Formative Assessment Exemplar - BIO.4.3

Introduction:

The following formative assessment exemplar was created by a team of Utah educators to be used as a resource in the classroom. It was reviewed for appropriateness by a Bias and Sensitivity/Special Education team and by state science leaders. While no assessment is perfect, it is intended to be used as a formative tool that enables teachers to obtain evidence of student learning, identify gaps in that learning, and adjust instruction for all three dimensions (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas) included in a specific Science and Engineering Education (SEEd) Standard.

In order to fully assess students' understanding of all three dimensions of a SEEd standard, the assessment is written in a format called a cluster. Each cluster starts with a phenomenon, provides a task statement, necessary supporting information, and a sequenced list of questions using the gather, reason, and communicate model (Moulding et al., 2021) as a way to scaffold student sensemaking. The phenomenon used in an assessment exemplar is an analogous phenomenon (one that should not have been taught during instruction) to assess how well students can transfer and apply their learning in a novel situation. The cluster provides an example of the expected rigor of student learning for all three dimensions of a specific standard. In order to serve this purpose, this assessment is NOT INTENDED TO BE USED AS A LESSON FOR STUDENTS.

Because this assessment exemplar is a resource, teachers can choose to use it however they want for formative assessment purposes. It can be adjusted and formatted to fit a teacher's instructional needs. For example, teachers can choose to delete questions, add questions, edit questions, or break the tasks into smaller segments to be given to students over multiple days.

General Format:

Each formative assessment exemplar contains the following components:

1. Teacher Facing Information: This provides teachers with the full cluster as well as additional information including the question types, alignment to three dimensions, and answer key. Additionally, an example of a proficient student answer and a proficiency scale for all three dimensions are included to support the evaluation of the last item of the assessment.
2. Students Facing Assessment: This is what the student may see. It is in a form that can be printed or uploaded to a learning platform. (Exception: Questions including simulations will need technology to utilize during assessment.)

Accommodation Considerations:

Teachers should consider possible common ways to provide accommodations for students with disabilities, English language learners, students with diverse needs or students from different cultural backgrounds. For example, these accommodations may include: Providing academic language supports, presenting sentence stems, or reading aloud to students. All students should be allowed access to a dictionary.

References:

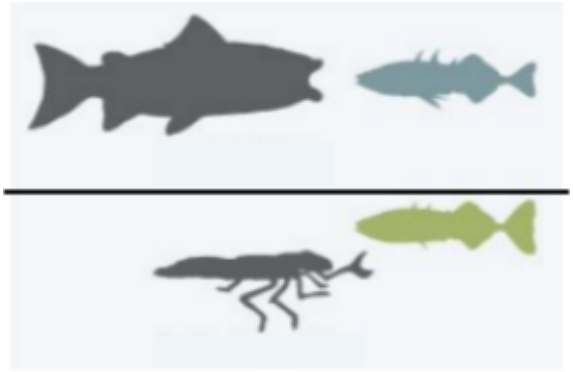
Moulding, B., Huff, K., & Van der Veen, W. (2021). *Engaging Students in Science Investigation Using GRC*. Ogden, UT: ELM Tree Publishing.

Teacher Facing Information

Standard: BIO.4.3

Assessment Format: Printable or Online Format (Does not require students to have online access)

