



Investigation: The Science of Light and Color in the Deep Ocean

Overview

TOPIC:	Bioluminescence
FOCUS:	Students explore the phenomenon of light and color in the ocean through sense-making. This process includes investigating how light interacts with different materials, making connections between the observed phenomenon and what happens to light as it passes through the ocean.
GRADE LEVEL:	6th–8th; extensions and differentiation provided to adapt to other grade levels
TIME NEEDED:	One block (80-90 minutes) or two 50-minute class period (plus additional time for optional extensions)



The oblique-banded snapper or gindai (*Pristipomoides zonatus*) lives in the twilight, or mesophotic, zone where only dim blue light penetrates. *Top image courtesy of NOAA Ocean Exploration; bottom image courtesy of Bruce C. Mundy, NOAA Pacific Islands Fisheries Science Center.*

PHENOMENON (DRIVING QUESTION): Animals throughout the ocean depths are different colors and use different colors of bioluminescence. Why? How?

OBJECTIVES/ LEARNING OUTCOMES:	<p>Students will:</p> <ul style="list-style-type: none"> analyze the results of a deep-sea simulation investigation to develop an understanding of how depth impacts light availability create a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave evaluate the relationship between color, energy, and wavelength of light and the relationship between those aspects of light and depth in the ocean develop a model of how light availability impacts coloration of organism bodies and bioluminescence
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NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectations (PEs): MS-PS4-2

Disciplinary Core Ideas (DCIs)

PS4.A: Wave Properties
PS4.B: Electromagnetic Radiation

Crosscutting Concepts (CCs)

Energy and Matter
Structure and Function

Science & Engineering Practices (SEPs)

Analyzing and Interpreting Data
Constructing Explanations
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 b



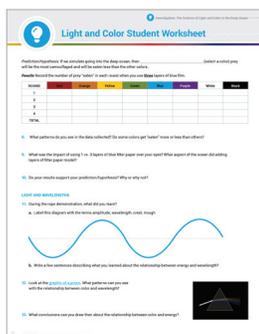
Overview cont.

MATERIALS:

Note: All materials, aside from copies of worksheets can be saved and reused between classes and years.

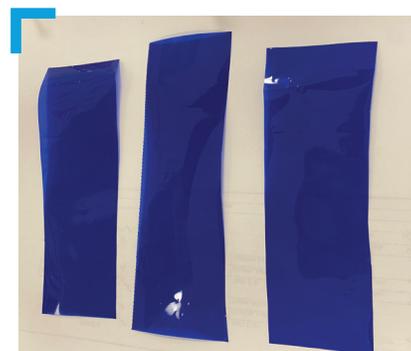
Per group

- Large piece of black paper or fabric if tables/desks are light colors
- Bag of small (approximately 2 cm²- exact size does not matter as much as consistency between pieces) squares of felt or construction paper in several colors (red, orange, yellow, green, blue, purple, black, and white, ideally; equal number of each color in each bag)
- A cup or container to gather the “prey” squares during the game
- *Optional:* small whiteboard and dry erase markers for group work
- *Optional:* a prism and flashlight



Per student

- [3-4 strips of blue transparent gel filter](#); each strip cut to ~7 cm x 20 cm to cover a student's eyes like glasses
- 2 binder clips or strong paper clips to hold the strips together
- Copy (paper or electronic) of the [Light and Color Student Worksheet](#)



Viewing images through three sheets of blue film clipped together can simulate color in the deep ocean.

For the class

- Long rope to demonstrate wave energy
- Whiteboard and dry erase markers
- Computer and projector are highly preferred for video clips. If that is not an option, print-outs of the following color images to share with the class:
 - [Prism graphic](#)
 - [NOAA graphic of color in the ocean](#)
 - [Diagram of the visible spectrum](#)
- Videos
 - [A Dark World of Color](#), NOAA Ocean Exploration
 - [Light in the Deep Sea with Dr. Edie Widder](#), NOAA Ocean Today
 - *Optional:* [Deep Ocean Creatures](#), NOAA Ocean Today

SET-UP INSTRUCTIONS:

- Prepare materials above for distribution to each group and/or class
- Cue up videos
- Print copies of the worksheet and Fact Sheets: [Light and Color in the Deep Sea](#) and [Bioluminescence](#) for students (or share the digital versions).

Educator Guide (in the 5E Model)

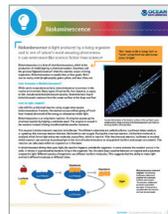
EDUCATOR BACKGROUND:

As one travels from surface waters to deeper waters, the amount and visible colors of light change, because water refracts, absorbs, and scatters wavelengths differently. Red light disappears at a shallower depth in the water column and blue light penetrates deepest. This affects how different colored pigments appear at different depths.

