



Investigation: Bioluminescence - An Adaptation for Deep-sea Survival

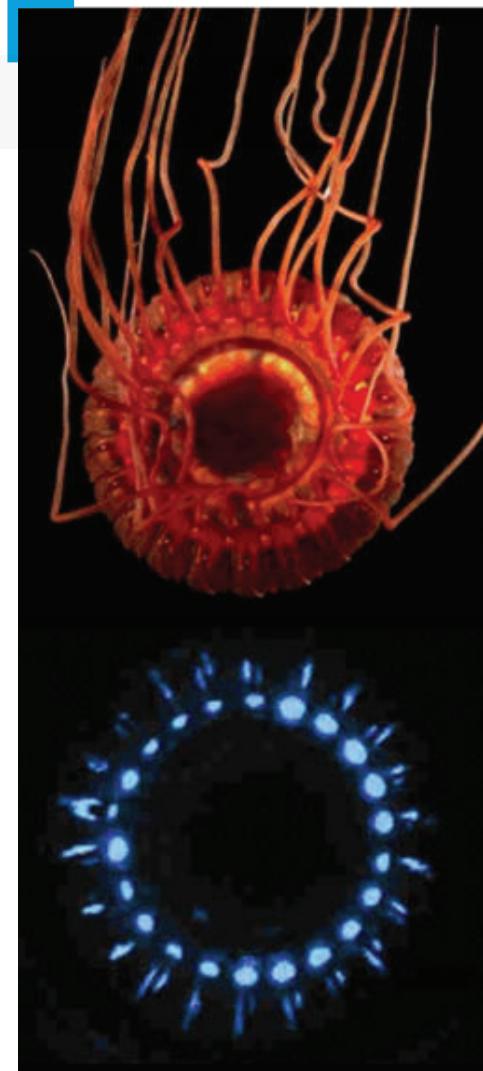
Overview

TOPIC:	Bioluminescence
FOCUS:	Students explore the phenomenon of bioluminescence in deep-sea organisms and theorize about how it might help them to survive.
GRADE LEVEL:	6th–8th; extensions and differentiation provided to adapt to other grade levels
TIME NEEDED:	Two 50-minute class periods (plus additional time for optional extensions or student mini-symposium)

PHENOMENON

(DRIVING QUESTION): Why do many deep-sea organisms glow in the dark?

OBJECTIVES/ LEARNING OUTCOMES:	<p>Students will:</p> <ul style="list-style-type: none"> observe bioluminescent deep-sea organisms (video, images) and document their observations, thoughts, and questions. identify and describe the behavioral and physical adaptations of bioluminescent deep-sea organisms (from videos, images, Creature Cards) and develop theories as to how certain behavioral and physical adaptations help bioluminescent organisms survive and/or reproduce in the deep sea. create a detailed and annotated model of a bioluminescent organism and its physical and/or behavioral adaptations for survival in the deep sea.
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Deep-sea jellyfish, *Atolla wyvillei*, seen in white light (top), is believed to use bioluminescence as a “burglar alarm” (bottom) to attract a larger predator to attack the jellyfish’s attacker. *Image courtesy of NOAA Ocean Exploration, Journey into Midnight: Light and Life below the Twilight Zone.*

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectations (PEs):
MS-LS1-4, MS-LS2-2

Disciplinary Core Ideas (DCIs)
LS1.B: Growth and Development of Organisms
LS2.A: Interdependent Relationships in Ecosystems

Crosscutting Concepts (CCs)
Structure and Function
Patterns

Science & Engineering Practices (SEPs)
Engaging in Argument from Evidence
Obtaining, Evaluating, and Communicating Information
Developing and Using Models

COMMON CORE CONNECTIONS

ELA-LITERACY.SL.6.1
ELA-LITERACY.SL.6.4
ELA-LITERACY.SL.6.6
ELA-LITERACY.WHST.6.4

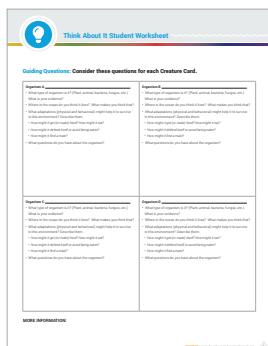
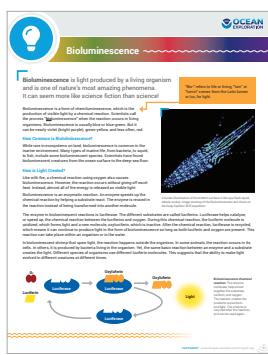
OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
Principle 5, FC d; Principle 7, FC d





Overview cont.

