



TULSAZOO
AND LIVING MUSEUM

Bioluminescence

Bioluminescence– Intro

What's in a name?

Bioluminescence (BYE-oh-loo-muh-NESS-ens) – What is it? The name comes from the Greek word *bios* for “living” and the Latin word *lumen* for “light”. So, put it together and you have “living lights!” This light is produced by a chemical reaction converting chemical energy to light energy. Some bacteria, animals, and fungi have special chemicals that they can mix together to produce light. Different chemicals create different colors, some are green, red, blue, or yellow.

Bioluminescence– What is it?

All bioluminescence is produced the same way – by combining molecules of luciferins with luciferases and oxygen in a chemical reaction to produce light.

Means of Display

There are three different ways: *external* – outside the body, *internal* – inside the body, or *borrowed* – some species use bioluminescent bacteria to glow.

External: Some squid and other animals expel a cloud of luminescence to confuse or repel a predator while they escape.

Internal: Fireflies and some bacteria mix the chemicals in their bodies. They have tissues with special cell structures called “photophores.”

Borrowed: Flashlight fish, some mollusks, squid, nematodes, and other fish get their bioluminescence from glowing bacteria that they host in or on their bodies.

Why Glow?

Bioluminescence is used to **attract, camouflage, escape, or communicate.**

Attract: To avoid being eaten, some sea creatures such as the deep-sea jellyfish and the scaly dragonfish activate a “burglar alarm.” They light up when attacked, hoping to attract a larger predator that might want to eat the bully. Bioluminescence is also used to attract food. Several deep-sea fish, like the anglerfish, have glowing, dangling body parts that act like lures to attract other fish near their mouths.

Camouflage: To find food, predators deep in the ocean look up toward the sunlight to spot the shapes or silhouettes of potential victims swimming above. But prey with bioluminescent bellies can hide or obscure their own silhouettes by matching the surrounding light, making themselves almost invisible to predators. This counter-illumination camouflage technique is used by some squid and fish like the cookiecutter shark.

Escape: To avoid predators, some animals use deception or confusion. One deep-sea shrimp spits out a bioluminescent slurry at attackers. The vampire squid releases a cloud of bioluminescence instead of ink to confuse or repel a predator while it escapes. Flashlight fish also use the bioluminescent patches under their eyes to help them flee from predators by flashing them off and on while swimming in different directions.

Communicate: To communicate their mating signals, fireflies and click beetles flash. Many of the 2,000 species of fireflies have unique flash sequences, with the male flashing his code and the female responding with hers. Railroad worms use bioluminescent flashes to warn predators of their bad taste. It is believed that bioluminescence also plays a role in bacterial communication.

Bioluminescence on land and in the sea...

Would you believe that up to 90% of deep-sea life are “living lights,” meaning they are capable of producing bioluminescence? In the deep-sea, it’s very dark so these animals must produce their own light in order to find food, locate mates, or avoid being eaten.

Not nearly as many species that live on land are bioluminescent. Can you think of any? Probably the most well-known example is the firefly. There are also some species of fungi (mushrooms), other insects (and larva), centipedes, snails, and earthworms that are bioluminescent. Sometimes in the forest, you might see some wood that appears to be glowing. It’s actually bioluminescent fungi that are decaying the wood.

Layers of the Ocean

You might think the ocean is the same from top to bottom, but actually there are 5 distinct layers or zones. Different animals tend to gather and feed in certain zones. Bioluminescence is found in every ocean and sea, from the surface to the seafloor. In the deeper and darker water, bioluminescent animals have distinct advantages in finding food, locating mates, and avoiding predators. In the deepest waters, you would find only invertebrates eating the organic material that settles to the seafloor.

Epipelagic Zone

This surface layer is also called the **sunlight zone** and is where most of the visible light exists. This is the ocean’s greenhouse and most ocean animals are adapted to its warmer and lighter waters. Surface-dwelling fish are often greenish-blue above and white below, so that they blend with their backgrounds when seen from above or below.

