

Science & Literacy Activity

ACTIVITY OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to animal body parts.

This activity has three components:

- 1. Before your visit**, students will read a content-rich article about the spiny pufferfish and the adaptations that protect it from predators. This article will provide context for the visit, and also help them complete the post-visit writing task.
- 2. At the Museum**, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, and models). This information will help them complete the post-visit writing task.
- 3. Back in the classroom**, students will draw on the first two components of the activity to complete a CCSS-aligned explanatory writing task about animal body parts.

Materials in this packet include:

For Teachers

- Activity Overview (p. 1-2)
- Article (teacher version): "Who Wants a Spiny Snack?" (p. 3-5)
- Answers to the student worksheets (p. 6-7)
- Essay scoring rubric (teacher version) (p. 8)

For Students

- Article (student version): "Who Wants a Spiny Snack?" (p. 9-11)
- Student worksheets (p. 12-13)
- Student writing task (p. 14)
- Essay scoring rubric (student version) (p. 15)

1. BEFORE YOUR VISIT

Students will read a content-rich article about the spiny pufferfish and the adaptations that protect it from predators. This article will provide context for the visit, and help them complete the post-visit writing task.

Preparation

- Familiarize yourself with the student writing task and rubric (p. 8, 14-15).
- Familiarize yourself with the teacher version of the article (p. 3-5), and plan how to facilitate the students' reading of the article.

Instructions

- Explain the goal: to complete a writing task about animal body parts.
- Tell students that they will need to read an article before visiting the Museum, and read additional texts during the visit (including printed text, digital and physical/hands-on interactives, videos, and models).
- Distribute the article, student writing task, and rubric to students.

Common Core State Standards

- RI.2.1 Ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text.
- RI.2.2 Identify the main topic of a multi-paragraph text as well as the focus of specific paragraphs within the text.
- W.2.2 Write informative/explanatory texts in which they introduce a topic, use facts and definitions to develop points, and provide a concluding statement or section.

New York State Science Core Curriculum

LE3.1a

Next Generation Science Standards

DCI: LS1.A: Structure and Function

All organisms have external parts. Different animals use their body parts in different ways to see, hear, grasp objects, protect themselves, move from place to place, and seek, find, and take in food, water and air. Plants also have different parts (roots, stems, leaves, flowers, fruits) that help them survive and grow.

SEP 8: Obtaining, Evaluating and Communicating Information

- Obtain information using various texts, text features, and other media that will be useful in answering a scientific question.
- Communicate information in written forms using drawings and writing that provide details about scientific ideas.

- Review the rubric with students and tell them that it will be used to grade their writing.
- Read and discuss the article, using the teacher notes to facilitate.
- Distribute the student worksheets (p. 12-13). Have students fill in the “spiny pufferfish” section based on what they’ve learned from the article. Tell them that at the Museum, they will complete the second worksheet about two other animals and their body parts.

2. DURING YOUR VISIT

At the Museum, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, and models). The information they’ll gather from these multiple sources will help them complete the post-visit writing task.

Preparation

- Review the educator’s guide to see how themes in the exhibition connect to your curriculum and to get an advance look at what your students will encounter. (Guide is downloadable at amnh.org/lal/educators)
- Familiarize yourself with the student worksheets (p. 12-13) and the map of the exhibition.

Instructions

- Explain the goal of the Museum visit: to read and engage with texts (including printed text, digital and physical/hands-on interactives, videos, and models), and to gather information to help them complete the post-visit writing task.
- Review the worksheet. Clarify what information students should collect.

Suggestions for Facilitating the Museum Visit

- Have students explore the exhibition in pairs, with each student completing his or her own student worksheet.
- Encourage student pairs to ask you or their peers for help locating information. Tell students they may not share answers with other pairs, but may point each other to places where answers can be found.
- Teachers and chaperones may use the worksheets to transcribe the observations of any students who have trouble taking notes. Teachers and chaperones may also take photos for reference back in the classroom.

3. BACK IN THE CLASSROOM

Students will use what they have learned from the pre-visit article and information gathered during the Museum visit to complete a CCSS-aligned explanatory writing task about animal body parts.

Preparation

- Plan how you will explain the student writing task and rubric (p. 14-15) to students.

Instructions

- Review the writing task and rubric with students. Explain that they will use it while composing, and also to evaluate and revise what they have written.

Suggestions for Facilitating Writing Task

- Before they begin to write, have students use the writing task to frame a discussion around the information that they gathered at the Museum. They can work in pairs, small groups, or as a class, and can compare their findings.
- Referring to the writing task, have students underline or highlight all relevant passages and information from the article and from the notes taken at the Museum. Instruct each student to write down any useful information gathered by their peers.
- Students should write their essays individually.

Supports for Diverse Learners

This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It represents information in multiple ways and offers multiple ways for your students to engage with content as they read about, discuss, view, and write about scientific concepts. Different parts of the experience (e.g. reading texts, or locating information in the Museum) may challenge individual students. However, the arc of learning is designed to offer varied opportunities to learn. We suggest that all learners experience each activity, even if challenging. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

Alternate Version of Article

Another version of the same article with a lower lexile level is available for download at amnh.org/lal/educators. You can use this same activity with that article.

ARTICLE: TEACHER VERSION

About this Article

- **Lexile:** 580
- **Wordcount:** 444
- **Text Complexity:** There is no Lexile level specified by the Common Core State Standards for grades K and 1. Although this text falls within the 2-3 grade level band (450-790 Lexile), since shared reading/interactive read aloud is suggested, it is appropriate for use by kindergarten and first-grade teachers. Second-grade teachers may opt to assign part or all of the text as independent reading, but this should be based on the teacher’s professional judgment and assessment of students’ independent reading levels.
- **Note:** Assign partners prior to reading this text aloud with students and have them assign a “partner A” and “partner B.”

Key for Teacher Notes

- **Green text**
specific strategies
- Regular text
instructions for teachers
- *Italicized text*
teacher’s instructions to students
- Underlined text
important domain-specific words

Who wants a spiny snack?

Not many animals! How the spiny puffer stays safe in the ocean

A hungry shark looks for its next meal. It spots a small fish.



© iStock Photo/GlobbalP

But as the shark gets close, PUFF-PUFF-PUFF! The fish puffs out into a big ball. And it’s covered with sharp spines! Ouch! The shark swims away. The small puffer fish is safe for now.



© iStock Photo/FLaudGirl

For a small fish, the ocean is full of danger. Bigger fish, sharks, and even birds eat small fish. Animals that hunt other animals are called predators. Puffer fish have their own way to stay safe from predators.

All animals have special ways to stay alive. These are called adaptations. An adaptation is a body part or action

Prompt to **think/pair/share**: *What do you think this text will teach us about?*

Listen in to student pairs. Repeat some of the good ideas that you heard, or pre-select one or two students to share out to the whole group.

Before reading this paragraph, assign each partner a role: Partner A is the “hungry shark” and Partner B is the “spiny puffer” (“small fish”).

Instruct students to listen very carefully because they will act out their assigned “character” after you read this section.

Select one partnership to act out the “scene” in front of the class, and as they do so, you can narrate what each animal is doing. (Have the text available on a projector or as hardcopies for students to refer to as needed).

Turn and talk to your partner: *What is a predator?* Listen in and select a student to share out.

Write on chart paper or sentence strip: “predator = animal that hunts other animals.”

What did we learn from acting out the text with our partners just now? How does the puffer fish protect itself? **Turn and talk**. Listen in to students’ conversations. Share out an exemplary response.

that helps an animal live. Predators have adaptations that help them hunt. Imagine a shark's sharp teeth. This adaptation helps a shark catch and eat fish.



A shark uses its sharp teeth to catch and eat fish.

Look at the picture of the shark. Give me a "thumbs up" if you can see its teeth. Its teeth are an adaptation - a body part that helps the shark live.

How do you think the shark's teeth help it live? **Turn and talk.** Listen in to partners' conversations.

Write on chart paper or sentence strip: "adaptation = a body part or action that helps an animal live". You may want to put a copy of the photo of the shark with its teeth labeled next to this definition as a reminder. You may want to add other examples of types of adaptations that you encounter throughout the rest of the text.

Fish have adaptations too. These adaptations help keep them safe from predators. Some fish might be fast enough to escape a predator. Others might be able to blend in and hide on the ocean floor.



Can you find the flounder?



Porcupines have long sharp spines that protect them.

This part is telling us about other adaptations - adaptations that fish have to keep themselves safe from predators. What are the two kinds of adaptations that fish can have to protect themselves? **Turn and talk.** Listen in and select student to share out.

The two types of adaptations students should be aware of are: (a) moving fast enough to escape a predator and (b) blending in and hiding on the ocean floor. Prompt students to notice the photo of the fish that is blending in to the ocean floor.

But some animals don't run or hide. They have bodies that are hard to eat. Porcupines have long sharp spines. So do sea urchins in the ocean. Spines protect these animals. Predators don't like spiny food!



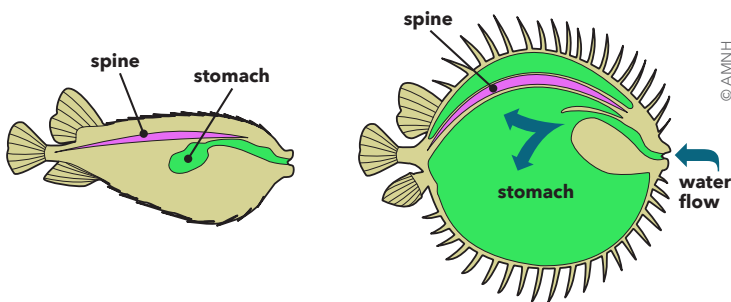
A pufferfish's skin is hard and covered with sharp spines.

Ooh! This is a different type of adaptation... having bodies that are hard to eat. Give me a **thumbs up** if you see the photo of the porcupine above... **Turn and talk:** Why do you think the porcupine would be hard for a predator to eat?

Some toads and snakes have another way to scare away a predator. They puff up to look bigger. Puffer fish do both of these things. They puff up AND they have spines.

Swimming along, a puffer fish looks like any other fish. When a predator gets close, the puffer swells up like a big balloon. Some people call it a balloon fish. But this fish is not soft and smooth like a balloon. Its skin is hard and covered with sharp spines. These spines usually lie flat on the side of the fish. When the fish puffs up, the spines stick out in all directions.

How does the puffer “puff” up? It’s not filled with air like a balloon. It’s full of water. The fish gulps lots of water into its stomach. Filled with water, its stomach becomes almost one hundred times bigger. Other body parts



inside the puffer are pushed to the side to make room.

A puffer can turn into a spiny ball in a few seconds. Then only the biggest animals can eat it. The ocean may be full of dangers, but the puffer is ready. Adaptations like sharp spines and puffing up help keep the puffer safe.

Article adapted from “A Fish Story” by Adam Summers, *Natural History* magazine, October 2001.

Prompt students to look at the two pictures of the puffer fish and its spines on the previous page. Ask them to **turn and talk** in response to the following questions:

- How does the puffer fish look different after it swells up?
- How do you think it would feel to touch the puffer’s skin after it puffs out? What words in the text make you think that? (e.g., “not soft and smooth”...“hard and covered with sharp spines”...)

Think Aloud: I think I am beginning to understand why predators would stay away from the puffer fish when it puffs up!

Think Aloud: Wow! The puffer’s stomach becomes almost one hundred times bigger when it is puffed up!!

Direct students’ attention to the labeled diagram. Ask students to use the picture to explain to their partner how the puffer fish swells up. It is important for students to realize that the puffer fills its stomach with water (not air), and that the other organs get pushed out of the way. Invite a student to explain what the diagram shows.

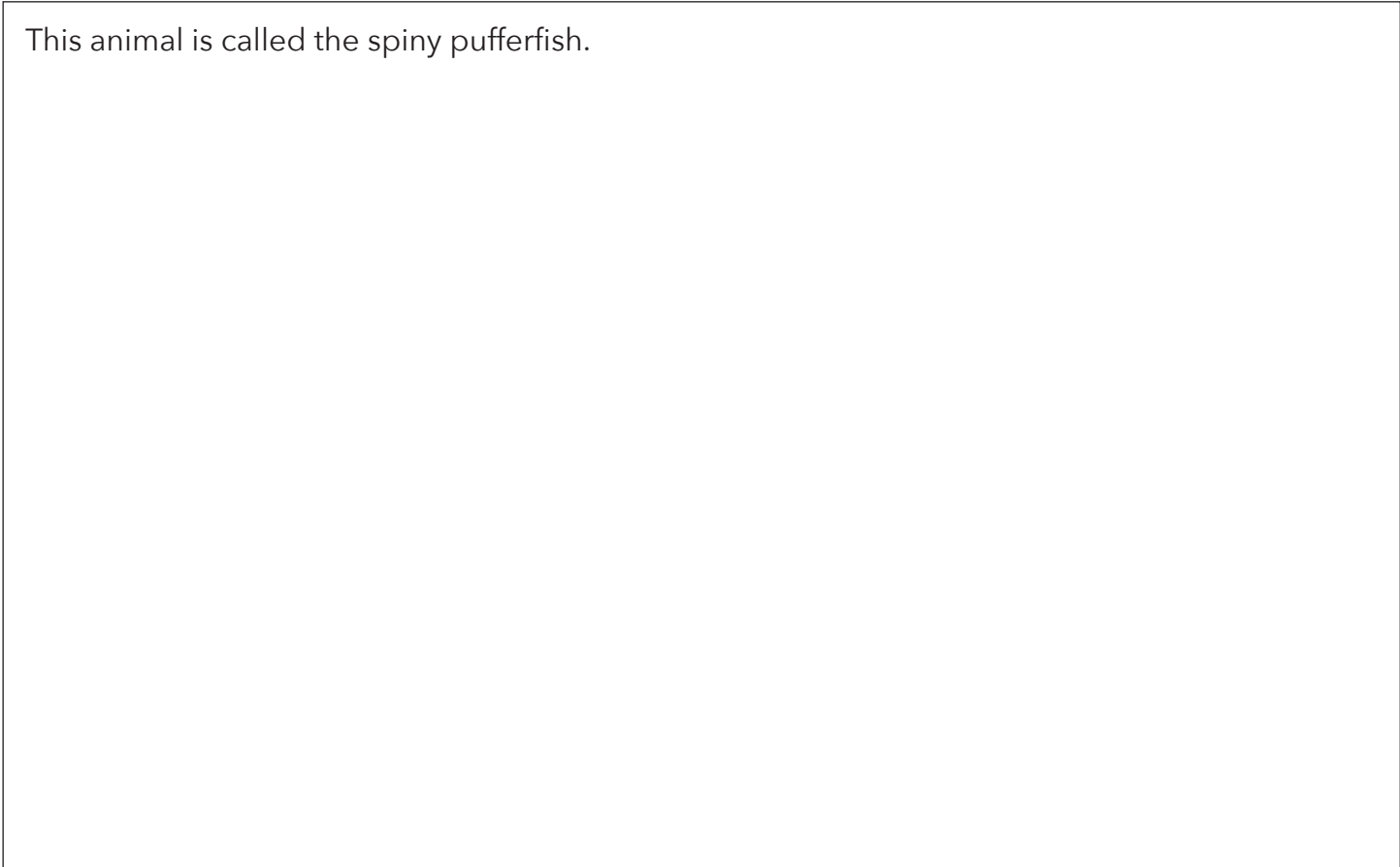
Formative Assessment: Invite students to draw/write in response to the following open-ended question: *What did you learn about the puffer fish? OR, How does the puffer keep safe from bigger fish that want to eat it?*

STUDENT WORKSHEET: Part 1

Name: _____ **ANSWER KEY**

Draw a spiny pufferfish. **Label** the spines.

