Natural Selection Unit

Lesson 4: Natural Selection Simulation

Grade: 9–10 General Biology

Length of lesson: 145 minutes

Placement of lesson: Lesson 4 of 6

Unit Overarching Goal

Populations of organisms change over time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (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.

Unit Central Question

What is the process that leads to changes in populations of organisms over time?

Lesson 4 Main Learning Goal

The interaction of four factors of natural selection influences the changes that occur in populations of organisms.

Lesson 4 Focus Question

How do the four factors of natural selection explain the changes we see happening in populations?

Ideal student response

The interaction of all four factors are necessary to explain the changes of population we see in nature.

> Without Factor 1, the population cannot grow because reproduction is essential.
>
> Without Factor 2, the entire population would survive and reproduce, or the entire population would eventually die out depending on how well the traits are adapted to the environment. The lack of variation means the population cannot adapt to changing environmental conditions.
>
> Without Factor 3, competition doesn't exist. The snail population would increase without limit.
>
> Without Factor 4, the variations in the population would not change since the environment doesn't favor the survival and reproduction of one variation over the other.

Science Content Storyline

The changes that occurred to the snail population in tidal pools can be explained using the four factors of natural selection. The change in the proportion of thick and thin shells that occurred in the snail population was a result of crab predation and the variations in the shell thickness trait that individual snails possessed. Snails with thicker shells were better able to escape predation and, as a result, had a better chance of surviving and reproducing.

This phenomenon mirrors the changes that occurred to the freshwater stickleback population in Loberg Lake, which can also be explained using the four factors of natural selection. The change in the proportion of traits that occurred in the stickleback population was a result of dragonfly nymph predation and the variations in the body armor trait that individual fish possessed. Fish with little body armor were better able to escape predation and, as a result, had a better chance of surviving and reproducing.

Therefore, to account for the changes that we observe in populations in nature, all four factors of natural selection must interact with one another.

Materials

- Simulation Handout (describes the simulation)
- M&Ms (150 per group)
- Raisins (150 per group)
- Labeled container to hold extra M&Ms including those "deceased/captured"
- Labeled container to hold extra raisins including those "deceased/captured"
- Tweezers/forceps (1 per group)
- Tin pail/Cup (1 per group) Note: This should **not** be a clear container to avoid students seeing the contents inside. We don't want students to be able to choose to pick up raisins or M&Ms.
- Stopwatch (1 per group)
- Die (1 per group)
- Calculator (1 per group)

Advance Preparation

- Write the four factors that comprise Darwin's ideas of natural selection on the board or on chart paper. The four factors are listed below:
  - **Factor 1:** More individuals are born than can survive and reproduce.
  - **Factor 2**: Individuals within a population inherit traits from their parents. These traits show variation.
  - **Factor 3**: Individuals in a population compete for limited resources (e.g., food, habitat, or mates).
  - **Factor 4**: Some offspring inherit variations of traits that help them better survive and reproduce in their environment.

Time (min)	Phase of Lesson	How the science content storyline develops
5	**Through short class discourse, revisit the Unit Central Question and link to prior learning:** *What is the process that leads to changes in populations of organisms over time?* **Read lesson Focus Question, which will not be answered until after the activity:** *How do the four factors of natural selection explain the changes we see happening in populations?*	• There are four factors that comprise Darwin's idea of natural selection. • There is evidence that supports the four factors of natural selection.
10	**The Snail Phenomenon** Parts 1 and 2 Activity Setup Students read about a phenomenon involving a population of Nucella lapillus, a snail that lives on the rocky shores of oceans and in nearby tidal pools. Students compare the snail phenomenon to the stickleback phenomenon through completion of a chart comparing important aspects of each population, including habitats, variations in traits, predators, reproductive habits, etc.	• There are variations within populations in nature. • Similarities can be seen across various populations of organisms.
45	**Snail Simulation, Part 1** Activity Setup Students are provided the activity materials and instructions on how to setup the simulations. Students use the simulation setup to complete an analogy map linking the materials of the simulation to the snail phenomenon. Activity Students engage with a simulation that allows them to generate data about how the proportion of trait variations in snail populations changes over 5 generations due to the four factors of natural selection. Activity Follow-up Students compare their results from the activity to the data from the Loberg Lake stickleback and the findings of the scientific study of Nucella lapillus in nature. Students use these comparisons to predict how each factors plays a role in population changes seen in nature. This prediction will be an important link to part two of the snail simulation.	• More individuals are born than can survive and reproduce. • All individuals in a population have the same traits, but there are different versions of the trait in different individuals in the population. • Survivability rates are affected by both biotic and abiotic factors. • Predation can affect how many organisms within a population survive and reproduce. • Selection pressures can favor a certain trait variation. • A trait variation can be selected for, be selected against, or be neutral. • A favorable trait variation can help an organism survive and reproduce. • If over time, a certain selection pressure continues, a favorable trait can become more prevalent in the population. • Trends such as a change in proportion of traits seen across various populations in nature are similar.

45	**Snail Simulation, Part 2** <u>Activity Setup</u> Students consider what variables within the simulation (model) were representing each factor. Groups are assigned one of the natural selection factors to remove from the simulation and they discuss what they could do in the simulation to represent the removal of that factor. They will also predict how removing the factor would affect the population. <u>Activity</u> Student groups are assigned a variable (factor) to remove from the simulation (model). The students describe how the simulation would be modified to remove their assigned factor. <u>Activity Follow-up</u> Students conduct a thought experiment to describe how this modification would be expected to change the data generated by the simulation. The expected results are compared to those obtained in part 1. Groups discuss the effect that removing one variable (factor) had on their population and record their conclusions in the cause-and-effect chart.	• If one of the four factors of natural selection is removed from a population, the trends do not match what is observed in nature.
10	<u>Activity Follow- up</u> Students use the completed cause and effect chart and as they complete this step, they are reminded that the goal of the second trial is to observe the effect that removing one of the four factors has on the population.	• When a particular trait is favored in the environment for long enough, the four factors of natural selection work together to change the proportion (percentage) of the population that exhibit that trait.
25	**Summarize and Link** Students use their cause-and-effect chart to decide which factors play a role in population changes in nature. Students use the Loberg Lake stickleback data, the *Nucella lapillus* study findings, and their results from the snail simulation to support their answer.	• To replicate the trends seen in nature, all four factors of natural selection must be interacting.