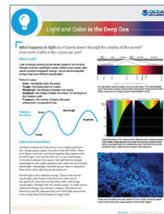
Organisms that live in water use light, color, and vision for many things: to find prey, to hide from predators, and to find mates. For example, a red fish swimming at the ocean surface looks red because there is red light in shallow water. In 100 meters of water, that same fish is difficult to see, appearing grey or black. There is no red light to reflect at that depth, and the fish absorbs all other wavelengths. In the twilight zone (approximately 200 to 1,000 meters or ~660 to 3,300 feet), many species are black or red. At depth, these organisms are virtually invisible unless they are silhouetted against the distant surface viewed from below.

FOR MORE INFORMATION:

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



► [Bioluminescence Fact Sheet](#)



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



Engage

Tell students that we are working to investigate and explore the phenomenon: **Animals throughout the ocean depths are different colors and use different colors of bioluminescence. Why? How?** Guide them through the questions below. Depending on the background of students, approach options include think-pair-share or class brainstorming discussions:

Following the discussion, have the students write out their thoughts on #1-4 on the [Light and Color Student Worksheet](#).

- *Animals on land are all different colors. Can you think of animals of different colors and what their colors help them do?*
- *Do you know what a firefly or lightning bug is? What is special about their colors? Why?*
- *When you picture a fish, whale, or shark at the surface of the ocean, what color(s) are their bodies? Why do you think that is the case?*
- *What colors do you think animals like fish, sea stars, etc., are deeper in the ocean where there is less light?*
- *What about in the deepest parts of the ocean where there is no light? Do you think they are different or the same as they are at the surface? (Consider having them draw and color a diagram of their preconceptions of animals at different depths.)*
- *What questions do you have at this point about color and organisms in the deep ocean?*

Set the stage by taking students through the following guided imagery. Ask the students to close their eyes and imagine as you read the following story. Tell them you are going to ask them to describe what they saw and thought at the end.

- You are a scientist on a mission. You are seated in a control room with several other people. Several large video monitors are on the wall in front of you. One of the monitors shows an image of a sun-lit ocean, just a few feet above the surface. The person next to you is the pilot and she says “Here we go,” as she moves a large joystick slightly. As you watch, the sea surface seems to rise up. There is a sudden splash in front of the lens and the monitor now shows rays of sunlight shining through the blue ocean water. Every minute or so, the pilot with the joystick calls out a number. As the numbers increase, the scene on the monitor grows steadily darker.

By the time the pilot says “Fifty meters,” the monitor is almost completely black. The pilot touches a switch and beams of light shine out into the darkness. She continues to call out larger and larger numbers. Strange animals appear in the path of the lights, then quickly disappear. Time passes, but no one wants to look away from the monitor because they might miss something amazing.

Educator Guide cont.

Engage cont.

The scientists constantly talk about what they see, and their words are recorded along with the video images. Suddenly the scene on the monitor changes as the pilot says “Two thousand meters.” You see a horizontal surface that must be the ocean bottom. Large branching objects seem to be growing out of the seafloor. You ask the pilot to collect a few of these. A robotic claw attached to a metal arm appears on the monitor, tightens onto one of the branching objects, and then pulls the object back toward the video camera. The claw and the sample disappear, and the pilot says, “OK, it’s in the basket.” Another scientist notices things moving in the mud, and asks the pilot to collect more samples. As the camera moves around, you can see that the ocean floor is covered with animals, tracks, and holes. After collecting more samples, the pilot says, “Let’s watch for a few minutes with the lights off.” The monitor is completely black for what seems like a long time, but then a glowing object flashes across the screen. “WHAT WAS THAT???” There is another flash of light, and it almost seems to be following the first object. Several scientists are busily speaking into their microphones to record every detail of something they have never seen before.

Ask students what they remember and what they thought and felt during the guided imagery and to record that on their [Light and Color Student Worksheet](#) (#5). The rest of the lesson is going to model going into the depths of the ocean and learning and exploring why the animals look and behave the way they do because of where in the ocean they live.

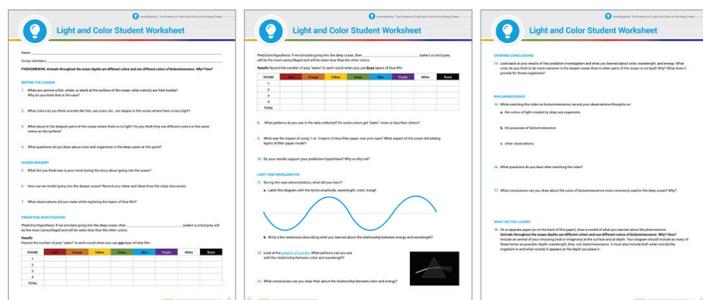
OPTIONAL

If all students feel comfortable, you might act on one or more of those ideas that are easy to implement, such as turning off the lights, looking into a mostly closed box, and/or closing the window blinds. Explain that since much less light is able to penetrate deep ocean water, it therefore becomes darker and darker with depth.

