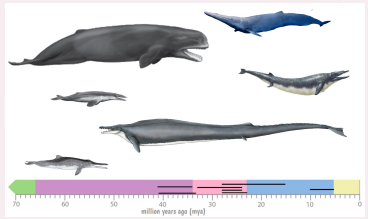
LESSON 11: Can our model explain changes over really long periods of time?

PREVIOUS LESSON *We planned and carried out an investigation using a new bacteria simulation to test what we predicted would happen when we changed the environment by a different factor other than predation. Then we ran our experiment, collected data, and used our model (General Model for Natural Selection) to explain our results.*

THIS LESSON

PUTTING PIECES TOGETHER

3 days



We attempt to apply our model of natural selection to explain differences in traits in horses over very long periods of time. We use our model of natural selection to explain differences in traits in penguins over very long periods of time. We revisit our Driving Question Board to answer our questions and ask new ones.

NEXT LESSON *There is no next lesson.*

BUILDING TOWARD NGSS

MS-LS1-4, MS-LS4-1, MS-LS4-2, MS-LS4-3, MS-LS4-4, MS-LS4-6

WHAT STUDENTS WILL DO

11.A Use a model of adaptation by natural selection acting over generations to describe cause and effect relationships that predict how and why organisms' traits changed over time (millions of years) in response to changes in environmental conditions.

11.B Construct a scientific explanation to account for how natural selection (cause) could explain why the traits of modern penguins are different than the traits of very ancient penguins (effect) and why traits changed in penguins over millions of years (effect).

11.C Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information regarding cause and effect relationships and stability and change in lines of evolutionary descent.

WHAT STUDENTS WILL FIGURE OUT

- Natural selection could be the mechanism that is causing changes.
- Those changes could link modern penguins with ancestors far back in time.
- We can answer many of our DQB questions, but now we have more questions.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Raise the question of whether the natural selection model could help us explain some of the differences we saw in ancient and modern organisms.		large class copy of the General Model of Natural Selection
2	7 min	**CHOOSE A TRAIT TO EXAMINE** Orient to changes in horses' toes over time.	A-B	2 sheets of purple paper, tape
3	35 min	**MODIFY THE GENERAL MODEL OF NATURAL SELECTION TO EXPLAIN A SPECIFIC CASE** Read a short text on the changing environment and the function of multiple and single toes, and use this information to fill in the rest of the model.	C-D	*Information About Ancient and Modern Horses*, large class copy of the General Model of Natural Selection, 3 sheets of paper of the following colors: 1 green, 1 blue, 1 pink, several large yellow sticky notes (as needed), several pieces of white paper (as needed), tape
				End of day 1
4	3 min	**NAVIGATION** Raise new questions or comments that students have about whether natural selection can be used to predict and explain other possible connections and patterns between ancient and modern organisms.		
5	7 min	**ORIENT TO TRAITS IN PENGUINS** Orient to changes in penguins' beaks or body sizes over time.	E-F	*Information about Ancient and Modern Penguin Environments*, General Model of Natural Selection for the Progress Tracker (the same document that you prepared and distributed in Lesson 9), 2 purple, 1 green, 1 blue, 1 pink and several yellow sticky notes
6	25 min	**MODIFY THE GENERAL MODEL OF NATURAL SELECTION TO EXPLAIN PENGUINS** Read a text on the changing environment and the function of large and small body size, and long and short beaks, and use this information to modify the natural selection model.	G	*Information about Ancient and Modern Penguin Environments* if not distributed in the previous activity, General Model of Natural Selection for the Progress Tracker (the same document that you prepared and distributed in Lesson 9), 2 purple, 1 green, 1 blue, 1 pink and several yellow sticky notes, large class copy of the General Model of Natural Selection as modified on day 1
7	10 min	**GALLERY WALK** Record noticings and wonderings about other groups' modified models explaining penguins' beaks or body sizes.	H	each group's modified General Model of Natural Selection
				End of day 2
8	10 min	**EVALUATE OUR DRIVING QUESTION BOARD (DQB) QUESTIONS** In pairs, students evaluate our list of questions and determine ones they think we have made progress on. Students place sticky dots on the questions they think we have made progress on and move into their Scientists Circle.	I-J	*Reviewing Our Driving Question Board*, 10 sticky dots, Driving Question Board

