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BIODIVERSITY
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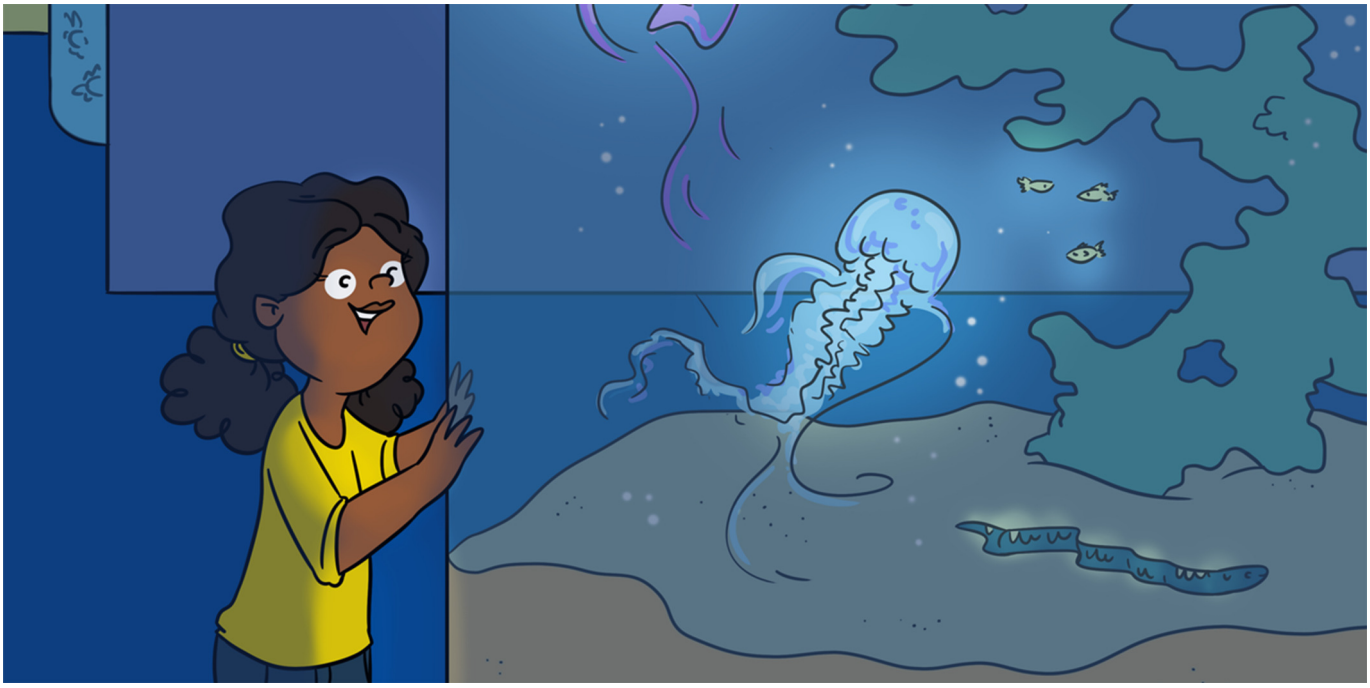

THE DARK OCEAN IS FULL OF LIGHTS

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Imagine that your body could emit light whenever you needed it. You would never be afraid in the dark or at night, because you could light up the world around you. You could shoot a flashing cloud under your bed so that monsters in the darkness would be blinded, while you escape. Many animals in the ocean can actually do that; this superpower is called bioluminescence! In the open sea, about three quarters of all animals are bioluminescent, and these animals can live anywhere from the surface down to 4,000 meters deep. This light emission is an efficient way to communicate with mates, attract prey, or escape predators in the darkness of the oceans.

INTRODUCTION

Do you know that most marine animals have a superpower that we do not have? It is called **bioluminescence**, from the words "bios," meaning life in Greek, and "lumen," meaning light in Latin. Bioluminescence is the ability of some living organisms to emit their own light. The word bioluminescence may sound similar to other

BIOLUMINESCENCE

The emission of light by living organisms.

