Book Review

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Shortly before this issue of ***Life: The Excitement of Biology*** went to press, I received two books for possible review. Instead of being technical creative works (*opera* or *opi* are also used as plural of the singular word, *opus*), filled with nomenclature that only the proverbial seven colleagues worldwide that read our technical papers can follow, I was absolutely delighted to realize that both *Silent Sparks* and *Modern Poisons* were written to be "accessible". As the wife of a colleague once said, these books were written "to communicate, not to impress", one of the core missions of ***Life: The Excitement of Biology.***

Silent Sparks: The Wondrous World of Fireflies

by Sara Lewis. 2016. Princeton University Press.
Princeton, New Jersey, USA. Woodstock, Oxfordshire, England, United Kingdom. 223 pp. ISBN: 978-0-691-16268-3 (hardbound, in English)

"To myself I am only a child playing on the beach, while vast oceans of truth lie undiscovered before me" - Isaac Newton
(https://www.goodreads.com/author/quotes/135106.Isaac_Newton)

Reading *Silent Sparks*, written by Dr. Sara Lewis (Tufts University, Medford, Massachusetts, USA), filled me with memories, including some from an old familiar neighborhood. There, during late 1983 to early 1984, I suddenly noticed hundreds of sparks of what turned out to be rather large fireflies (beetles that often glow in the dark and belong to the family Lampyridae, from the Latin, *lampyris* or glow-worm) that turned out to be a new record for Puerto Rico, *Aspisoma ingitum* (Linnaeus, 1767), perhaps yet another accidental introduction into this Caribbean island. Along with agile children, we bottled a few fireflies and marveled our families. Elements of fireflies are part some cultures. For instance, one of the best known Latin American romantic songs of the 1930's, *El Día que me Quieras* (*The Day that You Love Me*, https://www.youtube.com/watch?v=WqHhmcNUVeg) mentions a "luciérnaga curiosa" (curious firefly). In the USA, the barbershop *genre* of music has its own *Firefly*, a rather racy song of the 1950's, https://www.youtube.com/watch?v=cwnvpgpN35c .

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Silent Sparks - the *Silent* part is reminiscent of Rachel Carson's *Spring* - is divided into eight chapters followed by an easy-to-follow field guide to the common fireflies of the USA (mostly eastern) and Canada – I wish this section could be tailored to readerships in different parts of the world, a chapter encouraging readers to learn more, a modest *Glossary* (with guides for pronouncing non-English words), tellingly, at times funny, and a warmheartedly grateful *Acknowledgments*, followed by *Notes*, where Lewis places her sources, a *References* section, with digital object identifiers (doi), and an *Index* that, thus far, works. Simply, I could not put *Silent Sparks* down.

The Preface sets the tone of the entire book and my first feeling was, "wow, this is going to work for me because we speak the same 'language' ". Instead of being a science book filled with "obscure technical jargon", Lewis entices intelligent readers to explore what is to come using curiosity and wonderment, fearlessly expressing our "feeling[s] of awe for the natural world" and lacing her narrative with personal stories.

Silent Sparks, Chapter 1, into which I proceeded without noticing, introduces us to the world of fireflies, of which there are about 2,000 described species, most of them tropical. Not all fireflies are bioluminescent or use light (brief flashes or prolonged glows) to communicate reproductive intentions. Instead, some species use chemicals. Although we are used to winged fireflies using light, sometimes the adult females of some species are wingless and they may use lights.

Chapter 2, *Lifestyles of the Stars*, introduces readers to the biology of lampyrids through the flashes of *Photinus carolinus* (Green, 1956), which Lewis calls "travelling symphony of lights", in the Great Smoky Mountains National Park, near Elkmont, Tennessee, USA. Beetles, like most insects, go through several developmental changes, collectively called metamorphosis, in their life history (egg, then a generally underground dwelling, voracious larva, a pupa, finishing with the generally adult we are most familiar with). Interestingly, although not all beetles produce light, all larvae and pupae are luminous, possibly a mechanism to startle predator wannabes. Larvae often subdue generally larger prey items by injecting neurotoxins, paralyzing the prey and steadily ingesting the enzyme-liquified prey's contents. If a species uses flashes to communicate, those signals, which are generally produced by the males, can be produced by a group of individuals (or leks) of the same species, or conspecifics, at the same time, or synchronously, as in the case of *P. carolinus* (an example of synchronized flashing can be seen here, https://www.youtube.com/watch?v=a-Vy7NZTGos). In other species, the flashes can be asynchronous. At times, females respond to conspecific males with a brief flash. The ultimate causes of synchronous flashes are not known although there are several competing hypotheses.

