How Attractive Are You? To Mosquitoes, That Is

For years people have known about animal attraction. Perfume and cologne are the primary "weapons of choice" many use to attract the opposite sex.

But we don't need to do anything to attract insects. We give off hundreds, maybe thousands, of natural scents that bugs, particularly mosquitoes, just love.

"So far, we have found more than 340 different chemical scents produced by human skin, and some of these attract mosquitoes," says ARS chemist Ulrich R. Bernier.

"Scientists have known for years that lactic acid—present on human skin—is a mosquito attractant. So far, this is true for only a handful of species, one of which is the yellowfever mosquito, *Aedes aegypti*. Finding what attracts mosquitoes will ultimately help us find ways to control them." Bernier is with the ARS Center for Medical, Agricultural, and Veterinary Entomology's Mosquito and Fly Research Unit in Gainesville, Florida.

For more than 30 years, scientists have been searching for compounds that attract mosquitoes. Bernier started his quest back in 1992, when ARS research leader Donald R. Barnard, head of the Gainesville unit, arranged funding of his doctoral research aimed at finding which chemicals or scents on a human-handled petri dish were driving mosquitoes crazy. It was evident to Bernier that a glass petri dish readily adsorbed some human scents. From then on, using glass to collect samples became the foundation of Bernier's research.

"I developed a technique using glass beads to help me identify organic compounds from humans that are attractive to mosquitoes," says Bernier. "The beads are rubbed repeatedly between human palms to collect skin emanations." The beads allow Bernier to take samples without collecting excess water, which distorts the chemical analysis.

The Gainesville scientists are testing individual scents and combinations for attractiveness to different mosquito species.

PEGGY GREB (K8747-19)

A female yellowfever mosquito probes a piece of Limburger cheese, one of few known mosquito attractants.

They use an olfactometer, a cage separated by a screen, where mosquitoes are placed on one side and an attractant is pumped through the other, to see if mosquitoes will come to the screen. Bernier says it's difficult to find an attractant because unlike a pheromone (a single substance that attracts one sex of an insect species to another), it appears that multiple compounds or kairomones (care-ah-mones) are needed to attract mosquitoes.

Simply Irresistible!

Since 1997, Bernier has been combining different blends and screening them at different levels to see which blends draw mosquitoes best. A promising scent is later combined and tested in a blend. "Some blends beat out a human-handled dish every time," says Bernier. "Those blends have proven to be some of the most efficient and consistent attractants we've used. We can get about 90 percent of the mosquitoes in the cage to come to the mixture. This is impressive considering my own arm and hand attract only about 70 percent of them.

"We still don't have a perfect blend," Bernier notes. "But, we're a lot closer than we've ever been." Several promising blends, for which Bernier has filed a patent, are combinations of human-produced odors with and without lactic acid.

In 1968, Gainesville scientists discovered lactic acid is an attractant for the yellowfever mosquito. At that time, carbon dioxide (CO_2) was also thought to be necessary to attract mosquitoes. Bernier says what might be the single most important discovery about these blends is they don't use CO_2, unlike most other blends or attractants. CO_2 is a bother, he says, because a person would have to lug a huge tank or a brick of dry ice into the field. All of the specific chemical combinations he's isolated for both the yellowfever mosquito and *Anopheles albimanus*, a tropical mosquito that spreads malaria, don't need the CO_2.

"It's difficult improving synthetic blends when you increase the number of chemical compounds in the blends," says Bernier. "Two components will look as good as four, unless you put them in direct competition with human hands. We're working toward improving the blends for attracting yellowfever mosquitoes and adjusting the blends to attract other mosquito species."

Finding a blend and testing it isn't all that has to be done. "You have to have consistency when doing tests," says Barnard. "Many things could affect why a blend is attractive or not. For example," he says, "we use three olfactometer cages, stacked one on top of the other. How do we know mosquito responses will be the same in the top cage as in the bottom? We test to see if the location or position of the cages affects the results.

"Time of day is also extremely important. Mosquitoes tend to have cycles when they are more active and will or will not feed," says Barnard. To minimize experimental error," Barnard says, "we test the blends under circumstances where light conditions, air temperature, airspeed, and so on are controlled."

