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Illinois Research

Agricultural Experiment Station
Fall/Winter 1994

A Look into the Lives of Insects

College of Agriculture, University of Illinois at Urbana-Champaign, Volume 36, Numbers 3/4

The Cover

Two age-marked honey bees from the UI Bee Research Facility inspect the contents of the honeycomb. The red spots on their backs tell researchers their age. They were marked upon emergence as adults so that their age-related changes in behavior could be monitored. Photo by David Riecks.

Illinois Research

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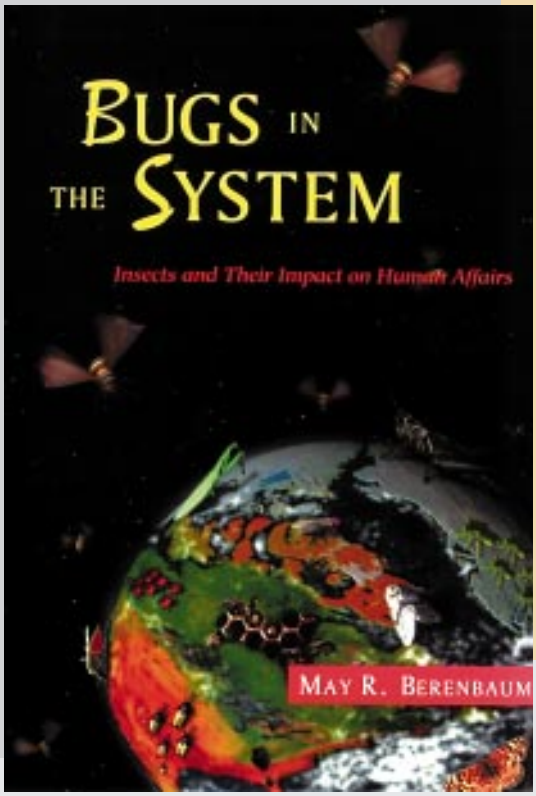

Did You Know...?

The insect facts found throughout this issue are based on information from the new book Bugs in the System: Insects and Their Impact on Human Affairs*, written by Professor May Berenbaum and published by Addison-Wesley. This entertaining book, packed with interesting facts and illustrations, is available at your local bookstore. The cartoons in this issue that accompany the insect facts were drawn by Jerry Barrett.*

A Look into the Lives of Insects

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Directions

Entomology at the University of Illinois

This issue of *Illinois Research* records many of the successes that the great institutions and scientists in this state have registered in the field of entomology, then goes on to discuss current endeavors and future needs.

Every citizen of Illinois benefits from our work with insects. Yet through the decades the support and recognition given to entomology in this state have ebbed and flowed. For this reason, two underlying messages in this issue are particularly significant: (1) the entomological work that was initiated with commitment and foresight well over a century ago is yielding great dividends because of the continuity of these efforts over time, and (2) the need for such work has never been greater!

By the time the University of Illinois was founded in 1867, Illinois already had a state entomologist, a testimony to the well-recognized importance of entomology dating back to settlement agriculture. The UI offered its first entomology course in 1869, emphasizing "classification of insects, habits of insects injurious to the region with means of checking their ravages, and habits of beneficial insects." By 1875 the UI harbored one of the largest insect collections in the "West," setting the stage for world-renowned contributions in collections and systematics that continue today.

During the late 1800s entomology was institutionalized in a unique fashion on the UI campus with the formation of the Illinois Natural History Survey and UI Department of Entomology. Entomological research, teaching, and outreach had become part and parcel of the land-grant mission on this campus by the early 1900s, contributing substantially to the rapidly growing agricultural economy.

The fact is, the early investment by the Illinois legislature, coupled with the scientific acumen and foresight of the first entomologists, institutionalized entomology in the state and profoundly benefited Illinoisans in short order while also bearing a strong influence on the emerging fields of natural history and ecology. For example, Steven A. Forbes, state entomologist, first chief of the Natural History Survey, and first head of the Department of Entomology, is considered to be the father of ecology.

The leadership trend continues.

During the past century, numerous faculty and alumni from this campus have assumed strategic roles in entomology and ecology at state, national, and international levels. Currently entomology on this campus is supported primarily by the Natural History Survey, the Department of Entomology in the School of Life Sciences, and the Office of Agricultural Entomology in the College of Agriculture. These units work closely together, addressing unique objectives while also having recognized areas of overlap. Most entomology scientists on campus accomplish various teaching, research, and extension responsibilities with appointments in more than one unit.

As you read this issue of *Illinois Research*, you may wish to contemplate how entomology at UI has contributed to:

- Our understanding of the interrelatedness of living and nonliving things
- The need for exploiting the wealth of information contained in our large entomological research databases
- The importance of insects as carriers of disease
- The vast array of beneficial insects, the real possibility of finding new life forms (even in Illinois), and the significance of insects to biodiversity on our planet
- How teaching, research, and extension should reflect our changing technology and knowledge base
- How nonnative insects established in Illinois portray both the good and bad consequences of exotic species
- How teaching about insects has become extraordinarily creative
- How team and systems approaches are required to address the emerging complex questions in entomology.

— Richard E. Warner, interim assistant director for natural resources, Agricultural Experiment Station

Photo-composite by David Recks

Experience a World That Until Now You've Only Stepped On

Doug Peterson

"Fish gotta swim and birds gotta fly; insects, it seems, gotta do one horrible thing after another," writes Annie Dillard in her Pulitzer Prize–winning book *Pilgrim at Tinker Creek*.

Insects are neither man's nor woman's best friend.

"Most of our encounters with insects are unwelcome and unpleasant," says May Berenbaum, head of the University of Illinois Department of Entomology. "People tend to run across them in their cereal and in their closets. And when your child comes home with head lice, it does not endear him to his classmates."

Because of the often adversarial relations between insects and humans, it's easy to overlook the contributions of these crawling, flying life-forms. But according to Berenbaum, one-third of our diet is due to the pollination services of insects. As she puts it, "Our meals would be pallid without insect-pollinated plants."

If not for insects, the germ theory of disease would have had to wait a while longer to be discovered. Louis Pasteur discovered the link between germs and disease when the silk industry in France hired him to study why silkworms were dying.

"Most people are completely unaware of the extent to which life and culture are shaped by insects," Berenbaum continues. "Insects have been present on every battlefield of every war and have determined the outcome of those battles more often than have bullets or bombs."

Case in point: When Napoleon's army marched on Moscow, his freezing troops pilfered the clothes from dead bodies. As a result, they were infected by typhus, a louse-borne disease that devastated the troops. Napoleon's army dwindled from 500,000 to 5,000 in a matter of months.

"Like it or not," Berenbaum says, "insects are part of where we have come from, what we are now, and what we will be. It seems to me that's a pretty good reason for getting better acquainted with them."

The University of Illinois has been doing just that — helping people become better acquainted with insects. A variety of UI programs teach young and old how to appreciate insects and how to manage their populations to produce healthy crops. The following are just a few examples.

Insect Theater

Broadway has its *Cats*, and the Illinois Natural History Survey has its Bugs.

Aimed at grades K–6, this joint effort between UI and the Survey combines puppets, people, music, and slides to teach basic biological concepts. The Theater's theme: Experience a World That Until Now You've Only Just Stepped On.

"Insects are very charismatic; you either love them or you hate them," says Mike Jeffords, public relations and education liaison for the Natural History Survey. "They are also so diverse that you can teach just about any biological concept using insects as models."

In addition to hand puppets, Jeffords makes use of colorful, human-sized costumes, which include a tiger swallowtail butterfly, lady beetle, garden spider, praying mantis, tiger mosquito, green stinkbug, and yellowjacket.

The Insect Theater debuted at the College of Agriculture's annual Open House in March, an event that drew more than twenty-one thousand visitors. Jeffords says they now hope to take the show on the road to schools.

"We want to show children that science can also include theater, art, and literature," he says. "We want to show that science has no hard borders."

Illinois Agricultural Pesticides Conference

Between 1978 and 1990, the percentage of Illinois corn acres treated with soil insecticides dropped from 65 percent to 33 percent. UI educators are partly responsible for this dramatic cutback, for they have been bringing home a basic message since the 1970s: Most corn following soybeans does not need a soil insecticide treatment.

One way that UI entomologists deliver such insect-control recommendations is through the Illinois Agricultural Pesticides Conference, conducted during the first week of January every year. The conference is one of the oldest of its kind in the nation, dating back to the 1940s, when

pesticides were just beginning to make an impact on agriculture.

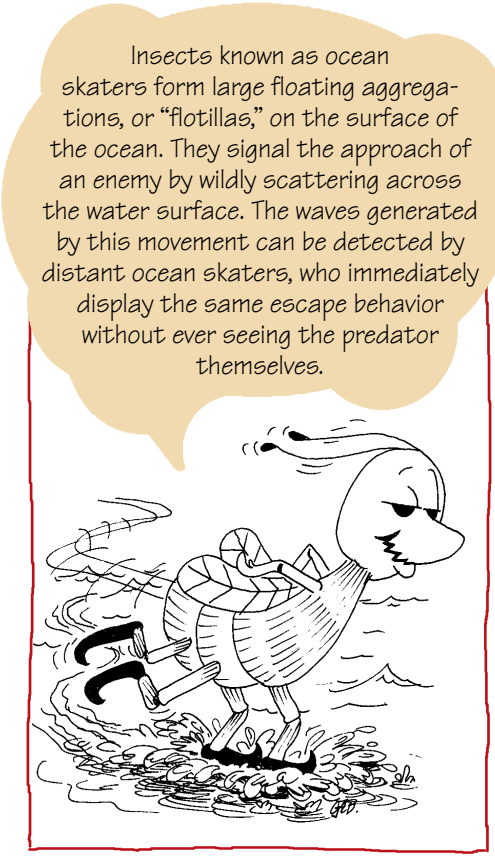
"At that time, pesticides were new and nobody knew how to deal with them," says Kevin Steffey, a UI Extension entomologist and chair of the committee that pulls together the conference.

According to Steffey, the conference was originally aimed at companies that sold and applied agricultural pesticides. But today it attracts anyone who does consulting work with farmers.

As more attention has come to bear on pesticides and the environment, the conference has adapted by putting greater emphasis on environmental issues, Steffey points out. It deals with groundwater contamination, pesticide drift, pesticide container recycling, environmental regulations, and ways to reduce chemical use.

In 1995, for instance, the conference featured new UI research on crops that have been genetically engineered to produce *Bt* — a microbial insecticide that can kill insect pests without posing a risk to humans. Organic gardeners often use *Bt* to control insects.

The key is helping farmers discover techniques that can reduce both costs and environmental damage, Steffey says.



Bugs BIGGER than Life

For readers connected to the Internet, here's a brand-new information resource. The UI Department of Entomology has a new "home page" on the World Wide Web. This fount of information includes not only details about the Department's academic program (including short biographies of faculty members, course offerings, and even an application for admission) but also a database of insect images and descriptive information.

The address for the home page is "http://www.life.uiuc.edu/Entomology/home.html". You need a World Wide Web browser and a link to the Internet to access it. Questions? Call Dave Lampe, Entomology Department, at (217)333-0489, or send e-mail to d-lampe@uiuc.edu.

Other on-line resources for insect information include the College of Agriculture's Cooperative Extension Service home page, "http:www.ag.uiuc.edu/welcome.html", and the Illinois Natural History Survey home page, "http: www.inhs.uiuc.edu:70/".

As he points out, "Education combined with economics is a powerful tool."

Pesticide Applicator Training Workshops

In addition to the Agricultural Pesticides Conference, the UI conducts about thirty-three workshops each year for commercial pesticide applicators, and anywhere from 150 to 188 workshops each year for private applicators. The purpose of these workshops is to assist professionals in obtaining certification.

Anyone who applies "general-use" pesticides commercially must be certified every three years. And anyone who applies "restricted-use" pesticides — even on their own property — must be certified, says Phil Nixon, UI Extension entomologist and pesticide training specialist. Many common insecticides used by farmers fall under the restricted-use category.

In 1993, Nixon says he and his colleagues trained more than ten thousand people in the private applicator training workshops and more than seven thousand in the commercial applicator workshops.

Crop Protection Workshop and Field Crop Pest Management Short Course

The annual Crop Protection Workshop is an in-depth, two-day event that covers the biology, identification, and management of insect, weed, and disease pests in Illinois.

The workshop attracts about three hundred people each year, most of them crop consultants, agronomists, agrichemical representatives, soil conservationists, farmers, Extension educators, pesticide dealers and applicators, seed company representatives, and anyone else interested in agriculture and environmental issues.

One unique feature of the Crop Protection Workshop is that participants can tailor their schedule to zero in on a few specific pest problems, says Mike Gray, a UI Extension entomologist and workshop coordinator.

For those more interested in a snapshot look at a wide variety of pests, rather than an in-depth examination of one or two pests, UI also offers a Field Crop Pest Management Short Course. This course serves as a good introduction for those who are new to agricultural consulting; it is also a good refresher course for veterans.

