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Shedding Light on the Dinosaur-Bird Connection

By American Museum of Natural History

When people think of dinosaurs, two types generally come to mind. There were the huge herbivores, like *Apatosaurus*, with their small heads and long tails. There were also those fearsome carnivores, like *Tyrannosaurus rex*, that walked on two legs and had a mouthful of teeth like kitchen knives.

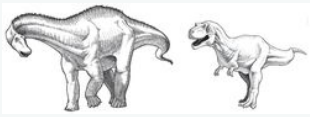


Image Credit: © AMNH

Living Dinosaurs

These large dinosaurs are no longer around, but dinosaurs still live among us today. They are the birds. It's difficult to imagine that a bird on your window sill and a *T. rex* have anything in common. One weighs less than a pound. The other was the size of a school bus, tipping the scales at eight tons. But for all their differences, the two are more similar than you might think. In fact, birds and *T. rex* are close relatives. They all belong to a group of dinosaurs called theropods.

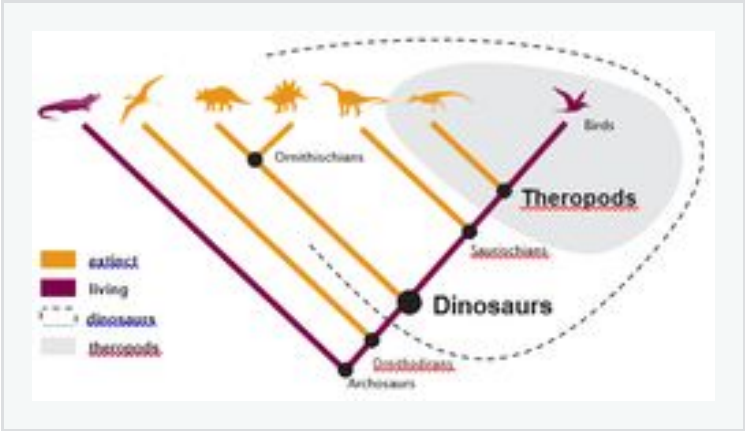


Image Credit: © AMNH

This is a cladogram, a "tree" showing the relationships among organisms. The group called dinosaurs includes the extinct dinosaurs and all their living descendants. All its members, including living birds, descended from the very first dinosaur—their common ancestor. That's why birds are a kind of dinosaur (just as humans are a kind of primate).

Finding the Evidence

To better understand the link between non-bird dinosaurs and birds, scientists look for features they share. When studying

Photo Credit: © Pamala Wilson

living birds, they can observe their behavior and study their anatomy. It's a different story altogether when it comes to long-extinct dinosaurs. Behavior cannot be observed, and all that's left of these animals are the clues found in ancient rocks. This evidence includes fossilized bones, teeth, eggs, footprints, teeth marks, and even dung.

Skeletal Evidence

When paleontologists compare a skeleton of a living bird to the fossilized skeleton of a non-bird theropod, like *Sinornithosaurus*, they see many similarities. They both have a hole in the hipbone, a feature that distinguishes most dinosaurs from all other animals. This feature allows an animal to stand erect, with its legs directly beneath its body. All theropod dinosaurs, including birds, have a furcula, also known as a wishbone. Another shared characteristic is the presence of hollow bones. Hollow bones reduce the weight carried by an animal. This feature enables the animal to run faster. It probably also played a role in the evolution of flight.

