-term implications for resource availability and long-term functioning of the Arctic ecosystem if trends continue. (DCI LS2.C.1; CCC: 3.1) - Whether trends observed in declining of ice over the Arctic as well as Western Hudson Bay will affect where polar bears hunt or live both in and outside of Wapusk. (DCI LS2.C.1; CCC: 3.1) - Whether changes to greening of Arctic tundra will also affect the ability of bears in Wapusk to get food. (DCI LS2.C.1; CCC: 3.1) 1.B When to check for understanding: On day 2, as students discuss what they learned in the fishbowl discussion or from reading their responses on <i>Comparing Polar Bear Populations</i>.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
	1.C Develop and revise models to predict how Arctic bear populations will expand or decline in response to anticipated changes to their environment. (SEP 2.3; DCI: LS4.C.4; CCC: 2.2) 1.D Ask questions at different scales that lead to investigations about whether Arctic bear populations will expand or decline in response to ongoing changes to polar ice. (SEP 1.1; DCI LS4.C.4; CCC 3.1)	What to look/listen for in the moment: Responses that reference evidence from the visual inquiries, video, and Traditional Knowledge, such as: (SEP 8.3; CCC: 1.5) • Ice is available for polar bears all year round (islands & convergent) or only in the winter (seasonal ice & divergent). • When ice is available only in the winter (divergent and seasonal), there is some evidence of polar bear population decline, declining body condition and reproductive trends. (DCI LS2.C.2; CCC: 1.5) • When ice is available all year long (islands & convergent), there is some evidence of polar bear population stability and/or increase, stable and/or increasing body condition and reproductive trends. (DCI LS2.C.2; CCC: 1.5) • Population trend data was available for most populations and was useful in supporting claims. (SEP 8.3; DCI LS2.C.2) • For the seasonal ice ecoregion, body conditions and reproductive trend data was useful because it was complete. For the other ecoregions, it was less useful because there was more uncertainty. (SEP 8.3; DCI LS2.C.2) 1.C When to check for understanding: On day 3, as students develop their initial models and as those models are revised to create the consensus model. What to look/listen for in the moment: Students revise their initial models to develop a class model (SEP 2.3) that includes the following: • Predictions that climate change will continue to cause a change in Arctic sea ice in some areas and a greening of the tundra. (DCI: LS4.C.4; CCC: 2.2) • Loss of Arctic sea ice in ecoregions with seasonally available ice, leaving less habitat for polar bears. (DCI: LS4.C.4; CCC: 2.2) • A decline in the polar bear population in some regions in response to habitat changes. (DCI: LS4.C.4; CCC: 2.2) • Expansion of ice-free habitat for brown and black bears. • An expansion of brown bear populations in response to warming temperatures and greening tundra. (DCI: LS4.C.4; CCC: 2.2) 1.D When to check for understanding: On day 4, when students write and share questions for the Driving Question Board. What to look/listen for in the moment: Students use their initial models to ask questions that lead to investigations about (SEP 1.1): • The ability of polar bears to adapt to new environmental conditions in the future. (DCI LS4.C.4; CCC 3.1) • The history of polar bears that lived under different environmental conditions than the present. (DCI LS4.C.4; CCC 3.1) • Genes that may affect the survival of polar or brown bears. (DCI LS4.C.4; CCC 3.1) • Changes to the ecosystem that may affect the survival of bear populations. (DCI LS4.C.4; CCC 3.1) • Ways to protect polar bear populations from the effects of climate change. (DCI LS4.C.4; CCC 3.1) • The rate at which Arctic ice conditions may change over time. (DCI LS4.C.4; CCC 3.1)

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	2.A Make and defend claims about effects of internal conditions on bear behavior. (SEP 7.5; DCI LS1.A.4; CCC 2.4) 2.B Evaluate a claim to determine the merit of thermoregulation as a cause to explain polar and brown bear interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4)	2.A When to check for understanding: On day 1, when students revise initial claims. What to look for/listen for in the moment: Claims that cite the evidence as seen in <i>Bear Data Analysis</i> for sample student responses. 2.B.1 and 2.B.2 When to check for understanding: On day 2, when students evaluate and revisit claims. What to look for/listen for in the moment: - Evidence about thermoregulation that supports claims that explain interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4) - Polar bear temperature rises during exercise. - To cool off, polar bears use snow. - Our body temperature did not rise that much during exercise. - We had a lot of ways to cool off (sweating, breathing hard, etc.) 2.B.3 When to check for understanding: On day 3 during the consensus discussion. What to look for/listen for in the moment: - Evidence about thermoregulation that supports claims that explain interactions. (SEP 7.2; DCI LS1.A.4; CCC 2.4) - Polar bears have a difficult time cooling off due to the NOS3 gene variant they have. - It will be hotter and there will be less snow, so it will be even harder to cool off. - Brown bears have variation in the NOS3 gene and will be better able to deal with heat than polar bears.
Lesson 3	3.A Integrate empirical evidence, including anatomical and genetic information, to infer evolutionary relationships in bear species. (SEP 8.2; DCI: LS4.A.1; CCC 1.5)	3.A.1 When to check for understanding: On day 1, during the whole-class discussion. What to look for/listen for in the moment: - Anatomical evidence from skulls, claws, and teeth suggests the bear species are closely related. (SEP 8.2; DCI: LS4.A.1; CCC 1.5) - Evidence raises questions about which bears are more closely related. (SEP 8.2; DCI: LS4.A.1) 3.A.3 When to check for understanding: On day 2, when students complete an Electronic Exit Ticket. What to look for/listen for in the moment: See <i>L3 Electronic Exit Ticket</i> for guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	4.A Construct an argument based on data and evidence to explain how and why speciation of polar and brown bears occurred over geologic time due to environmental changes caused by glaciation. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) 4.B Construct an argument based on the mechanism of evolution by natural selection to explain how and why speciation of polar and brown bears occurred over geologic time. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)	4.A.1 When to check for understanding: On day 1, when students write initial claims. What to look for/listen for in the moment: As students write a claim about the split of polar and brown bears from a common ancestor, look for arguments that include: (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4): - Evidence of glacial and interglacial periods creating a changing environment for bear populations. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Separation of different populations of bears in different climates, one with Arctic ice year round and one without. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Isolation of bears on ice where natural selection favored traits with variations adapted to cold climates. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Natural selection acted over many many generations (over glacial and interglacial periods) to cause a new species to form. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) 4.A.2 When to check for understanding: On day 2, during the Building Understandings Discussion and while students fill in <i>Developing an Argument</i>. What to look for/listen for in the moment: As students participate in the Building Understandings Discussion and construct an initial argument on <i>Developing an Argument</i> about the split of polar and brown bears from a common ancestor that includes: (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4): - Evidence of glacial and interglacial periods creating a changing environment for bear populations. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Separation of different populations of bears in different climates, one with Arctic ice and one without. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Isolation of bears on ice where natural selection favored traits with variations adapted to cold climates. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Natural selection acted over many many generations (over glacial and interglacial periods) to cause a new species to form. (DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) - Questions about evidence for which genetic traits caused evolution by natural selection. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4) - Questions about additional fossil data to provide evidence for where bears were located during glacial and interglacial periods when new species could have evolved. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.4; CCC: 3.2) 4.B. When to check for understanding: On day 3, when students revise their arguments. What to look for/listen for in the moment: When you collect <i>Developing an Argument</i>, use <i>Developing an Argument Key</i> for guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 5	5.A Revise a model based on evidence to explain and predict what will happen to Arctic bear populations as their environment changes. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4; CCC: 3.1)	5.A When to check for understanding: When the class revises the consensus model. What to look/listen for in the moment: As the class revises the initial consensus model (SEP: 2.3), look/listen for: • Brown bear populations will expand their population because climate change melts the ice earlier than before, increasing their available range and making more food available to them. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4) • Polar bear populations on seasonally available ice will decline because: • They will overheat on land. • They will interact more often with brown bears at food sources and lose. (SEP: 2.3; DCI: LS2.C.2; LS4.C.4; CCC: 3.1) • Polar bear populations on permanent ice will decline because they will have less ice habitat every year into the future. • Uncertainty about whether ice will melt more quickly in the future due to human-induced climate change compared to past glacial cycles. (DCI: LS2.C.2; LS4.C.4; CCC: 3.1) • Uncertainty about the ability of polar bear species to evolve fast enough to adjust to climate change. (DCI: LS2.C.2; LS4.C.4; CCC: 3.1) • Uncertainty about what will happen to the black bear populations. (DCI: LS2.C.2; LS4.C.4; CCC: 3.1)
Lesson 6	6.A Use a model to generate new evidence to support claims about the survival of polar bears in the changing Arctic. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2)	6.A.1 When to check for understanding: On day 1, when students make claims based on evidence from their models. What to look for/listen for in the moment: Claims using evidence from student models to predict fitness of hybrids in changing Arctic such as: • Roughly half of the hybrids will be well adapted to changing Arctic conditions. Those that gain alleles for less fat that do not overheat will be able to survive and reproduce as it gets warmer. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2) • Some of the hybrids will be well adapted to changing Arctic conditions, but some will not. Those that have darker fur and do not overheat will be able to hunt well and will be able to fight over food to survive and reproduce. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2) 6.A.1 When to check for understanding: On day 1, when students complete an Electronic Exit Ticket. What to look for/listen for in the moment: See <i>Unknown material with identifier: bc.l3.key4</i> for guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 7	7.A. Construct an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1) 7.B. Revise an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth and its effect on biodiversity. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1)	7.A When to check for understanding: On day 1, when students write arguments about the main cause of mass extinction with their group on <i>Extinctions Graphic Organizer</i>. What to look for/listen for in the moment: Arguments supported by evidence (SEP 7.4) that include: • Mass extinctions were caused by patterns of significant biological and geological events that caused drastic swings in Earth's temperatures and changes to ocean chemistry. (DCI LS.4.D.1, ESS2.E; CCC 1.1) • Most of the significant biological and geological events had evidence of major increases or decreases in atmospheric carbon dioxide levels, which caused drastic swings in Earth's temperatures and ocean chemistry. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1) • Requests for evidence related to the effect of extinctions of biodiversity. 7.B When to check for understanding: On day 2, when students revise their arguments about the main cause of mass extinction. What to look for/listen for in the moment: Arguments supported by evidence (SEP 7.4) that include: • Mass extinctions were caused by patterns of significant biological and geological events that caused drastic swings in Earth's temperatures and changes to ocean chemistry. (DCI LS.4.D.1, ESS2.E; CCC 1.1) • Most of the significant biological and geological events had evidence of major increases or decreases in atmospheric carbon dioxide levels, which caused drastic swings in Earth's temperatures and ocean chemistry. (SEP: 7.4; DCI: ESS2.E.1, LS.4.D.1; CCC: 1.1) • Patterns of mass extinctions causing decreases in biodiversity followed by an increase in biodiversity over millions of years. • Reasoning that increases in biodiversity occurred because of natural selection and speciation over long periods of time.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	8.A Integrate and evaluate information from multiple sources to explain how well a solution designed to prevent extinction reaches its goal, taking into account a range of constraints. (SEP 8.2; DCI: ETS.1B.1, LS4.C.5; CCC 7.1) 8.B Communicate information in multiple formats to explain how well a solution designed to prevent extinction reaches its goal, taking into account a range of constraints. (SEP 8.5; DCI: ETS.1B.1, LS4.C.5; CCC 7.1) 8.C Evaluate proposed solutions to protect polar bears from extinction, taking into account a range of constraints. (SEP 7.6; DCI: ETS.1B.1, LS4.C.5; CCC 2.3)	8.A When to check for understanding: On day 1, when students conduct research on their case study using <i>Research Notes Organizer</i> and <i>Evaluating Information Checklist</i>. What to look for/listen for in the moment: Students integrate and evaluate information from multiple sources on (SEP: 8.2) to explain (CCC 7.1): - How well a solution to prevent extinction reaches its goal. (DCI: ETS.1B.1, LS4.C.5; CCC 7.1) - Constraints on the system. (DCI: ETS.1B.1) - Whether evolution of the species can continue. (DCI: ETS.1B.1, LS4.C.5) - Acceptance or rejection of sources as (un)reliable for addressing the problem. (SEP: 8.2, DCI: ETS.1B.1, LS4.C.5) 8.B When to check for understanding: On day 2 during the gallery walk where student groups present their extinction prevention case study. What to look for/listen for in the moment: As students communicate information on their posters during the gallery walk (SEP: 8.5), look and listen for them to explain (CCC 7.1): - How well a solution to prevent extinction reaches its goal. (DCI: ETS.1B.1, LS4.C.5; CCC 7.1) - Constraints on the system. (DCI: ETS.1B.1) - Whether evolution of the species can continue. (DCI: ETS.1B.1, LS4.C.5) - Information about the method for protecting the species from extinction presented in multiple formats (writing, visuals, data). (SEP: 8.2, DCI: ETS.1B.1, LS4.C.5) 8.C When to check for understanding: On day 3, when students write their revised argument on <i>Extinction Prevention Argument</i>. What to look for/listen for in the moment: As students argue for whether to protect polar bears from extinction (SEP 7.6; DCI ETS.1B.1, LS4.C.5), look and listen for: - Evaluation of the benefits of proposed solutions. (SEP 7.6; DCI ETS.1B.1, LS4.C.5; CCC 2.3) - Consider a range of social, economic, cultural, and/or environmental constraints for the proposed solutions. (SEP 7.6; DCI ETS.1B.1, LS4.C.5; CCC 2.3) - Consideration of evidence if a solution could maintain genetic diversity in the polar bear population over the long term. (SEP 7.6; DCI ETS.1B.1, LS4.C.5; CCC 2.3)
Lesson 9	9.A. Evaluate claims and evidence about the future of bumble bee species on a global scale. (SEP: 7.2; DCI: LS4.C.5; CCC: 3.1)	When to check for understanding: On day 1, when students complete <i>Bumble bee Transfer Task</i>. What to look for/listen for in the moment: See <i>Bumble bee Transfer Task Key</i>.



Lesson-Specific Teacher Materials

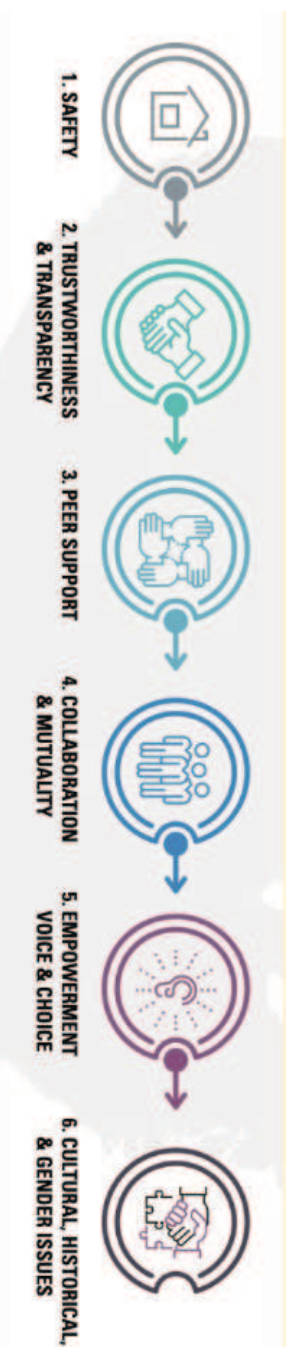
Trauma-Informed SEL Supports

In this unit, students will investigate a puzzling science phenomenon: polar, black, and brown bears observed in the same location at Wapusk National Park in Northern Canada for the first time. The phenomena is connected to climate change, and polar bear populations in particular could be at risk due to the shrinking amount and shortened seasonal duration of sea ice. Less sea ice leaves them less time to hunt for seals, their primary food source.