MATERIALS:



[Bioluminescent Creature Cards](#) 1-18 (for student groups; print or digital copies)

- Set 1 (slides 3-10): images only
- *Think About It* card (slide 2)
- Set 2 (slides 11-18): image and organism description

Fact Sheets

- [Bioluminescence Fact Sheet](#) (for each student/pair/group; print or digital copies)
- *OPTIONAL:* [Three Mysterious Light Effects Fact Sheet](#)

Videos

- [Dragon Fish Charms ROV](#) (0:49) NOAA Office of Ocean Exploration
- [Fish With Flashlights-Glowing Jellies](#) (0:07) Woods Hole Oceanographic Institution
- *OPTIONAL:* [Strange Bioluminescence](#) (2:00) Blue Planet, BBC Earth
- [Bioluminescence](#) (1:40) NOAA Ocean Today
- [Light in the Deep Sea with Dr. Edie Widder](#) (Bonus 1) (4:00) NOAA Ocean Today
- [Creatures of Light: The Chemistry of Bioluminescence](#) (2:47) NOVA
- [The Ocean Twilight Zone: The Earth's Final Frontier](#) (4:39) Woods Hole Oceanographic Institution

Art supplies for model making (diagram or 3D)

- Colored paper, paint (e.g., glow in dark), colored pens/pencils, scissors, model magic/clay, etc.

Individual Student Materials

- Pen/pencil
- [Think About It Student Worksheet](#)
- *OPTIONAL:* [I Notice, I Wonder, It Reminds Me Of \(N-W-R\) Student Worksheet](#)

Equipment

- Whiteboard and dry erase markers (or online tool such as Google Jamboard)
- Data projector (or video-conferencing software with screen sharing and breakout room capability for online learning)

SET-UP INSTRUCTIONS:

- Prepare student materials: handouts, worksheets, slidedeck, videos, etc.
- *OPTIONAL:* Introduce and practice using N-W-R Worksheet if students are unfamiliar
- Establish a location and logistics for displaying/sharing student models and communication products



Educator Guide

EDUCATOR BACKGROUND:

The ocean is divided into three zones based on light level and depth. The upper 200 meters (656 feet) of the ocean is called the “Sunlight Zone” (euphotic) where a vast majority of commercial fisheries are found. Only a small amount of light penetrates beyond this depth. The Twilight (or Dysphotic) Zone is located between 200 meters and 1000 meters (about 3,300 feet) deep in the ocean. The Midnight (or Aphotic) Zone is below 1000 meters and is bathed in total darkness. Yet, organisms at depth prove that light is still important for survival. In fact, it is estimated that more than 75% of the animals that live in the water column in the open ocean produce their own light! This phenomenon of light production is called bioluminescence.

Bioluminescence is a form of **chemiluminescence**, which is the production of visible light by a chemical reaction. Scientists call the process bioluminescence when the reaction occurs in living organisms. The light produced by these living organisms can be bright purple, blue, green, and sometimes red. In the ocean, bioluminescent light is usually blue or blue-green.

Scientists do not yet understand the full purpose or function of this specialized adaptation. But “living light”, or bioluminescence, can help organisms:

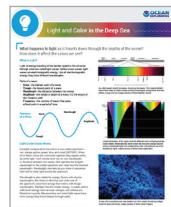
- Locate food/Attract or detect prey
- Defend against or warn predators
- Hide from predators by blending in with their surroundings or creating a distraction
- Attract mates
- Communicate between members of their own species

Bioluminescence is an enzymatic reaction. The enzyme **luciferase** helps catalyze, or speed up, the chemical reaction between the substrate **luciferin** and oxygen. The reaction creates the products oxyluciferin and light. In bioluminescent shrimp that spew light, the reaction happens outside the organism. In some animals, the reaction occurs in its cells. In others, it is produced by bacteria living in the organism. Yet, the same basic reaction between an enzyme and a substrate creates the light. (See the [Light and Color in the Deep Sea Fact Sheet](#) for more information).

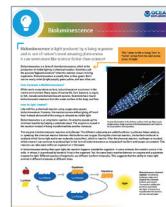
Scientists still don't know all the answers about how light is used in the deep ocean or how organisms originally evolved to have these specialized light effects. Continued data collection during ocean exploration of deep-sea environments can help solve these questions!

