Smart, for Fish, the Cichlid Proves to Be a Model of Diversity

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family tree.

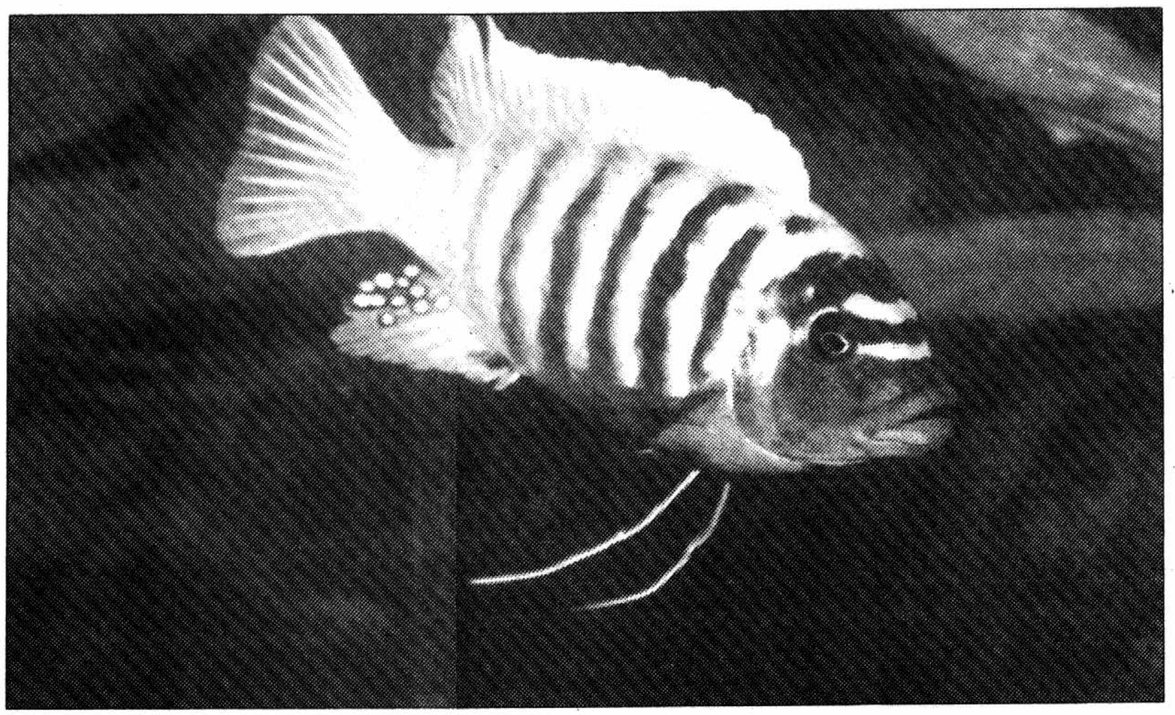
More than 1,000 species of cichlid fish live in the lakes and rivers of Africa, Madagascar, India and Latin America. They are a highly successful tribe, frequently dominating their environment through a blend of intelligence — unusually high for a fish — and elaborate rituals of parental care. But what makes them so unusual is the number of species that often coexist in the same place. Over 500 different varieties of cichlids swim in Lake Malawi, in southeast Africa, while about 200 other species live in Lake Tanganyika, in Tanzania. Some species are bigger than goats, others could fit in a thimble. Some are thick and boxy, others lean and long. They are brown or turquoise or every shade of a neon rainbow painted on a single beast.