In this unit, students will investigate data about polar, brown, and black populations and make predictions about the future stability of the bear populations across the Arctic. They will deepen their understanding of how people around the world are investigating ways the bear populations have changed historically, as well as currently, as the environment around them changed over long periods of time.

We take a trauma-informed approach by providing accurate information and including information and prompts that help students explore how they can feel empowered addressing these issues in their own context. Learning about endangered species and climate change can be troubling and even heighten anxiety for students and adults alike, particularly if they have had previous exposure to traumatic events. Trauma reminders can be distressing <https://www.nctsn.org/resources/complex-trauma-facts-educators>. According to the CDC, "Adopting a trauma-informed approach is not accomplished through any single particular technique or checklist. It requires constant attention, caring awareness, [and] sensitivity."

Trauma-informed approaches are designed to promote a positive, safe, and resilient learning experience for all students, regarding those who have experienced trauma. Six principles for trauma-informed approaches have been widely adopted.



CDC and Substance Abuse and Mental Health Services Administration

Strategies to Strengthen Trauma-Informed Approaches in the Classroom (adapted from <https://transformingeducation.org/>)

1. Safety
 - The classroom environment feels physically and psychologically safe.
 - Interpersonal interactions between all educators and students promote a sense of safety.
2. Trustworthiness & Transparency
 - Decisions about changes in the classroom are made with transparency.
 - Building and maintaining trust among teachers and students, and between peers, is a top priority.
 - Teachers openly acknowledge when they don't know an answer or when a subject could be hard to learn about for some people (adults and students alike).
3. Peer Support
 - Peer support, mutual help, and collaboration are foundational for establishing safety and hope in the classroom.
4. Collaboration & Mutuality
 - The identities and stories of members of the school and classroom community are acknowledged and celebrated.
 - Partnering on work (between teachers and students, and peer to peer).
5. Empowerment, Voice & Choice

- There is meaningful sharing of power and decision-making when possible.
 - Students' strengths and experiences are recognized and built upon.
 - The school and classroom communities believe in its students' resilience, empowerment, and ability to make good choices.
6. Cultural, Historical, & Gender Issues
- Members of the school and classroom community strive to move past cultural stereotypes and biases, promote culturally responsive teaching, and celebrate and welcome all students' identities.

Social emotional learning (SEL) is the explicit teaching of skills to support emotion regulation and health relationships https://casel.org/fundamentals-of-sel/?gclid=CjwKCAjwwb6lBhBJEiwAbuVUStq6wDrY9Dbzq4VKmV13AYkf5H4NvfXzWHSBk9HWcIXoTKC7pbACIxOCbCOQAVD_BwE. Trauma-informed approaches integrated with SEL work towards ensuring all students, including those who have experienced trauma, have the skills, knowledge, and attitudes to regulate emotions and be productive, engaged learners <https://www.aier.org/sites/default/files/2021-09/Trauma-Sensitive-Schools-and-SEL-Integration-Brief-June-2021rev.pdf>; <https://transformingeducation.org/resources/trauma-informed-sel-toolkit/>. The following skills support the development of self-regulation, a key principle of trauma-informed SEL <https://transformingeducation.org/resources/trauma-informed-sel-toolkit/>.



Transforming Education's Trauma-Informed SEL Toolkit, CC BY-NC-SA 4.0

Check, Reflect, Connect.

Throughout this unit, opportunities to develop self-regulation skills are embedded as optional activities using Check, Reflect, Connect.

- **Check.** Feelings awareness is a critical component of self-regulation and is included as standard practice in many social emotional learning programs <https://files.eric.ed.gov/fulltext/ED612292.pdf>. Students are invited to use a Feelings Wheel (see image below) to check with themselves about how they are feeling as they work through lessons. Key points to reinforce include:
 - A key to self-regulation is being able to acknowledge a person can feel multiple emotions at the same time, including seemingly "opposite" feelings. Encourage students to log these.
 - Ex) When learning about the zombie fires I felt curious and nervous.
- **Reflect.** Once a feeling is identified, taking a moment to reflect on the intensity of those feelings and what thoughts, past experiences, and beliefs may be related to those feelings is a key to self-reflective learning and developing regulation. The students are provided a space to jot down a couple of notes or thoughts.
 - If reflecting is an emerging skill for your students, modeling and providing an example can be really helpful. This could be done for the full class or in small groups or one-on-one as needed.

- **Connect.** This is where students are empowered to rely on strong, supportive relationships and connect with a caring, supportive adult if they'd like to discuss their experiences within the lesson or unit. If needed, teachers can help students think about their connections at the beginning of the unit using the following strategies:
 - Ask students in their first Check, Reflect, Connect activity to identify at least one supportive adult they could talk with about their learning through the unit.
 - If a student is unable to identify someone, connect with them and help them think through options.
 - This person does not have to be a guardian or family member. Suggest adults such as a home room teacher, a neighbor, a member of their faith community, the parent of a friend, a coach.

Engaging in Mindfulness

Mindfulness exercises can help all students regulate emotions, including those who have experienced trauma <https://transformingeducation.org/wp-content/uploads/2019/01/2019-BCRC-Mindfulness-Brief.pdf>. These strategies can help students feel more calm, centered, and ready to learn. These can be done before a lesson, mid-lesson, or at any point that you feel students might benefit from these strategies. They can also be done as a whole group, in small groups, or individually.

Strategy #1: 5-4-3-2-1.

This strategy can be done either as a whole class, with partners, or in small groups.

- 5- Look at five things around you. Make note of their qualities. What color are they? What shape are there? What other qualities do they have?
 - 4- Acknowledge 4 things that you are touching or things you can touch. How do they feel? How would they feel?
 - 3- Listen for 3 sounds you can hear. Tune into them individually.
 - 2- Breathe in and identify two smells around you. What do these smells remind you of?
 - 1- identify one thing you can taste around you. What would it taste like?
- Some alternatives to this approach can be found at: <https://cognitiontoday.com/5-step-mindfulness-grounding-technique-to-ease-anxiety-why-it-works/>.

Strategy #2: Check In

This strategy works well at the beginning of a lesson.

- Have students reflect on these questions:
- Think about the previous lesson. What went well? What was hard?
- Ask students to share their answers with peers and consider how they can become more invested and present in the lesson today.

Strategy #3: Box Breathing

This strategy can be done at any point in a lesson, and can be helpful to do during or after any point where students show signs of stress or anxiety. Box breathing helps students with stress management and is broken down into 4 steps.

- Ask students to visualize a box with 4 equal sides in their minds. Guide students as each inhale or exhale takes them around the perimeter of the box.
- Step One: Breathe in through the nose for a count of 4.
- Step Two: Hold breath for a count of 4.
- Step Three: Breathe out for a count of 4.
- Step Four: Hold breath for a count of 4.
- Repeat.

Note: The length of the steps can be adjusted to accommodate the individual (e.g, 2 seconds instead of 4 seconds for each step).

Strategy #4: Progressive Muscle Relaxation

This strategy works well at any point during a lesson, individually, in small groups, or classwide as the teacher narrates. This exercise asks students to relax muscles in order through the body to help foster relaxation.

- **Step One:** Have students sit down and minimize distractions.
- **Step Two:** Starting at the feet, curl the toes under and tense the muscles in the foot. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Three:** Tense the muscles in the lower legs. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Four:** Tense the muscles in the hips and buttocks. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Five:** Tense the muscles in the stomach and chest. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Six:** Tense the muscles in the shoulders. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Seven:** Tense the muscles in the face (e.g., squeezing eyes shut). Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.
- **Step Eight:** Tense the muscles in the hand, creating a fist. Hold for 5 seconds, then slowly release for 10 seconds. During the release, focus attention on the alleviation of tension and the experience of relaxation.

Strategy #5: Guided Imagery

This can be done at any point in the lesson. Students visualize a relaxing environment to help manage stress and walk through what they would sense in the environment. Guided imagery can be practiced individually or with the support of a narrator.

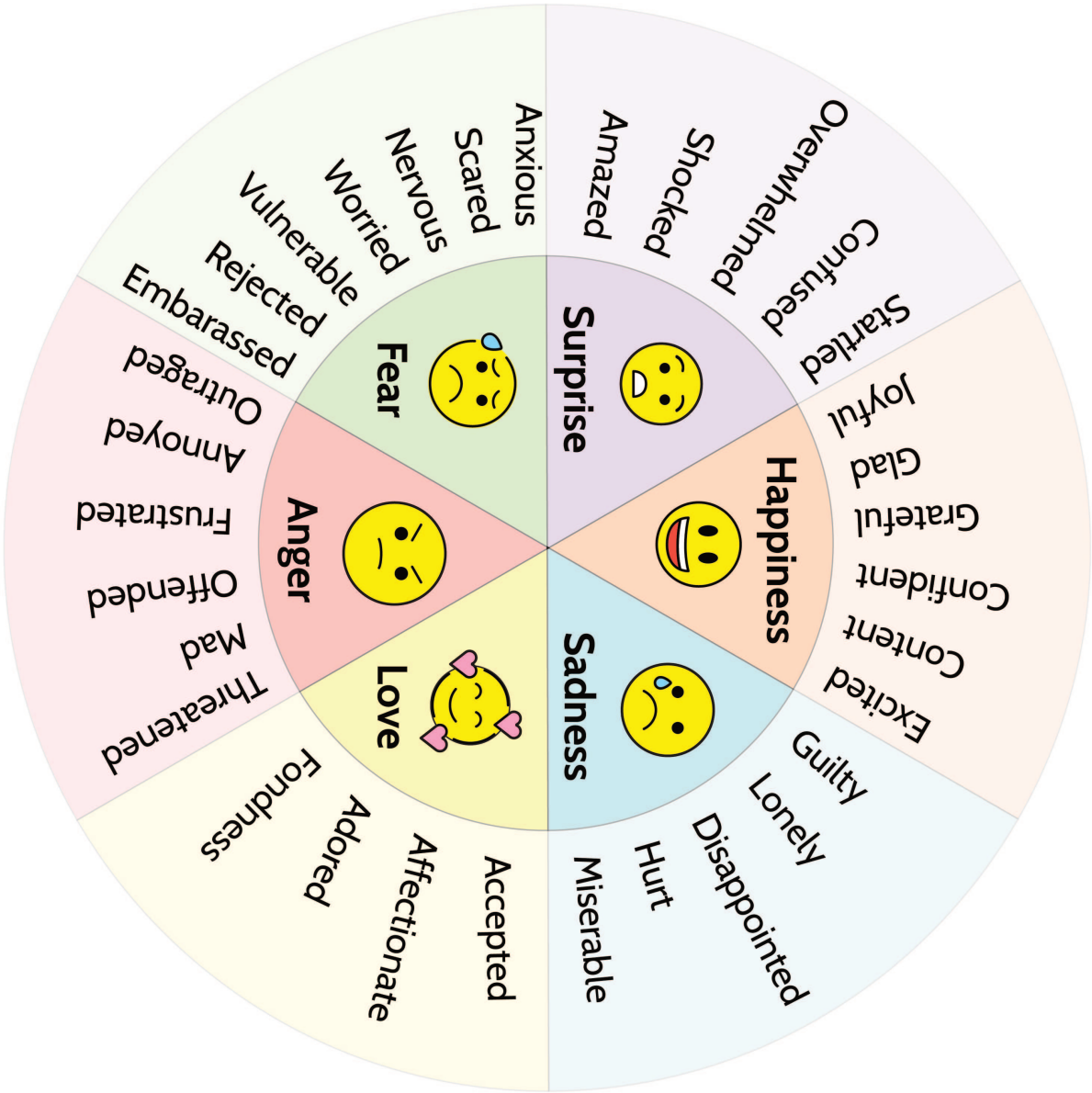
- **Step One:** Have students sit down. Ideally, the space will have minimal distractions.
- **Step Two:** Visualize a relaxing environment by either recalling one from memory or creating one through imagination (e.g., a day at the beach). Elicit elements of the environment using each of the five senses using the following prompts:
 1. What do you see? (e.g., deep blue color of the water)
 2. What do you hear? (e.g., waves crashing along the shore)
 3. What do you smell? (e.g., fruity aromas from sunscreen)
 4. What do you taste? (e.g., salty sea air)
 5. What do you feel? (e.g., warmth of the sun)
- **Step Three:** Sustain the visualization as long as needed or able, focusing on taking slow, deep breaths throughout the exercise. Focus on the feelings of calm associated with being in a relaxing environment.

These are not the only mindfulness activities available for use. Consider using other mindfulness techniques as suggested by your school counselors. As experts in their fields, they can recommend strategies that are relevant and targeted to your specific students.

Strategies #2-#5 were adapted from the following source for classroom specific use:

Norell SK, Long A, Krepps JM. Relaxation Techniques. Updated 2021 Sep 6. In: StatPearls Internet. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK513238/>

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CASEL (2003). Safe and sound: An educational leader's guide to evidence-based social and emotional learning (SEL) programs. Chicago, IL: CASEL.

CASEL (2015). CASEL guide: Effective social and emotional learning programs: Middle and high school edition. Chicago, IL: CASEL.

Guitierrez, A. S., Krachman, S. B., Scherer, E., West, M. R., & Gabrieli, J. D. (2019). *Mindfulness in the Classroom: Learning from a School-based Mindfulness Intervention through the Boston Charter Research Collaborative*. BCRC. <https://transformingeducation.org/wp-content/uploads/2019/01/2019-BCRC-Mindfulness-Brief.pdf>

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(n.d.). *Strategies to Strengthen trauma-informed Approaches in the classroom*. Transforming Education. Retrieved July 19, 2023, from <https://transformingeducation.org/>

Norelli SK, Long A, Krepps JM. Relaxation Techniques. Updated 2021 Sep 6. In: StatPearls Internet. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from <https://www.ncbi.nlm.nih.gov/books/NBK513238/>

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Wigelsworth, M., Verity, L., Mason, C., Humphrey, N., Qualter, P., Troncoso, P. (2019). Primary Social and Emotional Learning: Evidence review. London: Education Endowment Foundation. The report is available from: <https://files.eric.ed.gov/fulltext/ED612292.pdf>

Bear Adaptation Poster

Timeline	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Polar bear												
Brown bear												
Black bear												

