Biology's Amazing Processes: Bioluminescence

The biological world is full of amazing creatures with even more amazing adaptations and abilities. Bioluminescence is one of the most striking and baffling adaptations of the natural world.

PRACTICAL SCIENCE WITH PHIL FREDA

A welcome addition to a muggy summer night is myriad fireflies buzzing through the trees. It really doesn't feel like summer has officially come until the first firefly is spotted.

Have you ever sat and wondered how fireflies produce their light or why?

This article aims to "shed some light" on how the mechanism of bioluminescence works and also to introduce many other amazing species that also have this amazing adaptation.

How does bioluminescence work?

There are actually many different bioluminescent systems out there, but all of them have the same basic blueprint.

The first is a chemical called a luciferin. If you look at the word, what do you immediately see?

That's right—Lucifer.

So what does the devil have to do with bioluminescence?

Actually nothing, but, according to the Judeo-Christian tradition, Lucifer was God's most praised angel and was called the **light-bringer.**

According to the University of California, Santa Barbara's Bioluminescence Web Page, in the presence of oxygen and an enzyme called luciferase, luciferin is oxidized to an inactive oxyluciferin molecule.

This chemical reaction leads to the production of light.

Here is the overall equation:

- ***Luciferin + O_2→ (Luciferase) → oxyluciferin + light***

There are many different types of luciferin molecules produced, or absorbed through diet, in the biological world, but the overall mechanism is the same.

Why do creatures produce light?

Creatures produce light for a variety of reasons, according to UCSB's Bioluminescence Web Page, including **defense**:

- **Startle**: The bioluminescent species can produce a flash of light to ward of predators.

- **Counterillumination**: This is used so that a prey species can illuminate the underside of its body to effectively become invisible by not producing a shadow. Many species of predatory marine animals swim upward to detect prey, but if the prey species produces light in the right way, they may be impossible to see.
- **Misdirection (Smoke Screening):** By producing a series of scattered light while evading a predator, the prey species can distract the predator and get away safety.
- **Distractive body parts:** As a last resort, some species of squid, sea star and sea worms can abandon a bioluminescent section of their body to attract the predator while they make it to safety. The prey can usually re-grow the lost appendage.
- **Warning coloration:** Some prey species emit light to actually bring attention to themselves, but not to attract the predator at all. What these species are actually doing is warning the predator that 'if you eat me, you may find me poisonous or just downright disgusting.'
- **Burglar alarm:** Some species produce light to warn others that a predator is near.

  Another possible usage of bioluminescence is to **attract or find prey**:

- **Lure prey:** The most famous species that uses bioluminescence to lure prey is the anglerfish. The anglerfish produces light on an appendage attached to its head to lure prey dangerously close to its large mouth lined with sharp teeth.
- **Stun or confuse prey:** Bioluminescence can also be used to confuse or stun prey so that a predator can perform a surprise attack.
- **Illuminate prey:** Bioluminescence can also be used to light up prey that would otherwise be hard to see in dark environments.

  Finally, bioluminescence can be used too as a **social communications** ability:

- **Attract a mate:** Mating, all across the biological spectrum, usually involves extravagant showmanship, whether it is an elaborate dance or a complicated mating call. Some bioluminescent species, famously squid and cuttlefish, have the ability of attracting mates this way with amazing displays of color.
- **Communication:** In addition to finding a mate, bioluminescent squid and cuttlefish species can also “signal” other individuals for many reasons. The light signaling can be used to run from a predator, ward of other competing males, or even as a way to recognize other individuals.

What is the source of bioluminescence?

There are three main sources of luciferin in the natural world.

One way is that the species produces the luciferin needed to create the light through biosynthesis (Metabolism).

Another way is that the species acquires the raw materials from its diet.

The third and most fascinating way, though, is that some creatures have formed symbiotic relationships with bioluminescent bacteria.
These bacteria actually live inside the light organ of the creature and constantly produce light through a process called quorum sensing.
Quorum sensing is an amazing process in itself.

Bacteria produce certain proteins that diffuse (move) out of the cell. If there is an adequate amount of the same bacteria in the immediate environment, the concentration of these proteins becomes so great that they start to diffuse back into the cell.

This causes a cascade effect in the bacterial cells, which leads to expression of light producing genes.

To regulate the amount of light emitted, the host organism must have a mechanical or chemical way to inhibit the light.

In other words, the host can produce a chemical to stop the light for a period of time or has some part of the body to cover up or pull in the light organ when the light isn't needed.

Examples of species that use this type of system are the anglerfish and many types of squid and cuttlefish.

What I find terribly interesting is the fact that a symbiotic species living in the tissue of these animals is responsible for the light emitted.

Not only that, but the squid and cuttlefish species control the path and pattern of light emitted in very complicated ways to express various emotions from anger and rage, to fear and lust.

However, since there is another species involved, how do the hosts know what they look like, or if they are producing the right signal?

The fact that these species can control such complex physical coordination with another species involved is simply amazing.

Think about that for a second!

The most common bacteria that produces the light in these symbiotic relationships are members of the bacterial genus *Vibrio*.
Fireflies, on the other hand, actually produce their luciferin material.
Fireflies, which are actually a species of beetle, use their bioluminescence for mainly two reasons.

As larvae, research shows that they use the light to ward off potential predators. The signal conveys that fact that they taste bad.

Adults, on the other hand, use the light to attract and signal potential mates.

As a side note, the production of light in fireflies is extremely efficient in which only a small amount of heat is given off as a byproduct of the reaction.

According to Ohio State University's "The Firefly Files" webpage, nearly 100 percent of a firefly's energy is given off as light. By comparison, a normal light bulb gives off only 10 percent of its energy as light, while nearly 90 percent of the energy is wasted as heat!

Where did bioluminescent abilities come from?

This is a very hard question to answer, but, according to howstuffworks.com and many other academic sources, most biologists agree that bioluminescence evolved in many different types of creatures independently of one another.
This means that creatures in totally different ecological, spatial and temporal environments came to the same evolutionary end without directly shared ancestry.

Proof of this comes from the fact that there are so many different types of luciferins and that the ability is found in so many different species that are separated by many eons of evolution.

Also, bioluminescent ability is found in every kingdom of life, from bacteria to fish.

I could literally go on and on about this amazing and interesting topic, but I leave the rest of the research up to you.

As always, happy hunting, and don't forget to think about it!

Feeling confident about your knowledge of bioluminescene? Take the bioluminescence quiz provided by howstuffworks.com
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For more on the bioluminescence of fireflies, check out excerpts from the Fireflies Power Point presentation by Pennypack Ecological Restoration Trust director of stewardship Brad Nyholm **in the video above**.
