Evolution in a Toxic World: How Life Responds to Chemical Threats

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natural history of each species, and it also focuses on the multiple kinds of approaches taken by investigators to devise and test hypotheses of how insect prey reduce their predation risk. Each chapter provides appropriate and interesting case studies to illustrate its main points, and the author's chosen examples are a blend of contemporary studies mixed with important classics. Both the scientific audience and those who simply appreciate organismal diversity and who are keenly interested in the natural world will enjoy this book.

Each chapter section describes how a specific adaptation might work in certain instances. In each of these cases, the author surveys previous studies to inform the reader about the general scope of evidence documenting how the mechanism in question serves to limit predation risk. Few examples are presented that refute specific hypotheses, but some are acknowledged. One example surprised me: Despite widespread acceptance of its efficacy, there is no evidence offered for or against the adaptation of disruptive coloration to reduce predation risk as a successful tactic in natural systems. In most cases, however, affirmative studies dominate the text in order to make the point that successful adaptations by insects are manifested in the many types of their effective defenses.

Despite the range of fascinating examples described in the book, I was somewhat disappointed in one aspect: The book does not offer a developed presentation of the underlying evolutionary dynamics associated with these complex relationships. After all, most traits are the result of integrated morphological and behavioral features that match fairly closely in a finely tuned adaptation. Although Waldbauer presents some evidence that even rudimentary change in antipredator traits confers fitness benefits that lead to the evolution of more complex combinations, such discussions are dispersed casually throughout the book, thus diluting a critical message.

What is missing, for the most part, are theoretical contexts and hypotheses of the more complex ecological and evolutionary dynamics that are critical for understanding the evolution of predator–prey adaptations and their ecological consequences. For example, the relative roles of density- and frequency-dependent selection and their significance to the evolution of mimicry systems are not explained directly. Recent studies on sensory bias, which have been focused on constraints on predators' perceptual capabilities (e.g., sensitivities to different wavelengths of light), and the resulting evolution of antipredator traits are also not included. Lip service is given to the role of natural selection in the evolution of many interesting interactions, but the details about how natural selection acts in specific cases are not well developed overall.

Although evolutionary dynamics are critical to fully understanding the adaptations included in the book, these concerns are fortunately not a major distraction, because the examples are so interesting. Besides, this was not a major goal of the author, and my desire for more detail attests to the interest generated throughout by his examples.

With case studies that combine natural history, observation, and some manipulation to illustrate the diverse approaches used by insect prey to reduce predation risk, Waldbauer succeeds in highlighting the intense and captivating evolutionary arms race taking place among insects. Some examples described in this book are already part of the public consciousness, and other, lesser-known examples are now presented for all to appreciate. In *How Not To Be Eaten*, Waldbauer provides not only a life history but a roadmap for developing new fascinating studies of interactions between insect prey and their predators. Moreover, the book gives us motivation to spend a little more time wandering out into the world and taking a closer look at insects as they fight back in an intense, ongoing battle.

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DEFENSE SYSTEMS IN EVOLUTION

Evolution in a Toxic World: How Life Responds to Chemical Threats. Emily Monosson. Island Press, 2012. 232 pp., illus. $35.00 (ISBN 9781597269766 cloth).

It is the general impression in environmental toxicology that life has had to cope with toxic stresses only since the industrial era, an awareness that was stimulated by Rachel Carson's publication of *Silent Spring* 50 years ago. As Emily Monosson demonstrates in *Evolution in a Toxic World: How Life Responds to Chemical Threats*, however, living things have been dealing with chemical and physical threats for millennia and have developed defenses against these threats. Many of these defenses are highly conserved—DNA repair, for example, and antioxidants. Yet, toxicologists seldom consider evolution when they plan their studies and should integrate such awareness in order to have better understanding of their findings and to develop more interesting hypotheses to test. Moreover, only a tiny fraction of chemicals in use have ever been tested for toxicity, but improvements in analytical chemistry allow us to detect ever-smaller concentrations of chemicals in environmental and tissue samples, including our own bodies—the effects of which are unknown.

In this book, Monosson traces the development of defense systems from primitive organisms millions of years ago to today. In chapter 2, she focuses on ultraviolet radiation—the first environmental hazard to primitive life and a cause of DNA mutations. Over time, living things developed the enzyme DNA photolyase, which repairs the DNA damage. The ozone layer that subsequently formed provides a protective shield against ultraviolet B, although it also is at risk from human chemicals.

