A Study of Changes in Population Unit

Lesson 3: A Closer Look at Darwin

Grade 9-10 General Biology

Length of lesson: 90 minutes

Placement of lesson: Lesson 3 of 6

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 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 3 Main Learning Goal

Darwin's idea of natural selection consists of four factors supported by evidence. The four factors are 1) the potential for a species to increase in number; 2) organisms have variations in traits inherited from their parents; 3) competition for environment's limited supply of resources that individuals need to survive and reproduce; and 4) the ensuing proliferation of those organisms that are better able to survive in reproduce in that environment.

Lesson 3 Focus Question

What evidence supports Darwin's idea of how populations of organisms change over time?

Ideal student response

The changes that occurred to the Loberg Lake stickleback population fit well with Darwin's ideas of natural selection. Natural selection is caused by four factors that, over time, can change a population. These four factors are stated below:

1. More individuals are born than can survive and reproduce.
2. Individuals within a population inherit traits from their parents. These traits show variation.
3. Individuals in a population compete for limited resources (e.g., food, habitat, or mates).
4. Some offspring inherit variations of traits that help them better survive and reproduce in their environment.

Over time, as more individuals are born with traits that help them survive and reproduce, the population will change. The changes that occurred to the Loberg Lake stickleback seem to fit with Darwin's ideas of natural selection. The stickleback have many offspring, and not all offspring survive and/or reproduce, which aligns with factor 1. Variations exist within the body armor trait, and this trait can be passed down from parents to offspring. This aligns with factor 2. Also, the stickleback that do survive and reproduce have traits, like low body armor and short spines, that help these fish survive and reproduce, and this fits with factor 4.

Science Content Storyline

Evidence generated from studying the Loberg Lake stickleback population supports Darwin's ideas of natural selection. Stickleback fish have many offspring, and not all offspring survive and/or reproduce. Variations exist within the stickleback body armor trait, and this trait can be passed down from parents to offspring. Also, as time went on, a larger proportion of the stickleback population had the low body armor trait variation that helped them escape dragonfly nymph predation.

Materials

- Stickleback Cards (1 card set for 3 to 4 students) Please print from https://www.biointeractive.org/sites/default/files/Stickleback_F2_Cards.pdf, which is linked from https://www.biointeractive.org/classroom-resources/using-genetic-crosses-analyze-stickleback-trait
  Note: Print the set, divide into sets of 10 cards (1-10, 11-20, etc.)
- rulers (1 per student)
- Loberg Lake Cause and Effect Cards (1 card set per student)

Lesson 3 General Outline

Time (min)	Phase of Lesson	How the science content storyline develops
10	**Revisit the Unit Central Question and Link to Prior Learning:** What is the process that leads to changes in populations over time? **Lesson Focus Question:** What evidence supports Darwin's idea of how populations of organisms change over time?	
65	**Taking a Closer Look at Darwin's Ideas** <u>Activity Setup</u> Students read about the four factors of natural selection and discuss what these principals mean to populations of organisms over time. Students then transition to a series of activities that help develop a deeper understanding of these factors by looking for evidence that supports the existence of these factors in nature. <u>Activity</u> Students are engaged in a series of tasks that have them looking for evidence that supports the four factors that make up Darwin's ideas for natural selection. Tasks include a reading, making observations from photographs of fish, and an examination of stickleback research data. As students complete the tasks, they are encouraged to think about and note evidence for the four factors of natural selection. <u>Activity Follow-up</u> The teacher facilitates a discussion about evidence students found that supports the four factors of natural selection**.**	• Adult stickleback produce more offspring than can survive and reproduce. • Armor and spines are heritable traits. • A given trait is fixed during the lifetime of an individual stickleback. • Some heritable traits are more advantageous than others in a particular environment. • Stickleback offspring look similar to parents, but traits among parents and offspring can vary.
15	**Summarize and Link:** The teacher summarizes the lesson and links to the next lesson.	

Lesson 3: Cause and Effect: Changes over Time

Phase of Lesson: *Lesson Focus Question*

Main Learning Goal: Darwin's idea of natural selection consists of four factors supported by evidence. The four factors are 1) the potential for a species to increase in number; 2) organisms have variations in traits inherited from their parents; 3) competition for an environment's limited supply of resources that individuals need to survive and reproduce; and 4) the ensuing proliferation of those organisms that are better able to survive in reproduce in that environment.

Focus Question: What evidence exists to support Darwin's idea of how populations of organisms change over time?

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 andpredictions
- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy G: Link science ideas to other science ideas
- ❖ Strategy B: Set the purpose with a focus question

Science Ideas

- There is evidence to support Darwin's idea of natural selection.
- Science accepts the evidence that supports natural selection.

Common Student Ideas

- Changes in the environment cannot lead to 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.

Lesson 3: A Closer Look at Darwin

Introduction

Darwin's idea of natural selection has four specific factors. In this lesson, you will have a chance to consider whether the stickleback fish provide evidence of the four factors. This will help you determine if Darwin's ideas are accurate to describe how populations change over time.

Process and Procedure

1. Write the focus question for the lesson in the box below. Underneath the box, write your best ideas about the question. Leave space to revise your ideas as you learn more.

What evidence exists to support Darwin's (Scientist 2's) idea pf how populations of organisms change over time?