This animal is called the spiny pufferfish.



Explain how the pufferfish uses its spines.

The pufferfish uses its spines for protection.

Sharks won't eat an animal that is covered in sharp spines.

STUDENT WORKSHEET: Part 2

Name: _____ **ANSWER KEY**

Pick one animal in the exhibition. **Draw** it and **label** one body part.

This animal is called the
Answers will vary.

Explain how the animal uses its body part.

Answers will vary.

Pick another animal. **Draw** it and **label** one body part.

This animal is called the
Answers will vary.

Explain how the animal uses its body part.

Answers will vary.

ESSAY SCORING RUBRIC: TEACHER VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Who Wants a Spiny Snack?"	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the article	Presents information from the article relevant to the prompt with accuracy and sufficient detail	Presents information from the article relevant to the purpose of the prompt with minor lapses in accuracy or completeness	Attempts to present information in response to the prompt, but lacks connections to the article or relevance to the purpose of the prompt
	Museum Exhibition: <i>Life at the Limits</i>	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the exhibition	Presents information from the exhibition relevant to the prompt with accuracy and sufficient detail	Presents information from the exhibition relevant to the purpose of the prompt with minor lapses in accuracy or completeness	Attempts to present information in response to the prompt, but lacks connections to the exhibition content or relevance to the purpose of the prompt
SCIENCE (worth 1/3)	Science Explanations	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of animal body parts	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of animal body parts	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of animal body parts; minor errors in explanation	Attempts to include animal body parts in explanations, but understanding of the topic is weak; content is irrelevant, inappropriate, or inaccurate
		Uses three labeled illustrations to accurately communicate relevant information about the spiny pufferfish and two other animals; each illustration has at least one labeled body part	Includes two labeled illustrations to communicate relevant information about the spiny pufferfish and one other animal with one label per animal	Includes three illustrations without labels or only one properly labeled illustration	No illustrations
WRITING (worth 1/3)	Focus	Maintains a strongly developed focus on the writing prompt for the entire essay	Maintains focus on the writing prompt for the majority of the essay	Addresses the prompt but is off-task some of the time	Does not address the prompt for most or all of the essay
		Introduces the topic of animal body parts	X	X	Does not introduce the topic of animal body parts
		Provides a concluding statement/section	X	X	Provides no sense of closure
	Development	The description of each animal includes its name and one body part along with accurate information about the function of that body part	The description of each animal includes its name and one body part but does not include information about the function of that body part	Does not include animal names or does not include a description of body parts for all of the selected animals	Does not name any animals or body parts

ARTICLE

Who wants a spiny snack?

Not many animals! How the spiny puffer stays safe in the ocean

A hungry shark looks for its next meal. It spots a small fish.



© iStock Photo/GlobalP

But as the shark gets close, PUFF-PUFF-PUFF! The fish puffs out into a big ball. And it's covered with sharp spines! Ouch! The shark swims away. The small puffer fish is safe for now.



© iStock Photo/FtLaudGirl

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Can you find the flounder?



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But some animals don't run or hide. They have bodies that are hard to eat. Porcupines have long sharp spines. So do sea urchins in the ocean. Spines protect these animals. Predators don't like spiny food!

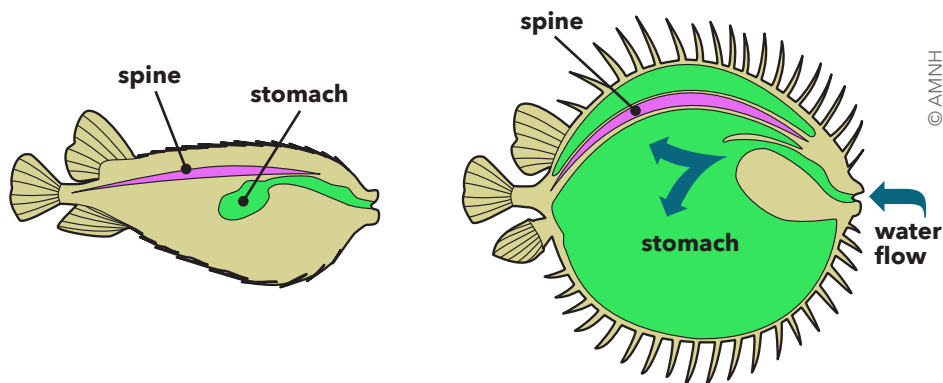


A pufferfish's skin is hard and covered with sharp spines.

Some toads and snakes have another way to scare away a predator. They puff up to look bigger. Puffer fish do both of these things. They puff up AND they have spines.

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How does the puffer “puff” up? It’s not filled with air like a balloon. It’s full of water. The fish gulps lots of water into its stomach. Filled with water, its stomach becomes almost one hundred times bigger. Other body parts



inside the puffer are pushed to the side to make room.

A puffer can turn into a spiny ball in a few seconds. Then only the biggest animals can eat it. The ocean may be full of dangers, but the puffer is ready. Adaptations like sharp spines and puffing up help keep the puffer safe.

Article adapted from "A Fish Story" by Adam Summers, *Natural History* magazine, October 2001.

STUDENT WORKSHEET: Part 1

Name: _____

Draw a spiny pufferfish. **Label** the spines.

This animal is called the spiny pufferfish.

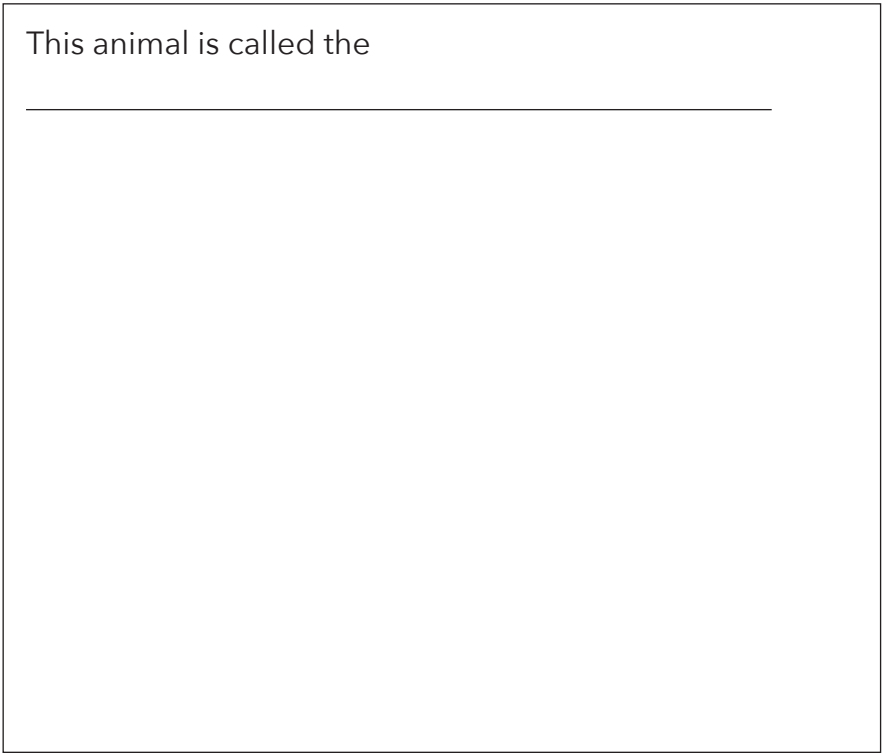
Explain how the pufferfish uses its spines.

STUDENT WORKSHEET: Part 2

Name: _____

Pick one animal in the exhibition. **Draw** it and **label** one body part.

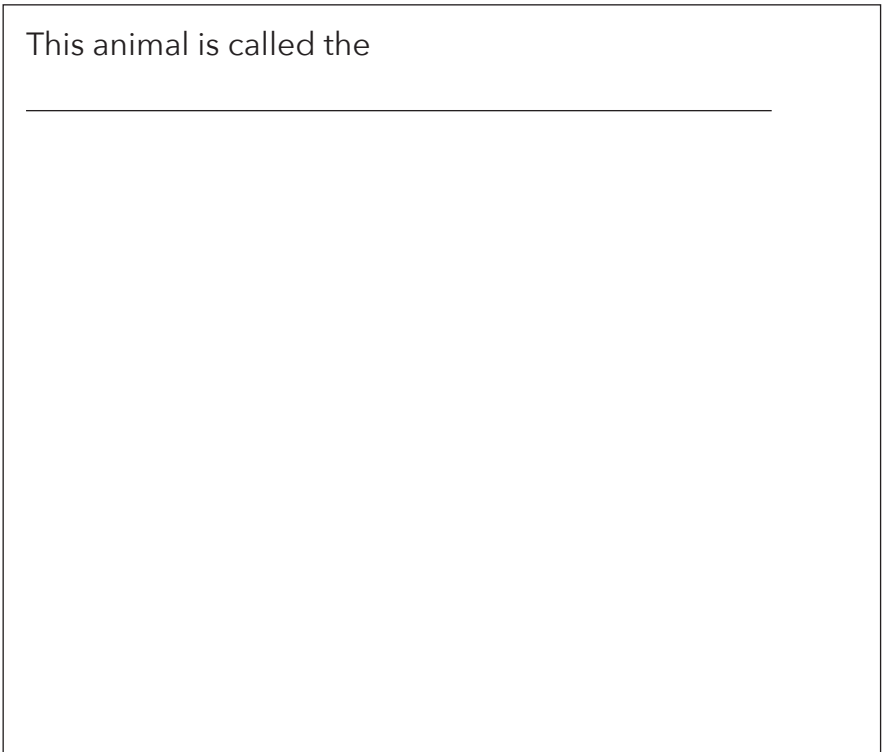
This animal is called the



Explain how the animal uses its body part.

Pick another animal. **Draw** it and **label** one body part.

This animal is called the



Explain how the animal uses its body part.

STUDENT WRITING TASK

You have learned about animals by reading the article, "Who Wants a Spiny Snack?" and by exploring the *Life at the Limits* exhibition.

Now you will write a book to teach your friends about these animals.

Your book will include three animals. The first animal will be the spiny pufferfish. The other two animals will be from the *Life at the Limits* exhibition.

For each animal, name one body part that helps this animal. Then explain in your own words how this body part works. Include a drawing of each animal and label the body part that you have described.

ESSAY SCORING RUBRIC: STUDENT VERSION

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Who Wants a Spiny Snack?"	I used what I learned in the article to write a detailed book in my own words	I used what I learned in the article to write my book	I used what I learned in the article to write my book but I am not sure if everything I wrote is correct	I did not use any information from the article to write my book
	Museum Exhibition: <i>Life at the Limits</i>	I used what I learned in the exhibition to write a detailed book in my own words	I used what I learned in the exhibition to write my book	I used what I learned in the exhibition to write my book but I am not sure if everything I wrote is correct	I did not use any information from the exhibition to write my book
SCIENCE (worth 1/3)	Science Explanations	All of the information I wrote about animal body parts is correct	Most of the information I wrote about animal body parts is correct	Some of the information I included about animal body parts is correct	None of the information I wrote about animal body parts is correct
		I drew pictures of the spiny pufferfish and two other animals and labeled their body parts to show how they work	I drew pictures of the spiny pufferfish and two other animals and labeled their body parts	I drew pictures of two animals and labeled their body parts	I did not include any illustrations
WRITING (worth 1/3)	Focus	My whole book is about animals and their body parts	Most of my book is about animals and their body parts	Some of my book is about animals and their body parts	My book is not about animal body parts
		I introduced my topic	X	X	I did not introduce my topic
		I wrote an ending to my book	X	X	I didn't write an ending to my book
	Development	I explained how the body parts of the puffer fish and two other animals work in detail	I explained how the body parts of the puffer fish and two other animals work	I explained how the body parts of the one or two animals work	I did not explain how any animal body parts work

Science & Literacy Activity

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This activity has three components:

- 1. Before your visit**, students will read a content-rich article about the spiny pufferfish and the adaptations that protect it from predators. This article will provide context for the visit, and also help them complete the post-visit writing task.
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- Student worksheets (p. 13-14)
- Student writing task (p. 15)
- Essay scoring rubric (student version) (p. 16-17)

1. BEFORE YOUR VISIT

Overview

Students will read a content-rich article about the spiny pufferfish and the adaptations that protect it from predators. This article will provide context for the visit, and help them complete the post-visit writing task.

Preparation

- Familiarize yourself with the student writing task and rubric (p. 8-9, 15-17).
- Familiarize yourself with the teacher version of the article (p. 3-5), and plan how to facilitate the students' reading of the article.

Instructions

- Explain the goal: to complete a writing task about animal body parts.
- Tell students that they will need to read an article before visiting the Museum, and read additional texts during the visit (including printed text, digital and physical/hands-on interactives, videos, and models).
- Distribute the article, student writing task, and rubric to students.
- Review the rubric with students and tell them that it will be used to grade their writing.
- Read and discuss the article, using the teacher notes to facilitate.

Common Core State Standards

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.

RI.4.2 Determine the main idea of a text and explain how it is supported by key details; summarize the text.

New York State Science Core Curriculum

LE3.1a

Next Generation Science Standards

DCI: LS1.A: Structure and Function

Plants and animals have both internal and external structures that serve various functions in growth, survival, behavior, and reproduction.

SEP 8: Obtaining, Evaluating and Communicating Information

- Obtain and combine information from reliable media to explain phenomena.
- Communicate scientific information orally and in written formats.

- Distribute the student worksheets (p. 13-14). Have students fill in the “spiny pufferfish” section based on what they’ve learned from the article. Tell them that at the Museum, they will complete the second worksheet about two other animals and their body parts.

2. DURING YOUR VISIT

At the Museum, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, and models). The information they’ll gather from these multiple sources will help them complete the post-visit writing task.

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- Review the educator’s guide to see how themes in the exhibition connect to your curriculum and to get an advance look at what your students will encounter. (Guide is downloadable at amnh.org/lal/educators)
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- Have students explore the exhibition in pairs, with each student completing his or her own student worksheet.
- Encourage student pairs to ask you or their peers for help locating information. Tell students they may not share answers with other pairs, but may point each other to places where answers can be found.

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- Before they begin to write, have students use the writing task to frame a discussion around the information that they gathered at the Museum. They can work in pairs, small groups, or as a class, and can compare their findings.
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Alternate Version of Article

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ARTICLE: TEACHER VERSION

About this Article

- **Lexile:** 840
- **Wordcount:** 504
- **Text Complexity:** The Lexile level for this text falls in the middle of the 4-5 CCSS grade level band. This text is suitable as a read aloud for students in grades 3 and beginning of grade 4. Teachers should use their professional judgment and knowledge of students' independent reading levels regarding assigning this text for independent reading.
- **Note:** Assign partners prior to reading this text aloud with students and have them assign a "partner A" and "partner B."

