Insects took off when they evolved wings

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When insects such as this Meganeura monyi, which had a wingspan of about 27 inches, developed wings roughly 325 million years ago, the insect population exploded, Stanford researchers found. Credit: Alexandre Albore, Wikimedia Commons

The evolution of wings not only allowed ancient insects to become the first creatures on Earth to take to the skies, but also propelled their rise to become one of nature's great success stories, according to a new study.

Comprising up to 10 million living species, insects today can be found on all seven continents and inhabit every terrestrial niche imaginable.

But according to the fossil record, they were scarce before about 325 million years ago, outnumbered by their arthropod cousins the arachnids (spiders, scorpions and mites) and myriapods (centipedes and millipedes).

The oldest confirmed insect fossil is that of a wingless, silverfish-like creature that lived about 385 million years ago. It's not until about 60 million years later, during a period of the Earth's history known as the Pennsylvanian, that insect fossils become abundant.

"There's been quite a bit of mystery around how insects first arose, because for many millions of years you had nothing, and then just all of a sudden an explosion of insects," said study first author Sandra Schachat, a graduate student at Stanford's School of Earth, Energy & Environmental Sciences (Stanford Earth).

Many ideas have been proposed to explain this curious lacuna in the insect fossil record, which scientists have dubbed the Hexapod Gap.

According to one popular hypothesis, insect size and abundance were limited by the amount of oxygen available in Earth's atmosphere during the late Devonian period.

The strongest evidence for this theory is a model of atmospheric oxygen during the past 570 million years that the late Yale geologist Robert Berner developed by comparing ratios of oxygen and carbon in ancient rocks and fossils.

According to Berner's model, the atmospheric oxygen level about 385 million years ago during the start of the Hexapod Gap was below 15 percent, so low that wildfires would have been unsustainable. (For comparison, today's atmospheric oxygen concentration is about 21 percent.)

Another possibility is that insects were abundant before 323 million years ago, but don't show up in the fossil record because the kinds of terrestrial sediments capable of preserving them didn't survive.

No excuses

In the new study, published this week in the journal Royal Society Proceedings B, Schachat and her colleagues tested both of these arguments - that low oxygen limited insects or that the rocks weren't right to preserve fossils. First, the team updated Berner's nearly decade-old model using updated carbon records.

When they did this, the dip in atmospheric oxygen during the late Devonian disappears. "What this study shows is that environmental inhibition by low oxygen can be ruled out because it is not compatible with the most current data," said study coauthor and Stanford Earth paleontologist Jonathan Payne.

To test the "bad rocks" hypothesis, the team analyzed a public database of North American rock types for different periods in the Earth's history and found nothing unusual about the sediments of the late Devonian. "The rocks could have contained insect fossils. The fact that they don't indicates the dearth of insects during this period is real and not just an artifact of bad luck with preservation," said Schachat, who is also a fellow at the Smithsonian Institution in Washington, DC.

A transformative effect

Not only do the two most popular explanations for the Hexapod Gap appear to be unsubstantiated, the scientists said a study of the insect fossil record suggests that the Hexapod Gap itself might be an illusion.

As part of the new study, the team reexamined the ancient insect fossil record and found no direct evidence for wings before or during the Hexapod Gap. But as soon as wings appear 325 million years ago, insect fossils become far more abundant and diverse.

"The fossil record looks just how you would expect if insects were rare until they evolved wings, at which point they very rapidly increased in diversity and abundance," Payne said.

Schachat said it's notable that the first two winged insects in the fossil record are a dragonfly-like insect and a grasshopper-like insect. These represent the two main groups of winged insects: dragonflies have "old wings," which they cannot fold down onto their abdomens, and grasshoppers have "new wings," which are foldable.

"The first two winged insects in the fossil record are about as different from each other as you could possibly expect," Schachat said. "This suggests that, once winged insects originated, they diversified very, very quickly. So quickly that their diversification appears, from a geological perspective and the evidence available in the fossil record, to have been instantaneous."

New niches

Being the first and only animals able to fly would have been extremely powerful. Flight allowed insects to explore new ecological niches and provided new means of escape. "All of a sudden, your abundance can increase because you can just get away from your predators so much more easily," Schachat said. "You can also eat the leaves that are at the top of a tree without having to walk up the entire tree."

Flying insects could also create niches that didn't exist before. "Imagine an omnivorous insect that flies to the top of trees to feed," Schachat said.

"Suddenly, there's a niche for a predator that can fly to the top of the tree to eat that insect. Wings allowed insects to expand the suite of niches that can be filled. It really was revolutionary."

While the new study links the evolution of flight to the ascension of insects, it raises new questions about how and why they evolved wings in the first place, said study coauthor Kevin Boyce, an associate professor of geological sciences at Stanford Earth. "In the Devonian, there were only a few insects, all wingless," Boyce said. "But you come out the other side and we have flight. What happened in between? Good question."

More information: Phanerozoic pO2 and the early evolution of terrestrial animals, *Proceedings of the Royal Society B*, rspb.royalsocietypublishing.or … .1098/rspb.2017.2631

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