Lesson 1: Answer Key 1

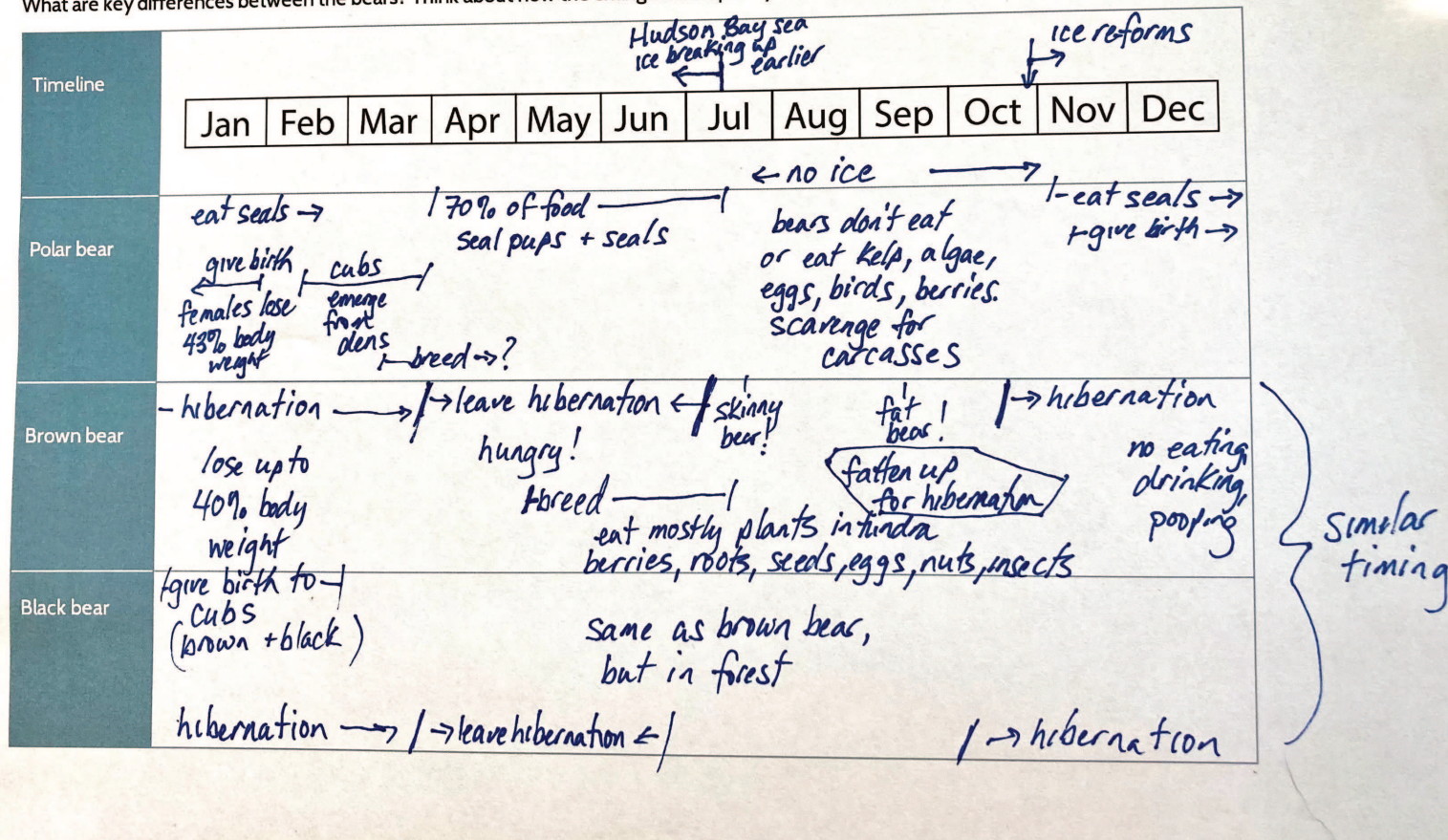
Key Bear Adaptation Readings

Lesson 1: Answer Key 1

Key Bear Adaptation Readings

Part 2: Bear Adaptation Readings

Read your bear topic as a group. Take notes on the following questions: What adaptations does each type of bear have to life in different parts of Wapusk? What are key differences between the bears? Think about how the changes in Wapusk you learned about in Part 1 might impact the bears.



Lesson 1: Answer Key 2

Key Comparing Polar Bear Populations

How are polar bear populations in different ecoregions affected by changes to Arctic sea ice?

Part 1: Investigate one ecoregion

Name of ecoregion investigated _____

Video Notes

Allow any notes. Focus will be similar to question 2.

1. What types of data are we given to determine how the polar bear populations are affected by changes to Arctic sea ice? Evaluate the usefulness of this data to provide evidence to answer our question. (What makes data useful?)

Condition of sea ice, short-term population trends, 2018 population estimate, polar bear body condition, reproductive trends

2. What happens to the ice in these regions over the course of a year? What does that mean for the polar bear population?
 - Seasonal: Ice melts in summer and polar bears come to shore.
 - Islands/Archipelago: Most ice persists all year. Polar bears can stay on ice all year.
 - Divergent: Ice forms near shore and drifts with currents. Ice is moving farther north away from food recently. Some polar bears move to shore.
 - Convergent: Floating ice piles up on shore lines. Polar bears can hunt from there.
3. How are polar bear populations in this ecoregion affected by changes to Arctic sea ice?

See table in part 2 for additional information.

- Seasonal: 2 likely decreasing, including Western Hudson Bay (Wapusk) 500-1000 bears, one area stable, most areas in decline for body condition and reproductive trends, except Foxe Basin and Southern Hudson Bay are stable for reproduction.
 - Islands/Archipelago: 2 regions population is increasing, one stable, 3 unknown. Kane Basin condition increased and reproduction is stable. 5 areas are uncertain for condition and reproduction.
 - Divergent: 2 areas stable population, one decreasing, 2 unknown, Barents has 2001-3000 bears. Southern Beaufort Sea condition and reproductive decline, and population decreasing. Others unknown.
 - Convergent: Not enough data about population trends. Northern Beaufort (same area as Inuvialuit) has 1,001-2000 bears and stable reproductive trends. But other areas are uncertain for condition and/or reproductive trends.
4. What questions do you still have?
 - Accept all questions.
 - Why is so much uncertain or unknown?
 - How can we figure out how the bears are doing when we do not have good information everywhere?

Part 2: Fishbowl Discussion

Evaluate all of the evidence we have been given for each region. Take notes using the graphic organizer below.

Fishbowl questions:

- How are polar bear populations in different ecoregions affected by changes to Arctic sea ice?
- What specific evidence supports your claim?
- How confident are you in your claim? Why?
- What is the relationship between ecoregion ice behavior and the bear population data?

Region	Inuvialuit	Seasonal Ice	Convergent Ice	Divergent Ice	Islands/Archipelago Group
Data source	quotes	Research from multiple surveys, local knowledge, research	Research from multiple surveys, local knowledge, research	Research from multiple surveys, local knowledge, research	Research from multiple surveys, local knowledge, research
Usefulness of evidence	Detailed about individual bears and ice conditions. Observations about ice types, ice movement, and polar bear behavior similar to ecoregions. Less ice is a trend, but bear condition varies so patterns difficult to find.	Some data missing, but trends can be seen. Data for all categories is present.	Data on north Beaufort Sea population only. Missing East Greenland. No body condition data.	Some data on 3 of 5 regions. Missing body condition and reproductive trends for 4 of 5.	Some data for all regions, Missing body condition and reproductive trends for 5 of 6.
Ice condition	Melting more than before, quality of ice has changed, harder to move on.	In Wapusk, ice breaking up earlier . Climate change could melt earlier in all areas (no direct evidence provided).	Ice piles on shore give polar bears access to seals all year.	Ice floats away with current. Moving farther away where bears cannot hunt. Either stay and do not eat for a period or come to land.	Ice persists all year.

Stability of polar bear population	Some say smaller bears and fewer bears. Some say no change. (Note: The Inuvialuit communities overlap geographically the most with convergent ice, but also divergent and island ice.)	Decline in population for 3 regions, body condition, and reproduction in most areas where we have complete data. Some stable regions.	North Beaufort Sea stable , East Greenland uncertain .	Stable or declining , but missing any data on 2 regions and incomplete data for 2 more. Southern Beaufort declining for all measures.	Kane basin increasing with stable reproduction, and M'Clintock increasing with some missing data , another stable . 3 unknown .
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Notes on discussion:

- Some of the seasonal ice and divergent populations are in danger, data is incomplete for some regions. Ice melts or moves away in these regions on a seasonal basis.
- One convergent population is stable, while data is missing for the other. The Islands group population data seems to be more stable or increasing, but data is incomplete. Ice piles up or stays around permanently all year in these areas.
- Without information about the behavior of ice in the ecoregions, it would be difficult to find patterns that suggest an explanation for the stability of some polar bear populations and decline of others.

Part 3: After the Discussion

Stop and Jot: Based on what you know about how polar bear populations in different ecoregions are affected by changes to Arctic sea ice, What might the future look like for polar bear species?

Accept any well reasoned response. Students will bring these ideas into their initial models.

Name: _____

Date: _____

Lesson 2: Answer Key

Bear Data Analysis

	brown bear and black bear	polar bear and black bear	polar bear and brown bear
Make a claim. How and why will these bears interact in the Arctic as their environment changes? Consider where and when these interactions will take place. NOTE: ANSWERS WILL VARY	Black bears will avoid brown bears in the Arctic as the environment changes because they are small.	Black bears will avoid polar bears in the Arctic as the environment changes because they are small.	Polar bears will fight and win with brown bears because they are bigger.
Cite SUPPORTING evidence. What evidence supports your claim?	Black bears change the time they are active and the habitat they use when brown bears are around. Brown bears sometimes kill black bears. Brown bears prefer open habitat, and black bears prefer trees. Black bears are smaller than brown bears.	No evidence of interaction study. Black bears are much smaller than polar bears. Black bears climb trees; polar bears do not spend time in trees.	Around food, brown bears are aggressive, and polar bears are submissive. In September, when the data was collected, the brown bears would be getting ready to hibernate, and the polar bears are really hungry and maybe weak. Polar bears overheat quickly.
Cite REFUTING evidence. What evidence does not support your claim?			Polar bears do not fight; they run away from brown bears.

Revised Claim with reasoning. How does the evidence help you explain why and how the bears are interacting?	Black and brown bears will live in the same areas as more brown bears move into the Arctic, but black bears will avoid brown by keeping to the trees and being active at different times of day because black bears are smaller and are at risk of being killed by brown bears.	Black bears will avoid polar bears in space (any maybe time) because they have really different habitats and diets. If black bears are at risk for being killed by brown bears, they might also be killed by polar bears because black bears are much smaller.	Polar bears will come into more contact with brown bears on seasonal ice, especially in the fall, as the Arctic warms but will avoid/run away from brown bears because they are weak (low body mass and fat) and overheat easily.
Reflect. Explain any evidence that is hard to reason with or does not support your claim.			

Name: _____

Date: _____

Lesson 2: Answer Key

Thermoregulation Investigation Key

Materials:

- Timer
- Infrared thermometer

Procedure:

1. Choose 1-2 group members to be the study participants. They will do jumping jacks for 8 minutes, pausing every 2 minutes for a temperature check.
2. Use the thermometer to measure their temperature before they begin jumping jacks. Record any additional data that your class agreed on in your data table. Label the column headings for each type of data.
3. Have your study participant(s) start doing jumping jacks and start the timer.
4. Measure their body temperature and any additional data your class agreed on in the data table every 2 minutes for 8 minutes.

Data Table.

Time (min)	Temperature (name)___Studnet 1__	Temperature (name)___Studnet 2__	Face Redness	Out of Breath (breathing harder than normal)	
0	98.1	98.7	none	not at all	
2	98.1	98.7	none	not at all	
4	98.2	98.7	increased	not at all	
6	98.1	98.8	increased	a little	
8	98.3	98.8	increased	a little	

Making Sense

1. How did human body temperature change during exercise?

It varied a little but remained fairly consistent around 98.6 degrees F.

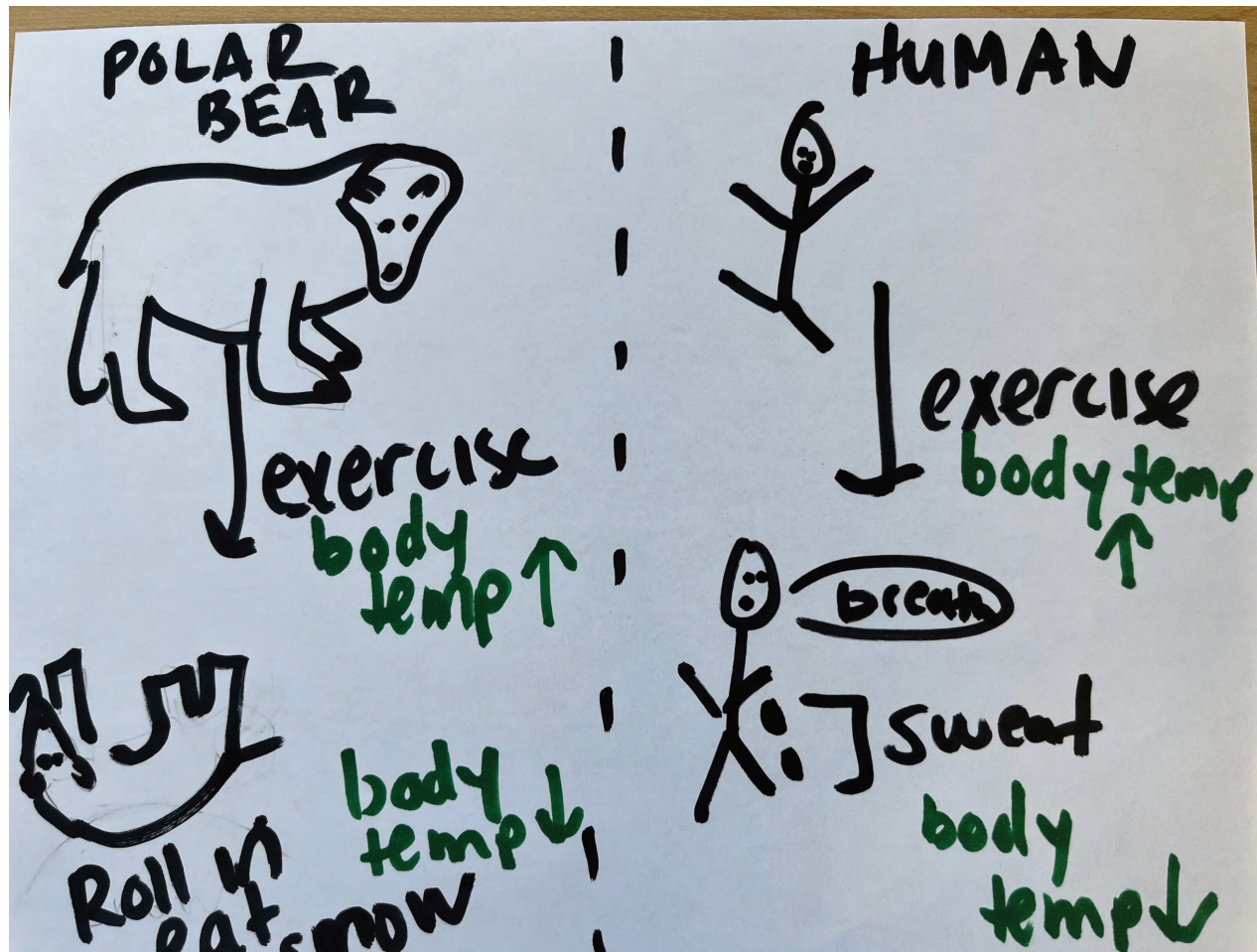
2. How does this compare to how the polar bear responded to exercise in the treadmill study?

Our human body temperature varied much less than the polar bear.

3. In the space below, use pictures, symbols and/or words to explain the differences between the human response and the polar bear response.

Be sure to include:

- what happened to body temperature during exercise
- what caused body temperature to change/stay the same
- any thermoregulation mechanisms



4. Recall the claim we have been evaluating. *“Polar bears have more problems with overheating than they do with cold. That’s why they typically walk at a slow pace. They can run for a short distance but quickly overheat.”*

-Polar Bears International

How does the additional evidence we collected help us determine whether the claim has merit? What else do we need to know?

The additional evidence indicates that unlike polar bears, our body temperature did not raise drastically during exercise. Our muscles generated heat but we had a mechanism to get that heat out of our bodies, like sweating, turning red, breathing hard, etc.

Lesson 3 Teacher Reference

Exit Ticket Guidance

What are Electronic Exit Tickets?

