



THE BUZZ



UC RIVERSIDE – DEPARTMENT OF ENTOMOLOGY
NEWSLETTER

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INSECT CHEMICAL ECOLOGY

By Jocelyn Millar

The discipline of chemical ecology involves study of the origin, structure, function, and significance of natural chemicals that mediate interactions between organisms of all kinds, from microbes to whales. In a broad sense, chemical ecology can be viewed as the study of chemicals that are used for communication. Although we normally think of communication in terms of sound or vision, for example human speech and writing, for many organisms, sending and receiving chemical signals constitutes their primary method of communication.

For these microbes, plants, and animals, individual chemicals might be viewed as our equivalent of letters or words, that can be combined in various ways to create many different messages. Thus, in the same way that we

use an alphabet of 26 letters to make thousands of words, a large number of different chemical signals can be generated by blending a small number of simple chemicals together in different combinations. When these chemical signals are used for communication by members of the same species, they are known as pheromones. When they are used for communication between members of different species, they are known as allelochemicals, with a number of subcategories depending on whether the sender of the signal (e.g., defensive chemicals), the receiver of the signal (e.g., prey odors used by a predator), or both (e.g., flowers and their pollinators), benefit from the signal.

Chemical signals were the first type of communication that evolved on earth, and some of the effects of chemical signals are obvious. For example, we and other animals identify suitable foods using taste and smell. Conversely, we have strong aversions to potential food items that smell or taste bad, or even items that smell or taste strange or unusual, no matter how nutritious they may be. We and other animals also rapidly learn the potency of chemical signals that are used in alarm or defense, such as the defensive spray of skunks. However, some of the more subtle chemical messages, and their significance, were only discovered fairly recently. For example, the remarkable potency and effectiveness of the chemical signals known as sex pheromones, that one sex uses to attract the other, were only



The stink bug *Chlorochroa uhleri*. Males produce pheromones to attract females



A female of the saturniid moth *Hemileuca electra*, producing pheromones to attract males.

really recognized by some of the late 19th century naturalists such as J.H. Fabré, who demonstrated that male moths were attracted to pheromone-producing females over distances of a kilometer or more. However, identification of these extraordinarily effective signals was hindered by the small quantities of pheromone that each insect produces, often less than one billionth of a gram per individual. Research on the first identification of an insect pheromone began in earnest in the mid-1930s with the pioneering efforts of Adolf Butenandt, and culminated 25 years later in the identification of a few milligrams of the chemical (10E,12Z)-hexadecadienol as the sex pheromone of the silk moth. To give an idea of the enormity of this undertaking, the pheromone was identified from an extract of 500,000 virgin female silk moths. The pheromone was remarkably potent, with amounts of 10^{-15} of a gram stimulating male moths to actively search for females. Since that extraordinary effort, the development of optimized techniques for collection, analysis, and bioassay of pheromones, coupled with quantum leaps in methods of isolating and identifying very small amounts of biologically active chemicals, has greatly accelerated

the process of identification of these signals. Several thousand insect pheromones of various types are now known, along with a number of pheromones from other organisms. Identifications of new pheromones have also been aided by “biosynthetic parsimony,” in that related organisms tend to produce signaling

chemicals with similar or identical structures. In optimal cases, it has been possible to identify a complete pheromone blend from less than ten individuals. However, this is usually the exception rather than the rule. In general, the identification of pheromones remains challenging, particularly if the bioactive compound(s) are new to science, because of the very small quantities that can be collected.