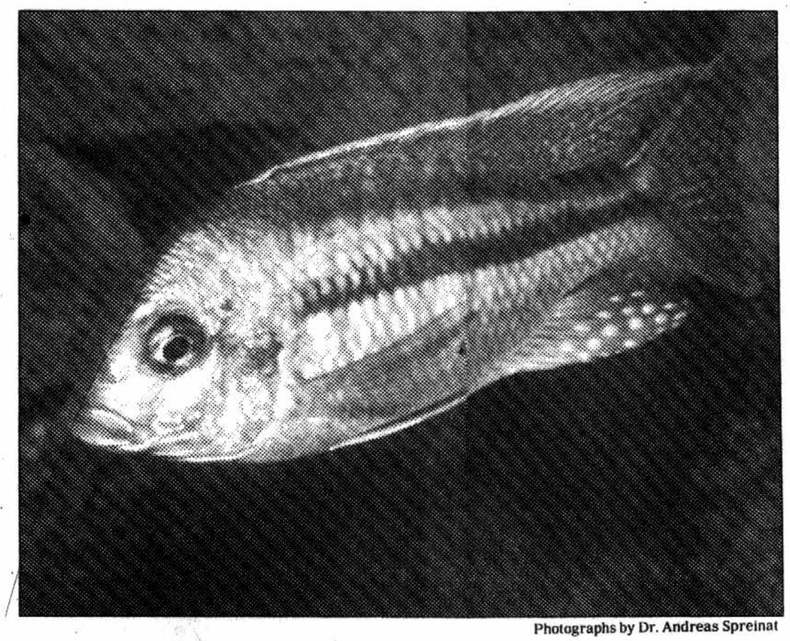
And the cichlid's rate of speciation has been explosive. In Lake Victoria of East Africa, for example, 300 species of cichlids arose in less than 200,000 years, an evolutionary pace that no other animal group has rivaled. Certainly none of the other fish groups found in the three African lakes has undergone anything approaching the spectacular diversification managed by the cichlid family.

Scientists have long been captivated by cichlids, seeing in them a far greater opportunity to probe essential evolutionary patterns than was afforded by another famous family, Darwin's finches. Until recently, much of the research has relied on traditional taxonomic and observational approaches, tallying up species by studying fish anatomy, as well as by watching fish behavior. Now biologists have added molecular analysis to their research, tracing cichlid lineages and cichlid radiations by studying the fish's DNA.

In the current issue of the journal Trends in Ecology and Evolution, Dr. Axel Meyer, a molecular geneticist at the State University of New York at Stony Brook pulled together much of the recent molecular data on cichlid fish. The DNA work has confirmed previous results from the taxonomists that cichlids are monophyletic, that is, they all originate from a single ancestral fish that arose perhaps 120 million years ago, when India, Africa and Latin America were one giant continent. Since the breakup of the continents, the founder fish that were carried off to different regions of the planet have gone their own ways, speciating wildly in all cases yet by very distinctive genetic mechanisms from one lake or river to another.

In some instances, species of cichlid fish that look and behave radically differently from one another turn out to be almost identical genetically.





More than 500 kinds of cichlids swim in Lake Malawi in Africa. Pseudotropheus zebra, above, and Chilotilapia rhoadesi, a mollusk-eater, are two of these varieties.

Photographs by Dr. Andreas Spreinat

For example, Dr. Meyer compared the DNA of 14 Lake Victoria cichlid species, choosing fish with radically divergent feeding behaviors: a snail eater, a cichlid that feeds on its fellow cichlids, a cichlid that eats only the eyes of other cichlids, another that exclusively sucks young cichlid fry out of the protective mouths of their parents. Yet despite the fishes' specialized appetites, their genes differ from one another by a mere two or three bases, or chemical subunits, out of the many hundreds of bases that constitute the genes examined. "This genetic invariance was a very big surprise to us," said Dr. Meyer. "There's more variation among human populations than I had among my fish." And humans, of course, are all members of the same species.

Bizarre Hunting Strategies

The new work suggests that much of the success of the cichlid family could lie in its unusual degree of molecular flexibility, with minor differences in genes able to yield enormous disparities of comportment. And it is the cichlid's ability to specialize, scientists believe, that helps explain how so many species can live cheek by gill in the same body of water with each still managing to earn a living. If all cichlids were bottom grazers, for example, one species would likely outcompete the others into oblivion. But each cichlid has evolved its own hunting method, and each strategy seems more bizarre than the last. There is a cichlid that resembles a rotting fish and spends a lot of time floating as though dead; but when another fish approaches, thinking it has happened on an easy meal, the corpse springs to life and attacks the would-be scavenger.

A recent paper in the journal Science describes a newly discovered cichlid in Lake Tanganyika that has its head bent permanently to the left, an adaptation that enables its teeth to efficiently scrape a meal of scales off the right side of a passing fish's body. More improbable still, the researchers found a second type of cichlid that has evolved a head curving to the right, the better to shave scales from a prey fish's port side.