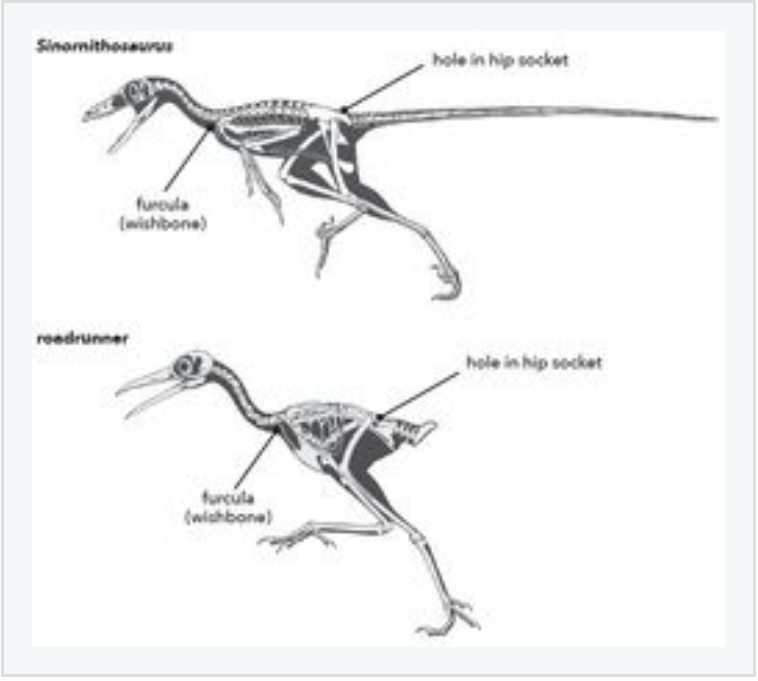


Image Credit: © AMNH / Sean Murtha

Sinornithosaurus and the roadrunner are both theropod dinosaurs.

Behavioral Evidence

Birds build nests, lay eggs, and brood their nests. When scientists look at some non-bird theropod fossils, they see evidence of these same behaviors. The first discovery of this evidence was in 1993 in the Gobi Desert in Mongolia. Scientists unearthed a *Citipati* fossil brooding a cluster of eggs. Its limbs were folded back against its body. It is one of the few fossils ever found that demonstrates behavior. In this case, parental care. It shows that the behavior of brooding the nests that we see in living birds was already present in the non-bird ancestors of birds.

Photo Credit: © AMNH / Mick Ellison

Citipati, like many other non-bird dinosaurs, had feathers. Yet it could not fly. Feathers were once thought to have evolved for flight. The discovery of more and more non-flying dinosaurs with feathers disproved that explanation. For these dinosaurs, feathers may have served other functions, like gliding, insulation, protection, and display. Feathers play that same role in many bird species today.

Based on the evidence of shared characteristics, scientists have concluded that birds are a type of theropod dinosaur.

Brain Evidence

Birds are the only dinosaurs with the ability to fly. This is very interesting to scientists who want to know when the capability of flight emerged. To find out, some scientists study the brains of bird and non-bird dinosaurs. Soft tissue, such as brains, is almost never preserved in the fossil record. What is preserved is the imprint the brain left on the inside of the skull. Now

scientists are using computed tomography (CT) scanners to create endocasts. These are detailed, three-dimensional reconstructions of the interiors of fossilized skulls.

Photo Credit: © AMNH / Mick Ellison

Sinornithosaurus had feathers similar to those of modern birds—even though it could not fly.

In a recent study, researchers were able to peer inside the braincases of more than two dozen specimens. "Technology allows us to look inside these specimens without destroying them," says Dr. Amy Balanoff, a Museum research associate. "It's a non-destructive way to basically slice up a dinosaur brain. We look inside and see what it can tell us about the evolution of the brain within dinosaurs. Most of us grew up thinking that dinosaurs had tiny brains, but actually some had really big brains."

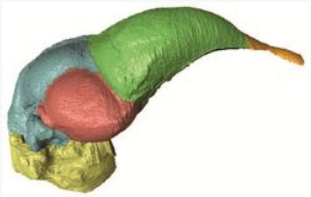


Image Credit: © AMNH / Amy Balanoff

Scientists use computed tomography (CT) scans of dinosaur skulls to create detailed, 3-D reconstructions of their interiors. This one shows the space inside the skull of Archaeopteryx.

The endocasts allow Balanoff and other researchers to explore the outer shape of the brain in more detail. In addition, the casts also provide new information about the volume and shape of different regions of the brain. For example, scientists looked at a detailed view of the dinosaur cerebrum, a region of the brain related to cognition and coordination. They found that this region was very large in non-bird dinosaurs closely related to birds. Dr. Balanoff's research suggests that these dinosaurs developed big brains long before flight and that these bigger brains prepared the way for them to fly.

