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*.

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.

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.

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.

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

An Eye-Opening Experiment

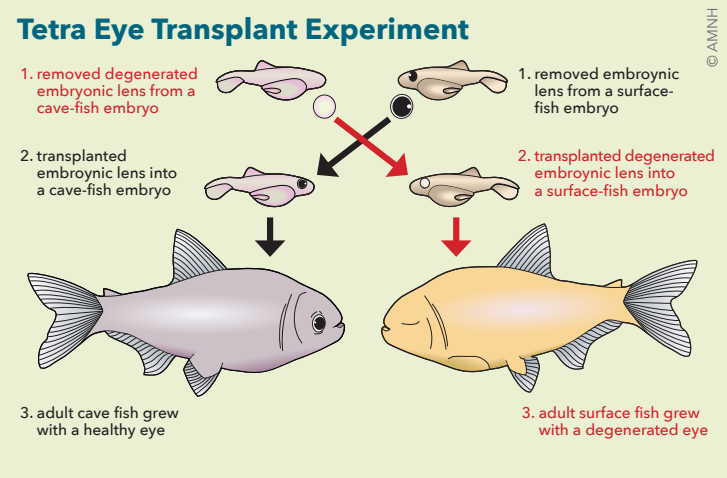
A group of scientists at the University of Maryland set out to investigate the developmental causes of blindness in the cave fish. They carried out an experiment with two varieties of the same species of Mexican tetras. One variety lives in bodies of water near the surface where there is sunlight and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

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 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 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 READING

Why Do Cave Fish Lose Their Eyes?

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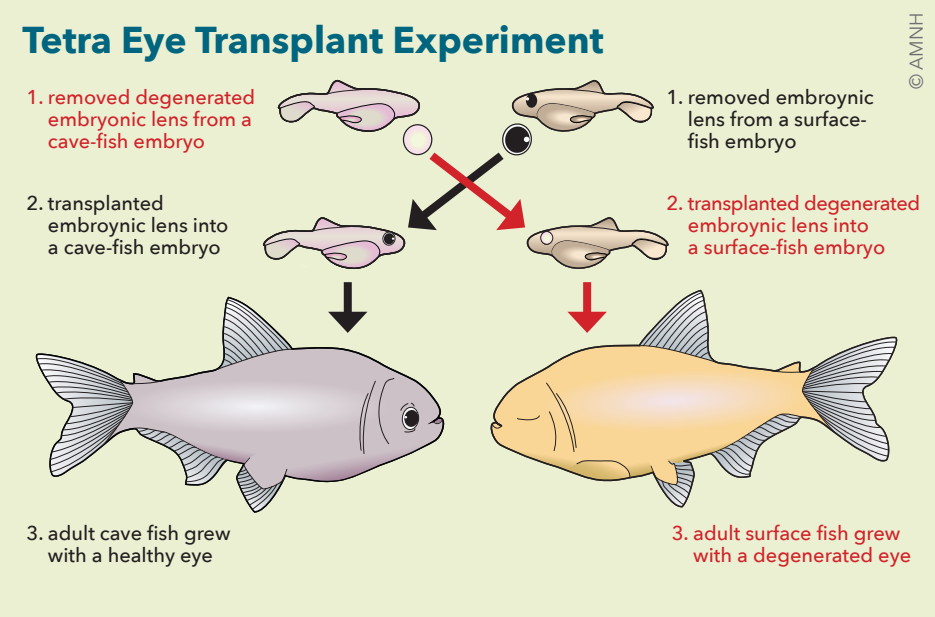

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