www.oceanexplorer.noaa.gov

Bioluminescence 2009:
Living Light on the Deep Sea Floor Expedition

A Bioluminescent Gallery

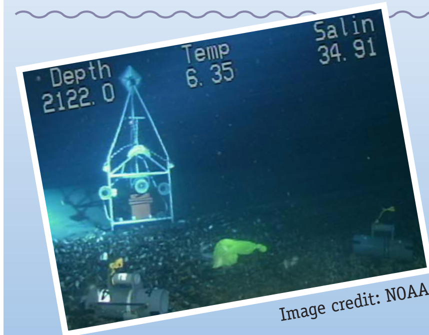


Image credit: NOAA.

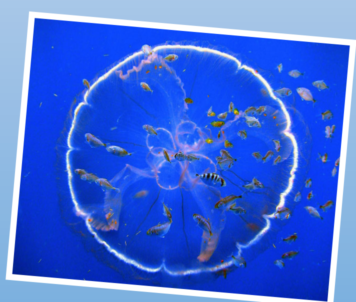


Image credit: NOAA.


Image credit: NOAA.

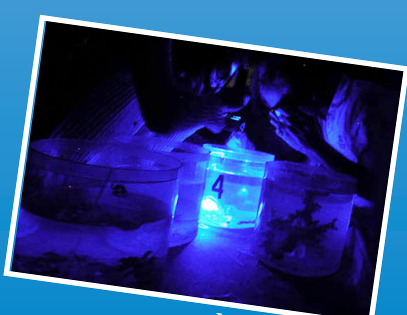


Image credit: NOAA.

Image captions on Page 2.

lesson plan

Focus
Bioluminescence 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 compare and contrast chemiluminescence, bioluminescence, fluorescence, and phosphorescence.

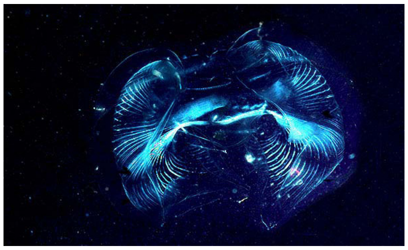
- Students will be able to explain at least three ways in which the ability to produce light may be useful to deep-sea organisms.

Materials
- Copies of "Bioluminescence in Deep Sea Organisms Inquiry Guide," one copy for each student group
- Copies of outline images of marine organisms that exhibit bioluminescence found at the end of this lesson plan
- Crayons, colored markers, or colored pencils
- Glow-in-the-dark crayons or markers, or fluorescent crayons or markers if you plan to use ultraviolet illuminators (see Learning Procedure, Step 1d)
- (Optional) Materials for ultraviolet illuminator (see Learning Procedure, Step 1d)

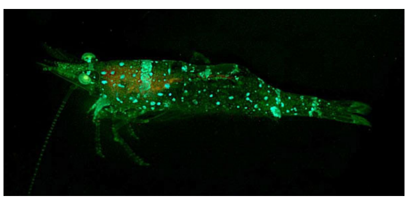
Audio/Visual Materials
- Images showing bioluminescence in deep-sea organisms (see Learning Procedure, Step 1)

Teaching Time
One or two 45-minute class periods; additional time will be needed to construct optional ultraviolet illuminators

Seating Arrangement
Groups of two to four students



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

Maximum Number of Students

30

Key Words

Light
Chemiluminescence
Bioluminescence
Fluorescence
Phosphorescence
Camouflage
Counter-illumination

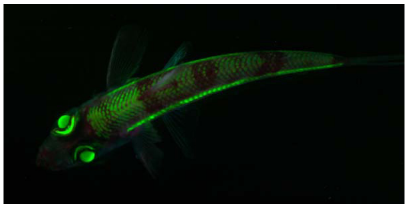
Background Information

[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.*]

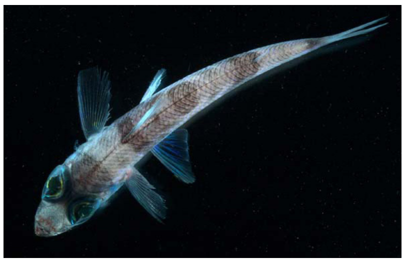
Deep ocean environments are almost completely dark; yet light is still important in these environments. Many marine species are able to produce "living light" through a process known as bioluminescence, but very little is known about specific ways that deep-sea organisms use this ability. Part of the 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.

Bioluminescence is a form of chemiluminescence, which is the production of visible light by a chemical reaction. When this kind of reaction occurs in living organisms, the process is called bioluminescence. It is familiar to most of us as the process that causes fireflies to glow. Some of us may also have seen "foxfire," which is caused by bioluminescence in fungi growing on wood.



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

Bioluminescence is relatively rare in terrestrial ecosystems, but is much more common in the marine environment. Marine organisms producing bioluminescence include bacteria, algae, cnidaria, annelids, crustaceans, and fishes.