"There's always a new amazing story when you study cichlids," said Dr. Meyer. "The standard idea in ecology is that there are various niches waiting to filled, and species arise to fill them. But cichlids seem to create their own niches."

Scientists believe that in a lake like Victoria or Tanganyika, the cichlids that originally founded the flocks were generalists, which then became specialists as competitive pressure increased.

Some scientists have suggested that cichlids have been able to evolve so many eating strategies by the grace of an unusual feature: They have two sets of jaws, one in their mouth, as the average fish does, and a second in their throat. With the throat jaws available to process food, the mouth jaws can be extremely flexible, evolving very specific methods for capturing food. "The idea here is that if you split the function into two jaws, there's less evolutionary constraint," said Dr. Melanie Stiassny, a cichlid expert at the American Museum of Natural History in New York. "In essence what you have here is a throat jaw that's a jack of all trades, and a mouth jaw that's a master of one."

Variations in dining strategies, however, are not always the major distinguishing traits of cichlids. Reporting in the journal Nature last year, Dr. Meyer and Dr. Christian Sturmbauer, a co-worker, looked at the DNA of six cichlid species from Lake Tanganyika and found considerably more genetic variation than they had observed in Lake Victoria cichlids, but in this case the predominant differences between the species were in their colors. And many cichlid biologists now believe that coloration holds another essential key to the fish family's story, for coloration often goes with sexuality and mating preferences, among the more potent driving forces in evolution.

"A Fish Called Wanda"

Cichlids have always been popular fish among home aquarium hobbyists; Wanda in the movie "A Fish Called Wanda" was a South American cichlid. Fish keepers claim cichlids are so bright, they recognize individual humans, but people are especially taken with the fish's courtship and fry-rearing practices. Most fish lay eggs and abandon them, or the father may remain to watch the eggs until they hatch. But among cichlids, both parents often engage in protracted parental care. They brood their eggs in their mouths, and even after the fry are born, they protect the little fish by taking them back into the safety of their mouths when predators approach. "They'll suck the fry back in as though they're sucking in strands of spaghetti," said Dr. Barlow of the University of California at Berkeley.

The habit of mouth brooding has led to a few outstanding features on male cichlids. Because predatory pressure in a cichlid's habitat can be extreme, many females, after laying their eggs, frantically turn around and begin scooping them into their mouths before the eggs have been fertilized. Males have adapted to this by evolving bright spots on their rear fins that strongly resemble eggs. When the female is sucking in her eggs, the male gives his rear fin a shake, she tries to take the dummy eggs into her mouth, and — whoosh! — the male releases a stream of semen into the female's mouth that then fertilizes the eggs.

In some species, both parents also feed their fry with their own flesh, allowing the young fish to nibble at the scales and nutritious mucus cells on the surface of their bodies. "The parent is a big breast is what it amounts to," said Dr. Barlow.

Given the high investment that parents make in their young and in each other, scientists propose, cichlids must have ways of selecting worthy partners. Fish are visually oriented, so it is likely that they pick mates based on cues of color. Dr. Meyer suggests that sexually selected traits like color may undergo far more rapid divergence than would traits that affect an animal's ability to survive, and hence could partly explain the explosive evolution of cichlids.

In experiments with the Midas cichlids, Dr. Barlow and his co-workers are trying to tease out the details of mate preference. They have learned that although only about 8 percent of the species develop a gold coat, both other golds and the dull zebra-stripers prefer a mate of gold when given the choice.

That could be because the golds look more threatening. Cichlids must often fight off outsiders when rearing their brood, and so toughness in a mate is highly valued. Through their detailed matchmaking trials, the scientists have learned that mate choice proceeds in two steps. First, the female finds a male who appeals to her, for reasons that the scientists have yet to glean. But once the female has demonstrated a liking for the male, he will start exerting his own choosiness by behaving extremely aggressively toward her.

"He's testing the female to see if she's aggressive enough," said Dr. Barlow. "She's got to threaten him back in the right way if he's going to accept her." Once the male has determined that the female is tough enough, he will mate with her and treat her gently ever thereafter.

The odds of a male and female cichlid sharing just the right color and chemistry are slim, which is why so many Midas encounters end in fish ennui and a giant fish yawn.