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2005 Operation Deep Scope Expedition

Now You See Me, Now You Don't

Focus
Light, color, and camouflage in deep ocean environments

Grade Level
5-6 (Life 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 or fish (see Learning Procedure, Step 1)
- ❒ Crayons or colored markers
- ❒ 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
In the deep ocean, even the simplest tasks can become surprisingly complex. One of the primary objectives of ocean exploration is to observe

living organisms in deep-sea environments. The near-total darkness of these environments poses an obvious obstacle to such observations, but it would seem relatively easy to overcome this obstacle with artificial lights. Turning on the bright lights carried on deep-diving submersibles, however, creates other problems: mobile organisms often move away from the light; organisms with light-sensitive organs may be permanently blinded by intense illumination; even sedentary organisms may shrink away and possibly become less noticeable. Even with strong lights, transparent and camouflaged organisms may be virtually invisible, and small cryptic creatures may simply be unnoticed. In addition, some aspects of deep-sea biology such as production of light by living organisms (bioluminescence) can't be studied under ordinary visible light (for more information and lesson plans about bioluminescence, visit http://oceanexplorer.noaa.gov/explorations/04deepscope/background/edu/edu.html.

The 2005 Ocean Exploration Deep Scope Expedition is dedicated to the concept of "seeing with new eyes." Using advanced optical techniques, scientists will be able to observe deep-sea animals under extremely dim light, as well as under different types of illumination that may reveal organisms 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. Since the Deep Scope Expedition is concerned with other eyes in addition to human ones, 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. These 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 they form 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 (violet light) to 700 billionths of a meter (red light).

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 fairly 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 visibile light present at the surface). Deep-sea environments below 1000 m appear almost completely dark to humans; yet vision and "light" are still important to many of the organisms that live in these environments.

In this lesson, students will explore some of the properties of color and light, and make inferences about how these properties might be important to deep-sea organisms.

Learning Procedure

1. To prepare for this lesson, read the introductory essays for the 2005 Deep Scope Expedition at http://oceanexplorer.noaa.gov/explorations.05deepscope/welcome.html, and review some of the images and video clips from http://oceanexplorer.noaa.gov/explorations/04deepscope/logs/photolog/photolog.html.

Download or copy several images showing light and color in deep-sea environments and organisms from these sites and/or one or more of the following Web sites:

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html
http://www.europa.com/edge.of.CyberSpace/deep.html
http://www.europa.com/edge.of.CyberSpace/deep2.html
http://www.pbs.org/wgbh/nova.abyss/life.bestiary.html
http://www.lifesci.ucsb.edu/~biolum/

Download and print a clip art image of a crab or fish (e.g, from http://school.discovery.com/clipart/), adjusting the image size so it occupies an area roughly 12 cm x 12 cm on a printed page. Make one copy for each student group.

2. Review the concept of the visible and near-visible light spectrum. Students should understand 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. Students should understand that in additive mixing red, green, and/or blue light (the additive primary colors) are added together 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.

   Contrast additive mixing with subtractive mixing, in which materials selectively absorb certain wavelenths 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.

   Give each student group a copy of the clip-art crab or fish image, a flashlight and a red, green, or blue filter. Tell students that their assignment is to create a background and camouflage design for their animal that will make the animal blend into the background when illuminated by the filtered flashlight, but easy to see under white light. You may want to have students brainstorm their design first, do a few tests with the filtered flashlight, then submit their idea for approval before actually coloring the page.

4. 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 Deep Scope 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.html

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, Physical Science

Evaluation

Student camouflage assignments and class discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations.05deepscope/welcome.html to keep up to date with the latest discoveries by the 2005 Deep Scope Expedition.

2. Visit http://www.woodrow.org/teachers/esi/1999/princeton/projects/uv/classroom.html, http://siobiolum.ucsd.edu/Biolum_demos.html, http://www.lifesci.ucsb.edu/~biolum/organism/dinohome.html, and http://www.fotodyne.com/education/safelumi.php for activities involving fluorescence and bioluminescence.

Resources

http://oceanexplorer.noaa.gov/explorations.05deepscope/welcome.html – The 2005 Deep Scope Expedition Web site.

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

http://www.nightsea.com/ – Web site offering products for studying fluorescence underwater

http://www.biolum.org/ – Harbor Branch Oceanographic Institution Web site on bioluminescence

http://ice.chem.wisc.edu/materials/light/lightandcolor7.html – Web site with links to other activities involving fluorescence and phosphorescence

http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html – NOAA Ocean Explorer photo gallery

http://oceanica.cofc.edu/activities.htm – Project Oceanica Web site, with a variety of resources on ocean exploration topics

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
- Transfer of energy

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

Content Standard F: Science in Personal and Social Perspectives
- Populations, resources, and environments

For More Information

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Acknowledgements

This lesson plan was produced by Mel Goodwin, PhD, The Harmony Project, Charleston, SC for the National Oceanic and Atmospheric Administration. If reproducing this lesson, please cite NOAA as the source, and provide the following URL:
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