The fundamental chemiluminescent reaction occurs when an electron in a chemical molecule receives sufficient energy from an external source to drive the electron into a higher-energy orbital. This is typically an unstable condition, and when the electron returns to the original lower-energy state, energy is emitted from the molecule as a photon. Lightning is an example of gas-phase chemiluminescence: an electrical discharge in the atmosphere drives electrons in gas molecules (such as N_2 and O_2) to higher-energy orbitals. When the electrons return to their original lower-energy orbitals, energy is released in the form of visible light.

Chemiluminescence is distinctly different from fluorescence and phosphorescence, which occur when electrons in a molecule are driven to a higher-energy orbital by the absorption of light energy. Both processes may occur in living organisms. Atoms of a fluorescent material typically emit the absorbed radiation only as long as the atoms are being irradiated (as in a fluorescent lamp). Phosphorescent materials, on the other hand, continue to emit light for a much longer time after the incident radiation is removed (glowing hands on watches and clocks are familiar examples). Chemiluminescent reactions are different because they produce light without any prior absorption of radiant energy (since the energy for chemiluminescence comes from chemical reactions). Another light-producing process known as triboluminescence occurs in certain crystals when mechanical stress applied to the crystal provides energy that raises electrons to a higher-energy orbital.

The production of light in bioluminescent organisms results from the conversion of chemical energy to light energy. The energy for bioluminescent reactions is typically provided by an exothermic chemical reaction.

Bioluminescence typically requires at least three components: a light-emitting organic molecule known as a luciferin; a source of oxygen (may be O_2, but could also be hydrogen peroxide or a similar compound); and a protein catalyst known as a luciferase. In some organisms, these three components are bound together in a complex called a photoprotein. Light production may be triggered by the presence of ions (often calcium) or other chemicals. Some bioluminescent systems also contain a fluorescent protein that absorbs the light energy produced by the photoprotein, and re-emits this energy as light at a longer wavelength. Several different luciferins have been found in marine organisms, suggesting that bioluminescence may have evolved many times in the sea among different taxonomic groups. Despite these differences, most marine bioluminescence is green to blue in color. These colors travel farther through seawater than warmer colors. In fact, most marine organisms are sensitive only to blue light.

This lesson guides student inquiry into bioluminescence in a variety of marine organisms, and how the ability to produce light may benefit these 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. Assemble materials for each student group listed under "Materials." Copy outline drawings of organisms that exhibit bioluminescence, making a copy of at least one drawing for each student group. Copy "Bioluminescence in Deep-sea Organisms Inquiry Guide," one copy for each student group. If you want to include other organisms, see "Extensions" for a partial list of groups that include bioluminescent organisms.
   c. Download or copy 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/
   d. (Optional) You may want to construct (or have your students construct) ultraviolet illuminators as directed in the "Construction Guide." Using these illuminators, or another source of ultraviolet light, students can use their colored drawings to create a dramatic display of bioluminescent organisms in a darkened room. Materials for one illuminator cost $5 – $10. **If you use ultraviolet light sources, be sure to caution students NEVER to look directly at the source.**

2. Ask students to describe characteristics of deep-sea environments (depth = 1,000 meters or more). Focus the discussion on light in the deep ocean. You may want to show images of various deep sea environments and organisms. Ask students how color might be important under conditions of almost total darkness. Students should infer that deep-sea organisms may be able to detect low light levels and wavelengths that are beyond the perception of humans.

Ask whether plants and animals are ever able to produce their own light. Most students will be familiar with fireflies, and may mention bioluminescence in other species. Review the basic concept of chemiluminescence, and contrast this process with fluorescence and phosphorescence. Students should understand that every light-producing process requires a source of energy (chemical, electrical, mechanical, or light). Tell students that bioluminescence is a form of chemiluminescence that occurs in living organisms, but do not explain the details of bioluminescence at this point. Briefly discuss the mission plan and activities of the Bioluminescence 2009 Expedition.

3. Tell students that their assignment is to investigate bioluminescence in deep-sea organisms. Give each student group a copy of the "Bioluminescence in Deep-Sea Organisms Inquiry Guide" and other materials assembled in Step 1b. Have them complete their Inquiry Guides and color their organisms.

4. Have each group present and discuss their colored drawing of a bioluminescent organism. Discuss results from students' Web inquiries. Key points include:

(1) Distinctions between chemiluminescence, bioluminescence, fluorescence, and phosphorescence are described in "Background Information." Depending upon their familiarity with basic atomic theory, students may not fully understand explanations involving electron orbitals. For purposes of this inquiry, it is sufficient that they understand that:

- All four processes involve molecules that receive energy from an external source, and that some of this energy is emitted from the molecules as light;
- Chemiluminescence is light produced by a combination of chemicals;
- Bioluminescence is a form of chemiluminescence that takes place in living organisms;
- Fluorescence and phosphorescence take place when molecules absorb light energy, then emit some of this energy as light of another color;
- Fluorescent materials typically emit light only as long as the molecules continue to receive external energy; and
- Phosphorescent materials continue to emit light for a period of time after the external energy is removed.