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 populations of organisms over time? Let them know that as the lessons progress, they will be able to better answer this question. ● Ask students to share the Loberg Lake scenario from Lesson 2 and what they learned about the stickleback population that lived in the lake. They may need to refer to their notebooks to refresh their memories. Following are key ideas students might share (STeLLA Strategy G): ○ The focus question was, "What would happen to a population if there were a change in the environment where the population lived?" ○ The scenario described changes in the stickleback population in Loberg Lake. ○ In the 1980s, the stickleback in the lake had short spines and low body armor. This population of fish was exterminated to improve recreational fishing. ○ In 1990, the stickleback were found in the lake, and this new population looked like saltwater stickleback as the fish had long spines and full body armor. ○ However, by 2015, the stickleback population looked much more like the 1982 stickleback population and less like saltwater versions found in the lake in 1990. ○ From the data, we found that the stickleback population did change and that these changes could be explained using ideas from Lamarck and Darwin. ○ Evidence from the data we observed supports Darwin's ideas more than Lamarck's ideas. Evidence that supported Darwin included the fact that individual fish cannot willfully change their bodies, and it took many generations for the population to go from most fish having long spines and full body armor to most of the fish having short spines and low body armor. However, the idea that characteristics can be passed from parent fish to their offspring supports both Darwinian and Lamarckian ideas. ● Highlight key ideas, particularly evidence they discussed in the last lesson and how the evidence supported Darwin's ideas over Lamarck's. Let students know that *scientists accept* Darwin's ideas about how populations change. In today's lesson they will take a closer look at evidence for the factors that make up Darwin's idea of natural selection. ● **STEP 1:** Introduce the focus question: "What evidence supports Darwin's idea of how populations of organisms change over time?" Write this question on the board so the students can write it in the box on step 1 and refer to the question throughout the lesson. ● Let students know that they will be answering this focus question at the end of the class period. However, encourage them to write down notes that will help them answer the focus question in the blank space under the box.	

Lesson 3: Cause and Effect: Changes over Time

Phase of Lesson: *Taking a Closer Look at Darwin's Ideas*

Main Learning Goal: Darwin's idea of natural selection consists of four factors supported by evidence. The four factors are 1) the potential for a species to increase in number; 2) organisms have variations in traits inherited from their parents; 3) competition for an environment's limited supply of resources that individuals need to survive and reproduce; and 4) the ensuing proliferation of those organisms that are better able to survive in reproduce in that environment.

Focus Question: What evidence supports Darwin's idea of how populations of organisms change over time?

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: 15 minutes

STeLLA Strategies

- ❖ Strategy 1: Ask questions to elicit student ideas andpredictions
- ❖ Strategy 2: Ask questions to probe student ideas andpredictions
- ❖ Strategy 3: Ask questions to challenge student thinking

Science Ideas

- Adult stickleback produce more offspring than can survive and reproduce.
- Armor and spines are heritable traits.
- Stickleback offspring look similar to parents, but traits among parents and offspring can vary.
- A given trait is fixed during the lifetime of an individual stickleback. (The trait cannot be willfully changed by the individual to make the trait advantageous.)
- Some heritable traits are more advantageous than others in a particular environment.

Common Student Ideas

- Changes in the environment cannot lead to 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.

Taking a Closer Look at Darwin's Ideas

2. In the last lesson, you found that Darwin's idea of natural selection better explains the changes that occurred to the Loberg Lake stickleback population. There are four factors that make up natural selection. Read about the factors below. Discuss each with your group to make sure you know what each factor means.

   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.*

Focus on Student Thinking

- Ask students what information or datum about the sticklebacks could provide evidence for factor 1 (STeLLA Strategy 1).
  - Student responses may include the following:
    - We need to know how many stickleback babies an adult stickleback produces during its lifetime.
    - We need to know how old stickleback are when they begin to reproduce.
    - We need to know how long stickleback live.
  - As students respond, ask probe questions (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) to ensure that students have thought about why the piece of information or datum is important to determining whether there is evidence to support that factor.
  - Following is an example dialogue between teacher and student:
    - T: What pieces or types of information do you need to know in order to help you see if changes in the stickleback population seem to follow natural selection? (Elicit)
    - S: We need to know how many stickleback babies are produced during a stickleback's lifetime.
    - T: Can you expand on this idea and share with the class why this piece of information is important? **(Probe)**
    - S: If more stickleback babies are born than can survive, we need to know how many stickleback babies, on average, are produced by one adult stickleback.
    - T: And can you say more about how knowing the number of babies could help us? (Probe)
    - S: Well, we need to know more than just the number of babies that are born. We need to know how many die before they reach adulthood and have babies. To support factor 1, the information needs to show more babies dying than reproducing.

3. Today, you will examine new information and data about the Loberg Lake stickleback population. As you examine the information and data, you may find evidence that supports one or more of the four factors listed in step 2. When you find evidence that supports one or more of the factors, fill in the appropriate box in the chart below related to the factor. *Do not write anything on this chart until you begin to examine the data.*

Implementation	Notes
Activity Setup ● **STEP 2:** The purpose of this step is to introduce the four factors that make up natural selection and have students begin thinking about how these factors could have caused the changes in the stickleback population. In doing so, students will begin to develop a deeper understanding of natural selection and how it can change a population of organisms over time. ● In groups, ask students to take turns reading the four factors aloud. After reading each factor, the group should discuss what the factor means in everyday language and how it relates to the stickleback population they have been studying. As a class decide on a short descriptor (1-3 words) that represents the idea of each factor (i.e., Factor 1 – "too many born" or "too many offspring"). ● Further the discussion by asking students to think what information about the stickleback would provide evidence to show that the changes in stickleback population followed natural selection. As groups talk, circulate around the room to ask probe questions about their ideas. Refer to "Focus on Student Thinking" in the SE key for examples of probe questions that might fit with a discussion about factor 1. • **STEP 3:** Let students know that the chart in step 3 will help them summarize the information they will learn during this lesson about the Loberg Lake stickleback. As they learn more about each factor, they need to fill in the appropriate box with evidence related to the factor. The information they write in the boxes provides evidence for each factor as it relates to the stickleback fish population. Emphasize to students that they should only write information that they are confident about in the boxes.	