Splendors in the Grass, Chapter 3, tells us that, in part thanks to Dr. James Lloyd (Emeritus, University of Florida, Gainesville, Florida, USA), we have learned that the luminous language of different species of *Photinus*, the most common fireflies in North America, is the characterized by a behavioral trait, the timing of their flashes, not by their morphology or genitalia, the latter often considered a telltale of the species in many animals. Competition for mates is brutal as males tend to emerge well before females. In another study, Lloyd found that only about 1% of the males found a mate (or death by a predator). In *Photinus* fireflies from New England, Lewis and her collaborators have found that the couple remains in copula for hours, until dawn, possibly a type of male mate-guarding of the female. Male to male competition for the relatively scarce females can include physical contests as well as males trying to fool other males flashing like a real female. Yet, by mimicking flashes, several groups of researchers have found that females of some species of *Photinus* prefer male conspecifics with faster pulse rates; other congeneric females prefer males with longer pulses. Yet, later in the mating season, males are scarcer, thus, the remaining males can be choosy, by sizing the female's abdomen, apparently looking for the female with the most reproductive potential.

Chapter 4, *With this Bling I Thee Wed*, addresses the question, what happens to the females after they mate? Does she remain "faithful" to the one male? As in so many other animals studied, the answer is "no", she "plays around" with other males. And, in turn, males not only try to mate as much as possible but try to outcompete other conspecific males in the neighborhood using other mechanisms (e.g. mate guarding, scoping out another male's sperm, etc.). Interestingly, in *Photinus* fireflies, males insert a spermatophore into the female reproductive organs. The sperm gets placed in the females' spermatheca for release at the time of their choice and the rest of the spermatophore becomes a source of nutrients (see Figures 4.3-4.3, pages 52, 56). As spermatophores are energetically costly, the spermatophores produced after the first one are progressively smaller, particularly as males tend not to eat. Whose sperm does a female who has mated with two different males choose? The sperm from the males with the larger spermatophore is generally chosen. Male spermatophores are so coveted that female *Neotrogla* cave bark-lice (Psocoptera) penetrate the males getting his spermatophore with a penis-like organ (Nuzzo 2014, Yoshizawa et al. 2014)! In fireflies studied, the spermatophore gives females a longer life and larger progeny. Sometimes, the spermatophore size is related to the luminous qualities females are looking in conspecific males, but sometimes they are not.

Dreams of Flying, Chapter 5, discusses how to study fireflies or, for all it matters, anything that is or was alive. As Uexküll suggested, part of the "trick" is to try to put oneself in the world, or Umwelt, as it is perceived by other organisms. Among other techniques, light-emitted diode (LED) sources serve as an example of easy ways to mimic, communicate (and sometimes fool) fireflies.