Lesson 4: Natural Selection Simulation

Phase of Lesson: *Lesson Focus Question*

Main Learning Goal: The interaction of four factors of natural selection influence the changes that occur in populations of organisms.

Focus Question: How do the four factors of natural selection explain the changes we see happening in populations?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (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 thatare better able to survive and reproduce in that environment.

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Time: 10 Minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas and predictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy G: Link science ideas to other science ideas

Science Ideas

- There are four factors that comprise Darwin's idea of natural selection.
- Survivability rates are affected by both biotic and abiotic factors.
- A trait variation can be favored, not favored, or neutral.
- Selection pressures can favor a certain trait variation.
- A favorable trait variation *may* help an organism survive and reproduce.

Common Student Ideas

- Changes in the environment cannot cause changes in the traits of populations living in that environment.
- All individuals within a population are the same. Any differences are trivial and unimportant.
- Every difference has a purpose.
- Natural selection leads to perfection.
- Any of the four factors of natural selection can be removed and still explain the changes we see in various populations in nature.
- Only select factors of natural selection are necessary to explain observed changes in populations over time.

Lesson 4: Natural Selection Simulation

Introduction

In this lesson, you will use a simulation to decide if natural selection was the process that changed the stickleback population in Loberg Lake. In this simulation you will collect and analyze data from a simulation about a snail population in order to determine the importance of each factor of natural selection and the effect that the interaction of the four factors has on a population of organisms.

Process and Procedure

The focus question for today's lesson is, **"Which of the four factors of natural selection is necessary to explain the changes we see in populations in nature over time?"** You will respond to this question at the end of today's lesson.

Implementation	Notes

Link to Unit Central Question and prior learning
• Remind students that the overarching goal of this series of lessons is to answer the Unit Central Question: **What is the process that leads to changes in population of organisms over time?**
Introduce the Lesson 4 Focus Question
• Ask students to read the focus question for the lesson and inform them at the end of this lesson they will be able to answer it using evidence. However, they should think about and refer to the focus question as they work through the Snail Simulation.
• Write this question on the board or on a piece of chart paper. Doing so helps remind students of the focus question during the lesson.
• Refer to the four factors that are publicly displayed on the board or chart paper. The four factors are as follows:
  o Factor 1: More individuals are born than can survive and reproduce.
  o Factor 2: Individuals within a population inherit traits from their parents. These traits show variation.
  o Factor 3: Individuals in a population compete for limited resources (e.g., food, habitat, or mates).
  o Factor 4: Some offspring inherit traits that help them better survive and reproduce in their environment.	

Lesson 4: Natural Selection Simulation

Phase of Lesson: Snail Phenomenon and Simulation Part 1 Activities Part 1 and 2 Setup, Activity Setup, Activity Part 1, Activity Follow-up

Main Learning Goal: The interaction of four factors of natural selection influence the changes that occur in populations of organisms.

Focus Question: How do the four factors of natural selection explain the changes we see happening in populations?

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Time: 45 Minutes

STeLLA Strategies

- ❖ Strategy B: Set the purpose with a focus question
- ❖ Strategy 6: Engage students in developing and using content representations and models.

Science Ideas

- There are four factors that comprise Darwin's idea of natural selection.
- Survivability rates are affected by both biotic and abiotic factors.
- A trait variation can be favored, not favored, or neutral.
- Selection pressures can favor a certain trait variation.
- A favorable trait variation *may* help an organism survive and reproduce.

Common Student Ideas

- Changes in the environment cannot cause changes in the traits of populations living in that environment.
- All individuals within a population are the same. Any differences are trivial and unimportant.
- Every difference has a purpose.
- Natural selection leads to perfection.
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- Only select factors of natural selection are necessary to explain observed changes in populations over time.

The Snail Phenomenon

Nucella lapillus is the scientific name for Dog Wharf snails that live on the rocky shores of oceans. These snails reproduce approximately 1000 offspring annually. The snails eat barnacles and mussels. Scientists have found that snails in areas with a lot of waves have thinner shells and snails living in areas with no waves, like tidal pools, tend to have thicker shells. In the tidal pools, crabs are the main predator of the snails. Recently, scientists have discovered an area where a change in sea current has reduced wave action and created a new tidal pool. They want to investigate the population of snails living in this new tidal pool.

1. To help us make connections from previous lessons, compare the snail phenomenon described above to the stickleback phenomenon that we've been learning about by completing the chart below.

	Stickleback	**Snails**
Habitat	**Marine** **Freshwater**	**Tidal pool with no waves** **High wave areas near rocks**
Variation in traits	**Full armor or low/no armor** **Long spines or short spines**	**Thick shells** **Thin shells**
Predator(s)	**Dragonfly Nymphs** **Trout**	**Crabs (in tidal pools)**
Reproductive Habits	**75- 100 eggs annually**	**1000 hatching annually**
Food Source(s)	**Eat insects**	**Eat barnacles and mussels**

Implementation	Notes
Setup for Activities Parts 1 and 2 • Introduce the *Nucella lapillus* snail phenomena supporting students (as needed) as they read the paragraph. Background information for the teacher on *Nucella lapillus* can be found at this link: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0052134 • **STEP 1:** Direct students to complete the chart. This can be accomplished in a variety of ways that best meets the needs of the class. Some options for this are: ○ Complete the Stickleback column as an entire class and have groups complete the Snails column. ○ Complete the Habitat row as a class and then have groups complete the remaining rows. ○ Note that however you decide to complete the chart, it is important for students to recognize and understand the similarities that exist between the two populations. *Snail Simulation Part 1, Activity Setup* • To set up the snail simulation, have students obtain the following materials for their group: ○ Handout that describes the simulation ○ M&M's (150 per group, plus extra in case replacements are needed) ○ Raisins (150 per group, plus extra in case replacements are needed) ○ Opaque pail/bowl/cup ○ Discard container (where students will crush "captured" M&M's/raisins) ○ 2 containers (one for extra M&Ms and one for extra raisins) ○ Tweezers/forceps ○ Stopwatch ○ Die ○ Calculator Say, "In a few minutes you will place 5 M&Ms and 15 raisins in a bowl and "hunt" them using forceps over a series of 30-second "generations" as a simulation of the snail phenomenon we just read about. We will be collecting the data in our groups, but everyone will need to record information on their individual data tables. Before we do this, it will be necessary to understand how each of these components is representative of the snail phenomenon we see in nature. "	

Snail Simulation Part 1

2. Follow your teacher's directions to set up the snail simulation. Keep in mind that a simulation is one type of model. Complete the analogy map below based on the materials you will use in the simulation.