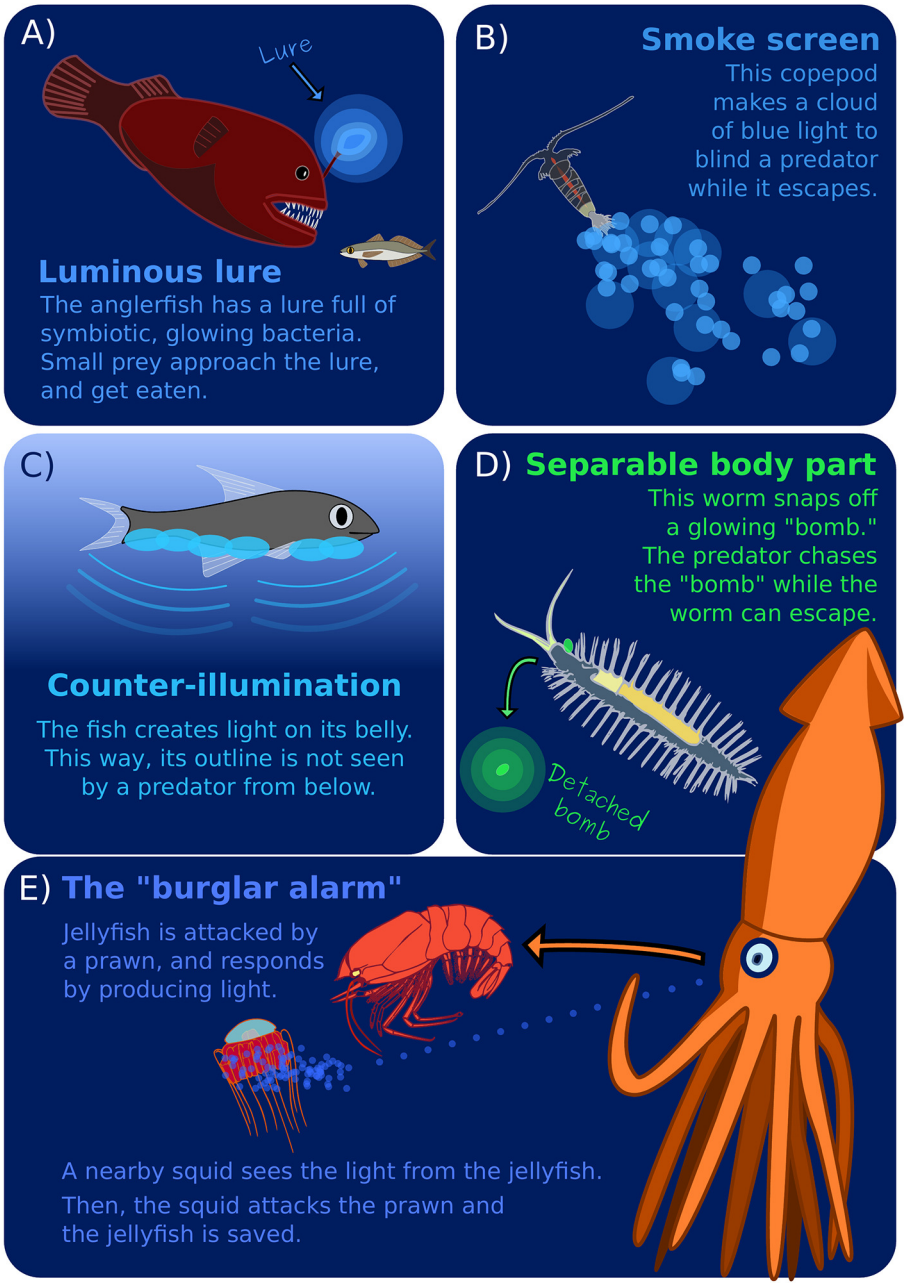

Figure 1

Various ways that deep-sea animals use bioluminescence. **(A)** Luminous lure, **(B)** smoke screen, **(C)** counter-illumination, **(D)** separable body part, **(E)** "burglar alarm".