These are short **formative** assessments that occur 2-3 times per unit in between other assessments. They include items to check for understanding of lesson-level PEs, to make connections between content and students' lives, and to elicit information about their experiences and to help students reflect on their own progress in focal SEPs and CCCs. **They are built in Google Forms, but can be ported to any survey software.**

How to create Electronic Exit Tickets

Select the link for the Electronic Exit Ticket that corresponds with the lesson you are teaching.

Lesson 3: https://docs.google.com/forms/d/1Ln6ypozASssLBwCpFn_YlQFg59ezXcusRvyHzZin28/copy

Lesson 6: https://docs.google.com/forms/d/1VvUP5uOT8Mo_Em-mBb3wuWzrqHWkOdio_xSps8m8Cl/copy

Spanish versions are available here:

Lesson 3: <https://docs.google.com/forms/d/1s5eYPOKrNOEZ-jXV/aCB0tPzP3e519cQzQXHKmYGNk/copy>

Lesson 6: <https://docs.google.com/forms/d/1BSXFDXXP-EPRSX-iiikaRWjvK0YtGUDPv2PoqtGWF/copy>

Attending to Equity

Some students may benefit from completing the Electronic Exit Tickets on a printed version. Complete the steps below to create a copy of the Electronic Exit Ticket. Once you have created a copy in your own Google Drive, click on the 3 dots in the upper right side of the form next to the SEND button. This should give you an option to print a paper copy of the Electronic Exit Ticket.

When you select the link, it will ask you to make a copy in your own Google Drive.

Copy document

Would you like to make a copy of **Family and Friends MRE Survey**?

Make a copy



The student survey will open in your own Google Drive.

Family and Friends MRE Survey ☆

Questions Responses

Family and Friends MRE Survey

⊕

⊖

⚙

⋮

Send

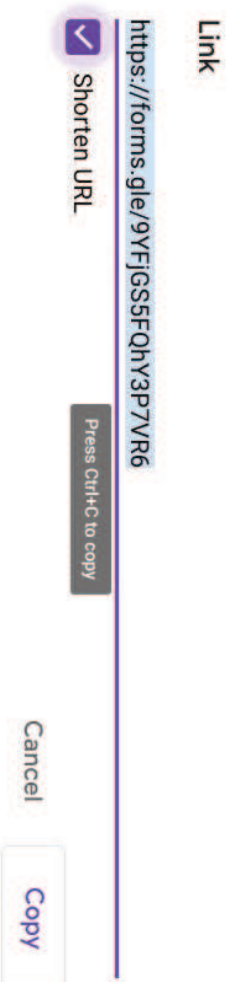
Select the "Send" button in the upper right corner to get a link to give to students.



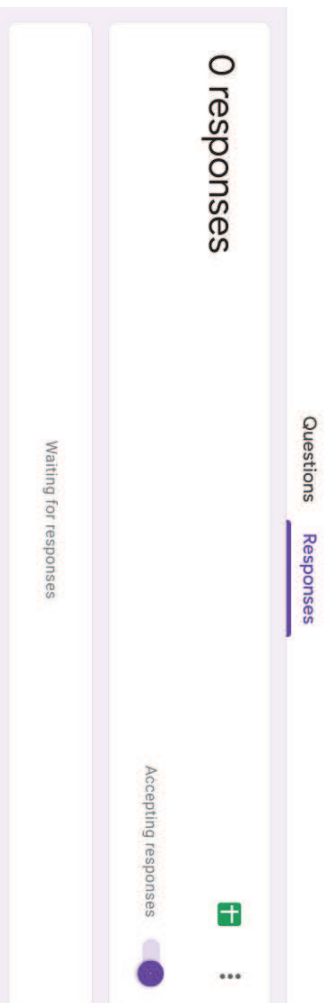
In the "Send via" panel, select the middle icon in order to choose to send the survey via a link.



Copy the link it provides you or select the "Shorten URL" box, then copy the link. This second option creates a link that will be easier for students to type.



Once people submit responses, they will show up in your Google Form under "Responses." Google will automatically provide you with some visualizations of these responses.



If you want to see the data in a spreadsheet format, click the sheet icon to create a Google Sheet of your data. It will automatically populate when people respond to the survey.

For each survey, you will need to repeat the process above. You can choose to make a copy of the survey for each of your classes or choose to have one survey for all your classes.

Lesson 3: Answer Key

L3 Electronic Exit Ticket

3.A Integrate empirical evidence, including genetic sequences, to infer evolutionary relationships in bear species. (SEP 8.2; DCI: LS4.A.1; CCC 1.5)

Where these elements are addressed in this assessment.	8.2 Obtaining, Evaluating, and Communicating Information Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.	LS4.A.1: Evolution Evidence Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence. (HS-LS4-1)	1.2 Patterns Empirical evidence is needed to identify patterns.
Q1	X	X	
Q2		X	X
Q3			
Q4	X		X
Q5	X		
Q6			X
Q7			

Question 1

Not all bees are honey bees. There are two species of honey bees that scientists have been watching closely lately. Humans brought *A. mellifera* bees into India to help with pollinating the crops farmers are growing in those places and to make honey. More than 90% of the local population of *A. cerana* bees in India died off when humans first introduced *A. mellifera* bees to India. A third bee, *X. furnicornis*, that is not a honey bee but is native to India was added to the table below for comparison.

<i>A. mellifera</i> (honey bee)	<i>A. cerana</i> (honey bee)	<i>X. furnicornis</i> (carpenter bee)
 Andreas Trepte, CC BY-SA 2.5	 tjeales, CC BY-SA 4.0	 Yercaud-elango, CC BY-SA 4.0

- Can scientists use these [two pictures](#) to tell how closely these two species of honey bees are [related](#)?
- **Yes, because body structures are coded by genes. So if they have similar body structures, then they have genes in common and are probably closely related.**
 - No, because scientists can never determine relatedness with physical structures. They can only use genetic information to find relatedness. Therefore, these pictures do not provide enough data.
 - No, because these pictures only show individual bees instead of each species. Scientists would need to look at more pictures of each type of bee to determine if they are related.
 - Yes, because the pictures show that the organisms have similar behavior. Therefore, they must be closely related.

Correct response:

Yes, because body structures are coded by genes. So if they have similar body structures, then they have genes in common and are probably related.

Rationale for correct response:

Relatedness can be inferred indirectly by comparing anatomical similarities that are derived from DNA sequences.

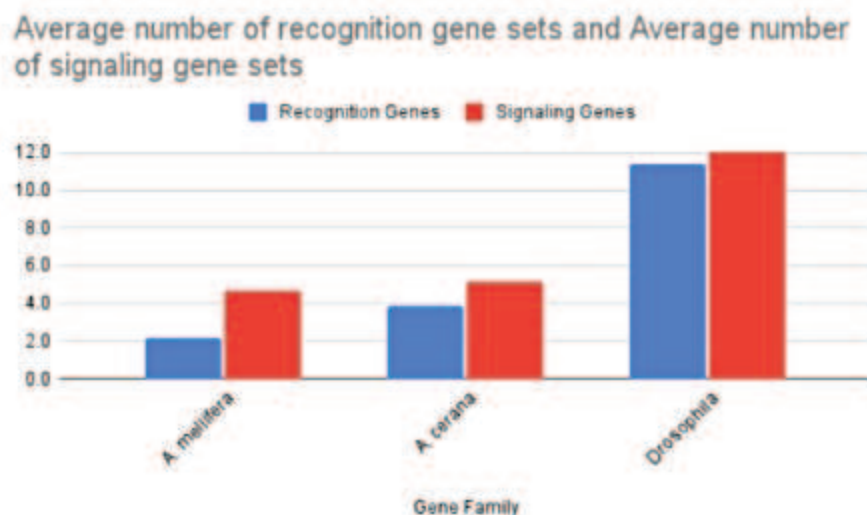
What to do:

Prompt students to think about the relationship between genes and anatomy as evidence for relatedness. Refer to their science notebooks to use evidence from the bears as an example of another organism.

Question 2

Biologists have spent a lot of time studying bees because they are so important to agriculture and the global environment. As a result, there is a lot of information about the honey bee genome.

The graph below shows the number of groups of genes related to immunity. The table shows numbers in the two honey bee species and a third species of a non-social insect, *Drosophila melanogaster* (fruit fly), just for comparison with something *not* a bee. Scientists have been studying the fruit fly genome for years as a model organism.



The table below compares the overall percentage of A-T base pairs and C-G base pairs there were in the genome for the two honey bee populations and *Drosophila melanogaster* (fruit fly).

	<i>A. mellifera</i>	<i>A. cerana</i>	<i>D. melanogaster</i> (fruit fly)
	 Andreas Trepte, CC BY-SA 2.5	 tjeales, CC BY-SA 4.0	 Hannah Davis, CC BY-SA 4.0
A-T base pairs	60.42%	61.88%	57.95%
C-G base pairs	39.47%	38.12%	42.05%

Using the **genetic data** from above, how can **patterns** be used to explain the relatedness of the two species of honey bees?

- Not related because the patterns between each of the bars on the graph for both species are not the same, and the percentages of base pairs in the table are not the same.
- **Related because of the similar patterns between each of the bee species compared to the fruit fly for both the graph and the data table.**
- They are the same type of bee because the patterns in the genetic data are practically the same. These bee species just originated from different places.
- Not enough information to determine if these two species are related.

Correct response:

Related because of the similar patterns between each of the bee populations compared to the fruit fly for both the graph and the data table.

Rationale:

There was evidence of relatedness in the gene sets between the bee populations that were more alike to each other than the fruit fly. Additionally, the fact that they almost have the same percentages of base pairs in common with each other and different that the fruit fly shows a pattern of relatedness across the data.

What to do:

Encourage students to revisit their science notebooks to see how relatedness was defined and the relationship with genes. They should come up with the idea that the more genetic information that two populations have in common, the more likely it is they have a common ancestor and are, therefore, related to each other.

Question 3

How might we use what we learned about common ancestry today to benefit others in the community, either now or in the future?

What to look for in response:

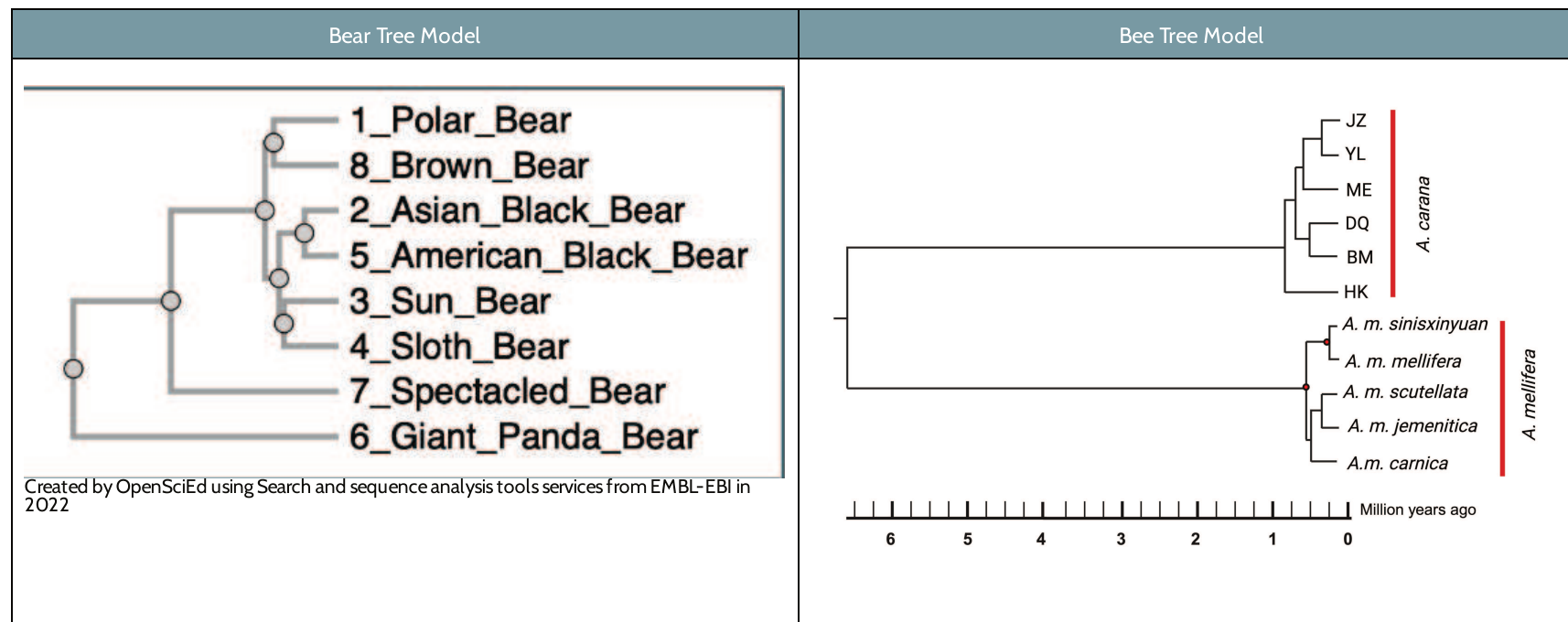
Accept all responses. Validating these responses engages students in activating their **relevance** and **interest** in these issues, which can motivate future questions.

What to do:

Have students imagine how they would explain today's lesson to a community member. Prompt them to think about why it was important to figure these ideas out about both honey bees and polar bears and how it could protect human and nonhuman populations.

Question 4

In this lesson, we created tree model relationships to group similar organisms together.



Are there **patterns** in the **images above for bears and bees** that help explain how species observed today became different from their common ancestor? Explain your answer by discussing the strengths and limitations of tree models.

Correct response: The tree model does not help us explain how *A. cerana* and *A. mellifera* split into two different species. Similarly, the tree model does not show how each of the different bear species became their own species. Tree models are useful because they can show us how similar or different species are from each other, but we would need more data from the past to figure out how they became different species.

Rationale:

Tree models show branching that produces multiple lines of descent that is inferred by comparing the DNA sequences of different organisms. Genetic information provides evidence of evolution but does not show how each of these species evolved. To understand that, students would need more information about these species in the past to understand the environmental selection pressures that lead to speciation.

What to do:

Have students think about what data was used to create tree models and what question we were trying to answer when we were creating them. Have students compare how the question we are answering here is similar and different from the questions used to create the model. Ask students what additional data would be needed to answer this new question.

Question 5

How did **obtaining and evaluating information from multiple sources** during the lesson help you make sense of bear relatedness?

What to look for in response: *Note: These could be different for each student.*

- Students should consider how **images of the different species of bears, DNA similarities from their BLAST data, and their phylogenetic trees** help them determine how closely related species are to each other.

What to do:

Encourage students to think about **which genetic information is stronger evidence in determining relatedness** and the value of having different types of information to analyze.

Question 6

How did **patterns of information at different scales** help you make sense of bear relatedness?

What to look for in response:

- Students should mention that the **patterns** in the similarities in DNA and phylogenetic trees help determine which bear species are more closely related to each other and which species are not as closely related. This is more helpful than just looking at anatomical data.

What to do:

If students are having difficulty answering, you may want to separate the **patterns** between the two types of data to think about the information separately. Prompt them to think of how the similarities between data relate to the phylogenetic trees and the conclusions that they can derive from them.

Question 7

I understand how today's class ties to the bigger picture for what we're studying in this unit.

- Yes
- No

What to look for in response:

Student answers may vary.

What to do:

Prompt students to think about how they can use ideas that they figured out today to make progress on the unit question: *What will happen to Arctic bear populations as their environment changes?*

Bears and Glacial Cycles Key

What would it be like for bear populations to live through 700,000 years (or more) of glacial cycles?

