Understanding Bioluminescence & Fluorescence

OVERVIEW

Students will learn how bioluminescence and fluorescence work, and how organisms use light to survive and reproduce.

- **Before Your Visit:** Students will be introduced to the phenomenon of bioluminescence and prepare for their Museum visit.
- **During Your Visit:** Students will collect data about bioluminescent and fluorescent organisms.
- **Back in the Classroom:** Students will share their findings and explore how scientists study bioluminescent and fluorescent organisms.

Major Understandings

LE 1. 1.1b: Learning about the historical development of scientific concepts or about individuals who have contributed to scientific knowledge provides a better understanding of scientific inquiry and the relationship between science and society.

LE 6.2b: Biodiversity also ensures the availability of a rich variety of genetic material that may lead to future agricultural or medical discoveries with significant value to humankind. As diversity is lost, potential sources of these materials may be lost with it.

BACKGROUND FOR EDUCATOR

Bioluminescence is visible light generated by a living organism through a chemical reaction. One type of chemical, luciferin, is acted on by another type of chemical, an enzyme called luciferase, in the presence of oxygen (other molecules are sometimes involved). The energy produced by this reaction takes the form of photons, or units of light.

Fluorescence is another process that can cause things to emit light. Things that fluoresce absorb light of shorter wavelength and re-emit it as longer-wavelength light. This changes the color, such as from blue to red.

Organisms use a variety of body parts to emit light in different colors and for different purposes. In a few organisms, both bioluminescence and fluorescence occur.

BEFORE YOUR VISIT

Activity: Why Do So Many Organisms Glow in the Dark?

Part 1: Observe Organisms That Glow in the Dark
Begin the lesson with a short discussion. Ask:

- Do you own anything that glows in the dark? (Answers will vary.)
- What is meant by the term "glow in the dark"? (Answers will vary.)
- What makes something glow in the dark? (Accept all answers.)
- What are some examples of living organisms that also glow in the dark? (Answers will vary.)

Project this short video of organisms found in the deep sea and how scientists study them:

Submarine Dives Capture Bioluminescence
amnh.org/explore/videos/research-and-collections/explore21-expedition-to-the-solomon-islands-the-fish

After the video, ask:

- How do you think scientists study these organisms? (Accept all answers.)
- Why do you think these organisms would light up? (Accept all answers.)

Plan how your students will explore *Creatures of Light* using the student worksheets. Since the exhibition will be dark, we recommend that students record notes after the exhibition.

Before your visit, distribute copies of the **two worksheets** to students and review them together. Tell students that they will be filling in the worksheets after the exhibition, but should use the questions on the worksheets as a guide.

Part 2: Prepare for Your Museum Visit
Divide your class into groups of two or three. Distribute the "Preparing for *Creatures of Light*" worksheet to each student. (You can also project the *Creatures of Light* exhibition map.)

Tell students that the goal of the visit is to observe these organisms and learn how and why they light up. Ask each group to pick two or three sections to explore in the exhibition and come up with their own questions. Tell students the space will be too dark to take notes. Review the guiding activities in advance.

Optional Activity: Demonstrating Fluorescence of Chlorophyll
Use this classroom experiment to introduce students to the concept of fluorescence. See the full activity at the end of this PDF.

DURING YOUR VISIT

Creatures of Light: Nature's Bioluminescence
3rd floor (45 minutes)
Review the second part of the "Preparing for *Creatures of Light*" worksheet with students. Encourage them to use all their senses to explore what life in darkness might be like. Have them use the worksheet to guide their observations in the exhibition. Tell them that they will regroup in the Milstein Hall of Ocean Life to record their observations.

Milstein Hall of Ocean Life
1st floor (30 minutes)
This hall provides a great opportunity to reinforce key ideas of the *Creatures of Light* exhibition as well as provide a space for students to sit and record notes about what they learned.

BACK IN THE CLASSROOM

Activity: Exhibition Wrap Up
Have students gather in small groups to share their notes from the visit about how and why so many organisms in the open ocean produce light.

Then as a class, have students make a list of ways we benefit from the biodiversity of the ocean. Ask: How many of the organisms in the exhibition do you think we benefit from? (Accept all answers.)