LUCIFERIN

A chemical acting with the luciferase during the bioluminescence chemical reaction.

LUCIFERASE

An enzyme involved into the bioluminescence chemical reaction.

words, like "phosphorescence" (think of glow-in-the-dark toys), or "fluorescence" (think of highlighter markers), but they are completely different phenomena [1]. The main difference is that bioluminescence does not require any source of external light, like the sun or a flashlight. Bioluminescence is actually a chemical reaction (more like a glow-stick). This reaction was described for the first time in 1887 by the French biologist Raphael Dubois. The bioluminescent reaction requires two chemicals, one called a **luciferin** (which gets used up like batteries) and the other called a **luciferase** enzyme. The two chemicals react together, with a bit of oxygen, to produce light.

WHY EMIT LIGHT?

Why do animals put their energy into making light? One reason to emit light is that, in the ocean, the sunlight barely penetrates deeper than a few hundred meters. Below that, it is completely dark. During the night, even the ocean surface is dark, except for the faint glow from the moonlight, so light is a great way for animals to communicate. But who are they communicating with and who else is seeing these signals? For marine species, emitting light or looking for light in the darkness helps them to find partners or even something to eat. For example, the angler fish uses its glowing lure to attract small prey that will undoubtedly end up in its stomach (Figure 1A). Of course, since the prey do not want to be eaten, they can use bioluminescence too, but as a defense. Many different strategies can be used [2]. Shooting a cloud of luminescent mucus is a way to leave predators dazzled for a few seconds (Figure 1B). Indeed, imagine that you have been in a dark room for a few minutes. If someone comes in and points a flashlight at your eyes, you will be blinded for a few seconds and unable to see anything—just enough time for the potential prey to escape.

Some fish and squid use bioluminescence for counter-illumination (Figure 1C). Normally, if these animals swim at the surface during the day, their silhouette against the sun would be visible to predators swimming beneath them. However, some fish and squid can produce light from their bellies to disrupt the silhouette and hide them from would-be predators. Another strategy used by some squid and worms is to detach part of their body as a sacrificed luminous target (Figure 1D). A predator then chases the glowing detached part while the prey escapes, similar to the way some reptiles can detach their own tails to escape predators. Lastly, some animals use light to attract help if they are being chased, which is sometimes called their "burglar alarm" (Figure 1E). Animals that are slow or fragile can have trouble escaping a predator by themselves, so they use the light to call out to something bigger and meaner that might want to eat the organism harassing the fragile animal.

DIVERSITY OF LUMINOUS MARINE ORGANISMS

Bioluminescent organisms are uncommon on land, though perhaps you have seen bioluminescent fireflies in your garden or in the countryside. In the ocean, however, they are found everywhere. There is a wide diversity of luminescent animals: fish, squid, jellyfish, some corals, different kinds of marine worms, ctenophores (pronounced "TEEN-o-fours," comb-jellies), sea stars, and crustaceans (some shrimps, for example). Among even stranger luminous animals, pyrosomes are organisms that look like long, gelatinous tubes (Figure 2A). They emit unusual brilliant, sustained light and, more amazingly, they luminesce in response to external light stimulation (Figure 2B).

Figure 2

Pyrosomes: interesting bioluminescent animals. Pyrosomes are free-floating tube-shaped animals. They can range from a few centimeters to few meters in length. **(A)** A pyrosome observed under white light, which is like the light from the sun, or a lightbulb (©MBARI). **(B)** A pyrosome glowing, using bioluminescence (with permission from S.H.D. Haddock, ©biolum.eemb.ucsb.edu/).