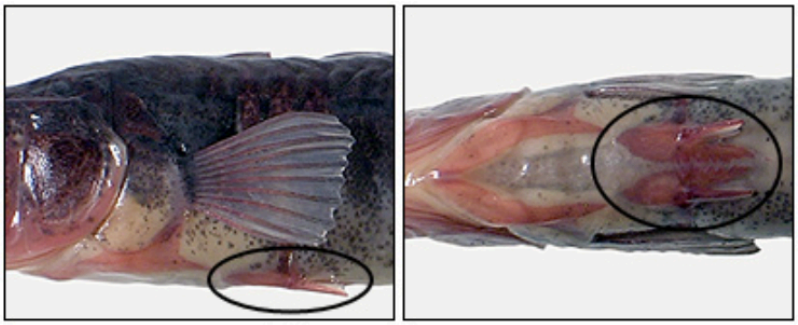
Phenomenon	
The **ancestral** forms of stickleback fish are small ocean dwellers that sport heavy armor in the form of bony plates and spines projecting from the back and **pelvis**. However, in many freshwater populations, the ocean sticklebacks' fully formed pelvic girdle, with long spines, became greatly reduced.	Proficient Student Explanation of Phenomenon: Because the frequency of fossil stickleback with pelvic spines decreased over the 15,000-year time span, we can infer that pelvic spines did not provide an advantage to stickleback fish that had them. Because pelvic spines in living three-spined stickleback populations provide a defense against large predatory fish, we can infer that there probably were no predatory fish in the ancient lake. Dr. Bell and colleagues have found fossils of other fish in the quarry, but most of them were small species that could not eat stickleback fish.
Cluster Task Statement	
(Represents the ultimate way the phenomenon will be explained or the design problem will be addressed) In the questions that follow, you will analyze and interpret data collected from fossils of threespine stickleback fish as well as living populations to identify **patterns** that explain how the **proportion** of traits tend to increase or decrease over time.	
Supporting Information	
The threespine stickleback fish is a model organism for studying evolution.Three-spined sticklebacks are small fish that live in oceans, streams, and lakes across the northern hemisphere.The ancient or fossil forms of stickleback fish are small ocean dwellers that have heavy armor in the form of bony plates and spines projecting from the back and pelvis. Scientists have been able to study both well preserved fossils of ocean dwelling Sticklebacks as well as many ocean and freshwater varieties that exist today. In both ocean and freshwater environments, Stickleback fish have predators. Large predatory fish can be found in the ocean while smaller insect predators are found in freshwater habitats. Scientists hypothesize that different amounts of body armor make these small fish more or less protected against different types of predators. See the image below for examples of Stickleback predators.	



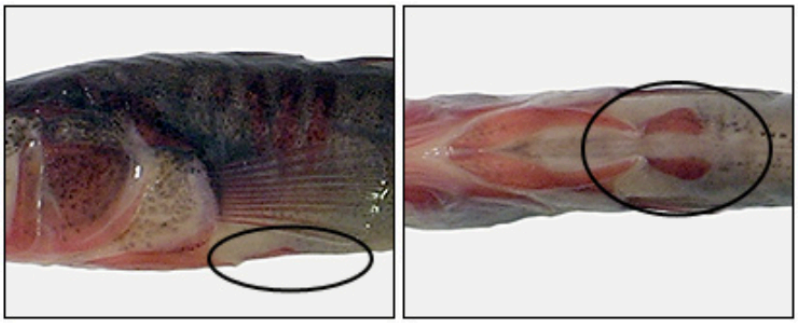
Stickleback adaptations for surviving specific predators. Sticklebacks with spines are better adapted to survive large predators. Sticklebacks with small or reduced spines are better suited for surviving predation by insects.

Experiment One:
Specimens of sticklebacks were collected and treated with a solution of dye that stains bones red, thereby making pelvic structures much easier to see. Individuals were then categorized as having a **complete, reduced,** or **absent** pelvic girdle structure.

Complete: a pelvis with a full pelvic girdle and two pelvic spines. (Note that only the fish with a complete pelvis have pelvic spines.)