Part	Duration	Summary	Slide	Materials
9	10 min	**REVISIT THE DQB** Revisit the DQB with the whole class and take stock of all of the questions we've now answered.	K	
10	5 min	**ADD TO OUR PROGRESS TRACKERS (OPTIONAL)** Update Progress Trackers, if time permits.	L	
11	20 min	**CELEBRATING OUR YEAR OF SCIENCE LEARNING** Reflect on science learning through a "Tweet Blizzard." Build a new Driving Question Board.	M-N	piece of scrap paper, sticky notes, marker

End of day 3

Lesson 11 • Materials List

	per student	per group	per class
Lesson materials	• *Information About Ancient and Modern Horses* • *Information about Ancient and Modern Penguin Environments* • *Information about Ancient and Modern Penguin Environments* if not distributed in the previous activity • science notebook • *Reviewing Our Driving Question Board* • 10 sticky dots • piece of scrap paper • sticky notes • marker	• General Model of Natural Selection for the Progress Tracker (the same document that you prepared and distributed in Lesson 9) • 2 purple • 1 green • 1 blue • 1 pink and several yellow sticky notes	• large class copy of the General Model of Natural Selection • 2 sheets of purple paper • tape • 3 sheets of paper of the following colors: 1 green • 1 blue • 1 pink • several large yellow sticky notes (as needed) • several pieces of white paper (as needed) • large class copy of the General Model of Natural Selection as modified on day 1 • each group's modified General Model of Natural Selection • Driving Question Board

Materials preparation (40 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.

Day 1:

- **Group size:** 2 students (elbow partners would be appropriate)
- **Setup:** Display each large class copy of the General Model of Natural Selection in a place that is visible to the whole class.
- **Materials**
    - *Information About Ancient and Modern Horses*
    - 2 sheets of purple paper per class
    - 1 sheet of green paper per class
    - 1 sheet of pink paper per class
    - 1 sheet of blue paper per class
    - large yellow sticky notes
    - several sheets of white paper

Day 2:

- **Group size:** 3 students (maximum)
- **Setup**
    - Display the large class copy of the General Model of Natural Selection as modified on day 1 in a place that is visible to the whole class.
    - Print one copy of the General Model of Natural Selection for the Progress Tracker (the same document that you prepared and distributed in Lesson 9) for each group.
    - You may want to set up an activity "kit" for each group in a class consisting of one copy of the General Model of Natural Selection for the Progress Tracker along with the 5 or more multicolor 3 x 3 sticky notes they will use in the activity. Alternatively, these can be distributed at the beginning of the activity.

- **Materials**
    - *Information about Ancient and Modern Penguin Environments*
    - 2 purple 3 x 3 sticky notes per group
    - 1 green 3 x 3 sticky note per group
    - 1 pink 3 x 3 sticky note per group
    - 1 blue 3 x 3 sticky note per group
    - several 3 x 3 yellow sticky notes per group
    - sheets of white paper as needed

Day 2 and 3:

- **Set up**
    - Students may finish early on day 2 of this lesson. There are several options provided at the end of day 2 and in day 3 of this lesson, and doing all of them will require more than 2 full class periods. Read through the teacher guide, judge the time you have remaining, and modify this part of the lesson accordingly.
        - If you have more than 2 full class periods, complete all steps and give each step more time than is allotted in the Learning Plan.
        - If you have less than 2 full class periods, skip the "Evaluate our DQB" small group work and "Progress Tracker." Instead, move straight to the "Revisit the DQB" in a Scientists Circle. Allow students to post sticky dots on questions that they believe are answered and to discuss those. Complete the "Celebrate our Science Learning," which involves a tweet blizzard reflection and building a new DQB of questions.