When examining skeletal, behavioral, and brain evidence, scientists see that birds and non-bird dinosaurs share many features. This helped them conclude that dinosaurs aren't extinct after all. They're living among us today.

Naturally Selected to Survive

By Michael Stahl

The earth has changed, over and over again, throughout the course of its history. Some of these changes have happened quickly. Others have occurred over long stretches of time. For example, the planet has experienced ice ages that took place over *thousands* of years. During those eras, huge sheets of ice covered much of the surface of the globe. Then for a few thousand years between the ice ages, the earth warmed up. Scientists believe that this cycle has actually occurred a few times, and it might be one of the many reasons behind the recent global warming we have experienced.

As the planet goes through this cycle, environments may go through changes. In order to survive in changing environments, species oftentimes must undergo a process of adaptation. Adaptation refers to a mutation or genetic change that enables an organism such as an animal or plant to survive in its environment. This trait is passed down from one generation to the next, becoming an inherited trait of the species. A species may have to adapt to warmer temperatures, increased precipitation, or even developing air pollution. If the organisms of a species cannot change along with the area in which they live, they risk dying out. Though an uncountable number of species that have roamed the earth have become extinct, the planet has seen many others adapt as well. These select organisms have been able to go on living in their environment.

A species adapts to a changing environment as organisms with favorable traits reproduce and survive. These favorable traits, which help the species survive, are passed down through different generations of the species. This process is called "natural selection." Recent history has given us an important example of how organisms are able to survive once their environments change.

Light gray peppered moths and dark-colored peppered moths lived in the countryside between the cities of Manchester and London in England. Many years before the 19th century, more of the light gray peppered moths had been able to survive in their environment mostly because of their color. Their thin layer of skin, as well as their large wings, was mostly gray with a little bit of black

"peppered" all around. This color was advantageous because the light gray peppered moths were camouflaged when they stayed on gray-colored areas on the sides of trees in their habitat. Predators, which were mostly birds, could not see the light-colored moths on the trees because the color of the moths blended in with the color of the trees. Instead, the predators were able to see the dark-colored peppered moths more easily.

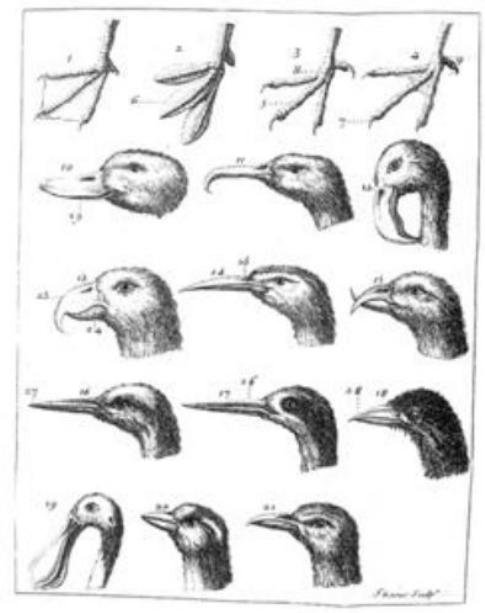
In the early 19th century, though, England began the first years of its Industrial Revolution. Many areas, especially in and between the cities of Manchester and London, became populated by a growing number of factories. This was because companies began to use a lot of new machinery that had been invented in the decades before. These machines made work a lot easier in many ways. The companies could build more products faster than ever before. However, many of these factories needed coal to provide energy for the machines. When coal burns, it gives off a lot of dark-colored smoke. Soot is a black substance that collects on a surface that comes into contact with smoke. Smoke's dark particles stick onto surfaces like paint. In the English countryside near industrialized areas, the trees began to blacken with soot because of all of the smoke in the air from the factories. This made the light gray peppered moths much more vulnerable. Predators could see them on the trees more clearly and easily hunt them down.