Next, tell students that although we cannot take them into the ocean in a submersible or follow a live ROV (underwater robot) today, we can model that same imagery to learn to understand it. Guide students through the following questions (again, using a discussion technique that works with your class):

- *If we wanted to model going down into the ocean in our classroom, what could we do?*
- *How might things appear differently 200 meters below the surface to an animal or a scientist studying how light changes deep under water?*
- *Do you think the quantity (amount) of light changes? Do you think anything else about the light changes? (hint- hoping to get to COLOR, but do not give that away)*
- *How could we simulate or model that environment?*

Ask them to record their thoughts in #6 on the [Light and Color Student Worksheet](#). After 1–2 minutes, have them share their best ideas with the class and encourage feedback on the ideas. They should add additional thoughts after the discussion to their worksheet.



The ROV pilot controls ROV *Deep Discoverer's* grasping arm, while the co-pilot points the main camera. Image courtesy of NOAA Ocean Exploration, American Samoa.



Educator Guide cont.

Explore *Remind students that we are working to investigate and explore the phenomenon: Animals throughout the ocean depths are different colors and use different colors of bioluminescence. Why? How?*

Pass around the strips of blue filter paper (3-4 strips per student) and binder clips. *Do not give out the bags of felt/paper squares yet.* Invite students to think about how the materials might be used to help create a model of how things appear differently in the deep ocean environment. Tell them you don't expect them to know what to do in this quick exploration of the materials, but that they should play with them and see what they discover about light and color. Have them discuss in their groups and record observations in #7 on the [Light and Color Student Worksheet](#).

- As they explore using the items, guide them with the following questions:
 - *How does the film affect the appearance of light? Do things appear clearer, less clear, different colors, etc.?*
 - *Do different things around the room get affected the same or differently? What is it about the items that changes how they appear through the film?*
 - *How do your observations change if you use more than one layer of film?*
 - *How do you think this film can help us model (or simulate) going into the deep ocean?*
- As a class, discuss the results of their exploration of the layers of film. Do not directly provide answers or tell them what they should see, but guide them through a discussion about how adding layers of film (going from 1 to 2 to 3 layers) models going deeper and deeper into the ocean where little light penetrates. They should keep this in mind during the predation simulation investigation they are about to do.

Through play, guide students through the following investigation:

1. Divide students into groups of 2-4.
2. Have the students put aside the strips of blue filter paper. They should *not* have those out until the investigation begins and only the predator will use them.
3. Pass out the bags of felt/paper squares and black paper if you have light-colored desks- one per group. Tell the students these squares represent their "prey" and each of them will take a turn being the predator. Predators are going to use their thumb and forefinger only as their "mouth" to pick up the prey, one at a time, and put it in a cup or container on the side.
4. Ask students to imagine that they are down in what is called the "Twilight Zone" of the ocean, hundreds of meters deep, where very little light can reach. Remind them that they should model going deeper into the ocean using the layers of blue filter paper.
5. Ask students to complete the prediction or hypothesis statement on their worksheet by filling in the blank with what color they think will be the most camouflaged or hidden in the deep ocean.
6. Have each group select a student to be the first predator fish to "eat" the colored squares. That student should turn their back to the desk or close their eyes while holding ONE strip of blue filter paper.
7. Ask the other students in each group to spread the colored squares out randomly and evenly on the **black** paper or fabric to be the prey for the predator.
8. Announce to the predators that when you say "GO," they will have just 7 seconds to place the single layer of blue film over their eyes, open their eyes, pick up **one of the most visible prey items at a time** (again using just their thumb and forefinger), and place it in the cup. Explain that they can do that for as many pieces of prey as possible in the 7 seconds.
9. When students are ready, say "GO!" Count to seven slowly out loud while the predators pick up as many of the **most visible prey squares** as they can. Then shout "STOP!"

TEACHER NOTES

Through questioning and guidance, but not pointing out directly, help students start to see that some colors appear clearer/brighter (blues) and other colors (reds) appear darker and harder to see. They may also notice that each additional layer of film makes the effect more significant (blues stand out more and reds seem to disappear against a dark background). The more layers, the stronger the effect.

Educator Guide cont.

Explore cont.

10. Have the students record their results in the table on their worksheet.
11. Repeat the process for a total of 2–4 rounds to give every group member a chance to play (or pairs of students to play more than one round), and have students record data in the table after each round.
12. After all rounds are complete, students should calculate a total number eaten for each color.
13. Tell students to consider how changing the number of layers of film impacted their earlier observations. Have them repeat steps 6-12 with three layers of film, filling out the second chart on the worksheet. They can use binder clips to hold the layers together while they hold the film over their eyes as predators.

Discuss the results as a class. Guide students through the following questions:

- Which color of prey was picked up most often?
- Which color was most visible to you? Why do you think that was the case?
- How do the blue filters affect visibility of the different colors of prey?
- Remember that the blue filters help us model how light penetrates the ocean. So, what colors of light do you think are least/most visible in the ocean below the surface?
- Why were you asked to add layers of filter paper for the second version of the investigation?
- What feature of the ocean did that model? What impact did it have on the prey's appearance?
- Do your results support your prediction/hypothesis? Why or why not?