Day 3:

- **Group size:** 2 students
- **Set up**
    - If completing the "Evaluate our DQB" in small groups, type up the questions from the DQB or take a high resolution photograph of all of the questions on the DQB. If typing up the questions, modify the handout, *Reviewing Our Driving Question Board*, with the questions. If you take a photograph, insert the photograph in place of the table on the handout. If using the table format, add as many rows as needed to the table.
    - Make sure the DQB is displayed and space is available for the class to gather in a Scientists Circle.
- **Materials**
    - *Reviewing Our Driving Question Board*
    - Sticky dots
    - Scrap paper
    - 3 x 3 sticky notes

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

In the explanations that students develop in this lesson, students use their model of natural selection to explain that changes in the environments that organisms lived in drive the changes in traits we see in many of them over time. The lesson focuses on two specific examples of this to account for trait differences between ancient and modern types of organisms. One is horses and the other is penguins. It is anticipated, that these two cases will be sufficient for students to develop a general sense that natural selection is a plausible mechanisms for accounting for changes in traits in any population over millions of years, even if they don't spend time going back to apply the model to whales and horse-shoe crabs (from lesson 5).

Students use their general model of natural selection to develop trait specific explanations for horses and penguins. These explanations are layered over their diagramatic system model. This parallel structure of the explanation and the model, may make the difference between explanation and model difficult for students to distinguish on the surface. This lesson provides an opportunity to help students recall that explanations are phenomena specific accounts for why or how something happened, while models are generalized sets of ideas that describe the parts, interactions, and mechanisms we believe work across a broader class of phenomena.

By the end of the lesson, students will likely argue that most of their exisiting questions on the driving question board have been answered but now they have many more new questions. These are likely to include things that are beyond the scope of this unit such as:

- What were ancestors of ancient penguins (or whales, or horses) like?
- How have other organisms changed over time?
- What type of changes have happened in humans over time?
- Where do the trait variations initially come from?
- What did the first living things descend from?

One goal of this lesson is to not only celebrate the progress we made on initial questions, but to also revel in new lines of questions that have now opened up. The last day of this lesson is designed to help students reflect on the nature of science and their own journey through the OpenSciEd middle school program. They should see themselves as active agents in the knowledge building they have participated in and recognize that that scientific inquiry can be exciting and rewarding, in part, because it doesn't always end with answers, rather it often "ends" with setting up new lines of questions for further future investigation.

Where We Are NOT Going

Students may raise questions about where some variations initially came from (e.g. the first penguins with shorter beaks) and may identify it as a possible gap in our model that needs revision. While that is a great line of questions to encourage for adding to the DQB, no attempt will be made to answer those questions in this version of the unit. We are not taking into account the role of mutation in these explanations, nor in this version of the unit. In future revisions to the unit, the role of mutation as a mechanism for introducing variation into the ancestral population at some point in the past, will be reintroduced in subsequent lessons, and the class model for explaining why traits change in populations over time will include both natural selection and mutation. That will lead to a more sophisticated understanding of how traits in populations change over time and will include a gradual, incremental accumulation of adaptations over time in a line of descendants. For now, however, the explanations that students develop in this lesson simply assume that the variations we see today must have existed at some point in the ancestral population.

LEARNING PLAN for LESSON 11

1 · NAVIGATION

3 min

MATERIALS: large class copy of the General Model of Natural Selection

Facilitate a brief discussion about the natural selection model. Point out the large class copy of the General Model of Natural Selection. Ask students whether they think the general model of natural selection could help us explain some of the differences we saw in ancient and modern organisms using the prompts below.

Suggested prompt	Sample student response
Are we satisfied with how well our natural selection model can explain what happens in the different organisms we've looked at?	*Yes. It's a general model that explains what happens for all the organisms we've looked at so far.* *We showed that it explains what happened in bacteria in addition to explaining the cases we used to build it.*
Do you think the natural selection model would work to explain all changes we see in the traits of all different organisms?	*Yes. It's very general, and we already saw it work for several different kinds of organisms, so it should work for everything.* *Probably. It works for lots of different types of organisms so far.* *Maybe. We didn't try it with anything bigger than a bird yet, and we didn't look at any mammals. Maybe they're different.*
Could the natural selection model help us explain the cases we've looked at over very long periods of time (penguins, horseshoe crabs, horses, whales)?	*Maybe. If it works over a short time it might work over a long time.* *Probably. A long time is just a really large number of generations, so it should work the same over long periods of time.*

Say, *Let's look at one of the organisms for which we have ancient and modern types and see if the model could explain what happened.*