(2) Bioluminescence typically requires a light-emitting organic molecule known as a luciferin, a source of oxygen, and a protein catalyst (enzyme) known as a luciferase. The luciferin receives energy from a chemical reaction catalyzed by the luciferase and

using oxygen, then releases the energy in the form of light. A few animals, like the anglerfish, grow bioluminescent bacteria in their light organs. In this mutualistic symbiotic relationship, the fish supplies bacteria with food and the bacteria provide the fish with light needed to attract prey.

(3) Bioluminescence comes in all colors—red, orange, yellow, green, blue and violet, but most marine bioluminescence is blue or blue-green. Light at the blue end of the spectrum has higher energy than light at the red end of the spectrum. Consequently, blue light penetrates farther through seawater than light having longer wavelengths (toward the red end of the spectrum). Most marine organisms only seem to be able to detect blue light.

(4) One bioluminescent bacterium produces about 1,000 to 10,000 (10^3 to 10^4) photons per second, while a single bioluminescent dinoflagellate will emit 10^{10} to 10^{11} photons per second. A 100 W light bulb emits about 10^{18} photons per second. So you would need 10^7 to 10^8 (ten million to one hundred million) dinoflagellates all flashing at once to equal the light output of a single 100 watt bulb. Of course, the light bulb stays lit continuously, while the output of the dinoflagellates is intermittent.

(5) We almost certainly don't know all of the ways that bioluminescence is used by deep-sea organisms. In general, bioluminescence most often is thought to be used for communication, feeding, and/or defense.

Some organisms seem to use bioluminescence to locate other members of the same species, and we infer that this would be useful for mating. Others (such as the anglerfish) use bioluminescence to attract prey species. Fishes in the malacosteid family have a "floodlight" system that allows them to see nearby organisms. These fishes have organs that produce red light and eyes that can detect red light (both unusual features in marine animals). Since most other species (as far as we know) cannot see red light, the malacosteids can sneak up on their prey without being detected.

Bioluminescence may also be useful as camouflage. It may not be immediately obvious how emitting light could make an organism less visible, yet this is the strategy involved in counter-illumination. You can illustrate this by holding a white index card against a window in a darkened room. The card will block out light coming through the window and be visible as a darker object against the bright background. If you shine a flashlight on the card, the illumination on the "dark" side of the card will be closer to that of the background, making the card less visible. Counter-illumination could thus be a useful strategy to a swimming organism trying to be less visible to a potential predator swimming below; and is a probable explanation for how ventral photophores are useful to squid.

Some animals use bioluminescence for defense in a different way. Some tube-dwelling worms spew out clouds of glowing blue material when they are threatened. Certain jellyfish emits bright flashes of light when they are disturbed. The strategy is believed to be similar to the fear scream of monkeys or birds, which are intended to attract the attention of other predators that may attack a threatening organism. So light produced by the worm or jellyfish exposes a threatening invader and makes the invader vulnerable to attack by a higher order predator.

5. (Optional) LED ultraviolet illuminators provide an opportunity for students to apply basic concepts of electricity and electrical circuits to create an interesting device that can be used in a variety of other investigations. If students use fluorescent crayons or markers to color the bioluminescent portions of their drawings, the illuminators can be used in a darkened room to show how these animals might appear in the deep ocean. Instructions and sources of materials are provided on the "LED Ultraviolet Illuminator Construction Guide." Be sure to caution students to NEVER look directly at any source of ultraviolet light.

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 about how bioluminescence affects (or might affect) their own lives.

Connections to Other Subjects

English/Language Arts, Earth Science

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. If you want to include other organisms in student inquiries, here is a partial list of groups that include bioluminescent species:
   Bacteria
   Dinoflagellates
   Cnidaria
   Ctenophores (Comb Jellies)
   Mollusca
      Squid
   Annelid worms
      Polychaetes
   Crustaceans
      Ostracods
      Amphipods
      Decapod shrimp
      Euphausiids (krill)
   Echinoderms
   Urochordates
   Chordates
      Sharks
      Fish
      Anglerfish
      Black Dragonfish
      Loosejaws (malacosteids)

3. For other activities involving light, color, and bioluminescence, visit:
   http://www.exploratorium.edu/snacks/iconlight.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.
   [*NOTE: Mention of trademarks or proprietary names does not imply endorsement by NOAA.*]

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 obtain new observations of these organisms.

