s2100018 Biology/Entomology/Insects/Cockroaches/Senses/Grooming Robots Lead Roaches Into the Light Social Bee-havior: It's in the Genes Pheromone, the Ultimate Cockroach Weapon? World Almanac Encyclopedia: Cockroach 20130300

The Well-Groomed Roach

by Ker Than

Most people associate cockroaches with filth and consider them pests to be eliminated, but the insects are surprisingly clean. American cockroaches, for example, can often be observed grabbing one of their two antennae with a front leg and threading it through their mouthparts — a form of grooming. Many insects, in fact, groom themselves, but scientists have had little understanding of why — until now.

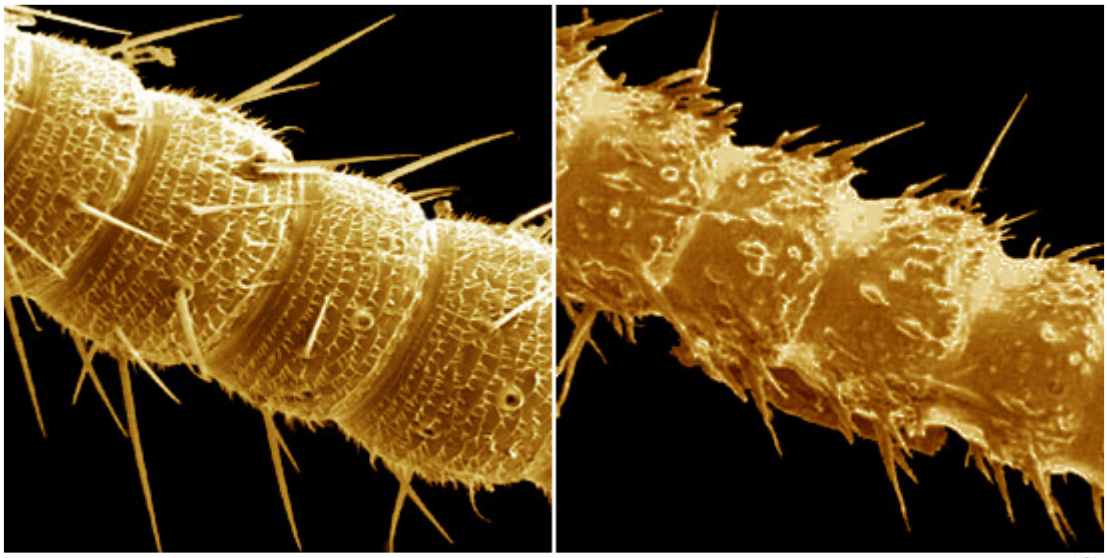
Ayako Wada-Katsumata

Most people associate cockroaches with filth and consider them pests to be eliminated, but the insects are surprisingly clean. American cockroaches, for example, can often be observed grabbing one of their two antennae with a front leg and threading it through their mouthparts—a form of grooming.

In a new study, detailed in a recent issue of the *Proceedings of the National Academy of Sciences (PNAS)*, scientists show that insects such as cockroaches actively clean their antennae to prevent the buildup of a waxy gunk that can affect their function. Study co-author Katalin Böröczky, a chemical ecologist at North Carolina State University, called the finding a "serendipitous discovery."

Roach Runners

Böröczky's colleague Marianna Zhukovskaya, an evolutionary physiologist at the Russian Academy of Sciences, was conducting an experiment with American cockroaches that involved restraining the insects. When Zhukovskaya studied the roaches under a microscope, she noticed that their antennae eventually became coated with a shiny, waxy substance.



ASU

Marianna Zhukovskaya, an evolutionary physiologist at the Russian Academy of Sciences, was conducting an experiment with American cockroaches that involved restraining the insects. When Zhukovskaya studied the roaches under a microscope, she noticed that their antennae eventually became coated with a shiny, waxy substance.

Curious about what the material might be, Zhukovskaya contacted Böröczky, and the pair teamed up with other scientists to investigate. The team designed an experiment in which they used various techniques to prevent a dozen male American cockroaches from grooming their antennae for 24 hours. In some cases, a small plastic clip was used to tether the antennae to the base of the roaches' heads so they could not grab hold of them and clean them. Some roaches had their mouthparts glued together and others were kept in a box that was too small to allow for grooming.

