Low oxygen triggers moth molt

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A new explanation for one of nature's most mysterious processes, the transformation of caterpillars into moths or butterflies, might best be described as breathless.

The research shows that a baby moth's respiratory system is fixed in size at each stage of development, which limits its oxygen intake. Sensing it is low on oxygen apparently signals to the insect that it cannot continue to grow without proceeding to the next stage of its development, by molting.

Caterpillars molt four to five times before morphing into an adult as a moth or butterfly. Duke University biologist Fred Nijhout knew from earlier work that tobacco hornworm caterpillars, or *Manduca sexta*, only start a molt when they reach a critical weight -- exactly 4.8 times more than their weight immediately after they last shed their exoskeleton.

Still, he and other scientists didn't understand how the caterpillars sensed they had reached that specific size.

In the new study, Nijhout and his graduate student, Viviane Callier, measured the size of the caterpillar's respiratory system. They found that the insect's tracheal tubing is fixed in size at each stage of its larval life. Other parts of the caterpillar's body can grow, but not the respiratory tubing. As a result, the insect eventually begins to suffocate. The only way it can continue to mature is to shed the old tubing for newer, longer ones.

This is the first time scientists have figured out a factor – in this case, lack of oxygen -- that regulates an animal's body size during specific developmental stages, said Nijhout, who led the study. The research appears online Aug. 22 in the *Proceedings of the National Academy of Sciences*.

"This is a neat paper," said Arizona State University biologist, Jon Harrison, who was not involved in the research. It shows how oxygen is one important factor in controlling the size, growth and overall development of insects, he said.

Body size is a fundamental trait for all organisms and affects everything from how they move to the mates they choose. In humans, size, measured as height, is also associated with risks for disease, Callier said.

In the new study, she and Nijhout tested oxygen's effects on the caterpillars' body size by placing the larvae into airtight glove boxes and pumping in air with different amounts of oxygen. Under hypoxic conditions, the caterpillars molted at body sizes well below the critical weight. And, despite the caterpillars doubling in body size during the growth phase, they did not increase the size of the tracheal tubes, according to the results.

Harrison said that together, these observations suggest that insects molt to the next juvenile or adult stage partly to ensure that their oxygen delivery capacity can match the oxygen needs of the tissue.

The new study also tested whether the caterpillars could molt after being decapitated. Even without mouths to eat and brains to release the molt-triggering hormone, ecdysone, the insects still shed their exoskeleton and tracheal tubing.

Nijhout said the tobacco hornworms likely secrete the molt-initiating

hormone in their brain and also in their abdomen, which explains why the insects molted even when they lost their heads. Secretions from only the abdomen, however, take longer to build up and trigger a molt, explaining the delay, he said.

Because the research is specific to caterpillars, it cannot explain why humans grow to a specific size. But, Nijhout said, caterpillars' abdomen-based, low-oxygen sensor may be related to the system that produces insulin-like growth hormones in humans, and studying it further could provide information about a broader biological process that affects how diverse organisms travel their paths to adulthood.

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