Crop Diagnostic Training and Research Center

On 20 acres in Indiana, they're intentionally infesting agricultural fields with insects. But it is not the work of entomological terrorists. It is routine at Purdue University's Crop Diagnostic Training and Research Center, where UI and Purdue specialists conduct hands-on workshops for professionals who work with farmers.

During these one-day workshops, agriculture professionals roll up their sleeves and venture into the 20-acre outdoor laboratory, says Gray. In the fields, they learn how to identify pests and pest damage, and they sharpen their crop troubleshooting skills.

"For example," Gray says, "we might infest the plants with European corn borer larvae. Then we take participants into the field, talk about the biology of the insect, and explain how to scout for the pest."

After participants break into smaller groups and arm themselves with calculators, they try their hand at estimating pest populations. They ultimately must decide: Based on these numbers of pests and other economic factors, should they treat with insecticides?

Insects and People

This brings us full circle back to May Berenbaum, who teaches one of the more popular entomology classes on the Urbana campus — "Insects and People." Berenbaum's course takes a broad look at how people and insects have interacted over the centuries, covering everything from insects in laboratories to insects in literature.

The course includes a honey biochemistry lab, where students measure the chemical and culinary attributes of honey; an aquatic biology lab, where they learn how to design an insect that can survive in an aquatic environment; and a forensic entomology lab, where they find out how insects can help determine the time of death. (Hint: It has something to do with maggots.)

In the silk lab, students unreel a silkworm cocoon, which consists of a single strand of silk one-half mile long. And in the edible insect lab, they create stir-fried silkworm pupae, as well as maengdana, a chili paste made from giant waterbugs.

David Reeks

Students in the University's "Insects and People" class examine insects' form and structure.

If expecting students to eat their homework in the edible insect lab sounds like cruel and unusual punishment, Berenbaum says to keep in mind that insects are not only nutritionally and economically suitable as a food source but also constitute part of the regular diet in many regions of the world.

According to Berenbaum, "Worldwide the most commonly consumed insects are those that are available in large quantities — specifically, migratory locusts or social species such as termites."

In the words of Alexis, the third-century Greek poet:

> For our best and daintiest cheer
> Through the bright half of the year,
> Is but acorns, onions, peas,
> Ochras, lupines, radishes,
> Vetches, wild pears nine or ten,
> With a locust now and then.

Doug Peterson, Extension communications specialist, Office of Agricultural Communications and Education

Honey Bees: Unlocking the Secrets of Colonial Rule

Gene E. Robinson

A honey bee sipping nectar from a flower in a garden, orchard, or field is a sight familiar to most of us. However, honey bees are not native to North America — they were brought to the continent by European settlers beginning in the 1600s. According to Professor Elbert Jaycox, an apiculture specialist retired from the University of Illinois, honey was so prized by early settlers of the Midwest that people even fought over it. The mercifully brief "Honey War" apparently started after a Missouri farmer cut down a few trees housing bee colonies packed with honey — on land also claimed by Iowa.

Honey continues to enjoy strong consumer demand, but honey bees now play a central role in U.S. agriculture primarily because of their pollination activities. Many of our nation's crops, including some grown in the Midwest, such as apples, alfalfa, and sunflowers, depend on insects to transfer pollen from one blossom to the next for high yields. According to a recent study conducted at Cornell University in New York, the value of crops that require insect pollination has been estimated at $10 billion. And honey bees are the premier insect pollinators of these highly valued crops.

Courtesy Agricultural Research Service-USDA

Courtesy Gene Robinson

UI bee expert Gene Robinson, top, examines the health of a hive and smells for bees releasing pheromones, chemical agents used for communication.

A bee researcher, left, places a powder containing biocontrol bacteria into a tray for dissemination by the honey bees.

Growers "rent" honey bees from beekeepers because they can be easily transported to the farm, by the millions, precisely when a crop is in bloom. Honey bees work relentlessly from dawn to dusk pollinating, though their behavior is actually motivated by the simple need to gather as much food as possible to feed the thousands of hungry mouths back at the hive.

The Cornell study also reported that recent changes in the U.S. diet have led to substantially higher production and consumption of many crops that rely on bee pollination. This trend is predicted to continue, especially for fruits and vegetables — so honey bees will assume even greater economic importance to agriculture.

How ironic, then, that while honey bees are becoming increasingly important, the U.S. beekeeping industry faces three grave threats. First, its profitability is being undermined by very low world honey prices, a consequence of "dumping" practices by some countries, according to several economists. Second, the recent introduction of two parasitic mites, *Acarapis woodi* and *Varroa jacobsoni*, has resulted in decreased colony productivity and the deaths of hundreds of thousands of colonies. Third, Africanized (alias "killer") bees have entered the United States from Latin America. Because they defend their hives more vigorously than do their European counterparts, Africanized bees are more difficult to manage for either honey production or pollination.

Of these three threats to the beekeeping industry, the first is economic and political. The second and third problems, however, are biological. The ability

of beekeepers to continue working with strong and manageable colonies of bees, despite these problems, will play a crucial role in determining whether enough bees are available to meet the current and future pollination requirements of U.S. agriculture.

Current bee research in the United States addresses both short-term and long-term concerns. Fundamental questions of basic bee biology are being studied at the UI Bee Research Facility. To maintain and increase colony productivity over the long term, I believe, we need to learn more about the physiological and genetic mechanisms that regulate honey bee social order, especially the colony's elaborate division of labor. Improved knowledge of hormonal and neurobiological factors that regulate bee behavior may lead to new techniques for manipulating the division of labor to improve colony performance for honey production and pollination. Understanding the genetic basis of bee behavior may lead to improved breeding programs to produce less defensive and more productive stocks of bees.

A number of research projects are under way at the Bee Research Facility to reveal bee secrets.

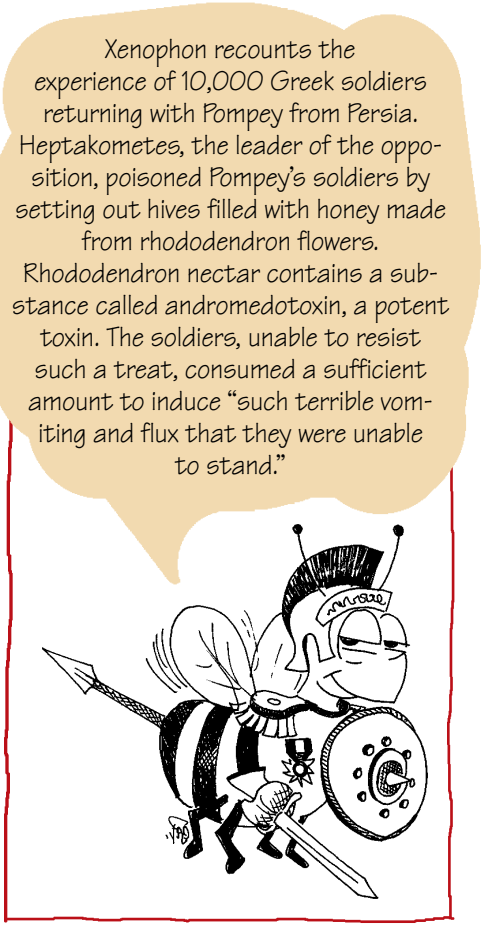
Flexibility in Honey Bee Career Choices

At the heart of colony organization is an age-based division of labor among the worker bees. A honey bee colony typically consists of reproductives — a single long-lived queen and anywhere from zero to several thousand drones — and tens of thousands of workers that perform all tasks related to colony maintenance and growth. Workers generally labor in the hive for the first two to three weeks of adult life; then they forage, gathering food outside the hive, for the next — and final — one to three weeks of their life.

This pattern is not written in stone, however. Bees can accelerate, retard, or even reverse the aging process on demand. For example, a surge in worker birth rates, due perhaps to favorable environmental conditions in late spring, may soon result in a colony that has too few foragers to handle the food demands of all the new young bees. Under these circumstances some young bees shorten dramatically their tenure as hive bees, from three weeks to one, and become "precocious foragers."

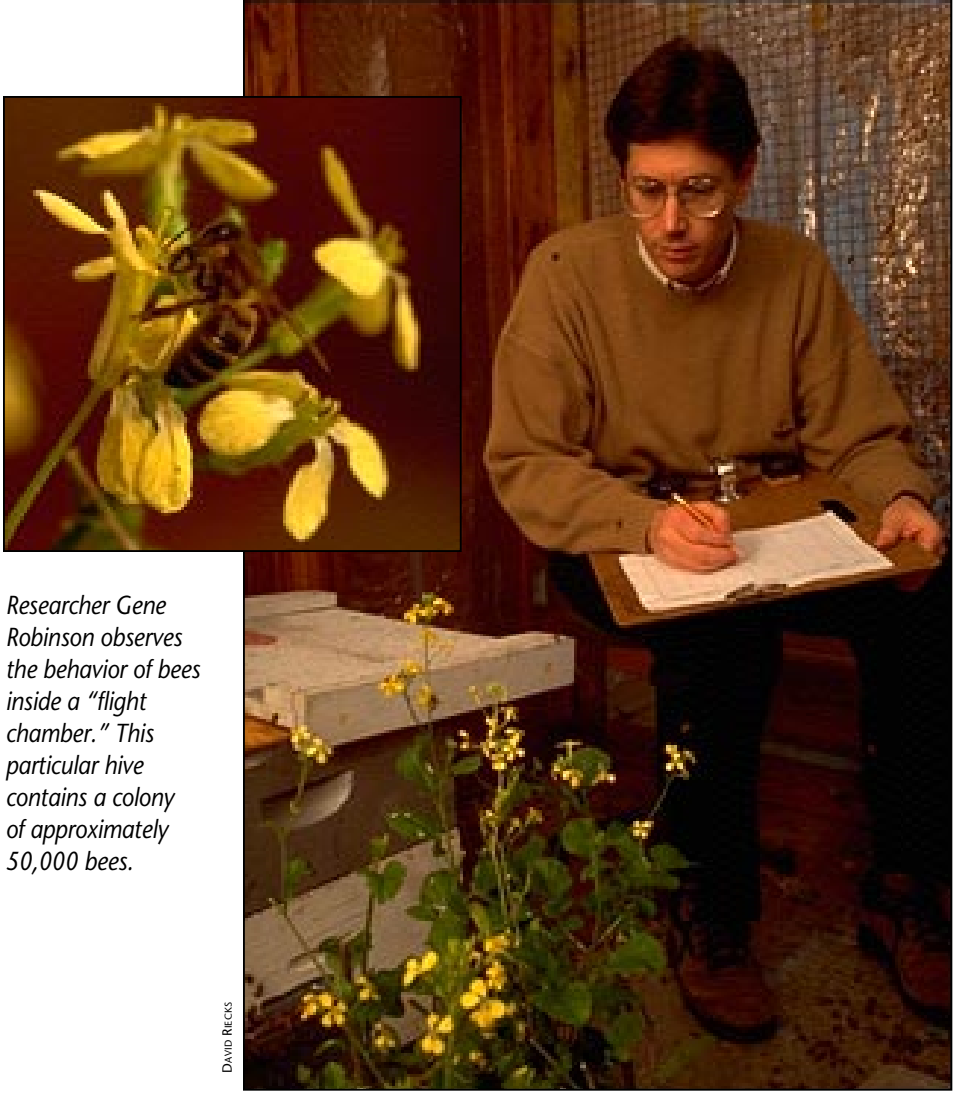
How can a young bee, in a society of more than 40,000 individuals performing a dozen or more tasks simultaneously, "know" that there is a shortage of foragers and change its occupation accordingly? It is inconceivable that each individual bee can monitor the state of the whole colony and then perform the tasks that are needed most. Another challenge to our understanding is that a honey bee colony apparently governs itself in a way alien to us — it functions without centralized government. There is no evidence of colony leaders — even the queen does not appear to direct worker bees from one task to another. It is necessary to solve the puzzle of how a colony can reassign its workforce in the face of changing conditions if we are to have any chance of someday manipulating the division of labor to increase pollination efficiency.

Research at the Bee Research Facility is probing mechanisms that underlie this remarkable behavioral flexibility. Scientists have discovered that juvenile hormone (one of the most important hormones influencing insect development) acts as a behavioral pacemaker in honey bees. Indirect evidence of its role can be found



Courtesy Gene Robinson

Gene Robinson demonstrates the installation of a new colony to students in his beekeeping class.



Researcher Gene Robinson observes the behavior of bees inside a "flight chamber." This particular hive contains a colony of approximately 50,000 bees.

David Recks

in the fact that hive bees have low levels of this hormone, and foragers have high levels. Direct proof has also been obtained: young bees given hormone treatments become precocious foragers.