Sometime in the next hundred years, scientists began to notice a huge change in the moth population living in and between the cities of Manchester and London near where many of those factories had been constructed. Most of the peppered moths were the dark-colored kind! What caused this change was the fact that predators had eaten a lot of the light gray peppered moths because the moths were clearly visible on the black-colored trees. The dark-colored peppered moths in the area survived much more easily and mated with other dark-colored peppered moths until most of the population of peppered moths became dark-colored.

Many scientists feel that this example of evolution in a species supports Charles Darwin's theory of natural selection. An author named J.W. Tutt published a report about the moths a few years after Darwin's death, writing that the change in the peppered moth population seemed to support Darwin's ideas. Though Darwin was not alive to read the Tutt report, his teachings about nature live on.

When Fish First Walked

By ReadWorks



A few hundred million years ago, the competition for food between fishes was fierce. So much so that gradually, some fish developed the ability to get out of the water and reach food sources that none of the other fish could get to. They survived long enough to successfully reproduce, and passed this characteristic on to future generations. In fact, from these fish eventually originated the animals with two pairs of limbs, including human beings.

This is an example of natural selection. An organism that develops a trait that helps it survive in its environment will have a better chance of reproducing and passing that trait on to the next generation. As a consequence, organisms with this helpful trait will become more prominent while other organisms of the same species die out. Why do giraffes have long necks? Why do rabbits produce so many offspring? Natural selection can help us understand why some species are the way they are.

The term "natural selection" was coined by Charles Darwin, who developed the scientific theory of evolution. Darwin was born in England in 1809 and spent his life observing animals and plants from around the world. He explained the theory in his landmark book *On the Origin of Species*.

Sometimes, the changes that occur among a group of organisms will seem very small but still play an important role in their survival. Take, for example, the peppered moth. The peppered moth was light in color and had speckled wings. It was hard to pick out against many of the trees and buildings in England and could camouflage itself easily. But during the Industrial Revolution, London became polluted, and the smog turned everything black. Now the moths could be seen more easily by predators; they had nowhere to hide. Around this time, dark-colored peppered moths, which are almost invisible against a dark background, began to appear and soon became widespread. The lighter moths, on the other hand, became scarce in these sooty industrial areas.

Another case that has to do with survival through camouflage involves the little deer mouse.

Typically, deer mice are dark brown, which makes it easier for them to hide from owls and other predators in the dark soil of the woods. The deer mouse that lives in Nebraska's light-colored Sand Hills, however, has gone from brunette to blonde so it can blend in and have a better chance at survival. It took thousands of years for these mice to change the color of their coats, which may sound like a long time, but when it comes to evolution, that's pretty quick!

One interesting case study is that of the Galápagos finches, about 14 species of bird that were studied by Darwin on the Galápagos Islands. Often referred to as "Darwin's finches," these birds look very much alike. The most significant difference among them is the size and shape of their beaks. Every different beak evolved the way it did so as to be suited to a particular feeding task. When, in 1977, a drought hit the island, vegetation withered and the only seeds left were large and tough. The finches with deeper, stronger beaks were able to crack through these seeds, and many more of them survived than their smaller-beaked brothers. However, in the mid-1980s, during an especially rainy time, smaller, softer seeds flourished. The birds best adapted to eat them had smaller beaks and they fared much better.

Where have all the dull male peafowl (peacocks) gone? Well, female peafowl (peahens) choose their mates based on the color and brightness of their plumage. This means that peacocks with impressive tail feathers are able to find mates more easily. A few thousand years ago, there were many more males with dull feathers, but they kept getting passed over by the females and did not reproduce. Their numbers therefore began to dwindle. These days, they're quite rare.

Darwin's theory teaches us that an animal or plant that adapts to its environment and remains alive long enough to procreate will thrive. The dodo bird, which has gone extinct, was not lucky in this respect. A lack of predators for thousands, and maybe even millions, of years meant that the dodos never learned to fly. When humans finally arrived to their home on the island of Mauritius, the dodos had no way of protecting themselves and, in the 17th century, were wiped out. It isn't easy being on the wrong side of natural selection. Fortunately for us humans, the fish with the fleshy, leg-like fins came out on top.