Analogy Map

Part of the Model		Part of the Natural World
The raisins	Represent(s)…	**Thin-shelled snails**
The M&Ms		**Thick-shelled snails**
The forceps/tweezers		**Crab's pinchers**
The tall cup or pail		**Tidal pool**
Raisins or M&Ms placed in the discard container		**Snails eaten by the carbs**
Rolling the die		**How successful the snail population is at surviving and reproducing based on the availability of food.**

Implementation	Notes

• **STEP 2**: Have students work in their groups to complete the analogy map. It is essential that students understand what each material represents in the snail phenomenon. Once the simulation starts, students should refer to the raisins as thin-shelled snails and the M&Ms as thick-shelled snails in order to reinforce this simulation as a representation of a natural phenomenon.
  ○ The forceps/tweezers represent the crab's pinchers.
  ○ The raisins represent thin-shelled snails
  ○ The M&M's represent thick-shelled snails
  ○ The opaque pail/bowl/cup represents a tidal pool
  ○ Raisins/M&Ms placed in the discard container represent snails that have been eaten by crabs
  ○ The rolling of a die represents how successful the snail population is in terms of obtaining food.	

3. Record the number of each variation of snail **at the beginning of each generation** in the table below. Determine the percentages of each variation **after** you complete the simulation. Record the percentages in the last two columns of the table.

Note: Sample class data is shown in the table below. Actual data may vary.

Generation	Number of Thin-Shelled Snails	Number of Thick-Shelled Snails	Total number of snails in population	Percentage of Thin-Shelled Snails	Percentage of Thick-Shelled Snails
1	15	5	20	75%	25%
2	21	1	34	62	38
3	27	27	54	50	50
4	69	91	160	43	57
5	221	312	533	41	59

Implementation	Notes
Snail Simulation part 1, Activity • **STEP 3**: Using the handout, review steps with students or read the step to the students. Emphasize how the simulation will be run: o Each group needs to choose one person to be the crab. This person needs the tweezers/forceps. Have the person from each group who will be the crab raise their hand to ensure that each group has chosen a crab. o Each group needs to choose one person to be the timer. This person needs the stopwatch. Have the person from each group who will be the timer raise their hand to ensure that each group has chosen a timer. o Each group needs to choose one person to be the recorder. This person will record the number of thin-shelled crabs and the number of thick-shelled crabs at the beginning of each generation in the data table on page SE L4-2. Have the person from each group who will be the recorder raise their hand to ensure that each group has chosen a recorder. o Optional (if four members in a group): Each group needs to choose one person to be population control. This person will add new snails (raisins/M&Ms) to the population at the end of each hunt. Have the person from each group who will be the population control raise their hand to ensure that each group has chosen a population control member. If only 3 students are in a group, then have the timer also be the population control. o The crab (student with forceps/tweezers) will hunt for 30 seconds. To do this, they will use the tweezers to grab one snail (raisin/M&M) at a time, move it over the discard cup and place it in the cup. o The timer will say when to start and when to stop hunting. The crab (student with forceps/tweezers) must stop hunting as soon as the timer says stop. o Half of snails of each variation (raisin/M&M) that are still in the tidal pool (opaque container) when the timer says stop will then reproduce. o To represent survivability, a die roll is used. If the die roll shows a 1, 2, or 3, then survivability is 50% and half of the snails are removed. If the die roll shows 4, 5, or 6, then survivability is 100%. o To represent reproduction, for each reproducing snail (raisin/M&M) add five new snails (extra raisins/M&Ms) of the same variation to the tidal pool. Note: If there are four students per group, this should be done by the population control member. For example, if a student has 6 thick-shelled and 10 thin-shelled snails surviving at the end of a hunt and they rolled a "3" on the die, then they would add 15 new thick-shelled snails (3 females x 5 offspring each) and 25 new thin-shelled snails (5 females x 5 offspring each).	

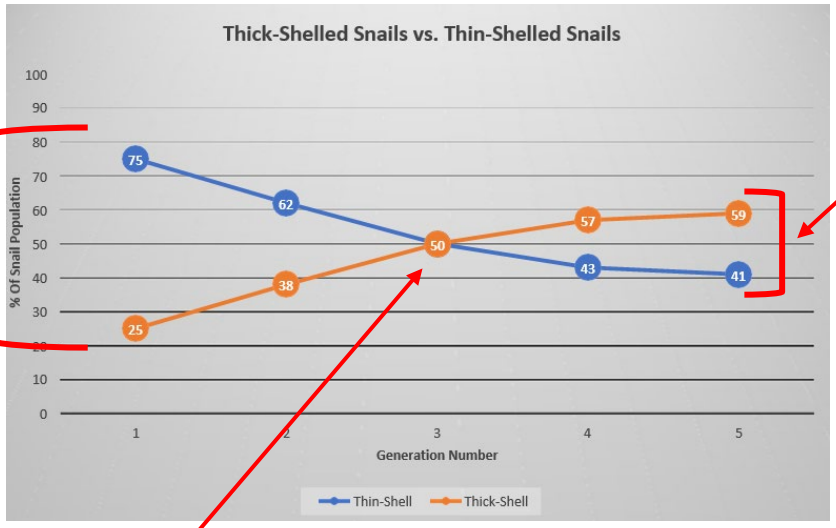
Implementation	Notes
Teacher note: Have students reflect on the aquarium math from Lesson 3 and have a brief discussion about factor 1 and the fact that all offspring will not survive to adulthood. Use this to explain to the students that we will not be adding 1,000 raisins/M&Ms at the end of each generation to represent the offspring of each adult. Instead, we will modify this simulation by having the adults produce 5 surviving offspring each. However, since males do not reproduce, only half of the surviving crabs from each population—thick and thin-shelled—will reproduce. For example, if a student has 6 thick-shelled and 10 thin-shelled snails surviving at the end of a hunt, then s/he would add 15 new thick-shelled snails (3 females x 5 offspring each) and 25 new thin-shelled snails (5 females x 5 offspring each). If an odd number of snails survived, students should round up to the next even number; half of that number will be the reproducing snails. ○ The recorder will then count the number of each variation of snail (raisin/M&M) and record it in the data table on page SE L4-2. This represents the number of snails present at the beginning of the next generation. ○ Note: the number of each variation should not be recorded until after the students have represented survivability and reproduction. The new snails should count toward the total number recorded in the chart. ○ Once the number of snails (raisins/M&Ms) has been recorded, the next hunt can begin. ○ Each group will conduct hunts to represent 5 generations of snails. ○ When you finish all 5 generations, each group member should copy down the data from the recorder in their group before moving on to Step 6. • Have students determine the percentage of thin-shelled snails and thick-shelled snails for each of the 5 generations of data in the last two columns of the table. Write these equations on the board to assist students in their calculations: % of thin-shelled snails= (# of thin-shelled snails/total number of snails) x 100 % of thick-shelled snails= (# of thick-shelled snails/total number of snails) x 100	

4. Use the percentages of each variation to create a graph showing the changes in the thick-shelled and thin-shelled snail population over 5 generations. Be sure to title your graph, label the axes, and provide a legend.

