Bioluminescence 2009:  
Living Light on the Deep Sea Floor Expedition

Now You See Me, Now You Don’t  
(adapted from the 2005 Operation Deep Scope Expedition)

Focus  
Light, color, and camouflage in deep ocean organisms

Grade Level  
5-6 (Life Science/Physical Science)

Focus Question  
How are light and color important to organisms in deep ocean environments?

Learning Objectives  
- Students will be able to explain light in terms of electromagnetic waves, and explain the relationship between color and wavelength.
- Students will be able to compare and contrast color related to wavelength with color perceived by biological vision systems.
- Students will be able to explain how color and light may be important to deep-sea organisms, even under conditions of near-total darkness.
- Students will be able to predict the perceived color of objects when illuminated by light of certain wavelengths.

Materials  
- Copies of clip-art images of a crab and/or squid (see Learning Procedure, Step 1) 
- Crayons, colored markers, or colored pencils 
- Flashlights; one for each student group 
- Red, green, and blue filters (colored cellophane), one for each student group 
- Colored paper; at least five different colors (see Learning Procedure, Step 2) 
- Scissors 
- (Optional) Red, green, blue, and white floodlights (from hardware store or home center)

Audio/Visual Materials  
- (Optional) Images showing light and color in deep-sea environments and organisms (see Learning Procedure, Step 1)
Teaching Time
One or two 45-minute class periods

Seating Arrangement
Groups of two to four students

Maximum Number of Students
30

Key Words
Light
Vision
Electromagnetic spectrum
Color
Wavelength
Camouflage
Additive mixing
Subtractive mixing

Background Information
[NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators usually will need to adapt the language and instructional approach to styles that are best suited to specific student groups.]

Deep ocean environments are almost completely dark; yet light is still important in these environments. Many marine species are able to produce “living light” through a process known as bioluminescence, but very little is known about specific ways that deep-sea organisms use this ability. Part of the problem is that these organisms are difficult to observe: turning on bright lights can cause mobile animals to move away, and may permanently blind light-sensitive sight organs. In addition, transparent and camouflaged organisms may be virtually invisible even with strong lights, and many types of bioluminescence can’t be seen under ordinary visible light. Overcoming these obstacles is a primary objective of the Bioluminescence 2009: Living Light on the Deep Sea Floor Expedition.

Like the 2004 and 2005 Ocean Exploration Deep Scope Expeditions (http://oceanexplorer.noaa.gov/explorations/04deepscope/welcome.html and http://oceanexplorer.noaa.gov/explorations/05deepscope/welcom.html), Bioluminescence 2009 will use advanced optical techniques to observe animals under extremely dim light that may reveal organisms and behaviors that have never been seen before. In addition, these techniques will allow scientists to study animals whose vision is based on processes that are very different from human vision.
These investigations are concerned with the basic properties of light in seawater, as well as different ways in which certain forms of light may be perceived by living organisms. “Light” is usually defined as the portion of the electromagnetic spectrum that is visible to the normal human eye, but since the Bioluminescence 2009 Expedition is concerned with eyes other than human ones, we need a broader definition. It is helpful to think of light as a series of waves that consist of energy in the form of electric and magnetic fields that together are known as electromagnetic radiation. Light waves can have many different wavelengths (the distance between any two corresponding points on successive waves, such as peak-to-peak or trough-to-trough), so “light” is a spectrum of wavelengths. The full range of wavelengths in the electromagnetic spectrum extends from gamma rays that have wavelengths on the order of one billionth of a meter, to radio waves whose wavelengths may be several hundred meters. The wavelength of light visible to humans ranges from 400 billionths of a meter (400 nanometers; violet light) to 700 billionths of a meter (700 nanometers; red light), but we know that some organisms are able to detect light wavelengths outside these limits.

The amount of energy in a light wave is related to its wavelength: shorter wavelengths have higher energy than longer wavelengths. In the portion of the electromagnetic spectrum visible to humans, violet has the most energy and red the least. In seawater, light waves with more energy travel farther than those with less energy. Warm colors such as red and orange are absorbed near the surface, so red objects appear black at depths greater than 10 meters. In clear ocean water, visible light decreases by about 90% with every 75 m increase in depth (so at 150 m depth, there is only 1% of the visible light present at the surface). Deep-sea environments below 1,000 m appear almost completely dark to humans; yet vision and “light” are still important to many of the organisms that live in these environments.

This lesson guides student inquiry into some of the properties of color and light, and how these properties might be important to deep sea organisms.