Part 1: Glacial Period

(example answers shown. Students may choose a different time period)

1. Choose a glacial time period to begin: G_6__
2. Calculate the length of the glacial period. __550-535=15 thousand years__
3. Scientists estimate that the average polar bear generation lasts for 11.35 years. If we assume the common ancestor had a similar generation length, how many generations of bears would occur during the whole glacial period?

15,000 divided by 11.35=1,322 generations

4. Scatter the chips randomly around the glacial map. These represent all of the common ancestor bears that lived at that time.

5. Small-group discussion questions

(answers below would be discussed orally while using the maps and chips, not written):

- a. Do you think this realistically shows where bears would be during a glacial period?
- No, bears would not live in the ocean, on the North Pole, could they live on a really thick glacier?, etc.

- b. What options would they have during this time period?

They could stay where they are or migrate to places without ice.

- c. What habitats are available?

Arctic ice in most places, maybe tundra or forest farther south at the edge of the ice.

- d. Where could bears go as the glaciers formed?

If they do not stay where they are, they are likely to travel to the south as it becomes colder. They could go farther into Canada and the northern US or into Europe and Russia/China.

- e. Use the chips to represent where you think the bears might go on the glacial map during this time.

6. What might cause some bears to move off the ice?
- If they are too cold, cannot find food, cannot find shelter.

7. Why might some bears stay on the ice?

If they can hunt seals/find food, they can stay warm and find shelter.

Part 2: Interglacial Period

As you saw in the visualization, the ice melted gradually between the glacial and interglacial period.

8. Small-group discussion questions:

- a. What options would bears have as climate changes from the glacial to interglacial time period?

They could stay where they are or migrate to areas where there used to be ice.

- b. What habitats are available?

Arctic ice, increasing amounts of tundra or forest.

- c. Move the chips from the glacial map to the interglacial map to represent where you think bears might go during the interglacial period.

9. Why might some bear populations move from where they were during the glacial period as the ice melts?

There might be more habitat that opens up as the ice melts where they can find food and shelter. It will be warmer in more places, and they can survive and reproduce there.

10. Why might some bear populations stay on the ice even as it melts in most areas?

If they have enough to eat, can stay warm enough, and survive and reproduce, they may stay. Some bears may also get trapped on islands in the middle of the ocean as they ice melts in other places. They will not be able to swim far enough to leave.

11. Calculate the length of the interglacial period that follows the glacial period (move to the right towards the present day).

From G6 to G5: $535 - 470 = 65$ thousand years.

12. If some bears stayed on the ice through the entire interglacial period, how many generations would occur?

$65,000$ divided by $11.35 = 5,727$ generations.

Part 3: Consider possible explanations for how polar and brown bears became different species.

13. Discuss when, where, and why polar and brown bears may have split from their common ancestor.

(Answers will vary and will be discussed orally, not written.)

When the G6 glacial period set in 550,000 years ago, some common ancestor bears stayed on the ice, and some went south to where it was warmer, depending on their ability to stay warm and find food. Different small populations may have been separated from each other during the whole 15,000 year glacial period. 1,322 generations of bears were born during this time.

Some bears got trapped on an island where there was ice during an interglacial period for 65,000 years from 535-470,000 years ago. Those bears mated with one another over 5,727 generations and became really different from bears that did not live on ice. The ones on the island became polar bears. The ones not on ice became brown bears.

References

Liu, S., Lorenzen, E. D., Fumagalli, M., Li, B., Harris, K., Xiong, Z., ... & Wang, J. (2014). Population genomics reveal recent speciation and rapid evolutionary adaptation in polar bears

Lesson 4: Answer Key 2

Developing an Argument Key

4.B Construct an argument based on the mechanism of evolution by natural selection to explain how and why speciation of polar and brown bears occurred over geologic time. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)

3D Elements Addressed in This Assessment	
SEP	Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.
DCI	The many dynamic and delicate feedbacks between the biosphere and other Earth systems cause a continual co-evolution of Earth's surface and the life that exists on it.
	Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)
CCC	Some systems can only be studied indirectly as they are too small, too large, too fast, or too slow to observe directly.

Develop an argument to answer the question: *How did polar and brown bears become different species?*

Arguments should contain the following (not necessarily in the order shown):

1. Claim: *Answer the question including both when, where, and why you think this occurred.*
2. Evidence: *Describe what data you have to support each part of your claim.*
3. Reasoning: *Use science ideas to describe how the evidence supports your claim. Create a story that links the evidence to your claim using science ideas.*

Note you will have MULTIPLE pieces of evidence and need reasoning to explain how ALL evidence supports part of your claim. Evidence and reasoning will be many sentences long.

Claim

Polar bears and brown bears split from a common ancestor between 626,000 and 550,000 years ago because one population of common ancestor bears got trapped in Greenland and reproduced in isolation for thousands of years during an interglacial period while another population remained in Canada.

(Note: The exact timing and location are not important, but claims should include a complete interglacial period to allow for isolation and enough time for speciation to occur. Greenland is a large island that is an obvious place for isolation, but the scientific community does not currently have evidence that this is where speciation occurred. Students should choose a time period from before 130,000 years ago because there are polar bear fossils that are that old. The oldest brown bear fossil students are presented with is 550,000 years old, so the claim above is a likely scenario for a split from a common ancestor. Using the evidence provided, students could also argue that polar bears evolved from brown bears.)

Evidence (what data supports your claim?)	Reasoning (connect each piece of evidence to your claim)
Evidence Options: Day 1 evidence: –Glacial ice always covers Greenland in the visualization. –There were repeated glacial and interglacial periods of warming and cooling. –Our data: Some bears might get trapped in Greenland or another island in the Arctic during interglacial periods where there would still be ice. Day 2 evidence: –They found 110,000 year old polar bear fossils in Alaska and Norway. –All of the brown bear fossils are found farther to the south than the polar bear fossils. –Brown bear fossils are both younger and older than polar bear fossils (3,900-550,000 years old). Day 3 evidence: –There are particular allele variations of 4 genes (LYST, apoB and ARID58, NOS3) that are only found in polar bears. LYST alternative makes white fur and apoB helps move fat out of the blood and ARID58 helps make fat cells, NOS3 helps them stay warm. –Polar bears are less genetically diverse than brown bears (Wang et al. 2022 quote). –Brown bears have very broad ranges (Wang et al. 2022 quote).	Common ancestor bears lived all over the Northern Hemisphere. During a glacial period, a group of ancestor bears lived in a place that became glaciated. They wandered all over the ice looking for food. Some had better inherited traits for catching food on the ice and survived and reproduced. They passed on those adaptive traits to their offspring, so they had them too. Others without adaptive traits died. When the glaciers retreated, those bears that stayed on the ice survived. The ones that stayed on the ice and adapted over thousands of generations became polar bears. Polar bear fossils are only found in areas that would have been glaciated and there were polar bears at least 130,000 years ago so polar bears must have split from a common ancestor before that. It takes thousands of years for speciation to occur, so I chose 426,000 and 380,000 years ago. Some of the common ancestor bears lived far enough south that they were not impacted by glaciers or migrated south as the cold climate approached and back north when it warmed up. They were already well adapted to the warmer climate and passed on those inherited traits to their offspring. Brown bears today are similar to the common ancestor bears. Bear fossils are found farther south than polar bear fossils, which supports this idea. Evidence supports reasoning because Greenland has always been covered in ice, even during interglacial periods. If a group of common ancestor bears were stranded there, they would be isolated from others in the same species and could not share genes with bears that lived on the mainland. In this case, the ones trapped on Greenland had alleles for white fur that helped them sneak up on seals so they could eat. They outcompeted bears that did not have that variation. Because seals are so fatty, the apoB variation got fat out of their blood so they did not have a heart attack and die. The ARID58 variation helped them make extra fat so they can stay warm. NOS3 variation helped them stay warm. Bears with those three variations survived longer in the cold Arctic climate and had more offspring than those that may have had heart attacks or froze. After many generations, a new kind of bear, the polar bear, evolved that had white fur, and the apoB and ARID58 altered function alleles, along with other adaptations. Polar bears are closely related to brown bears because the common ancestor was close to today's brown bears. Brown bears that stayed south of the glaciation did not have selection pressures to change and could carry a wider diversity of alleles that did not matter for survival.

	Foundational Pieces	Linked Understanding	Organized Understanding
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3D Elements	In this explanation, look for: Student claim describes a reason for speciation without naming a specific time period. Students name two evidence sources without linking them to their claim.	In this explanation, look for: Students' arguments link two out of 3 evidence sources (glacial and interglacial periods, fossils, genetic variations) to their claim.	In this explanation, look for: Student argument is based on indirect evidence from glacial and interglacial periods, fossil age, and genetic variations. It explains when and how polar bears evolved in the past from a common ancestor with brown bears when populations became isolated from one another during glacial and/or interglacial periods, allowing for bears living in cold, icy Arctic environments to adapt through the mechanism of evolution by natural selection. –Evidence of glacial and interglacial periods creating a changing environment for bear populations. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2) –Proposed separation of different populations of bears in different climates, one with Arctic ice and one without. (DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2) –Isolation of bears on ice, where natural selection favored traits with variations adapted to cold climates. (DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2) –Natural selection acted over many many generations (over glacial and interglacial periods) to cause speciation. (DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2) –Evidence for genetic traits that provided polar bears a competitive advantage in cold climates that spread through the population through the proliferation of individuals with favorable traits. (SEP: 7.4; DCI: LS4.C.1) –Evidence of fossil data that supports an argument for when and where speciation occurred. (SEP: 7.4; DCI: ESS2.E.1 & LS4.C.1; CCC: 3.2)
Example	Polar bears and brown bears split from a common ancestor because one	Polar bears and brown bears split from a common ancestor between	See example above in the reasoning column.

population of common ancestor bears got trapped in Greenland during an interglacial period and another population remained in Canada.

During a glacial period, a group of ancestor bears lived in a place that became glaciated. They wandered all over the ice looking for food. Some had better inherited traits for catching food on the ice and survived and reproduced. They passed on those adaptive traits to their offspring, so they had them too. Others without adaptive traits died. The ones that stayed on the ice and adapted became polar bears.

The bears on ice had alleles for white fur that helped them sneak up on seals so they could eat. They outcompeted bears that did not have that variation.

426,000 and 380,000 years ago because one population of common ancestor bears got trapped in Greenland during an interglacial period and another population remained in Canada.

Common ancestor bears lived all over the Northern Hemisphere. During a glacial period, a group of ancestor bears lived in a place that became glaciated. They wandered all over the ice looking for food. Some had better inherited traits for catching food on the ice and survived and reproduced. They passed on those adaptive traits to their offspring, so they had them too. Others without adaptive traits died. When the glaciers retreated those bears that stayed on the ice survived. The ones that stayed on the ice and adapted became polar bears.

The evidence supports reasoning because Greenland has always been covered in ice, even during interglacial periods. If a group of common ancestor bears were stranded there, they would be isolated from others in the same species and could not share genes with bears that lived on the mainland. In this case, the ones trapped on Greenland had alleles for white fur that helped them sneak up on seals so they could eat. They outcompeted bears that did not have that variation. Because seals are so fatty, the apoB variation got fat out of their blood so they did not have a heart attack and die. The ARID58 variation helped them make extra fat so they can stay warm. Bears with those two variations survived longer in the cold Arctic climate and had more offspring than those that may have had heart attacks or froze. After many generations, a new kind of bear, the polar bear, evolved that had white fur,

		and the apoB and ARID58 altered function alleles, along with other adaptations. Polar bears are closely related to brown bears because the common ancestor was close to today's brown bears. Brown bears that stayed south of the glaciation did not have selection pressures to change and could carry a wider diversity of alleles that did not matter for survival.	
Feedback/ What to Do	<i>Linking:</i> Ask students to use <i>Unknown material with identifier: bc.l4.ho3</i> along with fossil evidence from <i>Bear Fossils Map</i> to choose when speciation may have occurred. Ask students how fossil or genetic evidence supports or refutes their argument. Listen as students talk through <i>Connecting Evidence For Speciation</i> with the genetic variation chips. Ask them why bears would or would not survive during glacial or interglacial periods. Ask them about what happens to bear populations in two locations, such as Greenland and Canada. Ask if the adaptations developed all at once or over many generations. Ask students to revise their arguments after review.	<i>Organizing:</i> Ask students how fossil or genetic evidence supports or refutes their argument. Ask how genetic variations spread through a population over many generations. What are possible sources for new variations in a population as the environment changes? Ask students to revise their arguments after review.	<i>Extending:</i> Ask students to support or refute alternate explanations for other time periods, that polar bears evolved from brown bears, or those raised by other students based on evidence. Ask when/how anatomical and behavioral differences (like claws, jaws, hibernation) between brown and polar bears evolved.

Bear Gene Data Key

How might natural selection act on these genes in bears?

Gene Name	Allele Variations		Which form of each gene would likely be selected for in an Arctic environment? Provide reasoning.	Which form of each gene would likely be selected for in a warmer environment? Provide reasoning.
	Common Function	Altered Function		
LYST	Protein that increases melanin production and leads to darker fur.	Mutation leads to less melanin and lighter fur.	The altered form of the LYST gene would likely be selected for. White fur with less hair pigment may help camouflage bears in a snowy and icy environment.	The common form of the gene would likely be selected for. White fur may make bears more visible to potential prey and predators in warmer environments.
apob	Increases the movement of fat from the blood into the cells. Less fat in the blood leads to lower rates of heart disease.	Mutations lead to even more movement of fat out of blood and lower rates of heart disease.	The altered form of the apob gene would likely be selected for. The main source of food in the Arctic, seals, have lots of fat for the bears to digest.	The common form of the apob gene would likely be selected for. There are more non-fatty foods available in warmer environments.
ARID5B	Regulates genes that promote the growth of fat cells.	Mutations leading to increased expression of ARID5B have been shown to increase the production and growth of fat cells in mammals.	The altered form of the ARID5B gene would likely be selected for, as additional fat may help the bears stay warm in a cold environment.	The common form of the ARID5B gene would likely be selected for, as extra fat that is not necessary for warmth may restrict movement or lead to health problems.

References

Liu, S., Lorenzen, E. D., Fumagalli, M., Li, B., Harris, K., Xiong, Z., Zhou, L., Korneliussen, T. S., Somel, M., Babbitt, C., Wray, G., Li, J., He, W., Wang, Z., Fu, W., Xiang, X., Morgan, C. C., Doherty, A., O'Connell, M. J., Wang, J. (2014). Population genomics reveal recent speciation and rapid evolutionary adaptation in polar bears. *Cell*, 157(4).

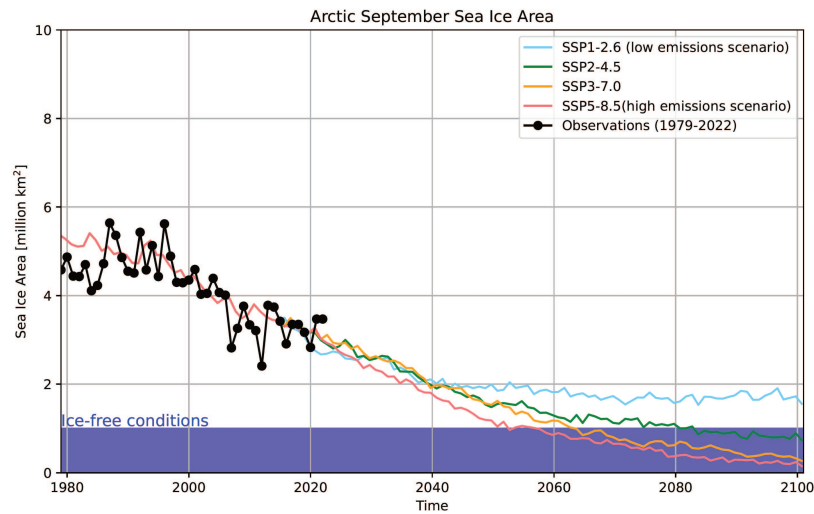
Lesson 6: Answer Key

L6 Electronic Exit Ticket Key

6.A Use a model to generate new **evidence** to support claims about the survival of polar bears in the changing Arctic. (SEP: 2.3; DCI: LS4.C.5; CCC: 2.2)

Where these elements are addressed in this assessment.	2.3 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.	LS4.C.5 Evolution Evidence Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost. (HS-LS4-5)	2.2 Cause and Effect Cause and effect relationships can be suggested and predicted for complex natural and human-designed systems by examining what is known about smaller-scale mechanisms within the system.
Q1	X	X	
Q2		X	X
Q3			
Q4	X		X
Q5	X		
Q6			X

Question 1



Richard Toohey

For which model projection are polar bears least likely to go extinct?