Graph 1:

WIS
Most snails have thin shells. A few have thick shells.

WIM
Variation of this trait exists in the population.



WIS
Fewer snails have thin shells. More have thick shells.

WIM
Variation of this trait exists in the population.

WIS
At Trial 3 about half the population had thin shells and the other half thick shells.

WIM
The proportion of the population with thin shells was decreasing and the proportion with thick shells was increasing.

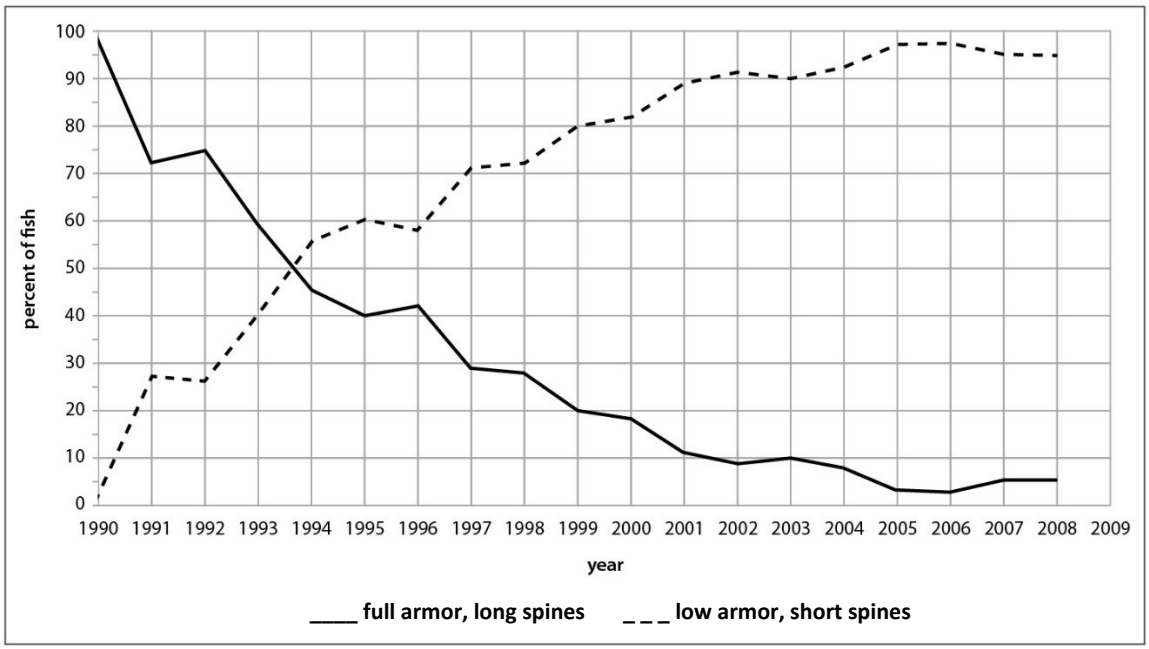
This graph shows percentage of a population of snails that have thick shells and thin shells. At the beginning of the test, most snails have thin shells, and few have thick shells which means variation exists in the population. At the end of the test, fewer snails have thin shells and more have thick shells which means variation still exists in the population. At Trial 3 about half the population had thin shells and the other half had thick shells which means that the proportion of the population with think shells was decreasing and the proportion with thick shells was increasing.

Implementation	Notes
• **STEP 4:** Students will now graph the percentage of each snail variation from their data table. Tell students that they will be comparing this graph to the graph of the Loberg Lake stickleback in the next step so they need to make sure that the two graphs will be comparable. Note that they are **not** graphing the *number of snails* but instead the *percent of each variation* just like the graph that they analyzed of the Loberg Lake Stickleback population. Have the students complete the following steps individually, in groups, or as a whole class: o Choose a title for the graph and record it at the top of the page. Make sure the titles are representative of the data that will be recorded. Titles should be something like Percentage of Snails with Thin and Think Shells in a Tidal Pool Population o Determine how the data should be graphed and label and fill in each axis. The students should decide that they will fill in each axis in the same way as the Loberg Lake Stickleback Population graph o Create a key to represent the two different variations within the population. o Graph the data from the table on page L4-2	

5. Use Identify and Interpret (I^2) on the graph you completed above by writing "What I see" and "What it means" statements. Be sure to draw an arrow from the "What I see statement" to the trend, pattern, high-point, or low-point on the graph.

6. Compare the trends you found in the graph that you completed on the previous page about your snail population with the trends that you found in the graph below from the Loberg Lake Graph. Discuss with your team any similarities or differences. Record your ideas in the space below.

Percent of Fish in Population Sample with Full and Low Body Armor



Focus on Student Thinking

The following is an example of teacher and student dialogue.

T: What pattern do you observe? (Elicit)

S1: The graphs look pretty similar.

T: What is similar? (Probe)

S2: The traits are both at 50% about halfway through the graph.

S1: And it switches at the end.

T: What do you mean by switches at the end? (Probe)

More small group conversation

T: How do your WIS/WIM statements compare? (Challenge)

Implementation	Notes
• **STEP 5:** Have students analyze the data in their graph from the previous step by using Identify and Interpret (I^2) as instructed in the student edition. *Snail Simulation Part 1, activity Follow-Up* • **STEP 6:** Have students compare trends that they found in their own graph with those of the stickleback population sample from Loberg Lake. Students should be able to see the similarities in the trends. Circulate the room and use question strategies as groups are discussing their ideas. It is important that students see that the trends are similar across the snail and stickleback populations. Try to uncover student-thinking. They need to understand that the trends show that in both cases the ***proportions*** of individuals with each variation changed within the population over generations. The proportion is represented as a percentage portion of the total population (100%). **Teacher Note:** Highlight the idea that the increase in presence of the thick-shelled variation in snails in the tidal pool or the low armor/short spined variation in the stickleback is the type of "change in population" we are talking about.	