Most of the bioluminescence emitted by ocean animals looks blue or green, which are the colors (or wavelengths, in physics) that travel the furthest underwater. It has been observed that green light emitters are mainly found in shallow environments, while blue-turquoise light emitters are more often **pelagic** creatures, meaning they live in the open water [3]. However, the entire rainbow is used by bioluminescent organisms. Some jellyfish make light that looks purple. The marine worm named *Tomopteris* (pronounced "toe-MOP-ter-iss") emits yellow light in the form of bright glowing particles, a very uncommon color to emit in the deep sea. Scientists still do not understand how or why *Tomopteris* produces yellow light. Lastly, some fish, called dragonfish, even make red light. At this extreme wavelength, our eyes can barely see the red light, but our cameras can. The red light is probably used to search for prey, since most of the dragonfish's prey cannot see red light either.

PELAGIC

Relating to the open water of the ocean, as distinguished from the benthic regions of the ocean.

The light emitted from bioluminescent animals is usually very short-lived, lasting from <1 s to about 12 s. The patterns of light are very diverse. Short flashes of bright light are emitted by copepods, and clouds of bioluminescence are produced from some ctenophores, siphonophores (relatives of jellyfish that form long chains), or chaetognaths (commonly called arrow worms). Another example is the sea cucumber, which does not look very pretty under normal light. However, in the dark, when some of them luminesce, we can see amazing, circular patterns of light over their entire bodies, like living fireworks[1]. The most incredible thing is that there are certainly many more bioluminescent patterns hidden in the deep ocean that nobody has ever seen.

[1] https://www.nature.com/articles/d41586-018-06660-2

Figure 3

Bioluminescent animals can be found throughout the ocean. Pelagic organisms are found in the water column, and around 76% of these animals are luminous. Benthic organisms are found close to the seafloor, and 30–40% of them are luminous.

