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Who needs a body? Not these larvae, which are basically swimming heads

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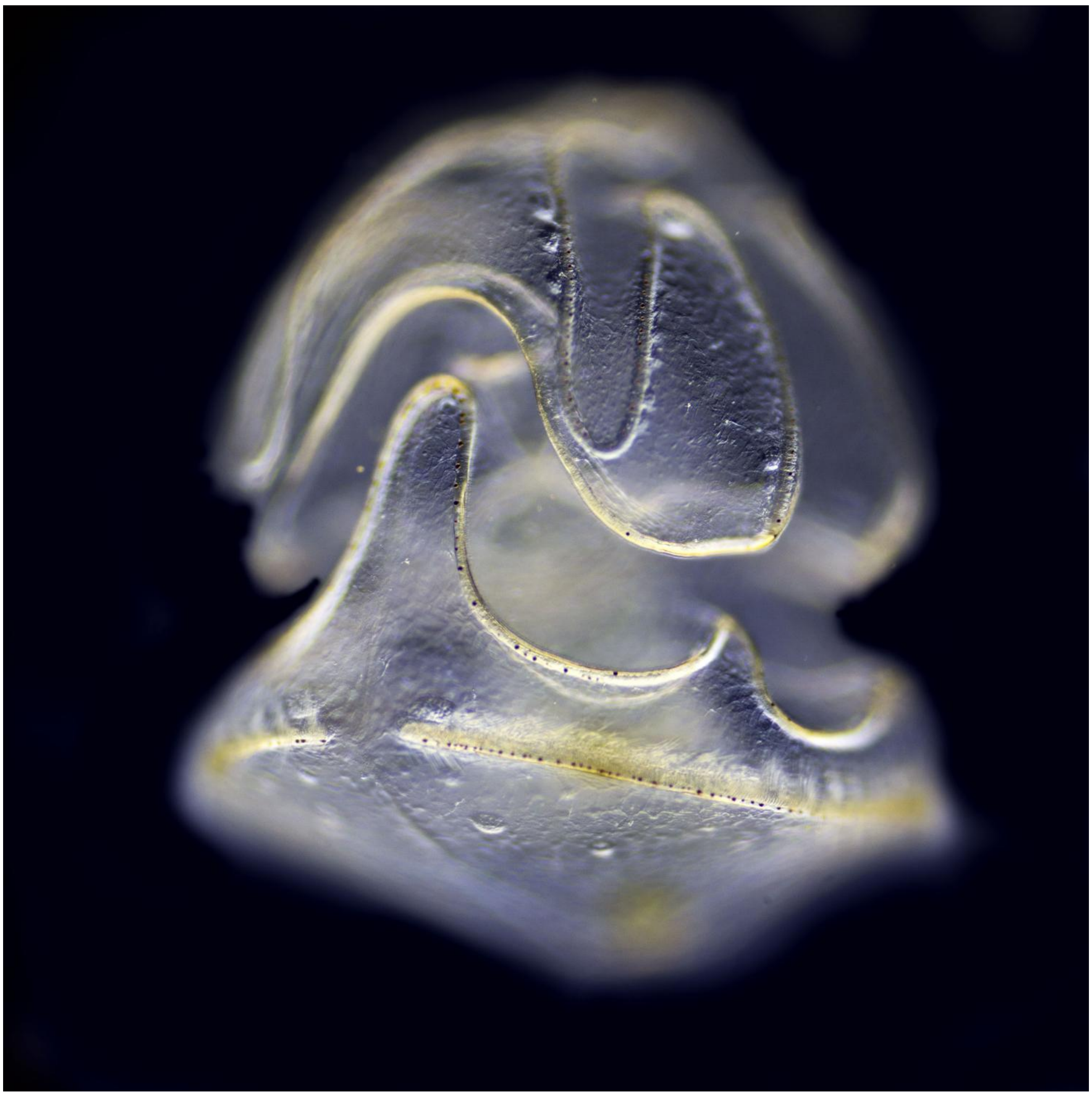

Schizocardium californicum as a larva. In the larval stage, *S. californicum* is little more than a swimming head. Credit: Paul Gonzalez, Hopkins Marine Station

Graduate student Paul Gonzalez at Stanford University's Hopkins Marine Station recently became a hunter, breeder and farmer of a rare marine worm, all to fill in a considerable gap in our understanding of how animals develop. He knew that some animals go through a long larval stage, a developmental strategy known as indirect development, and this rare worm was his chance to better understand that process.