7. A scientific study completed by Sonia Pascoal, Gary Carvalho, Simon Creer, Sonia Mendo, and Roger Hughes (2012) resulted in the following findings:

> *The intertidal snail* Nucella lapillus *generally has thicker shells at sites sheltered from wave action than at exposed sites. Crabs are abundant and pose a high risk of predation at sheltered sites, but they are rare at exposed sites.*

Compare the scientific findings of Pascoal and others explained above with the results from your snail simulation. How do your results compare to the changes found in nature?

In our simulation, the initial snail population came from an exposed site and was composed of snails with thin shells (75%) and thick shells (25%). As the environment changed to one protected from wave action, the proportion of snails with thick shells increased from 25% to 59% after five generations. This change in the population is consistent with the pattern reported by Pascoal and others.

8. Which factors of natural selection do you think influenced the findings of the snail study? Explain your thinking.

All four factors of natural selection influenced the findings of the snail study. First, the snails produced more offspring (1000 per year) than could be expected to survive. Second, the type of shell (thin or thick) was heritable meaning it was passed from parent to offspring. Third, individual snails within the population had to compete for resources such as food and habitat. Finally, the type of shell displayed by an individual snail affected its probability of surviving to reproduce. A thick shell conferred a survival advantage in the tidal pool environment and in the presence of the crab predator.

Implementation	Notes
• **STEP 7:** Read the findings of the scientific snail study as a class. This is an important place to have a whole-group discussion. If needed, draw or outline the events of the findings on chart paper to make it clearer for students. Before moving onto the next step, students need to understand what was happening in the study. You can prompt them to think about how the four factors are working in this phenomenon, but it is important not to lead their thinking or come to a conclusion. They will need to come up with their own conclusions as they work through the next steps. • Read the instructions to the class. Tell the students to discuss similarities between their data and the scientific findings of Pascoal and others in their small groups and record them in the space provided. Prompt students to consider the trends that they see in both sets of data as they discuss the question. As you circulate, look for evidence that students are noticing that in both populations, there were higher proportions of one variation in each environment. Note that you may need to guide student discourse by asking some elicit and probe questions, such as: o What do you notice about the proportion of each variation in the scientific findings described in step #7? o Based on these scientific findings what do you predict might be observed in the opposite environment (tide pools/sheltered sites)? o Which environment were we simulating in this activity? Why do you think that? o Was our activity simulating the same environment described in the scientific findings? Why or why not? o If our activity was simulating the opposite environment of the scientific findings, can the two be compared? If yes, how so? • **STEP 8:** Students will discuss in small groups which factors of natural selection they think influenced the findings of the snail study. Circulate and prompt students to explain their thinking. It is not enough to identify the factors; their responses should also use scientific ideas and their understanding of the snail phenomena. Be prepared for students to think it is only some of the four factors. Do not correct these misconceptions at this point. Instead, tell students that they will have a chance to test these predictions in part 2 of the simulation. Tell them to keep their ideas in mind during part 2 to determine if they can support their ideas with evidence.	

Lesson 4: Natural Selection Simulation

Phase of Lesson: *Snail Simulation Part 2 Activity Setup, Activity, Activity Follow-Up*

Main Learning Goal: The interaction of four factors of natural selection influence the changes that occur in populations of organisms.

Focus Question: How do the four factors of natural selection explain the changes we see happening in populations?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (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 thatare better able to survive and reproduce in that environment.

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Time: 45 Minutes

STeLLA Strategies

- Strategy 6: Engage students in developing and using content representations and models.

Science Ideas

- There are four factors that comprise Darwin's idea of natural selection.
- There is evidence that supports the four factors of natural selection.
- Survivability rates are affected by both biotic and abiotic factors.
- Predation can affect how many organisms within a population survive and reproduce.
- Competition for food can affect how many organisms within a population survive and reproduce.
- Selection pressures can favor a certain trait variation.
- A trait variation can be favored, not favored, or neutral.
- A favorable trait variation *may* help an organism survive and reproduce.

Common Student Ideas

- Changes in the environment cannot cause changes in the traits of populations living in that environment.
- All individuals within a population are the same. Any differences are trivial and unimportant.
- Every difference has a purpose.
- Natural selection leads to perfection.
- Any of the four factors of natural selection can be removed and still explain the changes we see in various populations in nature.
- Only select factors of natural selection are necessary to explain observed changes in populations over time.

Snail Simulation Part 2

To learn about how each variable affects a population, we will conduct a second snail simulation in which we remove one of the four factors of natural selection and analyze the effect it has on the population of snails.

9. Before completing the second part of the simulation, you will need to think about the different variables that relate to each of the four factors of natural selection. Draw an arrow from the factor listed on the left to a variable listed on the right that best matches with it. Some factors have more than one matching variable**. Note: Rather than drawing lines, connections are represented here by matching the letters to each corresponding factor.**

Factor 1: More individuals are born than can survive and reproduce. **c d f h**	a. Different variations of traits, like a thin shell or thick shell.
	b. The amount of available food
Factor 2: Individuals within a population inherit traits from their parents. These traits show variation. **a e**	c. The number of individual organisms competing for food or habitat
	d. The number of organisms that reproduce over a certain period of time
Factor 3: Individuals in a population compete for limited resources (e.g., food, habitat, or mates). **b (c) g**	e. The number of trait variations within a population of organisms
	f. The number of organisms that survive to adulthood
Factor 4: Some offspring inherit variations of traits that help them better survive and reproduce in their environment. **(d) (f)**	g. The amount of habitat available to the population
	h. The number of organisms that are born over a certain period of time

Focus on Student Thinking

- Let students know that lining factors and variables will help them in the next two parts of this activity.
- Following is an example dialogue between a teacher and student AFTER students have has a chance to test their ideas about matches:

  T: Let's work together to identify the matches we can all agree on. Can we agree on one or more variables that link to Factor 1? **[Elicit]**

  More small group conversation

  T: What did you decide? **[Elicit]**

  Repeat for other variables and identify those that were difficult to match.