2 · CHOOSE A TRAIT TO EXAMINE

7 min

MATERIALS: 2 sheets of purple paper, tape

Reorient to traits that changed over long periods of time. Display **slide A.** Remind students which organisms we looked at over long periods of time with both ancient and modern types. Say, *We need to start with an organism in which some interesting trait changed between ancient and modern types. Let's try this with horses.*

Focus on horses' toes. Display **slide B**. Ask, *What were some of the interesting traits that you saw were different over time in horses?* Someone is likely to mention that the number of toes changed over time. Suggest that we see whether the natural selection model could explain this change. Have students locate their general models in their science notebooks so they can refer to it.

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

Students have already worked through developing and refining this model multiple times in the last three lessons, and have used it as part of a summative assessment in Lesson 10. The purpose of this activity and the next is to have students think through

ADDITIONAL GUIDANCE

If you will be using the following partner work and whole class participation as an assessment, let students know that their participation will be assessed. See Assessment call out below for details.

Define the change in traits over time. Say, *We should first define what trait change we're going to try to explain.* Move to the large class copy of the General Model of Natural Selection in the classroom and ask the students to describe the traits of the ancient horse toes. They should mention that the ancient horses had multiple toes. Write "Almost all individuals had 4 (or multiple) toes" on one of the purple sheets of paper and post it over the purple "Population before the change" sheet on the model. Ask the students to describe the traits of the modern horse toes. They should mention that the modern horses have only one large toe, or hoof. If necessary, explain to students that a hoof is basically just a large toe with a very thick covering on it, like a really big toe nail. Write "Almost all individuals have a single toe or hoof" on the other purple sheet of paper and post it over the purple "Population after the change" sheet on the model.✱

the elements of the model and how they apply to the case of horses' toes over a long period of time. It is not necessary or desirable to focus on the process of assembling this information. Once students have articulated the general idea for each element, and there is general consensus in the class, feel free to quickly summarize or paraphrase and write on the paper yourself, in order to move things along and allow students to focus on the concepts rather than the process.

3 · MODIFY THE GENERAL MODEL OF NATURAL SELECTION TO EXPLAIN A SPECIFIC CASE

35 min

MATERIALS: *Information About Ancient and Modern Horses*, large class copy of the General Model of Natural Selection, 3 sheets of paper of the following colors: 1 green, 1 blue, 1 pink, several large yellow sticky notes (as needed), several pieces of white paper (as needed), tape

Introduce the short reading. Ask students to name the other main elements of the model that we need information about. They should mention that we need to know about the environment of the horses, their survival and reproduction, and offspring and inheritance. Distribute *Information About Ancient and Modern Horses*. Have students read and annotate the information in the reading in order to collect information about those three elements.

Define the Environment element of the model. Display **slide C.** Have students turn and talk with a partner to share information regarding what they learned about the horses' environment and what they think should go on the green "Environment" paper for the model regarding horses' toes. Facilitate a brief discussion to come to consensus about the green environment element using the prompts below.

Suggested prompt	Sample student response
What was the horses' environment like?	*The environments were different for the ancient and the modern horses.*
So we have different environments. What was the environment like for the ancient horses?	*It was like a rainforest.* *It was crowded with a lot of plants and animals.* *The terrain was uneven.* *The predators pounced on animals that wandered by.*
What is the environment like for the modern horses?	*It's open grassland.* *It has mostly grass and it's easy to see long distances.* *The terrain was flat and the soil was firm.* *The predators chase animals to catch them.*

✱ ATTENDING TO EQUITY

It is always important that all students' ideas are respected and taken seriously. Even though at this point in the unit there is a preponderance of evidence that supports the claim that natural selection is the mechanism underlying incremental changes in traits that can accumulate to produce large scale structural changes (evolution), dissenting claims should be welcomed into the conversation.

However, it is also critical that scientific claims are always supported with evidence. The arguments supporting evolution occurring over millions of years are solidly based in scientific evidence and reasoning and there is no evidence that contradicts them. The evidence cannot be based on direct observation since ancient organisms no longer exist and the fossil record is incomplete. Therefore students may feel the support is weak. Ask students to explain the connection between their claims and the evidence that supports them.