Light at the Bottom of the Deep, Dark Ocean???
http://oceanexplorer.noaa.gov/explorations/02sab/background/edu/media/sab_light.pdf
(8 pages, 476k) (from the 2002 Islands in the Stream Expedition)

Focus: Biology - Adaptations of deepwater organisms

In this activity, students will participate in an inquiry activity; relate the structure of an appendage to its function; and describe how a deepwater organism responds to its environment without bright light.

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

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

http://www.bioscience-explained.org/ENvol1_1/pdf/BiolumEN.pdf – Marine Bioluminescence by Edith A. Widder; Bioscience Explained; Vol. 1:1.

http://www.mbari.org/itd/retrospective/bioluminescence.pdf – “Deep-Sea Bioluminescence” Monterey Bay Aquarium Research Institute 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:
oceanexeducation@noaa.gov

For More Information

Paula Keener-Chavis, Director, Education Programs
NOAA Ocean Exploration and Research Program
Hollings Marine Laboratory
331 Fort Johnson Road, Charleston SC 29412
843.762.8818
843.762.8737 (fax)
paula.keener-chavis@noaa.gov

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: http://oceanexplorer.noaa.gov

A Bioluminescent Gallery

Bioluminescence in Deep-sea Organisms Inquiry Guide

Materials: You should have

- One or more outline images of marine organisms that exhibit bioluminescence
- Crayons, colored markers, or colored pencils
- Glow-in-the-dark crayons or markers, or fluorescent crayons or markers if your teacher plans to use ultraviolet illuminators

A. Web Inquiry

1. Compare and contrast: chemiluminescence, bioluminescence, fluorescence, phosphorescence

2. What is the basic chemistry of bioluminescence?

3. What color is bioluminescence?

4. How does the light output from bioluminescence compare to a 100-watt light bulb?

5. How does your organism use bioluminescence?

A Bioluminescent Gallery

Bioluminescence in Deep-sea Organisms Inquiry Guide - continued

B. Illustrate

When scientists bring animals from the deep sea to the surface, they appear very different than when they are in their natural habitat where it is almost totally dark. To get a better idea about their appearance in the deep ocean, use glow-in-the-dark or fluorescent coloring materials (your teacher will tell you which ones to use) to color the dotted areas on your outline drawing. Use regular coloring materials to fill in the white areas. Search for images of your organism on the Web to find out which colors to use for the white areas.

When your drawings are dry (if you used paints), you can see what bioluminescence looks like. If you used glow-in-the-dark paints, expose your drawing to a bright light for a minute or so, then take it into a darkened room (or put it into a large cardboard carton with small viewing holes). If you used fluorescent paints or markers, shine an ultraviolet light on your drawing in the darkened room (or carton).

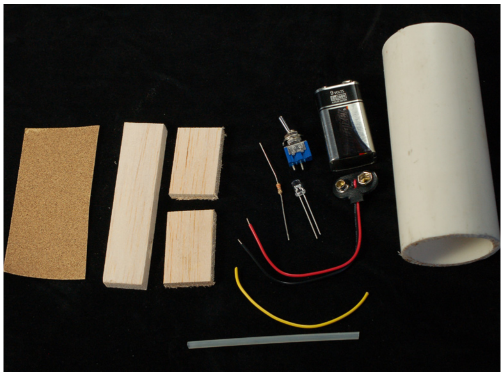
Be prepared to share your organism with the class and discuss its uses of luminescence for survival.

C. Infer

Many squids have their lower (ventral) surfaces covered with small light-emitting photophores which put out a soft glow when the squid turns them on. These squids also move up and down in the water column each day (vertical migration). They stay down deep during the daylight, but come up to the surface at night under cover of darkness. How are photophores on the ventral surface, or underside, useful to the squid?

A Bioluminescent Gallery

LED Ultraviolet Illuminator Construction Guide



Materials

- 1 Piece balsa or bass wood, 3-1/2" x 1" x 3/8" thick
- 2 Pieces balsa or bass wood, 1-5/8" x 1" x 1/4" thick
- 1 Toggle switch, SPST (Radio Shack Part Number 275-0612, or equivalent)
- 1 Resistor, 330 ohms, 1/4 watt (Radio Shack Part Number 271-1315, or equivalent)
- 1 9-volt battery
- 1 9-volt battery snap connector (Radio Shack Part Number 270-325, or equivalent)
- 1 Ultraviolet light emitting diode (Mouser Electronics Part Number 593-VAOL5GUV8T4, or equivalent)
- 3" Length, 22 gauge insulated hookup wire
- 3" Length, heat shrink tubing, 1/8" inside diameter
- 5-1/4" Length, 1-1/2" inside diameter PVC pipe
- Small piece of medium (100 grit) sandpaper

[*NOTE: Mention of trademarks or proprietary names does not imply endorsement by NOAA.*]