- SSP1-2.6 (low emissions scenario-light blue)
- SSP2-4.5 (green)
- SSP3-7.0 (yellow)
- SSP5-8.5 (high emissions scenario-red)

Correct response:

- SSP1-2.6 (low emissions scenario-light blue)

Rationale for correct response:

- SSP1-2.6 is the only scenario where some sea ice remains through 2100. This would provide polar bear habitat into the future so they would not go extinct.

What to do:

Ask students to focus on the lines, not the shaded colors on the graph. Ask them to point out where the Arctic is considered ice-free on the graph.

Question 2

Which combination of traits from **allele variations** do you predict will provide the **greatest benefit to the long-term survival** of **hybrid bear populations in the face of rapid changes to the Arctic climate**?

- Darker fur and overheating easily
- Increased fat cells and overheating easily
- **Decreased fat cells and not overheating easily**
- Darker fur and more heart disease

Correct response:

- Decreased fat cells and not overheating easily

Rationale:

Because the climate is expected to warm, it is important that bears not overheat. Reducing fat and inheriting the NOS3 allele variant that does not cause overheating will allow the bears to be more active so they can hunt, migrate, and do other activities in a warmer climate. Small-scale changes to genes within the whole population will help the hybrid bear population survive.

What to do:

Refer back to evidence from their Hybridization Model to choose which answer choice best fits the consensus understanding of the lesson.

Question 3

Describe a time in your own life when you experienced a change in environmental conditions where you saw a decline and how it impacted you.

What to look for in response:

Accept all responses. Validating these responses engages students in activating their **relevance** and **interest** in these issues, which can motivate future questions.

What to do:

Have students think about how the evidence of changing seasons has changed over time. Are the leaves changing color at different times? Has there been less rainfall or less sun than is usual? Has there been little to no ice when there used to be more snow?

Question 4

If polar bears go extinct **because all the sea ice disappears**, how do you **predict that will affect the rest of the Arctic ecosystem**?

Correct response: *Accept all logical responses.* Students should predict increases to the size of some populations and/or decreases to others.

Rationale: The model predicts that sea ice will disappear, which could possibly cause extinction of the polar bear. Polar bears hunt seals, so seal populations would likely increase without polar bears. Humans that hunt polar bears may lack food or clothing.

What to do: Have students think about what polar bears eat and how fewer polar bears would impact those animals.

Question 5

How did **using models** during the lesson help you predict the evolution of the polar bear?

What to look for in response: *Note: These could be different for each student.*

If students never thought of hybridization as an option, evidence from the Hybridization Model showed that it was plausible as a mode of evolution for polar bears instead of extinction being their fate. The models of how quickly Arctic ice could disappear also helped predict how soon polar bears could be faced with extinction.

What to do:

Review their notes and evidence from the investigation to decide on the role of hybridization in the evolution of the polar bear. Ask them how they used the models in question 1.

Question 6

How did thinking about **cause and effect** help you explain the lesson question: *What will happen to bear species in the Arctic in the future?*

What to look for in response: *Note: These could be different for each student.*

- The hybridization model provided a new cause for changes in polar bear populations that could cause them to evolve over time and develop new adaptations that might have the effect of preventing extinction.
- The models of how quickly sea ice could disappear put a timeline on the effect of climate change. They have an idea of how fast changes could occur.

What to do:

Have students reflect on the effect of looking at the different options for changing sea ice. Have students reflect on learning the mechanism of hybridization.

Question 7

Did you share any ideas out loud today to the whole class, a small group, or a partner? If you answered yes, did any of your ideas influence the class or help others?

What to look for in response:

- Student answers may vary.

What to do:

Have students reflect on their contributions in class and how they added to the classroom culture.

Lesson 6: Answer Key 1

Future Predictions Key

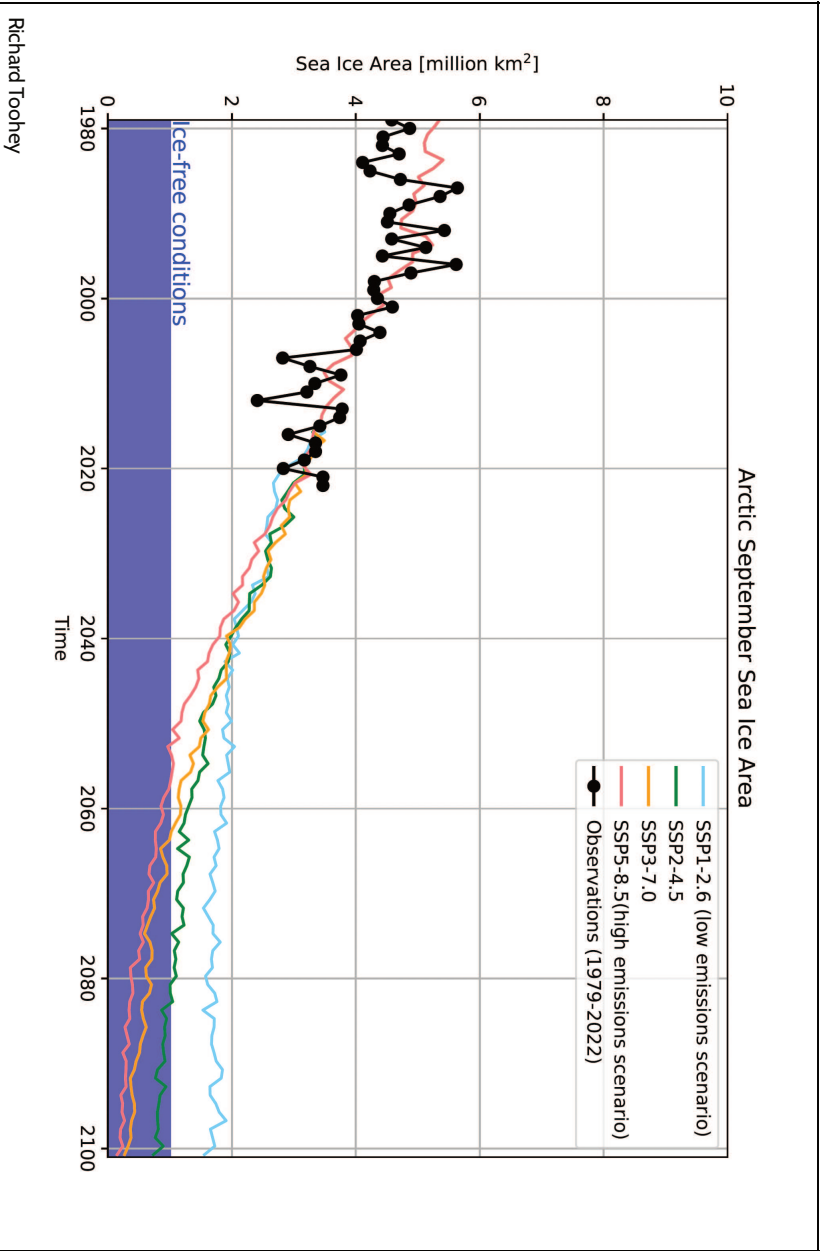


Figure 1. The black line represents the actual observations of the sea ice area each September (representing the minimum amount of ice) since 1980. Each of the other lines are projects using a model of what could happen to ice under different climate scenarios. The blue line represents a model with the lowest level of greenhouse gas emission, and the red line represents the highest level of greenhouse gas emission. The shading represents variability in the predictions.

Data source: Richard Toohey via Polar Bears International

1. What does Figure 1 above predict about the changing ice?

It predicts that in all but the low emissions scenario, the Arctic will be ice-free in September by about 2080.

In Lesson 4, we saw that the Earth went through cycles of glacial and interglacial periods over 700,000 years. We predicted that polar bears evolved from a common ancestor that they shared with brown bears during one of the interglacial periods in the past. Scientists do not believe the Arctic was ever ice-free in that 700,000 time period. The graph above measures and predicts the ice in September, which represents the end of summer, when the ice is at its minimum. Review the data in Table 1 and answer the questions below.

Table 1. Comparison of conditions for bear evolution past and present/future.

	Past	Present/Future
Selection pressure	Bears isolated on islands of ice during interglacial periods.	Warming temperature and melting ice.
Time (years for evolution to take place)	Common ancestor bears were isolated in an interglacial period between 45,000 and 75,000 years long.	26-56* years until polar bears live in an Arctic that is sea-ice-free. *This estimate is based on the time between 2024 and 2050 (26 years) and 2024 and 2080 (56 years)
Genetic variation in population	Yes, the common ancestor was estimated to have genetic variation.	Currently, polar bears have low genetic variation.
Estimated number of generations (11.35)	3,965-6,608 generations	2.2-4.9 generations

2. Based on scientists' predictions of future ice conditions in the Arctic, how likely is it that polar bears will be able to evolve and adapt to their changing environment? Please explain.

It is unlikely that polar bears will adapt via natural selection because they have low genetic diversity and the change is happening really fast. Even under the most conservative conditions, they only have about 5 generations to adapt, and that is not a lot based on what we saw in the past.

Lesson 6: Answer Key 2

Making Sense of Matings

1. Why might polar and brown bears interact on Banks and Victoria Islands? What might be going on with the ice?

They are islands near Canada that probably have seasonal ice where polar bears and brown bears will come into contact. It is also where the Inuvialuit (In-oo-vee-A-loo-weet) have seen polar and brown bears mating.

2. In the pedigree, we saw female polar bears mating with male brown bears and male hybrid bears. Consider the following interaction data. How does this interaction data help explain why female polar bears might mate with male brown bears and not the other way around?

Table 2. Kinds of interactions between polar bears and between polar and brown bears.

Polar Bear Class	Polar Bear-Polar Bear		Polar Bear-Brown Bear	
	Aggressive (n)	Submissive (n)	Aggressive (n)	Submissive (n)
Lone adult male	19	76	1	61
Lone adult female	10	17	0	9
Female with cubs	41	19	4	15
Sub adult	6	26	0	8

Female polar bears were more aggressive with male brown bears and less likely to be scared away.

3. If brown bears and polar bears were to mate and produce offspring more frequently, how well adapted for the environment do you think the hybrids would be? Explain.

Hybrid bears might be more fit because they would have traits from both bears. They might have some more variation from the brown bears that would make the bears better at dealing with changing conditions and eating different foods.

Lesson 6: Answer Key 3

Hybridization Model Key

Note: student answers will vary based on coin flip.

Mating 1	Brown Bear Allele Variations: For each mating, circle one for each offspring.		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Slightly darker fur.	Explain.
apoB	Less heart disease.	More heart disease.	Less heart disease.	A bit more heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Increased fat cells.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Overheats easily.	
Mating 2	Brown Bear Allele Variations		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Slightly darker fur.	Explain.
apoB	Less heart disease.	More heart disease.	Less heart disease.	Less heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Increased fat cells.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Overheats easily.	

Mating 3	Brown Bear Allele Variations:		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Slightly darker fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	Less heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Fewer fat cells.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Overheats easily.	
Mating 4	Brown Bear Allele Variations		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Lighter fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	Less heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Increased fat cells.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Overheats easily.	

Mating 5	Brown Bear Allele Variations:		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Lighter fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	Less heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Fewer fat cells.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Overheats less easily.	
Mating 6	Brown Bear Allele Variations		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Lighter fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	More heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Less fat.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Does not overheat.	

Mating 7	Brown Bear Allele Variations:		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Lighter fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	More heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Less fat.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Does not overheat easily.	
Mating 8	Brown Bear Allele Variations		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Darker fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	Less heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Increased fat.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Does not overheat easily.	

Mating 9	Brown Bear Allele Variations:		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Darker fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	Less heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	Less fat.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Does not overheat easily.	
Mating 10	Brown Bear Allele Variations		Polar Bear Allele Variations	Hybrid Offspring Traits	Adapted to warming Arctic?
Trait	Heads	Tails			Circle one: Yes No Explain.
LYST	More melanin and darker fur.	Less melanin and lighter fur.	Less melanin and lighter fur.	Darker fur.	
apoB	Less heart disease.	More heart disease.	Less heart disease.	More heart disease.	
ARID5B	Typical fat cells.	Increased fat cells.	Increased fat cells.	More fat.	
NOS3	Overheats easily.	Does not overheat easily.	Overheats easily.	Overheats easily.	

Key Extinctions Graphic Organizer

Part A. Mass Extinction Data

- Use the table below to organize the information at each station to find a pattern of evidence that explains the main cause of mass extinctions.

Extinction Event	Cause	Effects (on biosphere and other Earth systems)
Ordovician 444 MYA	Glacial period triggered by eroding mountains, which removed large amounts of CO ₂ from the atmosphere.	Reduced oxygen in ocean. Extreme cold. 86% of species died (trilobites, coral, etc.).
Devonian 359 MYA	Evolution of land plants. Used up carbon dioxide in the atmosphere.	Climate cooled. Dead plants ran into oceans and decomposed, causing algae blooms. Oxygen left ocean, killing ocean life 75% of species died (armored fish, coral).
Permian 252 MYA	Volcano in Siberia released huge amount of CO ₂ and sulfur dioxide.	Acid rain, ocean acidification. Global warming. 96% of species died (insects, coral, amphibians).
Triassic 201 MYA	Underwater volcano. CO ₂ levels rose.	Global warming, sea-level rise. Ocean acidification. Marine life died from change in ocean chemistry. 80% of species lost (reptile, coral, amphibians).
Cretaceous 66 MYA	Asteroid fell to Earth.	Blackened sky, blocked Sun. Rapid cooling. Ocean acidification. 76% of species died (dinosaurs, plants, mammals).

Part B. Put the Pieces Together

- What patterns did you notice in the evidence across the extinctions in terms of causes and effects?
 - In each event, something happened that caused rapid heating or cooling of the atmosphere. In 4 of 5 cases, changes to carbon dioxide levels from volcanic activity, photosynthesis, or erosion were responsible for the change in temperature.
 - Each cause (volcanic activity, photosynthesis, asteroid, or erosion) also changed the chemistry of the ocean, which killed marine life.
 - At least 75% of species died in each mass extinction, a huge drop in biodiversity.

Part C: Construct an Initial Argument (Day 1)

- Construct an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth. Sample argument:

Mass extinction events in the past have been caused by rapid changes to Earth's climate. In each of the 5 events, a major event occurred that altered Earth's systems (see examples in question 1) and resulted in the death of over 75% of species. Plants may have died when it got too cold or too hot, which could cause the

food web to collapse.

Note: Initial claims will not necessarily include biodiversity. Alternate student claims may focus on patterns related to changes in ocean chemistry. Additional examples of student reasoning could include: Chemicals from volcanic eruptions are poisonous and kill living things; Without oxygen in the ocean, no cellular respiration happens and many species die; Plants die if there is no sunlight hitting the Earth; changes to ocean chemistry could poison ocean life.