Implementation	Notes
Activity Set-Up • Let students know that to get started, they will think about possible variables related to the four factors. Model, with the entire class, the thought process they will need to follow in order to complete Step 9. Have students read Factor 1: More individuals are born than can survive and reproduce. Ask them what possible variables they would need to test to see if Factor 1 does indeed influence changes in stickleback populations (STeLLA Strategy 1). • The main purpose of this task is to help students link the variables in the simulation to Darwin's four factors. During the next part of the lesson, they will manipulate some of the variables to determine how each factor affects the population changes we observe in nature. • **STEP 9:** Students should work with a partner or their group when completing this step. Let them know that the group should discuss and consensually decide on a pairing of factor and variable prior to drawing the arrow. Also let them know that they should have a sound rationale for making the link between the variable and the factor. They may find the analogy map created in STEP 2 helpful in this step. Invite small groups to compare the arrows they drew. • Lead a discussion about the pairings that students made and ask probe questions (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) to ensure that students have thought about why a particular variable links to a particular factor. Refer to ***Focus on Student Thinking*** on the SE page to see an example student dialogue using Strategy F: Making explicit links between science ideas and activities.	

10. With your partner or group, decide what you will need to change for each factor and predict how the change will affect the population. Make a prediction about what will happen to the percentage of each trait (e.g., shell thickness) present in the population when you remove each factor. Record your prediction in the space below.

Focus on Student Thinking

- Remind students that we will revise the simulation (model) to determine the effect of removing each of the four factors. Ask students, What would you change in the simulation (refer to Simulation handout) to remove a factor. For example, you might change or delete a step in the simulation process.
- Following is an example dialogue between a teacher and student:

T: Which step in the Simulation represents Factor 1?

S1: I'm not sure. Step 1?

T: What do others think?

S2: I'm not sure either.

T: So, let's look at the Analogy Map you completes in STEP 2 and the matching activity you completed in STEP 9. What aspects of the model link most closely to Factor 1? Of you can't figure out Factor 1, see if there is another factor that you can figure out. [**Linking ideas and activities.]**

Small group talk

S3: We couldn't figure out Factor 1, but we think that we'd remove the crab step for Factor 3.

T: Why do you think that **(Probe)**

S3: Well, by removing the crabs, the snails can compete better.

T: What do others think? **(Elicit)**

Ss: We agree.

T: OK. What is it about removing the cabs that help the snails compete better? **(Challenge)**

S4: If they don't get eaten, they survive.

T: Let's read Factor 3 again. Is it about competition from BEING eaten or competition for food to EAT? **(Challenge; Leading question)**

S3: For food.

T: OK. So, removing the crabs does NOT link to factor 3. Now let's see if you can identify which factor links to "removing crabs" and which part of the simulation related to "food to eat". I'll leave you to it. **[Elicit]**

Implementation	Notes
Activity • **STEP 10:** Students should think through how they will change the simulation to remove each factor. Student will record their ideas in the table. They may find the analogy map created in STEP 2 helpful in this step. Refer to ***Focus on Student Thinking*** on the SE page to see an example student dialogue using Strategy F: Making explicit links between science ideas and activities.	

Cause	*Change to* the Simulation
Factor 1: More individuals are born than can survive and reproduce. To eliminate Factor 1 from the population, we need to…	Increase the reproduction factor from 5 to 1000 (the number of hatchlings typically born as reported by scientists).
Factor 2: Individuals within a population inherit traits from their parents. These traits show variation. To eliminate Factor 2 from the population, we need to…	Remove variation by only using raisins or M&Ms.
Factor 3: Individuals in a population compete for limited resources (e.g., food, habitat, or mates). To eliminate Factor 3 from the population, we need to…	Remove the survival die roll step.
Factor 4: Some offspring inherit variations of traits that help them better survive and reproduce in their environment. To eliminate Factor 4 from the population, we need to…	Remove the crab hunt step.

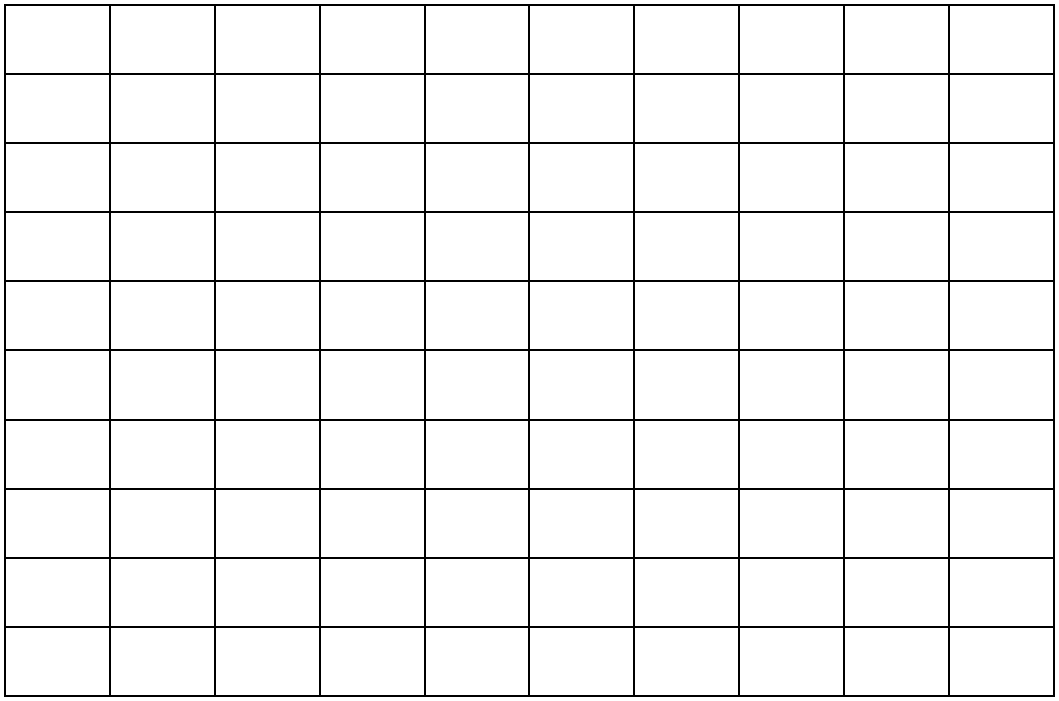
Implementation	Notes

11. Follow your teacher's directions and circle the variable that you and your partner or group will remove from your simulation.

