www.oceanexplorer.noaa.gov

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)

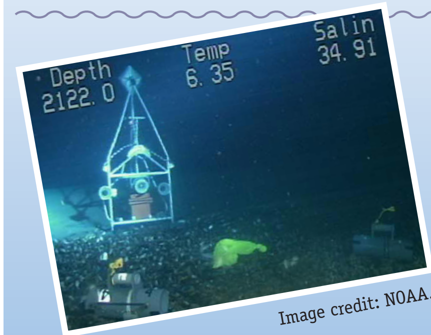
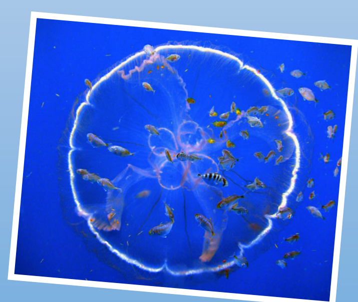


Image credit: NOAA.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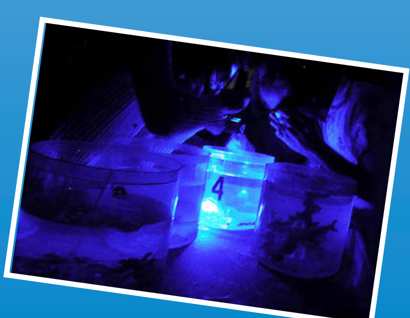


Image credit: NOAA.

Image captions on Page 2.

lesson plan

Focus
Light, color, and camouflage in deep ocean organisms

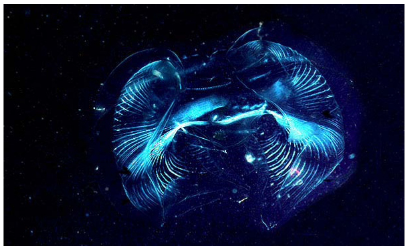
Grade Level
5-6 (Life Science/Physical Science)

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

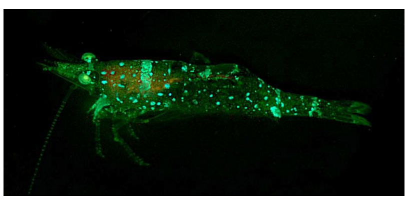
Learning Objectives
- Students will be able to explain light in terms of electromagnetic waves, and explain the relationship between color and wavelength.
- Students will be able to compare and contrast color related to wavelength with color perceived by biological vision systems.
- Students will be 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)



The lobate ctenophore *Ocyropsis maculata* as viewed under unpolarized light (top) and polarized light (bottom). Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/05deepscope/logs/aug27/media/ocyropsis_unpolarized_600.jpg
http://oceanexplorer.noaa.gov/explorations/05deepscope/logs/aug27/media/ocyropsis_polarized_600.jpg



Unidentified *Sargassum* shrimp bearing two colors of fluorescent patches. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/05deepscope/logs/aug22/media/fluorescent_shrimp_600.jpg

Images from Page 1 top to bottom:
The Eye-In-The-Sea camera system deployed on the edge of a brine pool, over 2,100 ft deep in the Gulf of Mexico. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04deepscope/logs/aug8/media/eye_600.jpg

A flotilla of fish follow a transparent drifting jellyfish, *Aurelia aurita*. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/05deepscope/logs/sep3/media/aurelia3_rs_600.jpg

The pontellid copepod *Pontella securifer*. Various parts glow fluorescent green when viewed under blue light. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/05deepscope/logs/aug26/media/horned_copepod_mf_600.jpg

Deep Scope 2005 science crew examines recently collected specimens. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/05deepscope/logs/sep4/media/examining_specimens_600.jpg

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of two to four students

Maximum Number of Students

30

Key Words

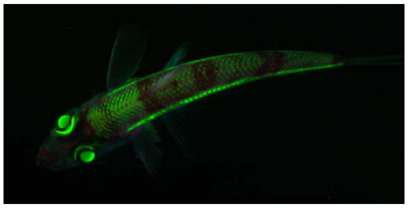
Light
Vision
Electromagnetic spectrum
Color
Wavelength
Camouflage
Additive mixing
Subtractive mixing

Background Information

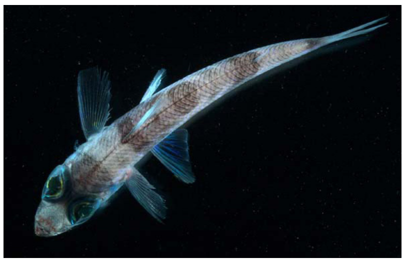
[NOTE: *Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators usually will need to adapt the language and instructional approach to styles that are best suited to specific student groups.*]

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/welcome.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.