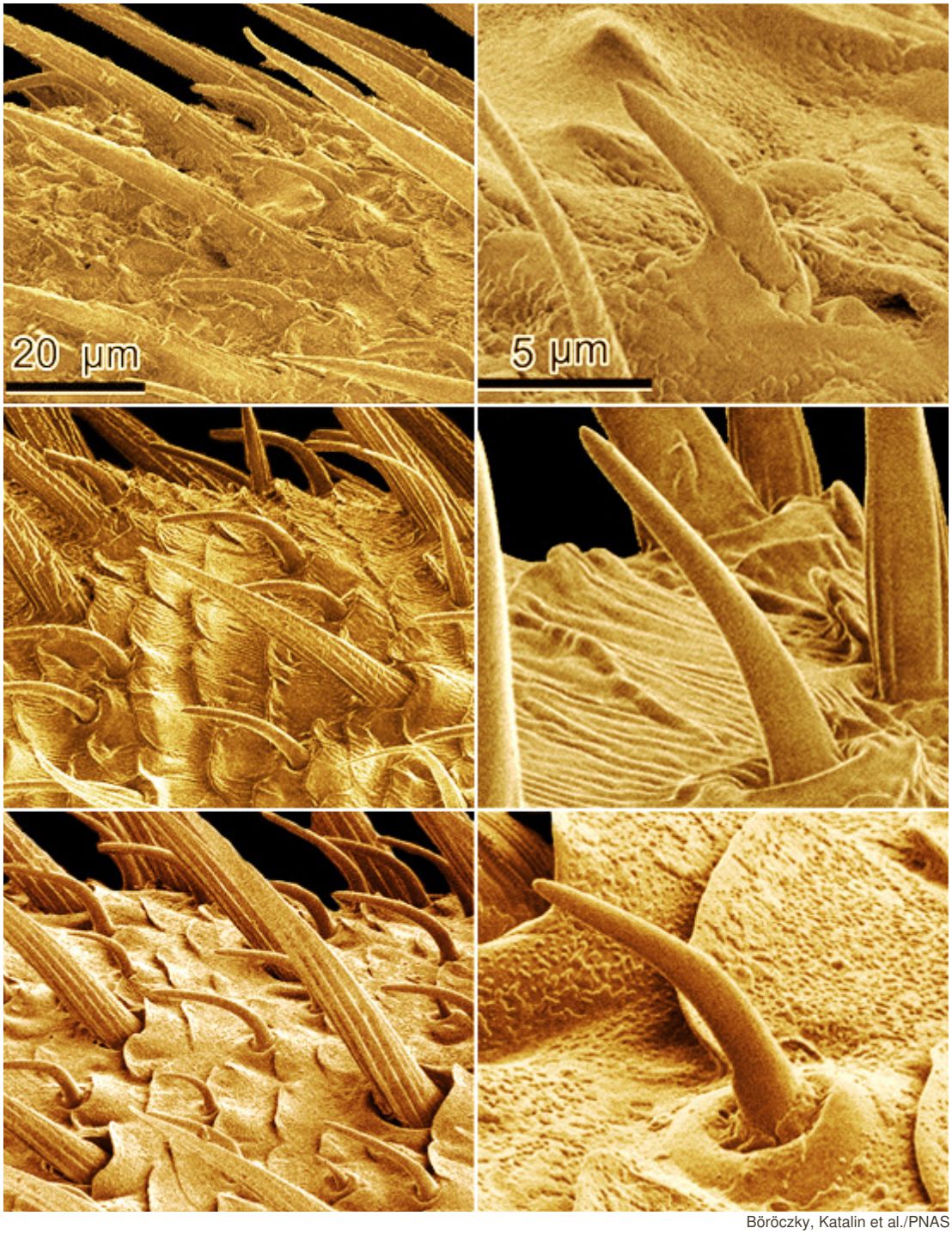
Ayako Wada-Katsumata

The team designed an experiment in which they used various techniques to prevent a dozen male American cockroaches from grooming their antennae for 24 hours. In this video, a small plastic clip was used to tether the right antenna to the base of a roach's head so that the roach could clean only the left antenna.

