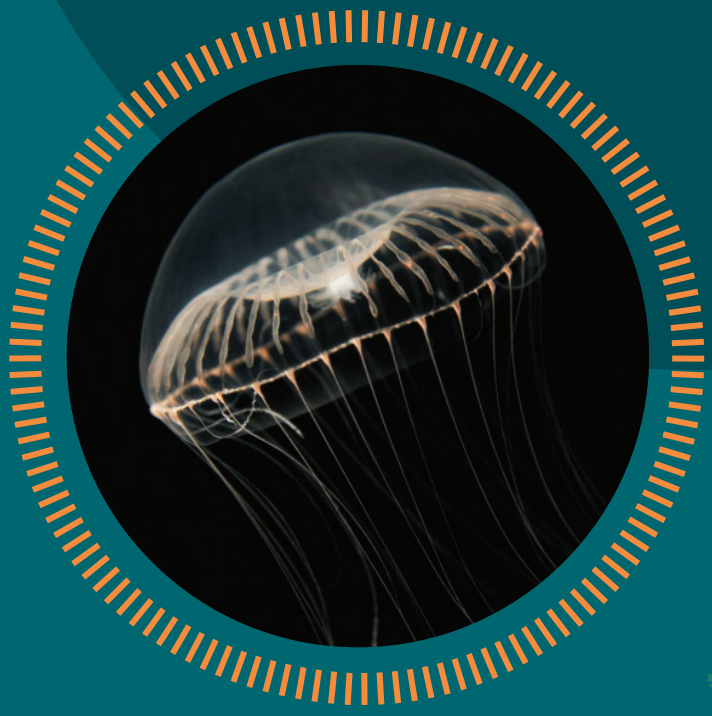
American Museum of Natural History

Educator's Guide

CREATURES OF LIGHT

NATURE'S BIOLUMINESCENCE



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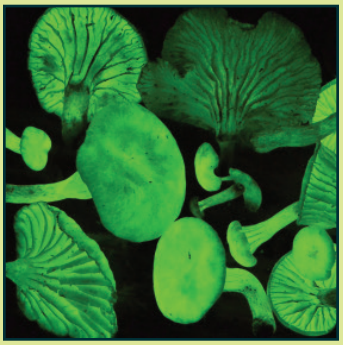
amnh.org/education/creaturesoflight

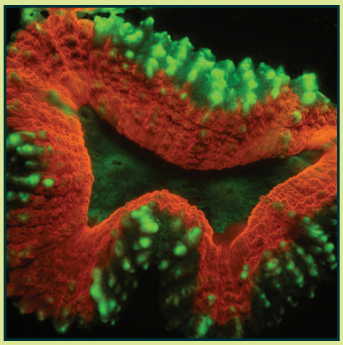
ESSENTIAL Questions

Travel from a warm summer meadow to the deep sea to explore the phenomenon of bioluminescence: living things that "glow," or emit light. What kinds of organisms are bioluminescent? Where are they found? What are some possible functions of the ability to glow? **Use the Essential Questions below to connect the exhibition's themes to your curriculum.**

What is bioluminescence?

Bioluminescence is a chemical reaction that takes place in an organism and produces detectable **light**. These organisms use a variety of body parts to emit light in different colors and for different purposes. This chemical process is different from **fluorescence**, another process that can cause things to emit light. In a few organisms, bioluminescence and fluorescence both occur.





Left: These bioluminescent mushrooms grow on decaying wood in North American forests. Right: These corals are fluorescent: they glow when blue or violet light shines on them.

How does bioluminescence work?

This **chemical reaction** requires at least three ingredients. An enzyme known as luciferase acts upon an organic molecule called luciferin in the presence of oxygen. The reaction produces a molecule called oxyluciferin, and energy. The energy takes the form of photons, units of light.

Some bioluminescent organisms produce their own light, either making all of the ingredients themselves or making everything but luciferin, which they take in through their diet. Other bioluminescent organisms, such as the flashlight fish, do not produce their own light. Instead, they have a **symbiotic** relationship with bioluminescent bacteria that live inside their bodies.

