Can moths or butterflies remember what they learned as caterpillars?

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Butterflies and moths are well known for their striking metamorphosis from crawling caterpillars to winged adults. In light of this radical change, not just in body form, but also in lifestyle, diet and dependence on particular sensory cues, it would seem unlikely that learned associations or memories formed at the larval or caterpillar stage could be accessible to the adult moth or butterfly. However, scientists at Georgetown University recently discovered that a moth can indeed remember what it learned as a caterpillar. Their findings are published in the March 5, 2008 edition of the journal *PLoS ONE.*

The Georgetown researchers found that tobacco hornworm caterpillars could be trained to avoid particular odors delivered in association with a mild shock. When adult moths emerged from the pupae of trained caterpillars, they also avoided the odors, showing that they retained their larval memory. The Georgetown University study is the first to demonstrate conclusively that associative memory can survive metamorphosis in Lepidoptera—the order of insects that includes moths and butterflies—and provokes new questions about the organization and persistence of the central nervous system during metamorphosis.

“The intriguing idea that a caterpillar’s experiences can persist in the adult butterfly or moth captures the imagination, as it challenges a broadly-held view of metamorphosis -- that the larva essentially turns to soup and its components are entirely rebuilt as a butterfly,” says senior author Martha Weiss, an associate professor of Biology at Georgetown University.

"Scientists have been interested in whether memory can survive metamorphosis for over a hundred years," says first author Doug Blackiston, who completed the interdisciplinary research while earning a PhD in Biology from Georgetown University in the labs of developmental biologist Elena Casey and behavioral ecologist Martha Weiss. The brain and nervous system of caterpillars is dramatically reorganized during the pupal stage and it has not been clear whether memory could survive such drastic changes.

The findings of the Georgetown researchers suggest the retention of memory is dependent on the maturity of the developing caterpillars' brains. Caterpillars younger than three weeks of age learned to avoid an odor, but could not recall the information as adults, whereas older caterpillars, conditioned in the final larval stage before pupation, learned to avoid the odor and recalled the information as adults. In addition, the results have both ecological and evolutionary implications, as retention of memory through metamorphosis could allow a female butterfly or other insect to lay her eggs on the type of host plant that she herself had fed on as a larva, a behavior that could shape habitat selection and eventually lead to development of a new species.

While most research on learning and memory in insects has centered on social insects, such as honeybees or ants, Weiss' lab is particularly interested in solitary insects, such as butterflies, praying mantids, and mud-dauber wasps. Weiss and her colleagues will continue to study how these self-sufficient, multitasking insects use learning and memory skills to adapt to their environments.

This study was farther afield from the neural cell specification research that is ongoing in Casey's lab. Casey, associate professor of Biology at Georgetown, focuses on identifying the signals that are required to direct a cell to develop into a neuron and determining how the complex human central nervous system evolved.

Blackiston, now conducting postdoctoral work at the Forsyth Center for Regenerative and Developmental Biology and the Department of Developmental Biology at the Harvard School of Dental Medicine, is currently examining learning and memory in aquatic vertebrates.

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