Four Factors of Natural Selection

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.**
The Stickleback Field Guide states that a stickleback fish lays 75- 100 eggs every year. SE 3-4 The Aquarium Study shows that the fish population will increase exponentially over time in an aquarium. For example, if there are 5 females in year 1 and each lays 100 eggs assuming (1/2 of the offspring are female and survive and lay 100 eggs), then in 3 years there will be over 1 million fish in the tank. SE 3-5 Note that page numbers for where the evidence can be found in the SE are included for each statement.	The stickleback Study Guide states that stickleback are between 30 and 80 mm in length and vary in color – gray, olive, black, and brown. SE 3-4 The stickleback measurement data showed that the fish vary in size and spine length. For example, the size of the 10-stickleback varied from ____mm to _____. Their spine length varied from ____mm to _____ mm. SE 3-6
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.**
The Stickleback Field Guide states that all stickleback eat worms, larvae of aquatic insects, small fish, etc.; therefore, they will have to compete for food. SE 3-4 The Stickleback and Limited Food Study shows that stickleback will compete for food and not all will survive. SE 3-12	The Stickleback Field Guide states that more ocean-dwelling stickleback tend to have full body armor, while fewer freshwater stickleback have full body armor. SE 3-3 The Stickleback and Trout Study shows that when in a tank with trout, more stickleback with long spines survived. In our study, more long-spine than short-spine stickleback survived in 20 out of 27 trials. SE 3-9 The Stickleback Field Guide states that all varieties of stickleback are eaten by other fish, birds, otters, and nymphs, so they compete for survival. Sometimes [in some environments] spines help the stickleback survive and sometimes no spines is the favored trait. SE 3 - 4, SE 3-9 The Stickleback and Trout Study shows that stickleback have to compete for survival when in a tank with trout. In each trial, there were originally 10 stickleback in the tank, but only 5 or fewer survived. In all 27 trials, trout ate more stickleback without spines so that was the favored trait. Fish with no spines survived more often. SE 3 - 8, SE 3 – 9

Implementation	Notes

Lesson 3: Cause and Effect: Changes over Time

Phase of Lesson: *Taking a Closer Look at Darwin's Ideas*

Main Learning Goal: Darwin's idea of natural selection consists of four factors supported by evidence. The four factors are 1) the potential for a species to increase in number; 2) organisms have variations in traits inherited from their parents; 3) competition for an environment's limited supply of resources that individuals need to survive and reproduce; and 4) the ensuing proliferation of those organisms that are better able to survive in reproduce in that environment.

Focus Question: What evidence supports Darwin's idea of how populations of organisms change over time?

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: 30 Minutes

STeLLA Strategies

- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy 4: Engage students in communicating in scientific ways
- ❖ Strategy 5: Engage students in analyzing and interpreting data and observations
- ❖ Strategy H: Highlight key science ideas and focus question throughout

Science Ideas

- Adult stickleback produce more offspring than can survive and reproduce.
- Stickleback offspring look similar to parents, but traits among parents and offspring can vary.
- A given trait is fixed during the lifetime of an individual stickleback. (The trait cannot be willfully changed by the individual to make the trait advantageous.)
- Some heritable traits are more advantageous than others in a particular environment. Armor and spines are heritable traits.

Common Student Ideas

- Changes in the environment cannot lead to changes in the traits of populations living in that environment.
- All individuals within a population are the same. Any differences are trivial or unimportant.

4. One way to collect more information about whether the Loberg Lake stickleback fit with Darwin's ideas of natural selection is to learn more about the fish in general. Read the following field guide to find out more about stickleback. As you read, highlight any information that would help you complete the chart in STEP 3. Be sure to label each highlighted piece with 1, 2, 3, or 4 depending on the factor it supports.

   Discuss ideas from the field guide and add them to the Four Factors of Natural Selection graphic organizer to in STEP 3.

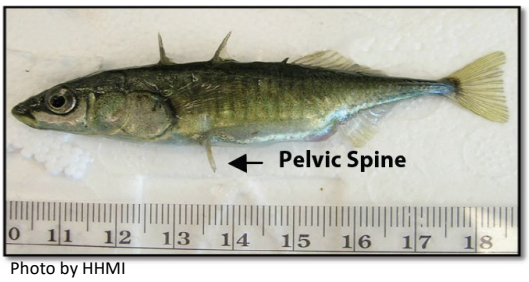


Photo by HHMI

Field Guide to Stickleback

Stickleback are small fish that can be found in freshwater and in the ocean. They are one of the most scientifically studied fish in the world.

Appearance: Stickleback fish are between 30 and 80 mm (1 and 3 inches) in length. They vary in color with gray, olive, brown, and black fish. Many stickleback have spines on their back, with some also having spines on their underside. They do not have scales. However, some stickleback have bony armor plates along their bodies. Spines and armor can protect stickleback from predators.

Habitat: Stickleback live in shallow water near shores where there is usually a lot of plant life. They can be found in the ocean and in freshwater. There are 16 different species of stickleback fish, and the ocean-dwelling fish tend to have full body armor. The freshwater fish are less likely to have full body armor. It is possible for ocean-dwelling fish to enter areas of freshwater during the time when females lay eggs.

Geography: Most species are found only in the Northern Hemisphere. There are a few species that can be found in the Southern Hemisphere. There are also species that travel into different areas at different times of the year, depending on the temperature.

