Researchers document rapid, dramatic 'reverse evolution' in the threespine stickleback fish

Evolution is supposed to inch forward over eons, but sometimes, at least in the case of a little fish called the threespine stickleback, the process can go in relative warp-speed reverse, according to a study led by researchers at Fred Hutchinson Cancer Research Center and published online ahead of print in the May 20 issue of *Current Biology* (Cell Press).

“There are not many documented examples of reverse evolution in nature,” said senior author Catherine “Katie” Peichel, Ph.D., “but perhaps that’s just because people haven’t really looked.”

Peichel and colleagues turned their gaze to the sticklebacks that live in Lake Washington, the largest of three major lakes in the Seattle area. Five decades ago, the lake was, quite literally, a cesspool, murky with an overgrowth of blue-green algae that thrived on the 20 million gallons of phosphorus-rich sewage pumped into its waters each day. Thanks to a $140 million cleanup effort in the mid-‘60s – at the time considered the most costly pollution-control effort in the nation – today the lake and its waterfront are a pristine playground for boaters and billionaires.

It’s precisely that cleanup effort that sparked the reverse evolution, Peichel and colleagues surmise. Back when the lake was polluted, the transparency of its water was low, affording a range of vision only about 30 inches deep. The tainted, mucky water provided the sticklebacks with an opaque blanket of security against predators such as cutthroat trout, and so the fish needed little bony armor to keep them from being eaten by the trout.

In 1968, after the cleanup was complete, the lake’s transparency reached a depth of 10 feet. Today, the water’s clarity approaches 25 feet. Lacking the cover of darkness they once enjoyed, over the past 40 years about half of Lake Washington sticklebacks have evolved to become fully armored, with bony plates protecting their bodies from head to tail. For example, in the late ‘60s, only 6 percent of sticklebacks in Lake Washington were completely plated. Today, 49 percent are fully plated and 35 percent are partially plated, with about half of their bodies shielded in bony armor. This rapid, dramatic adaptation is actually an example of evolution in reverse, because the normal evolutionary tendency for freshwater sticklebacks runs toward less armor plating, not more.

“We propose that the most likely cause of this reverse evolution in the sticklebacks is from the higher levels of trout predation after the sudden increase in water transparency,” said Peichel, whose Hutchinson Center lab has established the stickleback as a new model for studying complex genetic traits. By examining multifaceted traits in the fish, such as body type and behavior, Peichel and colleagues shed light on the genetic networks at play in other complex traits, such as cancer and other common human diseases.

The ability of the fish to quickly adapt to environmental changes such as increased predation by the cutthroat trout is due, Peichel believes, to their rich genetic variation. The sticklebacks in Lake Washington contain DNA from both marine (saltwater) fish, which tend to be fully plated, and freshwater sticklebacks, which tend to be low-plated. When environmental pressures called for increased plating, some of the fish had copies of genes that controlled for both low and full plating, and so natural selection favored the latter.

“Having a lot of genetic variation in the population means that if the environment changes, there may be some gene variant that does better in that new environment than in the previous one, and so nature selects for it. Genetic variation increases the chance of overall survival of the species," she said.

The researchers' findings challenge a widely held theory behind rapid evolutionary change, the idea of "phenotypic plasticity" – when an organism can take on different characteristics independent of genetic influences. Body type is one such example. "There is some genetic component to body size, but if you eat more nutritious food as a child you're probably going to grow taller than someone who has the same genes but may not have had as good of a diet growing up," Peichel said. "Our findings challenge the primary role of phenotypic plasticity in rapid evolutionary change."

The gene that controls for plating is called Eda, which comes in two forms: one causes low plating and the other complete plating. Peichel was the first person to home in on the neighborhood where the Eda gene lives while a postdoctoral researcher in the laboratory of David Kingsley, Ph.D., at Stanford University.

In humans, mutations in this gene cause a syndrome called ectodermal dysplasia, a group of more than 100 inherited disorders that impact the ectoderm, the outer layer of tissue involved in the formation of many parts of the body, including the skin, nails, hair, teeth and sweat glands.

"There's probably a developmental correlation between these external structures in humans and the bony plates on the fish," Peichel said. "It also looks like the Eda gene was probably important for human evolution although we don't really know in what context," she said.

Source: Fred Hutchinson Cancer Research Center