Chapter 1
From Caterpillars to Chemistry

M. Deane Bowers

Introduction

I remember v-e-r-y slowly putting my hand through the fence into my neighbor's yard to capture my first black female tiger swallowtail; no net available. I was nine. It was awesome! I still have the specimen with its sewing pin through the thorax (thankfully not the abdomen, as I was pretty inept in those days, Fig. 1.1) and a label the size of a business card. Those were the early days of excitement and fascination as I learned about butterflies and other insects.

Growing up in Florida (before it became as developed as it is now) was wonderful for a budding lepidopterist; there were so many different habitats and an incredible diversity of insects. My bibles were *A Field Guide to the Butterflies* by Alexander Klots (1958) and *The Amateur Naturalist's Handbook* (Brown 1948), both of which I still have. I constantly had checked out from the library *The Butterfly Book* (Holland 1898) and *The Moth Book* (Holland 1903), both of which I now own. From these inspiring resources, I learned how to collect, identify, and prepare butterflies and moths, how to keep a field notebook, and how to observe nature and think about doing experiments. I raised caterpillars in my bedroom and put together a weather station in my backyard. My parents got me my first butterfly net and encouraged me. I made butterfly jewelry by painting clear nail polish over butterflies I had collected and spread and by attaching safety pins to them.

High school intruded, but my fascination survived. My junior year, there was the big decision: try to capture the HUGE sphinx moth at the gas station light (which I learned was *Pseudosphinx tetrio*) or leave it and go with my friends. I made the right choice and captured it. I had been, and still was, hooked.

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Fig. 1.1 Female tiger swallowtail (*Papilio glaucus*, Papilionidae). Note the sewing pin instead of the more appropriate insect pin. (Photo by Brian Lobbes)

From Caterpillars to Chemistry

The move from rearing and collecting to thinking about butterflies and moths in a more scientific way began in college, when I did a small project looking at how feeding on different plants affected the growth and development of painted lady caterpillars and was encouraged to pursue my interest in insects. I was able to take some entomology courses at the nearby University of Massachusetts, where, despite being told that "women can't be entomologists, except possibly taxonomists," I decided that I could. My fascination with butterflies and moths led me to apply to graduate school in entomology, but I found that most entomology departments wanted students to work on projects that were ongoing in the labs of faculty members. So, I declined offers to work on alfalfa weevils or blowflies and ended up in the Department of Zoology at the University of Massachusetts. I had not had much experience with research as an undergraduate and was not sure exactly how to go about deciding what to focus on for my graduate research. My advisor, Ted Sargent, a specialist on *Catocala* (Noctuidae), told me to spend my first summer reading and looking for potentially interesting systems, finding something that excited me.

And I did! That first summer, I discovered the Baltimore checkerspot, *Euphydryas phaeton* (Nymphalidae) (Fig. 1.2), feeding in swampy habitats where its host plant, Turtlehead, *Chelone glabra* (Plantaginaceae), grew. I was fascinated by the brightly colored orange and black caterpillars and the striking black, red, and yellow adults, characteristics suggesting that this species might be advertising the fact that it was unpalatable. Indeed, Samuel Scudder, in 1889, first suggested that this species was unpalatable, noting that:

> …the butterflies are not touched by birds, probably having some quality obnoxious to smell or taste, and the caterpillars seem to have a similar immunity. …it would seem as if so sluggish a butterfly would soon be exterminated by birds, did it not possess some obnoxious character, for it is I think, the most sluggish butterfly we have.

My first attempt to turn my interest in this butterfly into a dissertation was deemed to be too much natural history by my committee—and they were right. I persevered, however, and ultimately, my thesis research on *E. phaeton* and other members of the genus investigated host–plant relationships in *E. phaeton* and showed that this species, as well as other species in the genus, were unpalatable to blue

Fig. 1.2 Life history of the Baltimore checkerspot (*Euphydryas phaeton*, Nymphalidae). Clockwise from *upper left*: Adult, egg mass on turtlehead (*Chelone glabra*, Plantaginaceae), pre-diapause larvae on web, post-diapause larvae on *C. glabra*. (Photos by Deane Bowers)

jays (Bowers 1980, 1981). It was the natural history of these relationships that first piqued my interest and that then informed the research.