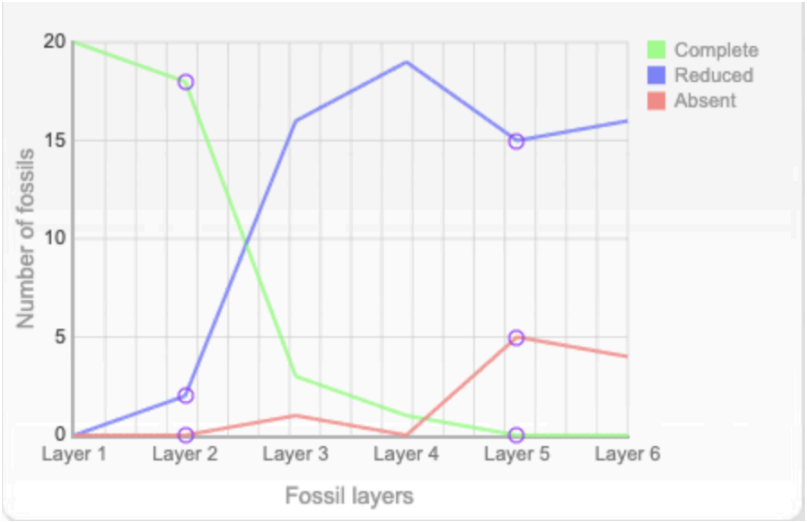


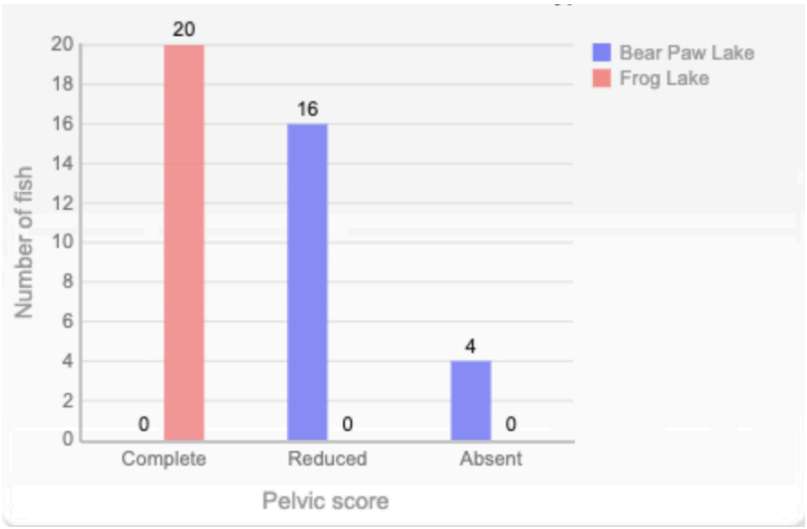
Reduced: a range of structures from a simplified girdle with no pelvic spines to an oval nub for a girdle.



Absent: no pelvic girdle and no spines.

Cluster Questions	
Gather (fossil): Cluster Question #___1___ Question Type: Short answer (fill	Question 1: **Experiment One**:

in the blank) Addresses: ____ DCI __x__ SEP: analyze and interpret data __x__ CCC: scale, proportion, quantity Answer: Pelvic spines were more common in layer **2**. Layer 5 contained mostly fish **without** pelvic spines.	In this experiment, scientists characterized the pelvic structures of **fossil** stickleback fish from the Truckee Formation in Nevada—the site of a lake that existed about 10 million years ago. The fossils analyzed represent fish that lived in the lake at different time points spanning about 15,000 years. Among the samples analyzed, layer 1 is the oldest. It coincides with a time when a population of sticklebacks with complete pelvic structures appeared in the lake. The next layers—2 to 6—are each spaced about 3,000 years apart, going from past to present. Fossil Stickleback Pelvic Phenotype Totals | | Layer 1 | Layer 2 | Layer 3 | Layer 4 | Layer 5 | Layer 6 | | Complete | 20 | 18 | 3 | 1 | 0 | 0 | | Reduced | 0 | 2 | 16 | 19 | 15 | 16 | | Absent | 0 | 0 | 1 | 0 | 5 | 4 |  Based on the pelvic phenotypes measured, how do the fossils in layer 2 differ from those in layer 5? Pelvic spines were more common in layer (2, 5). Layer 5 contained mostly fish (with, without) pelvic spines.
Question Type: Multiple Choice Reason (fossil): Cluster Question #____2__ Question Type: Addresses: __x__ DCI __x__ SEP: analyze and interpret data __x__ CCC: scale, proportion,	Question 2: On the basis of the data you have, what do you predict would happen to the pelvic girdles of stickleback fish 10,000 years after the ones observed in experiment 1? A. They would become complete. B. They would become reduced. C. They would become absent. D. None of the above.

