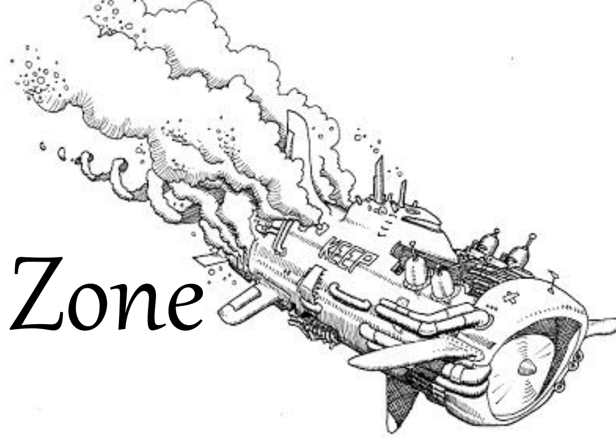
eXpedition inc.

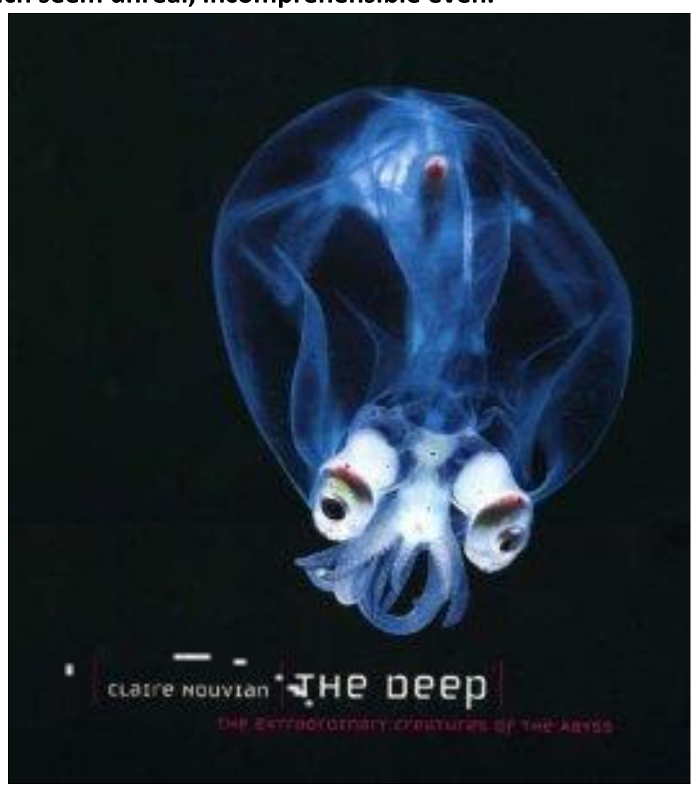
Life is the greatest adventure!

Diving Deeper: Midnight Zone



The second week of our three week window for our eXpedition is already gone! Those researchers and partners keep calling hoping for news and still no sign of the rare glowing jellyfish and special long fanged viperfish that could save so many lives. We've built our submarine and taken a few exploratory dives into the Twilight Seas, but now it's time to go deeper, all the way to the bottom, into the blackest pit in the sea. Are you ready to dive deeper, all the way to the Midnight Zone?

There are many non-fiction books available which can serve as a great introduction to this section, ex. *Creatures of the Deep* by Eric Hoyt or *The Deep: The Extraordinary Creatures of the Abyss* by Claire Nouvian has gorgeous photos of nearly 200 creatures, some of which have never been photographed before, many of which are unknown species, all of which seem unreal, incomprehensible even.

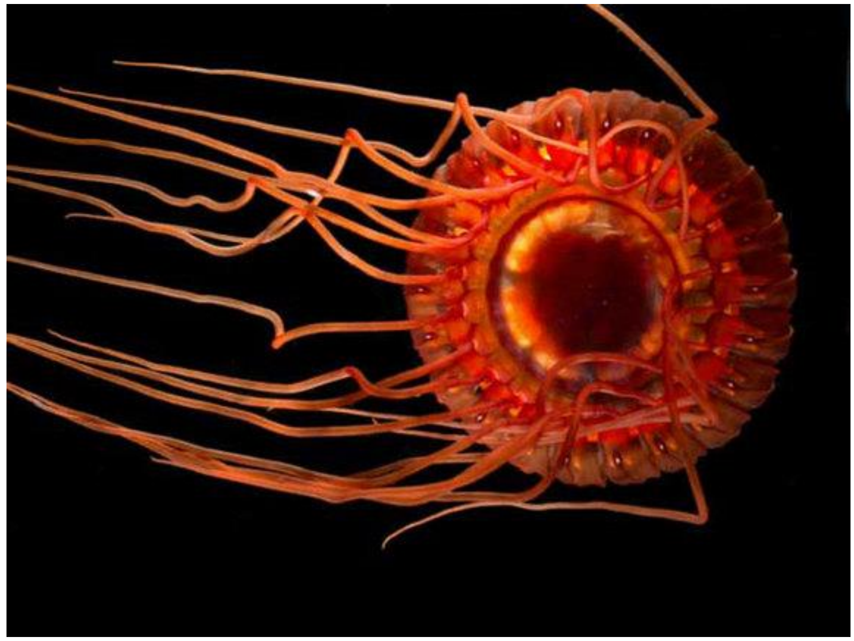


Another fabulous introduction is in BBC's series Blue Planet in the episode, "the deep." You may want to choose clips to show during the following discussions, some links are included to specific clips throughout the following information.