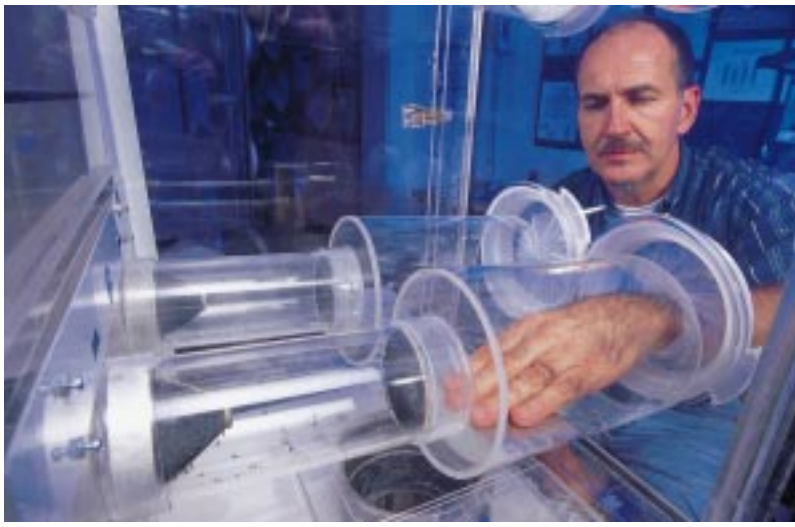
What Else Do Mosquitoes Like?

Entomologist Daniel L. Kline tested the attractiveness of socks worn by humans. The results: Mosquitoes love them. "I wore the socks for 12 hours on 3 consecutive days. When I wasn't wearing the socks, I put them in a sealed plastic bag," says Kline. "I also found mosquitoes love Limburger cheese. Interestingly enough, the main ingredient in the cheese is a bacterium that can be found on the human foot," he says. Incidentally, Limburger cheese was first made in The Netherlands by monks. They trampled the cheese with their feet to get the finished product.

Kline tested responses of female *Aedes aegypti* to the socks, human hands, and Limburger cheese. He used females because only they will take blood. They need it for reproduction.

In field studies, Kline says the socks alone attracted very few mosquitoes. However, a significant increase occurred to CO_2-baited traps when combined with a worn sock for most mosquitoes, including species of *Aedes, Anopheles, Coquillettidia, Culex, Culiseta,* and *Psorophora*—major disease-transmitting mosquitoes. Mosquito responses were favorable in the olfactometer, but the human hand still attracted the most. "If we can isolate the chemical scent in the socks, then we can use that as an additional attractant," says Kline.

PEGGY GREB (K8747-1)



Entomologist Donald Barnard demonstrates the attraction of female yellowfever mosquitoes to his hand in an olfactometer. The olfactometer contains a screen separating the attractant (in this case, his hand) from the mosquitoes.

Why Attract Them?

Attractants can be used as nontoxic baits in mosquito traps for surveillance purposes. "Many countries, particularly underdeveloped ones, need improved detection and population monitoring in areas where mosquitoes pose high risks of transmitting

diseases like yellow fever, dengue, and malaria," says Barnard. "If we can attract the mosquitoes to a trap, we can use this information to assess the mosquito distribution and population and develop ways to control them."

Also, Barnard says if you are using conventional traps to look for a particular mosquito that transmits a disease, but you don't find that mosquito in your trap, that doesn't mean the mosquito isn't in the area.

You have to make sure that the attractant you're using works for that particular mosquito. What may be attractive to one species may not be for another. For example, some species may be attracted to human blood while others may feed only on the blood of wild or domestic animals.

Since there are 4-6 dozen mosquitoes out of 2,700 worldwide that transmit diseases, it can be tricky to pinpoint an attractant, Barnard says.

PEGGY GREB (K8748-1)

Entomologist Daniel Kline inspects mosquitoes caught in a collection device. The bait used was a combination of a worn sock and carbon dioxide.

PEGGY GREB (K8745-18)

After being rubbed between palms to pick up human scents, glass beads are carefully loaded into a glass insert.

PEGGY GREB (K8747-10)

Chemist Ulrich Bernier examines glass beads that have adsorbed human scents. The glass insert containing the beads is ready to be installed in a gas chromatograph to identify the scents.

The potential also exists to use traps for reducing mosquito populations with minimal dependence on chemical insecticides.

"Our hope is to reduce reliance on pesticides, says Barnard. "We expect attractant-enhanced traps to eventually surpass pesticides in effectiveness. We hope to develop stand-alone traps that can be used by homeowners or livestock producers.

"In the future," he adds, "we hope to develop personal protection technology based on this research. By knowing what attracts mosquitoes, we can develop better defenses against them.

"One day we hope to develop systemic repellents that can be taken orally or devices that can be worn to neutralize the attractive effects of a person to a mosquito."

Animals also act as a magnet for mosquitoes. "The next phase of our research will be to look at what attracts mosquitoes to livestock," says Barnard.

"We're looking at mosquitoes that bite both livestock and people because mosquitoes spread some viruses between the two. Like St. Louis encephalitis, for example: A mosquito bites an infected mourning dove and later bites a human."

Ultimately, a better understanding of mosquito attraction should help in developing more effective, environmentally safe repellents for protection from insects that prey on humans and livestock.—By **Tara Weaver-Missick,** ARS.

This research is part of Arthropod Pests of Animals and Humans, an ARS National Program (#104) described on the World Wide Web at http://www.nps.ars.usda.gov/programs/appvs.

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