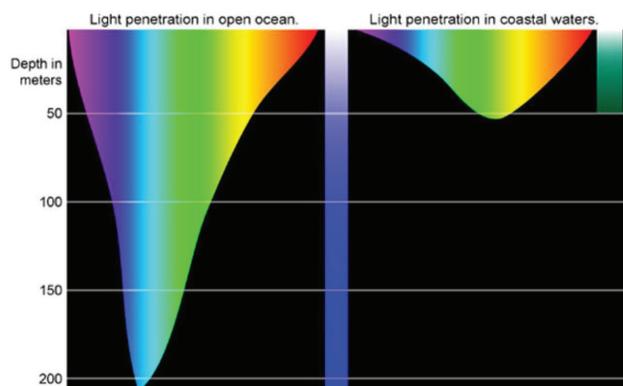
After the discussion, have them record their thoughts for #8-10 on the worksheet.

Gather the supplies and put them aside. Ask students to hold onto the blue strips of film with binder clips for later.



TEACHER NOTE

The red should be eaten least. The blue film removes the other wavelengths of light, similar to how light is filtered out in the ocean. Red disappears first and blue penetrates deepest. If no red wavelengths are available, they cannot reflect off the prey to the eye of the predator to be seen and caught! More layers of film represent deeper dives into the ocean as less and less of the other wavelengths are available.



A basic illustration of the depth at which different colors of light penetrate ocean waters. Water absorbs warm colors like reds and oranges (known as long wavelength light) and scatters the cooler colors (known as short wavelength light). Image courtesy of Kyle Carothers, NOAA Ocean Exploration.

Viewing images through three sheets of blue film clipped together can simulate color in the deep ocean.



Educator Guide cont.

Explain

Ask students if they have ever seen a rainbow outside or on a wall or ceiling in their house as light comes in? What causes that phenomenon?

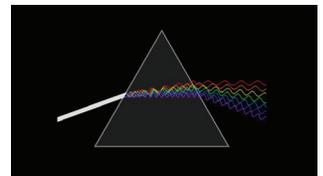
Explain to the students that light is a form of energy that moves as a wave. Ask the students what kinds of waves they can think of and ask individuals to describe them to the class. Many will think about ocean waves-- remind them that generally they see the water moving up and down until it gets shallow near the beach and then it crashes to shore.

- Air is a different medium than water, and we cannot see waves that move through the air. But, we can model them using a rope. Ask two students to volunteer to demonstrate wave energy. Give them each an end of the rope and have them stand far enough apart that the rope is not fully taught or lying on the ground between them. Guide them through the demonstration as follows:
 - First, we want to model a small amount of energy passing between the students holding the rope. Ask, *how should we do this?* Have one student stand still and hold the rope tightly while the other student gently moves the rope up and down.
 - *Does anyone know the word for the distance between two of these waves?* It is called the **WAVELENGTH**.
 - *We also need a term to describe the height of the wave. We use the term **AMPLITUDE** to describe the distance between the equilibrium point of a wave (where the rope was before it started to move) and the top (**CREST**) OR the bottom (**TROUGH**).*
 - *What if we want to increase the amount of energy? What will happen to the rope's movement?*
 - Have the student move the rope faster.
 - Ask the class what they observe. *Did the wavelength get bigger or smaller? What else is changing?* The number of waves in the rope at a time-- or **FREQUENCY** (the number of waves that pass through a fixed point in a set time).
 - *What if we increase the energy even more? What will happen to the waves in the rope?*

- Have a student draw a set of waves on the board and label this model with the class' guidance using the vocabulary: wavelength, amplitude, crest, and trough. Add a definition of frequency to the board.
- Ask students to record their observations from the rope demonstration on the [Light and Color Student Worksheet](#) (#11).
- **OPTIONAL:** if prisms and flashlights are available: Give pairs or small groups of students a flashlight and a prism and have them explore what happens as the light passes through the prism onto a solid color wall or paper. Ask them to discuss as a group what they see and what is causing the light to behave that way and create the patterns they see. Suggest that they draw a model on their small whiteboard (or the back of their worksheet) of what they think is happening in the prism.

Display a [graphic of a prism](#) separating out white light into different wavelengths on the board for all students to see. Then, explain to them that the light is being refracted (bent as the medium changes from air to the glass) in the prism and the different colors of light are bending differently based on their individual wavelengths. Guide them using questions such as:

- *What patterns or shapes do you see?*
- *How is the order of colors significant?*
- *How are the patterns the same and how are they different between the colors?*
- *Do you see a change in the waves as they enter and exit the prism?*
- Give students 1-2 minutes to observe and discuss in pairs or small groups, then discuss as a class. Important take-aways are:
 - *The order of colors is the same as in a rainbow/color spectrum.*
 - *Patterns are regular waves.*
 - *Different color wavelengths are longer or shorter, with red being the longest and violet being the shortest.*
 - *Each color/wavelength refracts at a different angle (the shorter the wavelength, the greater the angle of refraction).*



A triangular prism, dispersing light; waves shown to illustrate the differing wavelengths of light. Wikipedia.