Key for Teacher Notes

- **Green text** specific strategies
- Regular text instructions for teachers
- *Italicized text* teacher's instructions to students
- Underlined text important domain-specific words

Who wants a spiny snack?

Not many animals! How the spiny puffer stays safe in the ocean

A shark glides through the warm water, searching for its next meal. It spots an ordinary brown fish swimming slowly in the clear waters ahead.



© iStock Photo/GlobalP

But as the shark approaches, PUFF-PUFF-PUFF! The fish puffs out into a round, spiny ball. The startled shark swims away. The pufferfish is safe for now — at least until the next shark or big fish swims by.



© iStock Photo/FLaudGirl

The ocean can be a dangerous place for small fish like the puffer. Its waters are full of predators like sharks, squid, and bigger fish that eat small fish. But pufferfish have adaptations that protect them from predators.

All animals have adaptations to stay alive. An adaptation is a body part or behavior that helps an animal live in its environment. Predators have



© NOAA

A shark uses its sharp teeth to catch and eat prey.

Prompt to **think/pair/share**: *What do you think this text will teach us about?*

Listen in to student pairs. Repeat some of the good ideas that you heard, or pre-select one or two students to share out to the whole group.

Reread this paragraph aloud a second time. Prompt to **visualize**: *As I reread each sentence of this paragraph, close your eyes and visualize what is happening. When I tell you to **turn and talk**, tell your partner what you saw happening. You should be alternating so that each partner has a few turns to talk.*

*Optional for ELLs: Ask students to act out what is happening in the paragraph, with one partner playing the part of the spiny puffer, and one playing the part of the shark.

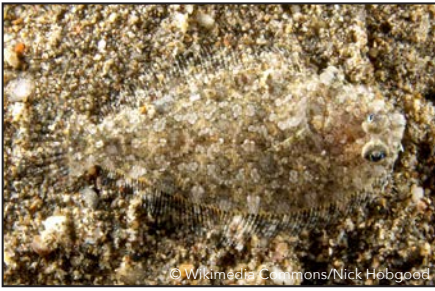
Before reading on, spotlight the two important terms that appear in this paragraph. Options:

If this is the first time students are encountering these words: Have students underline "predator" and "adaptation." Ask them to re-read the paragraph independently, and then try to determine what the words mean based on the context. Listen in and pre-select students to share out word meanings that are accurate, encouraging them to explain how they determined the meaning. If students need more support, guide them in determining the meaning of the words using the context. If you have several ELLs or SWDs, you may consider pre-teaching these two words prior to reading the text, using a student-friendly definition, and an example shown in an illustration on the smartboard or posted in the room.

If students have familiarity with the words based on prior teaching: Prompt students to give a definition of each term in their own words to their partner.

adaptations that help them hunt. A shark's powerful, torpedo-shaped tailfin and sharp teeth are two adaptations.

Other animals have adaptations that provide protection from predators. These animals may be fast enough to escape predators. Or they might use camouflage, special patterns or colors that help them hide in their environment.



Can you find the flounder?



Porcupines have long sharp spines that protect them.

But some animals don't run or hide. They have bodies that are hard to eat. Just picture the sharp spines of a porcupine, hedgehog, or sea urchin. Few predators are large or tough enough to make a meal of those animals!

Some toads and snakes have their own way to discourage predators. They puff themselves up to look larger. The bigger an animal, the harder it is to catch and eat. Puffer fish combine both of these adaptations. They puff up AND they have long, sharp spines.

Swimming along, a pufferfish looks like any other fish. But when it is threatened, it swells up suddenly like a big balloon. When this happens, it's easy to see why some people call it balloonfish. But this fish is no soft, squishy balloon. Its skin becomes rigid, with sharp spines sticking out in all directions. Usually these spines lie flat against the side of the fish. When the fish puffs up, the outer skin stretches out and pulls the spines up.



A pufferfish's skin is hard and covered with sharp spines.

This section gives definitions of the two important terms introduced in the previous paragraph, and offers examples for each.

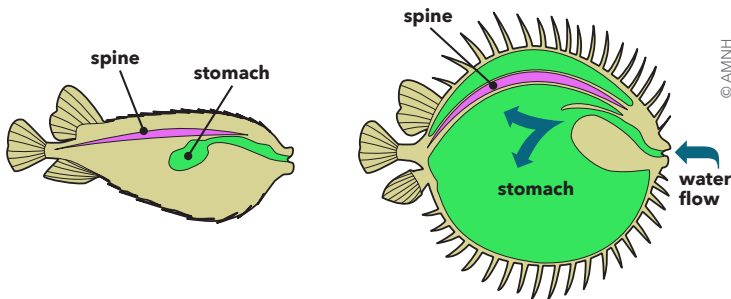
To provide scaffolding, construct a chart with students' help (**shared writing**) that includes these definitions and examples.

To provide more independence, ask students to create the chart in their notes with their partner (give template for blank web that students copy and complete in their notebooks). Provide time for a brief whole group discussion to clarify the meanings of these two terms.

This section is all about protective adaptations, narrowing the focus away from adaptations in general. After reading this paragraph, students should understand two types of protective adaptations. To ensure that they do, ask students to **think/pair/share** with a partner to answer the question, "What is this paragraph teaching us?" Listen in to student conversations and pre-select a student to explain the main idea of this paragraph. If clarity is needed, **think aloud**, demonstrating how you are able to determine the main idea of the paragraph.

It is important that students visualize this description of the spiny puffer making this change that helps ward off predators. Have students discuss the differences of the pufferfish before and after. You may want to ask them to refer to the two photos of the pufferfish on the first page of the article.

How does the pufferfish make this amazing transformation? Despite its nickname, it doesn't blow itself up with air like a balloon. Instead, it fills up with water. The fish pumps a huge amount of water through its mouth into its stomach. Filled with water, its stomach becomes almost one hundred times larger. The stomach can expand like this because it's usually crumpled into many tiny folds. As water rushes in, the stomach unfolds. To make room for the swelling stomach, other



organs like the liver and intestines are pushed to the side. A spiny puffer can change from an ordinary-looking fish into a menacing spiny ball in a few seconds. Then only the biggest animals dare to eat it. The ocean may be full of dangers, but adaptations like sharp spines and puffing up help keep the puffer safe.

Article adapted from "A Fish Story" by Adam Summers, *Natural History* magazine, October 2001.

This paragraph explains the mechanics of how the spiny puffer makes this transformation. Pause after reading the first sentence, and think aloud about how when we read informational texts and the author poses a question, we can usually expect that what follows will be an answer to that question. Say: *As I read the rest of this paragraph, listen very carefully for the answer to this question. I'd really like to know how this fish does this to its body! After I read, you will describe how this transformation happens, and I am hoping one of you will come up and describe it to the class.*

After you have prompted students to **think/pair/share**, select one student to describe the process to the class. They can refer to specific lines in the text and explain them in their own words.

Formative Assessment: After finishing the article, ask students to complete a **3-2-1** exit slip:

List three (3) important facts that you learned from this article.

Think of two (2) questions you have after reading the article.

Name the one (1) most interesting thing you learned from the article (this can be one of the 3 facts you listed above), and tell why you think it is interesting.

In addition to saying the above instructions to students, you should have the questions posted. Students will not find information to answer questions about puffer fish during the Museum visit, but if some questions require more than revisiting article content or classroom discussion, you can find more information on this webpage:

<http://animals.nationalgeographic.com/animals/fish/pufferfish/>

STUDENT WORKSHEET: Part 1

Name: _____ **ANSWER KEY**

Draw a spiny pufferfish before and after it puffs up. **Label** one structure that helps the pufferfish survive.

Before	After
Species Name: Spiny Pufferfish	

Describe the structure. **Explain** how it helps the pufferfish survive.

When it is attacked, the pufferfish fills its stomach with water and gets much larger than normal.

It is also covered in sharp spines and when it puffs up, its spines stick out. The spines protect the

pufferfish from predators.

STUDENT WORKSHEET: Part 2

Name: _____ **ANSWER KEY**

In the exhibition, **pick** two animals and **draw** them in the boxes. For each animal, **label** one structure that helps it perform a function, such as breathing, moving, sensing, eating, and avoiding predators.

species name:
Answers will vary.

Describe one structure. **Explain** how it helps the animal survive.

Answers will vary.

species name:
Answers will vary.

Describe one structure. **Explain** how it helps the animal survive.

Answers will vary.

ESSAY SCORING RUBRIC: TEACHER VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Who Wants a Spiny Snack?"	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the article	Presents paraphrased information from the article relevant to the prompt with accuracy and sufficient detail	Presents information from "Who Wants a Spiny Snack?" relevant to the purpose of the prompt with minor lapses in accuracy or completeness AND/OR information is copied from the text	Attempts to present information in response to the prompt, but lacks connections to "Who Wants a Spiny Snack?" or relevance to the purpose of the prompt
	Museum Exhibition: Life at the Limits	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the exhibition	Presents paraphrased information from the exhibition relevant to the prompt with accuracy and sufficient detail	Presents information from the exhibition relevant to the purpose of the prompt with minor lapses in accuracy or completeness AND/OR information is copied from the text	Attempts to present information in response to the prompt, but lacks connections to the exhibition content or relevance to the purpose of the prompt
SCIENCE (worth 1/3)	Science Explanations	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of animal body parts and their functions	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of animal body parts and their functions	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of animal body parts and their functions; minor errors in explanation	Attempts to include science content in explanations, but understanding of animal body parts is weak; content is irrelevant, inappropriate, or inaccurate
		Uses labeled illustrations of the spiny pufferfish and two other animals to accurately communicate relevant information	Includes labeled illustrations of the spiny pufferfish and two other animals but little information is communicated	Illustrations are unlabeled OR fewer than three illustrations are included	No illustrations
WRITING (worth 1/3)	Focus	Maintains a strongly developed focus on the writing prompt for the entire essay	Maintains focus on the writing prompt for the majority of the essay	Addresses the prompt but is off-task some of the time	Does not address the prompt for most or all of the essay
		Clearly introduces the topic of animal body parts and how these parts help animals survive	Introduces the topic of animal body parts and explains how these parts help animals survive; introduction may lack detail	Attempts to introduce animal body parts and how these body parts help animals survive; introduction is inaccurate or incomplete	Does not introduce animal body parts
		Provides a relevant concluding section	Provides a relevant concluding statement	Provides a concluding statement	Provides no sense of closure
		Accurately introduces the spiny pufferfish and two other animals	Introduces the spiny pufferfish and one other animal	Introduces only one animal	Does not introduce any animals

ESSAY SCORING RUBRIC: TEACHER VERSION - page 2

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		1	2	3	4
WRITING (worth 1/3)	Development	Clearly and accurately describes how each body part helps the animals survive	Describes how two body parts help two different animals survive	Describes how one body part helps an animal survive OR attempts to describe how two body parts help two animals survive in a manner that is inaccurate or incomplete	Does not describe how any animal body part helps an animal survive
	Clarity	Consistent use of precise and domain-specific language where appropriate	Some use of precise and domain-specific language	Little use of precise and domain-specific language	No use of precise and domain-specific language
Demonstrates and maintains a well-developed command of standard English conventions and cohesion, with few errors; response includes language and tone consistently appropriate to the purpose and specific requirements of the prompt		Demonstrates a command of standard English conventions and cohesion, with few errors; response includes language and tone appropriate to the purpose and specific requirements of the prompt	Demonstrates an uneven command of standard English conventions and cohesion; uses language and tone with some inaccurate, inappropriate, or uneven features	Attempts to demonstrate standard English conventions, but lacks cohesion and control of grammar, usage, and mechanics	

STUDENT READING

Who wants a spiny snack?

Not many animals! How the spiny puffer stays safe in the ocean

A shark glides through the warm water, searching for its next meal. It spots an ordinary brown fish swimming slowly in the clear waters ahead.



© iStock Photo/GlobalIP

But as the shark approaches, PUFF-PUFF-PUFF! The fish puffs out into a round, spiny ball. The startled shark swims away. The pufferfish is safe for now — at least until the next shark or big fish swims by.



© iStock Photo/FiLaudGirl

The ocean can be a dangerous place for small fish like the puffer. Its waters are full of predators like sharks, squid, and bigger fish that eat small fish. But pufferfish have adaptations that protect them from predators.

All animals have adaptations to stay alive. An adaptation is a body part or behavior that helps an animal live in its environment. Predators have



© NOAA

A shark uses its sharp teeth to catch and eat prey.

adaptations that help them hunt. A shark's powerful, torpedo-shaped tailfin and sharp teeth are two adaptations.

Other animals have adaptations that provide protection from predators. These animals may be fast enough to escape predators. Or they might use camouflage, special patterns or colors that help them hide in their environment.



Can you find the flounder?

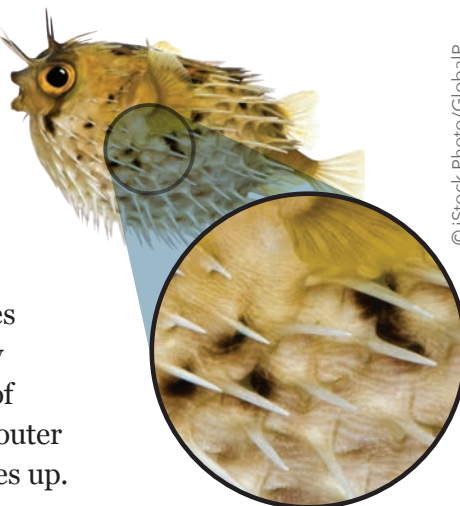


Porcupines have long sharp spines that protect them.

But some animals don't run or hide. They have bodies that are hard to eat. Just picture the sharp spines of a porcupine, hedgehog, or sea urchin. Few predators are large or tough enough to make a meal of those animals!

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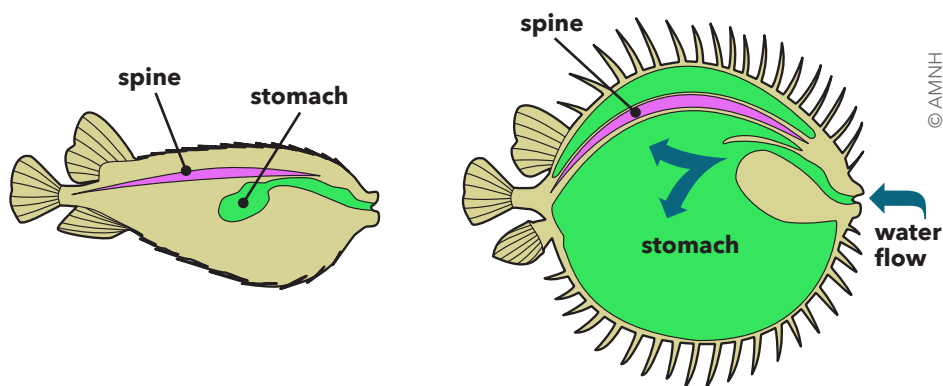


© iStock Photo/GlobalIP

A pufferfish's skin is hard and covered with sharp spines.

How does the pufferfish make this amazing transformation?

Despite its nickname, it doesn't blow itself up with air like a balloon. Instead, it fills up with water. The fish pumps a huge amount of water through its mouth into its stomach. Filled with water, its stomach becomes almost one hundred times larger. The stomach can expand like this because it's usually crumpled into many tiny folds. As water rushes



in, the stomach unfolds. To make room for the swelling stomach, other organs like the liver and intestines are pushed to the side.

