



Colored scanning electron micrograph of a female specimen of the mosquito species, *Anopheles gambiae*. This micrograph shows the mosquito's bulging abdomen, swollen after a meal of human blood. The female is distinguished from the male of the species by the relative sparseness of the bristles on her antennae. The proboscis consists of the piercing and sucking instruments, called stylets, which are seen as a slender red tube under the compound eye, which is colored green. MICROGRAPH BY DR TONY BRAIN, SCIENCE PHOTO

## **You really are a mosquito magnet. Here's what you can do about it.**

New research proves these bloodsuckers can pick you out in a crowd. Here are the odors they're drawn to, what scientists recommend to keep them away—and how a future personalized repellent might work.

By Connie Chang, June 16, 2023. (10 min read)

Mosquitoes love Kim Zarins. The insects' preference for Zarins, an English professor at Sacramento State University, is so extreme that her 18-year-old son likes her to come outside with him because she serves as a decoy and "he knows he'll be safe," Zarins says.

Now mosquito magnets like Zarins are helping scientists pinpoint what entices these thirsty bloodsuckers. Along the way, there's new hope for relief.

More than just a nuisance, mosquitoes can carry [devastating illnesses](#) like Zika, dengue fever, malaria, and West Nile disease and are responsible for [over a million deaths](#) every year. And while historically, they have been more prevalent in tropical climates, [mosquitoes carrying disease-causing organisms have expanded their reach](#) as the planet warms—including parts of the United States like Connecticut, California, and Arizona.

Mosquitoes use a variety of cues to home in on their targets. Odor distinguishes people from other animals, and some mosquitoes have evolved to seek out our unique bouquet. From up to 200 feet away, they follow the carbon dioxide plumes we exhale with each breath. As they approach several feet closer, they smell the odors emanating from our feet, underarms, and skin. At around 50 feet, they begin to see us as dark silhouettes against the light. Finally, pools of heat guide them to the choicest sites on which to land while taste receptors on their feet help them decide where to bite.

## What mosquitoes like to smell

“It’s very striking how good mosquitoes are at detecting us,” says Diego Giraldo, a neuroscientist at Johns Hopkins and co-author of a [new study](#) that characterizes human odor profiles that attract *Anopheles gambiae*, an African mosquito that transmits malaria. The work shows, for the first time, that mosquitoes can discriminate between multiple people in a large, spacious arena the size of an ice-skating rink. Previous research used much smaller chambers and pitted one person against another.

The arena used in Giraldo’s experiment was connected to eight tents via air ducts, which funnel odors from each tent’s occupant over a black, heated disk located in the experimental space. Infrared cameras capture the movements of mosquitoes that land on each disk. Over the course of the experiment, mosquitoes were four times more likely to land on the disk associated with the subject who attracted the most mosquitoes compared to the subject who attracted the least. “This just drives home the point that even in complex situations with multiple sources of odor, mosquitoes do seem to prefer some people over others,” Giraldo says.

Next, the researchers identified the chemicals in each subject’s odor profile using an instrument that can separate the gases making up the sample into its component parts. “Human odor, however, is incredibly complex,” says Stephanie Rankin-Turner, a chemist at Johns Hopkins, who also worked on the study. In human odors, “there are a lot of chemical compounds that no one’s ever classified before.” To narrow the field, the researchers focused on chemicals known to make up human scent.

## Fuel their curiosity with your gift

Their analysis uncovered 15 airborne compounds that were present in the odors produced by all subjects. But it was the concentrations of these various chemicals that determined how likely mosquitoes were to bite them. “If there’s a compound that mosquitoes really love and one person is releasing a lot of it, then that has the potential to increase their attractiveness to mosquitoes,” Rankin-Turner says.

The mosquitoes were especially beguiled by carboxylic acids, a class of fatty acids found in human sweat whose scent is sometimes compared to rancid butter or cheese, confirming [earlier work demonstrating](#) a similar preference in another mosquito species. We produce these acids in our sebum, the oily layer that protects our skin, but they’re also made when beneficial microbes living on our skin surface digest our secretions.

The insects were also drawn to acetoin, which is produced by skin microbes too. “So, it definitely seems like the skin microbiome is playing a big role in how we smell and how attractive we are” to mosquitoes, Rankin-Turner says.

And while factors like pregnancy, disease status, or what we eat and drink can influence our scent, some of its features are remarkably stable, [persisting across months and even years](#). This aligns with the observation that certain people, like Zarins, the English professor, tend to attract mosquitoes.

