Microsurgery and Super Glue show how antennae aid moth navigation

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Two-winged insects such as houseflies and mosquitoes that are active during the light of day rely on their vision for flight control, but they also get help from organs called halteres, which grow where a second set of wings might otherwise be found and aid in navigation.

Scientists have wondered how four-winged insects most active at low-light times of the day, such as moths, accomplish complex navigational maneuvers, since they lack halteres. A research team studying hawk moths, the species Manduca sexta, has found an answer, with the unlikely help of microsurgery and Super Glue.

A tiny structure called the Johnston's organ, just above the moth's head at the base of the antenna, contains mechanosensors that allow the organ to function like a gyroscope, sensing a tug on the antenna and sending signals to the brain if the insect gets turned around by, for instance, a gust of wind, said Sanjay Sane, a University of Washington postdoctoral researcher in biology. He is the lead author of a paper describing the research in the Feb. 9 edition of *Science*.

"Whenever a creature is moving about, it has to have sensory information to tell it what it has done," Sane said. "If a person unintentionally turns around, the inner ear system or eyes will provide that information and allow for a course correction. Flying creatures need to know that information too, and when the light is low and the visual cues are hard to see they have to depend more on the mechanosensory system."

Hawk moths are among crepuscular insects, which are most active during low-light times of the day, at twilight or just before dawn. Like other insects, their antennae allow them to smell. But the researchers suspected the antennae also provided moths with the means to stay on the proper heading while in flight.

To test the theory, Sane removed the long part of the antennae, called flagella, just above the Johnston's organ, then observed as the insects tried to fly inside a dimly lit glass chamber. The antenna-less moths flew backwards, collided with walls or crashed to the floor much more often than those with antennae. He then used Super Glue to reattach the flagella and observed as the insects' normal flight abilities were restored. He removed the flagella again and flight was impaired once more.

"This showed it was the mechanical stimulus, and nothing else, that caused the effect," he said.

Sane found that hawk moths hold their antennae at relatively fixed positions to guide them while in flight. If a moth's body begins to turn in relationship to the antennae, stretch receptors, specialized neurons in the Johnston's organ, sense the movement and send signals to the brain so the insect can move its body back to the correct heading.

The researchers measured neural responses within the receptors to determine the frequency at which the signals were sent. The receptors receive information from a variety of stimuli, something like a radio having access to the entire FM band, but the Johnston's organ sends signals to the brain on a narrower frequency, concentrated at roughly twice the speed of the insect's wing beats. The brain pays particular attention to those signals, the scientists found, like tuning a radio to a specific FM station.

"There is constant movement, but the receptors can't report everything.

They filter information, like our eyes filter information. These insects seem to care more about information that comes in the double-wing beat frequency," Sane said. "It's very fine tuned."

The research helps scientists understand locomotion and "how the brain carries out the complex business of moving around," he said. It allows the researchers to understand neural properties employing methods typically used to analyze electronic circuits, and the work also could be adapted in the development of robotic insects to test the understanding of flight itself.

The work raises questions about how the mechanosensory system functions in long-distance moth migration, he said, and could shed light on how the many forms of insect antennae found in nature actually work. It also sets the stage for his next round of experiments testing whether moths flying in bright light need less navigational help from their antennae.

Source: University of Washington

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