Manipulating hormone levels on a bee-by-bee basis is one thing. Demonstrating that the bees alter hormone levels themselves in response to changing conditions is another. To do this, Robert Page of the University of California–Davis, Colette Strambi and Alain Strambi of the Centre National de la Recherche Scientifique in Marseilles, France, and I induced precocious foraging by establishing colonies that consisted initially of only very young bees. Then, testing for blood levels of juvenile hormone, we found that one-week-old precocious foragers have levels higher than those of one-week-old hive bees, but about the same as those of three-week-old foragers.

Building on these results, research associate Zhi-Yong Huang and I studied how bees actually acquire information on changing colony conditions. Using techniques inspired by developmental biology reminiscent of cell culture and transplantation (but manipulating organisms within a colony rather than cells within an organism), we demonstrated that bees are influenced by contacts with their hivemates and not by assessing the contents of the hive. This was shown by transplanting a group of foragers to a colony that consisted initially of only very young bees.

The transplant inhibited precocious foraging, even when the hive entrance was closed to prevent transplanted foragers from bringing back fresh nectar and pollen from outside. If the resident bees had been influenced by the hive, rather than by the foragers themselves, they should have developed into precocious foragers because of the lack of fresh food.

A further indication that foragers inhibit the aging of younger bees was revealed when we reared individuals in isolation in the laboratory for seven days. In the absence of older bees, isolated individuals had precociously high levels of juvenile hormone, and when placed into a colony they even acted as precocious foragers.

Based on these results, we developed a model proposing that the time it takes for a bee to grow up is regulated by the interplay between an "activator" and an "inhibitor." Juvenile hormone appears to activate behavioral development in honey bees. We are actively searching for an inhibitor; recent unpublished results suggest that there must be direct, bee-to-bee contact for the inhibitor to be spread. This raises the possibility that the inhibitor is a "contact pheromone" (a chemical mediator of behavior). Identifying this factor and further elucidating the activator–inhibitor model will help us understand how a bee adjusts its career choices to best serve the colony.

Africanized Bees

New strategies are needed to ameliorate the defensive behavior of Africanized bees. UI researchers have begun basic research on the physiological underpinnings of differences in the behavior of Africanized and European honey bees. Earlier research by Mark Winston of Simon Fraser University in Vancouver, British Columbia, suggested that Africanized bees grow up more rapidly than do European bees. Using European bees, student Tugrul Giray and I have confirmed that differences in rates of behavioral maturation do have a genetic basis. Employing colonies composed of bees with genetic markers, we have learned that some strains grow up more rapidly than others.

Working in Mexico with Ernesto Guzmán of the Universidad Nacional de México, Giray and I have begun to determine whether differences between Africanized and European bees in rates of behavioral maturation are due to differences

Bee Lab Abuzzzz with Activity

Tucked next to a pocket of prairie on the so-called South Farms research plots sits a modest building with a few short towers of wooden boxes standing about in the grass. Here at the University of Illinois Bee Research Facility and eight other area apiaries, or beeyards, the behavior of millions of honey bees is being scrutinized and manipulated. The hope is that discoveries about how the bees organize their work will one day enable scientists and beekeepers to improve bee productivity.

The "bee lab," one of just twenty or so such facilities in the country dedicated to honey bee research, is a relative newcomer to campus. When Professor Gene Robinson was hired by the University's Department of Entomology in 1989, such a lab was a prerequisite for his work. The South Farms building was made available, and Robinson and technician Jack Kuehn set about outfitting the new lab.

Kuehn traveled throughout Illinois to find and buy colonies of bees from "sideliners," beekeepers who maintain a limited number of hives. A key selection criterion was that colonies be free from disease and from two species of destructive parasitic mites. The mites, though only patchily present in the state then, have in just five years become a serious problem in Illinois, as they already were in much of North America and the world.

The number of hives kept by the lab fluctuates between seventy-five and a hundred, with the highest populations in summer, when colonies are strong and bees are actively at work. In spring, after the queens have laid eggs, lab workers transfer the bee pupae to a temperature-controlled incubator one day before the pupae emerge as adults from their wax-capped cells. When they are a day old, these new adult bees, which cannot yet fly or sting, are put into a shallow bin. Each is picked up and marked — with paint or even a tiny numbered badge — according to the needs of the research under way.

The young bees might also get treated at this stage, perhaps with a hormone or neurochemical. Then the bees are placed in a hive, either outside or in one of the lab's observation spaces — thin, glass-walled structures that allow the activity inside to be easily monitored. Queens are typically artificially inseminated in the lab to control the genetics of the resulting bees.

Like the bee populations, the number of people working with them is highest in summer: typically five to seven graduate students and five to ten undergraduates assist with the work, along with postdoctoral researchers. Bee research dovetails unavoidably with beekeeping, and students who work with Robinson and Kuehn become adept at managing colonies. One student has already gone on to teach beekeeping with the Peace Corps in Ghana, West Africa.

One other activity keeps the bee lab busy in late summer — answering calls about local bee problems. Honey bees actually almost never go after picnic food. That pest trying to crawl into your soda can is probably a wasp instead. — *Molly Bentsen, publications editor, Office of Agricultural Communications and Education*

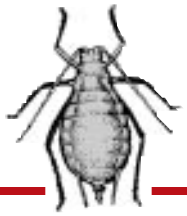
in their activator and inhibitor mechanisms. Recent unpublished results indicate that Africanized bees indeed grow up more quickly and that these differences can be explained in terms of the activator–inhibitor model. We also have begun to explore the intriguing possibility that differences in rates of behavioral maturation are related to differences in defensive behavior. Because older bees are more defensive than younger bees, it stands to reason that a colony of faster maturing bees might be more defensive than a colony in which bees grow up more slowly. It is hoped that these two studies together will provide fundamental knowledge useful for developing novel control strategies for Africanized bees.

Applied and Basic Research: A Lesson from Reverend Langstroth

As in other areas of agriculture, beekeeping has benefited tremendously from a healthy mix of applied and basic research. In fact, the practice was revolutionized by an observation of basic bee biology in 1851 by Reverend L.L. Langstroth, an amateur beekeeper from Philadelphia who documented his avocation in personal journals and a published instruction book.

Before Langstroth, beekeeping was a primitive affair. Honey harvesting often resulted in the death of the colony, because bees affixed their honeycombs firmly to the walls of the tree or skep (a beekeeping basket) in which they lived. Langstroth observed that there is always ¼- to ⅜-inch space between the honeycombs that bees build. He created a beehive with movable frames of honeycombs by ensuring that the combs were separated from the hive walls by this precise "bee space." Beekeepers were for the first time able to harvest honey without killing the bees and damaging other parts of the hive, thus greatly increasing productivity. The honey bee's vital pollination services may be further enhanced by future insights into bee behavior.

Gene E. Robinson, University Scholar and associate professor, UI Department of Entomology



Size Isn't Everything: Insects as Powerful Vectors of Disease

Tina M. Prow

When seven whooping cranes died a decade ago at the Maryland Wildlife Research Center, researchers traced the cause to mosquitoes. Mosquitoes had transmitted eastern equine encephalitis to the endangered species.

Once researchers identified the disease in whooping cranes, they captured and vaccinated adult birds. Young birds, which cannot be vaccinated, remain at risk.

Mosquitoes also are linked to lethal disease in other birds, such as sandhill cranes and scrub jays.

"These cases and many others show why we are still concerned with the mosquito as a nuisance and a transmitter of diseases that impact man and animals," says Robert Novak, a medical entomologist with the University of Illinois and Illinois Natural History Survey. Novak specializes in mosquito ecology, control, and surveillance and focuses his research program on mosquito management for protecting public health. Last year, he broadened his program to include wildlife, a move that fits the human health focus.

"When you think about the impact of these pests on an endangered species like the whooping crane and the possible long-term effect on other birds and animals, it's like a two-by-four to the head of a mule — if we look at pathogens in a preventive mode at the wildlife sector, it may be possible to interdict early. Why wait until we get human cases of disease? Why wait until an endangered species dies out?"

Human Ailments Brought by Insects

According to the National Academy of Sciences, eighteen of fifty-two infectious diseases of humans are insect-borne. Of those, sixteen are transmitted by mosquitoes. "The threat is there and increasing as the globe shrinks — as we move things and people so rapidly that there are virtually no quarantine periods," Novak notes.

Petroleum-based insecticidal oil products, such as No. 2 diesel oil, have been the mainstay for control of mosquito larvae in a variety of wetland habitats. These products coat the surface of water and suffocate larvae. "They work, but we are concerned about what petroleum-based products do to plants and aquatic life," Novak says.

One of Novak's most recent projects may provide an alternative to petroleum-based products and an alternative market for soybean producers. Collaborating with UI researchers David Seigler, a natural product chemist, and Robert Metcalf, an entomologist-toxicologist, Novak is looking at the potential for using soy oil products for mosquito control.

Soy oil appears promising because it is biodegradable. Furthermore, researchers are looking for a formulation that will break down quickly — in twelve to twenty-four hours. They will study how soy oil breaks down in the environment and what effects, if any, it has on plant and aquatic life.

Researchers also will look at the potential for soy oil to carry pathogens that could kill mosquitoes not suffocated by the oil. A soy-oil product might also carry other biological control agents that are toxic to or repel or attract mosquitoes.

"There are many neat things about this oil and a plethora of things we could look at. For instance, if secondary compounds that have insecticidal properties could be added to the oil, it could allow a holistic approach to pest management," Novak says.

Despite excitement over the possibilities, however, the team is starting at the

beginning, he adds. That is, they are reviewing research literature and screening formulations of soy oil to find an oil that spreads as desired and degrades quickly. They also plan to look at the effect of different doses and formulations on the larvae of "bad-news mosquitoes," those that carry malaria and other diseases. The team will assess toxicity to plants and aquatic life.

"We'll do a lot of laboratory work before we move into controlled field experiments," Novak says. "One of our goals is

to gain as much information as necessary, which then could be used for registration by the Environmental Protection Agency."

The research has potential applications beyond mosquito control, Novak notes. If successful, soy oil products could be used to control whitefly in greenhouses, borers in orchards, and other pests managed with petroleum-based insecticidal oil products.

Insects Can Transmit Disease to Crops, Too

Farmers contend not only with insects that feed on their crops but also with the diseases they spread. Aphids, leafhoppers, whiteflies, and several beetle species are among the most common carriers of disease pathogens in Illinois.

Cathy Eastman and Michael Irwin, entomologists with the University of Illinois and Illinois Natural History Survey, are studying barley yellow dwarf disease. Eastman ranks this disease of wheat, oats, and other small grains among the most important of plant diseases worldwide. Barley yellow dwarf virus strains are most commonly transmitted by certain species of aphids that can carry the disease into a field from as far away as the southern United States or as nearby as a neighboring plant.

"Barley yellow dwarf causes a sizable dollar loss to crops. Estimates from Indiana suggest 10 percent of losses in wheat are attributable to barley yellow dwarf," Eastman says.

Yellowing, stunting, poor grain production, and winter kill of plants with affected root systems are symptoms of barley yellow dwarf. However, these symptoms may be nondescript in wheat or may mimic nutrient deficiencies. As a result, barley yellow dwarf may go unrecognized in fields every year, Eastman says.

Eastman and Irwin's barley yellow dwarf research, conducted in cooperation with the UI Department of Plant Pathology and U.S. Department of Agriculture, as well as with the Natural History Survey, focuses on the epidemiology of the disease. Researchers are looking for clues to how aphids pick up the disease and then transmit it. They also are looking for factors that influence spread through a field.

The role of perennial grasses and grassy weeds as a reservoir for the virus is one aspect of the research. Eastman's team inoculated mini-plots with the virus and sampled them over time. Molecular biology techniques will allow the researchers to assess whether the strains of virus they detect are those they introduced or are those brought in by migrant aphids. From this study, the team hopes to determine how important local plants are as a reservoir for barley yellow dwarf.

A second phase of the project involves planting a spring oats–grass–wheat rotation. Researchers are sampling for presence of barley yellow dwarf virus and looking at the dynamics of aphid populations over time. This research may yield information on the role of grasses in disease spread and factors that set off an epidemic.