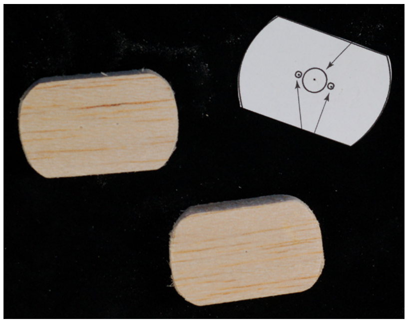
Tools

- Longnose pliers
- Wire cutters
- (Optional) Wire stripper
- Craft saw or coping saw
- Hand or electric drill
- 1/16" and 1/4" drill bits
- Hot glue gun
- Hair dryer or heat gun
- Soldering iron and rosin-core solder (do not use acid core solder in electronic circuits!)
- Safety glasses or goggles

A note about soldering: If you have never soldered before, you may want to visit http://www.instructables.com/id/How-to-solder/. Be sure to wear safety glasses or goggles when soldering, and work in a well-ventilated space (you can set up a small fan if necessary to blow away soldering fumes).

A Bioluminescent Gallery

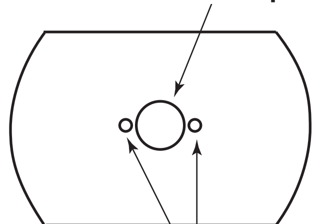
LED Ultraviolet Illuminator Construction Guide - continued

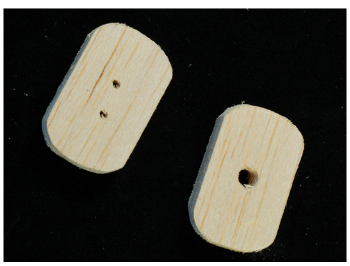
1


Construction Procedure

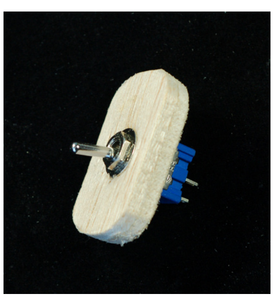
1. Use a craft saw or coping saw to cut the two short pieces of wood according to Pattern 1. These pieces should fit snugly inside the PVC pipe. Adjust the fit with sandpaper if necessary.

Pattern 1:



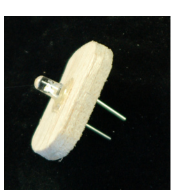
2


2. Drill two 1/16" diameter holes in one of the short wood pieces in the locations indicated on Pattern 1. Drill one 1/4" hole in the other short wood piece as indicated on the pattern.

3


3. Mount the toggle switch on the short piece of wood with the 1/4" hole. The switch comes with two hex nuts, a flat washer, and a lockwasher. Remove all of the hardware and insert the threaded portion of the switch through the hole. You may have to press the body of the switch slightly into the balsa wood to expose enough thread to start one of the hex nuts. Tighten the nut two or three turns, then remove the nut, install the flat washer, and re-install the nut. Tighten several turns until the switch is securely mounted. NOTE: The photograph shows the switch in the "Off" position. Be sure your switch stays in this position until all steps are completed. This is a good time to write "Off" on the wood near the switch handle.

4a


4b


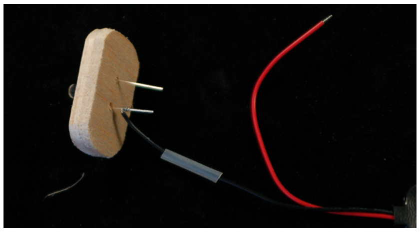
4. Bend the wire leads of the LED as shown so that the leads will fit through the 1/16" holes in the other short piece of wood. Put a small dab of hot glue on the wood between the holes, and hold the LED in place until the glue sets.

A Bioluminescent Gallery

LED Ultraviolet Illuminator Construction Guide - continued

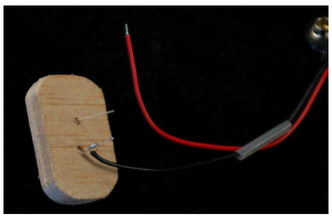
5a

5b

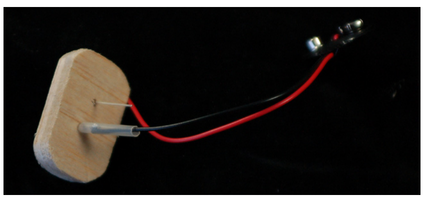


5. Notice that the base of the LED is flattened on one side. The lead that is closest to the flattened site is the cathode of the LED which connects to the negative side of the battery. Remove about 1/2" of insulation from the black lead of the 9-volt battery snap connector. Twist the strands together, then put a 3/4" piece of heat shrink tubing over the black lead. Now, wrap the bare wire around the cathode lead from the LED about 1/4" from where it emerges from the piece of wood (a pair of longnose pliers can be helpful for this step).