A spiny puffer can change from an ordinary-looking fish into a menacing spiny ball in a few seconds. Then only the biggest animals dare to eat it. The ocean may be full of dangers, but adaptations like sharp spines and puffing up help keep the puffer safe.

Article adapted from "A Fish Story" by Adam Summers, *Natural History* magazine, October 2001.

STUDENT WORKSHEET: Part 1

Name: _____

Draw a spiny pufferfish before and after it puffs up. **Label** one structure that helps the pufferfish survive.

Before	After
<p>Species Name: Spiny Pufferfish</p>	

Describe the structure. **Explain** how it helps the pufferfish survive.

STUDENT WORKSHEET: Part 2

Name: _____

In the exhibition, **pick** two animals and **draw** them in the boxes. For each animal, **label** one structure that helps it perform a function, such as breathing, moving, sensing, eating, and avoiding predators.

species name:

Describe one structure. **Explain** how it helps the animal survive.

species name:

Describe one structure. **Explain** how it helps the animal survive.

STUDENT WRITING TASK

Now that you have studied three animals and the structures that help them survive, write an illustrated essay to teach others what you have learned.

You will write about three different animals. The first will be the spiny pufferfish. Use the information from the article “Who Wants a Spiny Snack?” to draw the spiny pufferfish, label one structure, and explain how it helps the spiny pufferfish survive.

Next, you will do the same thing for two animals that you saw in the *Life at the Limits* exhibition at the Museum.

ESSAY SCORING RUBRIC: STUDENT VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Who Wants a Spiny Snack?"	I have used information correctly from the article to write my essay; I have given a lot of detail to explain the information in my own words	I have used information correctly from the article to write my essay in my own words	I have used information from the article to write my essay, but not all of my information is correct AND/OR I didn't use my own words	I did not use information from the article to write my essay
	Museum Exhibition: <i>Life at the Limits</i>	I have used information correctly from the exhibition to write my essay; I have given a lot of detail to explain the information in my own words	I have used information correctly from the exhibition to write my essay in my own words	I have used information from the exhibition to write my essay, but not all of my information is correct AND/OR I didn't use my own words	I did not use information from the exhibition to write my essay
SCIENCE (worth 1/3)	Science Explanations	All of the information I included about animal body parts and their functions is correct	Most of the information I included about animal body parts and their functions is correct	Some of the information I included about animal body parts and their functions is correct	None of the information I included about animal body parts and their functions is correct
		I included labeled illustrations of the spiny pufferfish and two other animals that helps the reader understand how their body parts work	I included labeled illustrations of the spiny pufferfish and two other animals	I included labeled illustrations of fewer than three animals	I did not include any illustrations
WRITING (worth 1/3)	Focus	My entire essay is about animal body parts	Most of my essay is about animal body parts	Some of my essay is about animal body parts	None of my essay is about animal body parts
		I included a clear introductory paragraph on animal body parts	I included an introductory paragraph to the essay	I included an introductory sentence to the essay	I did not include an introduction
		I wrote a concluding paragraph that relates to the information in my essay	I wrote a concluding sentence that relates to the information in my essay	I wrote a concluding sentence at the end of the essay	I did not write a concluding sentence at the end of the essay
		I accurately introduced the spiny pufferfish and two other animals	I introduced the spiny pufferfish and two other animals	I introduced only one animal	I did not introduce any animals
	Development	I correctly described how three body parts help three animals survive	I described how two body parts help two different animals survive	Describes how one body part helps an animal survive	I did not describe how any animal body part helps an animal survive
		I used all appropriate science vocabulary words correctly	I used most science vocabulary words correctly	I used some science vocabulary words correctly	I did not use any science vocabulary words

ESSAY SCORING RUBRIC: STUDENT VERSION - page 2

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
WRITING (worth 1/3)	Clarity	I edited my essay for spelling, punctuation, and grammar; there are no errors	I edited my essay for spelling, punctuation, and grammar; there are some minor errors but the reader can still understand my writing	I did not carefully edit my essay for spelling, punctuation, and grammar; there are errors that may make the essay hard for readers to understand	I did not edit my essay for spelling, punctuation, and grammar; there are many errors that make the essay hard for readers to understand

Science & Literacy Activity

ACTIVITY OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to animal adaptations.

This activity has three components:

- 1. Before your visit**, students will read a content-rich article about scientists who study cave fish to understand how blindness evolves in organisms that live in dark environments. This article will provide context for the visit, and also help them complete the post-visit writing task.
- 2. At the Museum**, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models). This information will help them complete the post-visit writing task.
- 3. Back in the classroom**, students will draw on the first two components of the activity to complete a CCSS-aligned explanatory writing task about animal adaptations.

Materials in this packet include:

For Teachers

- Activity Overview (p. 1-2)
- Article (teacher version): "Why Do Cave Fish Lose Their Eyes?" (p. 3-7)
- Answers to the student worksheets (p. 8)
- Essay scoring rubric (teacher version) (p. 9-10)

For Students

- Article (student version): "Why Do Cave Fish Lose Their Eyes?" (p. 11-14)
- Student worksheets (p. 15)
- Student writing task (p. 16)
- Essay scoring rubric (student version) (p. 17-18)

1. BEFORE YOUR VISIT

Students will read a content-rich article about scientists who study cave fish to understand how blindness evolves in organisms that live in dark environments. This article will provide context for the visit, and help them complete the post-visit writing task.

Preparation

- Familiarize yourself with the student writing task and rubric (p. 9-10, 16-18).
- Familiarize yourself with the teacher version of the article (p. 3-7), and plan how to facilitate the students' reading of the article.

Instructions

- Explain the goal: to complete a writing task about animal adaptations.
- Tell students that they will need to read an article before visiting the Museum, and read additional texts during the visit (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models).
- Distribute the article, student writing task, and rubric to students.
- Review the rubric with students and tell them that it will be used to grade their writing.

Common Core State Standards

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

New York State Science Core Curriculum

LE 3.1b

Next Generation Science Standards

DCI: LS4.C: Adaptation

Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions.

SEP 8: Obtaining, Evaluating and Communicating Information

- Integrate scientific information in written text with that contained in media and visual displays to clarify claims and findings.
- Read and synthesize information from multiple sources.
- Communicate scientific information in writing.

- Read and discuss the article, using the teacher notes to facilitate.
- Distribute the student worksheet (p. 15). Have students fill in the “cave fish” section based on what they’ve learned from the article. Tell them that at the Museum, they will complete the rest of the worksheet.

2. DURING YOUR VISIT

At the Museum, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models). The information they’ll gather from these multiple sources will help them complete the post-visit writing task.

Preparation

- Review the educator’s guide to see how themes in the exhibition connect to your curriculum and to get an advance look at what your students will encounter. (Guide is downloadable at amnh.org/lal/educators)
- Familiarize yourself with the student worksheets (p. 15), including the teacher answer key (p. 8), map of the exhibition.

Instructions

- Explain the goal of the Museum visit: to read and engage with texts (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models), and to gather information to help them complete the post-visit writing task.
- Review the worksheet. Clarify what information students should collect.

Suggestions for Facilitating the Museum Visit

- Have students explore the exhibition in pairs, with each student completing his or her own student worksheet.
- Encourage student pairs to ask you or their peers for help locating information. Tell students they may not share answers with other pairs, but may point each other to places where answers can be found.

3. BACK IN THE CLASSROOM

Students will use what they have learned from the pre-visit article and at the Museum to complete a CCSS-aligned explanatory writing task about physical and behavioral adaptations that make animals well suited to survive and reproduce.

Preparation

- Plan how you will explain the student writing task and rubric (p. 16-18) to students.

Instructions

- Review the writing task and rubric with students. Explain that they will use it while composing, and also to evaluate and revise what they have written.

Suggestions for Facilitating Writing Task

- Before they begin to write, have students use the writing task to frame a discussion around the information that they gathered at the Museum. They can work in pairs, small groups, or as a class, and can compare their findings.
- Referring to the writing task, have students underline or highlight all relevant passages and information from the article and from the notes taken at the Museum. Instruct each student to write down any useful information gathered by their peers.
- Students should write their essays individually.

Supports for Diverse Learners

This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It represents information in multiple ways and offers multiple ways for your students to engage with content as they read about, discuss, view, and write about scientific concepts. Different parts of the experience (e.g. reading texts, or locating information in the Museum) may challenge individual students. However, the arc of learning is designed to offer varied opportunities to learn. We suggest that all learners experience each activity, even if challenging. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

Alternate Version of Article

Another version of the same article with a lower lexile level is available for download at amnh.org/lal/educators. You can use this same activity with that article.

ARTICLE: TEACHER VERSION

About this Article

- **Lexile:** 950
- **Wordcount:** 1268
- **Text Complexity:** While the Lexile level for this article falls just short of the 6-8 CCSS band (955-1155), several qualitative factors make this text appropriately complex for grades 6-8, with the expectation that more scaffolding will be needed in the lower middle school grades. The knowledge demands of this text on the reader are high, as evidenced by the high level of detail in which complex scientific processes are described. Additionally, some of the complex domain-specific vocabulary terms will likely be unfamiliar for many middle school students.
- **Note:** Assign partners prior to reading this text aloud with students and have them assign a “partner A” and “partner B.”

Key for Teacher Notes

- **Green text**
specific strategies
- Regular text
instructions for teachers
- *Italicized text*
teacher's instructions to students
- Underlined text
important domain-specific words

Why Do Cave Fish Lose Their Eyes?



Carlsbad Caverns National Park

Deep underground there are caves where the sun never shines. If you found yourself in one of these caverns without a flashlight, you would see nothing at all; just total blackness.

In some of these underground caves, there are fishes, crustaceans, salamanders and other animals that have evolved to live without light. For example, more than one hundred species of cave fishes live their lives in constant darkness. They depend on senses other than sight to hunt, eat and reproduce.

Many of these species of fishes are blind or nearly blind—some don't even have eyes. Yet they all evolved from fishes that could see. Somehow, over millions of years, these fishes not only developed the ability to live without sight—they lost the ability to see altogether.

How did that happen? How can evolution cause a species to lose a trait? It's a mystery that evolutionary scientists have been struggling to unravel. The search for an answer gives us a fascinating look at how evolution works.

Regressive Evolution

We usually think of evolution as a process in which species *acquire new* traits. But in cave fishes we have an example of regressive evolution, a process in which species lose a trait—in this case, the ability to see.

Stop here and ask students to **summarize** this introduction - “**stop and jot.**”

After students have had time to do that independently, prompt them to **turn and talk**, comparing their summary to their partner's. While they are speaking in partners, listen in and select an exemplary summary to share with the class. (An exemplary summary should include key details about cave fish, and should mention the question about evolution this article will address).

Alternately, for more scaffolding, demonstrate this process for students: Construct a summary in front of students, referring to the text and **thinking aloud** as you jot your summary. Make this process interactive by inviting students to make suggestions as you write the summary.

Before reading this section aloud, direct students' attention to the photograph of a cave fish on p.4. Prompt them to **turn and talk** to their partners about what they notice about the cave fish's physical features.

Think aloud: *This part is making me think about the way we define evolution. Evolution does not only explain how species acquires a trait, but also how they lose a trait. I expect this article to give me more information about this idea of regressive evolution.*

How does this happen? Do cave fishes go blind because they don't use their eyes? Though at first this idea might seem to make sense, it actually has no basis in science. It is your **genes** that determine which **traits** you inherit. For example, you have five fingers on each hand because of the **genes** you got from your parents. However, if you have an accident and lose a finger, your children will still be born with five fingers on each hand. If you lift weights and become a body builder, it doesn't mean your children will be born with bulging biceps. In each case, your **genes** haven't changed—even though your body has.



Blind cave fish, Mammoth Cave National Park, Kentucky

The fact that cave fishes don't use their eyes has absolutely no effect on the DNA in their chromosomes. They are blind because something happened to the **genes** that control the development of their eyes. This change is passed on from parent to offspring. That explains why a blind fish would have blind offspring. But it doesn't explain how a whole species of blind fish came to exist.

Evolution works by a process called *natural selection*. If an animal is born with a **trait** that gives it an advantage over other individuals, it will be more successful at having offspring. When this happens, evolutionary scientists say that that animal is "selected" for having that trait. Its offspring and succeeding generations will **inherit** that trait, spreading it throughout the population. But in the case of cave fishes, how does being blind give a fish an advantage in the dark? And if being blind is not an advantage, then how did natural selection lead to a species of blind cave fish?

Think aloud as follows: *This paragraph gives an example of a misconception about **evolution** that sounds like it makes sense at first, but that has no basis in science. Turn and talk to your partner: explain what this misconception is, and why it is not true.*

Listen in to students' conversations and select a student to share out. Or, alternatively, provide a **follow-up think aloud** for clarification: *This paragraph explains the false idea that traits you have acquired during your lifetime are passed on to offspring, like the body builder example... the reason this does not make sense is that the traits that you have come from the **genes** you are born with, not from the activity or behavior of your parents before you were born. (If students have not yet studied heredity, you may want to discuss some of these vocabulary terms before reading this text. You may also consider reviewing these terms if students have studied heredity).*

Think aloud: *This elaborates, or explains more about, why the misconception described in the above paragraph is not scientifically valid.*

Turn and talk to a partner: *Why do blind cave fish have blind offspring? Use details from this paragraph but explain your answer in your own words. Listen in to students' conversations and select a student to share their thinking about this question with the class. Allow students to ask questions and provide clarification as needed.*

Think/Pair/Share: *This paragraph explains the question(s) that scientists have about cave fish. What exactly are the questions that this paragraph describes? Re-read it if you need to, and talk your partner through what this paragraph is saying.*

If clarification is needed, show students how you determine the main idea of the paragraph by **thinking aloud**. **Jot** the main idea in the margin. To provide more scaffolding, prompt students to paraphrase each sentence of this paragraph with a partner, or invite individual students to paraphrase aloud to the class so that you can step in to provide support when needed (guided practice). Students must understand the question that is being posed in this paragraph in order for the rest of the article to be meaningful for them.

Two Answers

Scientists have studied one species of blind cave fish, the blind Mexican tetra (*Astyanax mexicanus*). They have come up with competing explanations for blindness in that fish, which likely will help them to understand other cave fishes as well.



Mexican tetra (*Astyanax mexicanus*).

The first hypothesis assumes that blindness *does* give the fish some sort of evolutionary advantage, though not directly. What if the gene or genes that cause blindness also are responsible for some other change in the fish? And what if it was that change, not blindness, that gave the fish an advantage to reproduce? Scientists call this pleiotropy—when multiple effects are caused by the same mutation in one gene.

The second hypothesis is based on the fact that natural selection does not just reward success, it also weeds out failures. In a lake, where there is sunlight, a fish born blind would have trouble competing with other fish that can see. It probably would not survive to have offspring. But a fish born blind in a dark

You should be listening for these two different hypotheses as we read on. As you listen, take notes on each one so that you are ready to discuss them with your partner.

Alternately, to offer more independence, give students these same instructions to take notes, but have them read the next two paragraphs independently.