Feeding: Stickleback eat worms, larvae of aquatic insects, small fishes, and occasionally their own eggs and fry (very young fish).

Predators: Stickleback have a number of predators. They are eaten by other fish (including other stickleback), birds, otters, and dragonfly nymphs.

Lifespan: Stickleback live 1–3 years. They can reproduce after one year.

Reproduction: Some species of stickleback spawn, or release eggs, during a time frame of about two months in the spring. Others have a longer spawning season of six or seven months. The males develop red bellies or red pelvic fins during the breeding season. The males build nests, and females deposit 75-100 eggs into the nest. The males then care for the eggs and fry, attacking other fish if necessary, until the young fish can take care of themselves.

Implementation	Notes
Activity ● **STEP 4:** Let students know that the purpose of step 4 is to provide information about stickleback in general. This will help them as they continue to think about whether Loberg Lake stickleback fit with Darwin's ideas of natural selection. (STeLLA Strategy H) ● Emphasize that as they read, students should underline information that would help them complete the four factors chart in step 3. They should also label each highlighted piece 1, 2, 3, or 4 depending on which factor the highlighted piece supports. Students should add information from the reading to the Four Factors of Natural Selection graphic organizer in STEP 3. ● Students can work in small, independent working groups to complete STEPs 4–14. However, during the field test, teachers found it helpful to work through step 5 as a whole class.	

Focus on Student Thinking

- Use appropriate probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) as students are completing their calculations and answering the questions.

  Following are some question examples:

  - Where did you find that in the text? (Probe)
  - How do you see that connecting to factor X …. (Challenge)
  - Why do you think that's important? (Challenge)
  - I wonder what others think about the idea that S3 just shared. (Elicit)
  - Why do you think what you are finding out here in step 4 provides evidence for factor 1 in step 3? (Probe)

Implementation	Notes
Refer to “Focus on Student Thinking” in the SE key for examples of probe and challenge questions that might fit with the discussion.	

Aquarium Study

5. Imagine you had a population of 10 stickleback living in a 10-gallon aquarium. Five of them are female. Each year, half of the fish in the population are female and each of those females can lay 100 eggs.

   a. If all the fish survived, approximately how may fish would be in the aquarium at the end of 3 years?

Year	Total fish	Female fish	Number of eggs
1	10	5 (total fish / 2)	500 (female fish * 100)
2	510 (# of Y1 eggs + Y1 total fish)	255 (total fish / 2)	25,500 (female fish * 100)
3	26,010 (# of Y2 eggs + Y2 total fish)	13,005 (total fish / 2)	1,300,500 (female fish * 100)

   b. Do you think the aquarium could reasonably hold this many fish? Why or why not?

      No. There's not enough room (habitat) and likely wouldn't be enough food.

   c. Just as in an aquarium, the stickleback fish in Loberg Lake are contained in a specific amount of water. Remember that Loberg Lake contains approximately 62 million gallons of water as compared to a 10-gallon aquarium. Do you think all 75–100 eggs that each female stickleback can lay each year could reasonably survive in the lake? Why or why not?

      No. The lake contains a limited about of food and contains predators. Together these would reduce the number of fish that survive and reproduce.

Focus on Student Thinking

- Use appropriate probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) as students are completing their calculations and answering the questions.
  - Following are some question examples:
    - Can you say more about how you arrived at this number? **(Probe)**
    - Clarify what you mean by …. **(Probe)**
    - At the rate the stickleback fish in this scenario are reproducing, how long would it take to fill up a bathtub with fish? **(Challenge)**
    - Does what you are finding out here in step 5 provide evidence for any of the factors found in step 3? **(Challenge)**
    - Why do you think what you are finding out here in step 5 provides evidence for factor 1 in step 3? **(Probe)**

Implementation

Notes

- **STEP 5:** The purpose of this step is to provide evidence for factor 1: More individuals are born than can survive and reproduce. Students need to perform the calculations correctly in order to make the observation that not all fish could survive as the tank would be entirely overcrowded. At some point fish in the aquarium would most surely die due to competition for food and living space.
- Students may have trouble with the initial calculations. A common mistake students make is not reading the entire context and missing that there are five female stickleback in the aquarium during the first year, but during subsequent years, half of the eggs that hatch are female. Some students may miss this contextual factor and use five females for all their yearly calculations. If students do use only five females for each year, the total number of fish at the end of three years will be very low. The calculations should be as follows:

Year	Total fish	Female fish	Number of eggs
1	10	5 (Total fish / 2)	500 (female fish * 100)
2	510 (# of Y1 eggs = Y1 total fish)	255 (Total fish / 2)	25,500 (female fish * 100)
3	26,010 (# of Y2 eggs = Y2 total fish)	13,005 (Total fish / 2)	1,300,500 (female fish * 100)

- Ask students to share their reasoning behind their answers for 5a and 5b. The reasoning behind their response for 5a should be straightforward because a desktop aquarium would be quite small and would never hold over a million fish at the end of three years. However, comparing this desktop aquarium scenario to an actual population of stickleback living in a lake is a relatively large conceptual leap. To make the leap easier, you may want to point out a lake or pond with which students are familiar. Likewise, if students are struggling with 5c, have them calculate the number of fish using the same contextual parameters for five or more years.

Refer to "Focus on Student Thinking" in the SE key for examples of probe and challenge questions that might fit with the discussion.

6. Look back at the chart in STEP 3. If you have evidence related to any of the natural selection factors, add that evidence to the appropriate boxes. Use a different-colored pen or pencil to add any new ideas.