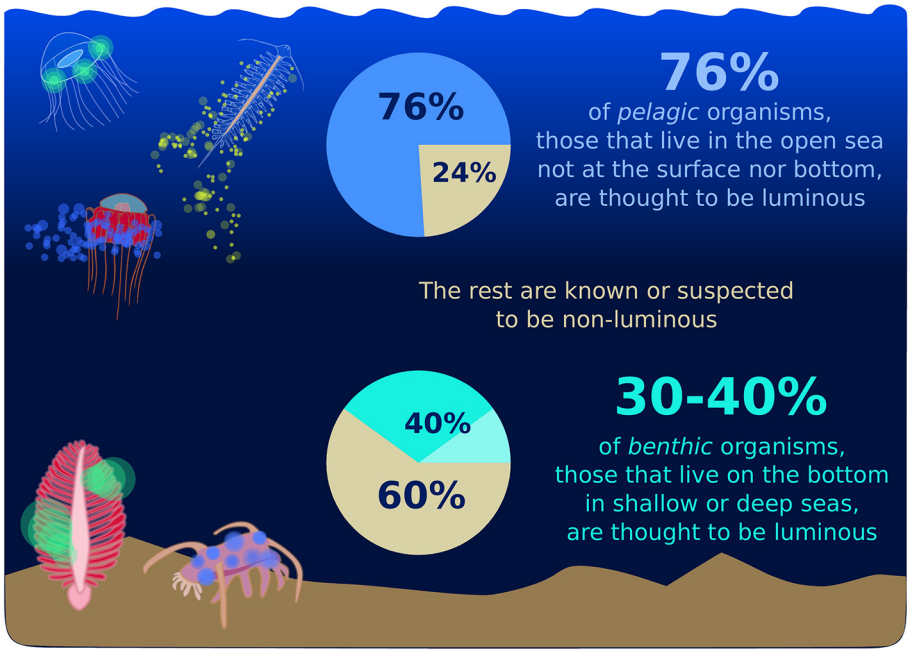

Figure 3

It is not just larger ocean animals that use light in these ways—some microscopic organisms can also be bioluminescent. Dinoflagellates (pronounced "dino-FLA-jel-lits") are often responsible for the bioluminescence observed at the sea surface. Their luminous traces can sometimes be seen at night behind sailing boats or if you disturb the water with your hand, at the beach. Even bacteria can be bioluminescent. Contrary to larger organisms, the light of bioluminescent bacteria is continuous. Bioluminescent bacteria can be found everywhere in the ocean: free in the water, attached to substances like plankton poop, or carcasses, or even in fish guts. These bacteria can also be found in a symbiotic relationship with other animals, living in specific light-organs of certain fish or squid. Like a team, in which each member of the team contributes something helpful, the larger animal provides nutrients (food) to the bacteria and, in return, uses the bacterial light to attract prey. A common example is the angler fish. This fish, which lives very deep down in the ocean, has a luminescent lure filled with luminous bacteria on its head, acting like a fishing rod. The anglerfish and bacteria are living together in a symbiotic relationship. However, bioluminescence through **symbiosis** is not common, and most organisms are self-luminescent, using specialized cells called **photophores**.

SYMBIOSIS

Interaction or close living relationship between organisms from different species, usually with benefits to one or both organisms.

PHOTOPHORE

Light-emitting organ present in some bioluminescent animals.

HOW COMMON IS BIOLUMINESCENCE IN THE OCEAN?

Researchers in submarines have reported that, during their descent into the deep ocean, a lot of the creatures disturbed by the vehicle were sparkling. However, it remains very difficult to observe these

glowing animals in their environments, several thousands of meters below the ocean surface. Recent analysis estimates that 76% of pelagic organisms (those that live in the open water) have the ability to emit light [4]. This means that most of the animals living between the surface and the deep ocean have this super-power. For **benthic** organisms (those that live close to the seafloor), the percentage is a little bit less—about 40% of these animals are bioluminescent (Figure 3). Such variability is linked to the wavelengths of light that are most visible in these environments. Why is there such a different percentage of luminous pelagic animals compared with benthic animals? One main hypothesis is that bioluminescence is a way to communicate. To communicate with someone far away, light is very effective in the pelagic environment. On the contrary, for benthic animals, there are a lot of obstacles like rocks, cracks, and caves, or the water can be cloudy due to sediment stirred up by ocean currents. As a result, using light is probably not as effective for benthic organisms. Light might also be less necessary for bottom-dwellers, since there are many places to hide.

BENTHIC

Relating to the bottom of the sea or to the organisms that live there.

CONCLUSION

Bioluminescence is a fascinating superpower possessed by many of the marine creatures living in our oceans and frequently shown in movies or TV shows. While scientists have been aware of this ability and its mechanism for centuries, we are still far from understanding everything about bioluminescence. Indeed, researchers have not discovered all the reasons why animals or bacteria are bioluminescent. Also, the chemical reaction that creates bioluminescence, while understood for some animals, still remains secret for many other animals, such as some worms and many fish.

It is important for scientists to keep studying bioluminescence, because this fascinating ability of organisms remains undescribed or barely understood in many animals, while it has a major importance in the dark ocean.

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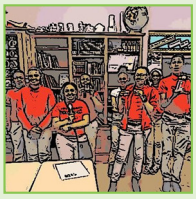

JOHN FISKE ELEMENTARY SCHOOL, AGES: 12–14
We are group of students at smart young scientists participating in SMART science club. We are interested in different chemicals and substances. We are in seventh and eighth grade at John Fiske Elementary School. We are excited about the opportunity to work with scientists who study and write about bioluminescence. Our names are Joi, Brianna, Kingsley, Taliya, Hallel, Shamari, Shamar, and Camron.

AUTHORS

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I started working on bioluminescent bacteria during my Ph.D. in Marseille, France, at the Mediterranean Institute of Oceanography. My goal was to understand how these microorganisms adapt to the deep sea (high pressure and darkness). To pursue my research on larger marine species (jellies, invertebrates...), I worked for 2 years at the Monterey Bay Aquarium Research Institute (MBARI), in California, USA. MBARI is a world-leading laboratory specialized in deep-sea research and technologies. *martini.severine@gmail.com

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My background is in biochemistry. I did my Ph.D. in California at the Monterey Bay Aquarium Research Institute, studying bioluminescence in a group of animals called ctenophores, the comb jellies. I have ongoing projects on a variety of luminous animals, polychaetes, squid, corals, and jellyfish, from both genetic and chemical perspectives.