How the insect got its wings: Scientists (at last!) tell the tale

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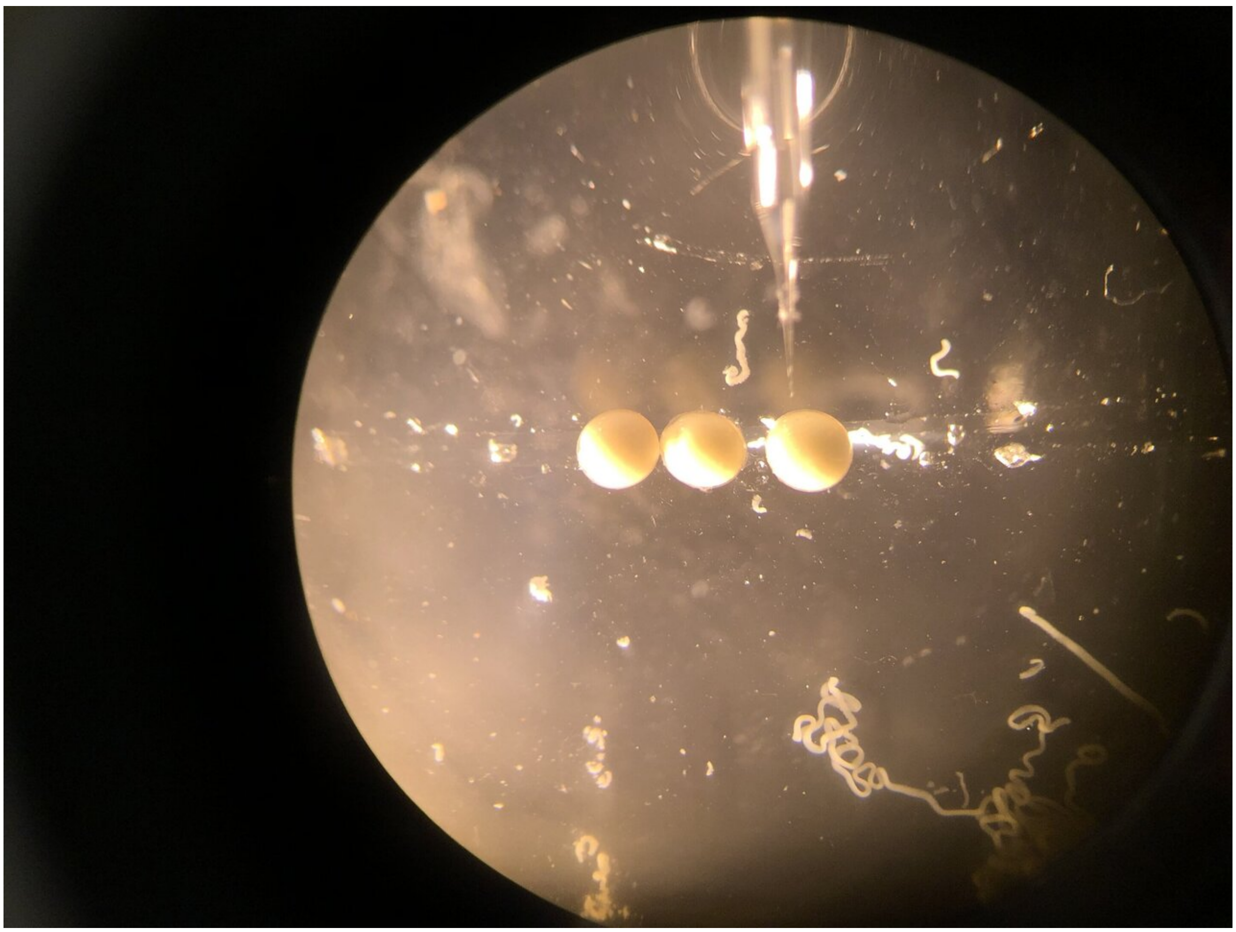


Injection of CRISPR solution into crustacean embryos (Parhyale hawaiiensis). Credit: Heather Bruce

It sounds like a "Just So Story"—"How the Insect Got its Wings"—but it's really a mystery that has puzzled biologists for over a century. Intriguing and competing theories of insect wing evolution have emerged in recent years, but none were entirely satisfactory. Finally, a team from the Marine Biological Laboratory (MBL), Woods Hole, has settled the controversy, using clues from long-ago scientific papers as well as state-of-the-art genomic approaches. The study, conducted by MBL Research Associate Heather Bruce and MBL Director Nipam Patel, is published this week in *Nature Ecology & Evolution*.