3. What additional information do you need to support your claim?

Answers will vary. Options include:

- Which species/families survived after the extinction?
- How do they know these events occurred?
- How long did the cooling/warming last?
- Which specific species died?

Part D: Revise Your Initial Argument (Day 2)

4. Revise your argument, including new evidence and ideas. Construct an argument using a pattern of evidence that explains the main cause of mass extinctions on Earth **and its effect on biodiversity**.

Mass extinction events in the past have been caused by rapid changes to Earth's climate. In each of the 5 events, a major event occurred that altered Earth's systems (see examples in question 1) and resulted in the death of over 75% of species. Plants may have died when it got too cold or too hot, which could cause the food web to collapse. This mass extinction caused a decrease in biodiversity at first, but then biodiversity increased over time due to natural selection and speciation.

We saw this pattern of biodiversity repeatedly on the marine biodiversity graph.

Note: Revised claim includes biodiversity.

UDL for Case Studies

Engagement	Representation	Action & Expression
Purposeful & Motivated	Resourceful & Knowledgeable	Strategic & Goal-Directed
Recruit interest: Allow students to choose readings. Sustaining effort: Students will work in groups, and all participants are treated as experts.	Perception: Electronic format supports screen reading; images support background knowledge. Language & Symbols: We pay attention to structure and text features. Comprehension: Students access key information relevant to the big question.	Physical action: Using computers optimizes access to translation/screen readers. Expression & Communication: The lesson encourages use of text features. Executive Function: Students have a distinct goal/purpose for reading and use handouts to organize ideas.

Here are some text structures and design features that benefit **all readers** in this lesson and can be applied to other texts your students may encounter:

1. **Images & graphics:** There is a reason “a picture is worth a thousand words.” Images help readers engage with the text on a sensory level before the reading activity begins. An image that is closely related to the text’s main content can activate sensemaking that includes students’ previous experiences, cultural funds of knowledge, and their curiosity.
2. **Titles, subtitles, and other section names:** Titles highlight the purpose of the text and “set the stage” for students to make conceptual connections to the text. Students can use their background knowledge and cultural funds of knowledge to connect with the reading right away. All of the Lesson 8 Case Studies contain the following sections: Background Information; Population Data; Interest Holders; Ongoing Concerns. Some students may benefit from a whole-class or small-group preview of content that they may expect to find in each section.

The Google versions of these articles are accessible to screen-reading technology and online translator services. Some articles have additional features that may help when differentiating readings for students:

Case Study	Text Features	Differentiation Guidance
Manatee	• Images • Line Graph	<i>Manatee Case Study</i> may be most accessible due to previous exposure in <i>Serengeti Unit</i> . The reading level and easy-to-interpret graph may further support students’ comprehension.
Saguaro	• Images • Line graph • Bar graph	<i>Saguaro Case Study</i> may be most accessible due to previous exposure in <i>Serengeti Unit</i> . The reading level and easy-to-interpret graphs may further support students’ comprehension.
African Wild Dog	• Images • Map	<i>African Wild Dogs Case Study</i> may be most accessible due to previous exposure in <i>Serengeti Unit</i> . The reading level and easy-to-interpret map may further support students’ comprehension.

Coral Reef	• Images • Bar graph with additional text and some complexity • Some challenging vocabulary	<i>Coral Reefs Case Study</i> may be a new topic for some students. While the vocabulary and graphs are more challenging, the companion videos <i>Unknown material with identifier: op.bc.vid18.100</i> and <i>Unknown material with identifier: op.bc.vid18.101</i> may provide additional support, interest, and motivation for some students.
Axolotl	• Images • Line graph	<i>Axolotl Case Study</i> may appeal to some students due to their prevalence in pop culture. https://youtu.be/KLqdn6J10o?si=i9wJuf9o5LIODAZC is a companion video in Spanish that may provide additional comprehension support, interest, and motivation for some students.
Seed Bank	• Images	<i>Seed Bank Case Study</i> is the only case study without additional visual data representation, which may be appealing or challenging, depending on the student.
Condor	• Images • Map • Pie chart • Line graphs	<i>California Condor Case Study</i> may be a new topic for some students. This case study contains multiple options to interpret data visually and numerically.
Bison	• Images • Map • Timelines with additional text and complexity	<i>American Bison Case Study</i> was introduced in <i>Serengeti Unit</i> , and students may be interested in learning more. The vocabulary, relatively longer length, and timelines may offer a challenge. The companion video https://youtu.be/echiaRuan2E may provide additional comprehension support, interest, and motivation for some students.

References

Universal Design for Learning Guidelines. (2018) Retrieved December 14, 2022, from <https://udlguidelines.cast.org/>

Lesson 8: Answer Key 1

Extinction Prevention Argument Key

Choose at least 2 of the solutions from the extinction prevention case studies that you think would be most useful in preventing the extinction of the polar bear. Fill in the table below with the solutions you chose and your evaluation of why they would work for the polar bear. Include evidence to support your argument.

These are sample responses only. There are many possible solutions students may choose and numerous arguments they could make for or against intervention. Look for students to refer to evidence from the case studies and past lessons to support their arguments. Accept any well reasoned argument students make.

	Choice 1	Choice 2	Choice 3 (optional)
Solution and case study What approach would you use? Which case study introduced it?	Manatee: Pass laws to protect habitat and control human behavior.	Coral reef: Save sperm and eggs and freeze them to create more individuals later.	
Evaluation Why would this solution work for the polar bear? What evidence supports this claim?	We could pass laws to cut down on greenhouse gasses to protect polar bear habitat. This is good for the polar bear because it is the only way to protect the loss of habitat. We have evidence that there is warming in the Arctic and that ice is melting faster than it ever has, and we know there cannot be enough generations of polar bears to evolve to warmer temperatures in that time. Polar bears have a gene that makes them overheat. If we do not cool temperatures by reducing greenhouse gasses, they will go extinct.	We learned in Lesson 4 that polar bears do not have high genetic diversity. If we can harvest sperm and eggs from polar bears, we can protect the diversity we do have and help polar bears reproduce in the future. We may be able to screen for genes that do better in this warmer climate and create babies with better adaptations. The coral reef project in x location was able to breed coral and increase its resistance to warming, therefore reducing bleaching.	

Above you evaluated solutions that could prevent the extinction of the polar bear. Based on constraints and/or ethical considerations, do you think people should put the solution you argued for above in place? Explain your thinking.

We should intervene because governments are already passing laws to reduce greenhouse gas emissions, and people care about the polar bear so they would be willing to make sacrifices to use cars less and burn less fuel so we can save the species. I think if we collect sperm and eggs and screen them for genetic variations that are adaptive, we will be able to breed polar bears that can survive. We caused this crisis, and it is our obligation to protect species from extinction.

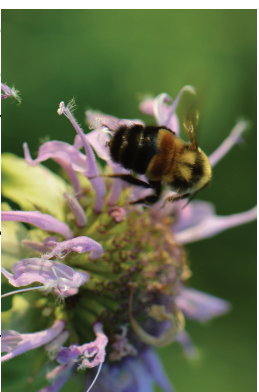
We should not intervene because it is unrealistic to think that we can halt climate change. Greenhouse gas emissions are going up, the climate is warming, and ice is melting. Governments have not been able to halt enough emissions to stop temperatures from rising so far. We cannot save the polar bears' habitat. If a small population can survive on permanent ice, that is great, but we should not interfere with natural processes. Polar bears have lived through fluctuations in climate in the past, and maybe they will breed with brown bears again and survive this crisis on their own. It is also too difficult and too expensive to capture enough polar bears and collect their sperm and eggs. I also do not want to harm them by doing so. I think humans already interfered too much, and we should leave them alone.

Bumble bee Transfer Task Key

7A. Evaluate claims and evidence about the survival of bumble bee species on a global scale. (SEP: 7.2; DCI: LS4.C.5; CCC: 3.1)

3D Elements Addressed in this Assessment						
SEPs	7.2 Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.					
DCIs	LS.4.C.5 Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to the change that is too fast or drastic, the opportunity for the species' evolution is lost.	X	X	X	X	X
CCCs	3.1 The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	X	X	X	X	X

When most people think of bees, they think about the European honey bee (*Apis mellifera*), brought to the US about 400 years ago. While European honey bees pollinate up to a third of the food we eat, bumble bees are also very important pollinators. The common Eastern bumble bee (*Bombus impatiens*) is often raised in managed hives for commercial use to pollinate crops in fields. Many of the bumble bee hives are kept in greenhouses to pollinate crops like tomatoes and peppers.

 Andreas Trepte, CC BY-SA 2.5	 Judy Gallagher, CC BY 2.0	 USFWS Midwest Region from United States, CC BY 2.0
Honey bee (<i>Apis mellifera</i>)	Eastern bumble bee (<i>Bombus impatiens</i>)	Rusty patched bumble bee (<i>Bombus affinis</i>)

Wild bumble bees, however, are also extremely important pollinators of both native plants and crops grown for human use, especially food. In recent years, scientists have become concerned about the status of wild bumble bee populations. The rusty patched bumble bee, for example, was placed on the endangered species list in 2017.

In this task, you will

1. Evaluate evidence related to factors that might affect the survival of bumble bees around the world.
2. Use that evidence to evaluate claims about ways to ensure wild bumble bee survival.

1. **Historical Range** To understand how rusty patched bumble bee populations have changed over time, scientists identified the bumble bees' geographic historical range and divided it into a grid. They counted how many squares from the original grid were occupied by bumble bees over time.

Time Period	Number of Grids Occupied
Pre-1950s	337
1950s	137
1960s	209
1970s	171
1980s	146
1990s	98

Data source: Szymanski, et al. 2016

a) Scientists claim that the range of the rusty patched bumble bee is getting smaller. Describe how the data above supports or refutes this claim.

The percentage of range that they occurred in has decreased from 38% to 11%. There were some ups and downs over time, but the data supports the claim.

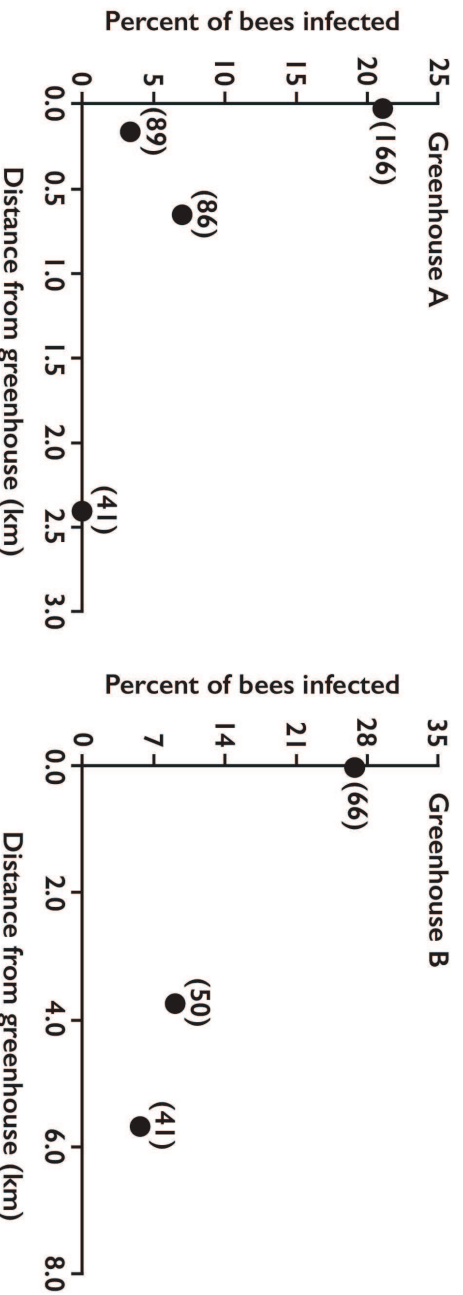
b) Why would this data about the number of grids occupied be of interest to scientists? They might want to know if they are in the same places as they used to be and if not, to find out why.

Much of the bumble bee habitat in the United States was tall grass prairie in the midwest that has been converted to farmland. Although scientists have been monitoring habitat loss, they do not think that this is the major cause of the decline in occupancy that they have observed. They identified a number of other factors that they believe affect the native bumble bee populations. Questions 2-4 include evidence about each of these factors.

2. **Pathogens** (e.g. viruses, fungi, and bacteria) can make bees sick and weak, sometimes even killing them. One particular pathogen, a fungus called *Critidia bombi*, is known to be a cause of bee population declines in Europe. This fungus has recently been found in Canada as well. Canadian researchers claim that the pathogen spreads from commercial bumble bees (*Bombus impatiens*) that escape from greenhouses into wild populations, like *Bombus rufocinctus* and *Bombus bimaculatus*.

The graph below shows the relationship between wild bumble bee species infection rates with *Critidia bombi* and the distance they live from two greenhouses (A and B) where bumble bees are commercially raised. Filled circles represent sites bees were collected, with the number of bees in parentheses.

Wild Bumble Bee Infection Rates vs. Distance from Greenhouse



Data Source: Otterstatter & Thomson (2008)

a) Why might the pathogen spread so easily between the bumble bee species in the greenhouses and the wild bumble bees?

They are probably closely related and have similar genes.

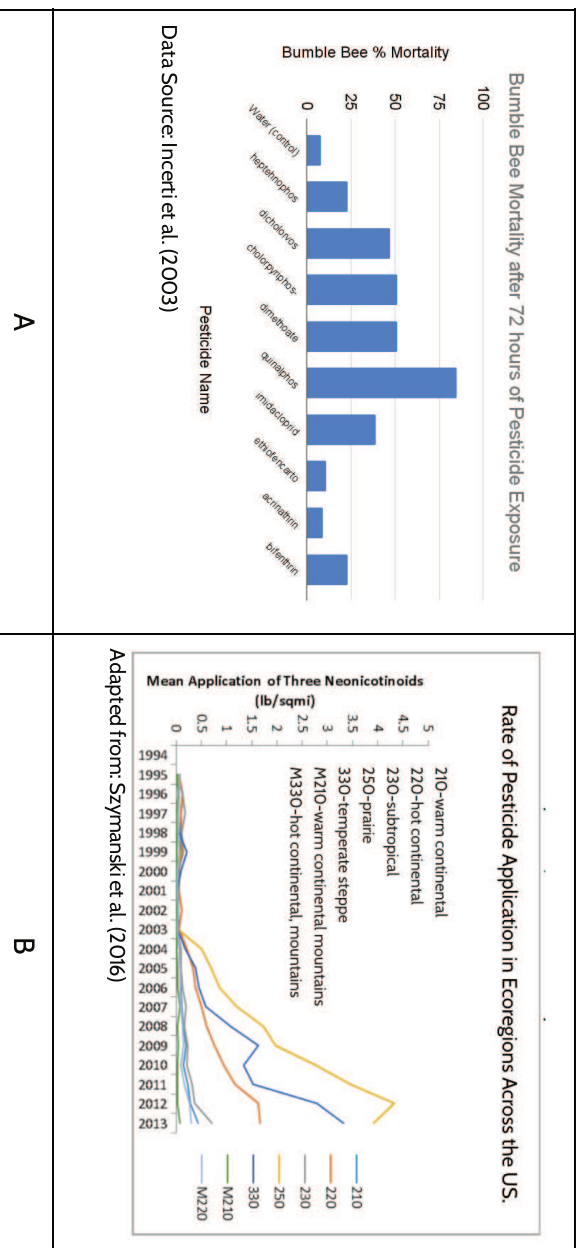
b) Describe the relationship between the level of infection in a wild bumble bee population and the population's distance from greenhouses with commercial hives.