FOR MORE INFORMATION:

► [Bioluminescence Fact Sheet](#)



► [Light and Color in the Deep Sea Fact Sheet](#)



► [Three Mysterious Light Effects Fact Sheet](#)





Educator Guide (in the 5E Model)

Engage

Explain that students will be investigating a fascinating phenomenon found in the ocean, as well as on land. To get the investigation started they are going to watch two short videos. Play the videos with sound and closed captioning off, [Dragon Fish Charms ROV](#) (NOAA Ocean Exploration) and [Fish With Flashlights-Glowing Jellies](#) (Woods Hole Oceanographic Institution). *Optional video selection: Strange Bioluminescence* (Blue Planet, BBC Earth). Ask students to think about what they are observing and what is interesting or unusual about it. Use guiding questions to prompt their thinking. Option: Use the [I Notice, I Wonder, It Reminds Me Of \(N-W-R\) Student Worksheet](#) to help facilitate student observation and documentation.

- *Where do you think these animals live? What part of the ocean?*
- *What do you notice about the environment?*
- *What do you notice about the animal's appearance?*
- *How might the physical (e.g., structures) and behavioral adaptations of these organisms help them?*

After the videos, and a moment of thinking time, invite students to talk with a neighbor and discuss their ideas. Tell them to be ready to share their most plausible or interesting ideas with the class. After two minutes, ask for partners to volunteer to share their ideas.

Use ideas from students' observations to highlight two core concepts from the lesson: (1) the animals glow or light up and (2) the ocean environment they are looking at is very dark. Share that the students will be investigating the phenomenon of glowing animals, specifically ***Why do many deep-sea animals glow in the dark?***

Ask the students to share anything they know about animals on land and in the ocean that might glow (e.g., what animals, where are they found, why they might glow). Keep conversation brief, but allow for sharing by a variety of students. Let them know their focus today will be on animals in the ocean, but they should remember that while this unique phenomenon (glowing animals) occurs on land too, it is rare.

Have students divide into exploration teams of 3–4. Share that as teams of scientists exploring life in the deep sea, they are going to be investigating this relatively poorly understood ocean phenomenon (glowing animals). They will be analyzing images of several unique and unusual organisms recently observed by ocean researchers from NOAA Ocean Exploration and their partners to help them explore the question *Why do many deep-sea animals glow in the dark?*

Journey into Midnight: Light and Life Below the Twilight Zone

Home / Expeditions / Light and Life Below the Twilight Zone

Mission Summary

From June 9 – 22, a team of researchers will explore the water column in some of the deepest parts of the Gulf of Mexico in order to determine what benthic deep sea animals are able to see in the dark. They will also take photographs and collect samples for further study on the characteristics of visual systems, bioluminescence, and fluorescence of organisms living below 1,000 meters (3,280 feet) in the bathypelagic (midnight) zone

Learn more

Recent Updates

Heading Home

"Never dreamt I was to say that that everyone wants to go to sea once, but only one out of a hundred ever went again. Those who do it again and again I believe with the animals, the people, the adventure and the ship themselves."

Mission Overview

From July 14 – July 27, 2015, scientists used their combined expertise in bioluminescence, taxonomy, visual ecology, imaging and molecular biology, together with the unique collecting capabilities and camera systems of the remotely operated vehicle, the *Global Explorer*, to continue studies of the deep-sea benthic environment in the Gulf of Mexico.

Recent Updates

Bioluminescence and Vision on the Deep Seafloor 2015

Home / Expeditions / Bioluminescence and Vision 2015

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Recent Updates

Final Days

"Despite some frustrations along the way, overall, the expedition was a tremendous success, with several findings and plenty of specimens and data to comb through to reveal even more discoveries."

Read more

Data and samples collected during NOAA Ocean Exploration expeditions help 'shed light' on this glowing phenomenon. Explore the webpages for two bioluminescence focused expeditions to learn more.



Video courtesy NOAA Ocean Exploration.



Video courtesy Woods Hole Oceanographic Institution.



Educator Guide cont.

Explore

Distribute Set 1 of the [Bioluminescent Creature Cards](#) (image only cards, slides 3-10) to each team (Cards can be shared in print or digitally). Ask teams to recall the videos they observed, as well as the ideas that were shared, as they examine the Creature Cards.