This research introduced me to the field of chemical ecology. I was fascinated and inspired by the work of people like Miriam Rothschild, Thomas Eisner, Gottfried Fraenkel, Jane Van Zandt Brower, Lincoln Brower, and Vincent Dethier (these last two serving on my doctoral advisory committee), as well as many others. This field was just beginning in the 1960s and 1970s as ecologists and evolutionary biologists started talking to natural products chemists. The publication of books like Harborne's (1972) *Phytochemical Ecology,* Sondheimer and Simeone's (1970) *Chemical Ecology,* and van Emden's (1973) *Insect Plant Relationships* was also happening and changing how chemical compounds in plants were viewed: They were starting to be thought of as more than just the waste disposal system of plants (Fraenkel 1959, 1969).

Although I was unable to do any chemical analyses in the course of my dissertation research, my thesis concluded with the idea that the host–plant relationships and unpalatability of *Euphydryas* were due to a particular group of chemical compounds that were found in most of the host plants of this genus, the iridoid glycosides (Bowers 1979). These compounds were found in all of the host plants of North American *Euphydryas* and were noted to be very bitter (Hegnauer 1973; Kubota and Kubo 1969). These observations suggested to me that it might be iridoid glycosides that were responsible for not only host plant specificity but also the unpalatability of these butterflies. Subsequently, these ideas with which I concluded my thesis were supported by the experiments that were begging to be done. I found that larvae of *E. chalcedona* used iridoid glycosides as larval feeding stimulants (Bowers 1983) and that, indeed, the unpalatability of checkerspots was due to sequestration of these compounds by larvae and their retention to the adult stage (Bowers and Puttick 1986; Bowers et al. 1992). The chemical ecology of checkerspots and other butterflies and moths that specialize on plants containing iridoid glycosides has continued to be a major focus of much of my research and the source of much of my passion for biology.

My 2-year postdoc with Paul Ehrlich introduced me to California (I had never been west of Ohio) and the western checkerspots. I was able to explore northern California, Oregon, and Washington in the search for checkerspot populations. On one of those trips, I ran into the results of the Mount St. Helens eruption! I was out in the middle of nowhere, with no radio reception, so had not realized what had happened. I started seeing piles of white dust on the side of the road, and when I reached a town, I found out what had occurred. In addition to some great fieldwork opportunities, it was there that I was able to do some of the experiments showing that iridoid glycosides were feeding stimulants for checkerspots and to begin working on another nymphalid that is an iridoid glycoside specialist, the buckeye *Junonia coenia*. This species has also served as a great study organism for many experiments.

I was fortunate in having a lot of freedom as a postdoc and to be able to learn from another postdoc, David Lincoln, about some of the basics of plant secondary chemistry. I also had the opportunity to attend the first Gordon Conference on the "Chemical Aspects of Plant–Animal Interactions," where I met many of the people whose work I had read, including Miriam Rothschild, who had been such an inspiration to me. This conference really clinched my research focus in the field of chemical ecology.

From California I moved back to the east coast for a beginning assistant professor position at Harvard, where I was the curator of the Lepidoptera collection and, with another curator, ran the entomology section. This was certainly an interesting time. Not only was I a woman entomologist, in a time when the field was dominated by men, but for 2 years I was the only woman in the department at Harvard. I will admit that I got tired of being introduced as "our pretty little lepidopterist." However, the collection there was amazing and I grew to love the museum part of my job. Despite some of the difficulties, my time there solidified my interest in the chemical ecology and evolution of insect–plant interactions and also my enjoyment of the museum side of entomology.

I got to a point in my research, however, when I realized that I either had to go learn some more chemistry and chemical techniques or I had to start asking different kinds of research questions. Through a National Science Foundation (NSF) program, "Visiting Professorships for Women in Science," I had the great good fortune to spend a year working in the lab of Frank Stermitz, a natural products chemist at Colorado State University, who also loved biology. That year changed my life! One of the focal groups of compounds in his lab was none other than iridoid glycosides!! At that time, there were no women in the Chemistry Department there, and they thought I was kind of strange: I had cages of butterflies hanging in the window of my office to try to get them to mate and plastic containers of caterpillars everywhere. But Frank Stermitz and his graduate students helped me learn a diversity of techniques that I was able to integrate into my own research program… and it took some patience on their parts. I learned so much. While I was there, I got to isolate pure iridoid glycosides and learned about nuclear magnetic resonance analysis, gas chromatography, and high performance liquid chromatography. I really, really wanted to discover a new iridoid glycoside, but I never did. Instead, I analyzed lots of known ones and used the knowledge that I gained there to integrate chemical analysis into my research program.

