OUTREACH

Moderator: Ruth Gustafson
University of California Davis
California, USA

BIOLUMINESCENCE: AN ADVENTURE IN LEARNING AND OUTREACH

Dorothy Barr
Ernst Mayr Library - MCZ, Harvard University
26 Oxford Street, Cambridge MA 02138 USA
dbarr@oeb.harvard.edu

Abstract:
In spring 2012, the Ernst Mayr Library – Museum of Comparative Zoology (MCZ) received a grant to purchase and place three exhibit cases in the heavily traveled lobby of an adjacent science building. The purpose was to highlight the connections between library resources and research at Harvard. The second exhibit, Bioluminescence, was especially ambitious and involved multiple departments and University entities, raising and broadening the library’s profile and enhancing recognition of its value. A LibGuide (http://guides.harvard.edu/Bioluminescence) was also created to accompany the exhibit. Since bioluminescence is especially widespread in the oceans, it is of interest to IAMSLIC members, and the paper briefly outlines the subject – what it is, how it works, what organisms use it and why. The paper also discusses how valuable collaborations with faculty, staff and researchers were forged and enhanced in the process of creating the exhibit.

Keywords: Bioluminescence, aquatic sciences, libraries, collaboration

Introduction
During the period from 2011-2013 the Harvard Library, with funding from the Arcadia Fund (http://www.arcadifund.org.uk/), sponsored a number of “Library Lab” projects (https://osc.hul.harvard.edu/liblab). The purpose was to encourage innovation and cooperation across the libraries. In spring 2012, the Ernst Mayr Library – Museum of Comparative Zoology (MCZ) received a Library Lab grant to purchase and set up three exhibit cases in the lobby of an adjacent science building that houses multiple departments. The purpose is to highlight the connections between library resources and research in the biological sciences. We also wanted to reach out to not only the Harvard community but beyond; a cafeteria at the other end of the lobby serves the public as well as faculty, staff and students. The exhibits, which rotate every six months, offer opportunities for scientists to do outreach and to showcase their research. It also broadens the library’s exposure and showcases its resources and expertise.

The second exhibit was on Bioluminescence. Organizing the exhibit offered an opportunity for the author to step outside the physical library and work directly with staff, faculty, and researchers in the Organismic and Evolutionary Biology Department (OEB), the Molecular and Cellular Biology Department
(MCB), and the MCZ. Highlights of the exhibit and the LibGuide that was created along with it are discussed here.

The Project
Although two exhibit cases were originally budgeted, a chance conversation with the Exhibits Director of the Harvard Museum of Natural History (HMNH) led to her suggesting that she and her team could custom build the cases for us. In the end they were not only able to build three cases for the same amount, there was enough money left over to provide ongoing support. This is important because the case covers, which are UV protected acrylic, are very heavy and require two strong men and special tools to remove. On the plus side, of course, this means that the cases are very secure and the objects inside are protected.

Because of the configuration of the space, two tall cases with display areas approximately 33”W x 20”D x 42.5”T were built to flank one long, low middle case, approximately 60”W x 23.5”D, with a slanted cover 19.5” tall in back and 10” in front. There is locked storage space under the tall cabinets.

The grant also provided for graphics. The MCB Graphics Department created and printed all the signage for the exhibit, and these added a great deal of visual interest to the displays.

The first exhibit was done by Lisa Decesare of Harvard’s Botany Libraries, who is experienced in creating displays. The subject was Wood, and it was in place for three months. The original plan was to rotate exhibits every three-four months, but since the subsequent exhibits have become more elaborate and interdisciplinary, requiring more planning and involving more people, the timeline has changed to a minimum of 6 months and longer as needed.

The second exhibit was on bioluminescence. The topic was chosen because of the recent retirement of J. Woodland (“Woody”) Hastings of Harvard’s MCB Department, an acknowledged expert on the subject. His retirement coincided with the publication of his new book on the subject (*Bioluminescence: Living Lights, Lights For Living*) written with Therese Wilson (Wilson and Hastings, 2013). The low middle case was devoted to the book, with eye-catching graphics and a brief excerpt.