The shortnose greeneye fish gets its name from fluorescent eyes. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04deepscope/logs/aug16/media/greeneye_fluor_600.jpg



Under white light, the greeneye fish looks very different, but its green lenses are still apparent. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04deepscope/logs/aug16/media/greeneye_600.jpg

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. (for a graphic image of the electromagnetic spectrum, see http://chemed.chem.purdue.edu/genchem/topicreview/bp/ch6/graphics/spectrum.gif).

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.html – 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 http://siobiolum.ucsd.edu/Biolum_demos.html, http://www.lifesci.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.*]
3. Visit http://oceanexplorer.noaa.gov/edu/curriculum/section5.pdf 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://oceanexplorer.noaa.gov/explorations.09deepscope/welcome.html – The Bioluminescence 2009 Expedition Web site.

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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For More Information

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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.

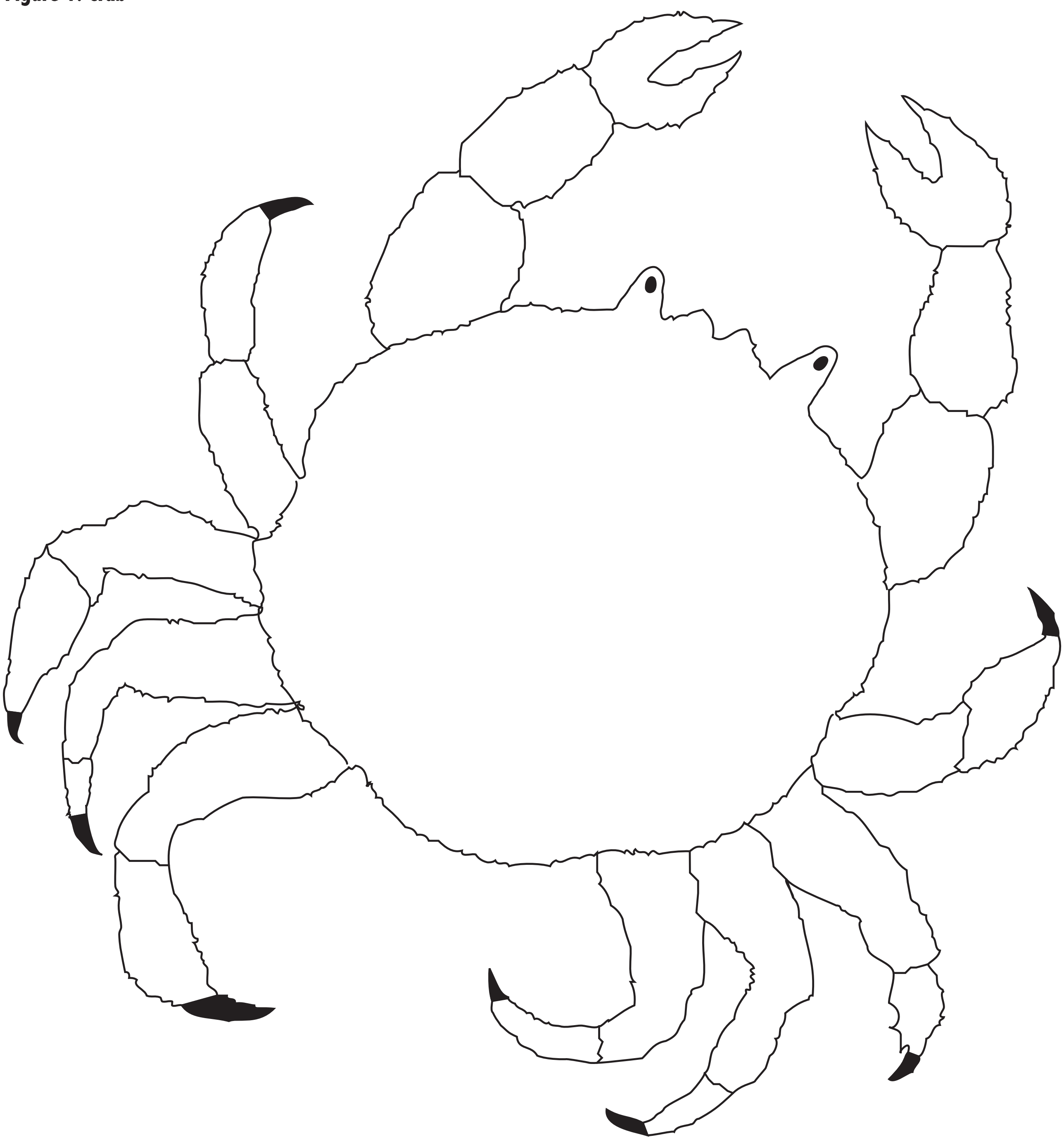
5) Explain:

Why does your design work? Be prepared to explain this to the class.

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