**Learning Procedure**

1. To prepare for this lesson:
   a. Read:
      - Introductory essays for the Bioluminescence 2009 Expedition (http://oceanexplorer.noaa.gov/explorations/09deepscope/welcome.html);
   b. Download or copy several images showing light and color in deep-sea environments and organisms from one or more of the
following Web sites:
http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html
http://www.pbs.org/wgbh/nova/abyss/life/bestiary.html
http://www.lifesci.ucsb.edu/~biolum/
c. Assemble materials for each student group listed under “Materials.” Copy images of a crab and a squid (Figures 1 and 2 (found on Pages 11 and 12) and make copies of one or both images for each student group.

2. Briefly discuss the mission plan and activities of the Bioluminescence 2009 Expedition. You may want to show images of various deep-sea environments and organisms.

Review the concept of the visible and near-visible light spectrum. Key points are that the “color” of light is related to the wavelength of light waves, and that the portion of the electromagnetic spectrum that is normally visible to humans is commonly divided into seven major colors (red, orange, yellow, green, indigo, and violet). When all of these colors are present, we see “white” light.

Review the concept of primary colors: colors that when mixed in various combinations can produce every color in the visible spectrum. Students should realize that our perception of the color of an object is the result of light reflected from the object to our eyes. For example, a red object viewed in white light appears red because the object is reflecting red light waves and absorbing the other colors (all of which are present in the white light). If there is no red light to be reflected, then the object appears black. You can demonstrate this in a darkened room using white and green floodlights.

Review the process of additive mixing, in which the additive primary colors (red, green, and/or blue) are combined to produce a specific color. You can illustrate this process on a white screen in a darkened room using red, green, and blue floodlights. When red light is projected onto the screen, the screen appears red because the light from the floodlight is reflected back to the observers’ eyes and we perceive it as red. When green light is added, the screen appears yellow because red and green light are reflected from the screen and we perceive the combination as yellow. If blue light is added (and the proportions of red, green, and blue are correct), we see the combination as white. One of the most familiar examples of additive mixing is color televisions that use red, green, and blue light sources to make pictures that we perceive to contain millions of different colors. Point out that perceived color depends upon the eye of the viewer. A person who lacks the ability to detect red
light or a species with eyes that detect ultraviolet light would not
see the same colors seen by a normal human eye.

Contrast additive mixing with subtractive mixing, in which
materials selectively absorb certain wavelengths of light. The
subtractive primary colors (magenta, yellow, and cyan) selectively
absorb green, blue, and red wavelengths respectively. When white
light passes through a magenta filter, the filter absorbs green
wavelengths and transmits red and blue wavelengths. If white
light passes through a magenta filter combined with a yellow
filter, the magenta filter absorbs green wavelengths and the yellow
filter absorbs blue wavelengths so that only red wavelengths are
transmitted. If magenta, yellow and cyan filters are combined, no
light is transmitted.

Subtractive mixing also is used by artists working with paint, but
the primary colors are red, yellow, and blue. Red paint absorbs blue
and yellow light; blue paint absorbs red and yellow light; yellow
paint absorbs red and blue light. If all three pigments are mixed
together, all visible wavelengths are absorbed and the pigment
appears black.

Be sure students understand the distinction between the “color”
of a specific wavelength of light (an objective property) and the
“color” that we perceive (a subjective property). Another way to
illustrate this distinction is by cutting four identical squares (about
10 cm x 10 cm) from a single sheet of colored paper. Then select
sheets of four different colors, and cut a larger square (about 20
cm x 20 cm) from each sheet. Place one of the smaller squares
on each of the larger squares. The perceived color of the smaller
squares will be different, even though the “wavelength color” of
the smaller squares is identical.

3. Ask students to describe characteristics of deep-sea environments
(depth = 1,000 meters or more). Focus the discussion on light in
the deep ocean. Briefly discuss the mission plan and activities of
the 2004 and 2005 Deep Scope Expeditions. Show images of various
deep-sea environments and bioluminescent organisms, and ask
students how color might be important under conditions of almost
total darkness. Students should infer that other organisms may be
able to detect low light levels and wavelengths that are beyond the
perception of humans. In this case, color could be an important
part of defensive strategies used to escape from predators.

4. Give each student group a copy of the “Light, Color, and
Camouflage Inquiry Guide,” a flashlight, a red, green, or blue filter,
and colored drawing materials. You may need to set up a darkened
corner of your classroom, or a large cardboard carton to provide
a darkened space for testing design ideas. Review the procedure
described on the Guide, encourage students to test their ideas
before creating their final designs, then turn them loose to create!

