Monarch butterflies use magnetic compasses

Built-in magnetic compasses may orient monarch butterflies during their mind-boggling, southwestern migration, according to new experiments in Kansas.

The butterflies flutter up to 2,500 miles in autumn from breeding grounds in the eastern United States and Canada to a winter haven in Mexico. These millions of migrants are going to a destination not one of them has ever seen.

The generation taking to the air in the fall represents the great-great grandchildren, or even more distant descendants, of the monarchs that left Mexico the previous spring. Yet the new generation returns to the same dozen or so roosting areas that their ancestors used.

Previous studies showed that monarchs can orient by the sun. The new work provides the first direct evidence that monarchs can also sense directions from the magnetic field, according to Orley R. Taylor of the University of Kansas in Lawrence. He, Jason A. Etheredge of Kansas, and their colleagues describe the results in the Nov. 23 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

"This is not the last word," Taylor says. "What the butterflies are doing is very complicated."

The researchers caught migrating monarchs in fall and released them into a tube, in which they crawled upward to a circular tabletop arena. In a room with no shielding from Earth's magnetic field, most of the butterflies took flight toward the southwest. In a shielded room, however, they flew in random directions.

Next, researchers created a magnetic field oriented in the opposite direction from Earth's. Butterflies then flew northeast, as if their compasses had reversed.

The team studied fall migrants because the same generation flying north in spring gets hard to handle, Taylor says. "They're completing a reproductive death run, like salmon," as he puts it. Females lay eggs daily even though their route covers 1,000 miles. By the end, "they have practically no wings left; they're crawling from plant to plant to lay eggs—it's awesome," Taylor says.

Charles Walcott of Cornell University calls the monarch paper "terrific" and notes that other researchers have been stumped by the challenge of devising a way to test butterflies for magnetic orientation.

For animal compasses, "we used to think there was a single secret," he says, sounding wistful. Studies now show that animals combine methods using "a Chinese-menu approach," Walcott explains. Night-migrating birds, for example, can orient by the sunset glow and star patterns as well as by the magnetic field.

Monarchs can check magnetic fields as a backup to their sun compass.

Kenneth P. Able of the State University of New York at Albany says he suspects that magnetic orientation "is a very widespread ability." Honeybees, some wasps, some fish, sea turtles, and even a species of mole rat can take bearings magnetically. Also, "it looks like every migratory bird you test, if you do it right, has a magnetic compass," Able says. However, he points out, discovering a compass takes the scientists just a small step toward explaining how monarchs navigate.

"I'm not sure anybody is ever going to answer that," says Karen S. Oberhauser, who studies monarchs at the University of Minnesota. "Insects sense the world in very different ways from humans. They use things we can't perceive, maybe even things we can't *con*ceive." —*S. Milius*

Genes reveal recent origin for the plague

One bacterium, carried by fleas, is the plague-causing microbe behind the Black Death, which slew 25 million people in the Middle Ages. Another, shed in rodent feces that can contaminate food, simply triggers a week or two of fever, vomiting, and diarrhea in people.

A new genetic analysis confirms that despite their dramatic differences, these two microbes share a remarkably close ancestry, like parent and child. *Yersinia pestis*, which causes bubonic plague, is a relatively recent offshoot, perhaps only 1,500 to 20,500 years old, of the less dangerous *Yersinia pseudotuberculosis*, Mark Achtman of the Max Planck Institute for Molecular Genetics in Berlin and his colleagues report in the Nov. 23 PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES.

Historians have documented three worldwide epidemics of the plague. The first started during the reign of the Byzantine emperor Justinian, around A.D. 542. The second, the Black Death, swept from Asia into Europe during the 14th century. The third broke out in China just before the turn of this century.

Some scholars have argued that *Y. pestis* has existed for millions of years and only betrayed its presence when human populations grew dense enough to sustain epidemics. However, there's little scientific data that establishes an age for the microbe, notes Achtman. To address that issue, he joined forces with Elisabeth Carniel of the Pasteur Institute in Paris. She and her colleagues maintain and study a collection of *Y. pestis* strains from around the world.

The researchers compared the DNA sequences of six fundamental genes among 36 strains. "There was no diversity. All the sequences were identical. That's a highly unusual finding and difficult to explain, unless you say that there simply hasn't been time for [mutations] to accumulate," says Achtman.

If *Y. pestis* experiences mutations at the same rate as the well-studied bacterium *Escherichia coli*, then it arose sometime within the past 20,500 years, the researchers calculate. If it was any older, it should show some diversity in the genes examined, they say.

"This age estimate will be controversial," admits Achtman, noting that scientists disagree on whether they can use the mutation rate of one bacterium to gauge the age of another.

The scientists also compared the *Y. pestis* genes with those from *Y. pseudotuberculosis*. They found so few differences in the DNA that the investigators argue that the microbes aren't distinct species. Two decades ago, less detailed DNA comparisons between the two bacteria also led scientists to suggest eliminating the *Y. pestis* designation, but tradition prevailed. "There's no justification, except for its medical significance, for the term *Yersinia pestis*," says Achtman.

"For a long time, it's been assumed that the bacterium that causes plague and *Y. pseudotuberculosis* were closely related, but no one has done a molecular analysis like Achtman and his colleagues did," says Tom G. Schwan of the National Institute of Allergy and Infectious Disease in Rocky Mountain, Colo.

Understanding its divergence from *Y. pseudotuberculosis* may help scientists explain how *Y. pestis* evolved into such a dangerous microbe. Investigators have nearly finished sequencing the plague bacterium's genes. They suspect that the largest difference between the two microbes stems from the two extra plasmids, or rings of DNA, that only *Y. pestis* possesses.

"We're in a perfect position to make some significant advances now that the genome of *Y. pestis* is being completed," says Schwan. —*J. Travis*