quantity Answer: They would be absent.	
Gather: Cluster Question #____3__ Question Type: MC Addresses: ____ DCI ___X_ SEP _X___ CCC Answer: The proportion of fish with complete pelvis structures have decreased in Bear Paw lake when compared to Frog Lake.	Question 3: **Experiment Two:** In this experiment, scientists scored 20 fish from Bear Paw Lake and 20 fish from Frog Lake. These lakes were originally inhabited by the same ocean population of stickleback but were separated into distinct environments thousands of years ago. Bear Paw lake is completely enclosed where Frog Lake is connected to other waterways by a small stream. With this connection Frog Lake is populated with large predatory fish, while Bear Paw has only freshwater insect predators.  Analyze the data from Experiment 2 to determine how the proportion of fish with complete pelvis and spines from Frog Lake compares to the proportion of complete pelvis fish in Bear Paw Lake? A. The proportions are essentially the same. B. The proportion of fish with complete pelvis have increased in Bear Paw Lake when compared to Frog Lake. C. The proportion of fish with complete pelvis structures have decreased in Bear Paw lake when compared to Frog Lake. D. The proportion of fish with absent pelvis structures are on the rise in Frog Lake.
Gather: Cluster Question #__4____ Question Type: Short Answer Addresses: ____ DCI ___X_ SEP _X___ CCC 1. different amounts of body armor make these	Question 4: What evidence from the data and background information, could be used to determine why there is a difference in the proportion of fish with pelvic structures when comparing Frog Lake and Bear Paw Lake.

small fish more or less protected against different types of predators 2. they were probably populated by the same sea-run population of threespine stickleback at the end of the last ice age. 3. Bear Paw Lake is completely enclosed which means no large predators 4. Frog lake is connected by a small stream so predatory fish can get into frog lake.	
Reason: Cluster Question #___5___ Question Type: Multi-select. Addresses: __X__ DCI __X_ SEP ____ CCC Answer: Correct answers are bolded	Question 5: **Analyze the data from experiment 2 and draw conclusions about the impact of large predators and the effect they have on the presence or absence of Pelvic spines in Stickleback fish.** ☐ **Pelvic spines protect sticklebacks from large predators.** ☐ Sticklebacks without spines would be eaten more frequently by freshwater predators. ☐ **The predators in the two lakes are different, which affects whether or not spines are an advantageous trait.** ☐ The absence of spines provides no advantage with either predator. ☐ **Having pelvic spines in Frog Lake protects Stickleback fish from being eaten by large predators.**
Communicate (fossil): Cluster Question #___6___ Question Type: Long answer Addresses: __x__ DCI _x___ SEP ____ CCC Answer: Because the frequency of fossil stickleback with pelvic spines decreased over the 15,000-year time span, we can infer that pelvic spines did not provide an advantage to stickleback fish that had them. Because pelvic spines in living	Question 6: What can be inferred about the presence or absence of predatory fish when the Truckee Formation was a lake from experiment 1? Describe the evidence.

three-spined stickleback populations provide a defense against large predatory fish, we can infer that there probably were no predatory fish in the ancient lake.	
Communicate (both experiments combined): Cluster Question #___7___ Question Type: Long Answer Addresses: __x__ DCI __x__ SEP __x__ CCC Answer: The data from experiment 2 shows that stickleback fish in Bear Paw Lake already have individuals with reduced and absent pelvic spines. A similar population was observed in fossil fish in experiment 1. Overtime, all fossils found had reduced or absent pelvic spines. Based on this evidence, one can predict that the population at Bear Paw Lake will eventually lose the pelvic spine trait.	Question 7: Using both studies as a reference, make a prediction about what would happen to the proportion of fish with pelvic girdles in Bear Paw Lake after several generations? Support your claim with evidence of evolutionary patterns from both studies.

Proficiency Scale

Proficient Student Explanation:

Because the frequency of fossil stickleback with pelvic spines decreased over the 15,000-year time span, we can infer that pelvic spines did not provide an advantage to stickleback fish that had them. Because pelvic spines in living three-spined stickleback populations provide a defense against large predatory fish, we can infer that there probably were no predatory fish in the ancient lake. Dr. Bell and colleagues have found fossils of other fish in the quarry, but most of them were small species that could not eat stickleback fish.

Level 1 - Emerging	Level 2 - Partially Proficient	Level 3 - Proficient	Level 4 - Extending
SEP:	**SEP:** Analyze and interpret data to provide	**SEP:** Analyze data using tools, technologies,	**SEP:** Extends beyond proficient in any way.

Does not meet the minimum standard to receive a 2.	evidence for phenomena.	and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims.	
CCC: Does not meet the minimum standard to receive a 2.	**CCC:** Proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.	**CCC:** The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.	**CCC:** Extends beyond proficient in any way.
DCI: Does not meet the minimum standard to receive a 2.	**DCI:** For any particular environment, some kinds of organisms survive well, some survive less well, and some cannot survive at all.	**DCI:** Natural selection relies on trait variation—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population. Natural selection leads to population adaptation to a **population** dominated by traits that are well suited to survive and reproduce in a specific environment which leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of	**DCI:** Extends beyond proficient in any way.

		individuals that do not.	