From the east coast, I was able to return to Colorado in 1989, when I began a position as a faculty member at the University of Colorado. Here, I was jointly appointed between the Museum of Natural History, where I was the curator of entomology, and the Department of Ecology and Evolutionary Biology. This was the perfect place for me: although not a systematist (as most curators are), I had developed a love for the museum side of entomology and was thrilled to be able to be in charge of a collection. It was also here that I gained a better understanding of the plant side of plant–insect interactions, and I began to view plants as something more than just caterpillar food.

My research has retained its focus on the chemical ecology and evolution of plant–insect–enemy interactions, with a clear predilection for members of the Lepidoptera. My major focus has been on temperate species, especially taxa that are involved with plants containing iridoid glycosides and the effects of those compounds at multiple trophic levels, the herbivores, as well as predators, parasitoids, pathogens, pollinators, and mutualistic fungi. This research has shown how plant secondary metabolites influence not only the interactions of plants with other organisms but higher trophic level interactions as well.

Advice for Future Lepidopterists

The Lepidoptera provide a diversity of lifestyles, interactions, and relationships with which to explore the dynamics of the natural world. Of all groups of insects, they are probably the best known; however, there is still a wealth of information to be discovered. The Lepidoptera have been used as model organisms for some of our most important discoveries in ecology and evolution, providing insights into such topics as mimicry, natural selection, speciation, plant–animal interactions, and conservation. They can be considered charismatic “microfauna” and, as such, provide a wonderful means of captivating both students and the public.

Some of the most important information I have used in my research has come not from professional lepidopterists but from amateurs. Indeed, most lepidopterists are not professionals; the number of amateur lepidopterists far outweighs the number of professionals. While one may quibble about the precise definition of an amateur, an amateur is essentially someone who is not paid to do the same job as a professional (who is paid). Yet, often these nonprofessional lepidopterists know more about the natural history, behavior, and ecology of butterflies and moths than any professional. And they have this knowledge because they love the natural world. They collect, photograph, and observe. The contributions of amateur lepidopterists are evident in their publications, books, and collections. As an amateur, there is much that you can add to our understanding of the biology of butterflies and moths; for example, describing and photographing life histories, documenting behavior, rearing parasitoids, participating in 4th of July butterfly counts, putting together a well-documented and well-curated collection. Several articles have highlighted the value and potential contributions of amateur lepidopterists (e.g., Munroe 1960; Ferris 1986; Miller 1986): there is much you can do!

For those interested in a future in lepidopterology, whether professional or amateur, get out into nature, meet other lepidopterists, participate in butterfly counts, get involved in restoration projects, and attend regional meetings or the national meeting of the Lepidopterists' Society. Joining one of the societies that focuses on Lepidoptera is also a great way to meet people and find out what kinds of projects are going on; for example, there is the Lepidopterists' Society, the North American Butterfly Association, and the Xerces Society. There are also many smaller, local societies. You can also take a look at the Butterflies and Moths of North America website (http://www.butterfliesandmoths.org), which has lots of resources about butterflies and moths, including identification, and lists some of the local lepidopterists societies.

If you are interested in a career as a professional lepidopterist, there are many possibilities. Again, making contact with other lepidopterists is very important. Professional lepidopterists can work at museums, at colleges and universities, for agencies such as the United States Department of Agriculture (USDA), and the Nature Conservancy. Their disciplinary specialties range from the systematics of particular groups to behavior, ecology, physiology, development, evolution, and interactions with other groups of organisms such as plants, predators, pathogens, and parasitoids. Not all who work with Lepidoptera would call themselves lepidopterists; their focus may be more on developmental regulation or restoration of native habitats. Yet, they work with butterflies or moths. If you want a future as a lepidopterist, think about what you want to do, meet other lepidopterists, and get the training that will best prepare you for your future goals. Go for it!

For myself, I consider myself particularly fortunate; being a lepidopterist is not only my job, but also something that brings me great satisfaction and joy!

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