Group A = Remove Factor 1	Group B = Remove Factor 2
Group C = Remove Factor 3	Group D = Remove Factor 4

You were asked to remove one of the four natural selection factors and to predict how the snail simulation would be affected. Use the graph below to illustrate what your prediction would look like. Assume that you again start with a snail population that has 75% thin shells and 25% thick shells. You don't need to include a number scale on the y-axis. We are just concerned with the shape of the data line(s).

Graph 2.



Compare Graph 2 (Snail Simulation Part 2) showing one factor of natural selection removed to Graph 1 (Snail Simulation Part 1) with all four factors included. Discuss the similarities and differences you notice with your group.

Implementation	Notes

• **STEP 11:** Students should continue to work in the same groups for the next steps. Assign each group to a specific variable by lettering off A-D; try to ensure that each factor is being studied by at least two groups. Make sure every student circles the correct factor to remove. Move around the room to see what students are thinking.
• As a class, discuss and make a final decision about how each group will represent the removal of each factor. Possible scenarios are:
  ○ Removing factor 1: All hatchlings survive, regardless of food availability. The reproductive factor in step 5 would go higher OR to zero if reproduction does not occur.
  ○ Removing factor 2: Only one type of snail exists. Either M&Ms or raisins. So, in step 1 we begin with all M&Ms or raisins.
  ○ Removing factor 3: Food is plentiful, so eliminate survivability die roll in step 4.
  ○ Removing factor 4: Remove crab hunt in step 2.	

12. Are the patterns you see in graph 2 consistent with what we see in nature? Explain your answer.

If all snails survive because there are unlimited resources and no predation, then the population will increase without limit. This is unrealistic because every natural environment has a carrying capacity that limits how large the population can get.

If there is no variation in shell type, then the population will increase due to reproduction but will be limited by resource availability and predation. The impact of predation will be greater if the snails have thin as opposed to thick shells.

13. With your group discuss the following question: What effect did removing this factor have on the change you observed in the population of snails? Record your response in the space below according to your teacher's directions.

Implementation	Notes

• **STEP 12**: Notice that the SE pages include a graph similar to Part 1 of the simulation, but not the table. Based on their assigned factor students should add titles (not numbers) to the axes and draw the shape of the graphed line. Basically, this is a thought experiment.
• **STEP 13**: The patterns students see in graph 2 will generally NOT be consistent with what is observed in nature.
  ○ The removal factor 1 (reproduction) either leads to exponential growth, which nature cannot support, or it leads to no growth at all and the extinction of the population.
  ○ The removal of factor 2 (variation) means that the population cannot adapt to changing environmental conditions. The entire population would survive and reproduce, or the entire population would eventually die out depending on how well the traits are adapted to the environment.
  ○ The removal of factor 3 (competition for resources) will allow the snail population to increase without limit; again, this cannot be supported by nature.
  ○ The removal of factor 4 (survival advantage) leads to snails of each type displaying the same growth pattern and eliminating any environmental effects.	

Lesson 4: Natural Selection Simulation

Phase of Lesson: *Activity Follow-Up*

Main Learning Goal: The interaction of four factors of natural selection influence the changes that occur in populations of organisms.

Focus Question: How do the four factors of natural selection explain the changes we see happening in populations?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (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 thatare better able to survive and reproduce in that environment.

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Time: 10 Minutes

STeLLA Strategies

- ❖ Strategy 9: Engage students in making connections by synthesizing and summarizing key science ideas.

Science Ideas

- There are four factors that comprise Darwin's idea of natural selection.
- There is evidence that supports the four factors of natural selection.
- Survivability rates are affected by both biotic and abiotic factors.
- Predation can affect how many organisms within a population survive and reproduce.
- Competition for food can affect how many organisms within a population survive and reproduce.
- Selection pressures can favor a certain trait variation.
- A trait variation can be favored, not favored, or neutral.
- A favorable trait variation *may* help an organism survive and reproduce.

Common Student Ideas

- Changes in the environment cannot cause changes in the traits of populations living in that environment.
- All individuals within a population are the same. Any differences are trivial and unimportant.
- Every difference has a purpose.
- Natural selection leads to perfection.

14. Share your findings from part 2 with other classmates that removed different factors from their simulation. Your discussions will be documented in the cause and effect chart below.

Cause	Effect
Factor 1: More individuals are born than can survive and reproduce. **If** Factor 1 is NOT present in the population…	…all snails survive and reproduce, **then** the population can increase without limit.
Factor 2: Individuals within a population inherit traits from their parents. These traits show variation. **If** Factor 2 is NOT present in the population…	…the snail population shows no variation in the shell trait, **then** all individuals will display the same type of shell regardless of their environment.
Factor 3: Individuals in a population compete for limited resources (e.g., food, habitat, or mates). **If** Factor 3 is NOT present in the population…	…competition for resources doesn't exist, **then** the snail population will increase without limit.
Factor 4: Some offspring inherit variations of traits that help them better survive and reproduce in their environment. **If** Factor 4 is NOT present in the population…	…both thick and thin shells allow snails to survive and reproduce at the same rate, **then** the proportions of individuals in the population with thick and thin shells will not change over time.

Implementation	Notes
Activity Follow-up • **STEP 14**: Groups should write down conclusions from their discussion in the cause-and-effect chart. As they work, move around the room to hear what students are thinking. • As students complete this step, remind them that the goal of the second trial is to observe the effect that removing one of the four factors has on the population. As groups share their ideas, ask them to consider the lesson focus question, How do the four factors of natural selection explain the changes we see happening in populations? The key idea is that all four factors interact to explain how populations change over time. **Specifically, when a particular trait is favored in the environment for long enough, then the four factors of natural selection work together to change the proportion (percentage) of the population with that trait.**	

Focus on Student Thinking

- Ask Students, What can you say now about what happens (effect) when each factor is removed (cause) from the model?
    - Student responses may include the following:
        - This seems too easy. What are we missing?
        - I'm not sure what would happen because the population includes both thin-shelled and thick-shelled snails.
        - The number of thin-shelled snails decrease, and the number of thick-shelled snails increase.
    - Following is an example dialogue between teacher and student:
        - T: What can we say now about what happens (effect) when each factor is removed (cause) from the model? **[Elicit]**
        - S1: This seems too easy. We didn't even have to play the game.
        - T: Why didn't you need to run the simulation, or play the game as you say?
        - S1: Because what would happen is obvious.
        - T: Can you give an example of something that was obvious and why it was obvious?
        - **[Probe]**
        - S1: Factor 1. Obviously, the population will increase completely.
        - T: You say the population will increase completely. What would that look like on the graph if you had drawn it? Let's hear from some of your teammates. **[Probe]**
        - S2: It would build up to the top.
        - T: Can you draw that and show us? **[Probe]**
        - S2: [Draws a line from "that looks a bit like the low armor stickleback"]
        - T: Team, can you say more about how you would label this graph? What would you put on the axis? What would you write in the legend? **[Challenge]**

Implementation	Notes
Refer to ***Focus on Student Thinking*** on the SE page to see examples of questions for Strategies 2 and 3.	