Selective Breeding

By ReadWorks

Charles Darwin, a British naturalist who lived in the 19th century, is best known for his book *On the Origin of Species*. In it, Darwin established the idea of evolution that is widely accepted today. He proposed that all species alive have evolved through adaptation to their surroundings. Natural selection, the process by which varied traits that increase survival and enable reproduction are passed down from generation to generation, is probably the most famous principle from the book. Darwin's book also addresses the perhaps less well-known concept of artificial selection. Today artificial selection is more often called "selective breeding." Selective breeding involves breeding animals or plants for a specific, typically desirable trait. By doing so, the desired genes from the plant or animal will be passed on to its offspring.

Dog breeding is one of the most common examples of artificial selection. You need only to tune into a dog show on TV to see the power of selective breeding at work. Crossbreeds, for example, are dogs born from parents of two different breeds. Mixed breeds are born from parents of more than two breeds, and pure breeds are born from a single breed. All three varieties are featured in most dog shows. Many of these dogs were bred to achieve certain desirable physical or behavioral traits.

Beyond the context of dog shows, dogs are a particularly interesting example of selective breeding. After all, we call dogs "man's best friend" for a reason. Dogs originally evolved from wolves. Eventually, humans were breeding different types of dogs to accomplish certain jobs. For

example, some dogs were bred to hunt well. Others were bred with desired traits to herd cattle. But it was a trait known as "tamability," or a dog's ability to be tamed and live among people, that resulted in humans keeping dogs as pets. Now that many people live relatively quiet, domestic lives, how well a dog can herd sheep is not of huge importance. What matters most is whether a dog makes a good companion.

Charles Darwin may have been the first to describe the process of selective breeding, but the practice may be more than 2,000 years old. The Romans are said to have practiced selective breeding among their livestock, favoring cows that produced a lot of milk. But it wasn't until the 18th century that farmers began practicing it on a large, industrial scale.

Today, farmers breed chickens to have extra-large breasts and to lay a lot of eggs. A wild fowl—a chicken that lives in the woods—lays between 20 and 30 eggs per year. In contrast, a chicken born out of selective breeding can lay as many as 300 eggs per year.

In the same way that chickens are selectively bred for having more meat and laying a greater amount of eggs compared to wild chickens, cattle are often selectively bred either for more meat or for more abundant milk production compared to cattle in the wild. Over the course of the 1700s, the size of bulls sold for slaughter increased dramatically—from around 300 pounds (about 140 kilograms) to nearly 800 pounds (about 360 kilograms)—as a result of selective breeding. Also as a result of selective breeding, the dairy cow, which does not display a lot of girth or muscle, can produce enough milk for 10 calves. One can identify a dairy cow by its udders, which can hold over 5 gallons (over 19 liters) of milk.

Even though people selectively breed to yield animals with desired traits, there are dangers to selective breeding. Temple Grandin, an animal welfare advocate, notes that breeding animals for size and strength interferes with natural animal processes. Breeding roosters for muscle, for example, can make them top-heavy and unsteady on their feet, interfering with their courtship dances. This, in turn, can alienate them from hens.

Speaking of hens, what about those that were bred to lay 300 eggs per year? Laying one egg a day makes a hen's bones brittle, since the eggs soak up the bird's calcium supply. And what about so-called broiler chickens—the ones that are bred for their large breasts? Often, their bodies grow so fast that their skinny legs can't support them.

Cows required to produce enough milk for 10 calves tend to burn out quickly. Cows not subject to selective breeding can live up to 30 years without burning out. But prolific dairy cows tend to make it just four or five years before they are considered worthless, and then they are sent to be slaughtered.

