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1215 K Street, Suite 2290
Sacramento, CA 95814

UC Davis Researchers Walter Leal and Zain Syed Identify Dominant Chemical That Attracts Mosquitoes to Humans

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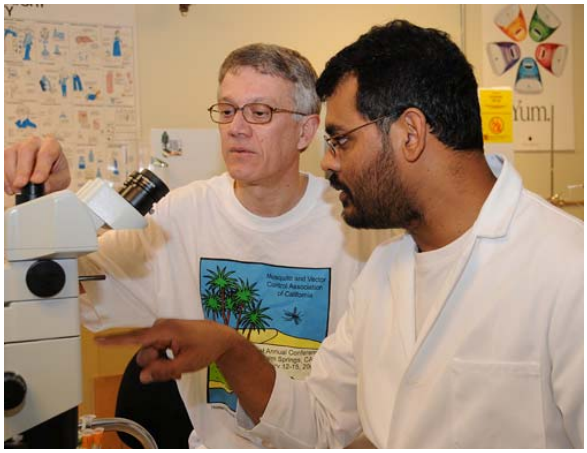
DAVIS—Chemical ecologists in the Walter Leal lab at the University of California, Davis, have identified the dominant odor naturally produced in humans and birds that attracts the blood-feeding Culex mosquitoes, which transmits West Nile virus and other life-threatening diseases.



Chemical ecologists Walter Leal (left) and Zain Syed. (Photo by Kathy Keatley Garvey)

The groundbreaking research explains why mosquitoes shifted hosts from birds to humans and paves the way for key developments in mosquito and disease control.

Entomology professor Walter Leal and postdoctoral researcher Zain Syed, UC Davis Department of Entomology, found that nonanal (pronounced "no-nan-al") is the powerful semiochemical that triggers the mosquitoes' keen sense of smell, directing them toward a blood meal. A semiochemical is a chemical substance or mixture that carries a message.

"Nonanal is how they find us," Leal said. "The antennae of the Culex quinquefasciatus are highly developed to detect even extremely low concentrations of nonanal." Mosquitoes detect smells with the olfactory receptor neurons of their antennae.

Yale University professor John Carlson, a leading scientist in insect olfaction, described the study as "exciting with important implications for the intriguing question of how mosquitoes find the humans they bite."

"Leal and Syed have identified a human odor that is detected with great sensitivity by the antennae of mosquitoes that transmit West Nile virus," Carlson said. "In addition to its scientific interest, the study may have important practical applications in the control of these mosquitoes and the diseases they carry."

Birds, the main hosts of mosquitoes, serve as the reservoir for the West Nile virus, Leal said. When infected mosquitoes take a blood meal, they transmit the virus to their hosts, including birds, humans, horses, dogs, cats, bats, chipmunks, skunks, squirrels and domestic rabbits. Since 1999, the Centers for Disease Control and Prevention has recorded 29,397 human cases and 1,147 fatalities in the United States alone.

The UC Davis researchers tested hundreds of naturally occurring compounds emitted by multiracial and multiethnic humans and multiple species of birds, including chickens and pigeons. They collected chemical odors from 16 human subjects, including two blacks, two Chinese, eight Caucasians, three Latinos and one East Indian, ranging in age from 20 to 55. "We then determined the specificity and sensitivity of the olfactory receptor neurons (ORNS) to the isolated compounds on the antennae of the mosquitoes," Syed said.

Their newly published research, titled "Acute Olfactory Response of Culex Mosquitoes to a Human- and Bird-Derived Attractant," appears in the current edition of Proceedings of the National Academy of Sciences. (Download research paper: PDF)

Leal and Syed found that nonanal acts synergistically with carbon dioxide, a known mosquito attractant. "We baited mosquito traps with a combination of nonanal and carbon dioxide and we were drawing in as many as 2000 a night in Yolo County, near Davis," Syed said. "Nonanal, in combination with carbon dioxide, increased trap captures by more than 50 percent, compared to traps baited with carbon dioxide alone."