After initial observation and discussion (~3-5 mins), show the [Think About It card](#) (slide 2) and distribute the [Think About It Student Worksheet](#) to help students further discuss and consider new questions about each organism. Have students record their thinking/responses using the worksheet and guiding questions:

- *What kind of organism is it? (Plant, animal, bacteria, fungus, etc.) What is your evidence?*
- *Where in the ocean do you think it lives? What makes you think that?*
- *What adaptations (physical and behavioral) might help it to survive in this environment? Describe them.*
 - *How might it get food? How might it eat?*
 - *How might it defend itself or avoid being eaten?*
 - *How might it find a mate?*
- *What questions do you have about the organism?*

Give teams 10 minutes to further explore the Creature Cards.

Challenge students to consider possible answers from their own observations and initial thoughts (e.g., what answers can the images and discussions provide?) and make note of what they still want to know or are curious about. Circulate the room and listen to team discussions, encouraging them to refer to guiding questions and drawing out their ideas.

Organism A

Image courtesy NOAA Office of Ocean Exploration and Research

Image copyright S. Miller, used by permission

Created for the Deep Ocean Education Project

Organism B

Image courtesy Brooke Johnson and Katie Thomas, NOAA: <https://oceanexplorer.noaa.gov/facts/medusa/bioluminescence.html>

Created for the Deep Ocean Education Project

Organism C

Image courtesy E. Widder

Created for the Deep Ocean Education Project

Organism D

Image courtesy NOAA: https://oceanexplorer.noaa.gov/expeditions/05bioluminescence/background/bioluminescence/media/images017_1000.html

Image courtesy NOAA: https://oceanexplorer.noaa.gov/expeditions/05bioluminescence/media/images017_1000.html

Created for the Deep Ocean Education Project

Think About It Student Worksheet

Guiding Questions: Consider these questions for each Creature Card.

Organism A	Organism B
• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?	• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?
Organism C	Organism D
• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?	• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?

MORE INFORMATION:

STUDENT | [www.DeepOceanEducationProject.org](http://DeepOceanEducationProject.org)

Think About It Student Worksheet

Guiding Questions: Consider these questions for each Creature Card.

Organism E	Organism F
• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?	• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?
Organism G	Organism H
• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?	• What type of organism is it? (Plant, animal, bacteria, fungus, etc.) • What is your evidence? • Where in the ocean do you think it lives? What makes you think that? • What adaptations (physical and behavioral) might help it to survive in this environment? Describe them. • How might it get food? How might it eat? • How might it defend itself or avoid being eaten? • How might it find a mate? • What questions do you have about the organism?

MORE INFORMATION:

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Think About It!

Plant, animal, bacteria, fungus, etc.

What kind of organism is it? What is your evidence?

Where in the ocean do you think it lives? What makes you think that?

What adaptations (physical or behavioral) might help it to survive in this environment? Describe them.

How might it get food? How might it eat?

How might it defend itself or avoid being eaten?

How might it find a mate?

What questions do you have about the organism?

Created for the Deep Ocean Education Project



Educator Guide cont.

Explain

Ask students what they notice these organisms have in common? What features or adaptations do they share? Restate a few of the key observations and ideas the students shared and that you overheard from their conversations. Use the student's own language or modify statements to include more science language. Ideas may include:

- *These organisms live in the deep (dark) ocean, where sunlight does not penetrate.*
- *All of the organisms have the ability to create light.*
- *Different organisms probably use light in different ways (different adaptations).*
- *Different types of organisms must use light to survive in the deep, dark sea.*
- *Several of the organisms are either black or red in color.*

Remind students they are investigating the question **Why do many deep-sea animals glow in the dark?** Share some additional information that may help answer some of their questions, or provide clarification/accuracy to their shared ideas. Students can add this information to their [Think About It Student Worksheet](#) (under the More Information section, or wherever they think the information fits).

- The ocean is divided into three zones based on sunlight penetration and depth. In order from the shallowest to the deepest: *Sunlight Zone, Twilight Zone and Midnight Zone*. The organisms the students explored are from the "Twilight" and "Midnight" zones, 200m and deeper. Share slide 1 from the slide deck to illustrate ocean light zones.
- Scientists estimate that more than 75% of the animals that live in the water column in the open ocean produce their own light! This ability to "glow" is rarer on land, even though we may be more familiar with it (e.g., fireflies).

- You might also share:
 - As you go deeper into the ocean the ability to see specific colors changes. In the ocean, colors with lower energy and longer wavelengths, such as reds, oranges, and yellows are filtered out quickly. Because blue and violet have more energy and shorter wavelengths, they travel deeper through water. *For more information, see the [Light and Color in the Deep Sea](#) lesson.*

Ask if anyone knows the scientific term for the 'illuminating' ability/adaptation to make light. Some students may know the term **bioluminescence**.