Selective breeding comes with both benefits and drawbacks. Think of all the joy that dogs have offered humans in the form of companionship over the last 100 years. Selective breeding is to thank for man's best friends. And yet, the pain and suffering that livestock endure makes us think twice. It is important to keep in mind that, in some cases, the negative consequences of selective breeding may outweigh the positive.

Why Do Cave Fish Lose Their Eyes?

By American Museum of Natural History

This article is provided courtesy of the American Museum of Natural History.

Wikimedia Commons/Daniel Mayer

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.

NPS

Blind cave fish, Mammoth Cave National Park, Kentucky

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.

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

Wikimedia Commons/H. Zell

Mexican tetra (Astyanax mexicanus)

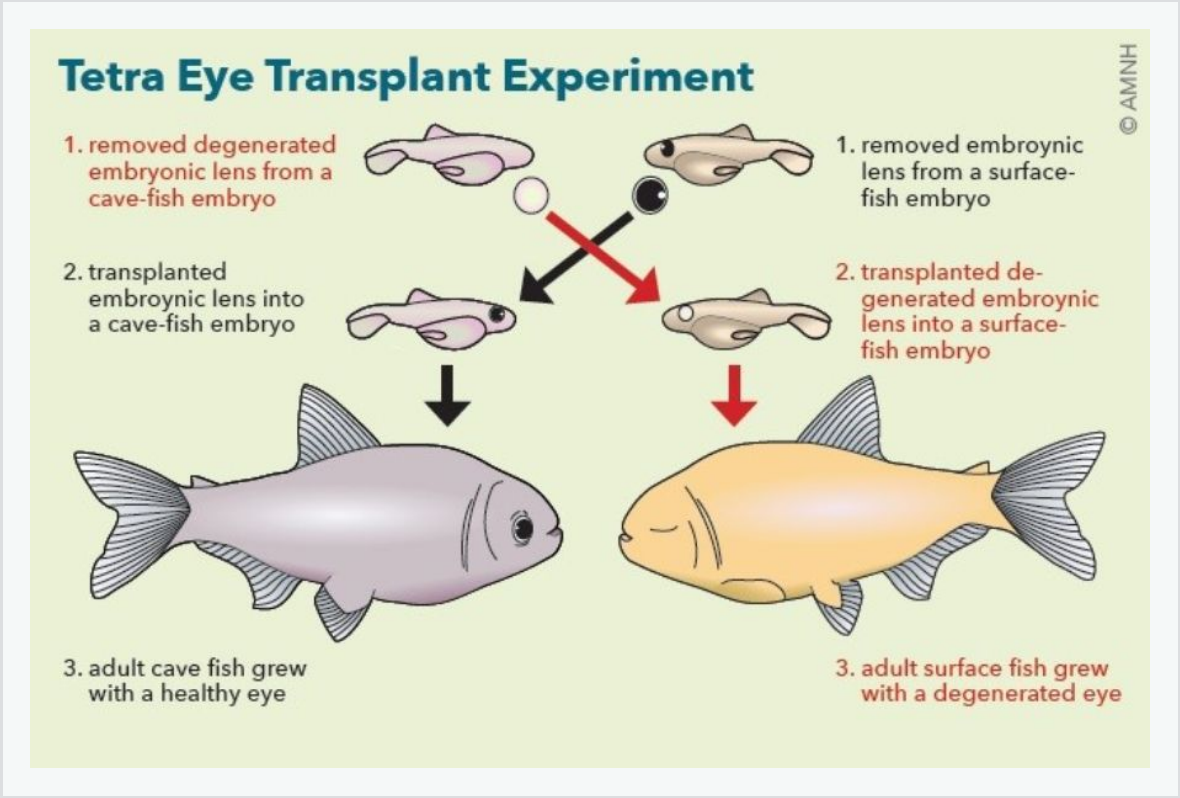
Scientists have studied one species of blind cave fish, the blind Mexican tetra (*Astyanax mexicanus*). They have come up with competing explanations for blindness in that fish, which likely will help them to understand other cave fishes as well.

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.



American Museum of Natural History

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.