Focus on Student Thinking

- Following is an example of student dialogue using elements from STeLLA Strategy 4:
  - S1: I think the idea we learned in step 5 was that not all fish that are born survive and reproduce.
  - S2: I agree with S1.
  - S3: I agree with S1 too, but I am wondering why you agree with her.
  - S2: I agree because if all the fishes lived, they would eventually fill up the lake.
  - S3: That's why I agree sort of because it's hard to really believe that these small fish could fill up an entire lake.
  - S1: It's hard to believe because we have never seen it happen. But I have another idea based on what we read. The reading said that these fish get eaten by bigger fish, so right there is evidence for factor 1.
  - S2: I also think that the calculations we did in step 5 provide evidence as well.
  - T (listening intently to the conversation): You all are doing great! Make sure you all agree with the two ideas that are being discussed. One idea is that your calculations in step 5 provide evidence for factor 1. The other idea on the table is that stickleback being eaten by larger fish also provides evidence for factor 1. Be sure you agree with both assertions. S2, you might need to explain your thinking a bit more as to why you think the calculations provide evidence (STeLLA Strategy 2).

7. Another way to learn about the population of stickleback is by observing individual fish. Use the Stickleback Cards and the data table below to record information about 10 fish from the population. Be sure to record information about all three traits for each fish. All of these fish were found in freshwater.

STICKLEBACK MEASUREMENTS

Fish number	Length of fish (mm)	Pelvic spines* present? (Yes or No)	Length of pelvic spines (mm)

*Pelvic spines are located on the bottom, near the middle of the fish and are pointing backward toward the tail. The spines have been stained red so you can see them better.

Implementation	Notes
● **STEP 6:** The step requires that students begin to make links between the data and information they are given, and the factors found on the chart in step 3. The links that they make provide evidence for and help students make sense of the four factors of natural selection as they relate to the stickleback population in Loberg Lake. Remind them to focus on the specific factors that the evidence supports; in this case, they should be adding information to the box about factor 1. ● Let students know that evidence statements should be in complete sentences and they include significant data points and trends in the data (see answer key for example evidence statements). There should be general agreement for each piece of evidence supporting a certain factor that they list on the chart. Encourage students to use the elements that are part of the communicating in scientific ways strategy (STeLLA Strategy 4) and discuss how a piece of information could be used as evidence. Refer to "Focus on Student Thinking" in the SE key for examples of a student dialogue using STeLLA Strategy 4. ● Remind students that they should be thinking about evidence for the factors chart found in step 3 as they continue through steps 7–14. ● **STEP 7:** Tell students that they will be using a set of 10 fish cards to complete this step. These fish represent a sample of fish. In this case, the sample is a small number of stickleback that were randomly chosen from a population of freshwater stickleback living in a certain lake. This sample could have been randomly chosen by dipping a net in the water at different places around the lake and keeping the fish that were captured. None were thrown back into the lake based on the presence or absence of spines or spine length. ● The purpose of this step is to allow students to see that there are variations among fish that look basically the same. ● Ask the students to distribute the set of 10 cards among their group members. Each person should be responsible for two or three fish. Students need to measure, in millimeters, the length of the fish and the length of the pelvic spines, if present. All the members of the group should then combine their data so that each person has a completed data table.	

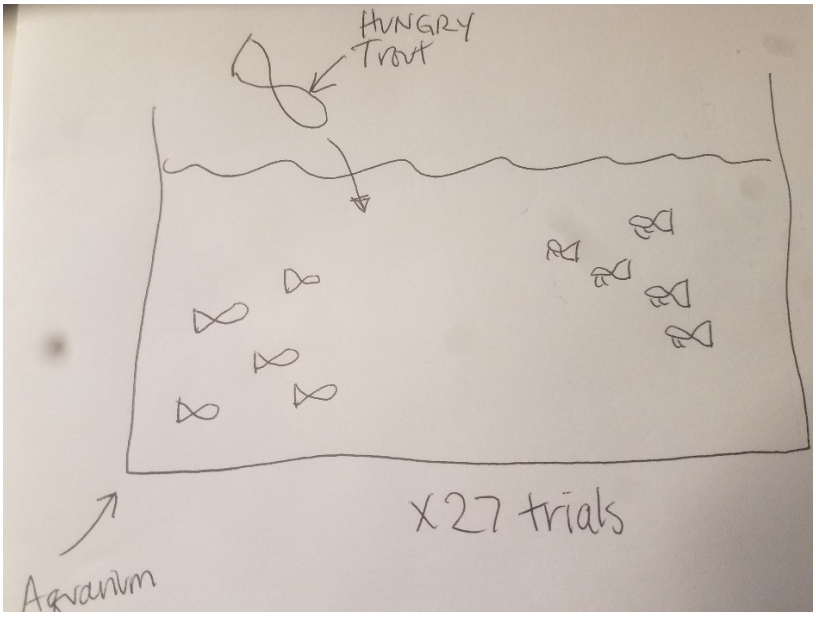
8. Look back at the chart in STEP 3. Consider which factor(s) the data you analyzed in the previous step might support. Based on your analysis of a sample of fish from a population, add any new evidence to the chart in the appropriate box.
9. So far, you have seen data collected from lakes. These types of data are good to see what happens in the natural world. At the same time, there are often complex factors that can affect results. In the next set of data, you will look at a study that happened in a laboratory. Because the experiments were carefully controlled in the lab, these data can give information that scientists might only infer in nature.

   Read the information below to learn about the details of the investigation.

The Study

- One trout was put into a tank with 10 adult stickleback. Five of the stickleback had pelvic spines, and five of the stickleback had no pelvic spines. Trout are a predator of stickleback.
- The trout was not fed for three days before the experiment.
- The scientists left the fish together with a goal of ending each trial when about half (five) stickleback had been eaten, usually after about 11 days.
- Sometimes the trout ate more than five stickleback before the scientists had a chance to stop the trial. In eight trials, the trout ate between six and eight stickleback.
- The scientists did a total of 27 trials.

