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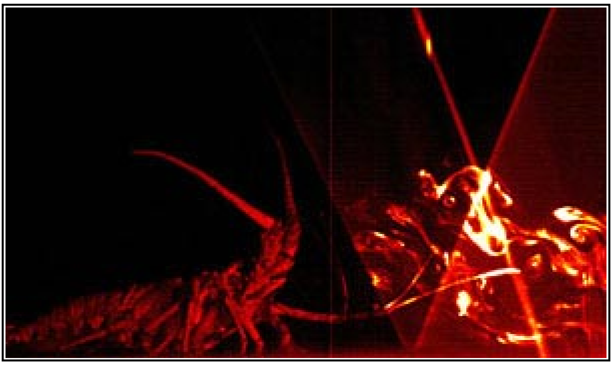
Scientists sniff out secrets of lobster's sense of smell

BY ETIENNE BENSON

For a lobster living on the ocean floor, the chemical trails left by prey, predators, mates and competitors must make a confusing tangle -- each filament of odor intertwining with the others until discovering the source of any one of them starts to seem as impossible as untangling a ball of liquid yarn. But somehow the lobster does it, and a new study by researchers at Stanford, the University of California-Berkeley and Bowling Green State University has brought scientists one step closer to understanding how.

The study focused on the Caribbean spiny lobster, *Panulirus argus,* which uses its two olfactory antennules -- 6-centimeter-long antennae covered with arrays of odor-sensitive hairs -- to sniff out odors. The findings, which will be published in the journal *Science* on Nov. 30, could help engineers design robots that can follow chemical trails underwater, a process known as plume tracing.



Researchers are using robots to solve the mystery of "lobster sniffing." Here, a plume of fluorescent dye, illuminated by a sheet of red laser light, floats towards the robotic lobster at a rate of 10 centimeters per second. The olfactory antennule is extended in front of the lobster. Photo courtesy of: Megan Wiley, Jeffrey Koseff and Mimi Koehl

"We're trying to understand how living organisms use information -- in this case, olfactory information, information that they sense by smell -- to find either a prey or a mate," says Jeffrey Koseff, professor of civil and environmental engineering and senior associate dean for faculty affairs in the School of

Koseff and his colleagues used fluorescent dye, high-speed video and a robotic lobster to model the flow of an odorant past the lobster's antennules, which the lobster rapidly flicks when it is "sniffing" for odors.

In order to have complete control over the flicking, the researchers filled a discarded exoskeleton with epoxy and replaced one of the antennules with a computer-controlled steel wire to create a robotic lobster. A real antennule was slipped onto the wire before each experimental trial. The lobster was then submerged in a tank of water, and a plume of fluorescent dye, illuminated by a sheet of laser light, was released at one end of the tank.

As the plume flowed downstream toward the lobster, the robotic antennule was flicked through the water over timescales similar to those seen in live lobsters -- about 100 milliseconds for the fast downstroke and 300 milliseconds for the slower upstroke, with a 400 millisecond pause between each flick.

A high-speed video camera recorded the movement of the dye over and around the flicking antennule. By illuminating the fluorescent dye with a sheet of laser light, the researchers were able to visualize a two-dimensional slice of the fluid flow. Video images of the flow then were analyzed to determine where and when the dye came into contact with the antennule's aesthetascs -- tiny hairs arrayed along the length of the antennule and covered with odor-sensitive cells.

The researchers found that the rapid downstroke at the beginning of the sniff turned the antennule into a "sieve," allowing water to flow between the aesthetascs and bringing the fluorescent dye directly into contact with the odor-sensitive cells. But when the antennule slowly returned to its original position, it acted more like a "paddle"; instead of rushing between the aesthetascs, most of the dye-laden water flowed around them, leaving the pattern of dye picked up by the aesthetascs during the downstroke intact. The researchers also found that during the beginning phase of the downstroke, samples of dye that had been previously trapped between the aesthetascs were washed out, effectively resetting the lobster's sense of smell between each sniff.

According to the study's authors, the fast downstroke may allow the antennule to capture high-resolution information about the structure of the odorant plume, while the slow upstroke may give the lobster's odor-sensitive cells and neural circuitry time to analyze that structure. Capturing the fine structure of the plume is important in natural air and water environments, where turbulence can cause odors to become patchy and intermittent. By providing highly detailed information about the structure of an odor plume, antennule flicking may allow the lobster to track down its source despite the plume's patchiness.

Although the findings are suggestive, the study did not address whether information gathered by the aesthetascs actually is used by the lobster. Much of the plume's structure is preserved during the slow upstroke, but it also is blurred by shearing of water around the aesthetascs. Future research will attempt to determine how the information is used by measuring nerve signals transmitted from the aesthetascs to the lobster's brain.

The study was funded by the Chemical Plume Tracing Program of the Defense Advanced Research Projects Agency and the Office of Naval Research, which are interested in lobster sniffing because it could serve as a model for artificial plume tracing systems. Such systems could be used to locate land mines or underwater explosives using chemical plumes in air or water.

The lead author of the study is Mimi Koehl, professor of integrative biology at the University of California-Berkeley and an expert on the mechanics of biological systems. The other authors, in order, are Koseff; John Crimaldi, an assistant professor of engineering at the University of Colorado who was a postdoctoral fellow at Stanford at the time of the study; Michael McCay, a graduate student at Berkeley; Tim Cooper, a Berkeley laboratory technician who built the model lobster; Megan Wiley, a graduate student in Koseff's Environmental Fluid Mechanics Lab at Stanford; and Paul Moore, an associate professor in biological sciences at Bowling Green State University.