- *Dinoflagellates*

Mesopelagic Zone

This layer is sometimes referred to as the **twilight zone** as sunlight is very faint. The eyes on the fishes are larger and generally directed upward to see silhouettes of other animals (for food) against the dim light. The pressure in this zone increases and plants can’t grow here. The animals have adapted to little light and colder water.

- *Ctenophores*
- *hatchetfish*
- *Copepods and krill*
- *Ostracods*
- *Amphipods*
- *Arrow worms (Chaetognaths)*
- *Jellyfish*
- *Siphonophores*
- *Comb jellies*
- *Larvaceans and pteropods*
- *Squid, including juveniles of the giant squid Architeuthis dux*

Bathypelagic Zone

Due to its constant darkness, this layer is also called the *midnight zone*. The only light at this depth (and lower) comes from the bioluminescence of the animals themselves. Deep-water fish are more uniformly black or dark red to blend in with their surroundings.

- *Vampire squid*

Abyssopeagic Zone - The name for this zone comes from a Greek word meaning "no bottom." The water temperature is near freezing, and there is no light at all. Very few creatures can be found at these depths due to the crushing pressures and very cold temperatures.

Hadalpelagic Zone - This zone extends from 6,000 meters (19,686 feet) to 10,000 meters (32,810 feet). These areas are mostly found in deep-water trenches and canyons. In spite of the unimaginable pressures and extremely cold temperatures, life can be found here!

Ocean Drifters

Plankton is from a Greek word for "drifters." It refers to all the plants and animals that drift with the ocean currents as inhabitants of the open waters of the sea. The animal members of plankton are called zooplankton, which range in size from tiny microbes to small jellyfish. All are weak or non-swimmers. Planktonic plants are called phytoplankton, and they do not swim at all. Phytoplanktons are the "trees" of the sea because they make most of the oxygen for the ocean through photosynthesis. They float near the surface to make the most of the sunlight.

Dinoflagellates are an important type of phytoplankton. Along with diatoms, they are the beginning of most food chains in the ocean. Without the phytoplankton, the other animals could not survive. Most Dinoflagellates are bioluminescent. At night, the ocean may look like it's glowing a bluish-green, like a "milky sea." Sometimes the breaking waves or a passing boat can trigger this glowing. Even though Dinoflagellates are single cells, they can occur in such large numbers that their combined "glowing" effect can be seen from outer space!

Flashlight fish

Fish with a flashlight? That's right, the light helps the flashlight fish attract and catch prey. Tiny animals (zooplankton) are drawn to the glowing light like moths to a flame. Some species of flashlight fish eat small fish and shrimp that are also attracted to the light.

Abnormal Eye?

The brightly glowing eyes of the flashlight fish are not eyes at all, but highly evolved organs (photophores) beneath each eye that contain light-producing bacteria. The name given to this family of fish is *Anomalopidae*, which is a Greek word for "abnormal eye." Six of the species within this family are bioluminescent. All of the fish are black with large mouths and generally live in shoals inside caves and dimly lit protected areas.

Flash and Dash

A retractable fold of skin covers the photophore. This has proven to be quite useful when avoiding predators. When being chased, the fish darts in one direction with lights on and then changes course and goes in a different direction with the lights off so it doesn't become dinner. This "flash and dash" action is repeated up to 75 times a minute!

Terrestrial Life Intro

In contrast to the sea, bioluminescent land animals are relatively rare. They include some species of fungi (mushrooms), snails, worms, insects, and arachnids.

Did You Know?

The bioluminescent rhizomorphs of the *Armillariella mellea* fungi form extensive underground networks, and genetically identical colonies have been known to cover areas as large as several football fields, making this species the largest organism on earth!