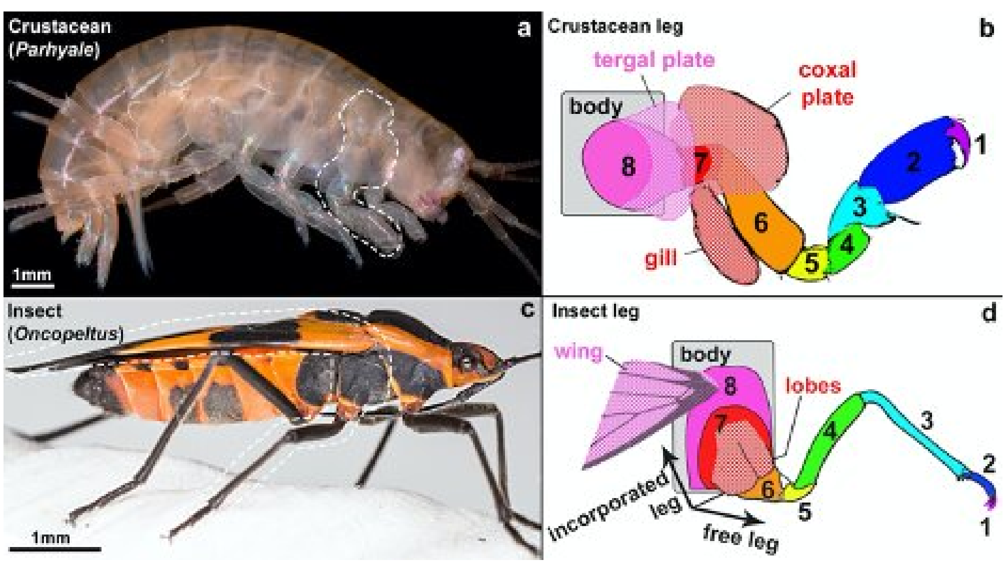
Insect wings, the team confirmed, evolved from an outgrowth or "lobe" on the legs of an ancestral crustacean (yes, crustacean). After this marine animal had transitioned to land-dwelling about 300 million years ago, the leg segments closest to its body became incorporated into the body wall during embryonic development, perhaps to better support its weight on land. "The leg lobes then moved up onto the insect's back, and those later formed the wings," says Bruce.

One of the reasons it took a century to figure this out, Bruce says, is that it wasn't appreciated until about 2010 that insects are most closely related to crustaceans within the arthropod phylum, as revealed by genetic similarities.

"Prior to that, based on morphology, everyone had classified insects in the myriapod group, along with the millipedes and centipedes," Bruce says. "And if you look in myriapods for where insect wings came from, you won't find anything," she says. "So insect wings came to be thought of as 'novel' structures that sprang up in insects and had no corresponding structure in the ancestor—because researchers were looking in the wrong place for the insect ancestor."

"People get very excited by the idea that something like insect wings may have been a novel innovation of evolution," Patel says. "But one of the stories that is emerging from genomic comparisons is that nothing is brand new; everything came from somewhere. And you can, in fact, figure out from where."

Bruce picked up the scent of her now-reported discovery while comparing the genetic instructions for the segmented legs of a crustacean, the tiny beach-hopper *Parhyale*, and the segmented legs of insects, including the fruit fly *Drosophila* and the beetle *Tribolium*. Using CRISPR-Cas9 gene editing, she systematically disabled five shared leg-patterning genes in *Parhyale* and in insects, and found those genes corresponded to the six leg segments that are farthest from the body wall. *Parhyale*, though, has an additional, seventh leg segment next to its body wall. Where did that segment go, she wondered? "And so I started digging in the literature, and I found this really old idea that had been proposed in 1893, that insects had incorporated their proximal [closest to body] leg region into the body wall," she says.



Insects incorporated two ancestral crustacean leg segments (labeled 7 in red and 8 in pink) into the body wall. The lobe on leg segment 8 later formed the wing in insects, while this corresponding structure in crustaceans forms the tergal plate. Credit: Heather Bruce

"But I still didn't have the wing part of the story," she says. "So I kept reading and reading, and I came across this 1980s theory that not only did insects incorporate their proximal leg region into the body wall, but the little lobes on the leg later moved up onto the back and formed the wings. I thought, wow, my genomic and embryonic data supports these old theories."

It would have been impossible to resolve this longstanding riddle without the tools now available to probe the genomes of a myriad of organisms, including *Parhyale*, which the Patel lab has developed as the most genetically tractable research organism among the crustaceans.

More information: *Nature Ecology & Evolution* (2020). DOI: 10.1038/s41559-020-01349-0

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