New study in electric fish reveals brain mechanisms for distinguishing self from other

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The electric elephant-nose fish *Gnathonemus petersii* of Africa. Credit: Curtis Bell

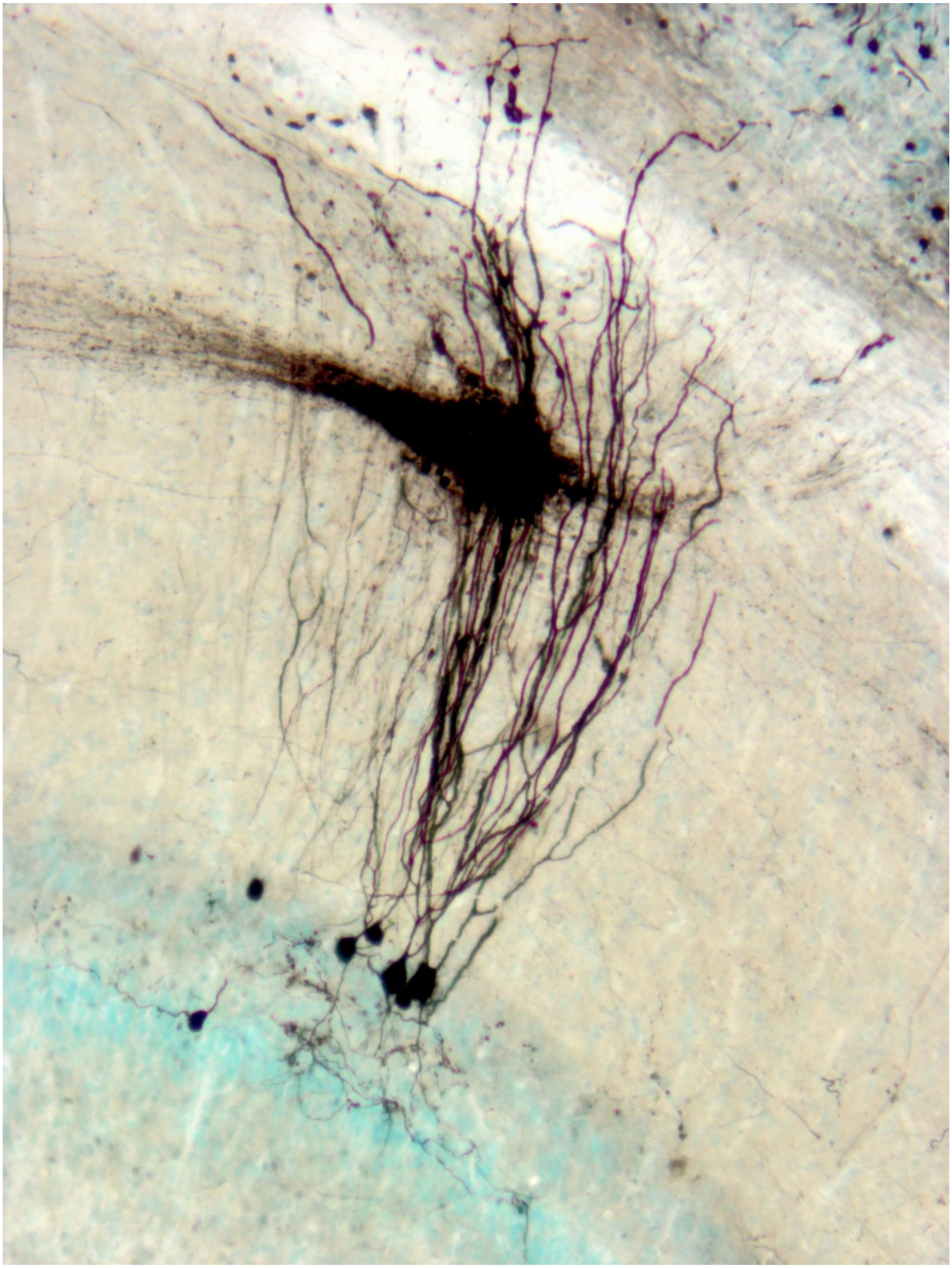
The brain's remarkable ability to perceive the outside world relies almost entirely on its capacity to tune out noise generated by the body's own actions, according to a first-of-its-kind study in electric fish led by scientists at Columbia University.