Firefly

The fireflies, or lampyrids, that you see blinking are mostly males who are searching for a mate. The male blinks his half of the code and the female, usually perched on a blade of grass, answers with the other half. There are more than 2000 species of fireflies throughout the world, many with their own code.

Mycena chlorophos and Panellus stipticus

Glowing Fungi (Mushrooms)

There are at least 27 different species of bioluminescent mushrooms! In some, such as the *Panellus*, only the gills under the cap glow. In other species, such as *Mycena*, a glowing secretion oozes up through the stem, enters the gills, and flows over the cap causing the entire mushroom to glow. Although there are several theories, no one knows exactly why mushrooms bioluminesce.

Foxfire (Armillariella mellea) and Jack O'Lantern (Omphalotus olearius)

Foxfire

As a source of myths concerning elves and ghosts, foxfire (or fairy fire) is the greenish light seen in the forest along the ground and in rotting wood. Fungi, usually honey mushrooms (*Armillariella mellea*), emit this greenish light while decaying wood. The mushroom's stem and cap do not glow. It sends out root-like structures called hyphae under organic material as it grows. These hyphae form rhizomorphs that bioluminesce.

Jack O' Lantern Mushrooms

The gills of the Jack O' Lantern mushroom produce a greenish bioluminescent glow. Its name comes from the orange color of its cap and its ability to give off light. This species smells good and many people have been tempted to eat them, but they're poisonous. The poisoning usually causes severe cramps, vomiting, and diarrhea, all of which can last up to a few days.

Railroad Worms

The railroad worm is actually the female adult of a species of beetle that remains in a larval state. Studies suggest that they use their flashing bioluminescent glow to let other night predators know that they taste bad. The females often glow continuously while they curl themselves around their eggs. Their name comes from the yellowish-green glow that looks like "lights in windows" on each body segment and the red light on the head of the worm, all of which makes them resemble a train at night. The railroad worm is one of only a few creatures that produce more than one bioluminescent color.

Earthworms

There are at least 33 different species of bioluminescent earthworms and they can be found worldwide! Earthworms give off a luminescent slime that is sticky and continuously glows. In the United States, bioluminescent earthworms are found in moist regions, usually in the southeast.

Did you know?

There are some bioluminescent earthworms in Australia that grow to over five feet in length!

Human Applications

Bioluminescent organisms are a focus for many areas of research. Genetic engineers have used the luciferase chemical reaction that results in bioluminescence as a tool. In the GloFish®, the goal was to create a fish that would bioluminesce when it came in contact with environmental pollutants. Created in 1999, researchers took a gene from a jellyfish that naturally produced a fluorescent protein and inserted it into the zebrafish, resulting in a “glowing” fish. Scientists further refined the process until the fish only glowed in the presence of the toxic pollutant.

Genetic engineering has been used to create a modified tobacco plant, and in January 2006, Taiwanese researchers successfully engineered bioluminescent adult pigs by fusing genetic information from jellyfish with a pig embryo. There are also many potential industrial and commercial applications. Industrial designers are looking at engineering bioluminescence to create glowing Christmas trees that don't need lights, to make glowing trees to line highways and save electricity, or to grow agricultural crops that luminesce when they need water! What other uses can you think of?

Bacterial Art

This arch was composed of petri dishes “painted” with bioluminescent bacteria. The 9 foot high by 5 foot wide piece was installed in December 2002, at the O'Malley Library, Manhattan College, Riverdale, NY.

GloFish®

During the day, they might look like ordinary fish, but turn out the lights and turn on a black or UV light and they glow like a neon sign! GloFish® are the world's first genetically engineered pets. Scientists transplanted a gene that fluoresces into the DNA of zebra danios creating GloFish®, which are becoming a popular aquarium species.

Suggested Websites:

<http://www.biolum.org/>

<http://www.bioscience-explained.org/EN1.1/pdf/BiolumEN.pdf>

http://www.sdnhm.org/exhibits/glow/glow_tguide.pdf (teacher's guide)