When they did this, the team noticed the same buildup of material on the antennae that Zhukovskaya first observed. "We checked the insects 24 hours after, and found that they had three to four times the accumulation of the waxy material compared to the control group," which were allowed to freely groom themselves, Böröczky explained.

Analyzing Roach Wax

To identify what the unknown buildup was, the researchers washed the roaches' "dirty" antennae with the chemical solvent hexane. This dissolved the waxy substance and allowed the scientists to analyze it with gas chromatography, a technique that separates different components of a chemical compound mix. They found that the material was made up mostly of wax-like molecules, or hydrocarbons, that consisted of repeated chains of carbon and hydrogen atoms.



Böröczky, Katalin et al./PNAS

ABOVE: The antenna of a cockroach under a microscope at 20µm (left) and at 5µm (right) shows

the waxy buildup over 24 hours with no grooming (top), with grooming (center) and after washing with the chemical solvent hexane (bottom).

Böröczky and her team speculate that the waxy substance is produced by certain cells in roaches and other bugs and is then distributed through the insect equivalent of a circulatory system to antennae and other body parts, where it functions as a protective coating to prevent the excessive loss of moisture and as a barrier against pathogens.

If the waxy material were allowed to build up too much, however, it could have a negative effect. For example, the antennae of roaches and other insects are covered with tiny sensory hairs that they use to gather information about their environment, and to find food and mates. If the sensory hairs are buried beneath an accumulation of wax, then their functionality could be impaired.

The team hypothesized that too much waxy buildup clogged tiny pores in the roaches' antennae that lead to odor-sensing cells. This was confirmed when they measured the electrical activity in those cells. Roaches with clean antennae were more sensitive to odors in their environment than those with dirty ones. "We conclude that the disruption of grooming interferes with general olfaction," the authors write in their paper.

Other Fastidious (but Gross) Insects

Böröczky and her team repeated the experiment with three other insect species — German cockroaches, carpenter ants and houseflies — and obtained similar results. When the insects were prevented from grooming themselves, the same waxy buildup could be seen on their antennae.

Böröczky explained that the team chose ants and houseflies for the follow-up experiments because they are not closely related to cockroaches. The fact that grooming was found to be important for divergent species indicates the behavior is fairly widespread among insects, the authors suggest. "Our observations with four phylogenetically diverse species indicate that this hitherto unknown role for grooming is common to a wide diversity of insects," they write in their paper.

Böröczky said she hopes other scientists will take a look at still other insects to see if their hypothesis is correct. "We expect it to be," she said.

The team speculates that their findings could lead to new pesticides. "It might be an easy way to get compounds inside insects," Böröczky said. For example, "if cockroaches take up some insecticide with their antennae, they will eventually groom the antennae and that way they might ingest the pesticide."

Böröczky said that the time she has spent working with cockroaches has made her see the creatures in a new light. The roaches' grooming behavior is not unlike that of humans taking showers to remove dead skin and dirt, she said. "They're fascinating animals, and they really keep themselves clean," she added. "That wasn't really obvious to me before I started to do this study."

Katalin Böröczky: Investigating Insect Behavior

Katalin Böröczky is a chemical ecologist and former postdoctoral research scholar in the department of entomology at North Carolina State University in Raleigh. Born in Hungary, Böröczky enrolled as an undergraduate at Eötvös Loránd University in Budapest in 1993 and earned her master's degree in chemistry in 1998. For the next two years, Böröczky worked as an analytical chemist, before resuming her Ph.D. studies in 2000 at Germany's Technische Universität Carolo-Wilhelmina zu Braunschweig. Relocating to the United States in early 2005, Böröczky worked for more than four years as a postdoctoral researcher at Penn State University before joining the North Carolina State University faculty.

Böröczky's research focuses on "the communication systems of animals and plants" with an emphasis on insects. More specifically, Böröczky identifies "chemicals that govern mate finding and host seeking behaviors of insects," and takes an integrated approach that includes "physiology, behavior, electrophysiology, and chemistry."