Activity: How do scientists study bioluminescence and fluorescence?
Working in small groups, have students read one of the scientist profiles (Edith Widder or Osamu Shimomura; see the end of this PDF). Then have them use the following questions to guide their reflections, and share their thoughts with the rest of the class.

Reflection Questions
1. What skills do you need to do this type of research?
2. What tools do you think scientists use in this kind of research? Why?
3. What is the best vehicle for observing deep-sea life? Why?
4. Describe the benefits to society of studying bioluminescence and fluorescence.
5. Would you be interested in working with the scientist you read about? Why or why not?
6. Defend this statement, using evidence gathered on your trip to the Museum: It is important to protect the biodiversity of bioluminescent and fluorescent organisms.

ONLINE RESOURCES

Science Bulletins: Jellies Down Deep
amnh.org/explore/videos/oceans/jellies-down-deep
Increasingly, marine researchers are finding that there are far more jellies and jellyfish in the world's oceans than previously believed. These creatures may play an unexpectedly large role in ocean ecosystems. This documentary, which was produced by the Museum's innovative multimedia program Science Bulletins, follows scientists at the Monterey Bay Aquarium Research Institute as they retrieve jellies from the deep and features spectacular underwater footage.

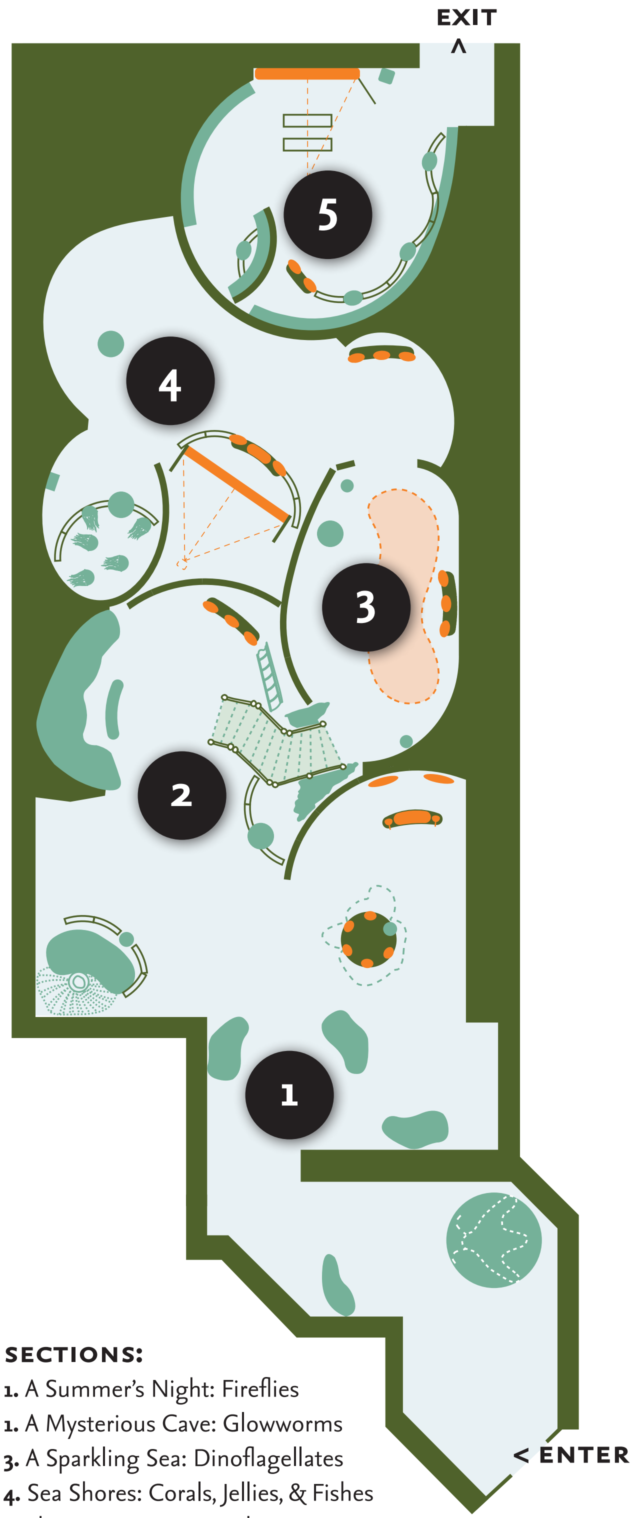
Illuminating the Perils of Pollution, Nature's Way
nytimes.com/2011/12/20/science/a-pollution-fight-powered-by-bioluminescent-sea-creatures.html