Oxygen is not usually thought of as a toxic stressor, since it is essential to life, but reactive oxygen species (ROS) are highly damaging. After early photosynthesizers created an oxygen-rich environment, life evolved the enzyme catalase, which can cope with toxic ROS like hydrogen peroxide.

In the chapter on metals (chapter 4), Monosson describes how the early atmosphere became more oxygenated, how iron became scarce, and how zinc became more available and eventually became essential, along with some other metals. Proteins called *metallothioneins* (MT) evolved that bind zinc, as well as other essential metals. Eventually, MT became used by a variety of organisms to bind the excessive levels of toxic metals produced by mining and industrial processes. The author describes the work of her former colleagues at Stony Brook University on metal tolerance in oligochaete worms living in a cadmium-rich environment along the Hudson River in Foundry Cove and the loss of tolerance once the site was cleaned up. Although this is a very interesting case study of a metal-tolerant population in a contaminated site, there have been many others that were not mentioned in the book, including algae, land plants, marine invertebrates, and vertebrates. Furthermore, MT is not the only defense that can be used against metals. Animals can also use lysosomes, stress (heat shock) proteins, and metal-rich granules to defend themselves against excess metals, and many plant species block the uptake of metals into their roots.

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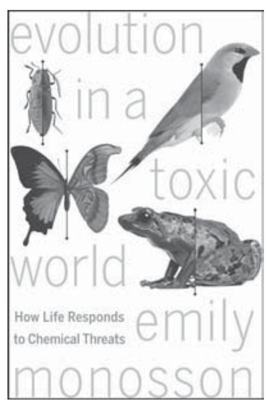
Chapter 5 is about cancer, a condition that is prevalent in multicellular organisms, which evolved a gene to code for a protein—P53—to suppress cancer. Chapter 6 discusses the defensive chemicals of plants and the arms race between plants and animals. As plants evolved chemicals to deter herbivory, animals responded by evolving detoxifying enzymes, the cytochrome P-450s (CYP), which are a family of thousands of proteins that metabolize and transform toxic chemicals. The CYP system is used to metabolize industrial chemicals, pesticides, oil, and other organic pollutants, as well as plant-derived toxins.



Chapter 7 is devoted to sensing chemicals (i.e., with receptors or ligands that attach to specific chemicals, such as hormones). A discussion follows about endocrine disruption, a hot topic in toxicology these days, because extremely low levels of some contaminants can mimic hormones, bind to these receptors, and affect the endocrine system. Although Monosson gives due credit to Theo Colborn for synthesizing disparate studies on different organisms and realizing that a common thread was the disruption of the endocrine system (i.e., endocrine disruptors, or ED), I was disappointed that she did not include the example of tributyltin (TBT) and snails. One of the earliest known examples of ED in the wild—even before the term was coined—involved the androgenic chemical TBT, which was used in boat antifouling paints. TBT produced a masculinized condition called *imposex* in female snails. This imposex condition, in which male reproductive structures become imposed on the female structures, caused reproductive failure and resulted in population crashes in many areas. (In an advanced condition, the male vas deferens blocks the oviduct.) Restrictions on the use of the chemical allowed a slow recovery to take place—perhaps the only example of a chemical being restricted because of its effects on marine invertebrates.

Chapter 8 covers coordinated defense—the reality that organisms are not exposed to single chemicals but to numerous ones with different types of effects. Chapter 9, on toxic evolution, discusses populations exhibiting rapid changes of increased tolerance to the contaminants in their polluted habitats. Genetic adaptation can happen rapidly in populations if they are variable to begin with. The book ends with a discussion of toxic overload—the emergence of contaminants in increasing number and kind, such as perfluorinated chemicals, brominated flame retardants, and nanoparticles. The book aptly portrays this as an issue of grave concern and questions how life will evolve with such a constant barrage of new types of chemical threats.

Evolution in a Toxic World is rather short—only 172 pages of text, not counting the notes and bibliography. As such, there would have been enough space to include additional information and examples, some of which are mentioned above. The book is written in an accessible style and is aimed at the general public, as well as at scientists. The third-person scientific writing is interspersed with personal anecdotes and thoughts, which should help to make the book more appealing. However, the nature of the science being discussed is sometimes difficult, and it may be too challenging for many nonscientists. An important audience for this book is toxicologists, who would greatly benefit from the perspectives provided here.

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