This noise-cancellation mechanism is so critical, the study found, that without it, the animals lost their ability to sense their surroundings—effectively rendering them blind to the world around them. These findings may help researchers better understand disorders such as tinnitus, the chronic and potentially debilitating ringing of the ears that may be due in part to disruptions in the brain's ability to cancel out self-generated sounds.

This research was published today in *Neuron*.

"At its most fundamental, the brain's purpose is to create an accurate and stable representation of the world around us, and we've long hypothesized that this noise-cancellation mechanism played a part in that," said Nathaniel Sawtell, Ph.D., a principal investigator at Columbia's Mortimer B. Zuckerman Mind Brain Behavior Institute and the paper's senior author. "With today's study, we offer direct evidence that this mechanism is essential to improve and enhance the brain's ability to sense its surroundings."

How the brain correctly perceives and reacts to the vast array of sensory stimuli from the outside world—without blurring them with those created by the body's own actions—has long been a subject of intense study. Previous work by Dr. Sawtell in electric fish and mice revealed how the brain cancels out predictable sensory information, generated by the animals' own bodies, that conveys no useful information.



The elephant-nose fish's neural circuit that encodes the negative images used in navigation and hunting. Credit: Sawtell lab

"The brain is constantly receiving both sensory information along with internal signals related to an animal's own behavior. Those internal signals act as a sort of ID tag, cluing the brain into which components are self-generated and which are not," said Dr. Sawtell, who is also an associate professor of neuroscience at Columbia University Irving Medical Center (CUIMC). "Over time, those internal signals form what is called a 'negative image' in the brain. This acts as a kind of subtraction mechanism, allowing animal to focus on behaviorally important, signals coming in from the outside world."

With today's study, the researchers examined in greater detail how creating this negative image impacts the animal's overall sensory experience. To do so, they focused on the elephant-nose fish, a fish from Africa that both generates electricity to communicate and sense its environment.

"These fish interact with the world by generating electricity, and then use that electricity to locate prey or to communicate with other fish," said Dr. Sawtell. "In the lab, we can study this characteristic as a model for how other animals, including humans, sense their surroundings."

For this study, the researchers recorded electrical activity in a specific class of neurons where negative images are generated. By doing so, the team found that these neurons were only capable of responding to external signals after the negative images had formed.

In a second set of experiments, they interfered with the animals' noise-cancellation mechanism, and monitored the difference in the animals' sensory abilities. The changes were striking.

"The fish could no longer distinguish between electrical signals generated by their environment and the signals generated by their own actions," said Dr. Sawtell. "This means they were essentially blind to their surroundings at the most basic level."

Experts had long suspected that the negative images created by the brain served such a purpose, but directly testing the idea has proven challenging. Electric fish represent an ideal system for making detailed links between the properties of neural circuits and their behavioral function.

"This neural circuit is unusual because so much is known about its physiology and function, but its direct role in behavior had never previously been verified," said the paper's co-author Larry Abbott, Ph.D., also a principal investigator at Columbia's Zuckerman Institute and the William Bloor Professor of Theoretical Neuroscience and Professor of Physiology and Cellular Biophysics (in Biological Sciences) at CUIMC. "This paper describes an elegant series of experiments showing that the computations being performed in this particular neural circuit are essential for the fish's ability to navigate their surroundings."

The scientists will continue efforts to build a model of how our own brains accomplish this same feat. Their work also lends insight into what happens when the system gets disrupted.

"One example of this is tinnitus, which causes a ringing of the ears and which may begin in the dorsal cochlear nucleus—a brain region we study in mice and that has striking similarities to the human equivalent in a brain region called the cerebellum," said Dr. Sawtell. "What we learn in electric fish is likely to be relevant for understanding how the human brain distinguishes self from other."

More information: *Neuron*, Enikolopov, et al.: "Internally generated predictions enhance neural and behavioral detection of sensory stimuli in an electric fish" www.cell.com/neuron/fulltext/S0896-6273(18)30474-4 , DOI: 10.1016/j.neuron.2018.06.006

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