Suggested prompt	Sample student response
Why are their environments different?	*The climate changed over long periods of time. The Earth cooled and dried out and the type of environment changed.*

On the green paper, write "The environment changed from rainforest to open grassland" and add a brief description of the biotic and abiotic factors in each environment. Post it over the green "Environment" sheet on the model.

Define the other two main elements of the model. Have students turn and talk with a partner to share information regarding what they learned about the horses' survival and reproduction and their offspring and inheritance. Ask partners to decide what they think should go on the pink and blue papers for the model. Facilitate a brief discussion to come to consensus about those elements using the prompts below. Then record a summary of their ideas on the pink and blue papers and post them over the pink "Survival and Reproduction" and blue "Offspring and Inheritance" papers on the model.

Suggested prompt	Sample student response
Did you find any evidence about the pink "survival and reproduction" element?	*Yes. We think that horses with multiple toes would have survived better in forests where they needed to move around on uneven ground to find food, or hide to avoid predators.* *We think that horses with one hoof would have survived better on grasslands where there is no place to hide and they need to run fast to escape predators.*
So as the environment changed to more open grassland over millions of years, which one of the traits had a competitive advantage?	*Horses with one toe or hoof (or at least horses with fewer toes) would have an advantage in grasslands.*
Did you find any evidence about the blue "offspring and inheritance" element?	*Yes. Horses have to survive for a few years before they can reproduce, so the offspring will come from the ones that survive better.* *It says the number of toes is inherited, so whichever horses survived would pass on the toe trait to their offspring.*
So as the environment changed to more open grassland over millions of years, which one of the traits was more likely to be passed on?	*Horses with one toe or hoof (or at least horses with fewer toes) would be more likely to pass on their traits to more offspring.*

Discuss any other parts of the model that need revising. Display **slide D.** Say, *So let's see if the whole thing works to explain what happened with horses' toes over millions of years.* Starting at the top of the model, point to each element (each colored paper, sticky note, and "Because of this . . . " statement) and read what is now posted on the model. Ask students whether each element works as written or whether it needs to be modified to explain specifically what happened with the horses' toes. Push students to be as specific as possible for each element, emphasizing what happens in the specific case of the change in the trait of horses' toes over time. Students may want to rephrase or add specific details to some or all of the elements. Quickly paraphrase or summarize their ideas and make the changes they suggest.

Come to an agreement about whether we think this model might work to explain trait changes over long periods of time in all organisms. Ask students if they think this model might work to explain trait changes in organisms over long periods of time.

Most, if not all students are likely to agree that the natural selection model can be used to help explain trait changes in all organisms over long periods of time. Point out to students that the natural selection mechanism in their model is supported by evidence from many shorter term studies and that we expect the same mechanisms have worked the same way in the past. If some students do not think the model could be used to explain trait changes over long periods of time, have them articulate why they disagree and ask them for evidence to support their claims.✱

Ask students if this raises any questions for them and allow them to share any questions they have.

ASSESSMENT OPPORTUNITY

Building towards: 11.A Use a model of adaptation by natural selection acting over generations to describe cause and effect relationships that predict changes in organisms' traits over time in response to changes in environmental conditions.

What to look for/listen for: Circulate among students as they talk with partners and listen closely as students share ideas with the whole class. Students should be actively engaged in connecting specific elements of the general natural selection model with specific information about ancient and modern horses, the environments they inhabited, and the functions of multiple and single toes. Listen for each student to make an accurate and specific connection between the model and the information about horses. An example of what specific information might be included is in *Examples of using General Model to explain Horses and Penguins*. However, keep in mind that student language will vary from what is shown in the example. Using specific information is important but the precise words used to describe connections are not.

What to do: If students are struggling to make connections, point out one element of the model they have in their Progress Trackers and ask them if any part of what they read connects with that element. Encourage them to look at one part at a time to see if it fits the general ideas. Or ask them what they found interesting about what they read and whether they can connect that with some part of the model. Celebrate accurate connections, even if they are tenuous, and encourage persistence.