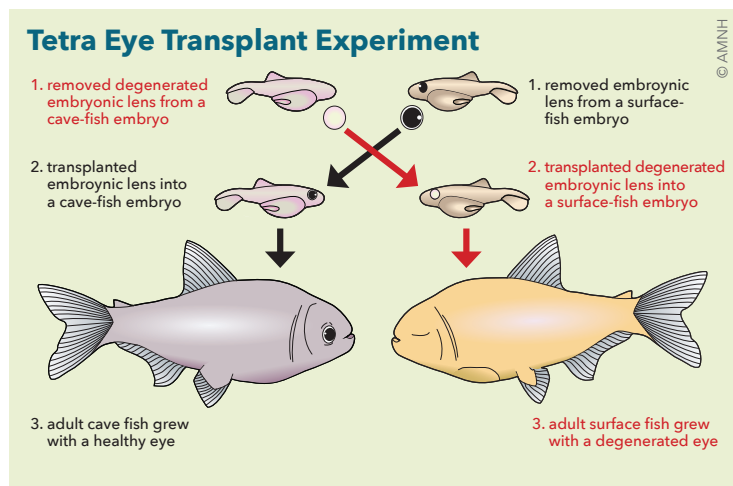
Turn and talk: Explain this first hypothesis in your own words.

Shared Writing: Using white board or chart paper, write bulleted notes on this first hypothesis, pleiotropy. Invite students to suggest what should go in the notes as you scribe.

cave would not be at a disadvantage, since in the darkness no fish can use their eyes. In those conditions, natural selection will not work to weed out the mutation for blindness. Over millions of years, many more mutations will accumulate and eventually the entire population of fish will be blind. This is called the *neutral mutation* hypothesis.

An Eye-Opening Experiment

A group of scientists at the University of Maryland carried out an experiment with two varieties of the same species of Mexican tetras. One variety lives in bodies of water near the surface where there is sunlight and can see. The other variety of tetras lives in dark caves and is blind.



In their experiment, the scientists transplanted a lens from the eye of a surface tetra embryo into the eye of a cave tetra embryo. The cave fish embryo would normally develop into a blind fish. But the lens from the surface tetra transplanted into the cave tetra caused all of the surrounding tissues to develop into a healthy eye. This experiment demonstrated that the genes involved in the development of the eyes of the cave tetra were still totally functional.

The scientists knew that there are many genes responsible for the development of each part of an eye (for example, the retina, iris, cornea and lens). Each part develops independently. The results of the experiment showed that the genes for eye development in the Mexican tetra were all ready to work properly, given the correct signal. The experiment seemed to suggest that blindness in the Mexican tetra was not caused by many mutations, but instead by a small number of mutations in genetic “master switches.”

These master switches are genes that control the function of many other genes. In this case, the switches control genes responsible for eye development. These master switches have the ability to disable the eye genes. These remain intact, but inactive. Putting a healthy lens into the cave tetra embryo seems to trigger

Turn and talk: Explain this first hypothesis on your own words.

Shared Writing: Using white board or chart paper, write bulleted notes on this second hypothesis, the neutral mutation hypothesis. Invite students to suggest what should go in the notes as you scribe.

Think aloud about the difference between these two hypotheses. Alternatively, to provide more independence, ask students to **think/pair/share** about the difference between the two hypotheses. Listen in to students’ conversations and select a student to share out. Allow for questions.

After reading this section, direct students’ attention to the illustration of the experiment. **Think/Pair/Share:** Ask students to use the text in this section and the illustration to explain to their partner how the scientists carried out this experiment. Facilitate brief whole class discussion.

Think/Pair/Share: What did the results of the experiment show?

Follow-Up Question: What did scientists learn from these results?

Listen in and select a student to share out. Allow for questions and clarification. It is important to check for understanding at this point in the text.

master switches to send a signal to the inactive eye genes, allowing cave tetras to develop eyes.

If scientists could find the genetic “master switches” that made cave tetras blind, they could discover if the same switches had effects on other traits of the fish that do give it an evolutionary advantage for surviving in caves.

The researchers did indeed find one of those genes. It is nicknamed *Hedgehog* or the *Hh gene*. They discovered that the *Hedgehog gene* does more than cause blindness in cave tetras—when the fish develops without eyes, the skull bones move into the empty eye socket, which at the same time enlarges its nose. Unlike other vertebrates, fishes use their nose only for smelling. It could be that the same control gene (*Hh*) that stops eye development in the fish also enhances its sense of smell. An enhanced sense of smell would be a definite advantage for a fish that lives in darkness.

As a result of these and other experiments, it now seems highly likely that blindness in cave tetras is in part the result of pleiotropy—one mutation that causes blindness in the fish and at the same time, gives them an enhanced sense of smell.

Evolution Works

Scientists are still studying cave fishes, and new discoveries are sure to be found. But one thing is already clear—the answer lies in the basic processes of evolution that are already well understood. With new tools that give scientists the ability to map genes, find specific mutations, and understand the development of embryos, we are increasing our understanding of how evolution works.

Article adapted from “Why Do Cave Fish Lose Their Eyes?” by Luis and Monika Espinasa, Natural History magazine, June 2005.

This section concludes with an explanation of the new understanding that scientists gained after the experiment, and provides the support for the first hypothesis mentioned earlier in the text, pleiotropy. After reading this section, ask students to look back at the chart where you jotted notes about both hypotheses. Review the notes for pleiotropy. Ask students to do a **quick-write** in which they **1)** explain the evidence for the pleiotropy hypothesis that the experiment yielded, and **2)** explain pleiotropy in more detail. It is important to require students to use their own words in their note-taking and not simply copy from the text. For formative assessment purposes, you may consider reading through students’ quick-writes to check for this. If students are merely retelling verbatim from the text, they may need more explicit instruction on the difference between retelling and paraphrasing, including modeling and guided practice.

To provide more support, students can work on **quick writes** in partners and/or use the questions as discussion questions for table groups.

Facilitate a whole-class discussion focused on the two questions above after students write about or discuss the questions in partners/groups.

After you have finished reading the text as a group, you may want to ask students to complete an **exit slip** in which they **1)** explain the key ideas of the text and **2)** list any lingering questions they have after reading the text.

STUDENT WORKSHEET

Name: _____ **ANSWER KEY**

Before your visit to the Museum, use the information you learned from the article, “Why do Cave Fish Lose Their Eyes?”, to complete the top row on cave fish.

During your visit, select two animals in *Life at the Limits* and use information from the exhibition to complete the rest of the rows. Be sure to fill in the name for each animal you choose.

<p>Type of adaptation</p>	<p>For each animal, draw and label an illustration of it. Then, describe the adaptation.</p>
<p>physical adaptation (a special feature of the animal’s body the helps it survive and/or reproduce)</p>	<p>cave fish <i>Using information and illustrations from the article “Why do Cave Fish Lose Their Eyes?”, students should complete this box in the classroom <u>before the Museum visit.</u></i></p> <p><i>Scientists in the article think that the cave fish are blind because the genetic mutation that causes blindness also gives them an enhanced sense of smell. So blindness itself isn’t an adaptation, but the fact that it allows the fish to have a better sense of smell, which is more useful in the dark than vision, is an adaptation.</i></p> <hr/> <p>an animal from the exhibition: _____</p> <p><i>A majority of the animals in the exhibition show examples of physical adaptations. Examples include:</i></p> <ul style="list-style-type: none"> • <i>axolotl: gills for breathing</i> • <i>sawfish: electrosensory pores in saw for detecting prey</i> • <i>tarsier: huge eyes</i> • <i>boreal Owl: assymetrical ear openings for excellent hearing</i> • <i>saturniid moths: feathery antennae for amazing sense of smell</i> • <i>mantis shrimp: striking limbs to punch prey</i> • <i>mimic octopus: by changing coloring and body shape, can mimic many other species to protect itself</i>
<p>behavioral adaptation (a behavior that an animal does that helps it survive and/or reproduce)</p>	<p>an animal from the exhibition: _____</p> <p><i>Behavioral adaptations in the exhibition are harder to find. The bowerbird is the first and perhaps most obvious example that students will encounter; this bird builds an elaborate bower to attract mates. Another section that highlights some behavioral adaptations is the section on shelter towards the end of the exhibition; examples here include the structures constructed by termites, prairie dogs, tailor birds, and hornets.</i></p>

ESSAY SCORING RUBRIC: TEACHER VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Why Do Cave Fish Lose Their Eyes?"	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the article	Presents paraphrased information from the article relevant to the prompt with accuracy and sufficient detail	Presents information from the article relevant to the purpose of the prompt with minor lapses in accuracy or completeness and/or information is copied from the text	Attempts to present information in response to the prompt, but lacks connections to the article or relevance to the purpose of the prompt
	Museum Exhibition: <i>Life at the Limits</i>	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the exhibition	Presents paraphrased information from the exhibition relevant to the prompt with accuracy and sufficient detail	Presents information from the exhibition relevant to the purpose of the prompt with minor lapses in accuracy or completeness and/or information is copied from the text	Attempts to present information in response to the prompt, but lacks connections to the exhibition content or relevance to the purpose of the prompt
SCIENCE (worth 1/3)	Science Explanations	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of different types of animal adaptations	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of different types of animal adaptations	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of different types of animal adaptations; minor errors in explanation	Attempts to include science content in explanations, but understanding of different types of animal adaptations is weak; content irrelevant, inappropriate, or inaccurate
		Uses labeled illustrations of the cave fish and two other animals' adaptations to support and add detail to the essay	Uses labeled illustrations of the cave fish and two other animals' adaptations	Illustrations are unlabeled OR fewer than three examples are illustrated and labeled OR labels communicate inaccurate information	No illustration, or illustration is unlabeled
WRITING (worth 1/3)	Focus	Maintains a strongly developed focus on the writing prompt for the entire essay	Maintains focus on the writing prompt for the majority of the essay	Addresses the prompt but is off-task some of the time	Does not address the prompt for most or all of the essay
		Clearly introduces the topic of different types of animal adaptations	Introduces the topic of different types of animal adaptations	Mentions different types of animal adaptations	Does not explicitly discuss animal adaptations
		Provides a relevant concluding statement/section	Provides a concluding statement/section	Provides a sense of closure	Provides no sense of closure

ESSAY SCORING RUBRIC: TEACHER VERSION - page 2

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
WRITING (worth 1/3)	Development	Clearly describes both physical and behavioral adaptations of animals that are well-suited to survive and reproduce	Describes both physical and behavioral adaptations of animals that are well-suited to survive and reproduce	Attempts to describe both physical and behavioral adaptations of animals that are well-suited to survive and reproduce but lacks sufficient development	Does not describe both physical and behavioral adaptations of animals that are well-suited to survive and reproduce
		Clearly presents three or more relevant animal adaptation examples to support the explanation	Presents at least three animal adaptation examples to support the explanation	Presents one or two animal adaptation examples to support the explanation	Doesn't present any animal adaptation examples to support the explanation
	Clarity	Consistent and effective use of precise and domain-specific language	Some or ineffective use of precise and domain-specific language	Little use of precise and domain-specific language	No use of precise and domain-specific language
		Demonstrates and maintains a well-developed command of standard English conventions and cohesion, with few errors; response includes language and tone consistently appropriate to the purpose and specific requirements of the prompt	Demonstrates a command of standard English conventions and cohesion, with few errors; response includes language and tone appropriate to the purpose and specific requirements of the prompt	Demonstrates an uneven command of standard English conventions and cohesion; uses language and tone with some inaccurate, inappropriate, or uneven features	Attempts to demonstrate standard English conventions, but lacks cohesion and control of grammar, usage, and mechanics

STUDENT READING

Why Do Cave Fish Lose Their Eyes?



Carlsbad Caverns National Park

Deep underground there are caves where the sun never shines. If you found yourself in one of these caverns without a flashlight, you would see nothing at all; just total blackness.

In some of these underground caves, there are fishes, crustaceans, salamanders and other animals that have evolved to live without light. For example, more than one hundred species of cave fishes live their lives in constant darkness. They depend on senses other than sight to hunt, eat and reproduce.

Many of these species of fishes are blind or nearly blind—some don't even have eyes. Yet they all evolved from fishes that could see. Somehow, over millions of years, these fishes not only developed the ability to live without sight—they lost the ability to see altogether.

How did that happen? How can evolution cause a species to lose a trait? It's a mystery that evolutionary scientists have been struggling to unravel. The search for an answer gives us a fascinating look at how evolution works.

Regressive Evolution

We usually think of evolution as a process in which species *acquire new* traits. But in cave fishes we have an example of regressive evolution, a process in which species lose a trait—in this case, the ability to see.

How does this happen? Do cave fishes go blind because they don't use their eyes? Though at first this idea might seem to make sense, it actually has no basis in science. It is your genes that determine which traits you inherit. For example, you have five fingers on each hand because of the genes you got from your parents. However, if you have an accident and lose a finger, your children will still be born with five fingers on each hand. If you lift weights and become a body builder, it doesn't mean your children will be born with bulging biceps. In each case, your genes haven't changed—even though your body has.



Blind cave fish, Mammoth Cave National Park, Kentucky

The fact that cave fishes don't use their eyes has absolutely no effect on the DNA in their chromosomes. They are blind because something happened to the genes that control the development of their eyes. This change is passed on from parent to offspring. That explains why a blind fish would have blind offspring. But it doesn't explain how a whole species of blind fish came to exist.

Evolution works by a process called natural selection. If an animal is born with a trait that gives it an advantage over other individuals, it will be more successful at having offspring. When this happens, evolutionary scientists say that that animal is "selected" for having that trait. Its offspring and succeeding generations will inherit that trait, spreading it throughout the population. But in the case of cave fishes, how does being blind give a fish an advantage in the dark? And if being blind is not an advantage, then how did natural selection lead to a species of blind cave fish?

Two Answers

Scientists have studied one species of blind cave fish, the blind Mexican tetra (*Astyanax mexicanus*). They have come up with competing explanations for blindness in that fish, which likely will help them to understand other cave fishes as well.



Mexican tetra (*Astyanax mexicanus*).

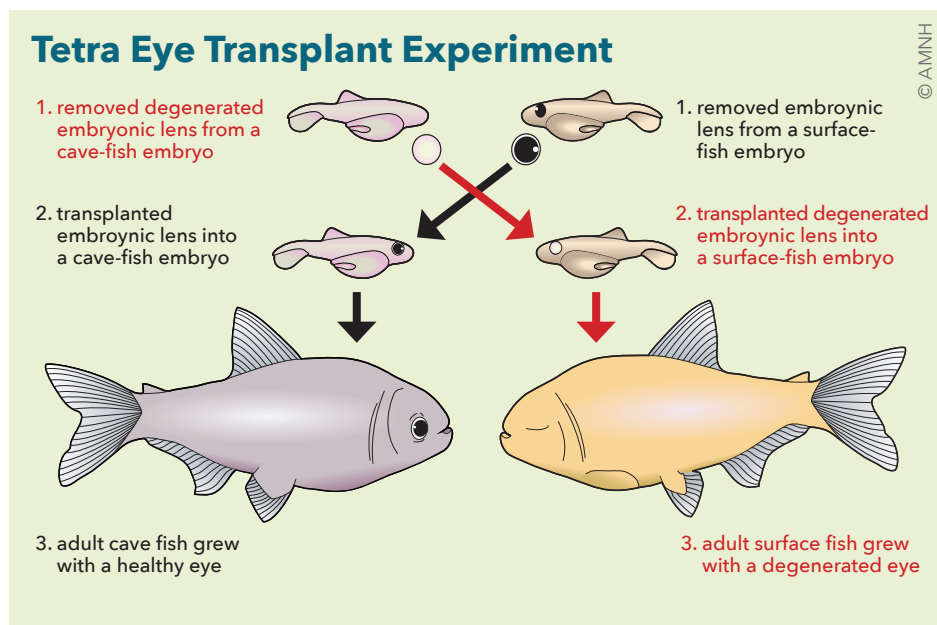
The first hypothesis assumes that blindness *does* give the fish some sort of evolutionary advantage, though not directly. What if the gene or genes that cause blindness also are responsible for some other change in the fish? And what if it was that change, not blindness, that gave the fish an advantage to reproduce? Scientists call this pleiotropy—when multiple effects are caused by the same mutation in one gene.