6a

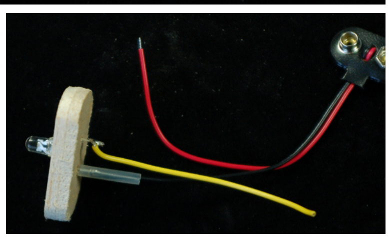


6b



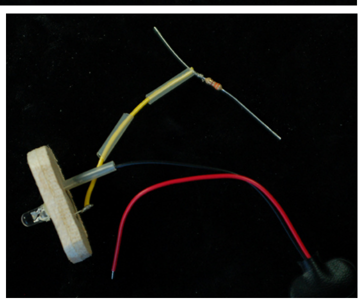
6. Solder the connection by holding the heated soldering iron against the twisted wires, then touching the solder to the opposite side of the connection (don't touch the solder to the soldering iron, because the wires being soldered must be hot enough to melt the solder; otherwise the joint will be weak). Trim the excess lead coming from the LED and slide the heat shrink tubing over the joint.

7

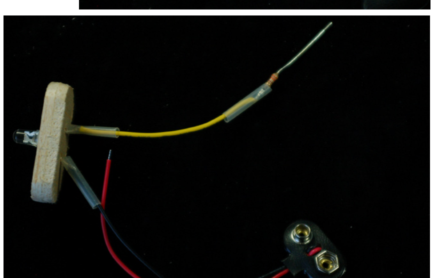


7. Remove about 1/2" of insulation from one end of the piece of hookup wire. Twist the strands together, then wrap the bare wire around the other lead from the LED and solder the connection. Trim the excess lead coming from the LED.

8a



8b

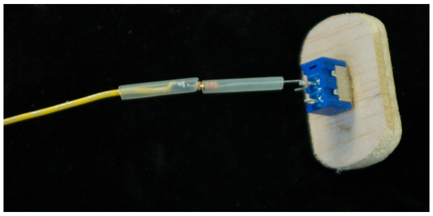


8. Remove about 1/2" of insulation from the other end of the hookup wire and twist the strands together. Put two 3/4" pieces of heat shrink tubing over the wire, then wrap the bare wire around one lead of the resistor about 1/4" from where it emerges from the resistor body. Solder the connection. Trim the excess lead coming from the resistor. Slide the heat shrink tubing over the joint with the LED and the joint with the resistor.

A Bioluminescent Gallery

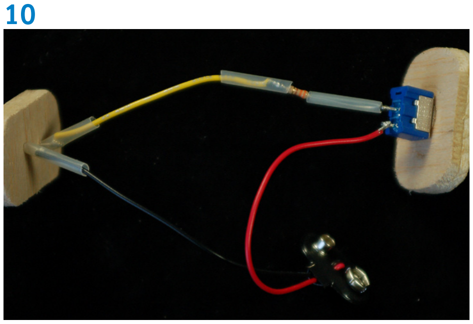
LED Ultraviolet Illuminator Construction Guide - continued

9



9. Put a 3/4" piece of heatshrink tubing over the other lead of the resistor. Bend the end of the lead into a U-shaped hook, and slide the hook through one terminal of the toggle switch. Crimp the hook tightly onto the switch terminal, then solder the connection.

10



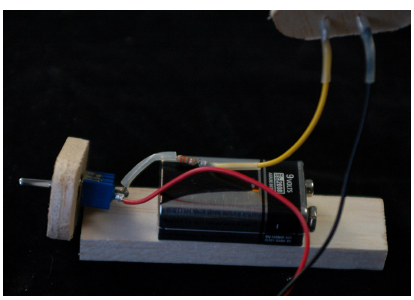
10. Remove about 1/4" of insulation from the red lead of the 9-volt battery snap connector, and twist the strands together. Bend the end of the lead into a U-shaped hook, and slide the hook through the other terminal of the toggle switch. Crimp the hook tightly onto the switch terminal, then solder the connection.

11. Heat all pieces of heat shrink tubing with the hair dryer or heat gun so that they shrink around the wires and connections they are covering.

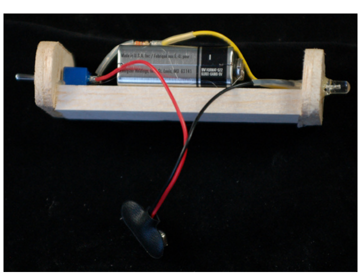
12

12. Using hot glue, glue the 9-volt battery near the center of the long piece of wood.

13a

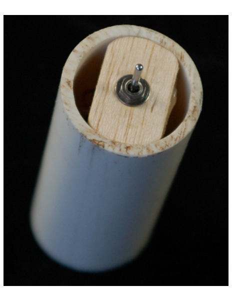


13b



13. Bend the long lead of the resistor as shown so that it will fit over the battery, then glue the short pieces of wood to the ends of the long piece of wood using hot glue.