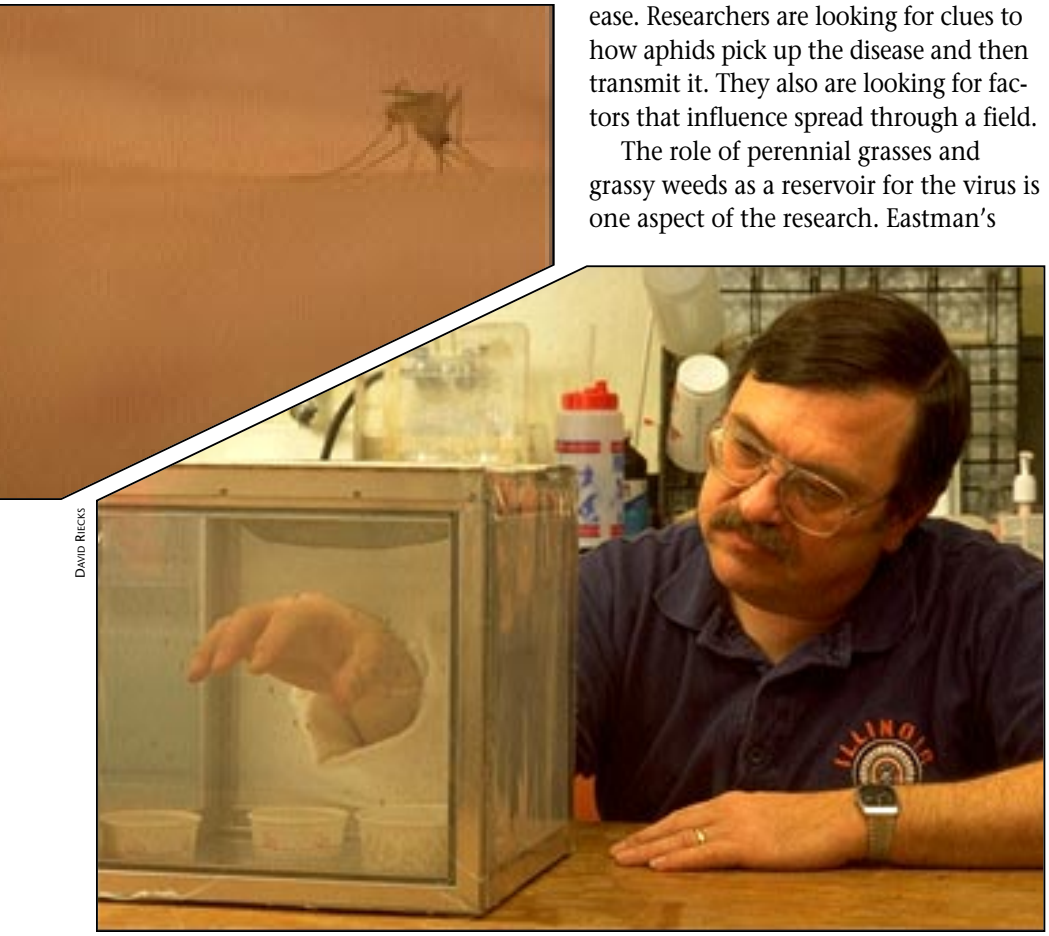
The Ins and Outs of Insect Flight

One key piece of information for managing aphids and other migratory insects is knowing when they are likely to show up. Michael Irwin's research in aerobiology, or insect flight, is a step toward developing an early forecast system.

"It is practical," he says. "The lack of research on how insects move is a major bottleneck, but researchers are finding ways to share technology and information across projects so that the costs will be more reasonable. Eventually, we will characterize the movement of weekly flying insects, such as aphids."

Irwin and his UI colleagues Scott Isard and Gail Kampmeier are part of the Alliance for Aerobiology Research, a national group of scientists coordinating plans to foster an integrated, multidisciplinary approach to research on how insects migrate and disperse. Irwin's pioneering research on the mechanics of aphid flight began more than a decade ago. Among the aphids that interest him are species that transmit soybean mosaic virus.

"We see soybean mosaic virus epidemics in this area when the aphids arrive at just the right time. If we imported seed that carried inoculum or if aphids native to China got in, we'd see a lot more of it," he says. "It behooves us to be prepared — if we don't know the mechanics of the causes, it will be hard to know how or when to intercede."



David Riecks

Culex molestus *mosquitoes feed on the arm of medical entomologist Robert Novak.*

Courtesy Mike Irwin

David Recks

A helicopter takes off with two large pods attached for collecting insects for research on insect flight.

At right, Mike Irwin (left) and Scott Isard of the Illinois Natural History Survey study flight patterns of aphids in a wind tunnel they constructed.

In Illinois, many of the most economically important species of aphids die out over the winter. Yet they are back each growing season, arriving on wind currents along with other insects, including the black cutworm and potato leafhopper.

To track aphids, Irwin collaborates with scientists having expertise in insects, diseases, engineering, crop development, and weather. For a 1984 project focused on corn leaf aphids, the scientists collected aphids in sampling "pods" attached to helicopters.

Since then, they have used radar to detect aphids in various air currents that move them from the Gulf of Mexico to Illinois and even farther northward. The scientists have tethered the tiny aphids and put them in a wind tunnel to measure use of energy in flight. Computer modeling has proven to be an important tool for studying population dynamics.

As a result of the broad collaboration, scientists can catch an aphid high in the air and determine how long it has been flying and where it came from. They know that aphids land only if they can see the ground. So if the aphids get caught in a wind current at night, they are likely to continue flying until daylight. Aphids are not distributed randomly through the air. Instead, they form layers in the air currents. Some are predisposed to flapping their wings and moving up into higher air currents, whereas some are not.

Aphids of different genetic backgrounds may travel together. In different years, researchers found, aphids invaded Illinois from different places. Irwin also notes that aphids ignore international boundaries. Studies show that aphid genetics are not consistent, which suggests there is no permanent source of aphids, at least not within the United States.

Studies using helicopters to sample aphids in different atmospheric conditions indicate temperature is a factor governing their distribution in the air. Strong night currents will move some aphids from the Gulf into Illinois, depending on where they are in the atmospheric layers. They land in waves throughout the season, arriving much like troops on a beachhead. Once a wave arrives, the aphids will move in a field but will not catch another air current.

"Now we can predict how far aphids go in the night and what level they will be at," Irwin says. "Understanding the whole system makes an areawide integrated pest management approach for controlling aphids feasible."

Tina M. Prow, science writer, Agricultural Experiment Station

Biological Pest Control: Good Guys vs. Bad Guys

Tina M. Prow

In an effort to reduce the amount of synthetic chemical pesticides used in crops and gardens, researchers are looking more closely at a strategy Mother Nature uses to keep pests in check — natural enemies.

Almost all pests of field, horticultural, and ornamental plants have natural enemies, according to Robert Wiedenmann, an entomologist with the University of Illinois and Illinois Natural History Survey. Wiedenmann is a member of the Ladybird Committee, a group of Midwest biological-control scientists whose emblem is the ladybird beetle, or ladybug. Wiedenmann and his colleagues not only are working on ways to make better use of the natural enemies that kill pests of important agronomic crops but also are taking steps to teach farmers, gardeners, and consultants how to use biological controls as a pest management option.

"There is some uncertainty associated with biological control," Wiedenmann acknowledges. "It may work one year and not the next, or it may work in one habitat and not another. But that doesn't mean the approach should be condemned."

In fact, he points out, biological control has a longer history as a pest management strategy than synthetic pesticides. Centuries ago, Chinese farmers used ant nests from the countryside to control certain orchard pests. When California's citrus groves were threatened in the 1800s by cottony cushion scale, an entomologist searched its native habitats in Australia and New Zealand for an enemy. He sent back the vedalia beetle, which brought cottony cushion scale under control.

Since the 1940s, many farmers have relied on synthetic chemical pesticides to manage pests. More recently, however, concerns about the risks synthetic chemical pesticides may pose to human health and the environment are causing farmers, regulators, and scientists to take a harder look at biological control.

"The problem of ag chemicals in groundwater is a serious and growing concern," Wiedenmann says. "In addition, many pest problems in agriculture aren't solved by pesticides but are in some cases *created* by pesticides."

For instance, chemical pesticides that eliminate insects, including natural enemies, actually can cause certain pest populations to explode. In contrast, the intent of biological control is not to eradicate pests but to keep pests at low enough levels that they cause little harm to the crop. After all, some levels of pests are required for the populations of natural enemies to feed on, Wiedenmann points out.

Another problem with synthetic chemicals is that the cost of developing and reregistering products soon may leave farmers with only broad-spectrum pesticides. These kinds of pesticides are more likely than others to cause resistance.

"There is potential for increased use of biological control to manage certain pests effectively without the risks we have from ag chemicals," Wiedenmann says. Biological control, he suggests, can fit into any integrated pest management program — and likely already is a part of many.

Beneficial Insects: The Good Guys

Illinois farmers see biological control, compliments of Mother Nature, at work almost every year in alfalfa fields when the fungal pathogen *Zoophthora phytonomi* and parasitic wasps wipe out the alfalfa weevil population.

Four broad groups of beneficial natural enemies control pest insects: predators, parasites, nematodes, and pathogens.

David Riecks

A Toxorhynchites mosquito larvae feeds on a Culex pipiens *(northern house mosquito) larvae. The* Culex pipiens *is known to transmit St. Louis encephalitis.*

New Resource on Biological Control

"Remember: many insects in a crop or garden are beneficial or are merely transients with no particular impact on the crop," say Daniel L. Mahr and Nino M. Ridgway, authors of a book on biological control published by the University of Wisconsin. Their book, *Biological Control of Insects and Mites: An Introduction to Beneficial Natural Enemies and Their Use in Pest Management,* is 92 pages long, with an index and color photos. It is available for $14 from the Office of Agricultural Communications and Education, 67-IR Mumford Hall, 1301 W. Gregory Drive, Urbana, IL 61801, (217)333-2007. Ask for North Central Regional Publication 481.

About one hundred types of predatory and parasitic insects, along with a variety of insect-parasitic nematodes and insect pathogens formulated as microbial insecticides, are commercially available.

The ladybird beetle is an example of a predator. Among its prey are aphids, scale insects, and white flies.

Parasites lay their eggs in or on pests. Later, the larvae from these eggs feed on the pest. Parasitic wasps kill a host of pests, including caterpillars, weevils, greenhouse whitefly, and moth eggs. These wasps are different than stinging wasps that chase people from picnic areas; those in Wiedenmann's laboratory are smaller than the period at the end of this sentence.

Ladybird beetles, or ladybugs, are important "good guys" in the fight to control crop pests.

Nematodes, which are tiny worms, kill several soil insects. A few types are mass-produced and sold for pest control.

Pathogens include bacteria, viruses, protozoans, and fungi, which act as lethal diseases in certain insects. *Bacillus thuringiensis*, or *Bt*, for example, kills caterpillars, some beetle larvae, and mosquito larvae. Several strains of *Bt* are marketed for insect control.

"The action of biological control on enemies is very specific," Wiedenmann says. "People who are interested in biological control must buy or look for the very particular natural enemy that preys on the very particular problem pest they have."

Researchers conduct extensive laboratory and field tests to find which biological control agent might work against a certain pest; why it works or fails; and against which other insects the control agent might be effective. They take three approaches to biological control.

Creating an Attractive Home for Beneficial Insects

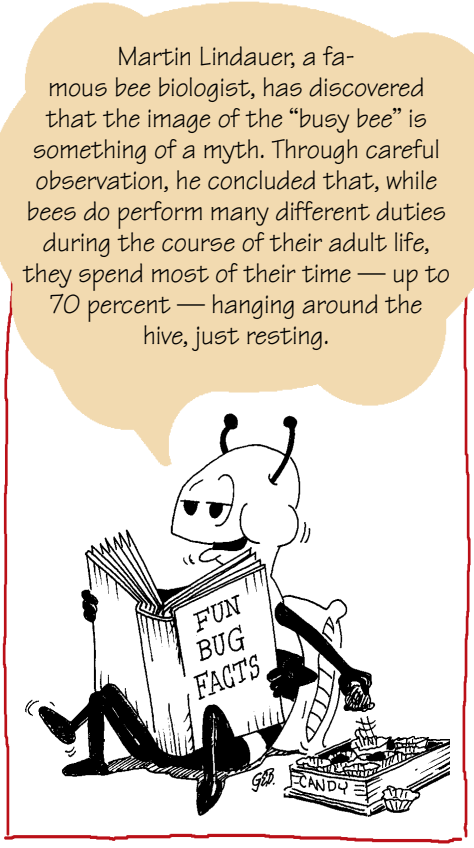
One approach to biological control is to manipulate the habitat to allow natural enemies that are already in a field to thrive. For instance, vegetation around a field may provide a habitat for ladybird beetles, minute pirate bug, spiders, and other predators. Row crops are especially unfriendly to many natural enemies of crop pests, Wiedenmann says.

"Much of the research with species that might control European corn borer has been unsuccessful," he says, "possibly because the corn environment simply doesn't provide a friendly habitat for these natural enemies."

Another approach is to augment the population of natural enemies by adding to what is there. For example, *Trichogramma* wasps in seed corn appear to be as functionally effective and cost-effective as chemical pesticides for controlling European corn borer.

"The intention with this strategy is not to establish a permanent population. In most cases, natural enemies would not overwinter," Wiedenmann says.

In contrast, a third approach to biological control is to bring in a natural enemy



from elsewhere and release it for permanent establishment. About three-quarters of the field-crop pests are exotic, notes Wiedenmann. They often are a problem because they arrive here without natural enemies.

"The idea is to return to the original home of the pest, determine what natural enemies were keeping it in check, and import a potential enemy to the United States to study," he says. The research on any imported biological control includes quarantine and extensive studies to ensure the natural enemy is an enemy of the target pest and not of Aunt Martha's tomatoes.