“A lot of us in the field want to understand what makes one person more attractive than another person because that secret may allow us to make the next generation repellent,” says Matthew DeGennaro, a mosquito geneticist at Florida International University, who was not a part of the current study. He cited the naturalistic, almost field-like conditions the researchers were able to achieve as a significant step towards further teasing out these associations.

## Fooling mosquitoes

From shampoo to deodorant to soap, most people use personal care products every day. And if body odor can attract mosquitoes, perhaps washing or layering scents on top of it can confuse them. But the reality is more complex, as scientists discovered in a recent proof-of-concept [study](#) that explored how these soaps impact mosquitoes’ ability to track us.

For their initial experiment, the researchers compared the number of times mosquitoes landed on a nylon sleeve that had been worn on the unwashed arm of a subject versus one that had been worn on the same subject’s washed arm. The experiment was repeated across four different subjects and four different soaps, including brands like Dial and Native.

To the researchers’ surprise, in some cases, washing increased the number of mosquito landings—indicating that soap amplified that person’s attractiveness to mosquitoes. But the effect wasn’t consistent—for example, Dove and Simple Truth soaps made some (but not all) people more enticing, while Native soap seemed to decrease people’s allure.

Contrary to expectations, a soap’s chemical contents may be less important than how those contents react with the individual body chemistry of the person using it. “All the soaps we used were largely dominated by a compound called limonene, which is a known mosquito repellent—but three out of four soaps actually increased mosquito attraction,” says Clément Vinauger, a neuroethologist at Virginia Tech and a co-author of the study. The same chemical, therefore, can be attractive or repulsive to mosquitoes depending on its concentration and how it’s combined with other natural chemicals present on human skin. In nature, Vinauger speculated, maybe one combination of chemicals is interpreted by the mosquito to mean “plant” while a different ratio of the same components might scream, “human.”

Maria Elena De Obaldia, a neurogeneticist who studied mosquito olfaction at Rockefeller University and who was not involved in the study, is not surprised that the results were not straightforward. Because humans are so important to the lifecycle of some mosquitoes (females need a blood meal before they can produce eggs), the wily insects have evolved redundancies in their people-detection mechanism. “They can’t rely on just one signal—so they have a really robust system for detecting a range of odors, which is really hard to profile,” De Obaldia says.

In the next phase of the personal products study, the researchers analyzed the nylon sleeves from the initial experiment to pick out combinations of chemicals associated with mosquito attraction and repulsion. With this data, they designed an attractive mix and a repellent mix and tested them with a fifth subject, who was not a part of the previous experiments. When given a choice between a sleeve spiked with the attractive mix and a sleeve spiked with mineral oil (the control), mosquitoes overwhelmingly favored the attractive mix, says Chloé Lahondère, an entomologist at Virginia Tech

and a co-author of the study. Similarly, mosquitoes preferred to land on the sleeve with mineral oil when the repellent mix was offered.

With future studies and more participants, Lahondère hopes to employ powerful tools like machine learning to say, “Based on the smell that you have, we can figure out if this would be a good soap for you to use to avoid mosquitoes.”

### **The best ways to repel mosquitoes**

Research to devise fail-safe repellents is still in its infancy, but scientists have some preliminary ideas based on the current science. Try products with a coconut scent, the aroma associated with the soap that more consistently deterred mosquitoes, Vinauger suggested. “And since it might depend on your personal body odor, experiment with different soaps to see which one works best.”

Lahondère recommended adopting strategies mosquito researchers use in the field. “When we collect mosquitoes, we wear long sleeves and light-colored clothes, because mosquitoes tend to be attracted to dark colors.”

But the best defense we have against mosquitoes remains traditional repellents like DEET, which experts recommend if you plan to be in regions where mosquito-borne illnesses are endemic. Natural repellents like lemon eucalyptus oil can also work, but they’re much less effective and must be reapplied more often. DeGennaro, who lives in Florida, recalled, “During the Zika phase, I would wear DEET every day.” It’s safe when used as directed and it also works great on ticks, he added.

According to DeGennaro, however, “the future lies in understanding the human skin microbiome and developing a probiotic solution that will manipulate that microbiome to help protect people from mosquito bites.” He and colleagues have shown that [more diverse skin microbiomes](#), cultured in a dish, emitted fewer odors that attract mosquitoes compared to less diverse populations.

For De Obaldia, continuing to conduct basic research is crucial if we’re going to outpace mosquito evolution. Some species of mosquitoes, for example, have begun to feed earlier in the day to thwart the use of bed nets. “Understanding how mosquitoes find us in our environment and how we attract them, will help us develop more effective repellents.”

As for Zarins—she can’t wait for the day when she can hang up her hat as her son’s personal mosquito magnet and find a repellent that works for both of them.