Deep-sea fishes were the subject of one of the two flanking cases since many of them bioluminesce. The author had earlier attended a seminar given by Chris Kenaley, a postdoc in Goerge Lauder’s lab in the Ichthyology Department of Organismic and Evolutionary Biology. He works on loose-jawed dragonfishes, which are among the many deep-sea fishes that are bioluminescent. When approached, he was enthusiastic about contributing to the exhibit, and shared material and photographs. Karsten Harter of the MCZ Ichthyology Department found specimens of the fishes in the photographs and arranged them in jars in the same positions as in the photographs. A mid-19th century book open to a charming line drawing of one of the fishes completed the exhibit.

The second tall case was set up with specimens from various departments in the MCZ, including Entomology (e.g., fireflies), Invertebrates (e.g., *Aequorea*) and Mollusks (e.g. the bobtail squid). There was also a tool called a BioScan made by GE. This small instrument uses bioluminescence to measure bacteria in water simply, accurately and almost immediately. This is a big improvement over conventional methods that require culturing and take hours or even days to give results. There were also colorful graphics in the cases to add visual appeal, and text was minimal.

What IS Bioluminescence?
Bioluminescence is biological light – light generated by living organisms. It involves a chemical reaction so efficient that it emits hardly any heat. A form of phosphorescence, it is different from fluorescence, which ceases when the illumination that causes it stops. Bioluminescence has evolved independently at least 40 times and has fascinated humans for centuries. Today it is being utilized in many ways, from medicine to warfare to biotechnology. Recent research has uncovered more and more bioluminescent organisms, especially in the deep oceans.

As Wilson and Hastings (2013) point out, bioluminescent organisms are scattered widely across the tree of life, though by no means all of the organisms in any group luminesce. Thus bioluminescence is found in some mushrooms but no plants; many fish but no other vertebrates; and essentially no freshwater organisms (only one is known, a tiny snail from New Zealand, though it’s not clear why there aren’t more). Of course, we don’t know how many times in the past it may have evolved and then disappeared.

On land luminescent animals include fireflies and other beetles, especially elaterids or click beetles; larvae of some flies; a couple of centipedes and millipedes; a snail; some earthworms; and that’s about it. Bioluminescence is common in the oceans, however. Haddock, Moline and Case (2010) speculate that the reasons include relatively stable environmental conditions; optical clarity compared to other aquatic habitats; comparatively large areas that receive little or no light; and a multitude of organisms interacting. As mentioned, one of the three cases in our exhibit was devoted to deep-sea fishes, and another included other marine organisms.

The How and Why Of Bioluminescence
Simply put, bioluminescence is produced within cells by chemical reactions. It involves the reaction of oxygen with specific molecules that vary in different groups of organisms, and requires specific enzymes to catalyze the reactions.

At least two types of chemicals are involved in every bioluminescent reaction. Luciferin is the generic term for the light-emitting molecule and is the component that produces the fuel for the chemical reaction. The enzyme that acts as the catalyst to create the glow is called a luciferase. Luciferins are highly conserved - they tend to stay the same within a group over time. There are only five types known, of which the most common is coelenterazine. It is found in nine different phyla, and was first discovered in the jellyfish Aequorea, a specimen of which was included in the exhibit.

While luciferins are conserved, luciferases are diverse - within a group there may be many different ones. They do tend to be species-specific, however.

For bioluminescence to have evolved independently so many times, and for it to be so widely distributed across taxa, it must serve definite purposes. There is an excellent chart on the uses of it by organisms in the oceans at http://www.lifesci.ucsb.edu/~biolum/functions.html (from Haddock et al. 2010). Below is an edited summary:

