Ctenophores Have a Mind of Their Own

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Transparent marine ctenophores have a neural system so different from all other animals that it likely evolved independently. Find out more...

Biologist Leonid Moroz calls them "aliens of the sea." Ctenophores—or comb jellies—are shimmering, gelatinous blobs that swim through the world's oceans by beating rows of unusually large cilia, feasting on plankton wherever they go. Apart from their alien-like appearance, Moroz has now found something else that sets the phylum apart from the rest of the animals on earth: Their neural systems are missing many of the molecules and pathways scientists traditionally consider integral to classic neurons and brains. And that suggests these small creatures evolved their own unique neural system, independent of other animals.

Building a Brain

One of the fundamental questions in neuroscience, according to Moroz, is whether there is more than one way to build a complete neural system or a brain. Researchers have long assumed that the basic chemical language of the brain is consistent amongst organisms; so lessons they learn about how neurons function in a fly or a mouse or a jellyfish can be directly translated to human biology. But this assumption, Moroz pointed out, is closely tied to hypotheses about the evolutionary origin of neurons and the nervous system: all animals with nervous systems likely evolved from a common ancestor.

Pleurobrachia bachei, one of the ctenophores studied by Moroz's group. Cory Baker / Creative Commons

During the mid-1990s, Moroz was studying how neural transmitters evolved from that hypothesized common ancestor. He looked at the structure and function of transmitters in a variety of marine organisms, including cnidarians and ctenophores, a diverse group of aquatic animals, many of which have simple and primitive neuronal systems, making them prime targets for basic research.

"I started to work on ctenophores not only because they're beautiful but also because they were viewed as a sister group of cnidarians," he said. "To my surprise, I found out that in cnidarians you can see classical neurons and classical transmitters, but in ctenophores there were none."

The molecular markers Moroz had used to pinpoint transmitters in other organisms didn't seem to work in ctenophores. In time, he began to suspect that the ctenophore neural system was driven by a different set of transmitters.

The problem for Moroz was that genomics technology wasn't advanced enough at the moment for him to launch right into sequencing ctenophore genomes. And by the time the technology matured, he struggled to get funding since no one saw the appeal of studying the unusual sea creatures. It would take five grant applications, and more than a decade, before Moroz finally got his money—and a group of students—to start probing the unusual biology of these "aliens of the sea."

Turning to the Sea

With the financing in place, the next hurdle Moroz's group had to overcome was a logistical one: how do you collect these slippery, slimy jellies, and transport them back to the lab? Ctenophores—as well as many of the other marine invertebrates that Moroz is interested in—are fragile. Typically, researchers would dive for the jellies, or accidentally collect them from the surface. But preserving these animals outside their marine habitats is an enormous challenge, Moroz said. Fixing the tissues often doesn't work. Some tissues can be frozen, and shipped back to the lab from far off-Pacific islands, northern Atlantic coasts, or Antarctica , but this process all too-often leads to thawed, destroyed, or lost biological samples.

Moroz realized that if he could conduct experiments—even sequence genes—right there on a boat, he could speed up the process of discovery. So, over the next year, he worked with private organizations and the Florida Biodiversity Institute to put together a floating lab. Assembled inside a shipping container, which could be loaded onto any boat, the lab contained all the equipment—yes, even a DNA sequencing machine—needed to study ctenophores and other organisms in the open ocean.

Leonid Moroz

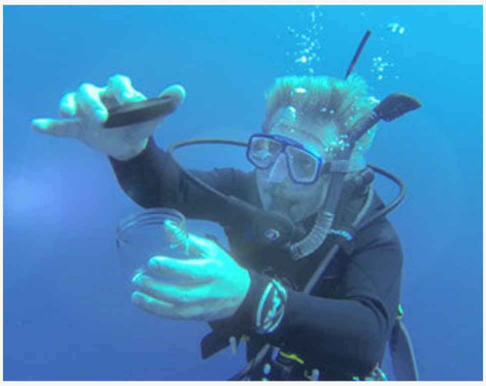
Moroz's group compared a dozen species of the jellies, collected from the coastal areas of Washington, Massachusetts, Florida, and the central Pacific. And he studied the biology of the creatures from as many angles as possible. "I didn't want to just do a standard genome analysis where you all you do is look at genes," said Moroz. "We literally applied all techniques available—proteomics, metabolomics, developmental analysis."

Missing Genes

When they eventually parsed the data, the researchers found that the differences between ctenophores and even the cnidarians—let alone less related species—didn't end with neural transmitters.

"It looks liked ctenophores were the earliest known organisms to branch off from the tree of animals," Moroz said of the data. "Despite superficial similarities, the genomic blueprints were not even similar to cnidarians."

Genes vital to embryonic development and gene patterning—like the HOX gene family—as well as those linked to microRNA and major classes of innate immunity genes in other animals, were missing from the ctenophore genomes. On the other hand, Moroz and his colleagues found genes unique to ctenophores, many of which are expressed in early development. And some genes families found in all eukaryotes seemed to be especially expanded in the comb jellies—they had more RNA-editing and RNA-binding enzymes, for instance.


Collecting jellies

When it came to the original question of the ctenophores neural systems, the differences were clear: apparently ctenophores use a different set of signaling molecules and transmitters to communicate and even build their neural system. "The majority of the part of the chemical language in our brain, these guys don't have," Moroz said.

Ctenophores have a more pared-down system, possibly suggesting that they began from the same neural system as other animals and lost parts throughout their evolution, "I would not call them simpler animals, and I would not call their neural systems simpler," Moroz said. "They have a very big diversity of signaling molecules and neuronal types, but they seem to recruit and use different molecular toolkits to make neural circuits."

Moroz's group found that ctenophores didn't respond to many of the chemical messengers used by other animals' brains; serotonin, acetylcholine, dopamine, noradrenaline, adrenaline, and histamine were lacking, among other molecules. In the end, Moroz's group concluded that L-glutamate is the only shared transmitter candidate between humans and ctenophores. However, he expects that other unique and novel signaling molecules mediate communications between neurons in ctenophores.

Lessons Left to Learn

The findings by Moroz don't just help complete a picture of where ctenophores fall in the evolutionary tree of life—they hold valuable lessons for synthetic biologists trying to design new neural circuits, and could even inform new treatments for brain disorders. After all, one of the unique properties of ctenophores is their amazing ability to regenerate tissues including neurons and even their elementary brains. But to figure out how the jellies do this—and other biological tasks—Moroz is sending his floating laboratory back to the seas.

Reference

Moroz, L.L., Kocot, K.M., Citarella, M.R. et al. (2014) The ctenophore genome and the evolutionary origins of neural systems. Nature 510:109-114.

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