14



14. Check to be sure the switch is in the "Off" position (see Step 3). Attach the snap connector to the battery, and slide the assembly into the PVC pipe so that the piece of wood with the switch is flush with one end of the pipe. If necessary, use a small amount of hot glue to hold the assembly inside the pipe. Your Ultraviolet Illuminator is finished! Test your illuminator by turning the switch on in a darkened room. Remember: NEVER LOOK DIRECTLY AT A SOURCE OF ULTRAVIOLET LIGHT!

A Bioluminescent Gallery

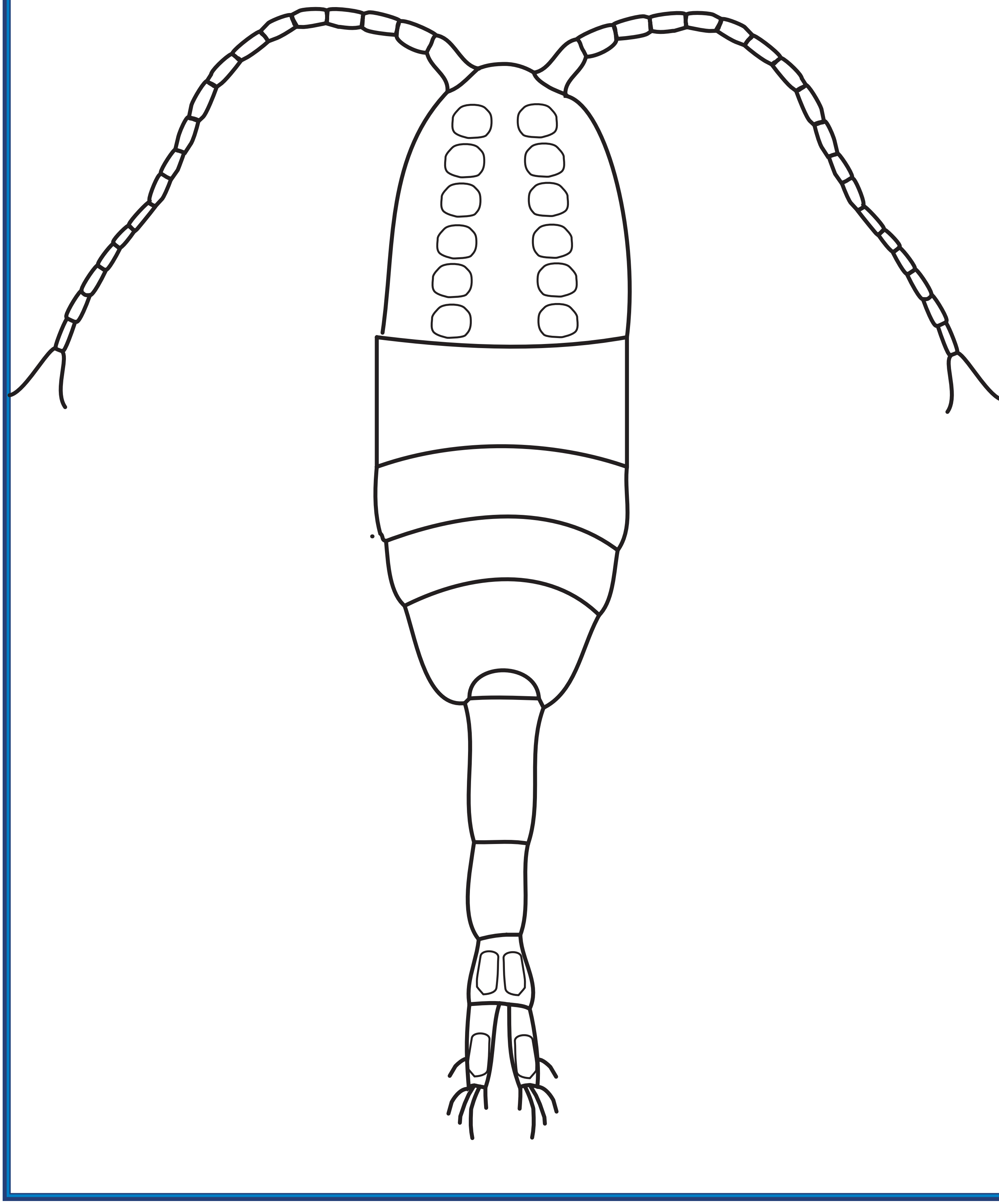
LED Ultraviolet Illuminator Construction Guide - continued

Notes About Components

A light emitting diode (LED) is a device that acts as a one-way gate to electric current, and that under some conditions will emit light. A diode is made with two small blocks of two different silicon compounds. The two blocks are held together by an encapsulating material, and a wire lead is attached to each block. One block is called the anode and the other is called the cathode. When the anode is more positive than the cathode, an electric current will flow through the diode. In an LED, this current flow causes light to be emitted. LEDs emit only one color of light, which depends upon the specific chemistry of the silicon compounds.