End of day 1

4 · NAVIGATION

3 min

MATERIALS: None

Have students share questions. Ask students if they have any questions or comments about whether natural selection can be used to predict and explain other possible connections and patterns between ancient and modern organisms. Allow them to share questions and ideas and discuss them with at least one other student.✱

ADDITIONAL GUIDANCE

This is as far as students will go in considering the applicability of natural selection for explaining the relationships between all living things in this unit. At this point, students have figured out how evolution can happen through natural selection. In future revisions to this unit, students will figure out how this mechanism, in combination with mutation and sexual reproduction can more completely account for changes occurring over longer periods of time. This will provide important groundwork for considering a broader set of mechanisms that contribute to how and why populations change over time in high school (e.g. genetic drift, migration and geographic isolation, speciation, sexual selection, etc...), all of which contribute additional mechanisms to explain different types changes in the traits of populations over time (evolution).

5 · ORIENT TO TRAITS IN PENGUINS

7 min

MATERIALS: *Information about Ancient and Modern Penguin Environments*, General Model of Natural Selection for the Progress Tracker (the same document that you prepared and distributed in Lesson 9), 2 purple, 1 green, 1 blue, 1 pink and several yellow sticky notes

Reorient to traits in the penguin that changed over long periods of time. Display **slide E.** Remind students that we started our unit with a question about an ancient penguin called "Pedro" and whether or how Pedro could be connected to modern penguins. Say, *It seems like we might have an answer to our original question: Can the model of natural selection be used to explain the connection between ancient and modern penguins? Today you're going to work with a group to show how the natural selection model could be used to explain something about penguins.*

Focus on penguins' body size or beaks. Display **slide F**. We need to start with an interesting trait. Ask, *What were some of the interesting traits that you saw were different over time in some of the penguins?* Someone is likely to mention both that the ancient penguins usually had a larger body size (giant), and that the shape and/or length of the beak changed over time. Tell students that they can choose either overall body size as a trait to explain, or that they can choose beak shape and/or length as a trait to explain. They must choose one or the other in their group and then use that single trait to work out how the natural selection model could explain this change.

Orient to what students will do in the activity. Divide students into groups of no more than three. Distribute a copy of the General Model of Natural Selection for the Progress Tracker to each group along with 2 purple, 1 green, 1 blue, 1 pink and several yellow sticky notes. Have students locate their copy of the General Model of Natural Selection in the progress trackers in their science notebooks so they can refer to it, along with any notes they may have written on it. Use the prompt below to focus students' attention on what resources they'll need to complete their task of showing how the natural selection model could be used to explain the changes in penguins' body size or beaks.

Suggested prompt	Sample student response
OK, you have the sticky notes you'll need to replace any information on the general model with information specific to a penguin trait that changed over time. Do you need anything else in order to show how the natural selection model could be used to explain the changes in penguins?	*We need instructions for how to do this!* *We need more information!* *We need to know about the . . . (any one of the elements on the general model, e.g. environment, environmental changes, selection, competitive advantage, the trait being heritable, etc.).*

Tell students you will give them complete instructions next. If students identify additional information they will need, distribute *Information about Ancient and Modern Penguin Environments* which contains information on all the elements they will need to complete the next activity. If they do not identify any information they'll need, wait to distribute *Information about Ancient and Modern Penguin Environments*, and move on to the next activity.

6 · MODIFY THE GENERAL MODEL OF NATURAL SELECTION TO EXPLAIN PENGUINS

25 min

MATERIALS: *Information about Ancient and Modern Penguin Environments* if not distributed in the previous activity, General Model of Natural Selection for the Progress Tracker (the same document that you prepared and distributed in Lesson 9), 2 purple, 1 green, 1 blue, 1 pink and several yellow sticky notes, large class copy of the General Model of Natural Selection as modified on day 1

Give instructions for the activity. Display **slide G.** Review the instructions on the slide with students and answer any clarifying questions.

If you did not distribute *Information about Ancient and Modern Penguin Environments* previously, distribute it as soon as students ask for additional information about the penguins, but not before they ask for it.

Allow students to work independently in their groups to modify the elements of the natural selection model. As they work, circulate among the groups to ensure that each group member is participating and provide assistance as needed.