The second hypothesis is based on the fact that natural selection does not just reward success, it also weeds out failures. In a lake, where there is sunlight, a fish born blind would have trouble competing with other fish that can see. It probably would not survive to have offspring. But a fish born blind in a dark

cave would not be at a disadvantage, since in the darkness no fish can use their eyes. In those conditions, natural selection will not work to weed out the mutation for blindness. Over millions of years, many more mutations will accumulate and eventually the entire population of fish will be blind. This is called the *neutral mutation* hypothesis.

An Eye-Opening Experiment

A group of scientists at the University of Maryland carried out an experiment with two varieties of the same species of Mexican tetras. One variety lives in bodies of water near the surface where there is sunlight and can see. The other variety of tetras lives in dark caves and is blind.



In their experiment, the scientists transplanted a lens from the eye of a surface tetra embryo into the eye of a cave tetra embryo. The cave fish embryo would normally develop into a blind fish. But the lens from the surface tetra transplanted into the cave tetra caused all of the surrounding tissues to develop into a healthy eye. This experiment demonstrated that the genes involved in the development of the eyes of the cave tetra were still totally functional.

The scientists knew that there are many genes responsible for the development of each part of an eye (for example, the retina, iris, cornea and lens). Each part develops independently. The results of the experiment showed that the genes for eye development in the Mexican tetra were all ready to work properly, given the correct signal. The experiment seemed to suggest that blindness in the Mexican tetra was not caused by many mutations, but instead by a small number of mutations in genetic “master switches.”

These master switches are genes that control the function of many other genes. In this case, the switches control genes responsible for eye development. These master switches have the ability to disable the eye genes. These remain intact, but inactive. Putting a healthy lens into the cave tetra embryo seems to trigger

master switches to send a signal to the inactive eye genes, allowing cave tetras to develop eyes.

If scientists could find the genetic “master switches” that made cave tetras blind, they could discover if the same switches had effects on other traits of the fish that do give it an evolutionary advantage for surviving in caves.

The researchers did indeed find one of those genes. It is nicknamed *Hedgehog* or the *Hh gene*. They discovered that the *Hedgehog gene* does more than cause blindness in cave tetras—when the fish develops without eyes, the skull bones move into the empty eye socket, which at the same time enlarges its nose. Unlike other vertebrates, fishes use their nose only for smelling. It could be that the same control gene (*Hh*) that stops eye development in the fish also enhances its sense of smell. An enhanced sense of smell would be a definite advantage for a fish that lives in darkness.

As a result of these and other experiments, it now seems highly likely that blindness in cave tetras is in part the result of pleiotropy—one mutation that causes blindness in the fish and at the same time, gives them an enhanced sense of smell.

Evolution Works

Scientists are still studying cave fishes, and new discoveries are sure to be found. But one thing is already clear—the answer lies in the basic processes of evolution that are already well understood. With new tools that give scientists the ability to map genes, find specific mutations, and understand the development of embryos, we are increasing our understanding of how evolution works.

Article adapted from “Why Do Cave Fish Lose Their Eyes?” by Luis and Monika Espinasa, Natural History magazine, June 2005.

STUDENT WORKSHEET

Name: _____

Before your visit to the Museum, use the information you learned from the article, "Why do Cave Fish Lose Their Eyes?", to complete the top row on cave fish.

During your visit, select two animals in *Life at the Limits* and use information from the exhibition to complete the rest of the rows. Be sure to fill in the name for each animal you choose.

<p>Type of adaptation</p>	<p>For each animal, draw and label an illustration of it. Then, describe the adaptation.</p>
<p>physical adaptation (a special feature of the animal's body the helps it survive and/or reproduce)</p>	<p>cave fish</p> <hr/> <p>an animal from the exhibition: _____</p>
<p>behavioral adaptation (a behavior that an animal does that helps it survive and/or reproduce)</p>	<p>an animal from the exhibition: _____</p>

STUDENT WRITING TASK

After reading “Why Do Cave Fish Lose Their Eyes?” and taking notes in the *Life at the Limits* exhibition at the Museum, write an essay in which you describe both physical and behavioral adaptations of animals that are well suited to survive and reproduce.

On your worksheet you have notes about (1) the cave fish from the article, (2) an animal from the exhibition that illustrates physical adaptations, and (3) an animal from the exhibition that illustrates a behavioral adaptation.

Use all three of these examples in your essay. Include a labeled drawing of each example that illustrates its adaptation.

ESSAY SCORING RUBRIC: STUDENT VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Why Do Cave Fish Lose Their Eyes?"	I presented accurate information from the article in my essay and included relevant details in my own words	I presented accurate information from the article in my own words	I included some relevant information from the article OR I didn't use my own words	I didn't include any information from the article
	Museum Exhibition: <i>Life at the Limits</i>	I presented accurate information from the exhibition in my essay and included relevant details in my own words	I presented accurate information from the exhibition in my own words	I included some relevant information from the exhibition OR I didn't use my own words	I didn't include any information from the exhibition
SCIENCE (worth 1/3)	Science Explanations	All of the information I included about different types of animal adaptations is correct	Most of the information I included about different types of animal adaptations is correct	Some of the information I included about different types of animal adaptations is correct	None of the information I included about different types of animal adaptations is correct
		I included labeled illustrations of the cave fish and two other animals that helps the reader understand different types of animal adaptations	I included labeled illustrations of the cave fish and two other animals	My Illustrations are unlabeled OR I included fewer than three illustrations OR my labels are inaccurate information	I did not include an illustration
WRITING (worth 1/3)	Focus	I stayed on-topic for the entire essay	I stayed on-topic for most of essay	I stayed on-topic for the some of essay	I did not stay on-topic
		I included a clear introductory paragraph on different types of animal adaptations	I included an introductory paragraph	I included an introductory sentence	I did not include an introduction
		I have written a concluding paragraph that relates to all of the information in my essay	I have written a concluding paragraph that relates to some of the information in my essay	I have written a concluding paragraph or sentence at the end of the essay	I have not written a concluding sentence at the end of the essay
	Development	I correctly and clearly described both physical and behavioral adaptations of animals that are well-suited to survive and reproduce	I described both physical and behavioral adaptations of animals that are well-suited to survive and reproduce	I described both physical and behavioral adaptations of animals, but didn't explain how they help them survive and reproduce	I did not describe both physical and behavioral adaptations of animals
I presented three or more relevant animal adaptation examples		I presented at least three animal adaptation examples	I presented one or two animal adaptation examples	I didn't present any animal adaptation examples	

ESSAY SCORING RUBRIC: STUDENT VERSION - page 2

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
WRITING (worth 1/3)	Clarity	I used relevant science vocabulary whenever possible, and I used all words correctly	I used science vocabulary words correctly	I used some science vocabulary words correctly	I did not use any science vocabulary words.
		I have edited my essay for spelling, punctuation, and grammar; there are no errors	I have edited my essay for spelling, punctuation, and grammar; there are some minor errors but the reader can still understand my writing	I have not carefully edited my essay for spelling, punctuation, and grammar; there are errors that may make the essay hard for readers to understand	I have not edited my essay for spelling, punctuation, and grammar; there are many errors that make the essay hard for readers to understand

Science & Literacy Activity

ACTIVITY OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to animal adaptations.

This activity has three components:

- 1. Before your visit**, students will read a content-rich article about scientists who study cave fish to understand how blindness evolves in organisms that live in dark environments. This article will provide context for the visit, and also help them complete the post-visit writing task.
- 2. At the Museum**, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models). This information will help them complete the post-visit writing task.
- 3. Back in the classroom**, students will draw on the first two components of the activity to complete a CCSS-aligned explanatory writing task about biological, behavioral, and physiological adaptations.

Materials in this packet include:

For Teachers

- Activity Overview (p. 1-2)
- Article (teacher version): "Why Do Cave Fish Lose Their Eyes?" (p. 3-6)
- Answers to the student worksheets (p. 7-8)
- Essay scoring rubric (teacher version) (p. 9-10)

For Students

- Article (student version): "Why Do Cave Fish Lose Their Eyes?" (p. 11-14)
- Student worksheets (p. 15-16)
- Student writing task (p. 17)
- Essay scoring rubric (student version) (p. 18-19)

1. BEFORE YOUR VISIT

Students will read a content-rich article about scientists who study cave fish to understand how blindness evolves in organisms that live in dark environments. This article will provide context for the visit, and help them complete the post-visit writing task.

Preparation

- Familiarize yourself with the student writing task and rubric (p. 9-10, 17-19).
- Familiarize yourself with the teacher version of the article (p. 3-6), and plan how to facilitate the students' reading of the article.

Instructions

- Explain the goal: to complete a writing task about animal adaptations.
- Tell students that they will need to read an article before visiting the Museum, and read additional texts during the visit (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models).
- Distribute the article, student writing task, and rubric to students.
- Review the rubric with students and tell them that it will be used to grade their writing.

Common Core State Standards

RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

WHST.9-10.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

New York State Science Core Curriculum

LE 3.1g

Next Generation Science Standards

DCI: LS4.C: Adaptation

Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment.

SEP 8: Obtaining, Evaluating and Communicating Information

- Integrate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question.
- Read scientific information from multiple authoritative sources.
- Communicate scientific information or ideas in multiple formats.

- Read and discuss the article, using the teacher notes to facilitate.
- Distribute the student worksheet (p. 15-16). Have students fill in the “cave fish” section based on what they’ve learned from the article. Tell them that at the Museum, they will complete the rest of the worksheet.

2. DURING YOUR VISIT

At the Museum, students will read and engage with additional texts (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models). The information they’ll gather from these multiple sources will help them complete the post-visit writing task.

Preparation

- Review the educator’s guide to see how themes in the exhibition connect to your curriculum and to get an advance look at what your students will encounter. (Guide is downloadable at amnh.org/lal/educators)

Instructions

- Explain the goal of the Museum visit: to read and engage with texts (including printed text, digital and physical/hands-on interactives, videos, diagrams, and models), and to gather information to help them complete the post-visit writing task.
- Review the worksheet. Clarify what information students should collect. Explicitly teach these three terms to students:
 - Anatomical adaptation: a feature of an organism’s body that helps it survive and reproduce
 - Behavioral adaptation: a action an organism takes that helps it survive and reproduce
 - Physiological adaptation: a process that takes place in an organism’s body that helps it survive and reproduce
- Note that there is space on the worksheet for students to note the definition for each term.

Suggestions for Facilitating the Museum Visit

- Have students explore the exhibition in pairs, with each student completing his or her own student worksheet.
- Encourage student pairs to ask you or their peers for help locating information. Tell students they may not share answers with other pairs, but may point each other to places where answers can be found.

3. BACK IN THE CLASSROOM

Students will use what they have learned from the pre-visit article and at the Museum to complete a CCSS-aligned explanatory writing task about anatomical, behavioral, and physiological adaptations.

Preparation

- Plan how you will explain the student writing task and rubric (p. 17-19) to students.

Instructions

- Review the writing task and rubric with students. Explain that they will use it while composing, and also to evaluate and revise what they have written.

Suggestions for Facilitating Writing Task

- Before they begin to write, have students use the writing task to frame a discussion around the information that they gathered at the Museum. They can work in pairs, small groups, or as a class, and can compare their findings.
- Referring to the writing prompt, have students underline or highlight all relevant passages and information from the article and from the notes taken at the Museum. Instruct each student to write down any useful information gathered by their peers.
- Students should write their essays individually.

Supports for Diverse Learners

This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It represents information in multiple ways and offers multiple ways for your students to engage with content as they read about, discuss, view, and write about scientific concepts. Different parts of the experience (e.g. reading texts, or locating information in the Museum) may challenge individual students. However, the arc of learning is designed to offer varied opportunities to learn. We suggest that all learners experience each activity, even if challenging. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

Alternate Version of Article

Another version of the same article with a lower lexile level is available for download at amnh.org/lal/educators. You can use this same activity with that article.

ARTICLE: TEACHER VERSION

About this Article

- **Lexile:** 1059
- **Wordcount:** 1565
- **Text Complexity:** While the Lexile level for this article falls just short of the 9-10 CCSS band (1080-1305), several qualitative factors make this text appropriately complex for grades 9-10. The knowledge demands of this text on the reader are high, as evidenced by the high level of detail in which complex scientific processes are described. Additionally, some of the complex domain-specific vocabulary terms will likely be unfamiliar for many high school students.
- **Note:** Assign partners prior to reading this text aloud with students and have them assign a “partner A” and “partner B.”

Key for Teacher Notes

- **Green text**
specific strategies
- Regular text
instructions for teachers
- *Italicized text*
teacher's instructions to students
- Underlined text
important domain-specific words

Why Do Cave Fish Lose Their Eyes?

How evolution can lead to losing abilities as well as gaining them

Deep underground there are caves where the sun never shines. The only light that enters these subterranean spaces is from the headlamps of occasional cave explorers. If you found yourself in one of these caverns and turned off your headlamp, you would see nothing at all; no shadows, no shapes, just total blackness.



Carlsbad Caverns National Park

In some of these underground caves, there are fishes, crustaceans, salamanders and other organisms that have evolved to live without light. For example, more than one hundred species of cave fishes live their lives in perpetual darkness. They depend on senses other than sight to hunt, eat and reproduce.

Many of these species of fishes are blind or nearly blind—some don't even have eyes. Yet they all evolved from fishes that could see. Somehow, over millions of years, these fishes not only acquired the ability to live without sight—they lost the ability to see altogether.

How did that happen? How can evolution cause a species to lose a trait? It's a mystery that evolutionary scientists have been struggling to unravel, and the search for an answer gives us a fascinating look at how evolution works.

Regressive Evolution

We usually think of evolution in a positive sense, that is, as a process in which species *acquire new* traits. But in cave fishes we have an example of *regressive evolution*, a process in which species lose a trait—in this case, the ability to see.



Blind cave fish, Mammoth Cave National Park, Kentucky

Think/Pair/Share: What do you already know about evolution?

Listen in and share out some of what you overheard students say. If there are misconceptions, make a note and consider if it can be addressed in this reading session, and if so, where.

Stop here and ask students to **summarize** this introduction – “**stop and jot.**”

After students have had time to do that independently, prompt them to **turn and talk**, comparing their summary to their partner's. While they are speaking in partners, listen in and select an exemplary summary to share with the class.

