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The Angelina Jolie Project

by Carl Zimmer

Lake Apoyeque, Nicaragua. Courtesy of Henrik Kusche

About 1800 years ago, a volcano in northern Nicaragua exploded. The crater formed by the eruption slowly filled like a rain barrel. Eventually the water rose high enough to warrant the title of lake. Today it is called Lake Apoyeque. Although Lake Apoyeque is over 300 feet deep, the rains have a long way to before they reach its brim. Lake Apoyeque remains ringed by volcanic cliffs towering as high as 1200 feet. And yet, despite its young age and its remote location, it is filled with fish.

For thirty years, Axel Meyer, an evolutionary biologist now at the University of Konstanz in Germany, has journeyed to Lake Apoyeque and other lakes of Nicaragua to study the evolution of their fish. He

and his colleagues have caught cichlids and sequenced their DNA. By comparing their genes, the scientists can work out how the fish spread across the country. At Lake Apoyeque, for example, they found that the cichlids shared a number of mutations with the cichlids of Lake Managua nearby. The fish of Lake Apoyeque have accumulated relatively few mutations of their own. Meyer and his colleagues studied those mutations to estimate how long it took for their genetic diversity to evolve. They concluded that the cichlids came from Lake Managua to Lake Apoyeque only about a century ago.

There are forests and cliffs dividing Lake Managua and Lake Apoyeque, and no one can say exactly how the fish leaped over them around 1900. One likely route is a water spout. Water spouts are known to pass over Nicaragua, and it's possible that every few thousand years one of them happens to suck up fish from one lake along the way and drops them in another.

But this aerial journey is not the most remarkable thing about the fish of Lake Apoyeque. What is most remarkable is obvious if you pick them up and take a close look at them.

It's their lips.

Thin- and thick-lipped cichlids from Lake Apoyeque. From Elmer et al BMC Biology 2010

Most of the cichlids in Lake Apoyeque, like the one on the top, have thin, pursed lips. But some have plump, full lips, with the sort of curves that Upper East Side plastic surgeons charge dearly to provide to human beings.

You can find the same two types of fish mouths in Lake Managua. In lake after lake in Nicaragua, you can find more thin-lipped cichlids living alongside thick-lipped ones. You can find them thousands of miles away, on the cichlids in African lakes. In many cases, cichlids that have colonized a new lake have rapidly evolved into two distinct populations: one with big lips, and one without.

Meyer and his colleagues study the cichlids of Africa and Central America to explore many of the most profound questions about how life evolves. They investigate how these fishes are diverging into new species, how they are evolving preferences about their choice of a mate, how they are evolving different

A thick-lipped cichlid from Lake Tanganyika in Africa. Photo by Ad Konings

ways of making a living. One of the most interesting things about cichlids is that once they become isolated in lakes, they end up evolving many of the same traits found in other isolated lakes.

Photo by Stefan Servos/Wikipedia/Creative Commons

To understand this parallel evolution, Meyer and his colleagues are taking a close look at those lips, investigating how the cichlids use them and how their genes produce them. In their lab back in Germany, the scientists like to call it "the Angelina Jolie project."

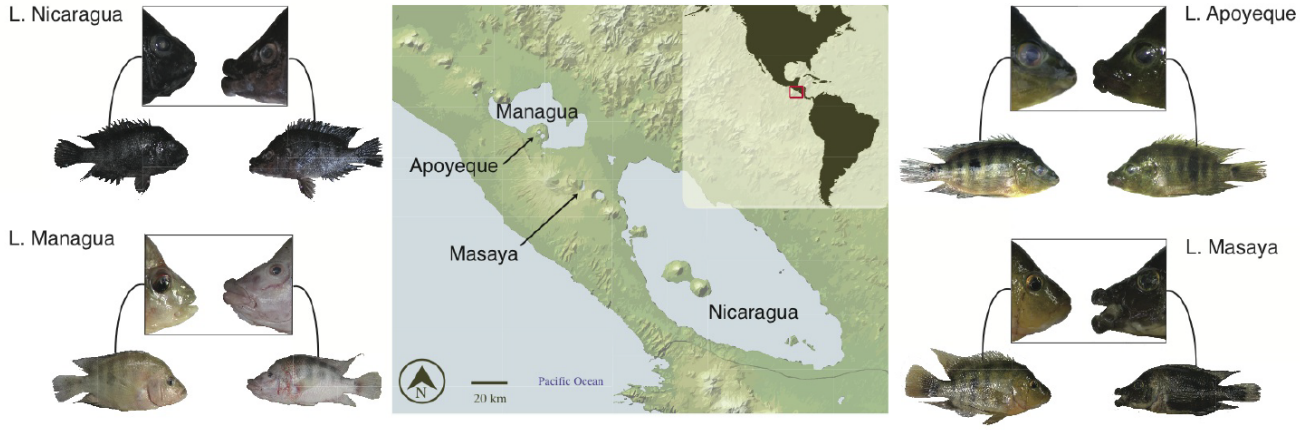
If you watch thick-lipped cichlids in action, you can see how natural selection could favor the mutations that plumped up their mouths. They typically push their mouths into crevices of rocks on the bottoms of lakes. They then use their ample lips to form a seal around their prey–they often choose crabs or other animals lurking in the crevices–which they then suck into their mouths. The volcanic rocks are sharp-edged, and the cichlid's padded lips provide them with protection. Thin-lipped cichlids, on the other hand, search for other kinds of food in the open water, where they don't need to vaccum up their prey.