Move students who are finished on to Evaluate Our Driving Question Board Questions. When a group finishes, ask them to briefly explain their work to you and add their names to their modified natural selection model. Position their modified natural selection model in the room to allow for a gallery walk. Give them a copy of *Reviewing Our Driving Question Board* and have them begin the initial day 3 activity while other groups are finishing.

ASSESSMENT OPPORTUNITY

Working toward: 11.B Construct a scientific explanation to account for how natural selection (cause) could explain why the traits of modern penguins are different than the traits of very ancient penguins (effect) and why traits changed in penguins over millions of years (effect).

What to look/listen for:
As you circulate among the groups while they work, listen for every student to participate. Conversations should refer to specific information about penguins, and/or specific parts of the General Model of Natural Selection.

Taken together, the written evidence on the sticky notes used to modify the General Model of Natural Selection should explain how and why the traits of ancient penguins changed to become more like the traits of modern penguins.

- All the elements in the model should be addressed.
- Written modifications should refer to specific information from the reading or from their investigations of penguins in earlier lessons. General statements are not sufficient to explain this particular case.
- The "Because of this . . ." statements should describe clear and accurate cause and effect relationships.

See *Examples of using General Model to explain Horses and Penguins* for potential examples. Keep in mind that student language will vary from what is shown in the examples. Using specific information is important but the precise words used in student explanations are not. Students who thoroughly understand and can apply the model of natural selection will provide a detailed set of statements containing all the elements specific for the trait of penguins they chose.

What to do:
If students are struggling to participate, assign them a particular model element to identify and describe from the *Information about Ancient and Modern Penguin Environments* reading. Point out if they have missed using an element in the model. Provide support, but do not provide answers to specific student questions. Rather, redirect them to the resources they have available and remind them that they have done this kind of analysis before with different cases in this unit. Allow them to proceed independently. Since this is the last student artifact in this unit, it is not necessary to provide formal feedback to students unless you are using this as a summative assessment.

7 · GALLERY WALK

10 min

MATERIALS: science notebook, each group's modified General Model of Natural Selection

Have a gallery walk. Display **slide H.** When all groups have completed their modifications and their modified models are positioned to allow for a gallery walk, have students create a noticings and wonderings chart in their science notebooks and circulate among all the modified models. Ask them to notice how many of the modified models are the same as, or very similar to, their own modifications. They can record all their noticings and wonderings in their science notebooks to share with the class.

Review what they noticed during the gallery walk. Have students share some of their noticings and wonderings. If any major differences were noticed, facilitate a discussion to resolve those differences. If not (or after resolving any differences), take a moment to celebrate the depth and complexity of their understanding, and all the hard work they have done to arrive at an answer to the unit question.

End of day 2

8 · EVALUATE OUR DRIVING QUESTION BOARD (DQB) QUESTIONS

10 min

MATERIALS: science notebook, *Reviewing Our Driving Question Board*, 10 sticky dots, Driving Question Board

Have students work in pairs to evaluate what questions the class has answered from the DQB. Display **slide I**. Provide students with one copy of *Reviewing Our Driving Question Board*, which you created to contain all of the student questions from the DQB, and have students tape it into their science notebooks. Have students work with a partner to mark questions they think the class has answered:

- We did not answer this question or any parts of it yet: **O** or **?**
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓✓

(Optional, depending on time) **Have students answer three questions of their choice.** Have students pick three questions they think the class has answered. Tell students to use the space on the handout *Reviewing Our Driving Question Board* to write down the answer to those questions.

Review and share the questions that students think we have answered. Present **slide J** and have students mark on the class DQB with sticky dots the questions that they think we have made progress on.✱ Then have students move into their Scientists Circle.

✱ ATTENDING TO EQUITY

Revisiting the DQB is important for students to feel as though their questions are valued and recognized. While not all questions will have been addressed (it's more likely that 50-75 percent will be at least partially answered), this helps students see that they have done this hard work to answer many of their own questions.

9 · REVISIT THE DQB

10 min

MATERIALS: science notebook

Look for patterns using the sticky dots. In the Scientists Circle, focus on the questions that have the most number of sticky dots.✱

Discuss as a class the questions that the class can now answer. Present **slide K** if needed. Have the class discuss the answers to those questions. If you have space, you might make a "Takeaways" board that has a record of the answers with which the class comes up.✱

Pose the unit question. To close out the discussion, pose the DQB question, *How could things living today be connected to the things that lived long ago?* Elicit students' new ideas to this question to prime students' thinking for adding a final entry to their Progress Tracker.