"The safety record is good," Wiedenmann says of this research. "Historically there are almost no recent examples of biological control agents having a bad effect or an impact on nonhost plants."

One of Wiedenmann's current projects is to find parasites of stalk-boring insects, such as the European corn borer. Japan, Pakistan, and East Africa have provided several parasites of corn borers, but their eggs do not hatch on European corn borer. Wiedenmann wants to know why and continues to study the interaction. As a practical measure, however,

This parasitic wasp, Xantho pimpla, *is laying eggs into the European corn borer pupa that is growing inside the cornstalk. In the future, this species of wasp may help control corn borer infestations in Illinois cornfields.*

Farmers Help Solve Pest Management Problems

As the eastern sky begins to glow on a crisp, fall morning, farmer John Smith gets ready for another day. He checks the combine and pulls the grain carts out to the field. But before today's harvesting begins, there's a different kind of chore he needs to do — data collection.

Nowadays farmers are doing more than farming. In addition to the tractor and hoe, farmers are taking up the clipboard and computer. They are using their farms as living laboratories to conduct what has come to be known as on-farm research.

On-farm research isn't new. Farmers have always "experimented," but much of today's on-farm research is substantially more technical than the side-by-side comparisons Grandpa use to fiddle with on the back forty. And we're not talking about a university researcher using the farmer's field to do university research. On-farm research today involves farmers working in partnership with university researchers using legitimate research methodology to test ideas for developing farm operations that are environmentally friendly and financially profitable.

Why should farmers do research on their farms? Isn't that the job of the land-grant university?

Land-grants have succeeded in developing the most productive food production system in the world. But the very system that has given us abundant, affordable food has also created problems that could threaten our ability to sustain a healthy, abundant food supply for the world population. Many in the land-grant system recognize the need to address these issues. Farmers, too, are becoming aware of problems as they come under fire from environmentalists for certain farming practices.

As end users of land-grant research, farmers need to be closely involved in the process of finding solutions to today's agroecological dilemmas. Researchers working in partnership with farmers are discovering the wealth of experiential knowledge farmers possess after generations of working with the land. At the same time, farmers are helping researchers apply scientific knowledge in ways that are practical and useful in the real world.

Mike Gray and Kevin Steffey, agricultural entomologists at the University of Illinois, are working with twenty-nine farmers on a two-year project to develop a method to determine the need for pesticide use in continuous corn. Even though research has shown that pesticides are not necessary every year in every field of continuous corn, farmers apply it routinely in those situations.

"Most studies show that an accurate count of the adult rootworm beetles can predict the extent of the damage in continuous corn the following year," Steffey says. The problem is, farmers aren't taking the time to count, or they don't feel confident when they do.

The entomologists are providing tools and training the farmers in a new method for determining the severity of rootworm infestations. As one part of the project, the farmers set out traps, replaced them weekly, counted the trapped beetles, and mailed the data in to Gray and Steffey. The scientists followed up by visiting the fields and assessing root damage in an attempt to correlate it to the beetle counts supplied by the farmers.

This kind of collaboration with farmers is the best way for researchers like Gray and Steffey to develop practical methods for improving pest management on the farm.

— Daniel Anderson, on-farm research coordinator, Agricultural Experiment Station and Cooperative Extension Service

Cool Tactics for Managing a Hot Crop's Pests

Illinois may be good at producing corn and soybeans, but it is tops at producing a lesser known but no less tasty crop — horseradish.

Illinois leads the nation in production of this fiery root. The state's horseradish is grown mainly on 1,200 acres in the "American Bottom" floodplain area of Madison, St. Clair, and Monroe counties (in the Mississippi River Valley near St. Louis), where it has been a valued specialty crop since the turn of the century.

David Voegtlin, Illinois Natural History Survey

A perennial crucifer grown commercially as an annual, horseradish is an unusual crop. Hand labor is needed throughout production. Secondary roots saved from the grower's previous crop provide the planting stock. The growing season is seven to twelve months, depending on market conditions. It is a dominant weed in rotation crops because it can sprout from root pieces buried deep underground.

Dan Sherrod, Illinois Natural History Survey

Cathy Eastman

The imported crucifer weevil adult, top, and larva, middle, kill horseradish by feeding on its roots. Fields of horseradish are a common sight in the Mississippi River floodplain near St. Louis.

The crop's availability year-round makes horseradish quite a challenge for insect pest management. Research and extension programs to improve methods of managing insect, disease, and weed pests of horseradish have been a unique part of the UI Agricultural Experiment Station and the Illinois Natural History Survey since the early 1930s.

Horseradish is attacked by several insect species, most of which are not native to this hemisphere. Studies by Illinois entomologists for nearly twenty years have made it possible to determine which species are truly pests. Today there are no insect pests on the crop that require treatment every year. There are several, however, that sometimes reach damaging levels on vulnerable stages of the crop's development.

Leading the list of horseradish insect pests are the imported crucifer weevil and beet leafhopper. Adults and larvae of the weevil, an introduced pest found in 1977, attack roots directly and can kill young plants or contaminate harvested roots if present in large numbers. The beet leafhopper was identified in 1980 as a vector of the spiroplasma causing brittle root, a devastating disease that has destroyed 60 to 80 percent of the Illinois crop during epidemics usually coinciding with drought. Several leaf-feeders are occasional pests, including diamondback moth larvae, flea beetles, and false chinch bugs, which can occur in huge numbers per plant during drought conditions but seldom produce more than minor frostlike damage.

Current pest management guidelines for growers of Illinois's hottest crop can be summed up with the words, "Keep cool — don't apply insecticides until there is a real need." Insect pests of this crop are sporadic and seldom require treatment, and overuse of insecticides can create additional pest problems. A hardy plant, horseradish can withstand nearly 50 percent defoliation without affecting yield.

The need for treatment to control the beet leafhopper (a migrant into Illinois) and other sporadic pests can be assessed by careful monitoring of insects present in individual fields. To this end, a pilot project between UI Cooperative Extension Service personnel and the consultant service Alvey Laboratories has resulted in a successful scouting program that provides specific pest information to participants and, through Extension advisories, shares leafhopper and disease findings with growers as a whole. These programs, backed by years of research, are helping to increase grower recognition of pest and beneficial insects and to reduce insecticide applications. — *Cathy Eastman, entomologist, Illinois Natural History Survey*

he also is moving on to another potential biological control agent, this one from China.

"In the search for biological control agents, real opportunities and unimagined benefits come from looking at pests in the field — how they work, and how the crop is grown, and seeing what we might do to make an amenable environment," Wiedenmann says. "It's a way to narrow down and cut the probability of failure — and to make discoveries that you just can't anticipate."

Identifying potential biological control agents is only a first step — scientists follow up with laboratory and field research to understand as much as possible about the agents. For instance, one of Wiedenmann's students is "vaccinating" soybean with soybean mosaic virus to study the effect on the minute pirate bug. This insect feeds on soybean but also may be an important predator of soybean pests.

"How does the neatest thing since sliced bread affect other players? Does it create worse pest problems? Better predators? We need to ask these questions and have answers before we move forward," Wiedenmann says.

Practicing What They Preach

Research in biological control is not all "egghead science done in the laboratory," Wiedenmann says. Some projects have components that will be carried out by Cooperative Extension Service specialists working with growers. Involving farmers is a way to ensure success and to get more farmers thinking about using biological control agents as part of their pest management operations.

"Education about biological control increased adoption in Texas and California," he says. "We think more farmers in the Midwest will consider adding biological control to their management strategies when they are involved and when the topic is common enough that they're talking about it over the fence or at the grain elevator."

To that end, the Ladybird Committee sponsors summer institutes and short courses on biological control to update farmers, consultants, and others in agriculture on research and biological control strategies.

"We know we're not going to change agriculture from reliance on chemical pesticides, and that's not the intention; chemical pesticides will probably always be a component of pest management programs. But there is greater potential for biological control than I think some in agriculture realize. So the challenge is: What small and acceptable change is possible?

"That's why research is important. We've got to have evidence in order to recommend that farmers leave grassy strips that support natural enemies, or put out parasites when corn borer eggs are predicted to hatch. That's our job — to provide them with the information they need to make rational choices," says Wiedenmann.

Computer Modeling

An increasingly important tool for organizing information into a "representation of reality" is the computer model. A computer model can be constructed to help researchers home in on a researchable question and to help farmers weigh the consequences of pest management decisions.

Computer models are among the tools used to develop economic threshold calculations. These thresholds — often expressed as the number of pests present or the percentage of crop damage that will affect yields — are a cornerstone to integrated pest management strategies developed to promote judicious, effective, and safe use of pesticides on crops.

For instance, a model developed for European corn borer management resulted in a spreadsheet exercise in the *Illinois Agricultural Pest Management Handbook*, a 360-page book published annually by the Cooperative Extension Service. The spreadsheet leads growers through a set of equations related to the European corn borer population, yield loss, and economic considerations. Farmers can use the spreadsheet to determine whether the corn borer population warrants treatment.

Computer models typically are developed for pests of crops grown on a large number of acres or highly valuable crops. Alfalfa weevil, potato leafhopper, European corn borer, corn rootworm, and black cutworm are among field-crop pests researchers focus on in Illinois.

Tina M. Prow, science writer, Agricultural Experiment Station

Chris Doll

The International Horseradish Festival, held annually in Collinsville (Madison County) on the first Saturday in May, attracts thousands of new converts to the delights of freshly ground horseradish. This year's festival will be held May 6–7. For information, call (618)344-2884.

Recording the Rich Natural History of Illinois

John Bouseman

When the early explorers and settlers entered the area destined to become the state of Illinois 250 years ago, they encountered a nature preserve 56,400 square miles in extent. Since then, much of the original natural diversity has been replaced by cultivated land, urban and suburban development, and a vast network of transportation.

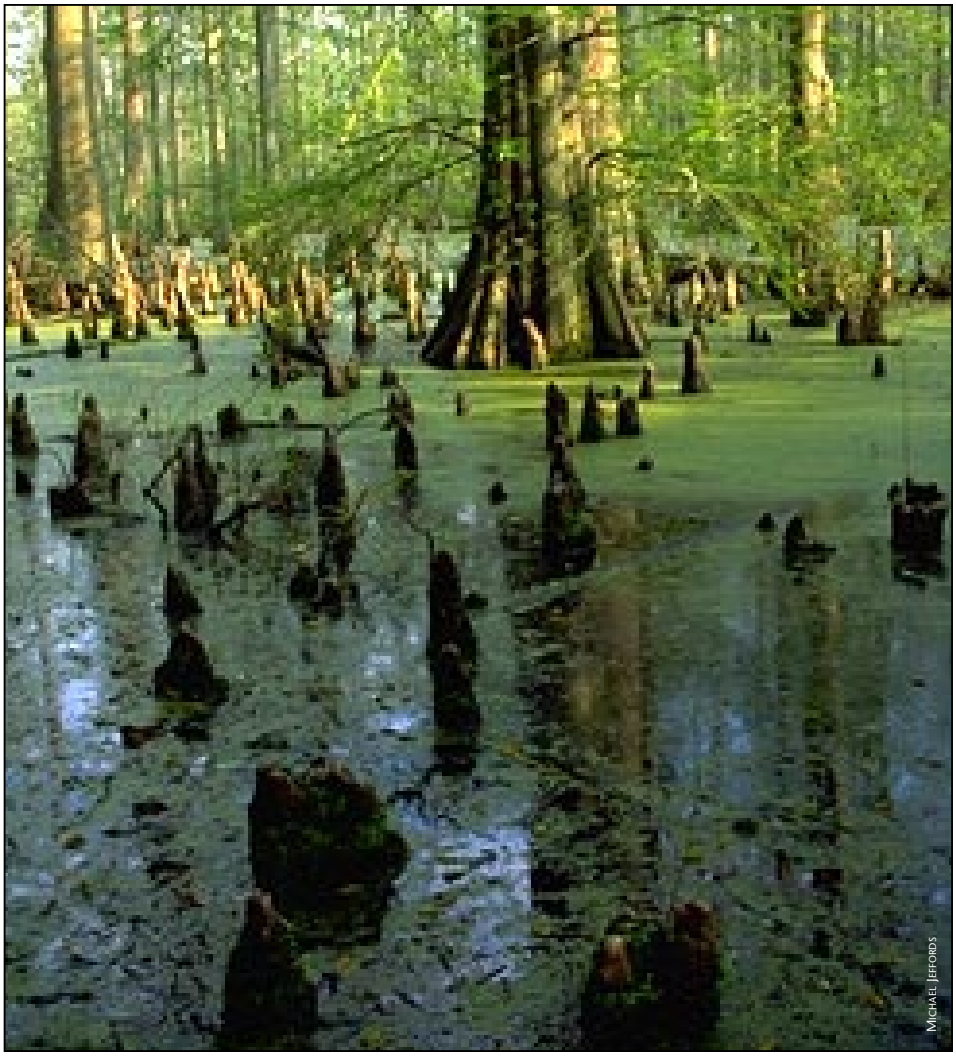
Of the state's 36.1 million acres, some 33,356 acres are preserved and protected in the Illinois Nature Preserves System. This number amounts to less than one-tenth of a percent of the state's overall area.