- Tell students to write down the term bioluminescence on their [Think About It Student Worksheet](#) under More Information, at the same time write the term where all students can view it. Share that this term has a prefix (circle it/highlight it) and a root (underline it/highlight it). Ask them what they think the prefix "bio" means, and to share why they think that. Clarify the prefix "bio" refers to life. Ask the students to share any words they already know with the "bio" prefix. Repeat one or two examples of the prefix in use (e.g., biology, biography). Ask students to think about what the root *lumin* (or lumen or lum) means and why they think that. After a few moments, clarify the root "lumin" refers to light. Ask students how they would define the term bioluminescence now that they know the prefix and root meanings. Clarify the definition if needed: *bioluminescence is the production and emission of light by a living organism.*

Have students watch the video [Bioluminescence](#) (NOAA Ocean Today). As they listen and watch the video, ask students to consider any new information that helps them better understand why and how deep sea animals use light. After the video, give students an additional minute to record their thoughts on their [Think About It Student Worksheet](#).



Educator Guide cont.

Explain cont.

Distribute Set 2 of the [Bioluminescent Creature Cards](#)

(image and animal descriptions, slides 11-18) to each team. Ask students to build upon the ideas they already have as they consider a new set of guiding questions. Tell them to focus their thinking and discussions on the bioluminescent adaptations and how they help the organism survive in the deep, dark ocean. At the bottom of each creature space on their [Think About It Student Worksheet](#) have students answer the following questions:

- *What do you think this organism uses its light/bioluminescence for? Why do you think it has this adaptation?*

If you are exploring color at depth with students, then ask one or all of these additional questions:

- *What colors of light seem to be most common in deep-sea bioluminescent organisms? Why do you think that is?*
- *How might certain colors of bioluminescence be helpful or harmful for these deep-sea organisms?*
- *How do you think these organisms produce light? Explain your thinking.*

Encourage students to record any questions they still have.

Show the short video "[Light in the Deep Sea with Dr. Edie Widder \(Bonus 1\)](#)" (NOAA Ocean Today). Invite students to then revisit their [Think About It Student Worksheet](#) and update their information as needed (i.e., record their additional understandings and questions). Give them 3-5 mins. to record their ideas/questions.

CREATURE CARD INFORMATION FOR EDUCATOR

Dragonfish (Organism A): Scientists believe the photophores are used for counter illumination, camouflaging the organism against the light above, disguising the animal from predators looking up from below. The glowing barbel attracts prey close to the large mouth of this predator. (This is the fish genus from the [introductory video](#) in this investigation).

Deep-sea Shrimp (Organism B): Scientists believe the behavior of spewing glowing blue material aids in evading predators. This might also attract larger predators that could feed on their attackers.

Atolla Jellyfish (Organism C): Scientists call this ring of blue light the jelly's "burglar alarm" and believe that this brilliant bioluminescent flashing display attracts larger predators that might eat its attacker. This display of light is mimicked in the optical lure of the [Medusa Lander](#), a specialized underwater camera. Known as the e-jelly (or electronic jellyfish), the Medusa Lander's light ring helps ocean explorers attract and observe deep-sea animals.

Sea Pen (Organism D): Scientists are not certain why sea pens glow, but they speculate these flashes of light are used to either communicate with members of the same species, attract prey or startle possible predators.

Ask students to share what they found most interesting in the video and any questions they still have about bioluminescence.

EDUCATOR GUIDANCE

One question that may arise is "How do the organisms create their own light?" Ask if they have any ideas about the ability/process that is taking place within or by the organism. Discuss student ideas. Share that bioluminescence is a chemical process, with some organisms producing the chemicals themselves, and others relying on bacteria within their body to produce the chemicals.

- Provide the student teams with copies (print or digital) of the [Bioluminescence Fact Sheet](#). Give them time to read and briefly discuss the information.

Additionally, show the short video

(NOVA).

Invite students to share what they found interesting or what ideas added to their understanding.

Use the Creature Card Information for Educators provided (below) for each Creature Card to expand student understanding.

- Ask students to share their explanations/reasoning for why so many deep-sea animals glow in the dark.
- **OPTIONAL:** Share the [Three Mysterious Light Effects Fact Sheet](#) along with [Bioluminescence Fact Sheet](#) to introduce other uses of light in the ocean – fluorescence and phosphorescence.