What organisms are bioluminescent?

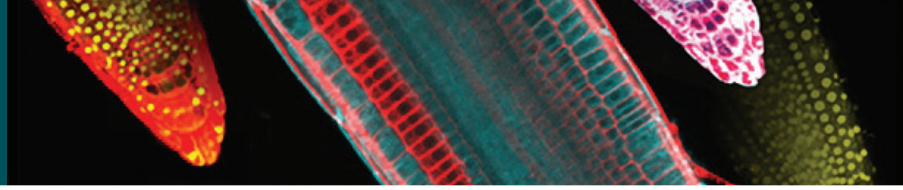
An astounding variety of creatures make their own light, and bioluminescence has evolved independently in organisms as different as mushrooms and sharks. In fact, this trait has evolved at least fifty times on the **Tree of Life**! Bioluminescent organisms range from marine bacteria and other **plankton**, to corals, sea slugs, crustaceans, octopuses, and fishes. There are also bioluminescent fungi, worms, and insects, but no bioluminescent flowering plants, birds, reptiles, amphibians, or mammals.

Where are bioluminescent organisms found?

Eighty percent of all bioluminescent groups live in the world's oceans, from the shallows to the deep sea floor. Some organisms that live near the surface, like flashlight fish and single-celled **dinoflagellates**, have evolved to use their bioluminescence at night. In the deep sea nearly all the organisms glow, an **adaptation** for living in perpetual dark. Less frequently, bioluminescence also occurs on land, ranging from fireflies flashing in the grass to mushrooms in dark woods and glowworms shimmering in caves.

How do organisms use bioluminescence to survive in their environment?

Scientists have observed organisms using bioluminescence in many different ways. These include self-defense, illuminating or luring prey, camouflage, and attracting mates. For example, the vampire squid squirts out a cloud of bioluminescent fluid that may confuse predators. Glowing spots on the "shoulders" of the click beetle give the impression of a much larger animal crawling at night. Some species of fireflies communicate with flash patterns to signal their availability and attract potential mates. Dinoflagellates light up when disturbed, perhaps to startle predators — or to attract animals that may eat their attackers. Rows of light organs on the undersides of the hatchet fish help it blend with light from above, making it barely visible to a predator looking up from below. The **larvae** of fungus gnats glow to attract insects to their sticky "fishing lines," while biologists think that the deep-sea stoplight loosejaw fish uses its red light (a color invisible to most deep-sea organisms) to illuminate its prey. While we know a lot about how bioluminescence works and how organisms use it, we have a lot more to learn. Many intriguing bioluminescent organisms await discovery as we explore Earth's final frontier, the **deep sea**.



GLOSSARY

adaptation: a physical or behavioral characteristic that allows organisms to better survive in a particular environment

bioluminescence: a chemical reaction in organisms that produces detectable light

chemical reaction: a process that occurs when two or more molecules interact, creating a substance that wasn't there before

deep sea: the ocean depths, typically below 1,000 meters (3,280 feet), where little or no light penetrates. Largely unexplored, the deep sea actually contains most of the habitable space on Earth.

dinoflagellate: single-celled animals, many of which photosynthesize

fluorescence: a process in which light of shorter wavelength is absorbed and re-emitted as longer-wavelength light that changes color, such as from blue to red. Many organisms fluoresce, including corals, sea anemones, and fish.

larva: the newly hatched, often wormlike form of many organisms before they metamorphose into adults

light: electromagnetic radiation. Visible light makes up a small fraction of the electromagnetic spectrum.

phosphorescence: a process in which light absorbed from one source is re-emitted very slowly, so that the glow persists even after the original source has gone dark. Naturally occurring minerals and manmade objects like glow-in-the-dark stickers phosphoresce, but no living things do.

plankton: tiny organisms (plants, animals, archaea, and bacteria) that drift in water

symbiosis: prolonged interaction between two different organisms that typically benefits both species

Tree of Life: a branching diagram that shows how all forms of life, both living and extinct, are related

COME PREPARED

Plan your visit. For information about reservations, transportation, and lunchrooms, visit amnh.org/plan-your-visit/school-or-camp-group-visit.