The sex pheromones that one sex uses to attract the other are by no means the only type of pheromone that exists. Instead, there are many other types of pheromones with different functions. For example, in addition to using odors to attract a mate from a distance, many insects have contact sex pheromones on their cuticles, that allow each sex to unambiguously identify the other once they contact each other. Similar contact

pheromones are widely used by social insects such as ants, termites, and honeybees to distinguish nestmates from non-nestmates, and to distinguish caste status. Marking pheromones are used, for example, by parasitic insects to mark hosts in which they have laid an egg. The marks deter oviposition by other females, limiting competition for the resource. The marks also may prevent the same female from superparasitizing a host. Scent marks are also ubiquitous in higher animals, being used to define territory and to display the dominance status of individuals. Alarm pheromones alert members of the same species to danger, and are used by insects that live in groups or colonies, such as ants, bees, and aphids. The alarm pheromone may cause receivers to move away from the signal or drop off the plant (e.g. aphids), or the pheromone may recruit nestmates to defend the nest, such as occurs with Africanized honeybees. In some cases, these pheromones may also have a secondary role as defensive compounds. For example, many true bugs (Hemiptera) produce copious quantities of volatile defensive secretions, and in addition to deterring predators, the compounds also cause conspecifics to move away. Trail pheromones are used by organisms such as ants to mark trails to food sources. Because the food sources are usually ephemeral rather than permanent, ant trail pheromones tend to be semivolatile, and must be continually reinforced in order for the trail to persist. Trail pheromones are also used by processionary insects such as tent caterpillars and bagworms, to establish trails between the protective tent and food sources. Aggregation pheromones, as distinct from sex pheromones that attract only one sex, are produced by one (or both) sex(es), and attract both sexes. They are used by insects such as bark beetles to assemble the critical mass of individuals needed to mass attack and overwhelm a host tree's defenses. Aggregation pheromones are also used by some beetle species that infest grain and related stored products, and by first instar stink bugs, causing the nymphs to cluster together.

There are a wide variety of other types of pheromones associated with all aspects of reproduction. For example, primer pheromones induce physiological changes such as egg maturation and ovulation, or the inhibition of reproduction by worker castes in bees. Aphrodisiac pheromones cause sexual stimulation and excitation in males, or render females compliant to mating attempts. Releaser pheromones trigger the release of specific behaviors, such as gregariousness in locusts, or the release of sperm or eggs into the water by aquatic organisms. Other pheromones transferred during mating reduce female

receptivity to further mating attempts, block further sex attractant pheromone production by females, and stimulate oviposition.

Our Entomology Department has a long history of research in chemical ecology, with the late Harry Shorey being one of the pioneers in the field. Dr. Shorey was one of the first scientists to recognize the enormous potential of pheromones for use in insect control, and he conducted some of the first large scale trials attempting to disrupt mating of a moth pest, the pink bollworm, by treating cotton fields with the pheromone chemical that female moths use to attract mates. In 1977, Shorey was the cowinner of the prestigious Alexander von Humboldt Award for his work on insect pheromones and their application to agriculture. He left UC Riverside in 1978, then returned in 1995, now focussing his efforts on developing the practical aspects of managing insect pests by exploitation of their chemical signals. He was killed in a tragic accident in 1998 while working on a large scale field experiment.

A number of other Entomology faculty also have worked with various aspects of chemical ecology. For example, Tom Baker and Ring Cardé are internationally known for their efforts to understand the basic mechanisms involved in disruption of insect mating behavior by use of insect pheromones, and for their efforts to translate this technology from the laboratory to large-scale field applications. More than a decade ago, John Trumble developed an IPM program for Mexican tomato growers that incorporated insect pheromones as a key component. Mir Mulla's group developed very effective attractants and control methods for eye gnats and mosquitoes based on chemical attractants. Others in the department who have been involved in chemical ecology include Mike Rust (ant and cockroach attractants and repellents), Tim Paine (bark beetle attractants and repellents), Dan Hare (chemicals used by parasitic insects to recognize their hosts), and Mike Adams (spider venoms). In my own group, we have investigated a wide variety of different types of chemical signals used by insects, including sex, aggregation, and alarm pheromones and analogous compounds, oviposition attractants and stimulants, and kairomones. At various times we have studied the chemical ecology of lepidopteran, dipteran, coleopteran, hemipteran, and homopteran species, frequently in the context of agricultural pests. Even so, chemical ecology researchers have barely scratched the surface in terms of understanding and exploiting the complexities of the chemical languages of insects. There will be plenty of work for all of us for many years to come!