Alternately, for more scaffolding, demonstrate this process for students: Construct a summary in front of students, referring to the text and **thinking aloud** as you jot your summary. Make this process interactive by inviting students to make suggestions as you write the summary.

Think aloud: This part is making me think about the way we define *evolution*. Evolution does not only explain how species acquires a given trait, but also how they lose a trait.

A common assumption is that the ancestors of cave fishes went blind in their evolution because they didn't use their eyes. Though at first this idea might seem to make sense, it actually has no basis in science. Genes determine the inheritance of traits. For example, the fact that you have five fingers on each hand is because of the genes you inherited from your parents. However, if you have an accident and lose a finger, your children will still be born with five fingers on each hand. If you lift weights and become a body builder, it doesn't mean your children will be born with bulging biceps. In each case, your genes haven't changed—even though your body has.

Darwin Is Stumped

The fact that cave fishes' ancestors didn't use their eyes had absolutely no effect on the DNA in their chromosomes. Yet clearly, at some point in the past something happened to their genes that stopped the development of their eyes. This new condition passed on from parent to offspring. How can this sort of regressive evolution be explained?

Charles Darwin himself, the scientist who first established a modern understanding of evolution, had trouble answering this question. Darwin lived in the 19th century when DNA hadn't been discovered and so he didn't know about genes or their role in heredity. But he understood that traits were inherited and that differences within a species give some individuals an advantage over others. Animals with traits that make them more successful at having offspring will pass on those traits to succeeding generations. He called this process evolution by *natural selection*.

However, Darwin had trouble applying his theory of natural selection to the problem of why some cave fishes are blind. He could not explain how being blind gave those cave fishes an advantage. And if being blind is not an advantage, then how did natural selection lead to a species of blind cave fish? Surprisingly, Darwin was convinced that the loss of eyes could be explained entirely to disuse, which is in fact a Lamarckian explanation. Today, scientists know that this explanation is unfounded.

Two Hypotheses

Most of what we know now is based on the study of the blind Mexican tetra (*Astyanax mexicanus*). Scientists have two competing explanations for blindness in the Mexican tetra, which likely apply in other cave fishes as well.

Lamarck's Mistake

Jean-Baptiste Lamarck was a French naturalist who lived from 1744 to 1829. He was a pioneer developing theories of evolution at a time when the very idea of evolution was not accepted. Lamarck tried to explain how species evolved but came to an incorrect conclusion—that traits acquired during an organism's lifetime could be passed down to its offspring. For example, he suggested that giraffes stretched their necks to reach higher leaves, and as a result their offspring were born with longer necks. The idea that cave fishes lost their eyesight because generations of fish didn't use their eyes is a Lamarckian mistake.

Think Aloud: *So, to clarify... an organism's activity or lack thereof (e.g., cave fish not using their eyes) does not impact their genes in any way... Something had to happen at the genetic level that resulted in the cave fish becoming blind... This paragraph ends by asking what that thing was... Let's read on and see if that question gets answered.*

Prompt students to read this text box and **turn and talk**, asking, *How does this text box connect with the previous paragraph?* Listen in and select a student to share out.

Alternately, to provide more support, you might **think aloud** as follows: *This text box gives an example of the kind of misconception about evolution that was explained in the previous paragraph – the false idea that traits you have acquired during your lifetime are passed on to offspring, like the giraffe example.*

Think/Pair/Share: *What is the main idea of each paragraph? Re-read each paragraph if you need to, and talk your partner through what each paragraph is saying. Partner A can talk about paragraph the first paragraph; partner B can talk about the second paragraph.*

If clarification is needed, show students how you determine the main idea of each paragraph by **thinking aloud**. Jot the main idea in the margin.

You should be listening for these two different hypotheses as we read on. As you listen, take notes on each one so that you are ready to discuss them with your partner.

Alternately, to offer more independence, give students these same instructions to take notes, but have them read the two paragraphs independently.

The first hypothesis assumes that blindness gives the fish some sort of evolutionary advantage. For example, it's possible that changes in the gene or genes that cause blindness are also responsible for some other seemingly unrelated change in the fish that is beneficial. Scientists call this *pleiotropy*—when multiple effects are caused by the same mutation in one gene. To support this hypothesis, scientists would have to look for some advantage to the cave fish that is linked to the same mutation that causes blindness.



Mexican tetra (*Astyanax mexicanus*).

The second hypothesis that could explain blindness in the cave fish is based on the fact that natural selection does not just reward success, it also weeds out failures. In a lake, where there is sunlight, a fish born blind would have trouble competing with other fish that can see. It probably would not survive to have offspring. But a fish born blind in a dark cave would not be at a disadvantage, since in the darkness eyes are useless. In those conditions, natural selection will not work to weed out the mutation for blindness. Over one to two million years, many more mutations disrupting the development of the eyes will accumulate and eventually the entire population of fish will be blind. This is called the *neutral mutation* hypothesis, based on the idea that the mutations for causing blindness have no effect (or have a neutral effect) on the survival of the fish living in a dark cave.

An Eye-Opening Experiment

A group of scientists at the University of Maryland set out to investigate the developmental causes of blindness in the cave fish. They carried out an experiment with two varieties of the same species of Mexican tetras. One variety lives in bodies of water near the surface where there is sunlight and can see. The other variety of tetras lives in dark caves and is blind.

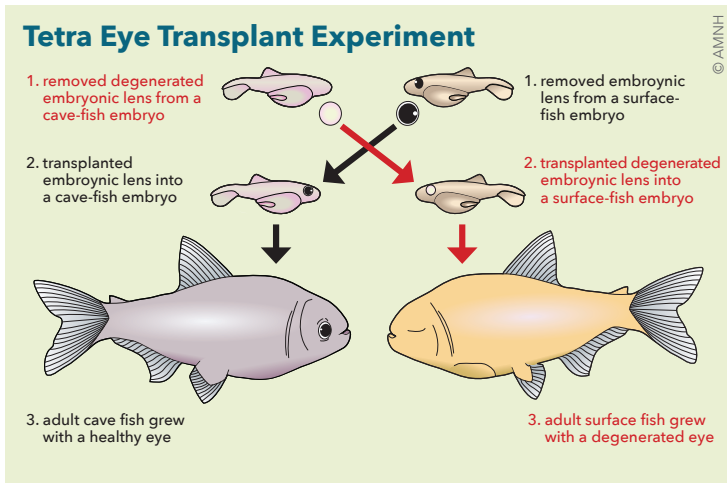
The scientists transplanted a lens from the eye of a surface tetra embryo into the eye of a cave tetra embryo. The result was striking—the surface tetra lens transplanted into the cave tetra caused all of the surrounding tissues to develop into a healthy eye. This experiment demonstrated that despite the degeneration of the eye in the tetra, the genes involved in eye development were still totally functional. This would seem to rule out the neutral mutation theory because, if blindness were caused by an accumulation of many neutral mutations over time, the transplant would not have resulted in the development of a healthy eye. The scientists knew that there are many genes responsible for the development of each part of an eye (for example, the retina, iris, cornea and lens), which develops independently. However, the results of the experiment showed that blindness in the Mexican tetra was not due to mutations in all those genes. Instead, it suggested a small number of mutations in genetic “master switches.” These master switches are genes that control the function of many other genes, including, in this case, those responsible for eye development. These “master switches” have the ability to disable the eye genes so that these remain intact, but inactive. Putting a healthy lens into the cave tetra embryo seems to trigger master switches to send a signal to the inactive eye genes, allowing cave tetras to develop eyes.

Before moving on, pause to discuss the two hypotheses, clarifying misconceptions.

Think/Pair/Share: *What did the results of the experiment show?*

Follow-Up Question: *What did scientists learn from these results?*

Listen in and select a student to share out. Allow for questions and clarification. It is important to check for understanding at this point in the text. Direct students to refer to the illustration on the next page as needed.



If scientists could find the genetic “master switches” that made cave tetras blind, they could discover if the same switches had effects on other traits of the fish that do give it an evolutionary advantage for surviving in caves.

The researchers did indeed find one of those genes. It is nicknamed *Hedgehog* or the *Hh* gene. They discovered that the *Hedgehog* gene does more than cause blindness in cave tetras—when the fish develops without eyes, the skull bones move into the empty eye socket, which at the same time enlarges the nose. Unlike other vertebrates, fishes use their nose only for smelling. It could be that the same control gene (*Hh*) that stops eye development in the fish also is responsible for enhancing its sense of smell. An enhanced sense of smell would be a definite advantage for a fish that lives in darkness.

As a result of these and other experiments, it now seems highly likely that blindness in cave tetras is in part the result of pleiotropy—one mutation that causes blindness in the fish and at the same time, gives them an enhanced sense of smell.

Evolution Works

Scientists are still studying cave fishes, and new discoveries are sure to be found. But one thing is already clear—the answer lies in the basic processes of evolution that are already well understood. With new tools that give scientists the ability to map genes, find specific mutations, and understand the development of embryos, we are increasing our understanding of how evolution works.

Article adapted from “Why Do Cave Fish Lose Their Eyes?” by Luis and Monika Espinosa, *Natural History* magazine, June 2005.

This section concludes with an explanation of the new understanding that scientists gained after the experiment, and provides the support for the first hypothesis mentioned earlier in the text, pleiotropy.

After reading this section, ask students to go back to their notes where they described both hypotheses and add on. Specifically, prompt them to 1) explain the evidence for the hypothesis that the experiment yielded, and 2) elaborate on the new thinking/explain pleiotropy in more detail. It is important to require students to use their own words in their notetaking and not simply copy from the text.

For formative assessment purposes, you may consider reading through students’ notes to check for this. If students are merely retelling verbatim from the text, they may need more explicit instruction on the difference between retelling and paraphrasing, including modeling and guided practice.

After you have finished reading the text as a group, you may want to ask students to complete an exit slip in which they 1) explain the key ideas of the text and 2) list any lingering questions they have after reading the text.

STUDENT WORKSHEET - page 1

Name: _____ **ANSWER KEY**

Before your visit to the Museum, use the information you learned from the article, "Why do Cave Fish Lose Their Eyes?", to complete the definitions for anatomical, behavioral, and physiological adaptations in the first column and the top row on cave fish.

During your visit, select three animals in *Life at the Limits* and use information from the exhibition to complete the rest of the rows. Be sure to fill in the name for each animal you choose.

Type of adaptation	For each animal, draw and label an illustration of it. Then, describe the adaptation.
<p>anatomical adaptation</p> <p>Definition:</p> <p><i>a feature of an organism's body that helps it survive and reproduce</i></p>	<p>cave fish</p> <p><i>Using information and illustrations from the article "Why do Cave Fish Lose Their Eyes?", students should complete this box in the classroom <u>before the Museum visit</u>.</i></p> <p><i>Scientists in the article think that the cave fish are blind because the genetic mutation that causes blindness also gives them an enhanced sense of smell. So blindness itself isn't an adaptation, but the fact that it allows the fish to have a better sense of smell, which is more useful in the dark than vision, is an adaptation.</i></p> <hr/> <p>an animal from the exhibition: _____</p> <p><i>A majority of the animals in the exhibition show examples of anatomical adaptations. Examples include:</i></p> <ul style="list-style-type: none"> • <i>axolotl: gills for breathing</i> • <i>sawfish: electrosensory pores in saw for detecting prey</i> • <i>tarsier: huge eyes</i> • <i>boreal Owl: assymetrical ear openings for excellent hearing</i> • <i>saturniid moths: feathery antennae for amazing sense of smell</i> • <i>mantis shrimp: striking limbs to punch prey</i> • <i>mimic octopus: by changing coloring and body shape, can mimic many other species to protect itself</i>

<p>Type of adaptation</p>	<p>For each animal, draw and label an illustration of it. Then, describe the adaptation.</p>
<p>behavioral adaptation</p> <p>Definition:</p> <p><i>a behavior that an animal does that helps it survive and/or reproduce</i></p>	<p>an animal from the exhibition: _____</p> <p><i>Behavioral adaptations in the exhibition are harder to find. The bowerbird is the first and perhaps most obvious example that students will encounter; this bird builds an elaborate bower to attract mates. Another section that highlights some behavioral adaptations is the section on shelter towards the end of the exhibition; examples here include the structures constructed by termites, prairie dogs, tailor birds, and hornets.</i></p>
<p>physiological adaptation</p> <p>Definition:</p> <p><i>a behavior that an animal does that helps it survive and/or reproduce</i></p>	<p>an animal from the exhibition: _____</p> <p><i>There are several places in the exhibition where physiological adaptations are highlighted.</i></p> <ul style="list-style-type: none"> • <i>On the panel titled "Altitude and Depth," there are many examples of how animal systems deal with the height above, or depth below, sea level. For example, humans, birds, and aquatic mammals.</i> • <i>The section dealing with hibernation, across from the elephant seal model, also gives some good examples, such as bears and bumblebees.</i> • <i>In the area on eating, there is a panel labeled "eating and Heating" that discusses animal metabolism in the context of feeding. Examples here include the polar bear and the European hare.</i> • <i>The lungfish shown towards the end of the exhibition demonstrates estuation, a process similar to hibernation that takes place in extreme heat rather than cold.</i> • <i>The tardigrade display at the back of the exhibition, more than the one at the front, discusses how this tiny animal is able to go through such extremes by regulating its body systems and changing form.</i>

ESSAY SCORING RUBRIC: TEACHER VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Why Do Cave Fish Lose Their Eyes?"	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the article	Presents paraphrased information from the article relevant to the prompt with accuracy and sufficient detail.	Presents information from the article relevant to the purpose of the prompt with minor lapses in accuracy or completeness and/or information is copied from the text	Attempts to present information in response to the prompt, but lacks connections to the article or relevance to the purpose of the prompt
	Museum Exhibition: <i>Life at the Limits</i>	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the exhibition	Presents paraphrased information from the exhibition relevant to the prompt with accuracy and sufficient detail.	Presents information from the exhibition relevant to the purpose of the prompt with minor lapses in accuracy or completeness and/or information is copied from the exhibit text	Attempts to present information in response to the prompt, but lacks connections to the exhibition content or relevance to the purpose of the prompt
SCIENCE (worth 1/3)	Science Explanations	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of anatomical, behavioral, and physiological adaptations	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of different types of animal adaptations	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of different types of animal adaptations; minor errors in explanation	Attempts to include science content in explanations, but understanding of different types of animal adaptations is weak; content irrelevant, inappropriate, or inaccurate
WRITING (worth 1/3)	Focus	Maintains a strongly developed focus on the writing prompt for the entire essay	Maintains focus on the writing prompt for the majority of the essay	Addresses the prompt but is off-task some of the time	Does not address the prompt for most or all of the essay
		Clearly introduces the topic of anatomical, behavioral, and physiological adaptations	Introduces the spiny pufferfish and two other animals; introduction may lack detail	Mentions the spiny pufferfish and one other animal	Only mentions one animal
		Provides a relevant concluding statement/section	Provides a concluding statement/section	Provides a sense of closure	Provides no sense of closure
		Accurately defines "anatomical, behavioral, and physiological adaptations"	Defines "anatomical, behavioral, and physiological adaptations"	Defines 1-2 of the adaptation types	Does not define any type of adaptation
	Development	Clearly describes anatomical, behavioral, and physiological adaptations of animals that are well-suited to survive and reproduce	Describes both physical and behavioral adaptations of animals that are well-suited to survive and reproduce	Attempts to describe both physical and behavioral adaptations of animals that are well-suited to survive and reproduce but lacks sufficient development	Does not describe both physical and behavioral adaptations of animals that are well-suited to survive and reproduce

ESSAY SCORING RUBRIC: TEACHER VERSION - page 2

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
WRITING (worth 1/3)	Clarity	Consistent and effective use of precise and domain-specific language	Some or ineffective use of precise and domain-specific language	Little use of precise and domain-specific language	No use of precise and domain-specific language
		Demonstrates and maintains a well-developed command of standard English conventions and cohesion, with few errors; response includes language and tone consistently appropriate to the purpose and specific requirements of the prompt	Demonstrates a command of standard English conventions and cohesion, with few errors; response includes language and tone appropriate to the purpose and specific requirements of the prompt	Demonstrates an uneven command of standard English conventions and cohesion; uses language and tone with some inaccurate, inappropriate, or uneven features	Attempts to demonstrate standard English conventions, but lacks cohesion and control of grammar, usage, and mechanics

STUDENT READING

Why Do Cave Fish Lose Their Eyes?