Unfortunately, the diversity that existed in presettlement times cannot be known completely. But it seems likely that a substantial proportion of the species composition of the original fauna and flora remains here in diluted form in our system of nature preserves, state parks, and state forests, and in hilly terrain near waterways and in remnant wetlands.

Some former residents, such as the Carolina paroquet and the passenger pigeon, have of course vanished not only

David Riecks

John Bouseman searches the Illinois Natural History Survey Insect Collection to find a match for an insect that needs identification. A cypress swamp in Heron Pond, southern Illinois, is an example of a habitat that contributes to the natural biodiversity of the state.



Michael Leffordos

from Illinois but also from the Earth. Others, such as the elk, the cougar, and the black bear, are gone from Illinois, and there is little likelihood that they could coexist with the state's human population if reintroduced. Some former inhabitants obviously are missed more than others. For example, few people would mourn the passing of the malarial agents from Illinois.

Contributing to the natural diversity found within the state are its mid-continental position and long north-to-south axis. There are tamarack bogs at the northern end of the state and cypress-tupelo gum swamps in the south. The central portion of the state was originally tall-grass prairie containing many western elements, and the remainder was largely in forest with strong relation to the eastern United States.

Putting Illinois Under the Microscope

The biota of Illinois has been the object of study by naturalists since the early nineteenth century. In those times the population of the state was sparse, and the investigators were often from institutions in the eastern United States or were amateurs from Europe.

Following the Civil War, the state's population rapidly increased. During the same period, institutions of higher learning were established, as were state agencies concerned with the natural history and geology of Illinois. Resident scientists began studying the natural resources of the state and assembling collections of animals and plants. These early generalists also began to shape the modern biological sciences of ecology, entomology, limnology, parasitology, and others.

In Illinois, the official state collections of plants and animals are housed in the Illinois Natural History Survey, located on the campus of the University of Illinois at Urbana-Champaign. Some materials incorporated in these collections date back to the 1870s. Such materials are, of course, irreplaceable. Groups of organisms represented by large state collections include vascular plants, fungi, mollusks, fish, reptiles, and arthropods, with insects

Insect Invaders

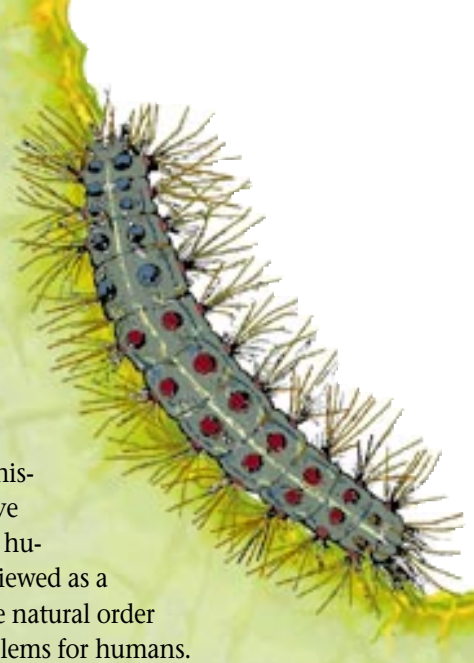


Illustration by Paula Wheeler

Humans are not the only highly mobile organism. Every plant or animal found on Earth originally existed in what biologists term its range, the region in which it naturally occurs.

Ranges expand or contract in response to a variety of natural events, such as changing weather, availability of food, volcanic eruptions, floods, and droughts. Throughout the course of history, however, the ranges of many organisms have been greatly altered in response to the actions of humans. In some instances, range expansions are viewed as a universal good. In others, such disruptions of the natural order have caused, and continue to cause, serious problems for humans.

Insects that now occur in regions where they originally were not present have in many cases become what we call "pests." North American examples include the European corn borer, Hessian fly, gypsy moth, and a host of others.

The gypsy moth is one of the most infamous invaders. Native to Europe and Asia, it was introduced into North America in 1869 by Leopold Trouvelet, a French scientist attempting to develop a silk industry who wished to cross the gypsy moth with the silk moth to produce a new and improved silk-producing caterpillar. Although the endeavor failed, he did succeed in "losing" a few gypsy moth caterpillars that he was growing on a tree near his house in Massachusetts.

The rest is history.

The gypsy moth soon became established and continues to be the most destructive forest pest in the eastern United States. Even though hundreds of millions of dollars have been spent on its control, the insect continues its inexorable march across the country. The tendency of female moths to lay their eggs on low-lying objects, including such items as lawn chairs, firewood, and car and camper bumpers, provides an easy means of relocation for this aptly named pest.

In 1973, infestations of gypsy moth were detected in Illinois. Since then, the state has continually eradicated the moth at numerous sites around the state, primarily in the northeastern counties, and is currently "holding the line."

Another immigrant pest, the Japanese beetle, was accidentally introduced into New Jersey on nursery stock, made its way into Illinois, and was the object of costly trapping and eradication programs during the 1950s. In spite of these programs, the beetle persists in Illinois and over the last several years appears to be increasing in abundance. Similarly, the cereal leaf beetle, a European pest of small grain, was the object of quarantine and eradication efforts after it was discovered in 1965. Repeated aerial sprays of malathion to hundreds of thousands of acres on which beetles had been detected failed to prevent its statewide establishment in a mere seven years!

The invasion continues.

Since 1960, at least fifty-four new insect species have appeared in Illinois. Seven species have become pests, eleven have only limited potential for economic or health consequences, and eight are actually beneficial (often purposely introduced as part of a pest management scheme). The remaining twenty-eight species are of unknown significance but may turn out to be of little consequence.

It appears that we must learn to live with, and learn to manage, many of our immigrant insect pests. — *Michael Jeffords, entomologist and public relations and education liaison, and Charles Helm, research scientist, Illinois Natural History Survey*

Aptly named, deer ticks can wreak havoc on deer populations; they also are known to transmit Lyme disease to humans.

Deer ticks are also known as black-legged ticks. Below, left to right: male, female, and engorged female.

Courtesy Agricultural Research Service-USDA

Courtesy J.M. Pound, Agricultural Research Service-USDA

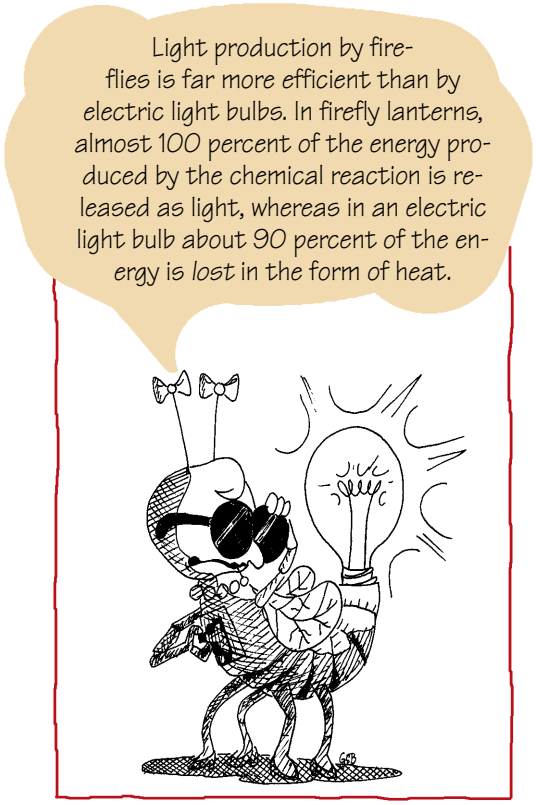
especially well represented. In general, the collections serve as a database of actual specimens that documents the changing state of the biota through time.

Collection Includes Large Insect Component

The insect collection is particularly strong, containing some six million specimens. The collection contains the largest holdings of midwestern insects to be found. It also incorporates materials from throughout North America and from other continents.

One of the important uses of the material in the insect collection is to serve as standards of reference for the identification of specimens submitted to Survey taxonomists for determination. Because all information known about an organism is stored under the scientific name of the organism and the retrieval of such information is possible only through knowledge of the name, the importance of accurate identification is evident. Equally important is the continual updating of names of specimens, which is a group effort involving not only the residents specialists but also researchers worldwide who use the collection.

The Natural History Survey's resident specialists receive thousands of specimens each year. These submissions come from a diverse clientele that includes agronomists, horticulturists, farmers, gardeners, extension personnel, conservation professionals, wildlife biologists, grocers, warehousers, elevator operators, pest-control operators, physicians, veterinarians, homemakers, and law enforcement officers.



Collections Serve Practical Purpose

Often the identification services of the Natural History Survey provide the first notice that an insect new to the state has arrived and possibly become established. Examples of such are numerous. Recent immigrants identified by the lab include the imported crucifer weevil, which threatened to devastate the important Illinois horseradish industry, and the deer tick, the vector of the causative agent of Lyme disease.

Provision of in-house identification services also supports studies in pest management and crop protection, ecological studies, conservation studies, and even medical and veterinary investigations. The tie to public health is of ever-increasing importance with the recognition of recently described diseases such as Lyme disease, human ehrlichiosis, and granulocytic ehrlichiosis.

In addition to the functions of service and support for other programs, the collections of the Illinois Natural History Survey have been and continue to be of vital importance to the personal research of the systematists, or taxonomists, who provide those services. Since the founding of the collections in the nineteenth century, numerous specialists have based revisionary studies of groups of organisms and formal works treating of the occurrence of animals and plants in the state upon them.

Illinois Flora and Fauna Are Ever-Changing

In summary, the biota of Illinois is rich and diverse — but it is not static. Throughout the history of the state there have been extinctions and immigrations. In addition, there have been purposeful introductions, some of which were successful, others that were not.

Most of the insect pests of current concern to Illinoisans represent introduced elements. Thus, there is continuing need to monitor the insect fauna of the state. Doing so can provide important indicators of environmental health and of new threats to the material resources of the state and to the health of its citizenry.

John Bouseman, associate professional scientist, Illinois Natural History Survey

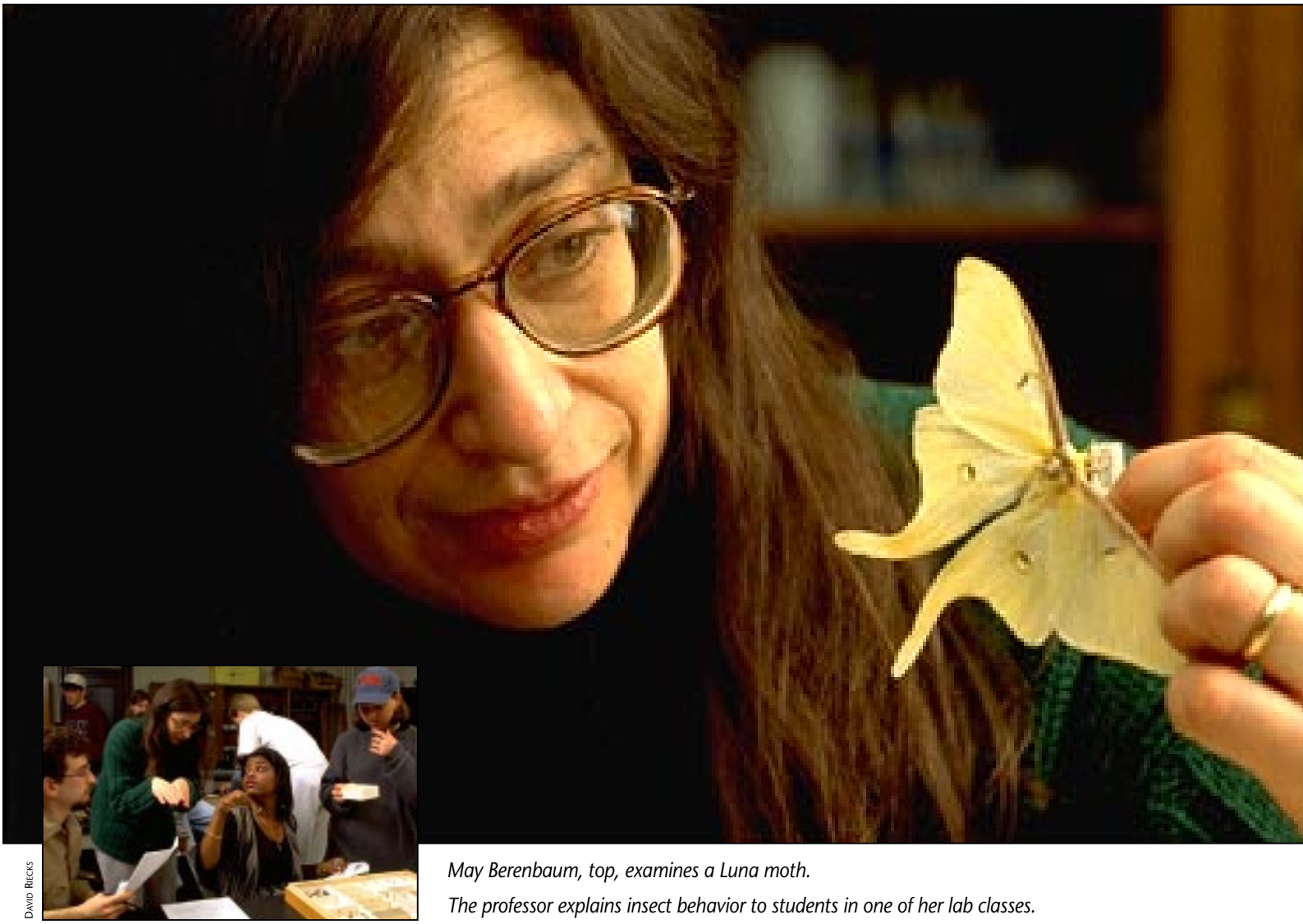
Entomology's Past, Present, and Future

May Berenbaum

When you visit the University of Illinois, you won't find all of the entomologists in the same office. In fact, you won't even find them in the same building.