(Student Facing Format on following page)

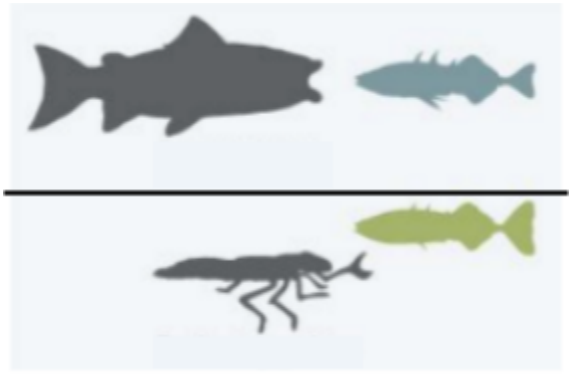
Name: _____ Date: _____

Stimulus

The threespine stickleback fish is a model organism for studying evolution.Three-spined sticklebacks are small fish that live in oceans, streams, and lakes across the northern hemisphere.The ancient or fossil forms of stickleback fish are small ocean dwellers that have heavy armor in the form of bony plates and spines projecting from the back and pelvis. Scientists have been able to study both well preserved fossils of ocean dwelling Sticklebacks as well as many ocean and freshwater varieties that exist today.

In both ocean and freshwater environments, Stickleback fish have predators. Large predatory fish can be found in the ocean while smaller insect predators are found in freshwater habitats. Scientists hypothesize that different amounts of body armor make these small fish more or less protected against different types of predators. See the image below for examples of Stickleback predators.

Figure 1: Stickleback Adaptations

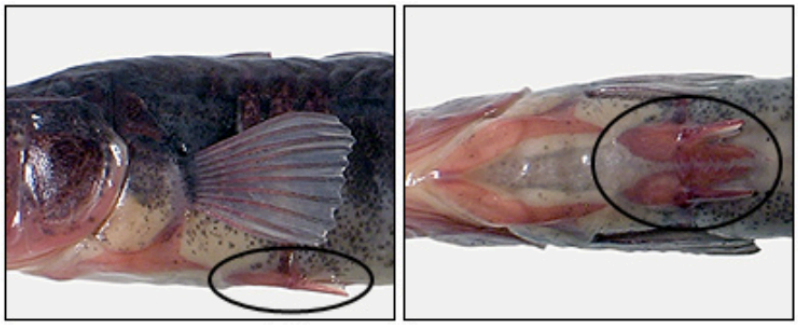


Stickleback adaptations for surviving specific predators. Sticklebacks with spines are better adapted to survive large predators. Sticklebacks with small or reduced spines are better suited for surviving predation by insects.

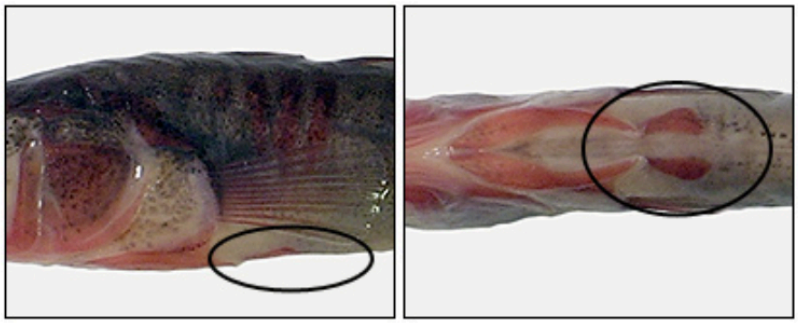
Figure 1 shows an image of two different stickleback fish and their predators.

FIgure 2: Stickleback Pelvic Structure

Complete: a pelvis with a full pelvic girdle and two pelvic spines. (Note that only the fish with a complete pelvis have pelvic spines.)



Reduced: a range of structures from a simplified girdle with no pelvic spines to an oval nub for a girdle.



Absent: no pelvic girdle and no spines.