Below are Böröczky's February 27, 2013 responses to questions posed to her by Today's Science.

Courtesy of Katalin Böröczky

"A piece of general advice for would-be scientists: It is good to be proud of what we know but it is essential to be aware of what we don't know. It inspires us to ask questions and learn."

Q. When did you realize you wanted to become a scientist?

A. I grew up in Hungary in a family where science was often the topic of conversation at the dinner table: My father and my oldest brother are both mathematicians, and my second-oldest brother studied physics. Since I liked chemistry and mathematics in school, it was a natural choice for me to study chemistry. Nevertheless, I think I truly became a scientist as a graduate student in Germany, where I started to analyze biological samples and learn about my current research field, chemical ecology, a cross between chemistry and biology.

Q. How did you choose your field?

By the time I received my doctorate in Germany I had become fascinated by chemical ecology, i.e., chemical communication systems in animals and plants. When the opportunity arose to take a postdoctoral research position in this field (at Pennsylvania State University) I did not hesitate.

Q. Are there particular scientists, whether you know them in person or not, that you find inspiring?

A. I am a very fortunate person to have had excellent mentors throughout my education and research career. In chronological order, I would like to mention Kornel Torkos, my diploma supervisor in Hungary, who pointed out the relevance of applied science to me; Stefan Schulz, my graduate adviser in Germany, who has very high standards for conducting research; James Tumlinson, my first postdoctoral adviser, who is always ready to ask a challenging question; and last but not least Coby Schal, my adviser at North Carolina State University [NCSU], who will never lose his genuine excitement about research no matter how hard it is to juggle with writing papers and grant proposals, and supervising a large number of people.

I also admire women in my field or related areas, e.g., Monika Hilker, a leading scientist in plant-insect interactions, for her integrity and Louise Vet for being an advocate of sustainability besides maintaining a very successful research career. Moreover, my appreciation goes out to all women scientists who tackle the challenging task of raising children while pursuing a career in science.

Q. What do you think is the biggest misconception about your profession?

A. People might think most people with a Ph.D. in science will do research. It is certainly not the case: for better or worse, many of them, especially women, leave academia. (This is a complicated topic and I don't have the insight to do it justice.)

Q. Your group concluded that cockroaches groom their antennae to improve their sense of smell. Do antennae serve other purposes — besides smell — for cockroaches? Are there any other, perhaps secondary, purposes you see the grooming as perhaps serving?

A. Insects use their antennae to gather information about their environment in order to find food, find a mate, or avoid danger. The antennae are covered with thousands of sensory hairs that house neurons to receive different types of stimuli from their environment: smell, taste, and different mechanical stimuli.

BSIG/UIG/Getty Images

"Insects use their antennae to gather information about their environment in order to find food, find a mate, or avoid danger. The antennae are covered with thousands of sensory hairs that house neurons to receive different types of stimuli from their environment: smell, taste, and different mechanical stimuli."

Insect grooming is well-known for its functions of removing dust or other powdery substances, as well as pathogens. Social insects, such as ants and termites, not only groom themselves but they groom each other to maintain the hygiene of the colony. The sequential organization and hierarchical structure of grooming events have been extensively studied in various insects (crickets, cockroaches and fruit flies, just to mention a few).

Q. Your study notes: "Cuticular hydrocarbons are often the predominant compounds on the epicuticular surface of insects. They prevent water loss from the cuticular surface and likely serve the same function on the antennal surface, which has an extraordinarily large area punctuated with numerous sensilla, membranes, and cuticular pores." One might think that, if the hydrocarbons primarily serve to prevent water loss, they might then be more strongly present in insects that live in dry environments (deserts, say) than in insects living in more humid areas. Do you know if this is the case?

