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Cornell Entomologists Redefine Insect Sexual Chemistry

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GENEVA, NY: A team of entomologists at Cornell University has unlocked a 320 million year mystery about species evolution, and is in the process of revolutionizing the way scientists think about the chemical communication system insects use to initiate sex.

Wendell Roelofs

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In a paper entitled, "Evolution of moth sex pheromones via ancestral genes," published on the web site of the Proceedings of the National Academy of Science (PNAS), Sept. 9-15, 2002, the team led by Wendell L. Roelofs, Liberty Hyde Bailey Professor of Insect Biochemistry, demonstrates the existence of a non-functioning gene they call "delta-14" in the female sex glands of the European corn borer moth. This gene can be suddenly turned on to change the pheromone components that females use to attract a mate. Furthermore, they discovered rare males in the male corn borer population-roughly 1 in 200-capable of responding to the chemicals produced by the new gene.

"This research culminates over 20 years of work on the biosynthetic pathways used by these moths," says Roelofs, whose pheromone research laboratory at the New York State Agricultural Experiment Station, in Geneva, NY, is one of the most highly regarded in the world. "The presence of a non-functional gene changes the evolutionary model previously thought responsible for 320 million years of development in the insect family tree. Genes similar to the delta-14 gene appear to have existed before flies diverged from moths."

In this new model, the entomologists demonstrate that insects evolve chemical systems in leaps rather than by slow evolutionary stages, as had been previously assumed.

The Cornell co-authors on the paper are: Weitian Liu, research associate in entomology; Guixia Hao, postdoctoral researcher in entomology; Hongmei Jiao, laboratory technician in entomology; and Charles E. Linn Jr., senior research associate in entomology. Alejandro P. Rooney, Mississippi State University assistant professor in biological sciences, also contributed to the paper.

Chemical signals called pheromones are the most common means of communication among insects and key to an individual's survival. In field and flight tunnel experiments conducted over many years, researchers at Geneva have demonstrated that males of a particular species are acutely sensitive to the slightest change in pheromone blend.

"In the past, we were always left with a population centered right on the specific pheromone blend of that species," said Roelofs, who likens insect pheromone 'channels' to radio frequencies. "If the female doesn't use precisely the right 'channel', there is no reception by the male. Hence, no sex, and no offspring," he said. "End of species and further proof-or so we thought-that 'slight' evolutionary shift could never occur."

But, believing this paradigm, entomologists were always left with a question they couldn't answer: How did closely related species evolve different pathways when even the smallest shift in the female pheromone blend could result in fewer, or no, matings?

In the paper, Roelofs' team describes finding that the European corn borer, Ostrinia nubilalis, contains two sets of genes that code for different pheromone blends. One set, delta-11, codes for the species' own pheromone. The other set, delta-14, is nonfunctional, but, when expressed, produces the pheromone blend of a related species, the Asian corn borer, O. furnicalis. Further experimentation showed that the Asian corn borer has the same two sets of genes-the only difference being in which set is expressed.

With the help of Richard Harrison, Cornell professor of ecology and evolutionary biology, the entomologists recognized that what they had found was a potential evolutionary mechanism, and that both sets of genes were present in the two species' common ancestor, although it only expressed one.

"At some point in the past, this nonfunctional gene must have been turned on and generated completely different pheromone compounds to give rise to the Asian corn borer species," said Roelofs.

The entomologists' evidence is based on highly involved and difficult gene functionality studies using yeast and baculovirus expression systems. The findings help explain insect speciation, and are of broad general interest to scientists in a wide range of fields, including biology, zoology, evolutionary theory, ecology, systematics, entomology, molecular biology, behavior, and agriculture.

Pest Control in the Field

Manipulation of insect chemistry is an effective behavioral tool. Pest control strategies for agriculture and turf involve the use of commercial formulations of pheromones to monitor insect populations and disrupt mating behavior. For over 20 years, Roelofs' research efforts at Cornell have focused on chemical analyses of the pheromone components. "Agricultural researchers have identified pheromones in over 1,000 species of insect, use them to monitor pest populations in 250 species, and use them to disrupt mating in more than 20 species," he noted.

The findings reported in PNAS impact the use of pheromones for pest control. In addition to explaining how pheromone evolution might have occurred in the past, the paper also demonstrates that the conditions required for dramatic shifts in pheromone blends may well be present today and in the future. Insect populations could be capable of shifting away from a pheromone blend being used for their control in the field, making such control ineffective, similar to the way insects develop resistance to pesticides.

"Based on the difficulty of generating even small changes in pheromone blends in the lab, we thought that such resistance could not develop because natural pressure would prevent the species from gradually shifting to a different blend," said Roelofs. The presence of a non-functioning gene capable of sudden activation might provide a mechanism for resistant to occur, although no evidence for this has been found so far.

In deference to the unique "delta-11" desaturase gene found in the moth pheromone compounds of many moth species, Roelofs' New York license plate used to read "delta-11." He won't say whether or not he's going to change it to "delta-14," but "who knows?" he says, "we're not finished yet."

He expects their discovery to stimulate research to determine how widespread the phenomenon is, and how it impacts the evolution of many insect communication systems. His research team will be working on the genomes of fruit flies, mosquitoes, crickets and silkworms to screen for gene pairs in closely related species to determine if non-functioning desaturase genes are present. "We would like to determine how far back in the phylogenetic tree this 'delta-14' gene can be traced," he said.

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