FIgure 2 shows specimens of sticklebacks and the differences in their pelvic structure.

Specimens of stickleback fish were collected and treated with a solution of dye that stains bones red, thereby making pelvic structures much easier to see. Individuals were then categorized as having a **complete, reduced,** or **absent** pelvic girdle structure.

Your Task

In the questions that follow, you will analyze and interpret data collected from fossils of threespine stickleback fish as well as living populations to identify **patterns** that explain how the **proportion** of traits tend to increase or decrease over time.

Question 1

Investigation 1: In this investigation, scientists characterized the pelvic structures of **fossil** stickleback fish from the Truckee Formation in Nevada—the site of a lake that existed about 10 million years ago. The fossils analyzed represent fish that lived in the lake at different time points spanning about 15,000 years.

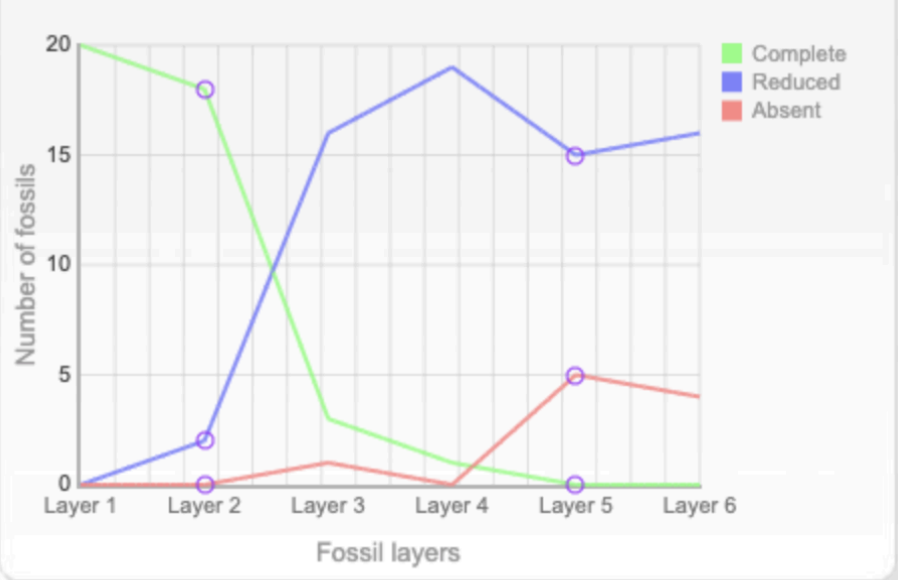
Among the samples analyzed, layer 1 is the oldest. It coincides with a time when a population of sticklebacks with complete pelvic structures appeared in the lake. The next layers—2 to 6—are each spaced about 3,000 years apart, going from past to present.

Table 1: Fossil Stickleback Pelvic Phenotype Totals

Fossil Stickleback Pelvic Phenotype Totals						
	Layer 1	Layer 2	Layer 3	Layer 4	Layer 5	Layer 6
Complete	20	18	3	1	0	0
Reduced	0	2	16	19	15	16
Absent	0	0	1	0	5	4

Table 1 shows the number of fossil stickleback found in lake layers with various pelvic structures.

Graph 1: Fossil Stickleback Pelvic Phenotypes



Graph 1 shows the data from Table 1 in line graph form.

Based on the pelvic phenotypes measured, how do the fossils in layer 2 differ from those in layer 5?

Pelvic spines were more common in layer _____ *(2, 5)*. Layer 5 contained mostly fish _____ *(with, without)* pelvic spines.