A. There is no comprehensive data yet on the relationship of the thickness of cuticular hydrocarbon and the dryness of the environment. Some hypothesize that the chemical composition of this protective layer might be tailored to environmental conditions; however, there are examples both for and against this hypothesis. It is worth noting that in many insects some of the molecules in the waxy layer are not hydrocarbons but polar lipids. I think a neat, though very special, example for adaptation of the cuticle to a dry environment is the Namib desert beetle. It has protruding hydrophilic ("water-liking") spots on its cuticle that attract water

condensing out of the morning fog. When the droplets are large enough, they roll down the back of the beetle to its mouth.

Q. You've commented that your cockroach grooming finding was a serendipitous discovery. Are you planning any particular follow-ups?

A. The Schal lab at NCSU is definitely planning to investigate differential grooming of body parts. I expect the range of insect species studied will be expanded, as well, by the contribution of other research groups.

Q. Where do you spend most of your workday? Who are the people you work with?

A. When I do research, I spend most of my day in the laboratory. Applied projects often require field work. Of course, a significant portion of a scientist's time is devoted to writing. I sometimes go to a public place (a library or a café) where I cannot be distracted by lab work and can focus better on writing.

Q. What do you find most rewarding about your job? What do you find most challenging about your job?

A. What I enjoy the most in being a scientist is to be surrounded by other scientists with whom I can have discussions and collaborate on projects. I like to challenge my mind every day and academia provides a very progressive environment. The most difficult part of being a scientist, I'd say, is being evaluated constantly, especially nowadays, when it is not enough for you to be good at doing research or teaching, but when you're expected to be a manager and a salesman in order to obtain financing for academic activities.

Q. What has been the most exciting development in your field in the last 20 years? What do you think will be the most exciting development in your field in the next 20 years?

A. To me, the most exciting new concept in chemical ecology is that the behavior of an insect is determined not only by what biologically active compounds it can detect but also in what context (what other odors it can smell or what colors it can see at the same time). Molecular biology and genetics are gaining importance in chemical ecology studies, so I expect to see immense progress in understanding the molecular mechanisms behind animal behavior.

Q. How does the research in your field affect our daily lives?

A. The most obvious applied aspect of chemical ecology is pest management. Once we are able to describe the chemical communication of a certain insect pest, we can intercept its communication channels and develop a means of monitoring and/or trapping it. Also, understanding how exactly insect olfaction (smelling) works may lead to the development of very sensitive and/or selective artificial sensors.

Q. For young people interested in pursuing a career in science, what are some helpful things to do in school? What are some helpful things to do outside of school?

A. I would like to encourage young students in high schools to try to learn HOW to learn. Teachers do a highly respectable job in showing the tip of the iceberg, but students should be active themselves in trying to find their area of interest. I recommend using the Internet as a source of information, though one must be careful: Not everything online is properly presented. Luckily, there are more and more scientific books and articles available online whose information is reliable.

Outside school, there are plenty of opportunities to volunteer: at natural-history or science museums, for example. I would also urge students to learn about the different types of work available to scientists inside and outside academia because after getting a degree a scientist will have to choose a job or a position that requires certain personal skills.

A piece of general advice for would-be scientists: It is good to be proud of what we know but it is essential to be aware of what we don't know. It inspires us to ask questions and learn.

Discussion Questions

Can you think of any other purposes grooming might serve for insects? How would you test your hypothesis?

How does insect grooming resemble how humans clean themselves, and how is it different?

Journal Abstracts and Articles

"Insects groom their antennae to enhance olfactory acuity." www.pnas.org/ content/ early/ 2013/ 01/ 29/ 1212466110.full.pdf.

Bibliography

Böröczky, Katalin et al. "Insects groom their antennae to enhance olfactory acuity." *Proceedings of the National Academy of Sciences (PNAS)* (February 4, 2013) [accessed February 6, 2013]: www.pnas.org/ content/ early/ 2013/ 01/ 29/ 1212466110.full.pdf.

Wolfe, Lauren K. "Grooming Keeps Insect Senses Sharp." *Chemical & Engineering News*, (February 11, 2013) [accessed on February 20, 2013]: cen.acs.org/ articles/ 91/ i6/ Grooming- Keeps- Insect- Senses- Sharp.html.

Keywords

cockroaches, insects, ants, flies, pesticide, insecticide, grooming, Katalin Böröczky