Giant Insects Might Reign If Only There Was More Oxygen in the Air

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The delicate lady bug in your garden could be frighteningly large if only there was a greater concentration of oxygen in the air, a new study concludes. The study adds support to the theory that some insects were much larger during the late Paleozoic period because they had a much richer oxygen supply, said the study's lead author Alexander Kaiser.

The study, "No giants today: tracheal oxygen supply to the legs limits beetle size," was presented at Comparative Physiology 2006: Integrating Diversity.

The Paleozoic period, about 300 million years ago, was a time of huge and abundant plant life and rather large insects -- dragonflies had two-and-a-half-foot wing spans, for example. The air's oxygen content was 35% during this period, compared to the 21% we breathe now, Kaiser said. Researchers have speculated that the higher oxygen concentration allowed insects to grow much bigger.

Tubes carry oxygen

First, a bit of background: Insects don't breathe like we do and don't use blood to transport oxygen. They take in oxygen and expel carbon dioxide through holes in their bodies called spiracles. These holes connect to branching and interconnecting tubes, called tracheae, Kaiser explained.

Whereas humans have one trachea, insects have a whole tracheal system that transports oxygen to all areas of their bodies and removes carbon dioxide. As the insect grows, tracheal tubes get longer to reach central tissue, and get wider or more numerous to meet the additional oxygen demands of a larger body.

Insects can limit oxygen flow by closing their spiracles. In fact, one reason insects are so hardy is that they can close their spiracles and live off the oxygen they already have in their tracheae. Kaiser recalled a caterpillar that fell into a bucket of water in his lab. When the creature was discovered the next day, lab workers thought it had drowned. But when they removed its apparently lifeless little body from the water, they were surprised to see it crawl away.

Tracheae grow disproportionately

This experiment was designed to find out:

• how much room the tracheal system takes up in the bodies of different-sized beetles
• whether tracheal dimensions increase proportionately as the beetles get larger
• whether there is a limit to the size a beetle could grow in the current atmosphere

The researchers used x-ray images to compare the tracheal dimensions of four species of beetles, ranging in size from 3mm (Tribolium castaneum, about one-tenth of an inch) to about 3.5 cm (Eleodes obscura, about 1.5 inches). Beetles were not in existence during the Paleozoic period, but Kaiser's team used the insect because they are much easier to maintain in the laboratory than dragonflies, which are quite difficult.

The study found that the tracheae of the larger beetles take up a greater proportion of their bodies, about 20% more, than the increase in their body size would predict, Kaiser said. This is because the tracheal system is not only becoming longer to reach longer limbs, but the tubes increase in diameter or number to take in more air to handle the additional oxygen demands.

The disproportionate increase in tracheal size reaches a critical point at the opening where the leg and body meet, the researchers found. This opening can get only so big, and limits the size of the trachea that runs through it. When tracheal size is limited, so is oxygen supply and so is growth, Kaiser explained.

Using the disproportional increases they observed among the beetles, the researchers calculated that beetles could not grow larger than about 15 centimeters. And this is the size of the largest beetle known: the Titanic longhorn beetle, Titanus giganteus, from South America, which grows 15-17 cm, Kaiser said.

And why wouldn't the opening between the body and the leg limit insect size in the Paleozoic era, too? After all, dragonflies and some other insects back then had the same body architecture, but they were much bigger.

It is because when the oxygen concentration in the atmosphere is high, the insect needs smaller quantities of air to meet its oxygen demands. The tracheal diameter can be narrower and still deliver enough oxygen for a much larger insect, Kaiser concluded.

The research was carried out by Alexander Kaiser and Michael C. Quinlan of Midwestern University, Glendale, Arizona; J. Jake Socha and Wah-Keat Lee, Argonne National Laboratory, Argonne, IL; and Jaco Klok and Jon F. Harrison, Arizona State University, Tempe, AZ. Harrison is the principal investigator.

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