When there is no distance (0) between the wild bees and the bees in greenhouses, the infection rate is high (.20-.27) The infection rate falls quickly as you move away from the greenhouse (under .10 when at least 0.2 km away).

c) Given that there are millions of commercial hives in North America, what might this claim mean for wild bumble bees?

At that scale of commercial bee use, there will likely be commercial bee colonies near almost every population of wild bees. This could cause the wild bees to become infected with pathogens and possibly become extinct, unless they have genetic variations that allow them to survive the infection and the population can adapt.

3. **Pesticides** are chemicals used widely in agriculture and at homes and businesses to kill unwanted insects and plants. Bees are exposed to these chemicals when they come into direct contact with them or eat a plant that has been sprayed with these chemicals. Scientists wondered if these chemicals affect the bees and conducted a lab study to figure this out. They sprayed cucumber plants with pesticides, allowed the bees to access the plants, and monitored the bees for 3 days. Graph A below shows the mortality rates (% that died) of bees after 3 days for each pesticide tested. Graph B shows how much of each chemical has been sprayed over time.



a.) What does graph A tell you about pesticides and bee mortality?
The mortality rate is really variable. Some cause high mortality, some as low as water.

b.) What does graph B tell you about the scale and/or significance of pesticide use?
The kinds of chemicals measured in the graph have been used a lot more over time, in some regions. And they have gone up a lot since 2003.

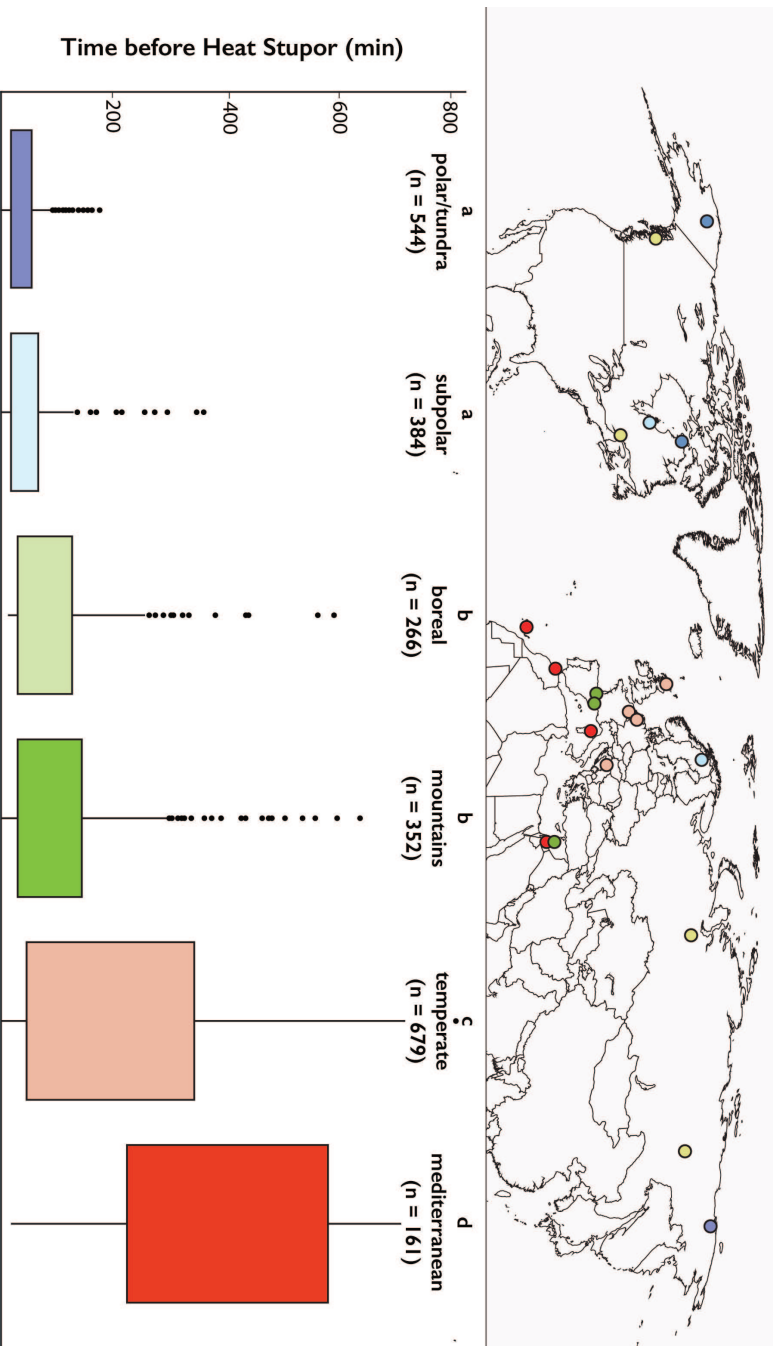
c.) Some scientists claim that bee mortality has increased as pesticide use has increased because bees did not have time to adapt. Based on the evidence provided,
i. What possible reasoning would scientists use to explain this claim?

ii. What additional evidence would strengthen the claim?

	Foundational Pieces	Linked Understanding	Organized Understanding
3D Elements	In this explanation, look for: Students provide evidence and reasoning that explains drastic increases in pesticide use as a significant change that causes bee deaths. Students propose the need for more data about bee mortality in more locations.	In this explanation, look for: Students provide specific evidence from one graph and reasoning that explains drastic increases in pesticide use as a significant change that causes bee deaths at a faster rate than favorable genetic traits can spread through bee populations through natural selection. Students propose the need for additional genetic evidence of immunity in the bee population.	In this explanation, look for: Students provide specific evidence from both graphs and reasoning that explains drastic increases in pesticide use as a significant change that causes bee deaths at a faster rate than favorable genetic traits can spread through bee populations through natural selection. Students propose the need for additional genetic evidence of changes to immunity in the bee population over time.

Example	The pesticide use went up really quickly after 2003 from 0 to 4 lb/sqm. The pesticide that went up the most is also the most fatal to bees. Bees could not develop any defense to the pesticide. We should find out if bees died from pesticides in more locations, not just one.	The pesticide use went up really quickly after 2003 from 0 to 4 lb/sqm. Even if there are some genes that create immunity to pesticide somewhere in the community, so many bees were killed so quickly that there were not enough generations for immunity to evolve and spread throughout the whole population. Most bees would have died, so very few of them would have been left (with not a lot of genetic diversity) to reproduce. If we looked at genetic information about bees and knew whether they had genes for immunity, that would strengthen the claim.	The pesticide use went up really quickly after 2003 from 0 to 4 lb/sqm. The pesticide that went up the most is also the most fatal to bees, causing over 80% of them to die. Even if there are some genes that create immunity to pesticide somewhere in the community, so many bees were killed so quickly that there were not enough generations for immunity to evolve and spread throughout the whole population. Most bees would have died, so very few of them would have been left (with not a lot of genetic diversity) to reproduce. If we compared genetic information about bees that lived and died each year and knew whether there were changes in genes for immunity, that would strengthen the claim.
Feedback /What to Do	<i>Linking:</i> Remind students about the bees in the Electronic Exit Ticket in Lesson 3, where they saw that some bees had genes for immunity. If genes for immunity exist, what reasoning could support the claim? Allow students to rewrite their responses.	<i>Organizing:</i> Ask students to connect the information provided on the two graphs. Why do we need to know the mortality rate/rate of pesticide application? Ask: How would we track changes to the genetics of the bees over time? Allow students to rewrite their response.	<i>Extending:</i> Ask students to determine how many generations would occur in the time frame, assuming one generation/year. How does that compare to what happened with the number of generations it took polar bears to evolve?

4. Some scientists are concerned about the effect **climate change** could have on bumble bees as Earth's temperature increases. They studied how long it took bees of 39 species to go into heat stupor (stunned into inactivity) when exposed to heat wave temperatures of 40 degrees C/104 degrees F. They found that different bees in different locations around the world have different tolerances for heat. Review the data below.



Date Source: Martinet et al. (2020)

a.) Summarize the data in the graph.

Bees that live in different regions of the world have different tolerances for heat. Bees in the Arctic overheat very quickly; bees in the Mediterranean take longer to overheat.

b.) Some scientists claim that bumble bees currently living in the polar/tundra regions will go extinct. Based on the evidence provided and what you know about climate change in the Arctic, which reasoning is the most logical?

1. The populations of bumble bees in the polar/tundra regions are smaller than in other locations.
2. The climate is warming too quickly and polar/tundra bees will not have time to adapt.
3. The bumble bee populations with the greatest genetic variation have the greatest heat tolerance.
5. Based on the studies like the ones described in this task, scientists have some ideas about what factors affect the rusty patched bumble bee and how the species might be protected from extinction. A group of scientists claimed the following solutions could save the rusty patched bumble bee.

Using the evidence you investigated throughout this task and what you have figured out in the unit, evaluate each claim by doing the following:

- a.) identify evidence that supports or refutes the claim.
- b.) explain why the evidence does or does not support the claim in the table below..

Environmental factors	Climate change	Pathogens	Pesticides
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Claim	To increase the ability to sustain populations into the future, it is necessary to: maintain genetic diversity in bumble bee populations from different regions of the world.	To increase the ability to sustain populations into the future, it is necessary to: reduce the number of managed colonies of honey bees for pollination.	To increase the ability to sustain populations into the future, it is necessary to: eliminate the use of pesticides in agriculture.
Is this claim supported by the evidence? Why or why not?	No, there are bees in Europe that have higher heat tolerance than bees in North America, but we do not know anything about their genes or if heat tolerance is a genetic trait in bumble bees.	Yes, when bumble bees are close to managed honey bees, they get infected with pathogens, so if there were fewer honey bees, there would be less disease to infect the bumble bees and there would be less bumble bee death/more bumble bees.	Yes, depending on the specific pesticide. Some pesticides cause high mortality in bumble bees. If fewer pesticides were used the bee mortality from pesticides would decrease and there would be more bees. (Note: Students could also say no because not all pesticides are associated with high mortality.)

6) Explain what you think could happen to rusty patched bumble bees if none of the recommendations are followed. Be sure to include scientific reasoning for your explanation.

The rusty patched bumble bee would be in danger of extinction because their populations would be very small if many of them were killed by pesticides AND disease introduced by commercial bees AND the global temperature increases and the bees that are left overheat and cannot survive to reproduce.

7) Describe how significant this declining bee phenomenon is, given the important role bumble bees play as pollinators of the food humans eat.

This is very significant because there are wild bees all over the world that could be threatened by these environmental factors, which could be a problem for our global food supply. Pesticide use and temperatures are rising rapidly, and bees may not have time to adapt to changes in their environment without going extinct.

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Lesson 9: Answer Key 2

Progress Tracker Key

Unit Driving Question(s)				
What will happen to Arctic bear populations as their environment changes?				
	What we figured out (WWFO)	How does WWFO help us make progress on figuring out the future of Arctic bear populations?	How does WWFO connect to me or my community or have a larger-scale impact?	What questions do I have now?
Lesson 1: How do changes in climate affect bear species coming together for the first time in the Arctic?	-The coverage and duration of Arctic sea ice is changing, leading to less sea ice habitat for polar bears in areas with seasonally available ice. Polar bears are adapted to the Arctic ecosystem and rely on Arctic sea ice. -Based on their adaptations, the polar bears are most at risk for population decline as the environment changes. Based on their adaptations, brown bears may expand their range as the Arctic warms. -Polar and brown bears are likely to interact more as the environment changes.	See previous.	People in my community have noticed changes in the environment over time due to climate change (droughts, storms, more ticks, plants not flowering, different garden vegetables growing better or worse, invasive species, heat waves).	See DQB
Lesson 2: How and why are bears interacting?	-Brown and polar bears will continue to interact as the Arctic warms in places where there is seasonal ice. -Brown bears may dominate because the polar bear overheats and runs away from brown bears around food.	-If the brown bears scare the polar bears away from food and the ice stays away for longer, the polar bears may not have enough to eat while they wait for the ice, and the population may decline.	We also behaviorally change if our body temperature is too high or too low.	-How did the bears get this NOS3 gene variant? -Why do brown and black bears not have this variant? -What other genes do bears have in common/different?

Lesson 3: How similar/different are the polar, brown, and black bears? (between days 1 and 2)	-Brown and black bears have some behaviors like hibernating in common and have the NOS3 gene it common -Black and polar bears both run from brown bears	-If brown and black bears are more similar, maybe they will do better in the changing Arctic and polar bears will not do as well.	-Species that have things in common might be hurt by the same kind of things (pollution) and helped by the same kinds of things (clean water).	-What does it mean that the polar bears are related? -Which bears are more closely related?
Lesson 4: How did polar and brown bears become different species?	-Cycles of glaciation created selection pressures on the common ancestor bears. Bears with genetic variations that helped them survive in Arctic environments survived to reproduce. -Some bears were isolated in the Arctic for thousands of generations and evolved into polar bears.	-Polar bears are genetically, behaviorally, and anatomically well adapted to live in Arctic conditions. -Bears have been through cycles of glaciation before. Maybe they still have the ability to survive changes in temperature.	-I wonder if other species have evolved to be adapted to the climate where I live. If the climate changes to be (drier, wetter, hotter), will they adapt?	-Does what we know about how bear speciation occurred in the past allow us to make better predictions about what will happen in their future?
Lesson 5: What will happen to Arctic bear populations as their environment changes?	See Gotta-Have-It checklist in TG.	See revised model in TG.	What might happen to other species that live near me as the environment changes?	-How quickly is the Arctic climate warming now compared to other interglacial periods? -How long will the ice last? -Will polar bears be able to evolve through natural selection to adapt to the warming conditions? -Will polar bears keep interacting with the brown bears? -Will polar bears go extinct? -What will happen to the black bears going forward?
Lesson 6: What will happen to bear species in the Arctic in the future?	-There is not enough time for polar bears to evolve to adapt to human-caused climate change. -Polar bears and brown bears sometimes hybridize	-Some polar bears could hybridize with brown bears to survive climate change, but many will not be able to and some may hybridize but not get the genes they need to survive.	I wonder if other animals and plants where I live can hybridize? It might help them survive the drought we are having.	If polar bears cannot evolve fast enough to adapt to climate change, will they go extinct?

Lesson 7: How do past patterns of extinction help us understand possible consequences of extinctions now and in the future?	Mass extinctions have happened in the past when massive climate change events occurred. Current climate change from human activities could cause the same to happen.	Polar bears could go extinct, which could affect the resilience of the Arctic ecosystem.	Many other species around the world could go extinct with human-caused climate change as well as other ways humans harm the environment, like pollution or fragmentation and habitat loss. Humans could also go extinct, and then life in the future may evolve to look completely different.	-Are we headed for another mass extinction? -Should we try to protect the polar bear and other key species from extinction? -How can we prevent the extinction of the polar bear and other species?
Lesson 8: What are our options for protecting species from extinction and should we implement them?	There are many ways to protect species from extinction, including putting animals in zoos and breeding them, freezing sperm and eggs to save for later, and reducing greenhouse gas emissions. But many of these can be expensive and require a lot of technology and are not guaranteed to protect genetic diversity over many generations.	Polar bears could be saved from extinction by saving the sperm and eggs of many bears and then keeping bears in captivity. We could breed them with diverse sperm and eggs to protect the species long enough until we can cool the planet enough that they can survive again in the Arctic.	I'm worried about climate change killing the bears. Ethically I think we have an obligation to protect animals from extinction and should do whatever we can to save them.	Is anyone actually going to implement our ideas? What could I do to help protect polar bears from extinction?