Viperfish (Organism E): The photophores on the viperfish's belly are for counter-illumination, camouflaging the organism against the light above, disguising the animal from predators looking up from below. The glowing barbel attracts prey close to the large mouth of this predator, and the flashing blue-green and yellow photophores may also attract prey.

Lanternfish (Organism F): Scientists think bioluminescence in lanternfish may be used for communication or courtship behavior. Photophores also play a role in counter-illumination, camouflaging the organism against the light above, disguising the animal from predators looking up from below. This lanternfish, *Diaphus sp.*, is believed to use its nasal light organ like a headlight.

Vampire Squid (Organism G): The vampire squid's photophores and flashes of light are thought to help it to confuse predators. If that doesn't work, they can release a large cloud of bioluminescent mucus to distract predators while they make a quick getaway (they don't have ink sacs like true squid).

Anglerfish (Organism H): In this symbiotic relationship, the tiny glowing bacteria gains nutrients and a safe haven. The bacteria's glow turns the fish's barbel into a fishing lure attracting prey close to the large mouth of this ocean predator.





Educator Guide cont.

Elaborate

This section of the lesson can be extended to a third class period, especially if the students are conducting presentations and making 3D models. Determine your approach prior to starting the lesson to ensure you, and the students, have sufficient time to complete their projects.

Share with students they will each select one bioluminescent organism to research and create a detailed model of (e.g., diagram or 3D). Each student will compile their research findings into a communication product to accompany the model that can be shared with a peer or public audience. Products might include a labeled and annotated diagram, infographic poster, a digital presentation, or a short video.

Remind students of the focus question: *Why do many deep-sea animals glow in the dark?* Their communication product should address this question by incorporating key information about their organism and its ability to use bioluminescence to survive and reproduce in the deep sea. Key information to include:

- Structural features and **behavioral and physical adaptations** (bioluminescence); Annotate and label structures
- Scientific name
- Where on the planet the organism lives and in which ocean zone
- Size (cm/in)
- Diet
- *OPTIONAL: Scale of model to real organism, other marine relatives, additional features or adaptations for survival and reproduction.*

Possible organisms include:

Anglerfish	Colonial Salps (Pyrosomes)	Deep-sea Copepod	Hydromedusa (<i>Aequorea victoria</i>)	Lanternfish	Siphonophores (like <i>Stephanomia amphyratidis</i>)
Barreleye, Spook Fish	Colossal Squid	Deep-sea Lanternshark (<i>Etmopterus spinax</i>)	Jewel Squid	Midwater Squid (<i>Abrotralia veranyi</i>)	Stoplight Loosejaw fish
Bioluminescent Octopod	Bioluminescent Dinoflagellates	Gulper Eel	Krill (such as <i>Euphausia pacifica</i>)	Tubeshoulder fish	Vampire Squid
Bristlemouth Fish		Hatchetfish			

Provide students with the appropriate materials or resources to create their models and conduct their research. A few possible Web resources for information on the bioluminescent species list below are:

- Deep Ocean Education Project [Website](#)
- Smithsonian [Ocean Portal](#)
- University of California Santa Barbara [Bioluminescence Webpage](#)
- Woods Hole Oceanographic Institution's [Ocean Twilight Zone](#)



Provide an opportunity for students to share their projects with a broader school, family, or community audience, such as displaying projects in the school library, conducting a classroom gallery walk, or hosting a mini symposium for invited guests. Collaborate with fellow teachers (English Language Arts, Social Studies, Visual and Performing Arts, etc.) to generate cross disciplinary student engagement on their projects.

Evaluate

Use student models and communication products to assess individual student understanding and application of knowledge.

Have students create their own trivia game (questions and answers) for others to play after experiencing

their bioluminescent organism models and communication products, or as a way to "test" audience knowledge of bioluminescence in the deep sea. See sample [Bioluminescence Trivia](#).





Educator Guide cont.

Extensions

- Use creative writing and visual arts to generate fictional stories, poems, graphic novelettes, or short videos/animations about their particular organism.
- Explore and try the [Light and Color in the Deep Sea](#) lesson, NOAA Ocean Exploration.
- Have students watch the video [The Ocean Twilight Zone: Earth's Final Frontier](#) (Woods Hole Oceanographic Institution) and consider the importance of the "Twilight Zone" to humans and our planet.
- Challenge students to apply what they've learned to an imaginary future scenario.