Question 2

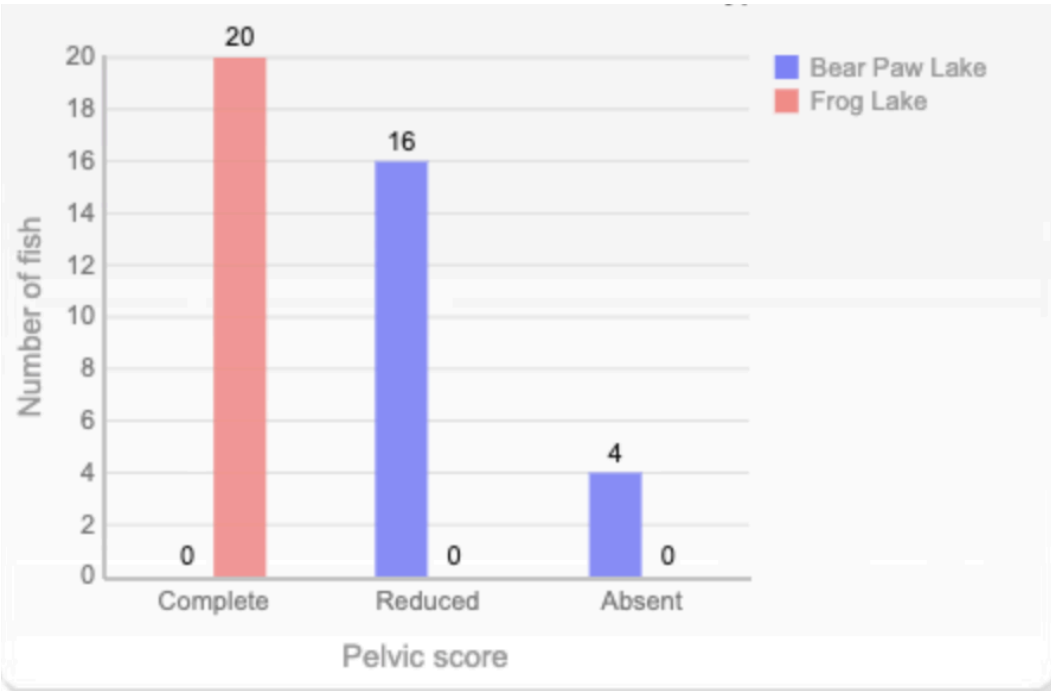
On the basis of the data from Table 1 and Graph 1, what do you predict would happen to the pelvic girdles of stickleback fish 10,000 years after the ones observed in experiment 1?

A. They would become complete.
B. They would become reduced.
C. They would become absent.
D. None of the above.

Question 3

Investigation 2: In this investigation, scientists scored 20 fish from Bear Paw Lake and 20 fish from Frog Lake. These lakes were originally inhabited by the same ocean population of stickleback but were separated into distinct environments thousands of years ago. Bear Paw lake is completely enclosed where Frog Lake is connected to other waterways by a small stream. With this connection Frog Lake is populated with large predatory fish, while Bear Paw has only freshwater insect predators.

Graph 2: Pelvic Structures of Stickleback Fish from Two Lakes



Graph 2 shows the data from the investigation of Bear Paw Lake and Frog Lake Stickleback fish populations.

Analyze the data from Investigation 2 to determine how the proportion of fish with complete pelvis and spines from Frog Lake compares to the proportion of complete pelvis fish in Bear Paw Lake?

A. The proportions are essentially the same.
B. The proportion of fish with complete pelvis have increased in Bear Paw Lake when compared to Frog Lake.
C. The proportion of fish with complete pelvis structures have decreased in Bear Paw lake when compared to Frog Lake.
D. The proportion of fish with absent pelvis structures are on the rise in Frog Lake.

Question 4

What evidence from Investigation 2 and the Stimulus background information could be used to determine why there is a difference in the proportion of fish with pelvic structures when comparing Frog Lake and Bear Paw Lake?

_____

_____

_____

_____

_____

_____

_____

_____

Question 5

Analyze the data from Investigation and draw conclusions about the impact of large predators and the effect they have on the presence or absence of Pelvic spines in Stickleback fish. Check all that apply.

- ☐ Pelvic spines protect sticklebacks from large predators.
- ☐ Sticklebacks without spines would be eaten more frequently by freshwater predators.
- ☐ The predators in the two lakes are different, which affects whether or not spines are an advantageous trait.
- ☐ The absence of spines provides no advantage with either predator.
- ☐ Having pelvic spines in Frog Lake protects Stickleback fish from being eaten by large predators.

Question 6

What can be inferred about the presence or absence of predatory fish when the Truckee Formation was a lake from Investigation 1? Describe the evidence.

_____

_____

_____

_____

_____

_____

_____

Question 7

Using both Investigations 1 and 2 as a reference, make a prediction about what would happen to the proportion of fish with pelvic girdles in Bear Paw Lake after several generations? Support your claim with evidence of evolutionary patterns from both studies.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____