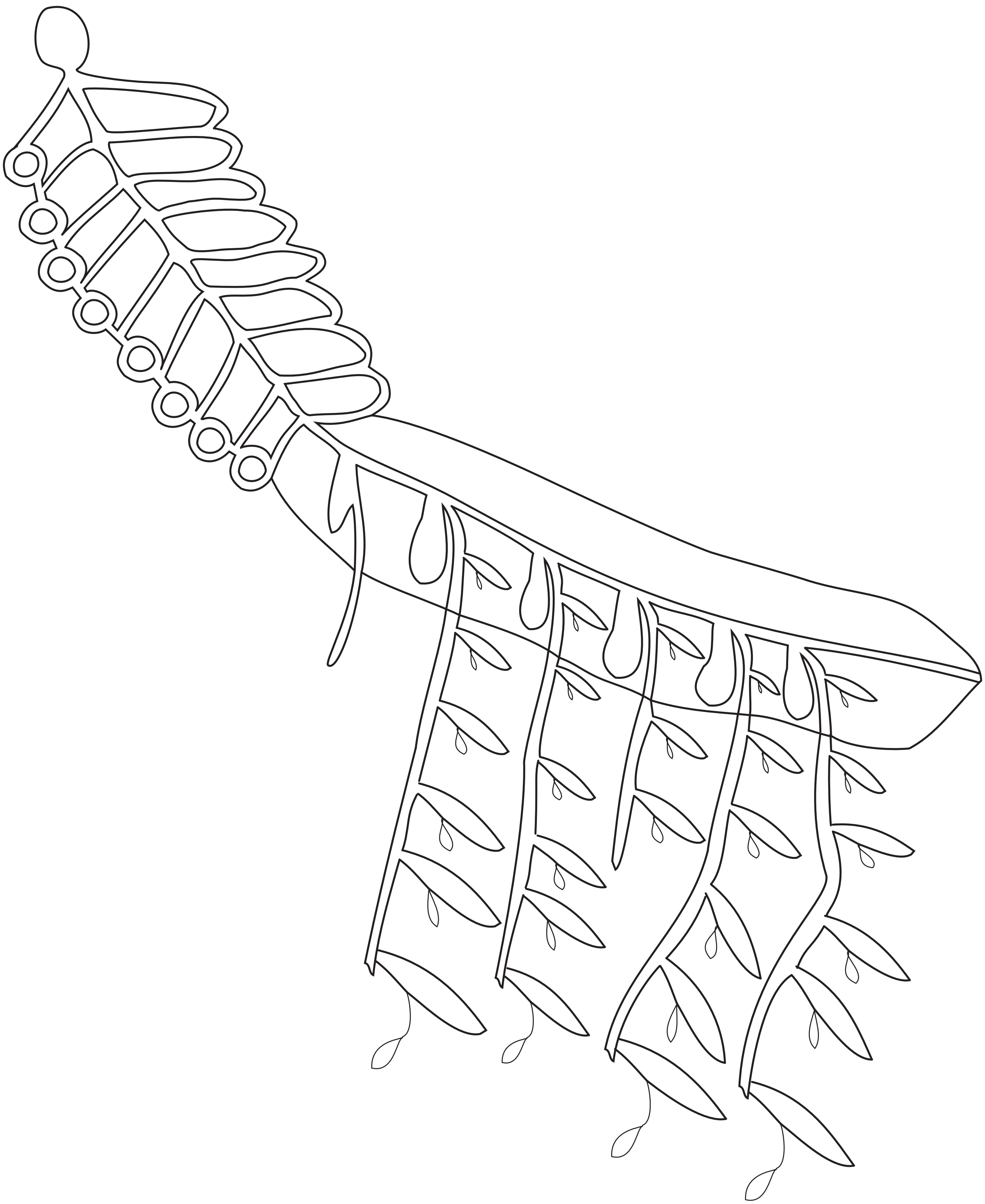
A resistor is an electrical device that resists the flow of electric current. The unit for resistance measurement is the "ohm." Resistors may have a single fixed resistance, or may be variable. Photoresistors and thermistors are variable resistors whose resistance changes with exposure to light and heat respectively. The resistor used in this Ultraviolet Illuminator is a fixed resistor made with a mixture of carbon and a glue-like binder.

A Bioluminescent Gallery
Coloring Sheet: Copepod



A Bioluminescent Gallery
Coloring Sheet: Loosejaw Fish

A Bioluminescent Gallery
Coloring Sheet: Siphonophore



A Bioluminescent Gallery
Coloring Sheet: Squid