Natural Light Photo Slideshow: nytimes.com/slideshow/2011/12/20/science/20BIO.html

Edith Widder: Glowing Life in an Underwater World: youtube.com/watch?v=IThAD5yKrgE

Student Worksheet: Preparing for the Exhibition

Working with your team, pick three sections of the exhibition to investigate the question: Why do so many organisms produce light?



SECTIONS:

1. A Summer's Night: Fireflies
1. A Mysterious Cave: Glowworms
3. A Sparkling Sea: Dinoflagellates
4. Sea Shores: Corals, Jellies, & Fishes
5. The Deep Ocean: Predators & Prey

Why did you pick these sections?

What questions do you have?

IN THE EXHIBITION

Although you can take notes in the exhibition, it will be challenging in the low light. So use all your senses to experience what life is like in the absence of light, and use the following activities to guide your observations.

Investigate two or three organisms from your sections that use bioluminescence or fluorescence.

Read and engage with iPads to learn more about how bioluminescence and fluorescence work.

Observe what part of the organism produces light.

Reflect with your team on how the process of emitting light might benefit the organism.

Watch the Deep Ocean video.

Think about what it must be like to work in the deep ocean.

Student Worksheet: At the Museum

1. *Creatures of Light* exhibition

Record information about three organisms that you observed in the exhibition.

Name of Organism	What part of the organism lights up?	Does it use bioluminescence, fluorescence, or both?

What is bioluminescence?

How might bioluminescence benefit organisms?

Where would you want to visit and why?

2. Milstein Hall of Ocean Life: Deep Sea Ecosystem

Observe the diorama and describe what you see.

Sketch an organism and label the parts that light up.

Working with your team, find five different organisms that use light.

Name of Organism	What part of the organism lights up?	Does it use bioluminescence, fluorescence, or both?

ACTIVITY

Demonstrating Fluorescence of Chlorophyll

Use this classroom experiment to introduce students to the concept of fluorescence.

Materials per Group:

- flashlight
- 100 g spinach
- ethanol
- coffee filter
- two 250 ml beakers

Put students in groups of three to four. Alternatively, you can also demonstrate this for the class.

1. Chop about 100 grams of spinach leaves into small pieces, and put into 250 ml beaker with 75 ml of ethanol.
2. Let the jar stand for 20 minutes.
3. Then pour through a coffee filter into a clean clear beaker.
4. Shine a flashlight on one side of the jar, and observe. Ask students to record their observations. (Students should observe a dark red fluorescence.)
5. Tell students that the red color is a result of fluorescence, and that they'll learn more about fluorescence in the exhibition.

Background for Educators and Students:

- Fluorescence is one way some organisms light up.
- In fluorescence, electrons of certain type of molecules become excited when they absorb high-energy light from an outside source. As the electrons calm down, the energy absorbed is released as lower-energy light. Since light fuels fluorescence, the glow is more intense when they are under high-energy radiation, like ultraviolet light.
- One of the most common fluorescent molecules in nature is chlorophyll, the green pigment found in plants. Leaves are green when lit by the Sun because they reflect the green light wavelengths. Chlrophyll absorbs mostly blue and red light wavelengths, which are the driving energy of photosynthesis. The energy of light is measured as wavelength: the shorter the wavelength, the stronger the energy of the light. When illuminated by ultraviolet light, the plant pigment glows red, which is lower in energy. The missing energy or difference in energy between the high-energy of the UV light and the lower-energy red light is released as heat energy A less intense fluorescence can be produced using a flashlight. In nature, plants fluoresce with daylight but this phenomenon can be seen only with special instruments.