Educator Guide cont.

Explain cont.

- Have them look back at the prism graphic and guide them to answer #12-13 on the worksheet.
- Show them the [diagram of the visible spectrum](#) (also available in the [Light and Color in the Deep Sea Fact Sheet](#)) with wavelengths to confirm their conclusions.
- Tell students that water can act like a prism - the water vapor in the air can make rainbows and water in the ocean also bends light! Remember that light refracts or bends as it changes medium.
- Next, begin having students draw conclusions by asking them to explore the [NOAA graphic of color in the ocean](#) with only the images and not the paragraph beneath them. Guide students using the following questions:
 - *What colors are found in the deepest waters in the open ocean?*
 - *What colors are only found near the surface?*
 - *Thinking back to the prism and wavelengths, what do you think is the relationship between wavelength, energy, and how deep color travels in the ocean?*
 - *Why is the ocean blue?*
- Have the students discuss their thoughts as a class and ask them to record their observations on their [Light and Color Student Worksheet](#) (#14). Important take-aways are:
 - *Light bends into different colors (rainbow) when it enters the ocean and some colors penetrate deeper than others.*
 - *Colors of longer wavelengths and lower energy (red, orange, and yellow) are absorbed by the water and particles in the water near the surface, and colors of shorter wavelengths and more energy (blue) penetrate deeper.*
- *Ocean water looks blue because red is absorbed near the surface and blue is absorbed by more of the volume of the ocean.* https://oceanservice.noaa.gov/facts/light_travel.html
- Give students a copy of the [Light and Color in the Deep Sea](#) Fact Sheet and show them the [A Dark World of Color](#) video (NOAA Ocean Exploration, 4:31). The video explores other reasons why animals in the deep, dark, sea are so colorful. After watching it through once, show the video a second time and pause on some of the animals (some blue and some red) and ask the students to put the layers of blue film over their eyes to see what happens with each of the colored animals. Remind them that adding layers of blue film models the light that is available to see deeper and deeper in the ocean. If red light is not available to reflect off the animals into your eye, you cannot see it! This is why the red animals are camouflaged in the deep and the blue animals are highly visible.
 - *OPTIONAL:* If your students are highly interested in this topic and ask questions about the deepest parts of the ocean where there is no light at all, ask them what color(s) they think those animals would be and consider showing them the [Deep Ocean Creatures](#) video (NOAA Ocean Today, 1:49).
- Have them add to their conclusions in #14 on the [Light and Color Student Worksheet](#), drawing conclusions about animal color in the deep sea. The primary conclusion is that red is a common color in the deeper ocean. It acts as camouflage because there are no red wavelengths of light that deep.

TEACHER NOTE

Ocean water is a different medium from air. The colors of light refract or bend into different wavelengths/colors and the particles in the ocean absorb (and scatter) different wavelengths of light at different depths. In general, cooler colors (with shorter wavelengths) penetrate deeper than warmer colors. However, purple/violet does not follow this pattern because this specific wavelength is scattered and absorbed more by water particles than blue.

TEACHER NOTE

Organisms in the deepest part of the ocean tend to be white/grey/colorless because there is no evolutionary advantage to creating pigment or color if there is no light for it to be seen.



This sea toad was seen at a depth of over 3000 meters in the Musicians Seamount group northeast of O'ahu, Hawaiian Islands. With the lights of the remotely operated vehicle, we can see that it is bright red, but in the dark, this fish appears black, well hidden in the deep sea. *Image courtesy of NOAA Ocean Exploration.*



In white light, at the surface, we see red.



As red light is filtered out in deeper water, red animals appear gray or black.



Educator Guide cont.

Elaborate

Explain to students that so far they have learned a lot about light and color in the ocean. Tell them that some organisms can even make their own light! Guide them through a discussion about these questions:

- *What challenges can you imagine organisms face in the deep ocean?*
- *Can you think of any challenges that could be addressed by organisms making their own light?*
- *Based on what you have learned so far, what colors of light do you think would help the organisms in the deep sea stand out and attract attention from other animals? What colors would help them blend in or camouflage?*
- Introduce the **phenomenon of bioluminescence**. Show students the [Light in the Deep Sea, Dr. Edie Widder](#) (NOAA Ocean Today, 4:00). Play the video until 2:30 or the end (depending on your time and the level of the students vocabulary and interest) and ask students to think about the phenomenon they are observing, especially paying attention to color. Another option is this [Bioluminescence](#) introductory video (NOAA Ocean Today, 1:15).
- Have them record their answers to #15-16 on the worksheet after the video.
- Ask students to take turns reading the [Bioluminescence Fact Sheet](#) (first page only) out loud. Ask them to think about what the video shows and the results from the color investigation and then ask them to brainstorm why bioluminescence is an important adaptation. Important take-aways are:
 - *Bioluminescence aids survival in a dark environment*
 - *Organisms use their own light in a variety of ways that include warning or evading predators, finding mates, and locating prey.*
- Next, have students begin to connect their observations about color in the deep sea to bioluminescence adaptations seen in deep-sea organisms. Guide students through the following discussion questions:
 - *How did the organisms featured in the video and fact sheet use bioluminescence?*
 - *Were there any similarities that you noticed?*
 - *What color did most of these organisms use?*