How evolution can lead to losing abilities as well as gaining them

Deep underground there are caves where the sun never shines. The only light that enters these subterranean spaces is from the headlamps of occasional cave explorers. If you found yourself in one of these caverns and turned off your headlamp, you would see nothing at all; no shadows, no shapes, just total blackness.



Carlsbad Caverns National Park

In some of these underground caves, there are fishes, crustaceans, salamanders and other organisms that have evolved to live without light. For example, more than one hundred species of cave fishes live their lives in perpetual darkness. They depend on senses other than sight to hunt, eat and reproduce.

Many of these species of fishes are blind or nearly blind—some don't even have eyes. Yet they all evolved from fishes that could see. Somehow, over millions of years, these fishes not only acquired the ability to live without sight—they lost the ability to see altogether.

How did that happen? How can evolution cause a species to lose a trait? It's a mystery that evolutionary scientists have been struggling to unravel, and the search for an answer gives us a fascinating look at how evolution works.

Regressive Evolution

We usually think of evolution in a positive sense, that is, as a process in which species *acquire new* traits. But in cave fishes we have an example of *regressive evolution*, a process in which species lose a trait—in this case, the ability to see.



Blind cave fish, Mammoth Cave National Park, Kentucky

A common assumption is that the ancestors of cave fishes went blind in their evolution because they didn't use their eyes. Though at first this idea might seem to make sense, it actually has no basis in science. Genes determine the inheritance of traits. For example, the fact that you have five fingers on each hand is because of the genes you inherited from your parents. However, if you have an accident and lose a finger, your children will still be born with five fingers on each hand. If you lift weights and become a body builder, it doesn't mean your children will be born with bulging biceps. In each case, your genes haven't changed—even though your body has.

Darwin Is Stumped

The fact that cave fishes' ancestors didn't use their eyes had absolutely no effect on the DNA in their chromosomes. Yet clearly, at some point in the past something happened to their genes that stopped the development of their eyes. This new condition passed on from parent to offspring. How can this sort of regressive evolution be explained?

Charles Darwin himself, the scientist who first established a modern understanding of evolution, had trouble answering this question. Darwin lived in the 19th century when DNA hadn't been discovered and so he didn't know about genes or their role in heredity. But he understood that traits were inherited and that differences within a species give some individuals an advantage over others. Animals with traits that make them more successful at having offspring will pass on those traits to succeeding generations. He called this process evolution by *natural selection*.

However, Darwin had trouble applying his theory of natural selection to the problem of why some cave fishes are blind. He could not explain how being blind gave those cave fishes an advantage. And if being blind is not an advantage, then how did natural selection lead to a species of blind cave fish? Surprisingly, Darwin was convinced that the loss of eyes could be explained entirely to disuse, which is in fact a Lamarckian explanation. Today, scientists know that this explanation is unfounded.

Two Hypotheses

Most of what we know now is based on the study of the blind Mexican tetra (*Astyanax mexicanus*). Scientists have two competing explanations for blindness in the Mexican tetra, which likely apply in other cave fishes as well.

Lamarck's Mistake

Jean-Baptiste Lamarck was a French naturalist who lived from 1744 to 1829. He was a pioneer developing theories of evolution at a time when the very idea of evolution was not accepted. Lamarck tried to explain how species evolved but came to an incorrect conclusion—that traits acquired during an organism's lifetime could be passed down to its offspring. For example, he suggested that giraffes stretched their necks to reach higher leaves, and as a result their offspring were born with longer necks. The idea that cave fishes lost their eyesight because generations of fish didn't use their eyes is a Lamarckian mistake.

The first hypothesis assumes that blindness gives the fish some sort of evolutionary advantage. For example, it's possible that changes in the gene or genes that cause blindness are also responsible for some other seemingly unrelated change in the fish that is beneficial. Scientists call this *pleiotropy*—

when multiple effects are caused by the same mutation in one gene. To support this hypothesis, scientists would have to look for some advantage to the cave fish that is linked to the same mutation that causes blindness.



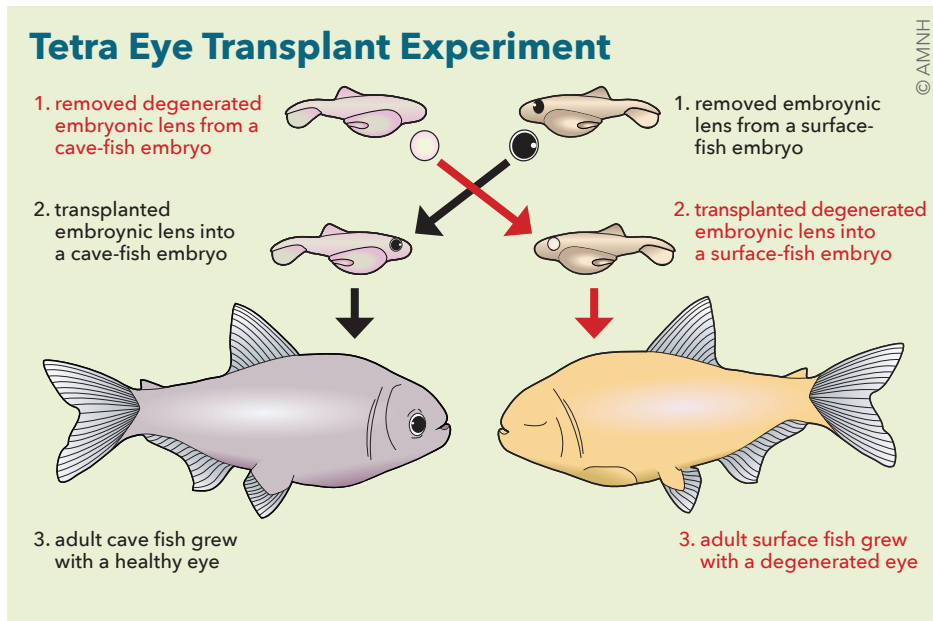
Mexican tetra (*Astyanax mexicanus*).

The second hypothesis that could explain blindness in the cave fish is based on the fact that natural selection does not just reward success, it also weeds out failures. In a lake, where there is sunlight, a fish born blind would have trouble competing with other fish that can see. It probably would not survive to have offspring. But a fish born blind in a dark cave would not be at a disadvantage, since in the darkness eyes are useless. In those conditions, natural selection will not work to weed out the mutation for blindness. Over one to two million years, many more mutations disrupting the development of the eyes will accumulate and eventually the entire population of fish will be blind. This is called the *neutral mutation* hypothesis, based on the idea that the mutations for causing blindness have no effect (or have a neutral effect) on the survival of the fish living in a dark cave.

An Eye-Opening Experiment

A group of scientists at the University of Maryland set out to investigate the developmental causes of blindness in the cave fish. They carried out an experiment with two varieties of the same species of Mexican tetras. One variety lives in bodies of water near the surface where there is sunlight and can see. The other variety of tetras lives in dark caves and is blind.

The scientists transplanted a lens from the eye of a surface tetra embryo into the eye of a cave tetra embryo. The result was striking—the surface tetra lens transplanted into the cave tetra caused all of the surrounding tissues to develop into a healthy eye. This experiment demonstrated that despite the degeneration of the eye in the tetra, the genes involved in eye development were still totally functional. This would seem to rule out the neutral mutation theory because, if blindness were caused by an accumulation of many neutral mutations over time, the transplant would not have resulted in the development of a healthy eye. The scientists knew that there are many genes responsible for the development of each part of an eye (for example, the retina, iris, cornea and lens), which develops independently. However, the results of the experiment showed that blindness in the Mexican tetra was not due to mutations in all those genes. Instead, it suggested a small number of mutations in genetic “master switches.” These master switches are genes that control the function of many other genes, including, in this case, those responsible for eye development. These “master switches” have the ability to disable the eye genes so that these remain intact, but inactive. Putting a healthy lens into the cave tetra embryo seems to trigger master switches to send a signal to the inactive eye genes, allowing cave tetras to develop eyes.



If scientists could find the genetic “master switches” that made cave tetras blind, they could discover if the same switches had effects on other traits of the fish that do give it an evolutionary advantage for surviving in caves.

The researchers did indeed find one of those genes. It is nicknamed *Hedgehog* or the *Hh* gene. They discovered that the *Hedgehog* gene does more than cause blindness in cave tetras—when the fish develops without eyes, the skull bones move into the empty eye socket, which at the same time enlarges the nose. Unlike other vertebrates, fishes use their nose only for smelling. It could be that the same control gene (*Hh*) that stops eye development in the fish also is responsible for enhancing its sense of smell. An enhanced sense of smell would be a definite advantage for a fish that lives in darkness.

As a result of these and other experiments, it now seems highly likely that blindness in cave tetras is in part the result of pleiotropy—one mutation that causes blindness in the fish and at the same time, gives them an enhanced sense of smell.

Evolution Works

Scientists are still studying cave fishes, and new discoveries are sure to be found. But one thing is already clear—the answer lies in the basic processes of evolution that are already well understood. With new tools that give scientists the ability to map genes, find specific mutations, and understand the development of embryos, we are increasing our understanding of how evolution works.

Article adapted from “Why Do Cave Fish Lose Their Eyes?” by Luis and Monika Espinosa, *Natural History* magazine, June 2005.

STUDENT WORKSHEET - page 1

Name: _____

Before your visit to the Museum, use the information you learned from the article, "Why do Cave Fish Lose Their Eyes?", to complete the definitions for anatomical, behavioral, and physiological adaptations in the first column and the top row on cave fish.

During your visit, select three animals in *Life at the Limits* and use information from the exhibition to complete the rest of the rows. Be sure to fill in the name for each animal you choose.

<p>Type of adaptation</p>	<p>For each animal, draw and label an illustration of it. Then, describe the adaptation.</p>
<p>anatomical adaptation</p> <p>Definition:</p>	<p>cave fish</p>
	<p>an animal from the exhibition: _____</p>

STUDENT WORKSHEET - page 2

Name: _____

<p>Type of adaptation</p>	<p>For each animal, draw and label an illustration of it. Then, describe the adaptation.</p>
<p>behavioral adaptation</p> <p>Definition:</p>	<p>an animal from the exhibition: _____</p>
<p>physiological adaptation</p> <p>Definition:</p>	<p>an animal from the exhibition: _____</p>

STUDENT WRITING TASK

After reading “Why Do Cave Fish Lose Their Eyes?” and taking notes in the *Life at the Limits* exhibition, write an essay in which you describe the different types of adaptations of animals that are well suited to survive and reproduce.

On your worksheet you have notes about the cave fish from the article that illustrates anatomical adaptations, as well as three animals from the exhibition that illustrate anatomical, behavioral, and physiological adaptations. Use all four examples in your essay.

In your essay, be sure to define the words anatomy, behavior, and physiology in the context of animal biology.

ESSAY SCORING RUBRIC: STUDENT VERSION - page 1

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
RESEARCH (worth 1/3)	Article: "Why Do Cave Fish Lose Their Eyes?"	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the article	Presents paraphrased information from the article relevant to the prompt with accuracy and sufficient detail.	Presents information from the article relevant to the purpose of the prompt with minor lapses in accuracy or completeness and/or information is copied from the text	Attempts to present information in response to the prompt, but lacks connections to the article or relevance to the purpose of the prompt
	Museum Exhibition: <i>Life at the Limits</i>	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the exhibition	Presents paraphrased information from the exhibition relevant to the prompt with accuracy and sufficient detail.	Presents information from the exhibition relevant to the purpose of the prompt with minor lapses in accuracy or completeness and/or information is copied from the exhibit text	Attempts to present information in response to the prompt, but lacks connections to the exhibition content or relevance to the purpose of the prompt
SCIENCE (worth 1/3)	Science Explanations	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of anatomical, behavioral, and physiological adaptations	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of different types of animal adaptations	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of different types of animal adaptations; minor errors in explanation	Attempts to include science content in explanations, but understanding of different types of animal adaptations is weak; content irrelevant, inappropriate, or inaccurate
WRITING (worth 1/3)	Focus	Maintains a strongly developed focus on the writing prompt for the entire essay	Maintains focus on the writing prompt for the majority of the essay	Addresses the prompt but is off-task some of the time	Does not address the prompt for most or all of the essay
		Clearly introduces the topic of anatomical, behavioral, and physiological adaptations	Introduces the spiny pufferfish and two other animals; introduction may lack detail	Mentions the spiny pufferfish and one other animal	Only mentions one animal
		Provides a relevant concluding statement/section	Provides a concluding statement/section	Provides a sense of closure	Provides no sense of closure
		Accurately defines "anatomical, behavioral, and physiological adaptations"	Defines "anatomical, behavioral, and physiological adaptations"	Defines 1-2 of the adaptation types	Does not define any type of adaptation
	Development	Clearly describes anatomical, behavioral, and physiological adaptations of animals that are well-suited to survive and reproduce	Describes both physical and behavioral adaptations of animals that are well-suited to survive and reproduce	Attempts to describe both physical and behavioral adaptations of animals that are well-suited to survive and reproduce but lacks sufficient development	Does not describe both physical and behavioral adaptations of animals that are well-suited to survive and reproduce

ESSAY SCORING RUBRIC: STUDENT VERSION - page 2

Scoring Criteria		Meets	Approaching	Developing	Needs Additional Support
		4	3	2	1
WRITING (worth 1/3)	Clarity	Consistent and effective use of precise and domain-specific language	Some or ineffective use of precise and domain-specific language	Little use of precise and domain-specific language	No use of precise and domain-specific language
		Demonstrates and maintains a well-developed command of standard English conventions and cohesion, with few errors; response includes language and tone consistently appropriate to the purpose and specific requirements of the prompt	Demonstrates a command of standard English conventions and cohesion, with few errors; response includes language and tone appropriate to the purpose and specific requirements of the prompt	Demonstrates an uneven command of standard English conventions and cohesion; uses language and tone with some inaccurate, inappropriate, or uneven features	Attempts to demonstrate standard English conventions, but lacks cohesion and control of grammar, usage, and mechanics