Culex quinquefasciatus transmits West Nile virus. (Photo by Kathy Keatley Garvey)

"This study highlights the importance of basic research not only to the advancement of science but also public health," said Laura Kramer, director of the Arbovirus Laboratories, Wadsworth Center, New York State Department of Health, and a professor in the School of Public Health, State University of New York. "The findings provide a mechanistic basis for host switching from birds to humans by mosquitoes feeding in late summer. The results are enticing as a tool that may be applied to mosquito control efforts, especially if the same semiochemical proves equally effective in attracting other important Culexvectors such as Culex pipiens and Culex tarsalis, and even more significantly, Aedes aegypti and Aedes albopictus, vectors of dengue and Chikungunya virus."

Chemical ecologist Coby Schal, a professor at North Carolina State University, described the research as representing "some of the best research on insect olfaction that I have ever read. By combining trapping experiments in the field with careful characterization of the response profiles of antennal and maxillary sensilla of Culex mosquitoes, Syed and Leal show not only that the combination of carbon dioxide and nonanal is an important beacon for blood-seeking mosquitoes, but also that a large fraction of the sensilla on the mosquito's nose (antennae) is dedicated to the detection of nonanal at incredibly low concentration.

"Such high sensitivity of olfactory receptor neurons to nonanal – rivaling the response characteristics of pheromone responsive neurons – suggests that nonanal has played an important role in the evolution of host-finding and host-preferences in Culex mosquitoes," Schal said. "This is a truly exceptional achievement by the outstanding Syed/Leal team, but in step with their previous outstanding contributions on a wide range of arthropods."

Leal and Syed previously discovered the secret mode of the insect repellent DEET in groundbreaking research published last year. Leal was recently selected one of 10 Fellows of the Entomological Society of America for 2009. Syed this year was named one of two recipients of the "Outstanding UC Davis Postdoctoral Scholars for Excellence in Research."

Research entomologist William Reisen of the Center for Vectorborne Diseases, UC Davis, said their work "potentially has important ramifications for disease surveillance programs and ecological studies measuring mosquito abundance and infection."

"Although large mammal feeding mosquitoes are readily attracted to dry ice baited traps, those vectors of malaria and dengue virus that feed specifically on humans or vectors of arboviruses that feed specifically on wild birds have been difficult to sample," Reisen said. "Syed and Leal discovered that a nonanal, a compound common to both host groups, when included with dry ice seems to synergize attractancy and therefore improve trap catch. This work potentially has important ramifications for disease surveillance programs and ecological studies measuring mosquito abundance and infection."

Sensory ecologist Gabrielle Nevitt, a UC Davis professor of neurobiology, physiology and behavior, also praised the importance of the research. "Few researchers of this caliber have examined odors emitted by birds, and I know of no other study that has examined them in this context. The researchers used a variety of methods, including field behavior, neurophysiological recording, and odor collection from live birds and humans to investigate whether they produce common odorants which are attractive to mosquitoes."

"Their results," she said, "could have implications for the control of West Nile and offers new insights into the evolution of odor production in birds."

Said UC Riverside entomology professor Jocelyn Millar: "This is a nice paper showing strong electrophysiological and behavioral responses by mosquitoes to a simple and common natural chemical, that was isolated using some clever methodology. It is interesting to note that this same compound had previously been shown to influence oviposition site selection choice by blood-fed, gravid mosquitoes, i.e., the compound appears to have several functions for the mosquito in different contexts.'

WNV, originating in Africa, was first detected in the Western hemisphere in New York in 1999, and quickly spread across the country and the continent. WNV was first identified in the West Nile district of Uganda in 1937.

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More information at http://entomology.ucdavis.edu/news/nonanalresearch.html

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Kathy Keatley Garvey
Communications specialist
UC Davis Department of Entomology
(530) 754-6894