Read the Essential Questions in this guide to see how themes in *Creatures of Light* connect to your curriculum. Identify the key points that you'd like your students to learn from the exhibition.

Review the Teaching in the Exhibition section of this guide for an advance look at the models, specimens, and interactives that you and your class will be encountering.

Download activities and student worksheets at amnh.org/exhibitions/past-exhibitions/creatures-of-light/for-educators. Designed for use before, during, and after your visit, these activities focus on themes that correlate to the New York State Science Core Curriculum.

Decide how your students will explore the *Creatures of Light* exhibition. Suggestions include:

- You and your chaperones can facilitate the visit using the **Teaching in the Exhibition** section of this guide.
- Your students can use the **student worksheets** to explore the exhibition on their own or in small groups.
- Students, individually or in groups, can use copies of the **map** to choose their own paths.

CORRELATIONS TO NATIONAL STANDARDS

Your visit to the *Creatures of Light* exhibition can be correlated to the national standards below. Visit amnh.org/resources/rfl/pdf/creaturesoflight_standards.pdf for a full listing of New York State standards.

SCIENCE EDUCATION STANDARDS

All Grades • A2: Understanding about scientific inquiry • E2: Understanding about science and technology • G1: Science as a human endeavor

K–4 • B3: Light, heat, electricity, and magnetism • C1: The Characteristics of Organisms • C3: Organisms and environments

5–8 • B3: Transfer of energy • C1: Structure and function in living systems • C3: Regulation and behavior • C5: diversity and adaptations of organisms • G2: Nature of science

9–12 • B3: Chemical reactions • B6: Interactions of energy and matter • C1: The cell • C4: Interdependence of organisms • C6: Behavior of organisms

Teaching in the EXHIBITION

This exhibition uses immersive environments, models, specimens, videos, and hands-on and computer interactives to investigate the phenomenon of bioluminescence. It moves from terrestrial environments into the marine environments where most bioluminescent organisms are found.

The Guided Explorations below are designed around the theme of observation. Students will explore what these organisms have in common — they all "glow," or emit light — and also observe that different phenomena are at work. Most are bioluminescent (make their own light), but some are fluorescent (absorb and re-emit light) and a few are both.

PREPARE FOR DARKNESS

The exhibition space will be dim, the Sparkling Sea and Deep Ocean sections in particular. Although there will be ambient light, we recommend reading this guide in advance so that you can guide students in the exhibition.

LAND

Bioluminescence is rare on land, which makes it seem even more surprising when we do come across it. Scientists are just beginning to delve into the mystery of why these unusual terrestrial organisms glow.

1. Woods: Mushrooms

OVERVIEW: In the forests of eastern North America, bioluminescent mushrooms grow on decaying wood.

GUIDED EXPLORATION:

- **Models of Mushroom Species:** Point out to students that very few land organisms glow. Ask students to note what part of each mushroom is glowing, and what color light it emits.

2. A Summer's Night: Fireflies

OVERVIEW: In a grassy clearing in eastern North America, fireflies are using a system of flashes to communicate: to attract mates and also to lure other firefly species close enough to catch and eat. The light may also discourage predators by signaling that the firefly will taste bad.

GUIDED EXPLORATIONS:

- **Wall Mural of Grassy Field:** Draw students' attention to the mural, and invite them to imagine a summer evening and describe this environment. (Descriptions may include: this is grassy countryside; it's lush and well-watered)
- **Larger-Than-Life Firefly Models:** Have students identify and observe the body part that's glowing, and to describe the color being generated. (Answer: The light comes from a tiny organ called a lantern, on the underside of the abdomen.) Ask: How do fireflies use bioluminescence? (Answer: to attract and find mates; to lure and prey on other species of firefly.)
- **"Talking to Fireflies" Hands-on Interactive:** Invite students to try to communicate with flash patterns. Ask if they know of a similar signaling system used by humans. (Answer: Morse code)

3. A Mysterious Cave: Glowworms

OVERVIEW: On the ceiling of New Zealand's Waitomo Cave, glowworms secrete threads studded with adhesive droplets that reflect light from their bioluminescent tails. These tails glow brighter when the animals are hungry. When aquatic insects from the stream below fly toward the light, they become tangled in these lines. The glowworms then reel in their catch.

