Why Do Cave Fish Lose Their Eyes?

This StepRead is based on an article provided by the American Museum of Natural History.

Carlsbad Caverns National Park

There are caves deep under the ground where the sun never shines. If you went into one of these caves without a flashlight, you would see nothing at all. There would just be blackness.

In some of these caves, there are animals that live without light. They include salamanders, crustaceans, and fishes. In fact, more than one hundred species, or kinds, of cave fishes live in constant darkness. They depend on senses other than sight to hunt, eat, and reproduce. These fishes have evolved, or changed over many generations, to live without light.

Many of these species of fish 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 both lost the ability to see and gained the ability to live without sight.

How did that happen? How can evolution cause a species to lose a trait such as the ability to see? That is a mystery that scientists have been trying to solve. Their 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 gain new traits. But in cave fishes we have an example of regressive evolution. This type of evolution is a process in which species lose a trait. In cave fishes, that trait is the ability to see.

Blind cave fish in Mammoth Cave National Park, Kentucky

How does this happen? Do cave fishes go blind because they don't use their eyes? This idea might seem to make sense at first, but it 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 lose a finger in an accident, 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 big muscles. In each of these examples, your body has changed, but your genes haven't. The genes in cave fishes work the same way. The fact that cave fishes don't use their eyes has no effect on their genes.

Instead, cave fishes 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 fish became blind.

Evolution works by a process called natural selection. If an animal is born with a trait that gives it an advantage over other animals of its species, it will be more successful at having offspring. When this happens, scientists say that that animal is "selected" for having that trait. Its offspring and later 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. It is called the Mexican tetra. The scientists have come up with two possible explanations for the fish's blindness. The explanations will probably help them to understand other cave fishes as well.

Mexican tetra

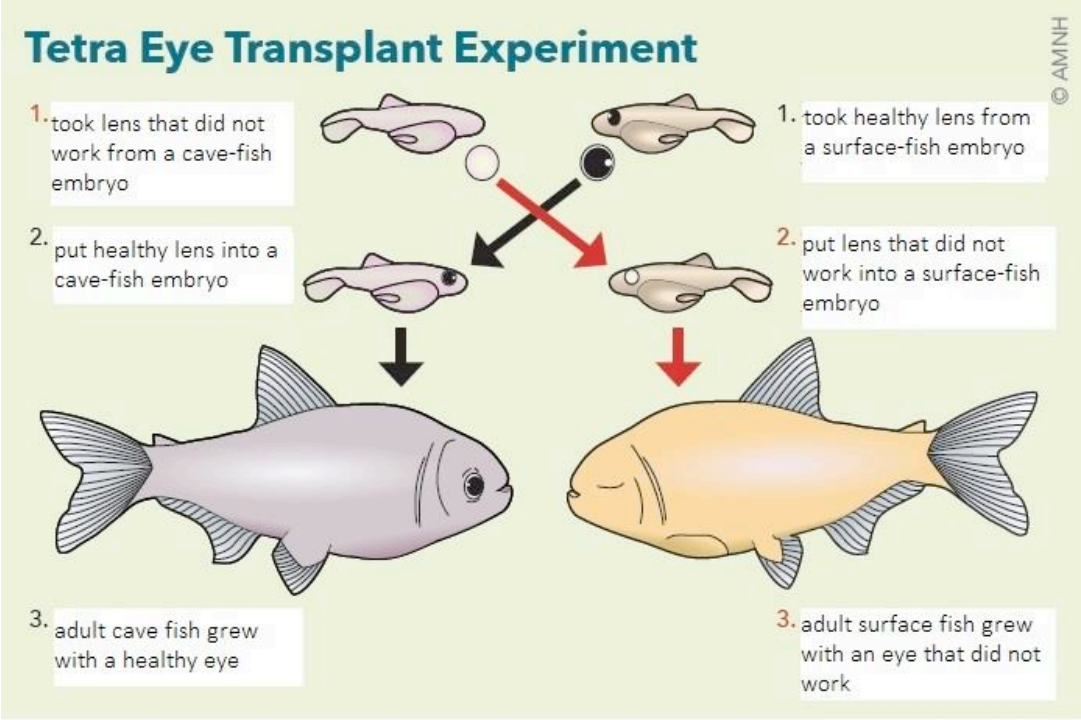
The scientists' first hypothesis is that blindness gives the fish some sort of evolutionary advantage, but not directly. What if the gene or genes that cause blindness are also responsible for some other change in the fish? And what if it was that change, not blindness, that gave the fish an advantage to reproduce? Scientists call this pleiotropy. This is when more than one effect is caused by the same change, or mutation, in a gene.

The second hypothesis is based on the fact that natural selection does not just reward success but also gets rid of failures. To understand this hypothesis, picture a lake where there is sunlight. In this lake, 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 the water of a dark cave would not be at a disadvantage compared to a fish that can see. That is because no fish can use its eyes in the dark. In such an environment, natural selection will not work to get rid of the mutation for blindness. Over one to two million years, many more mutations will occur and start to add up. After a while, the whole population of fish will be blind. This explanation is called the neutral mutation hypothesis.

An Eye-Opening Experiment

A group of scientists carried out an experiment with two varieties of the same species of Mexican tetras. One variety lives near the surface of water that gets sunlight. This variety can see. The other variety of tetras lives in water in dark caves and is blind.

In their experiment, the scientists took a lens from the eye of a surface tetra embryo and put it 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 fish that had been put into the cave fish caused all of the tissues around it to develop into a healthy eye. This experiment showed that the genes involved in the development of the eyes of the cave fish still worked.



The scientists knew that there are many genes in charge of the development of each part of an eye. (For example, one part is the lens, and another part is the iris.) Each of these parts develops on its own. The results of the experiment showed that the genes for eye development in the cave tetra were all able to work properly, if they were given the right signal. The experiment seemed to show that blindness in the cave tetra was not caused by lots of mutations in those many genes. Instead, the experiment suggested that blindness was caused by a small number of mutations in genes known as "master switches."

These master switches are genes that control the function of many other genes. In this case, the switches control genes in charge of eye development. These switches have the ability to deactivate the eye genes. When this happens, the eye genes are still able to work, but they are not doing anything. Putting a healthy lens into the cave tetra embryo seems to cause the switches to send a signal to the deactivated eye genes. The eye genes are then "turned on," and the cave tetra develops eyes. If scientists could find the switches that made cave tetras blind, they could find out whether the same switches had effects on other traits of the fish that do give it an evolutionary advantage for surviving in caves.

The scientists did indeed find one of those genes. It is nicknamed *Hedgehog* or the *Hh* gene. They discovered that this gene does more than cause blindness in cave tetras. When the fish develops without eyes, the skull bones move into the empty eye sockets. When the bones move into the eye sockets, the fish's nose becomes bigger. In this way, it could be that the same control gene (*Hh*) that stops eye development in the fish also improves its sense of smell. An improved sense of smell would be an advantage for a fish that lives in the dark.

As a result of this experiment and others, it now seems likely that blindness in cave tetras is in part the result of pleiotropy. That is because the same mutation in one gene (the master switch) has more than one effect (blindness and an improved sense of smell).

Evolution Works

Scientists are still studying cave fishes, and new discoveries are sure to be made. But it is already clear where the answers to their questions will be found. The answers will be found in the basic processes of evolution that are already well understood. With new tools that give scientists the ability to map genes, find mutations, and understand the development of embryos, we are increasing our understanding of how evolution works.