

Neurobiologists Discover Butterfly Chronometer

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Each fall, hundreds of millions of newly hatched monarch butterflies flit from the fields and forests in eastern regions of Canada and the United States to the alpine fir forests of central Mexico, converging on the same spot to wait out the winter. Scientists don't know exactly how these insects find their way, but a new study shows that, to navigate, the butterflies rely on biological clocks. Oddly enough, the clocks are located in their antennae, not in their brains as previously thought.

Migrating monarchs rely on the sun to maintain a constant heading. Because the sun drifts from east to west as the day wears on, the butterflies need a timekeeping device to help them compensate for its movement. Monarchs have a biological clock in their brains that relies on light cues to regulate their sleep-wake cycles and monitor day length. Scientists assumed they also used this clock to navigate. But the new study shows that the antennae possess a separate clock that controls time compensation. "That was a huge surprise," says Steven Reppert, a neurobiologist at the University of Massachusetts Medical School in Worcester and co-author of the new study.

Reppert and his colleagues began studying antennae because they thought the appendages might assist migration in other ways--by allowing the butterflies to pick up certain scents, for example. They soon saw something surprising. When they clipped the antennae off about 30 migrating monarchs and put them in a flight simulator, which can track the direction they try to fly, the butterflies were disoriented. Whereas butterflies with antenna flew south to southeast, those with clipped antennae flew in random directions, although each individual hewed to its heading fairly consistently.

At first, the researchers thought that the lack of antennae was throwing off the timekeeping ability of the butterflies' brain clocks. But when they looked at the expression of the clock genes in the brains of monarchs without antennae, everything appeared normal, suggesting that a separate clock existed in the antennae. So the researchers returned to the flight simulator. This time, rather than removing the antennae, they coated the antennae on some butterflies with opaque black paint and those of others with a clear enamel. If a sunlight-driven clock were in the antennae, the researchers hypothesized, only the monarchs with black paint would lose their ability to fly south.

Biological clocks can keep time without cues from the sun, but like faulty pocket watches, they tend to drift out of synch over time. Because these insects had only their antenna painted black for a couple of weeks, the researchers didn't expect to see complete disorientation but rather incorrect orientation. "And that's exactly what happened," Reppert says. Monarchs with normal antennae and those with clear paint flew toward the south or southeast, the researchers [report](#) today in *Science*. Monarchs with black antennae, however, flew north to northwest.

It's a "nifty" result, says Orley Taylor, an insect ecologist at the University of Kansas, Lawrence. Still, many questions remain with respect to monarch migration. For example, how do the butterflies know which direction to go in the first place? Earth's magnetic fields may play a role, Taylor says. In fact, one of the light-sensing proteins Reppert's team found in the antennae clock acts as a magnetic field sensor in fruit flies. "The deeper they dig," Taylor says, "the more they find out about how complicated this system is."