- Communication/mate attraction/recognition. There are many examples found in the oceans. They include octopus; squid; lanternfish; flashlight fish; anglerfish; ostracods; polychaetes; and others. (Fireflies provide another obvious example. They signal to attract mates, though some females - aptly dubbed femme fatale fireflies - mimic the signals of other species to attract males, who arrive hoping to mate and instead find themselves becoming dinner.)
• Luring, confusing or illuminating prey. Anglerfish and other deep-sea fishes attract prey with dangling luminescent lures. Squid and perhaps headlamp lanternfish flash to stun or confuse prey. Flashlight fishes and dragonfishes bioluminesce to illuminate prey.
• Defense. This is used in different ways by many ocean organisms, such as:
  ➢ Camouflage. Counterillumination is very effective in warding off attack from below; looking up towards the light from above, a predator may not see an animal that is luminescing.
  ➢ Startling. A sudden flash may startle a potential predator and allow the proposed victim to escape.
  ➢ Misdirection. Many ocean organisms bioluminesce to deceive predators. They include crustaceans, polychaetes, squid, ctenophores, some fishes, and more.
  ➢ Distraction. *Octopeuthis* squid, brittle stars, polychaetes and siphonophores among others luminesce to distract predators, prey or even both.
  ➢ Sacrificial tag. Some sea cucumbers, jellies and polychaetes do this; illuminate a disposable body part, drop it and escape while the predator concentrates on the glowing bit left behind.
  ➢ Burglar alarm – to warn others of its kind. Dinoflagellates and jellies definitely do this.
  ➢ Warning – “don’t eat me / settle on me, you’ll be sorry.” Jellies send this signal, and perhaps brittle stars and others as well. Bioluminescence used in this way can be regarded as an aquatic equivalent of aposematic coloring on land.

**Some Examples Of Bioluminescent Organisms**

![Image](image_url)

*Figure 1. Diaphus metopocampus, the spothead lanternfish. Photo © President and Fellows of Harvard College.*

Dragonfishes and hatchetfishes (Stomiiformes) are characterized by elaborate arrangements of photophores. They may sport barbels, photophores under their eyes, and others along their ventral (underneath) sides. A few stomiatoid fishes such as *Malacosteus niger* have photophores that produce two radically different frequencies of light: one behind the eye that produces blue light and one under the eye that can produce red light. This is unusual because long wave red light dissipates more quickly as it passes deeper into the ocean, where short wave blue-green light is the norm. Using specialized pigments capable of perceiving red light, fishes like *Malacosteus niger* can communicate with one another via a private wavelength and can also visualize prey.
**Figure 2.** Echiostoma barbatum. *The Threadfin Dragonfish, a Stomiid. Photo © President and Fellows of Harvard College. Photo on right, by Chris Kenaley, is of a freshly caught specimen; note especially the glowing barbel.*

*Himantolophus albinares* is another luminous deep-sea fish. Popularly called the football fish because of its soccer-ball-like appearance, it is an anglerfish in the group Lophiiformes. It produces light at the end of its modified dorsal ray using bacteria.

**Figure 3.** Himantolophus albinares - AKA the Football Fish. *Photo © President and Fellows of Harvard College.*

The Bioluminescence exhibit was so successful and the relationships that were developed were so rewarding that the next exhibit was even more ambitious. The subject, Time, was chosen to complement an exhibit at the Harvard Museum of Scientific Historical Instruments (HMSHI) ([http://chsi.harvard.edu/](http://chsi.harvard.edu/)) on Time. That exhibit covered all aspects of the subject – clocks, timekeeping, etc. - so we decided to focus on biological aspects. After reading a paper published by researchers in MCB on circadian rhythm in cyanobacteria, the author contacted the lab members, got a positive response, and met with a postdoc to talk about it. Before long it was obvious that there was a great deal of other relevant research in the University, and in the end members of four labs, two in MCB and two in
OEB, were involved, and those graduate students and postdocs contributed greatly both to the exhibit and to the LibGuide.

On display were a vial of cyanobacteria and a petri dish of *C. elegans* babies, which are too tiny to see with the naked eye so a magnifying glass was propped over them to emphasize their size. There were also short explanations, splashy graphics, old drawings from the Library’s collection and specimens from the MCZ. These included a box showing the life cycle of cicadas; fossils from the MCZ Invertebrate Paleontology collection; a hagfish from the MCZ Ichthyology department; a bird from the MCZ Bird collection mounted in the same position as a model of a predatory dinosaur to highlight the similarities; and models of Burgess Shale creatures from the HMNH Education Department. The middle case was a timeline of biological life on earth, beginning with cyanobacteria and ending with the demise of the dinosaurs. The LibGuide is [http://guides.library.harvard.edu/Time](http://guides.library.harvard.edu/Time).

**Conclusions**
The faculty, graduate students and staff members who contributed to the exhibits benefitted by having their research publicly highlighted. The Library enhanced its profile and received exposure beyond its walls that continues with use of the LibGuide. And most of all, the librarian forged new relationships and strengthened existing ones, to the benefit of all.

**References**