What Gonzalez and his colleagues found was that the worms go through a prolonged phase with little more than head. This work, published in the Dec. 8 issue of *Current Biology*, suggests that many animals in the ocean likely share this trunk-less stage, and it may even shed light on the biological development of early animals.

"Indirect development is the most prevalent developmental strategy of marine invertebrates and life evolved in the ocean," said Chris Lowe, senior author of the paper and associate professor of biology. "This means the earliest animals probably used these kinds of strategies to develop into adults."

Most research animals commonly found in labs, such as mice, zebrafish and the worm *C. elegans*, are direct developers, species that don't go through a distinct larval stage. To understand how indirect developers differ from these, Gonzalez needed to study an indirect developer that was very closely related to a well-studied direct developer.

His best bet was a group of marine invertebrates called Hemichordata because there is already a wealth of molecular developmental work done on direct developers in this group. A flaw in this plan was that the indirect developers in this phylum were uncommon in areas near the station.

Undeterred, Gonzalez poured through marine faunal surveys until a 1994 study gave him his big break: *Schizocardium californicum*, a species of acorn worm and indirect developer in the Hemichordata phylum, was once in Morro Bay, only two hours away.

Through contacting the researchers from that decades-old paper, Gonzalez obtained the exact coordinates of the worms. Once there, he pulled on a wet suit, readied his shovel and began his hunt for the odd-looking ocean-dwellers.

Schizocardium californicum as a larva, juvenile and adult. In the larval stage, *S. californicum* is little more than a swimming head. Credit: Paul Gonzalez and Chris Patton, Hopkins Marine Statio

Diversifying the study of diversity

Direct developers are more often used in research largely for reasons of practicality.

"Terrestrial, direct developing species develop fast, their life cycle is simple and they are easy to rear in the lab," said Gonzalez, who was lead author of the paper.

By comparison, indirect developers develop slowly, have a long larval stage, and their larvae are difficult to feed and maintain in captivity. The reproductive adults are also challenging to keep in the lab and, as Gonzalez has shown, collecting them can be an arduous process. However, the relative ease of studying direct developers has made for a lack of diversity in what scientists know about evolution and development, Gonzalez said.

"By selecting convenient species, we select a non-random sample of animal diversity, running the risk of missing interesting things," he said. "That's what brought me to the Lowe lab. We specialize in asking cool evolutionary questions using developmental biology and molecular genetics, and we're not afraid to start from scratch and work on animals that no one has worked with before."

Swimming heads

After spending months perfecting the rearing and breeding techniques needed to study these worms, the researchers were eventually able to sequence the RNA from various stages of the worm's development. They did this in order to see where specific genes are turned on or off in an embryo.

Paul Gonzalez, graduate student at Stanford University's Hopkins Marine Station, collecting worms in Morro Bay, California. Credit: Paul Gonzalez, Hopkins Marine Station

They found that in the worms, activity of certain genes that would lead to the development of a trunk are delayed. So, during the larval stage, the worms are basically swimming heads.

"When you look at a larva, it's like you're looking at an acorn worm that decided to delay development of its trunk, inflate its body to be balloon-shaped and float around in the plankton to feed on delicious algae," said

Gonzalez. "Delayed trunk development is probably very important to evolve a body shape that is different from that of a worm, and more suitable for life in the water column."

As they continue to grow, the acorn worms eventually undergo a metamorphosis to their adult body plan. At this point, the genes that regulate the development of the trunk activate and the worms begin to develop the long body found in adults, which eventually grows to about 40 cm (15.8 inches) over the span of several years.

Just the beginning

Even with such a fascinating result, this research is only the beginning of the Lowe lab's examination of indirect developers. These worms will never tell us about human diseases, unlike work with stem cells or mice, but they could reveal the intricacies of how life works for many organisms beyond the model species that we've studied so heavily. They may also show us how life in general came to be what it is today.

"Given how pervasive larvae are in the animal world, we understand very little about this critical phase in animal development," said Lowe. "These are not the kind of species you want to pick if you want deep, mechanistic insights into developmental biology. But, if your goal is to understand how animals have evolved, then you cannot avoid using these species."

Next, the researchers want to figure out how the acorn worm body development delay happens. They also have begun to sequence the genome of S. californicum.

Kevin R. Uhlinger, lab manager in the Lowe lab at Hopkins Marine Station, is also a co-author of this paper. Chris Lowe is also a member of Stanford Bio-X and the Stanford Neurosciences Institute.

More information: *Current Biology*, www.cell.com/current-biology/f … 0960-9822(16)31273-8

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