GUIDED EXPLORATIONS:

- **Glowworm Cave Model:** Have students take turns peering into the cave and describing both the light and the place where it occurs. (Descriptions may include: the ceiling of the cave is speckled with greenish-blue lights; the cave is dark and rocky; the bottom is wet.). Tell students that glowworms aren't worms at all (they're the larvae of small flies), and that one larva can produce more than forty adhesive lures. Ask students where they think the larvae live. (Answer: Students can trace threads to the ceiling of the cave, where the larvae live.) What is the function of the glowworms' bioluminescence? (Answers: The light reflected in the threads lures prey towards these sticky traps.)

The larva's "fishing lines" are mucus threads studded with adhesive droplets.

- **Display of Terrestrial Species:** Invite students to observe the millipede model and the click beetle specimen. Ask: What parts of their bodies glow? What color light do they emit? What purposes might their bioluminescence serve in these very different animals? (Answers may include: The whole millipede glows. The light is greenish-blue. It intensifies when they're disturbed, perhaps signaling that they're poisonous. The glowing green spots on the shoulders of the click beetle look like eyes, making it look like a bigger animal.)

Bioluminescence is much more common in water than on land. By far **the greatest diversity of bioluminescent organisms live in the deep sea**, where upwards of 80% of organisms exhibit the phenomenon.

4. A Sparkling Sea: Dinoflagellates

OVERVIEW: It's nighttime at a quiet lagoon in Vieques, Puerto Rico. The bay is full of marine organisms known as dinoflagellates, each the size of a pinprick. When something bumps into a dinoflagellate, the impact triggers a chemical reaction that ends in a burst of light. No one really knows why dinoflagellates flash on contact, but scientists think it may startle or expose predators, or help remove toxic oxygen from their bodies.

GUIDED EXPLORATIONS:

- **Interactive Lagoon:** Stop on the boardwalk and have students look around and describe the environment. (Descriptions may include: We're in a mangrove forest; it's nighttime.) Invite them to imagine that they're about to swim in a Caribbean lagoon. Have them describe the experience of walking on the interactive floor. (Answers may include: blue lights appear wherever my feet touch the floor) Explain that the glowing mimics the light caused by touching millions of dinoflagellates, microscopic organisms that live in this sheltered, shallow bay.

- **Live Dinoflagellates Tank & Model:** Have students look closely at these live plankton and examine the 11,000-times-life-size model of one species. Ask: What purpose do you think its bioluminescence serves? (Answers may include: The chemical reaction might act as an antioxidant, removing oxygen radicals from the organism, and releasing light as a byproduct; the light may startle attacking predators; the light may reveal other, larger species around the dinoflagellate to predators.)

5. Sea Shores: Corals, Jellies, & Fishes

OVERVIEW: Fluorescence can also cause organisms to glow by transforming and reemitting light from an external source. In the Caribbean Sea, shining a blue or violet light onto corals makes them glow in neon shades of pink, orange, and green. In the Pacific Ocean, spots on the rim of a jellyfish light up when touched. Its mysterious green glow is the product of both bioluminescence and fluorescence.

GUIDED EXPLORATIONS:

Remind students that all the organisms they've observed so far are bioluminescent — they create their own light. Tell them that this section displays some that are fluorescent, not bioluminescent: they absorb one color of light and emit another.