- *How did the organisms use this color to help them camouflage or stand out?*
- *Why would they have evolved an adaptation that uses blue to help them stand out?*

TEACHER NOTE

(not to share yet with students):

The focus here is to understand that there are a variety of behaviors and reasons for bioluminescence, but students should notice that BLUE is the primary color used for bioluminescence. As blue is the most abundant wavelength in the deep ocean, organisms that have evolved to create (or have a mutualistic symbiotic relationship with bacteria that create) blue light can attract attention.

- Have students read the [Smithsonian article on bioluminescence](#) (or a modified version). For typical students, consider just using the section on blue light.
- Guide them through a discussion about why blue is the primary color of bioluminescence (see Teacher Note). For advanced and interested students, consider discussing red as well. Have students record the answer to #17 on the [Light and Color Student Worksheet](#) following the discussion.

ADDITIONAL OPTIONS

- Dive deeper into bioluminescence adaptations. See [Extensions](#) (page 10).
- For classes who focus on scientific experimental design and inquiry, note that the independent and dependent variables of the ocean predator investigation (in explore) can be identified as:
 - IV: layers of blue film / depth of the ocean
 - DV: colors of prey most/least eaten
- Share the [Three Mysterious Light Effects Fact Sheet](#) along with the [Bioluminescence Fact Sheet](#) to introduce other uses of light in the ocean – fluorescence and phosphorescence.

Educator Guide cont.

Evaluate

Have the students draw a model of what they learned about the phenomenon. **Animals throughout the ocean depths are different colors and use different colors of bioluminescence.**

Why? How? (#18 on the worksheet). Have them include an animal of their choosing (real or imaginary) at the surface and at depth. Student diagrams should include as many of these terms as possible: depth, wavelength, blue, red, bioluminescence. They should also include both what color(s) the organism is and what color(s) it **appears** at the depth they place it.

Scientific Terms

Crest: the highest point of a wave

Trough: the lowest point of a wave

Wavelength: the distance between two waves

Amplitude: describes the height of a wave; the distance between the equilibrium point of a wave and the crest or trough.

Frequency: the number of waves that pass through a fixed point in a set time

Refract: a change in direction of a wave as it changes medium

Bioluminescence: light produced by organisms through a chemical reaction

Extensions

- [Bioluminescence - An Adaptation for Deep-sea Survival](#) student investigation from NOAA Ocean Exploration. Students explore the phenomenon: *Why do many deep-sea organisms glow in the dark?*
- [Hercules, Illuminating The Dark](#) STEM Learning Module from Ocean Exploration Trust.
- [Nautilus Career Connections Environmental Chemist: Chemistry of Bioluminescence](#) from Ocean Exploration Trust. It includes a profile of a scientist investigating bioluminescence and several activities.

Student activities using Ostracods (Sea Fireflies):

- [Glow: Living Lights](#) teacher's guide from San Diego Natural History Museum (includes 12 bioluminescence lessons).
- [Bioluminescence from Ostracods \(Sea Fireflies\)](#) NASA.

Other bioluminescent organism options you might investigate include:

- [The Deep Sea](#) by Neal Agarwal is an engaging resource students can explore to get a better sense of the diversity of life that has evolved in the deep sea and just how deep down in the "Midnight Zone" many of these creatures live.
- NOVA's video [Creatures of Light: The Chemistry of Bioluminescence](#) (2:47) explains how bioluminescence is created.

TEACHER NOTE

Ostracods and/or sea fireflies are available for purchase from [Carolina Biological](#) and similar supply companies.

Adaptations

DIFFERENT
GRADE/
LEARNING
LEVELS

- Guidance based on student background as well as possible extensions are provided within the Educator Guide.
- For use at the high school level and life science standards, consider using the predation investigation to introduce color in the ocean and then discussing pigments of algae at different depths of the ocean. Green algae live near the surface because they have red and blue light available (they absorb red and blue light and reflect/appear green), while red algae live deeper (they absorb blue light because that is all that is available but when you shine light on them, they appear red).