Draw a diagram below to show the setup of one trial at the start and at the finish of the trial. Explain your diagram to a partner to make sure you both understand what the scientists did.



Implementation	Notes
● **STEP 8:** Like STEP 6, this step requires students to make links between the data and information they are wrestling with in steps 7–9 and the factors found on the chart in STEP 3. As you circulate around the room, make sure that the students are focused on factor 2 because the fish they measured showed variation. ● Remind students that evidence statements should be in complete sentences and include significant data points and trends in the data. ● Ask probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) as students are filling in the chart. For example, o Tell the group a bit more about your thinking. (**Probe**) o Does the information in step 7 provide evidence for more than one factor? Why or why not? (**Challenge**) ● **STEP 9:** The purpose of this step is to have students think through a controlled laboratory study where 10 stickleback fish, five with spines and five without spines, are placed in a tank with a hungry trout. Twenty-seven trials were completed, where a trial ended when a total of five stickleback were eaten. The data show that fish without spines were caught and eaten more often than fish with spines. ● Ask students what a controlled study is and why it is sometimes important to perform controlled science investigations. In this example, a controlled study is important because we don't want to introduce factors that may favor a spined stickleback over a spineless one, or vice versa. The scientists want to see if trout predation occurs to one type of fish more than the other. ● Students may need help with this step. You have the option of having students continue to work with a partner and take turns reading each bullet, or you may want to work as a class with different students reading each bullet. Whichever method you choose, make sure students understand the importance of each bullet to the design of this controlled study. ● Having students draw a diagram that shows the start and the finish of one trial and then having them explain it to a partner is an important part in understanding the experiment and should not be skipped.	

10. The graph on the next page shows the number of survivors after each trial. The blue bars show the number of stickleback with long pelvic spines that survived. The red bars show the number of stickleback with short pelvic spines that survived. Use the graph to respond to the questions below.

    a. In how many trials did more fish with long pelvic spines survive? 20

    b. In how many trials did more fish with short pelvic spines survive? 6

    c. Why do you think that not all trials had the same results? Trout can eat both, but its easier to eat fish with no spines.

    d. Which natural environment does this graph simulate, saltwater or Loberg Lake? Why? Saltwater, because fish are predators of stickleback in saltwater and the fish eat stickleback with short spines more often.

    e. What do the results of the scientists' study mean? Include ideas about which fish could survive long enough to reproduce. The fish with short spines would be more likely to survive and reproduce.

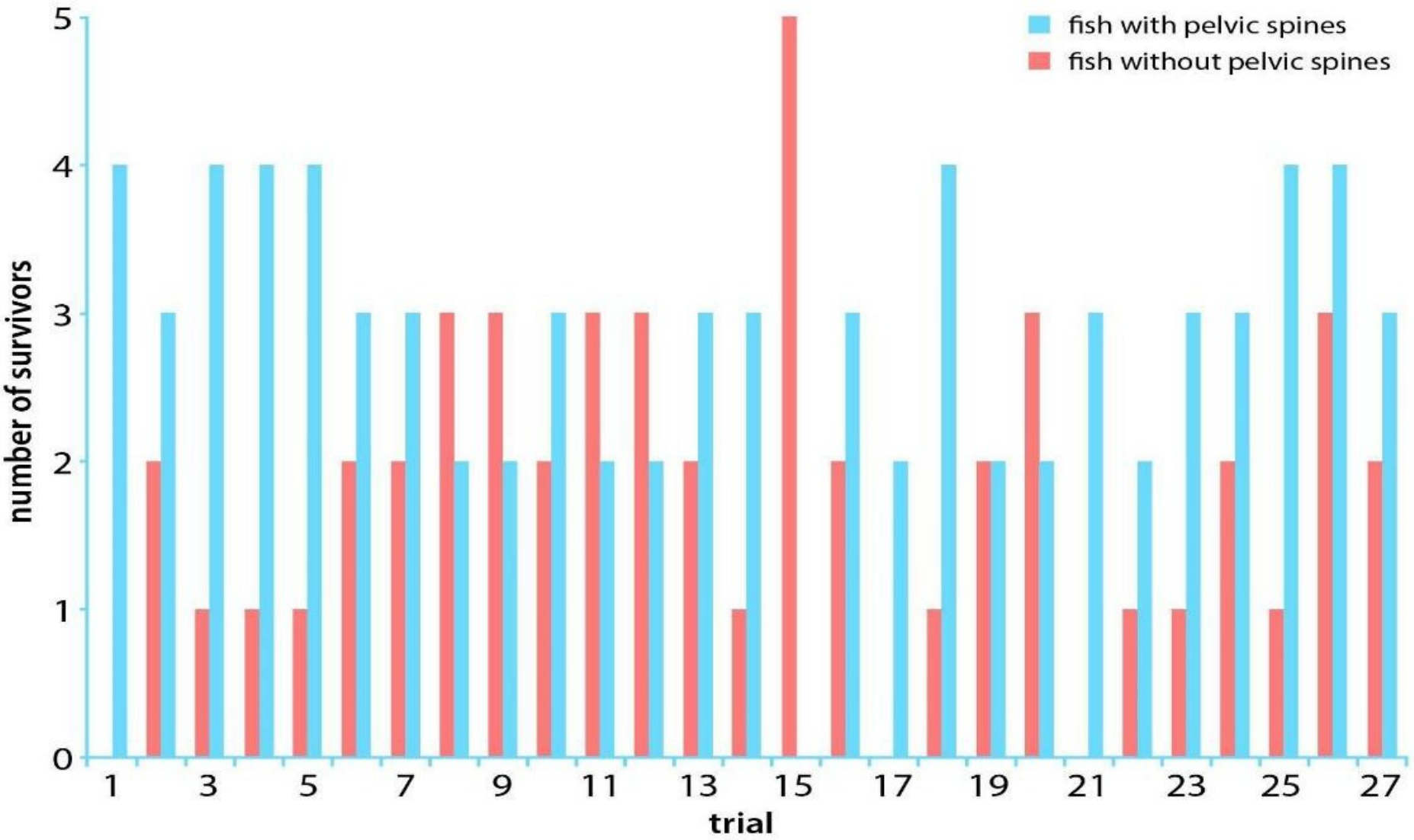
11. Return to the Four Factors of Natural Selection Chart. Consider which factor(s) the Effect of Pelvic Spines Study supports. Add any additional evidence to the appropriate box(es).