Set the stage by asking the students to close their eyes and imagine as you read the following story. Tell them you are going to ask them to apply what they've learned today to this future scenario at the end.

- It is now 50 to 100 years into the future and humans have developed the technology and the need to visit and live in the deep sea. They may be escaping a changing climate on land, seeking abundant resources in the deep ocean, or simply adventuring to environments that are now more accessible.

- With this new migration into the deep sea, there will likely be impacts on the natural environment. One possible impact is sustained light pollution. Humans are adapted to living in light and we will need it to travel, live, and adventure in the deep sea. The continued use of artificial light from our ocean-going vehicles and machines, living spaces, and activities will invade the surrounding deep-sea environments. Think about the amount of light you see or experience on a daily basis. Think about where this light comes from, what color it is, how intense or bright it is, and whether it is wide spread or directional (e.g., stadium lights vs. a car's headlights).

Ask students to use their current understanding of the deep sea, bioluminescent organisms, and their adaptations for survival and reproduction to ponder the three following guiding questions. Tell students to consider how their organism (from the research project) might be affected. Questions they should consider:

- *How might the sustained light pollution affect your bioluminescent organism and its ability to survive and reproduce in the deep sea?*
- *What benefits might arise for this organism? What challenges might arise?*
- *How might humans be able to reduce their light pollution impact on the deep-sea environments while still occupying these ocean spaces?*

Adaptations

YOUNGER STUDENTS/
EMERGING READERS

- “[10 Things You Should Know about BIOLUMINESCENCE](#).” WhaleTimes
- Use this activity to support NGSS Performance Expectation 4-LS1-1 From Molecules to Organisms: Structures and Processes; DCI LS1.A Structure and Function.
- Discuss higher level concepts in relation to student ideas, such as those listed in HS-LS4, Biological Evolution: Unity and Diversity, and HS-LS-4.B.1, Natural Selection.
- Explore the [Creatures of Light: The Chemistry of Bioluminescence](#) (NOVA) video.

HIGH SCHOOL STUDENTS

Scientific Terms

Adaptation: a body part or feature or a behavior that helps a living organism survive and function better in its environment.

Bioluminescence: the production and emission of light by a living organism.

Cheiloluminescence: the production of visible light by a chemical reaction.

Ecosystem: a community of interacting organisms and their environment.

Photophore: a light-emitting organ present in certain bioluminescent fishes and invertebrates.



Bioluminescence Trivia

1. Bioluminescence means...

- a. A community of plants and animals
- b. One organism depends on another to live
- c. Production of light by an organism
- d. Light is reflected by the surface of water

2. One example of a bioluminescent organism that lives on land is...

- a. A hummingbird
- b. A firefly
- c. An electric eel
- d. A fire-breathing dragon

3. Examples of bioluminescent organisms that live in the ocean are...

(Circle all correct answers)

- a. Fishes
- b. Bacteria
- c. Squid
- d. Whales

4. What color of light is most often given off by bioluminescent organisms?

- a. Blue-green
- b. Red
- c. Orange
- d. Purple

5. Different wavelengths of light are more visible in deep ocean water than others.

- a. True
- b. False

6. What produces bioluminescence in organisms?

- a. A chemical reaction
- b. Absorption of light from the Sun
- c. Scales that reflect light
- d. Minerals eaten by organisms

7. What are some of the likely benefits of having bioluminescence? (Circle all correct answers)

- a. Attracting prey
- b. Finding mates
- c. Distracting predators
- d. Seeing in the dark

8. Bioluminescence is much more common in deep ocean environments than on land.

- a. True
- b. False



Investigation: Bioluminescence - An Adaptation for Deep-sea Survival Resources

Page 1: ▶ Deep-sea jellyfish (image): <https://oceanexplorer.noaa.gov/explorations/19biolum/background/medusa/media/figure-2-250.jpg>