Light and Color Student Worksheet

Name _____

Group members _____

PHENOMENON: *Animals throughout the ocean depths are different colors and use different colors of bioluminescence. Why? How?*

BEFORE THE LESSON

1. When you picture a fish, whale, or shark at the surface of the ocean, what color(s) are their bodies? Why do you think that is the case?
2. What colors do you think animals like fish, sea stars, etc., are deeper in the ocean where there is less light?
3. What about in the deepest parts of the ocean where there is no light? Do you think they are different colors or the same colors as the surface?
4. What questions do you have about color and organisms in the deep ocean at this point?

GUIDED IMAGERY

5. What did you think/see in your mind during the story about going into the ocean?
6. How can we model going into the deeper ocean? Record your ideas and ideas from the class discussion.
7. What observations did you make while exploring the layers of blue film?

PREDATION INVESTIGATION

Prediction/Hypothesis: If we simulate going into the deep ocean, then _____ (select a color) prey will be the most camouflaged and will be eaten less than the other colors.

Results

Record the number of prey "eaten" in each round when you use **one** layer of blue film.

ROUND	Red	Orange	Yellow	Green	Blue	Purple	White	Black
1								
2								
3								
4								
TOTAL								



Light and Color Student Worksheet

Prediction/Hypothesis: If we simulate going into the deep ocean, then _____ (select a color) prey will be the most camouflaged and will be eaten less than the other colors.

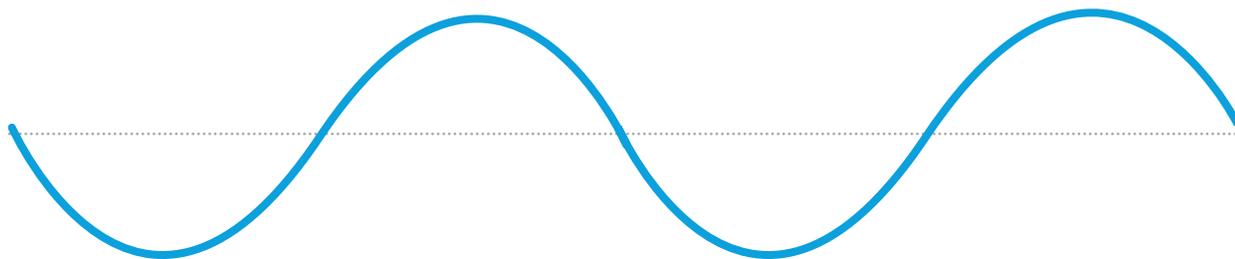
Results Record the number of prey "eaten" in each round when you use **three** layers of blue film.

ROUND	Red	Orange	Yellow	Green	Blue	Purple	White	Black
1								
2								
3								
4								
TOTAL								

8. What patterns do you see in the data collected? Do some colors get "eaten" more or less than others?
9. What was the impact of using 1 vs. 3 layers of blue filter paper over your eyes? What aspect of the ocean did adding layers of filter paper model?
10. Do your results support your prediction/hypothesis? Why or why not?

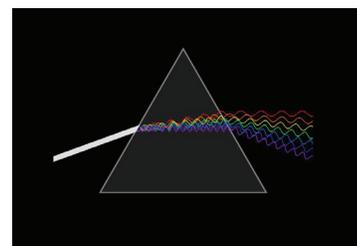
LIGHT AND WAVELENGTHS

11. During the rope demonstration, what did you learn?
 - a. Label this diagram with the terms amplitude, wavelength, crest, trough



- b. Write a few sentences describing what you learned about the relationship between energy and wavelength?

12. Look at the [graphic of a prism](#). What patterns can you see with the relationship between color and wavelength?



13. What conclusions can you draw then about the relationship between color and energy?



Light and Color Student Worksheet

DRAWING CONCLUSIONS

14. Look back at your results of the predation investigation and what you learned about color, wavelength, and energy. What color do you think is far more common in the deeper ocean than in other parts of the ocean or on land? Why? What does it provide for those organisms?

BIOLUMINESCENCE

15. While watching the video on bioluminescence, record your observations/thoughts on:
- a. the colors of light created by deep sea organisms
 - b. the purposes of bioluminescence
 - c. other observations
16. What questions do you have after watching the video?
17. What conclusions can you draw about the color of bioluminescence most commonly used in the deep ocean? Why?

WHAT DID YOU LEARN?

18. On a separate paper (or on the back of this paper), draw a model of what you learned about the phenomenon: **Animals throughout the ocean depths are different colors and use different colors of bioluminescence. Why? How?** Include an animal of your choosing (real or imaginary) at the surface and at depth. Your diagram should include as many of these terms as possible: depth, wavelength, blue, red, bioluminescence. It must also include both what color(s) the organism is and what color(s) it appears at the depth you place it.