Locating an entomologist on campus can be a daunting task because people who describe themselves as entomologists are housed in six different departments, in four different colleges, and in two different state institutions. These authorities on arthropods are found in the College of Liberal Arts and Sciences, in the College of Agriculture, in the College of Veterinary Medicine, at the Illinois Natural History Survey, and even in the College of Fine and Applied Arts.

Why are our entomologists so widely dispersed? The answer lies both in the history of entomology as an academic discipline and in the unique qualities of this area of science.

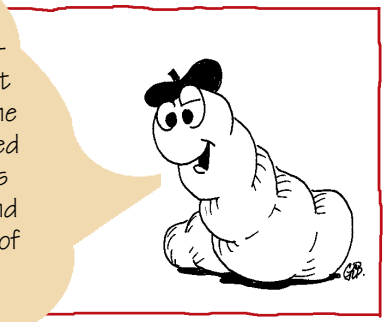


David Reeks

May Berenbaum, top, examines a Luna moth.

The professor explains insect behavior to students in one of her lab classes.

It wasn't until the sixth century that Westerners were able to break the Easterners' secret to silk production. The emperor Justinian sent two Nestorian monks to China to smuggle out some eggs of the silkworm caterpillar. The monks managed it by concealing the eggs inside the bamboo staffs that they as pilgrims were expected to carry around them. The ruse was successful, and as a result all of the silkworms in Europe and the United States were descendants of these eggs.



Metamorphosis of Entomology

Entomology began as an independent discipline at the UI and other public universities in a very different era. There was a time, not so long ago, when the study of insects was regarded at best as a harmless diversion and at worst as an indication of serious mental imbalance. Even after the publication of the decidedly scientific undertakings of Carolus Linnaeus and other early taxonomists, insect illustrations were benevolently regarded as "prints that would amuse children and keep them out of mischief" (Kirby and Spence 1822) or as challenging models upon which ladies might try out their artistic expertise.

In the early nineteenth century, entomology was thought to be the proper pastime for the idle, the effete, or foppish — for those who could find no better way to spend their time. This reputation was hardly merited by the realities of working with insects. Systematists, who classify insects, and collectors had to endure tremendous hardships and to face considerable physical danger to pursue their interests in the more remote parts of the planet, and physiologists who worked with insects faced operational challenges far greater than those posed by working with much more conveniently sized vertebrates. A human liver, for example, can be weighed in pounds; the midgut of a caterpillar, which functions as a liver, weighs on the order of one thousandth of an ounce. Dissecting tiny organs requires steady hands and tremendous patience.

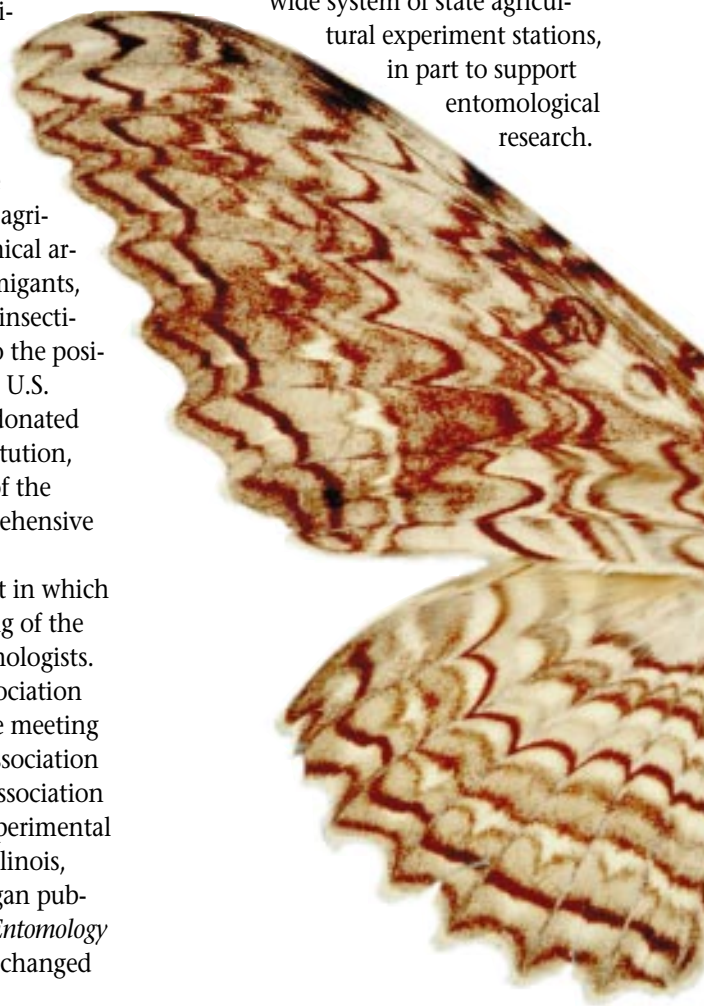
By the mid–nineteenth century, however, the public no longer had the luxury of indulging in this misperception of the discipline. Insects, by virtue of their numbers and voracity, began to put pressure on the U.S. government for increased recognition. The outbreak of the Rocky Mountain locust plague between 1874 and 1876, so enormous that observers reported seeing trains stopped by the crushed bodies of locusts covering the tracks, led to the appropriation by Congress of $18,000 in 1876 for the establishment of the U.S. Entomological Commission. Appointed as chief was one-time Illinois resident Charles Valentine Riley, whose lobbying had pushed the bill through.

Soon afterward, Riley assumed the position of USDA Entomologist and contributed considerably to the advance of so-called economic entomology by engineering the first successful application of biological control — introducing the Australian ladybird beetle to California to combat the cottony-cushion scale. He also pioneered the use of chemical insecticides in U.S. agriculture and expanded the chemical arsenal then in use to include fumigants, arsenicals, and other inorganic insecticides. Upon his appointment to the position of Curator of Insects at the U.S. National Museum in 1885, he donated his entire collection to the institution, thus forming the base for one of the world's largest and most comprehensive insect collections.

Yet another accomplishment in which Riley took part was the founding of the Association of Economic Entomologists. Established at an American Association for the Advancement of Science meeting in Toronto in early 1889, the association had its first meeting with the Association of Agricultural Colleges and Experimental Stations right here at Urbana, Illinois, that November. The society began publishing the *Journal of Economic Entomology* in 1908 and the following year changed its name to the American Association of Economic Entomologists.

That there were sufficient numbers of entomologists in 1889 to form a society is itself a little surprising. That there were enough entomologists of sufficiently different interests to start another national organization, the Entomological Society of America, in 1906 is even more surprising. And in view of the hitherto unflattering opinions of the public toward entomologists, it almost defies belief that several acts of Congress actually created this abundance of entomologists.

Yet Congress really had little choice in the matter. What with the encroachment of the gypsy moth, the San Jose scale, and the cotton boll weevil in the latter half of the nineteenth century, it was as if the forces of nature were lobbying in Washington on behalf of the entomologists. The Morrill Land Grant Act, passed in 1862, led to the establishment of the land-grant universities, where instruction in entomology was quickly established. The Hatch Act of 1887 created a nationwide system of state agricultural experiment stations, in part to support entomological research.



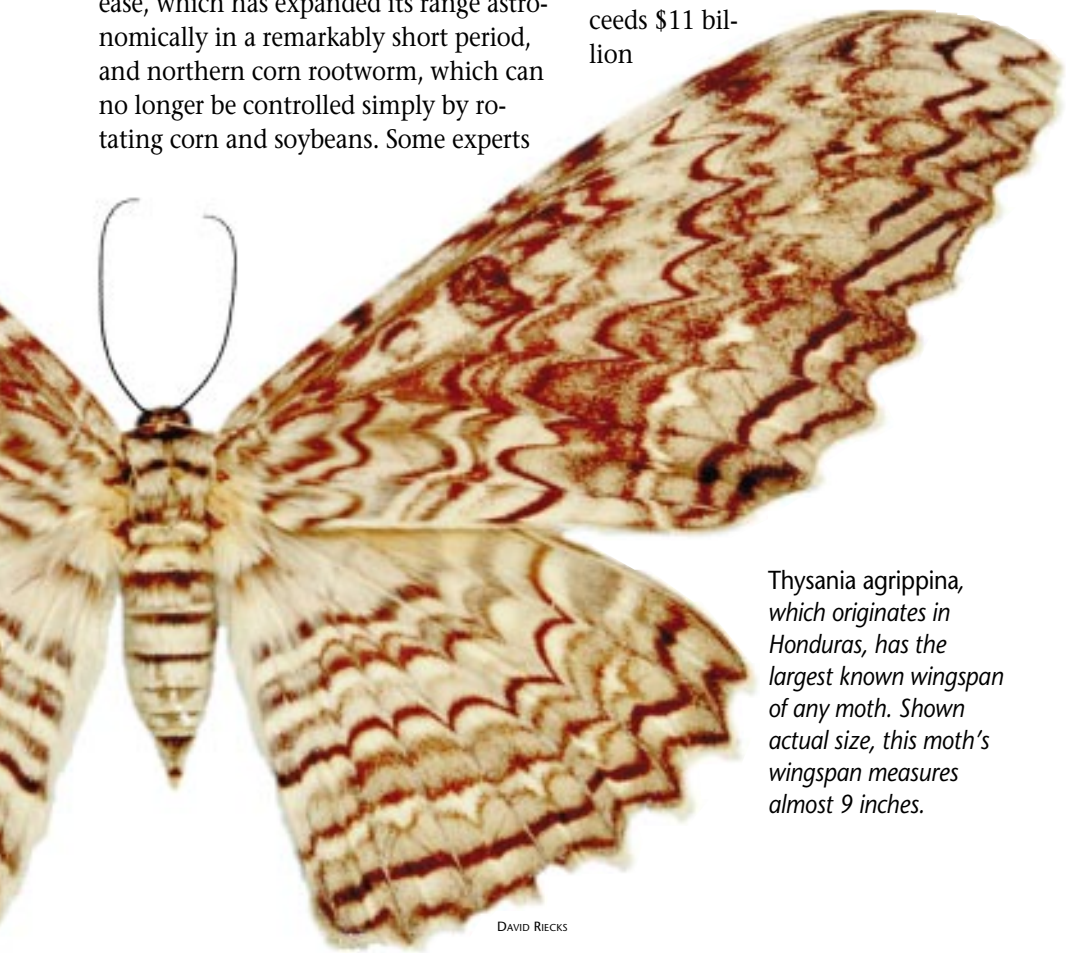
Insects Continue to Demand Our Attention

A century later, it is no less true that insects constitute the most economically important class of animals on the planet. Despite the outstanding successes of economic entomologists over the past century, insects continue to damage crops, spread disease, destroy property, and otherwise wreak havoc. For every insect that is tamed or eradicated, a few new pests are accidentally introduced into the country. The past few years have seen our borders invaded by Asian tiger mosquitoes, Asian gypsy moths, European pine shoot borers, Russian wheat aphids, and Africanized honey bees — all posing a serious threat to health and prosperity.

Even the most subtle alteration in an ecosystem can provide an opportunity for an inoffensive species suddenly to turn virulent, and in the latter half of the twentieth century, alterations to ecosystems have been anything but subtle. These hitherto inconspicuous arthropods-turned-troublemakers include the deer tick, principal vector of Lyme disease, which has expanded its range astronomically in a remarkably short period, and northern corn rootworm, which can no longer be controlled simply by rotating corn and soybeans. Some experts estimate that total insect damage in the United States exceeds $14 billion annually and continues to climb with no abatement in sight.