- **Coral Reef Wall, Jellyfish Models, Ponyfish Model, & Live Flashlight Fish:** Have students explore these three sections to discover and learn about the animals featured here. Then ask: What makes the corals, jellyfishes, and ponyfishes glow? How are these processes similar and how do they differ? (Answers may include: Corals are fluorescent; they absorb and re-emit light shined by divers in longer-wavelength colors. The jellyfish is both fluorescent and bioluminescent; luciferin and luciferase make blue light inside miniature light organs, and a fluorescent molecule turns the blue light to green. The ponyfish is bioluminescent; a ring of tissue around its throat is packed with bioluminescent bacteria.) Ask: What are some of the possible ways in which light may benefit these organisms in their environments? (Answers may include: In corals, fluorescent molecules may serve as a sunscreen, help injured corals heal, and capture damaging oxygen; light may also attract prey. On other animals, fluorescent markings may serve as mating signals. Ponyfishes use their bioluminescent light for camouflage and to attract mates.)

- **Fluorescent & Phosphorescent Objects:** Explain that fluorescence occurs when an object absorbs and then re-emits light, and that phosphorescence is a type of fluorescence in which the light is re-emitted very slowly, even after the original light source has gone out. Have students observe these minerals and household items.

6. The Deep Ocean: Predators & Prey

OVERVIEW: In the perpetually dark deep ocean, the only glimmers of light come from living things. Here, the vast majority of animals light up as they travel, hunt, and mate.

GUIDED EXPLORATION:

- **Theater & Models:** Tell students that they're now going to explore a completely dark environment. Point out that the animals they'll observe will have very different adaptations and behaviors than any they've seen so far. First, have students watch the movie about the deep-sea environment and its inhabitants. Then have students examine the models of deep-sea organisms and describe the ways in which different organisms use bioluminescence. (Answers may include: The female anglerfish uses a glowing lure to attract prey. The tubeshoulder, a type of fish, blasts a stream of lighted fluid that could stun an attacker while it escapes. The siphonophore, a relative of jellyfishes, uses red lures to entice fish towards its tentacles. The hatchetfish adjusts the light on the underside of its body to blend in with the faint light from above and hide from predators lurking below.)

ONLINE Resources

OLogy: The Museum's Website for Kids
amnh.org/ology/
Search for the term "bioluminescence" in the purple sidebar to find a bioluminescent creatures paper cutout activity and "They Glow!", a sing-along about ocean animals that glow.

Jellies Down Deep
amnh.org/explore/science-bulletins/(watch)/bio/documentaries/jellies-down-deep
In this seven-minute video, marine biologists study jellies in the deep-sea water column.

Photos of Luminous Organisms
lifesci.ucsb.edu/~biolum/organism/photo.html
An extensively annotated photo gallery of marine organisms and related phenomena.

Glow: Living Lights
sdnhm.org/archive/exhibits/glow/
The San Diego Natural History Museum's 2003 exhibition about bioluminescence. Includes Teacher's Guide.

Lanternfish Sticks
montereybayaquarium.org/lc/activities/lanternfish_sticks.asp
A make-your-own glow-in-the-dark fish activity.

Growing Dinoflagellates At Home
lifesci.ucsb.edu/~biolum/organism/dinohome.html
Experiment with them to understand more about bioluminescence.

New Glowing Fungi Species Found in Brazil
news.nationalgeographic.com/news/2006/10/photogalleries/glowing-fungi/
An article about bioluminescent mushrooms found in Brazil, with image gallery.

FACTS OF LIGHT

- **Bioluminescence** is "cold light" that gives off almost no heat.
- **In water, blue and green light** travel much farther than other wavelengths. Most marine animals are adapted to see only these colors of light.
- **Most of the ocean is dark.** Here in the deep sea, beyond the reach of sunlight, most animals — upwards of 80% — light up as they travel, hunt, and mate.
- **Fireflies aren't flies at all.** They're beetles! Sometimes they're called lightning bugs.

CREDITS

Creatures of Light: Nature's Bioluminescence is organized by the American Museum of Natural History, New York (www.amnh.org) in collaboration with the Canadian Museum of Nature, Ottawa, Canada and The Field Museum, Chicago.

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