Focus on Student Thinking

- Following is an example teacher/student dialogue:
    - T: Can you say a bit more about why you don't think spines have a big influence on whether the stickleback in this experiment got eaten by the trout? (**Probe**)
    - S: There were 20 trials where more fish with long spines survived, and six trials where more fish with short spines survived. That does not mean long spines are better.
    - T: You say that it does not mean long spines are better. Tell the group a bit more about what you mean. (**Probe**)
    - S: Well, if long spines really made a difference, then fish with long spines should have *never* been eaten.
    - T: OK, it sounds like you would agree with the pattern that fish with long spines survived more often than fish with short spines. So, let's focus on the pattern and not the number of fish eaten. If this pattern holds true, which type of fish has a better chance of surviving and reproducing? (**Challenge**)
    - T: If another 27 trials were completed, what do you think you'd see in the data? **(Challenge)**
    - S1: I guess the same.
    - T: Why do you guess? **(Probe)**
    - S1: Not sure.
    - T: What do others think? **(Elicit)**
    - S2: It's quite a few trials, so probably the same.
    - S3: The pattern would keep going.
    - T: So generally you think that the trout will eat more short-spine fish. **(Probe)**
    - T: If this pattern holds true, which type of fish has a better chance of surviving and reproducing? (**Challenge**)

Implementation	Notes
● **STEP 10:** Let students know that the graph shows the results of the study described in STEP 9. The different-colored bars represent the total number of survivors after each trial. The gray bars show the number of stickleback with long pelvic spines that survived. The black bars show the number of stickleback with short pelvic spines that survived. ● The purpose of STEP 10 is to provide students with data that show fish with long spines having an advantage over fish with short spines; namely, fish with short spines get eaten more often than fish with long spines. This allows more fish with long spines to survive and reproduce. ● It may help students if they focus on the pattern rather than on the number of trials. Refer to "Focus on Student Thinking" in the SE key for examples of questions that could be part of the discussion. • **STEP 11:** Invite students to add more evidence based on the Effect of Pelvic Spines Study.	

The Effect of Pelvic Spines on the Survivability of Stickleback in Presence of Trout



Implementation	Notes

12. Imagine that the scientists had been testing the effect of having limited food on the stickleback. Rather than a trout being placed in the tank, the scientists put five stickleback with long spines and five stickleback with short spines in a tank with an amount of food for only five fish. In this experiment, do you think the fish that survived were more likely to have long spines, have short spines, or to have either characteristic? Give reasons for your answer, including why you think the results would be the same or different from the study with the trout.

    The stickleback that survived in the tank could have either characteristic. With no predator, the fish with low armor and short spines are in no better position to survive than fish with high armor and long spines.

13. Return to the Four Factors of Natural Selection Chart. Consider which factor(s) the data you analyzed in the previous step might support. Add any additional evidence to the appropriate box(es).

Implementation	Notes
● **STEP 12:** The purpose for this question is to help students distinguish between "simple" competition for resources and the more complex interactions involved in natural selection. Emphasize to students that this study is different from the study introduced in STEP 10 as this study does not focus on predation but on competition for food resources. Students need to think about whether spines make a difference when competing for food resources. ● Students may believe that long spines would help fish better compete for food resources as they use them to ward off fish with short spines. If students have this idea, refer them to the field guide to see if they can find evidence to substantiate this claim. They will find that the field guide describes spines as a defense mechanism against predators, not against other stickleback. If students are still reluctant to give up the notion that long spines help stickleback compete with other stickleback, refer them to the video from Lesson 1 and the segment that talks about the importance of the spines in warding off predators. ● This is an opportunity to emphasize the idea of random vs. nonrandom death/selection. Since spine size poses no advantage or disadvantage when competing for food, death can be thought of as something random. This is different from the study and results in step 10. In that study, long spines were an advantage, so death was somewhat nonrandom in that the trout ate the fish with short spines much more often than fish with long spines. ● **STEP 13:** Like STEPs 6 and 9, this step requires students to make links between the data and information they are wrestling with in steps 11–14 to the principles found on the chart in STEP 3. The links that they are making provide evidence for the Darwinian factors of natural selection. ● Remind students that evidence statements written in the chart from STEP 3 must be stated in complete sentences. Likewise, there should be general agreement among group members for a piece of evidence supporting a certain principle if they list it on the chart.	

Lesson 3: Cause and Effect: Changes over Time

Phase of Lesson: *Taking a Closer Look at Darwin's Ideas*

Main Learning Goal: Darwin's idea of natural selection consists of four factors supported by evidence. The four factors are 1) the potential for a species to increase in number; 2) organisms have variations in traits inherited from their parents; 3) competition for an environment's limited supply of resources that individuals need to survive and reproduce; and 4) the ensuing proliferation of those organisms that are better able to survive in reproduce in that environment.