Page 2: ▶ Bioluminescent Creature Cards (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescent-creatures.pdf>
▶ Bioluminescence Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescence-fact-sheet.pdf>
▶ Three Mysterious Light Effects Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/3-light-effects-fact-sheet.pdf>
▶ Dragon Fish Charms ROV (video): <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1907/dailyupdates/nov4/media/dive04-dragonfish-1280x720.mp4>
▶ Fish With Flashlights-Glowing Jellies (video): <https://www.whoi.edu/news-insights/content/fish-with-flashlights/>
▶ Strange Bioluminescence (video): <https://www.youtube.com/watch?v=WD1OzDbMFYQ>
▶ Bioluminescence (video): <https://oceantoday.noaa.gov/bioluminescence/>
▶ Light in the Deep Sea with Dr. Edie Widder (Bonus 1)(video): <https://oceantoday.noaa.gov/fullmoon-lightinthedeepsea/welcome.html>
▶ Creatures of Light (video): <https://www.pbslearningmedia.org/resource/nvcol-sci-biolumine/wgbh-nova-creatures-of-light-the-chemistry-of-bioluminescence/>
▶ The Ocean Twilight Zone: The Earth's Final Frontier (video): <https://twilightzone.whoi.edu/the-ocean-twilight-zone-earths-final-frontier/>
▶ Think About It Student Worksheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/think-about-it-worksheet.pdf>
▶ I Notice, I Wonder, It Reminds Me Of (N-W-R) Student Worksheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/in-iw-irmo.pdf>

Page 3: ▶ Distance sunlight travels in the ocean (diagram): https://oceanservice.noaa.gov/facts/light_travel.html
▶ Deep-sea anglerfish (image): <https://twilightzone.whoi.edu/explore-the-otz/creature-features/anglerfish/>
▶ Bioluminescence Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescence-fact-sheet.pdf>
▶ Light and Color in the Deep Sea Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/light-and-color-fact-sheet.pdf>
▶ Three Mysterious Light Effects Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/3-light-effects-fact-sheet.pdf>

Page 4: ▶ Dragon Fish Charms ROV (video): <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1907/dailyupdates/nov4/media/dive04-dragonfish-1280x720.mp4>
▶ Fish With Flashlights-Glowing Jellies (video): <https://www.whoi.edu/news-insights/content/fish-with-flashlights/>
▶ Strange Bioluminescence (video): <https://www.youtube.com/watch?v=WD1OzDbMFYQ>
▶ I Notice, I Wonder, It Reminds Me Of (N-W-R) Student Worksheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/in-iw-irmo.pdf>
▶ Journey Into Midnight (webpage): <https://oceanexplorer.noaa.gov/explorations/19biolum/welcome.html>
▶ Bioluminescence and Vision (webpage): <https://oceanexplorer.noaa.gov/explorations/15biolum/welcome.html>

Page 5: ▶ Bioluminescent Creature Cards (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescent-creatures.pdf>
▶ Think About It Student Worksheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/think-about-it-worksheet.pdf>

Page 6: ▶ Think About It Student Worksheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/think-about-it-worksheet.pdf>
▶ Light and Color in the Deep Sea lesson (webpage): <https://oceanexplorer.noaa.gov/themes/bioluminescence/lessons/light-and-color.html>
▶ Bioluminescence (video): <https://oceantoday.noaa.gov/bioluminescence/>

Page 7: ▶ Bioluminescent Creature Cards (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescent-creatures.pdf>
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▶ Bioluminescence Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescence-fact-sheet.pdf>
▶ Dragonfish introductory video: <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1907/dailyupdates/nov4/media/dive04-dragonfish-1280x720.mp4>
▶ Medusa Lander (webpage): <https://oceanexplorer.noaa.gov/explorations/15biolum/background/medusa.html>

Page 8: ▶ Deep Ocean Exploration Project (DOEP)(website): <https://deepoceaneducation.org/topic/bioluminescence/>
▶ Smithsonian Ocean Portal (website): <https://ocean.si.edu/ocean-life/fish/bioluminescence>
▶ Bioluminescence Webpage: <https://biolum.eemb.ucsb.edu/organism/photo.html>
▶ Ocean Twilight Zone (website): <https://twilightzone.whoi.edu/explore-the-otz/life-in-the-otz/>

Page 9: ▶ Light and Color in the Deep Sea lesson (webpage): <https://oceanexplorer.noaa.gov/edu/themes/bioluminescence/lessons/light-and-color.html>
▶ The Ocean Twilight Zone: The Earth's Final Frontier (video): <https://twilightzone.whoi.edu/the-ocean-twilight-zone-earths-final-frontier/>
▶ 10 Things You Should Know about BIOLUMINESCENCE (pdf): <http://whaletimes.org/wp-content/uploads/2019/11/WhaleTimes-Ten-things-BIOLUMINESCENCE.pdf>
▶ Creatures of Light (video): <https://www.pbslearningmedia.org/resource/nvcol-sci-biolumine/wgbh-nova-creatures-of-light-the-chemistry-of-bioluminescence/>

Partners



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