Investigation: The Science of Light and Color in the Deep Ocean Resources

- Page 1:** ▶ Snapper (image): <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1605/logs/may9/media/1605snappercolors-hires.jpg>
- Page 2:** ▶ Transparent gel filter (image): <https://www.amazon.com/Selens-15-8X19-7inch-Correction-Flashlight-Blue/dp/B01GPICVY8/>
 ▶ Prism graphic (image): https://en.wikipedia.org/wiki/Prism#/media/File:Light_dispersion_conceptual_waves.gif
 ▶ NOAA graphic of color in the ocean (image): <https://oceanexplorer.noaa.gov/explorations/04deepscope/background/deelight/media/diagram3.html>
 ▶ Diagram of the visible spectrum (image): <https://www.weather.gov/jetstream/color>
 ▶ A Dark World of Color, NOAA Ocean Exploration (video): <https://oceanexplorer.noaa.gov/facts/red-color.html>
 ▶ Light in the Deep Sea with Dr. Edie Widder, NOAA Ocean Today (video): <https://oceantoday.noaa.gov/fullmoon-lightinthedeepsea/welcome.html>
 ▶ Deep Ocean Creatures, NOAA Ocean Today (video): <https://oceantoday.noaa.gov/deepoceancreatures/>
 ▶ Light and Color in the Deep Sea Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/light-and-color-fact-sheet.pdf>
 ▶ Bioluminescence Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescence-fact-sheet.pdf>
- Page 3:** ▶ Light and Color in the Deep Sea Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/light-and-color-fact-sheet.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>
- Page 4:** ▶ Control room operations (photo): <https://oceanexplorer.noaa.gov/oceanos/explorations/ex1702/logs/feb25/media/sampling-hires.jpg>
- Page 6:** ▶ NOAA graphic of color in the ocean (image): <https://oceanexplorer.noaa.gov/explorations/04deepscope/background/deelight/media/diagram3.html>
 ▶ Transparent gel filter (image): <https://www.amazon.com/Selens-15-8X19-7inch-Correction-Flashlight-Blue/dp/B01GPICVY8/>
- Page 7:** ▶ Prism graphic (image): https://commons.wikimedia.org/wiki/File:Light_dispersion_conceptual_waves.gif
- Page 8:** ▶ Diagram of the visible spectrum (image): <https://www.weather.gov/jetstream/color>
 ▶ Light and Color in the Deep Sea Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/light-and-color-fact-sheet.pdf>
 ▶ NOAA graphic of color in the ocean (image): <https://oceanexplorer.noaa.gov/explorations/04deepscope/background/deelight/media/diagram3.html>
 ▶ Ocean water (webpage): https://oceanservice.noaa.gov/facts/light_travel.html
 ▶ A Dark World of Color, NOAA Ocean Exploration (video): <https://oceanexplorer.noaa.gov/facts/red-color.html>
 ▶ Deep Ocean Creatures, NOAA Ocean Today (video): <https://oceantoday.noaa.gov/deepoceancreatures/>
 ▶ Sea toad (image): <https://oceanexplorer.noaa.gov/edu/materials/color-in-deep-graphic.jpg>
- Page 9:** ▶ Light in the Deep Sea with Dr. Edie Widder, NOAA Ocean Today (video): <https://oceantoday.noaa.gov/fullmoon-lightinthedeepsea/welcome.html>
 ▶ Bioluminescence (video): <https://oceantoday.noaa.gov/bioluminescence/>
 ▶ Bioluminescence Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescence-fact-sheet.pdf>
 ▶ Smithsonian bioluminescence (article): <https://www.smithsonianmag.com/science-nature/why-bioluminescence-evolved-be-red-light-and-blue-180969435/>
 ▶ Three Mysterious Light Effects Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/3-light-effects-fact-sheet.pdf>
 ▶ Bioluminescence Fact Sheet (pdf): <https://oceanexplorer.noaa.gov/edu/materials/bioluminescence-fact-sheet.pdf>
- Page 10:** ▶ Bioluminescence - An Adaptation... (webpage): <https://oceanexplorer.noaa.gov/edu/themes/bioluminescence/lessons/bioluminescence-adaptations.html>
 ▶ Hercules, Illuminating The Dark (webpage): <https://nautiluslive.org/resource/hercules-illuminating-dark>
 ▶ Nautilus Career Connections (pdf): <https://nautiluslive.org/sites/default/files/documents/2020-04/Chemistry%20of%20Bioluminescence.pdf>
 ▶ Glow: Living Lights: <https://serc.carleton.edu/resources/18674.html>
 ▶ Bioluminescence from Ostracods (Sea Fireflies) (pdf): https://er.jsc.nasa.gov/seh/Ocean_Planet/activities/ts3enac1.pdf
 ▶ The Deep Sea (webpage): <https://neal.fun/deep-sea/>
 ▶ Creatures of Light (webpage): <https://www.pbslearningmedia.org/resource/nvcol-sci-biolumine/wgbh-nova-creatures-of-light-the-chemistry-of-bioluminescence/>
 ▶ Carolina Biological (webpage): <https://www.carolina.com>

Partners



Created in cooperation with the National Marine Sanctuary Foundation
 under federal award NA19OAR0110405 for the Deep Ocean Education Project.

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