These are both perfectly suitable ways of making a living in a volcanic lake. But cichlids that are better adapted to one way or the other may have better luck than a cichlid-of-all-trades. Natural selection will then favor cichlids at the two anatomical extremes instead of those in the middle.

Until recently, it was impossible to probe the genes of the cichlids to see what mutations natural selection was acting on. Scientists like Meyer didn't know what to look for. But in recent years a large consortium of scientists (including Meyer) have sequenced the genomes of cichlids. Now they have a map to guide them as the zoom in on the molecular details of cichlid evolution.

To investigate cichlid lips, Meyer and his colleagues caught cichlids from four lakes. Two of the lakes were young (Apoyeque, 1800 years old; Mayasa, 6000 years old), while the other two were big, old lakes from which the young lake cichlids traveled. (Lake Managua and Lake Nicaragua are both about 500,000 years old.)

As you can see from this figure from their new paper, all four lakes have their own pairs of thin- and thick-lipped cichlids. (Click on the image to enlarge)



From Manousaki et al, Molecular Ecology 2012

Meyer and his colleagues clipped off a sample from the lip of each of their cichlids. They then looked for signs of active genes in the lip cells. They wanted to see if thick-lipped cichlids made a bigger (or smaller) supply of certain proteins than thin-lipped ones. Changing the levels of proteins has long been known to be a powerful engine for evolutionary change.

The scientists found many such genes. In Lake Apoyeque, for example, 149 genes had significantly different levels of activity in the thin- and thick-lipped cichlids. In Lake Managua, there were 512 genes that were different.

Across all four lakes, however, six genes consistently behaved differently in the two kinds of cichlids. Meyer argues that these genes are crucial for evolving big lips. Some of them are known to control the growth of cartilage and muscle. Changing the levels of the proteins made by these genes might allow cichlids to bulk up their lips. Some of the other genes Meyer and his researchers identified help build the nervous system. This discovery raises the intriguing possibility that the thick-lipped cichlids use their lips not just to form a seal over their prey. Their lips may be studded with odor-sensing receptors that help them sniff out their prey.

Meyer's new study suggests that evolution repeats itself, up to a point. In four different lakes, it appears that the same kinds of adaptations have evolved in cichlids through changes to the same six genes. If you want thick lips, there are not an infinite number of ways to get them. Meyer and his colleagues have also found that thick-lipped cichlids also evolve other traits in all four lakes. As you can see in the figure above, their heads have a conical shape, whereas thin-lipped cichlids have a blunter face. All those parallel traits may be part of the same suction-feeding package. To feed among rocks, it helps not just to have luscious lips, but also to have a narrow head you can push into crevices.

Carmelo Fruciano, Gonzalo Machado Schiaffino, and Axel Meyer check out cichlids for sale at a market in Granada, on

At the same time, however, evolution is playing out differently in the lakes. Most of the genes with different activities in Lake Apoyeque are not the same as the ones in Lake Nicaragua, for example. There are differences in anatomy, too. Thick-lipped fishes in the some lakes have narrow teeth, while thick-lipped fish in other lakes have broader ones.

There are several possible explanations for these differences. The lakes are not identical, for one thing.

the banks of Lake Nicaragua

Some lakes have a bigger variety of habitats for cichlids to adapt to; one lake may have a different collection of animals for the fish to hunt. And some of the differences Meyer and his colleagues have found may be little more than the result of a genetic roll of the dice. When a water spout picked up a few cichlids in Lake Managua, they may have had some peculiar mutations that were unusual in the population as a whole. But when they fell into Lake Apoyeque, those peculiar fish now became the *entire* population of cichlids in their new home.

Other scientists have also found a mix of similarities and differences in parallel evolution. They're finding this complex pattern in the legs of lizards on Carribean islands, in bacteria adapting to a starvation diet, and echolocation in bats and whales. The thick lips of Lake Apoyeque are not an odd reflection of a Hollywood star, it turns out. They are a clue to one of the most important patterns in the history of life.

[Unless otherwise noted, all images are courtesy of Axel Meyer. Jolie on Wikipedia]

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Russ Abbott
December 19, 2012

So the moral is: watch out when you kiss Angelina Jolie?

kylee
December 19, 2012

Wow. All these ideas do add up and seem very possible. I enjoyed how you researched all this information out to come up with ideas. Hope you succeed in your final analysis.

Aloysius Horn
December 19, 2012

My guess is that the thick-lipped variety morphotype is correlated with higher expression of lipoproteins.

220mya
December 19, 2012

Why aren't humans or birds considered likely dispersal mechanisms for the Lake Apoyeque cichlids?

winda
December 19, 2012

the lips of fishes like angelina jolie, or the lip of angelina jolie like the fishes??

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Carl Zimmer is an award-winning science writer whose work appears frequently in the *New York Times, National Geographic*, and other publications. He is the author of 13 books, including *Parasite Rex* and *The Tangled Bank: An Introduction to Evolution*. You can find him on Twitter, Facebook, Pinterest, and Google+.

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