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)

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.

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.

- 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 given 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: *How is blindness passed from parent to 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. Students should know that blindness is a trait that can be passed through genes.

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

Say to Students: *In the margin, make the following T-chart:*

HYPOTHESIS 1	HYPOTHESIS 2

Two Options: To provide more support, read each paragraph aloud, stopping after each to take notes on the T-chart in an interactive way.

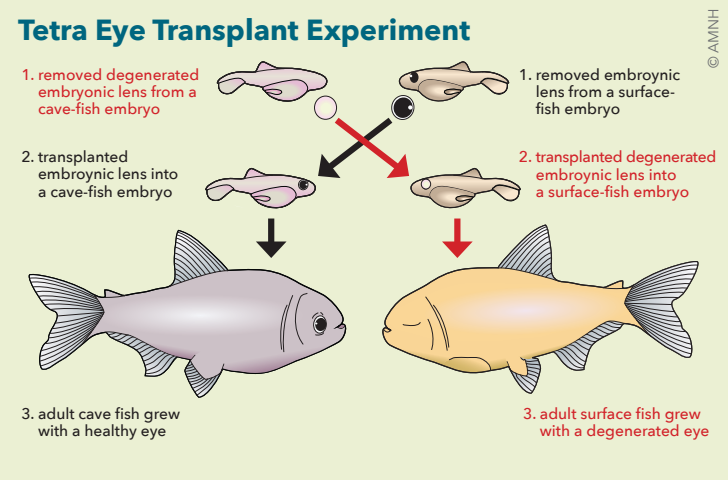
Students can turn and talk while you listen in and you can select a student to share out what to write on the T-chart (shared writing). Alternately, you can ask students to read the two paragraphs independently and fill in the T-charts, sharing their T-charts with a partner after.

Facilitate a brief whole class discussin about the two hypotheses, allowing time for questions and clarification.

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

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 the following **exit slip**:

Using your own words, answer the question expressed in the title: "*Why Do Cave Fish Lose Their Eyes?*" Your answer should be a brief summary of the key idea explained in the article.

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.

Type of adaptation	For each animal, draw and label an illustration of it. Then, describe the adaptation.
physical adaptation (a special feature of the animal's body the helps it survive and/or reproduce)	cave fish *Using information and illustrations from the article "Why do Cave Fish Lose Their Eyes?", students should complete this box in the classroom before the Museum visit.* *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.*
	an animal from the exhibition: _____ *A majority of the animals in the exhibition show examples of physical adaptations. Examples include:* • *axolotl: gills for breathing* • *sawfish: electrosensory pores in saw for detecting prey* • *tarsier: huge eyes* • *boreal Owl: assymetrical ear openings for excellent hearing* • *saturniid moths: feathery antennae for amazing sense of smell* • *mantis shrimp: striking limbs to punch prey* • *mimic octopus: by changing coloring and body shape, can mimic many other species to protect itself*
behavioral adaptation (a behavior that an animal does that helps it survive and/or reproduce)	an animal from the exhibition: _____ *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.*

ESSAY SCORING RUBRIC: TEACHER VERSION - page 1

Scoring Criteria		Exceeds	Meets	Approaches	Needs Additonal 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: *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 different types of animal adaptations	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding 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		Exceeds	Meets	Approaches	Needs Additonal 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 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*).

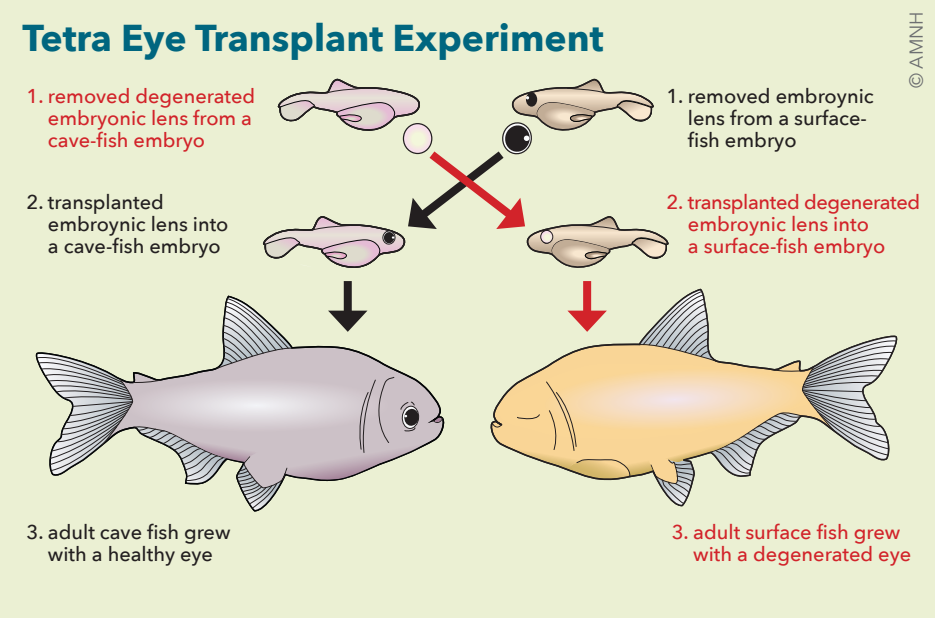
The first hypothesis assumes that blindness *does* give the fish some sort of evolutionary advantage, though not directly. What if the gene or genes that cause blindness also are responsible for some other change in the fish? And what if it was that change, not blindness, that gave the fish an advantage 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.

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

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		Exceeds	Meets	Approaches	Needs Additonal 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: *Life at the Limits*	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 the essay	I stayed on-topic for some of the 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 more than three 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		Exceeds	Meets	Approaches	Needs Additonal 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