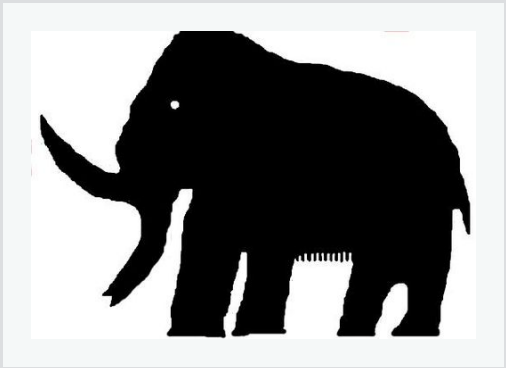
As a result of these and other experiments, it now seems highly likely that blindness in cave tetras is in part the result of pleiotropy—one mutation that causes blindness in the fish and at the same time, gives them an enhanced sense of smell.

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.

The Woolly Mammoth

By Edward I. Maxwell



The closest relative of the woolly mammoth is the Asian elephant. The main difference between the two is that the mammoth had an incredible coat of fur, made up of an outer layer of coarse "guard hair" with an inner layer of curly wool. The last known group of mammoths died off, or became extinct, around 4,000 years ago. The mammoth roamed the northern lands of the world during a period known as the Ice Age. It was among the largest land mammals to roam the earth. The mammoth was a tough beast and was able to endure extreme weather conditions and frigid temperatures.

The mammoth shared these northern territories with other mammals during the Ice Age. The most important mammal to interact with the mammoth, however, was the human. When the mammoths were at their greatest numbers, humans mainly hunted animals and foraged for food. These hunters would follow herds of animals over incredibly long distances in order to hunt them. The woolly mammoth provided a great amount of food and other important things for these humans. The fur, for example, could be used to make coats and blankets that would help keep out the cold in the icy environment. Bones from the mammoth could be used to make tools and weapons. Because one mammoth provided so many useful things to a large group of people, early humans would follow the herds wherever they went. There is even a theory that the humans followed the mammoth over a land-bridge from Asia into the Americas.

How do we know that the mammoth existed? Scientists have found countless mammoth fossils, or bones, all over the world. In fact, scientists have even found very well-preserved, or mummified, mammoth bodies in sheets of ice. These mummified remains are part of the reason scientists came to know exactly how hairy and woolly the mammoths actually were. Another reason scientists know

so much about mammoths is that early humans painted pictures of them on cave walls. These pictures depicted hunting parties chasing after mammoth herds and trying to bring down the great beasts with spears.

Certain features of the woolly mammoth allowed it to survive very well in this harsh environment. The most obvious feature was, of course, its hair and wool. This coat helped the mammoth maintain a warm and stable body temperature no matter how cold the landscape became. The coarse hair would keep ice and frost from collecting too close to the mammoth's body, which left the softer, wool inner-layer free to keep the animal extra warm. Another feature was the mammoth's large tusks. These tusks were very long and curved out wide from the mammoth's head. It was able to use these tusks for protection. Besides humans, there were other predators the mammoth had to face. The American lion was an incredibly large predatory cat. The mammoth's tusks could be swung into an attacking lion to keep the predator away or even injure it. Mammoths driven to stand and fight or protect their young might even have charged humans with their large tusks, looking to make a crushing blow.

Humans were very smart hunters, however. Hunting in large parties, the humans would most likely isolate a mammoth from its herd, and attack it all at once in great numbers. Wielding their spears expertly, the humans would bring the mammoth down as quickly as possible, and then set about butchering it with stone scraping tools, axes and knives. It is believed that the success of human hunters was a large part of why the mammoth became extinct. Another reason had to do with the climate. The Ice Age did not last forever. The earth's temperature rose again. The glacial ice receded, and many scientists believe the mammoth was not well suited for the warmer weather. The environment that had once been so hospitable to a great animal very well-adapted to the frigid conditions gradually became more hostile. Finally, the last group of mammoths died off 4,000 years ago. Now all that remain of the mammoth are fossilized bones and mummified mammoth bodies that were frozen over a long time ago.