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Fish fins can sense touch

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The pictus catfish can feel with its fins. Credit: Adam Hardy, University of Chicago

The human fingertip is a finely tuned sensory machine, and even slight touches convey a great deal of information about our physical environment. It turns out, some fish use their pectoral fins in pretty much the same way. And do so through a surprisingly similar biological mechanism to mammals—humans included.

In a study published in the *Proceedings of the Royal Society B* on Feb. 10, 2016 University of Chicago scientists have shown for the first time that pectoral fins in at least one species of fish possess neurons and cells that are exquisitely sensitive to touch. The discovery not only sheds light on the evolutionary biology of touch, it might also someday inspire new advances in the design of underwater robotics.

"It was a surprise to us that, similar to mammalian skin, fish fins are able to sense light pressure and subtle motion," said study author Adam Hardy, graduate student in the Department of Organismal Biology and Anatomy. "This information seems to be conveyed by a type of cell important for touch in mammals, which suggests that the underlying sensory morphology may be evolutionarily conserved."

Located just behind the gills, pectoral fins are a pair of distinctive appendages that correspond to forelimbs in four-legged animals. Usually involved in propulsion or balance during swimming, pectoral fins have evolved dramatic functions in certain species. They famously allow flying fish to fly and mudskippers to crawl, for example. Numerous studies have explored the biomechanics, evolution and development of these fins, but little is known about what role they play as a sensory mechanism.

So Hardy, with graduate mentor Melina Hale, PhD, William Rainey Harper Professor of Organismal Biology and Anatomy, asked a simple question: can fish feel with their fins?

There is evidence that fish possess the sense of proprioception, or awareness of where their fins are relative to their bodies (much like how we can tell where our arms are even with our eyes closed). Previous studies have identified fin neurons that send signals containing information about bending, movement and position back to the brain. But touch is distinct from proprioception, and as fins are almost always in motion, teasing apart the two senses in an experimental setting is difficult.

Hardy and Hale approached this challenge by focusing on the pictus catfish, a small, bottom-dwelling species native to the muddy waters of the Amazon river. Aside from a hardened, serrated spine used for defense, the pectoral fins of these fish are fairly typical—several bony rays connected by a soft membrane. However, pictus catfish don't appear to use their pectoral fins for locomotion, which the team confirmed through high-speed camera analyses.

Without conflicting signals from fin movement and positioning, the researchers were able to isolate and study neural activity in response to touch. They applied a variety of different stimuli with the flat end of a pin and a brush to the pectoral fin, and measured the activity of neurons that are responsible for sending information back to the brain.

The team discovered that neurons not only responded when contact was made, they carried information about the degree of pressure and the motion of the brush as well. An analysis of the cellular structures of the fin revealed the presence of cells that closely resemble Merkel cells, which are associated with nerve endings in the skin of mammals and are essential for touch.

"Like us, fish are able to feel the environment around them with their fins. Touch sensation may allow fish to live in dim environments, using touch to navigate when vision is limited," Hale said. "It raises a lot of exciting questions on how sensory cells shape the brain's perception of environmental features, and may provide insight into the evolution of sensation in vertebrates."

Intriguingly, this discovery could also have applications for underwater robotic design, especially in low-light environments.

"Understanding how membranous fins in fish are used to sense touch helps us identify what features are important for the design of underwater sensory membranes," Hale said. "For example, you can envision fish-inspired sensory membranes that can be used to scan surfaces in underwater environments where light may be obscured."

"In addition, animals use mechanical feedback to help control their limb movements," she adds. "Instrumenting underwater robots with touch sensors may help to improve their performance, particularly when navigating through complex environments."

The team are now studying touch sensitivity in the fins of other species of fish, such as flounders, as well as investigating the precise mechanisms for how fin neurons encode information about touch.

"One of big questions were trying to answer is whether this applies to all fish," Hardy said. "We predicted that touch sensitive fins would be very useful for bottom-dwelling fish, but you can imagine its utility in nocturnal or deep-sea environments as well."

More information: Adam R. Hardy et al. Touch sensation by pectoral fins of the catfish , *Proceedings of the Royal Society B: Biological Sciences* (2016). DOI: 10.1098/rspb.2015.2652

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