5. Have each group present their design, and explain how it works.
In general, these explanations should include which colors are
being absorbed and reflected under filtered and white light. Be sure
students understand that the filtered flashlights can be thought
of as representing vision systems that can only detect light of
certain wavelengths. In fact, scientists are just beginning to study
the visual physiology of deep-sea organisms, so many things are
possible! You may want to have students visit the Bioluminescence
2009 expedition Web site to find out more about how these studies
are done and what new discoveries have been made about light
and vision in the deep ocean.

The BRIDGE Connection
http://www.vims.edu/bridge/archive0305.htm – Activity on vision
in pelagic fishes

The “Me” Connection
Have students write a short essay describing how the limits of human
vision might allow undetected organisms to exist in their home or
school, and how they would organize a search for these organisms.

Connections to Other Subjects
English/Language Arts

Assessment
Students’ answers to Inquiry Guide questions and class discussions
provide opportunities for assessment.

Extensions
1. Have students visit http://oceanexplorer.noaa.gov/
explorations/09deepscope/welcome.html to keep up to date with
the latest discoveries by the Bioluminescence 2009 Expedition.
2. Visit http://www.exploratorium.edu/snacks/snacksbysubject.html
ucsb.edu/~biolum/organism/dinohome.html, and http://www.
fotodyne.com/content/molelabs_biolum for activities involving
light, color, and bioluminescence. [NOTE: Mention of trademarks or
proprietary names does not imply endorsement by NOAA.]
for “Light at the Bottom of the Deep, Dark Ocean,” a lesson on
feeding adaptations of some deepwater organisms; Lesson Plan 14
in the Learning Ocean Science through Ocean Exploration Curriculum
Multimedia Discovery Missions
http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the link to Lesson 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA’s Ocean Exploration and Research Program

Cool Lights
(7 pages, 220Kb) (from the 2004 Deep Scope Expedition)
http://oceanexplorer.noaa.gov/explorations/04deepscope/background/edu/media/CoolLights.pdf

Focus: Light-producing processes and organisms in deep-sea environments

In this activity, students compare and contrast chemiluminescence, bioluminescence, fluorescence, and phosphorescence. Given observations on materials that emit light under certain conditions, students infer whether the light-producing process is chemiluminescence, fluorescence, or phosphorescence. Students explain three ways in which the ability to produce light may be useful to deep-sea organisms and explain how scientists may be able to use light-producing processes in deep-sea organisms to make new observations of these organisms.

Other Resources
The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page’s publication, but the linking sites may become outdated or non-operational over time.


http://polarization.com/index-net/index.html – Web site with extensive information on polarized light and how polarization vision is used by various animals.

http://www.lifesci.ucsb.edu/~biolum/ —The Bioluminescence Web Page

http://www.pbs.org/wgbh/nova/abyss/ – NOVA Online “Into the Abyss” Web page

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – Ocean Explorer photograph gallery
National Science Education Standards

Content Standard A: Science As Inquiry
• Abilities necessary to do scientific inquiry
• Understandings about scientific inquiry

Content Standard B: Physical Science
• Properties and changes of properties in matter

Content Standard C: Life Science
• Structure and function in living systems
• Diversity and adaptations of organisms

Content Standard E: Science and Technology
• Abilities of technological design

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.

Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation’s explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.
Send Us Your Feedback
We value your feedback on this lesson, including how you are using it in your formal/informal education setting.
Please send your comments to:
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Now You See Me, Now You Don’t
Light, Color and Camouflage Inquiry Guide

Materials:
You should have
☐ a drawing of a crab or squid (or both)
☐ a flashlight
☐ a red, green, or blue filter
☐ crayons, markers, or colored pencils

1) Your Task:
Create a background and camouflage design for the crab and/or squid that will make the animal blend into the background when illuminated by the filtered flashlight, but easy to see under white light.

2) Brainstorm:
Discuss your ideas for designs that will accomplish your task.

3) Prototype (a test model that may be the basis for future designs):
Try your design ideas on scrap paper with the filtered flashlight before you start coloring your drawings.

4) Create:
Color one or both drawings using your design ideas that work best for accomplishing your task.

5) Explain:
Why does your design work? Be prepared to explain this to the class.

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Now You See Me, Now You Don’t
Light, Color and Camouflage Inquiry Guide - continued

Figure 1: Crab
Now You See Me, Now You Don’t
Light, Color and Camouflage Inquiry Guide - continued

Figure 2: Squid