HONORS AND AWARDS

Beth Grafton-Cardwell received the Extension Specialist Award for Outstanding Achievement for 2002 awarded by the Friends of Agricultural Extension. The awards dinner was held Feb. 27, 2002 and Dr. Grafton-Cardwell gave a presentation of her work in the area of citrus IPM. **Bob Krieger** served as the Editor with a distinguished panel of Associates for a 2 volume book: Handbook of Pesticide Toxicology, Fall 2001 (1908 pages). Over 125 contributors; including a Foreword on

Paracelsus, The Father of Toxicology by Dr. Krieger's brother, Bill Krieger, Ph.D., Walla Walla Community College. **Danel Vickerman** received the Sigma Xi Grant-in-Aid-of-Research for her work entitled "Transfer of selenium in insect herbivores to the third trophic level: Bioaccumulation in a model predator." Danel also won 1st Place Poster, Student Competition for the President's Prize, Section Cd Behavior & Ecology, December 2001 ESA meeting. **Mir Mulla** is Chairman of the Editorial Board for the Journal of Vector Ecology.

In January 2002 Dr. Mulla received the President's Service Award from the Mosquito and Vector Control Association of California. This Award was "In Recognition and Appreciation of his Continuous Commitment and Dedicated Service for the benefit of the Mosquito and Vector Control Association of California." The Award was presented at the Annual Meeting held at Fish Camp, California.

ALUMNUS FEATURE

Dr. Luko Hilje was recently appointed Head of the Plant Protection Unit, *Tropical Agricultural Research and Higher Education Center* (CATIE), where he has also served as senior entomologist for the last 11 years, as another UCR graduate, José Rutilio Quezada, did before him.

CATIE, based at Turrialba, Costa Rica, is a regional institution, whose aim is to conduct research and graduate education in agriculture, animal husbandry and natural resource sciences, to benefit countries from Mesoamerica and the Caribbean. IPM efforts at CATIE formally started in 1984, when a large initiative promoted by the Consortium for International Crop Protection (CICP) and funded by the U.S. Agency for International Development (USAID) was launched, to foster IPM in such region. This initiative made remarkable contributions, not only by endorsing and legitimizing IPM as a feasible alternative for crop protection in Mesoamerica and the Caribbean, but also by giving rise to an endurable tradition on IPM in this region, through joint efforts with several government and non-government organizations (NGOs), and accomplishing its institutionalization at CATIE and other agencies.

Born in 1952 in the countryside from a Croatian father and a Costa Rican mother, Luko pursued a "Licenciado" degree in Biology from Universidad de Costa Rica (UCR). Early in his career, he became interested in insects and realized that, by being an entomologist, he could make sound contributions to solve problems in agriculture and forestry. Therefore, he took several applied courses at the School of Agriculture, and later on succeeded in obtaining a scholarship from the Organization of American States (OAS) to take an international course on biological control of insects, in Mexico.

After graduating as a biologist, he taught courses in general biology and general entomology in the School of Biological Sciences, at the Universidad Nacional (UNA), where he was also involved in research projects dealing with pests like a native potato tuberworm (*Tecia solanivora*) and the human bot fly (*Dermatobia hominis*). Because of his convictions about the importance of entomology to society, he pursued graduate studies in entomology at the University of California, Riverside. He then obtained a scholarship from LASPAU (Latin American Scholarship Program for American Universities) and worked on cotton pests under Dr. Vahram Sevacherian's guidance, obtaining a Ph.D. degree in 1983.

After returning to Costa Rica, he taught courses in agricultural and forest pests, as well as in vertebrate pests, in the

School of Environmental Sciences (UNA). There, he conducted research on the biological control of the potato tuberworm, several forest pests, and pocket gophers, and was the main author of a book on pesticide use in Costa Rica, and a two-volume book (a handbook and a field guide) on Central American forest pests.