On the other side of the coin, even in today's technological society, insects contribute economically at a level unequalled by any other class of organism. The value of insect products — honey, wax, silk, and the like — alone amounts to more than $330 million annually. Rather than being replaced by synthetic substitutes, insect products such as silk and cochineal (a red dye) are experiencing a renewed popularity. Spider silk, for example, is under intense scrutiny by material scientists who have yet to develop a synthetic fiber with its strength and elasticity and by molecular biologists who want to clone the genes that produce silk protein into bacteria for mass production.

The positive economic benefits don't end with insect products. The value of insect products is greatly exceeded by the value of insect services such as pollination, recycling of organic wastes, and biological control. Collectively, the worth of such services exceeds $11 billion annually in the United States alone, and controlled, reliable delivery of those services depends critically on entomologists who are familiar with the systematics, population biology, and ecology of the insects that provide them.



Thysania agrippina, *which originates in Honduras, has the largest known wingspan of any moth. Shown actual size, this moth's wingspan measures almost 9 inches.*

David Riecks

Recently insects have gained in importance in another way. Largely through the efforts of university entomologists, insects have become increasingly more valuable to the entire scientific enterprise of the nation, if not the world. The value of insects as model systems for biological research of all descriptions was recognized centuries ago by such polymaths as Marcello Malpighi and Jan Swammerdam, but the scientific community as a whole was a little slower to catch on. A fundamental discovery in the 1920s forever altered the science of biology — Thomas Hunt Morgan discovered just how convenient it was to use *Drosophila melanogaster*, the famed "fruit fly" (referred to more precisely by entomologists as the vinegar or pomace fly) for his studies of genetics. As a result of that discovery, fruit flies in particular, and insects in general, are effectively irreplaceable as study organisms in biological subdisciplines as widely divergent as genetics, molecular biology, neurobiology, and evolutionary biology.

Understanding the limits of insects as model systems, however, and elucidating those aspects of biology that are unique to the class Insecta are still the job of the classically trained entomologist, who can study the life of the organism for its own sake and who can integrate all aspects of its biology in a holistic way. The importance of insects in this role is only going to increase in coming years, as working with vertebrates becomes economically and ethically more difficult to justify.

An increasing emphasis on the inventorying and conservation of biodiversity, evidenced by such recent developments as the creation of the National Biological Survey, will necessarily make the study of insects a higher priority for our nation and the world — after all, insects constitute at least 75 percent of all living organisms. Although more than 800,000 species of insects are known, estimates of the number of arthropods remaining to be discovered and described range from

This small collection shows some of the great variety found among the world's insects.

10 million to 34 million. These species, an untapped source of potentially useful goods and services, can only be recognized by people who have been trained as entomologists. And people can only be properly trained as entomologists in an academic setting, where collections are maintained, where colleagues with the appropriate expertise are nearby, where the latest techniques available for insect classification can be mastered, and where the necessary scientific literature is readily accessible.

Entomologists are versatile — too often a rare trait among scientists. For decades, they have found employment not only in the realm of academic basic research but also in government, the military, industry, and foreign service. There are few professions whose practitioners have so routinely found employment in such a broad range of sectors, and there are few whose disciplines require such broad training.

Perhaps one reason for the versatility of entomologists is that entomology, both basic and applied, is by nature multidisciplinary. Agricultural entomologists have long worked with soil scientists, plant pathologists, and even agricultural economists to devise integrated approaches for managing insect pests. Medical and veterinary entomologists have forged partnerships with microbiologists, animal scientists, and epidemiologists to solve some of the world's most pernicious health problems. And basic insect biologists have collaborated with colleagues in every area of life science to achieve a better understanding of the systematics, ecology, physiology, genetics, and cell biology of insects.

As emphasis on multidisciplinary work increases, entomologists should become more, not less, valued. Indeed, this ability to integrate into a wide range of disciplines is why entomologists are housed in so many different units on campus.

A Bright Future Ahead?

The future of entomology, then, appears to be bright. There is no question that entomology continues to contribute to the national good. Tangible proof of the importance of the field includes the fact that last year, of six scientists awarded the National Medal of Science, the highest honor bestowed upon scientists in this country, one is an entomologist. Last year, among the sixty scientists elected to the National Academy of Sciences, which selects its members from thousands of candidates in dozens of science disciplines, two were entomologists — quite an accomplishment for a field whose national society membership boasts fewer than ten thousand members.

As long as insects are intimately involved in the daily activities of humans, which has been the case since the dawn of time, the study of entomology will continue to occupy a unique and important position at land-grant universities throughout the nation.

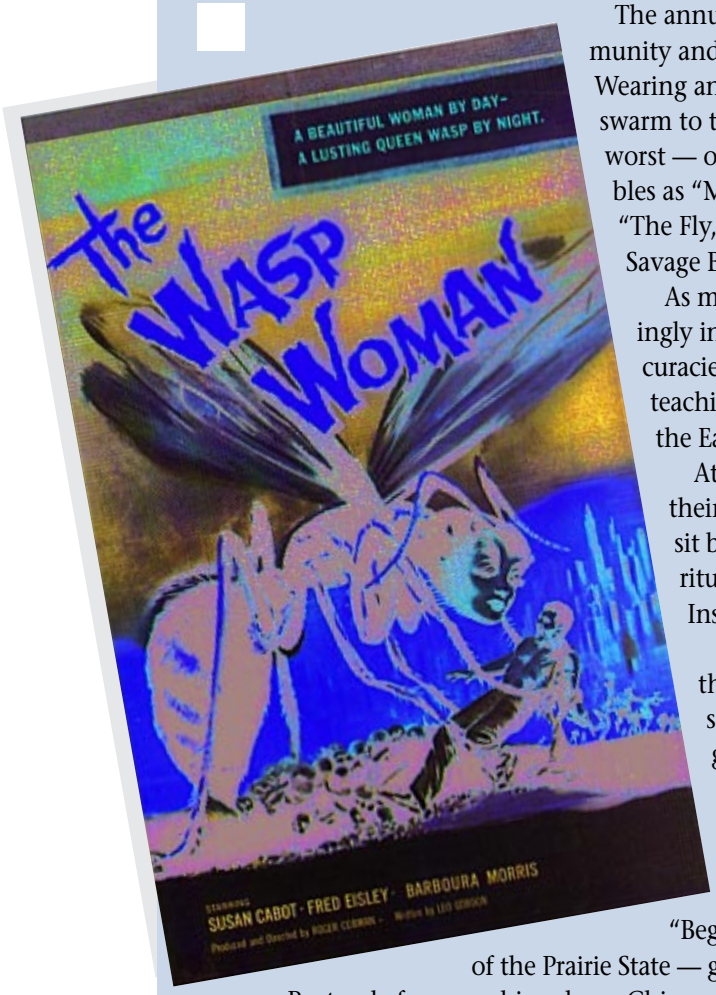
May Berenbaum, head, UI Department of Entomology

Two Thumbs Up for UI Film Fest

As she sat in her office enthusiastically describing the offerings of this year's Insect Fear Film Festival, May Berenbaum suddenly said she had to run. Her family expected her home soon to watch a new video — "Brain Eaters."

"It's one of the greatest secret pleasures that I allow myself," the UI entomology professor says of her fascination with insect films.

Both a love of cinematography and an unending drive to be creative led Berenbaum, head of the UI Department of Entomology, to found the Insect Fear Film Festival twelve years ago. She now co-directs the festival with her husband, Richard Leskosky, assistant director of the UI Unit for Cinema Studies.



The annual event attracts hundreds of viewers from the local community and brings the nation's journalists out of the woodwork. Wearing antennae and wielding fly swatters, spirited festival-goers swarm to the UI each February for some of the best — and the worst — of science-fiction cinematography, including such notables as "Mothra," "Godzilla vs. Mothra," "The Deadly Mantis," "The Fly," "The Return of the Fly," "Empire of the Ants," "The Savage Bees," "Of Thee I Sting," and "Invasion of the Bee Girls."

As might be expected, most of the festival's movies are glaringly inaccurate when it comes to insect biology. But these inaccuracies aren't all bad. They provide Berenbaum with a perfect teaching opportunity and a chance to set the record straight on the Earth's most populous group of organisms.

At the festival, young and old can get an up-close view of their favorite bugs, partake of edible insect munchies, or just sit back and get a quick lesson on the eating habits, mating rituals, and communication methods of members of the class Insecta.

"Actually, the truth about insects is often more amazing than the movie industry's fiction," Berenbaum says. For instance, many filmmakers have tried to impress moviegoers by portraying gargantuan mutants. But shouldn't we be just as impressed by the reality of an insect's incredibly complex system of muscles, nerves, and internal organs all packed into a tiny body?

Berenbaum's all-time favorite flick is the 1957 thriller "Beginning of the End." The film has great appeal for residents of the Prairie State — giant grasshoppers destroy the central Illinois town of Paxton before marching down Chicago's "Magnificent Mile" threatening to take over the city.

Let's face it — we've all jumped at the unexpected sight of a bug scurrying across the kitchen floor. Despite their diminutive size, insects do have the power to strike fear in the hearts of humans. — *Nancy A. Nichols, editor, Office of Agricultural Communications and Education*

The next Insect Fear Film Festival is scheduled for February 1996. For specifics on the event, call the UI Department of Entomology at (217)333-2910.

Movie posters taken from *Graven Images: The Best of Horror, Fantasy, and Science Fiction Film Art*; from the collection of Ronald V. Borst and Margaret A. Borst; edited by Ronald V. Borst, Keith Burns, and Leigh Adams; © 1992 by Borst Book Group.

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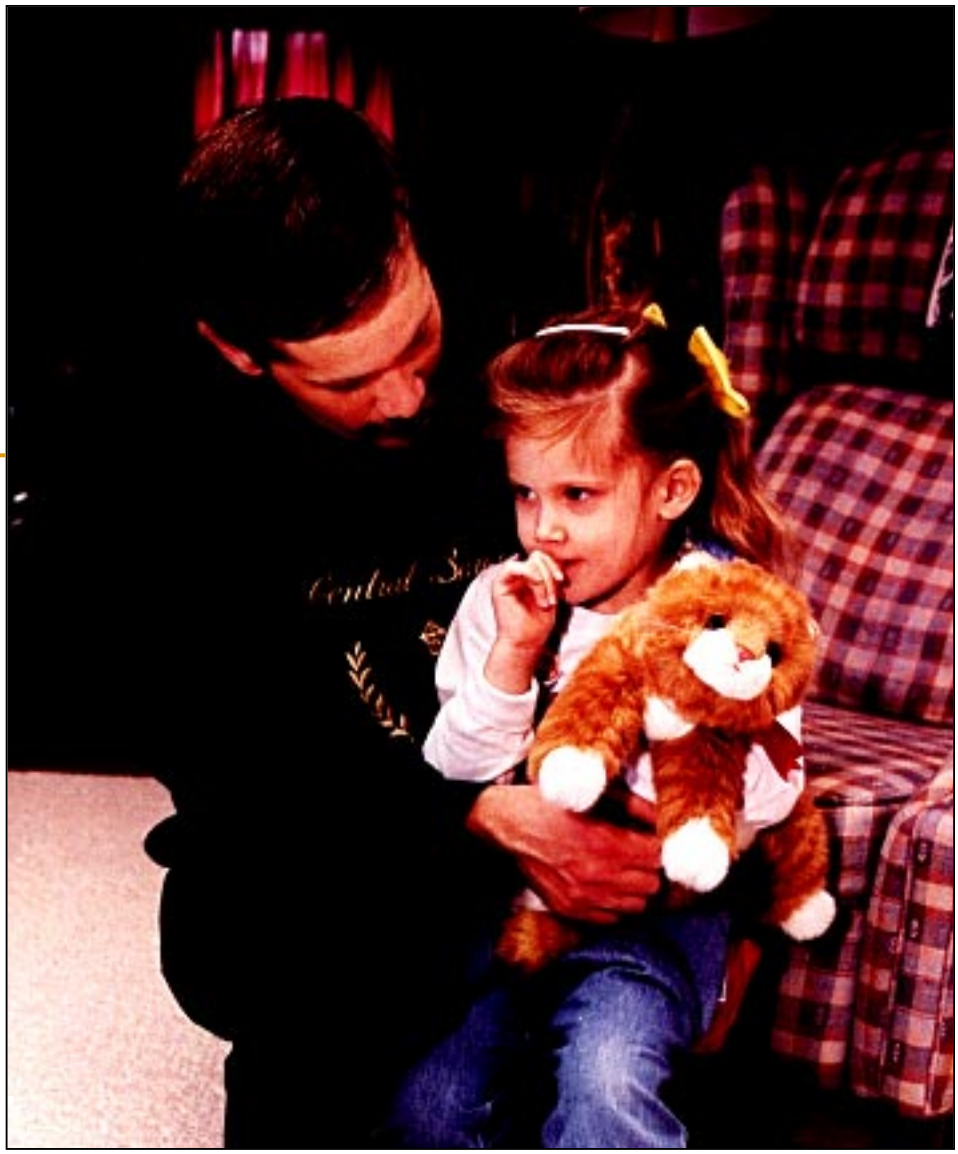

L. Brian Stauffer

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