Lesson 4: Natural Selection Simulation

Phase of Lesson: *Summarize and Link*

Main Learning Goal: The interaction of four factors of natural selection influence the changes that occur in populations of organisms.

Focus Question: How do the four factors of natural selection explain the changes we see happening in populations?

Unit Overarching Goal

Populations of organisms change over generational time (evolve) as a consequence of natural selection and adaptation due to the interaction of four factors: (1) the potential for a population (species) to increase in number, (2) variations in traits inherited from organisms' parents, (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 thatare better able to survive and reproduce in that environment.

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Time: 25 Minutes

STeLLA Strategies

- ❖ Strategy I: Summarize key science ideas.

Science Ideas

- There are four factors that comprise Darwin's idea of natural selection.
- There is evidence that supports the four factors of natural selection.
- Survivability rates are affected by both biotic and abiotic factors.
- Predation can affect how many organisms within a population survive and reproduce.
- Competition for food can affect how many organisms within a population survive and reproduce.
- Selection pressures can favor a certain trait variation.
- A trait variation can be favored, not favored, or neutral.
- A favorable trait variation *may* help an organism survive and reproduce.

Common Student Ideas

- Changes in the environment cannot cause changes in the traits of populations living in that environment.
- All individuals within a population are the same. Any differences are trivial and unimportant.
- Every difference has a purpose.
- Natural selection leads to perfection.

Implementation	Notes
Summarize • **STEP 15:** Invite students to respond to the prompt and circle the factor or factors required to explain the changes in populations over time. This step links to the focus question, How do the four factors of natural selection explain the changes we see happening in populations? • **STEP 16:** Students should use what they've learned to link ideas across their stickleback and snail activities to explain why they circled particular factors in STEP 15.	

Summarize and Synthesize Ideas

The focus question for this lesson is, **"How do the four factors of natural selection explain the changes we see happening in populations?"**

15. Based on your cause and effect chart on page L4-12, decide which factor or factors of natural selection are necessary to explain the changes that we see in populations in nature. Circle the factors below.

    Factor 1: *More individuals are born than can survive and reproduce.*

    Factor 2: *Individuals within a population inherit traits from their parents. These traits show variation.*

    Factor 3: *Individuals in a population compete for limited resources (e.g., food, habitat, or mates).*

    Factor 4: *Some offspring inherit variations of traits that help them better survive and reproduce in their environment.*

16. Use evidence from our stickleback and snail studies along with the ideas in your cause and effect chart to explain your answer to #15.

    In each case (sticklebacks and snails) the species can produce many more offspring than the environment can support (factor 1). This means that many offspring will die, either because they can't find enough food to survive and reproduce (factor 3) or because they are eaten by a predator (factor 4). Offspring inherit traits from their parents (factor 2). Some trait variations give a survival advantage depending on the environment (factor 4). For example, sticklebacks with the low armor and short spines variation are favored in a freshwater environment. Likewise, snails with thick shells are favored in tidal pools given their ability to better survive in the presence of predator crabs.

References

Pascoal, S., Carvalho, G., Creer, S., Mendo, S., & Hughes, R. (2012, December 13). Plastic and Heritable Variation in Shell Thickness of the Intertidal Gastropod Nucella lapillus Associated with Risks of Crab Predation and Wave Action, and Sexual Maturation. Retrieved January 17, 2019, from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0052134

Focus on Student Thinking

- Ask Students, what they can say now about the focus questions: How do the four factors of natural selection explain the changes we see happening in populations?
    - Student responses may include the following:
        - The most important factors are #1 and #3.
        - All four factors of natural selection are required to explain the patterns we see in the environment.
        - We've already written this. Why are we having to do it again?
          Note: *If students are reluctant to write their response, have them identify WHERE in their SE pages they've written their responses and help them add ideas to that text to respond to this question. A likely location may be in the cause and effect table. Remind them to refer to changes in both stickleback and snail populations.*
    - As students respond, ask probe questions (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) to ensure that students have thought about why evidence and models are important to fully answer this question.
    - Following is an example dialogue between teacher and student:
        - T: What can we say now about the focus question for this lesson, **How do the four factors of natural selection explain the changes we see happening in populations? (Elicit**)
        - S1: I think Factors 1 and 3 are most important
        - T: What do others think?
        - S2: I circled all four factors.
        - T: S1 thinks 1 and 3 are most important and S2 says they are all important. **(Probe)** Turn to a partner and see if you can point out evidence from the activities in lesson 4 that would help you argue for one idea, the other, or perhaps an idea that's not been shared, yet. **(Challenge; Linking ideas and activities)**

References

Pascoal, S., Carvalho, G., Creer, S., Mendo, S., & Hughes, R. (2012, December 13). Plastic and Heritable Variation in Shell Thickness of the Intertidal Gastropod Nucella lapillus Associated with Risks of Crab Predation and Wave Action, and Sexual Maturation. Retrieved January 17, 2019, from https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0052134

Implementation	Notes
Refer to ***Focus on Student Thinking*** on the SE page to see examples of questions for Student Thinking Lens Strategies 1, 2 and 3 as well as Science Content Storyline Lens Strategy F: Making explicit links between science ideas and activities. • Close the lesson by sharing that, in this lesson, we learned that all four factors are required to explain the patterns we see in nature when populations change over time. **Specifically, when a particular trait is favored in the environment for long enough, then the four factors of natural selection work together to change the proportion (percentage) of the population with that trait.** *Link to Next Lesson* • In the next lesson, we'll use all that we've learned to predict what might happen to the stickleback population in the future.	