Focus Question: What evidence supports Darwin's idea of how populations of organisms change over time?

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: 40 Minutes

STeLLA Strategies

- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy 4: Engage students in communicating in scientific ways

Science Ideas

- Adult stickleback produce more offspring than can survive and reproduce.
- Armor and spines are heritable traits.
- Stickleback offspring look similar to parents, but traits among parents and offspring can vary.
- A given trait is fixed during the lifetime of an individual stickleback. (The trait cannot be willfully changed by the individual to make the trait advantageous.)
- Some heritable traits are more advantageous than others in a particular environment.

Common Student Ideas

- Changes in the environment cannot lead to 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.

14. When your teacher directs you to do so, find a partner with whom to share your completed chart with from step 3. Your teacher will also provide additional directions concerning how you will share your evidence from the chart. After your conversation, draw a star next to each factor that has strong evidence to suggest it (the factor) may have helped contribute to the changes that occurred to the stickleback population in Loberg Lake

Implementation	Notes
Activity Follow-up ○ **STEP 14:** Now have the student pairs share and discuss their completed chart from STEP 3. Encourage students to compare the evidence they found by using the following steps. ○ The first partner shares the evidence for factor 1. As the first partner is sharing, the second partner listens and underlines evidence statements or parts of evidence statements that are similar to what he or she wrote. ○ The second partner then shares the evidence for factor 1. As the second partner is sharing, the first partner listens and underlines evidence. ○ The partners then share their similarities and compare differences. Each partner can modify their evidence statements during the conversation. ○ The partners then agree on the effect of the factor and write it in the chart in STEP 13. ○ Be sure to use appropriate probe and challenge questions as partners are discussing their evidence statements. ○ Once they have come to consensus in their group, have them draw a star next to the factor(s) that are most strongly supported by evidence to suggest that it may have helped contribute to the stickleback population change. In this case, they could argue for both factors 3 and 4. ○ Ask probe (STeLLA Strategy 2) and challenge questions (STeLLA Strategy 3) as students are filling in the chart. For example, ○ Tell the group a bit more about your thinking. (Probe) ○ Does the information in step 11 provide evidence for more than one principle? Why or why not? (**Challenge**) Optional Step • Provide students with the following instruction: Find a partner with whom to share your completed Cause and Effects chart AND your completed chart from step 3. (Note that students may need additional support about "how" to share their charts.) ○ After your conversation, draw a star next to each factor that has strong evidence to suggest it (the factor) may have helped contribute to the changes that occurred to the stickleback population in Loberg Lake. (Note that they could argue for both factors 3 and 4.)	

Lesson 3: Cause and Effect: Changes over Time

Phase of Lesson: *Summarize and Link*

Main Learning Goal: Darwin's idea of natural selection consists of four factors supported by evidence. The four factors are 1) the potential for a species to increase in number; 2) organisms have variations in traits inherited from their parents; 3) competition for an environment's limited supply of resources that individuals need to survive and reproduce; and 4) the ensuing proliferation of those organisms that are better able to survive in reproduce in that environment.

Focus Question: What evidence supports Darwin's idea of how populations of organisms change over time?

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: 15 Minutes

STeLLA Strategies

- ❖ Strategy 2: Ask questions to probe student ideas and predictions
- ❖ Strategy 3: Ask questions to challenge student thinking
- ❖ Strategy I: Summarize key science ideas

Science Ideas

- Adult stickleback produce more offspring than can survive and reproduce.
- Armor and spines are heritable traits.
- Stickleback offspring look similar to parents, but traits among parents and offspring can vary.
- A given trait is fixed during the lifetime of an individual stickleback. (The trait cannot be willfully changed by the individual to make the trait advantageous.)
- Some heritable traits are more advantageous than others in a particular environment.

Common Student Ideas

- Changes in the environment cannot lead to 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.

Summarize and Link

15. In this lesson, you have considered whether the four factors of natural selection caused the change in the stickleback population. Use the cause/effect card set to match the effect of each factor to the appropriate cause. Add a "star" to any factor that can help explain the changes in *any* population over time.

Cause and Effect Chart

Cause	Effect
Factor 1: More individuals are born than can survive and reproduce.	Some individuals in a population will die before they can reproduce.
Factor 2: Individuals within a population inherit traits from their parents. These traits show variation.	Some individuals in a population will have traits that are more favorable in the environment in which they live.
Factor 3: Individuals in a population compete for limited resources (e.g., food, habitat, or mates).	Not all individuals in a population will get the resources they need to survive and reproduce.
Factor 4: Some offspring inherit variations of traits that help them better survive and reproduce in their environment.	Over time, the population will have more individuals with the favorable trait and less individuals with the unfavorable trait.

16. The focus question for this lesson is *What evidence supports Darwin's (Scientist 2's) ideas of how populations change over time?* Write a response to this question based on what you learned in the lesson. Include your ideas about each of the four factors of natural selection. You may include diagrams with labels if they help you explain your ideas.

Implementation	Notes
Summarize • **STEP 15:** Ask students to think about their response to the lesson focus question considering what they learned during today's lesson. They should either add to their ideas under the box at the beginning of the lesson using a different color or write their response on the page under step 15. • Ask students to share their thoughts with the class. • **STEP 16:** Invite students to respond to the focus question. *Link to Next Lesson* • Today we found evidence that supports some of Darwin's four factors of natural selection. In the next lesson, we will consider how these factors work together to change a population of organisms.	