In addition to participating in several technical committees related to pest and pesticide management, as well as on the editorial boards of several local journals, he was a founding member of the *Interinstitutional Program on Forest Protection* (PIPPOF), which provides technical support to forest producers, and of the *National Institute of Biodiversity* (INBio), which since 1989 has played a key role in inventoring, protecting and using tropical biodiversity.

After serving for eight years at UNA, he was appointed as Senior Entomologist at CATIE. His initial work focused on the validation of IPM approaches to deal with insect pests of vegetables (tomato, bell pepper, cabbage, broccoli, potato, and snow peas) throughout Central America, which was later expanded to include research on insects affecting coffee and timber trees, especially mahoganies and cedars.

In addition to administration, graduate teaching, and technical assistance, Luko's current research work involves habitat management approaches and natural repellents involving key pests, such as whiteflies (*Bemisia tabaci*), the coffee berry borer (*Hypothenemus hampei*); and the mahogany shootborer (*Hypsipyla grandella*). Also, during the last decade he coordinated the *Iberoamerican and Caribbean Network on Whitefly and geminivirus Management* (www.catie.ac.cr/moscablanca), involving 21

Latin American countries, plus Portugal and Spain.

Major achievements include 24 M.Sc. students graduated; over 100 publications (books, handbooks, book chapters, papers, articles in trade journals, and handouts for growers); several research grants; the *Aquileo J. Echeverría National Award* for the book *Forest Pests in Central America* (1992); a Best Professor award at CATIE (1998); and the naming of the ichneumonid *Meniscomorpha hiljei*, in recognition for his duties at INBio (2000).

Away from work, Luko spends a lot of time at home with his wife Elsa and his 11-year old daughter Darinka in the peaceful CATIE campus, overlooking the Reventazón river and surrounded by patches of lush forest and coffee and sugarcane plantations. He enjoys writing essays and poetry, as well as reading novels, listening to music, and jogging. He can be reached at lhilje@catie.ac.cr



THE CHAIR'S MESSAGE

By Tim Paine, Department Chair

Two thirds of the 2001-2002 academic year are now complete and spring quarter is about to begin. As I mentioned in my last message, the physical surroundings for most of us have radically changed. Twenty-one faculty have moved their labs and offices to the new entomology building. All the business office staff are in their new spaces. The entomology annex has all but been abandoned. As soon as painting and some renovations to Chapman Hall are complete, the old entomology building will be completely vacated. The new Insectary and Quarantine building has new occupants and the new greenhouse complex is in the shakedown phase before it can be occupied. The frenzy of construction, planning, packing, sorting, disposing, moving, unpacking, losing, discovering, arranging, rearranging, and finally settling into new space is almost complete.

We are now planning a building opening ceremony for May 6, 2002. The ceremony will be held immediately following the annual Al Boyce Memorial Lecture. This year, the Lecture will be delivered by Dr. Dan Simberloff. Dr. Simberloff is one of the most outspoken leaders in the emerging field of invasion biology and the potential ecological and environmental problems posed by exotic species. We will send out invitations very shortly. I

was pleased that so many individuals formally associated with the Department took us up on our invitation to visit the Department when the Entomology Society of America meetings were held in San Diego in December. I hope that many of our friends and colleagues will also consider joining us in May for the Boyce Lecture and the opening ceremony of our new building.

The other big changes to the Department are still in the works. We will begin to interview for two new positions in April and May. Also, it looks like we will be more than doubling the collection capacity of the Entomology Research Museum with the installation of a storage compactor system. The old entomology building will take on a new life as a temporary home for the collections while the compactors are installed over the summer months. In some ways, it is a return to the past with the collections returning to the spaces in which they were formally housed. In other ways, however, it is progress to the future with museum capacity that will serve the foreseeable needs for many years. As I said last time, and now believe more than ever, all the new spaces will enable us to carry our legacy of excellence well into the future.

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