Chapter 6, *The Making of a Flasher*, discusses the mechanics, or proximal causes, of bioluminescence, a widespread phenomenon in life. The search for proximate and ultimate causes are of interest to biology. The mechanism in fireflies is similar to that in other organisms, needing several molecules to produce light: a 1) large protein, generically called luciferase, a 2) much smaller molecule, generically called luciferin, is "energized" by an 3) energy-rich molecule, called ATP, 4) oxygen, and 5) ions, their identity depending on the organism. When luciferin's added ATP-energy dissipates, it is given off as light. The "luciferases" apparently originated from enzymes that are also involved in other metabolic processes, through a process known as gene duplication. *Tenebrio molitor* Linnaeus, 1758 of the beetle family Tenebrionidae, which normally do not produce lights, glowed when injected firefly luciferin! Using the tools of genetic engineering, light production (or lack of thereof), inspired by the luciferase-luciferin genes, have catapulted numerous practical (e.g. public health, medicine, research) uses of light as a reporting tool at the micro level. The late John Buck (Johns Hopkins University, Baltimore, USA) and his live-long companion, Elizabeth Mast, discovered that the light-producing organ contains light-producing cells, or photocytes. The key ingredients in bioluminescence in fireflies are located inside subcellular vesicles, called peroxisomes. When fireflies sense diminished external illumination, or "dusk", they begin sending signals through their neurons to get a cascade of reactions going that will eventually produce light. In an important discovery that involved her family, Lewis et al. found that this cascade of reactions is regulated by nitric oxide (NO), a gas that shuts down oxygen gobbler mitochondria located inside cells. When mitochondria stop working, oxygen becomes available for the light-production mechanism. In other words, just like when a man wishes to have an erection, when a firefly uses his/her lantern (or say "yes"), NO comes to the rescue. In highly synchronously-flashing fireflies, like *Pteroptyx malacae* (Gorham, 1880), an internal timer, called "pulse-coupled oscillator", appears to be involved in getting having each beetle flash at the same time, akin to members of an experienced, directorless chorus singing the same part in nearly perfect synchrony.

Poisonous Attractions, Chapter 7, relates many anecdotes of vertebrates that are choosy, systematically avoid fireflies. Predators can be choosy and this choosiness can be related to genetic as well as environmental factors (see Literature Cited). Apparently, in fireflies a major component of the avoidance behavior of *Photinus* fireflies is a family of steroid-like chemicals, known as lucifagins and by reflex bleeding, whereby the beetle hemolymph (the "blood" of insects) is oozed upon attach and it becomes sticky on the small potential predator. Before a diurnal vertebrate predator experiences a distasteful, foul-smelling firefly, it sees the gaudy – and warning – colors of many fireflies; for nocturnal predators (e.g. spiders or bats), the flashes tend to serve as a warning. The warning, or aposematic, coloration of fireflies (and other insects) can be taken advantage of by tasty imitators, a phenomenon known as Batesian mimicry, or by distasteful ones that spread the fact-based warning – so to speak

– to the group, presumably strengthening the message to predators. Some female fireflies in the genus *Photuris* imitate the light "calls" of *Photinus* females, luring male *Photinus*. Why these *Photuris femme fatales*, as they have been known for decades, behave this way? Interestingly, they use the *Photinus* lucifagins as self-defenses.

Chapter 8, *Lights out for Fireflies?* Strongly suggests that fireflies are generally in decline worldwide and the prime culprits for this decline are habitat destruction, light pollution, overharvesting, and pesticides.

The *Field Guide to Common Fireflies of North America* avoids jargon and it beautifully illustrated. Additionally, it contains biological remarks on sexual dimorphism, life history, courtship, and other behaviors. Generously, Professor Lewis encourages her readers to contribute to the knowledge of fireflies by *Stepping Ou*t and engaging in learning adventures. *Silent Sparks* kept bringing me memories. My first college term paper was on bioluminescence and, as I read, I kept remembering Harvey's tome; later, in my life as editor, giant "starworms" from China; and recently, lights of understanding and acceptance.

I wholeheartedly recommend *Silent Sparks: The Wondrous World of Fireflies* to anyone who marvels at the wonders of nature and wishes to learn more. As for me, after reading this book, I wish I could have been teaching my diversity course for non-science majors this summer, rather than this spring 2016 as the course would certainly be made more engaging with activities centered on fireflies. For a hardcover book of over 200 printed relatively heavy pages, plenty of color images, and a hard cover, I find *Silent Sparks'* suggested retail price ($29.95) reasonable. I may out at night, net some fireflies, place them in a plastic container with some moss, marvel my wife, people in my new neighborhood, and anyone with the love for learning in their hearts. I shall "repatriate" them. If you are want to keep learning about fireflies, here is the blog of *Silent Sparks*: https://silentsparks.com/category/book-blog/ .

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The references on predator choosiness resulted, in part, from generous colleagues who made me aware of some of them.

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