SCIENTIST PROFILE

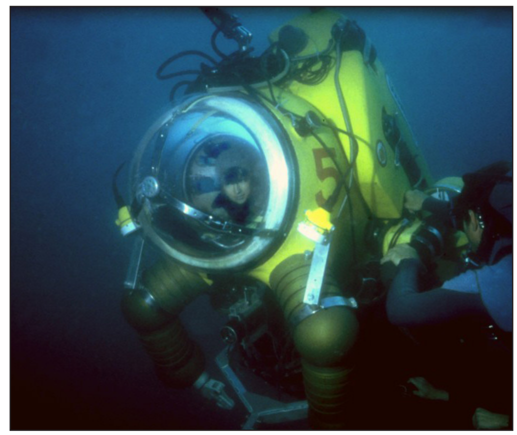
Edith Widder

Bioluminescence Advocate

In 1984, as she was testing a new diving suit, marine biologist Edith Widder descended 880 feet (268 meters) into the ocean and was overwhelmed: A display of blue bioluminescent light burst forth before her. Thus began her obsession with creatures of light!

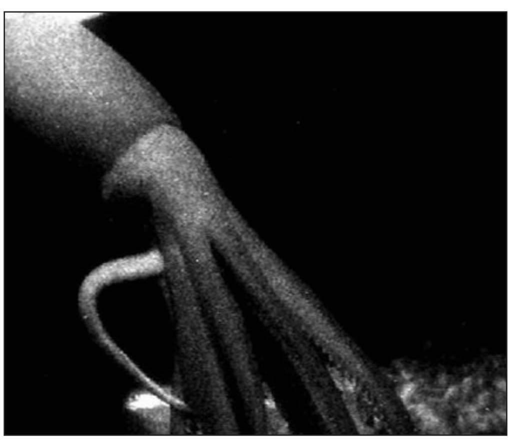
Filming in the Deep

So that others could appreciate the amazing variety of sea life, Widder began shooting videos from inside a submersible. Because the vehicle's noise and bright lights tended to scare away creatures, she developed a less obtrusive device.



An Eye in the Sea

This device, called "Eye-in-the-Sea," sits on the bottom of the ocean and sends images to the surface. It includes a camera that uses red light, invisible to most sea creatures. And it incorporates an epoxy "jellyfish" with programmable blue lights, seen here, to attract animals.



Success

The device's first foray in the Gulf of Mexico in 2004 was a triumph, capturing on film a previously unknown squid species. In a venture 3,000 feet (914 meters) down to the floor of the underwater Monterey Canyon off California's coast, a more advanced camera recorded many more species. The explorations continue.

A New Effort

Widder is working on a method to estimate pollution levels: She adds bioluminescent bacteria to lagoon sediment and measures how fast the bacteria's light diminishes.

SCIENTIST PROFILE

Osamu Shimomura

In 2008, scientist Osamu Shimomura won a Nobel Prize in Chemistry for discovering green fluorescent protein (GFP). But he hadn't actually been looking for GFP. He had been trying to purify the bioluminescent components of the jellyfish *Aequorea victoria*.

No Light?

In the early sixties, intrigued by the jellyfish's green luminescence, Shimomura managed to prepare a solution with the luminescent tissues of 10,000 jellyfish! He realized that the light wasn't produced by a typical luciferase/luciferine reaction but probably by a special protein. He tried many times but - unlike other bioluminescent reactions he knew – the solution did not light up outside the jellyfish. What was missing?

Strong Light!

By chance, he added a small amount of seawater to the solution, and was rewarded with what he called an "explosively strong" light! He realized that for the jellyfish's bioluminescence to work, it needed calcium ions from the seawater. He purified the luminescent protein and called it aequorin.

Green, Not Blue

Strangely, in the lab, the bioluminescent light was blue, not green as in the jellyfish. Upon examination, Shimomura found an additional molecule, Green Fluorescent Protein. The GFP absorbed the blue bioluminescent light produced by the aequorin and emitted it as lower-energy green light…and the puzzle was solved!

A Major Contribution

Shimomura's discovery, GFP, has been adapted by other scientists to become a vital tool in biological research.

Colorful Tool Kit

Naturally occurring fluorescent proteins have become important tools for researchers as they investigate questions like how stem cells specialize or how brain cells communicate. GFP—green fluorescent protein—was the first to be adapted for broad scientific use. Then, red fluorescent proteins from corals were adapted. Now fluorescent proteins of many colors can be expressed in living cells, where they literally illuminate biological processes.