✱ ATTENDING TO EQUITY

Revisiting the DQB is an important process in allowing students to feel their thoughts and questions are valued and recognized. This part of the lesson helps students see the hard work they have done to answer many of their own questions.

✱ SUPPORTING STUDENTS IN ENGAGING IN ASKING QUESTIONS AND DEFINING PROBLEMS

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them. In this unit, students were tasked with asking questions about some very complex phenomena. Their questions are likely to reflect sophisticated thinking they would not have been capable of as younger students. Through the

ASSESSMENT OPPORTUNITY

Building towards: 11C Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information regarding cause and effect relationships and stability and change in lines of evolutionary descent.

Look/listen for:

- We can clearly answer many of the questions through ideas learned throughout the unit.
- Some questions we can partially answer with some of our ideas learned, but they require more information/evidence.

What to do: If students struggle to answer questions from the DQB, place them in partners or small groups with one question or cluster of similar questions assigned to the group. Have them (1) locate where the questions most closely relate to the class's consensus models from Lesson 4 or Lesson 8 and then (2) examine their science notebooks and other documents to search for evidence that could answer or partially answer the question. Ask the group to co-construct, in writing or orally, an explanation to the question(s) using evidence from their previous work. Remind students what makes a good explanation is a how or why causal account that can be supported with evidence.

investigations in the unit and individual and whole-group sensemaking, they can now answer many of these complex questions.

10 · ADD TO OUR PROGRESS TRACKERS (OPTIONAL)

5 min

MATERIALS: science notebook

Add any new insights to the Progress Trackers. If time permits, have your students add a final entry to their Progress Tracker. If time does not permit, skip, and complete the whole-group reflection, which comes next.

Present **slide L** and modify the slide depending on the entry you want students to complete. Have students either make an entry about new insights about the unit question OR add an entry about new ideas or insights that may have surfaced during the DQB discussion. Have the students update their Progress Trackers with any additional ideas that they think are important.

11 · CELEBRATING OUR YEAR OF SCIENCE LEARNING

20 min

MATERIALS: science notebook, piece of scrap paper, sticky notes, marker

Tweet Blizzard reflection. Display **slide M**. Have students take 2-3 minutes to reflect on their own highlights/takeaways for the year in the format of writing a "tweet" on a piece of scrap paper, complete with hashtags of their choosing. Tweets can be about:

- a big idea you learned in this unit or school year that will always be with you,
- a challenge you faced in this unit or school year that you overcame, or
- a rewarding thing about this unit or school year that you want to share.

Have students crumple up their tweet into a "snowball," toss the snowball in the air, and pick up a new snowball to share with the class. Facilitate a sharing of tweets in a Scientist Circle.

ALTERNATE ACTIVITY

If COVID-19 precautions do not permit the blizzard activity, modify it so that students complete the reflection as a Quickwrite in their science notebook or virtual learning space. Ask students to write their reflection as a "tweet" with hashtags. If you are in a remote learning setting, have the students write their tweet in a Jamboard space or create a slide deck where each student is assigned a slide. If using slides or Jamboard, students can also add images of their favorite activity in the unit or the school year. Play the slide deck as a celebration of learning.

Generate New DQB. Ask students to think about the questions that remain unanswered in the unit or across the school year. Display **slide N**. Remind students that they will continue their science learning in high school next year. Their science learning in high school will allow them to continue to revise their scientific knowledge in light of new evidence they will encounter. Pose the question, *What questions did we pose this year that we didn't answer but we want to carry forward into future science learning?*

Give students time to write 1-2 new questions. Encourage students to write down questions that went unanswered in previous units and/or new questions that came up about phenomena they have observed in the world and want to explain. Have students post their questions to a new DQB.

Cluster the questions by OpenSciEd units taught this year and/or phenomena-based clusters. Include a cluster of topics that have not been addressed in OpenSciEd units, but that they might address in high school.

Ask students to share their questions, and how they may go about answering those questions on their own, and/or as part of their science learning in future years.