Have a student hold up a yardstick or meterstick. Tell the class that our expedition is traveling along the sea to the very deepest place in the world's oceans (the Mariana Trench in the Pacific) is 11,933 of these yardsticks (or 11,000 of these metersticks) deep. As we know, that's about seven miles (11.3 kilometers)!

Ask the class to hypothesize what it's like in the deep ocean. After they have provided some of their initial ideas, ask them to consider how much sunlight they think there would be in the deeper parts of the ocean. They should realize that the deeper areas are very dark. At approximately 220 yards (200 meters), it becomes more and more difficult to see. Below about 1,100 yards (1,000 meters), there's no sunlight at all and never has been. Have students try to Imagine a world where light is the main form of communication. Have students imagine that they are deep sea divers seeing one of these animals for the first time, what would that be like?

On dry land, most organisms are confined to the surface, or at most to altitudes of a hundred meters—the height of the tallest trees. In the oceans, though, living space has both vertical and horizontal dimensions: with an average depth of 3800 meters, the oceans offer 99% of the space on Earth where life can develop. And the deep sea, which has been immersed in total darkness since the dawn of time, occupies 85% of ocean space, forming the planet's largest habitat.



Yet these depths abound with mystery. The deep sea is mostly uncharted—only about 5 percent of the seafloor has been mapped with any reasonable degree of detail—and we know very little about the creatures that call it home. "In the first century A.D., Pliny the Elder—in a bout of oceanic hubris (extreme pride or arrogance)—pronounced that there were precisely 176 species of marine fauna and that, 'by Hercules, in the ocean . . . nothing exists which is unknown for us.' Would that we could summon Pliny from his celestial Hall of Shame and thwack him over the head with current estimates about the number of species yet to be found vary between ten and thirty million yet to be found by man. The ones that we do know are gloriously bizarre critters that appear to have been fashioned by a mad artist. They bear pulse-quickening names that are as if from some weird children's fable: naked sea butterflies, spookfish, pigbutt worms, cutthroat eels, helmet jellies, glasshead grenadiers and yeti crabs. Hued in pink, red, blue, orange, white and purple, these deep-sea denizens can seem repulsive, with their fangs and hooks and hooded eyes. Many of them, however, are balletic little beauties—bioluminescent, geometrical designs that hum with a life beyond our reach, but not, anymore, beyond our imagination. The deep sea no longer has anything to prove; it is without doubt Earth's largest reservoir of life.

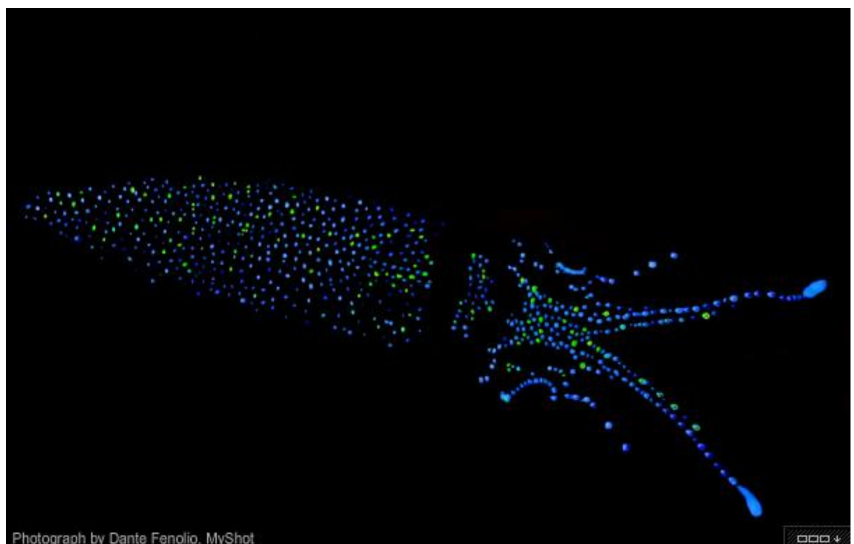
The deep ocean begins where the continental shelves and their shallow waters give way to the dark depths where little or no sunlight penetrates.

Here, in the layer underneath the sunlit open oceans, live some of the most bizarre and highly adapted creatures on the planet. With no plants or algae here to photosynthesize and form the base of the food chain, life here is largely dependent on the dead material, bodies, and droppings that sink down from above.

Watch the incredible time lapse of scavengers on the ocean floor in the clip "Deep Sea Scavenge" http://www.bbc.co.uk/nature/habitats/Deep_sea#p0038vr1 and Three-foot nemertean worms and carnivorous sea stars prowl the Antarctic in search of flesh. Finding a dead seal, the sea stars inject it with digestive juices... then suck it up like soup in "Scavenger Swarm. "

The deep sea is the darkest region of the ocean, where sunlight fades to blackness and plants cannot grow. It covers more than half the planet, and encompasses nearly 98% (by volume) of all living space on Earth. Scientists once assumed that life would be sparse in the deep ocean but virtually every probe has revealed that, on the contrary, life is abundant in the deep ocean. Volcanic activity breathes life into a barren void deep underwater.

Discuss with students the problems that might confront creatures of the deep sea. Ask: *What are the conditions like in the deep sea? Are there fewer sources of food available? Is the water that deep colder than the water closer to the surface? Why?* Ask students to think about how animals that live in the deep sea might have adapted to these conditions.



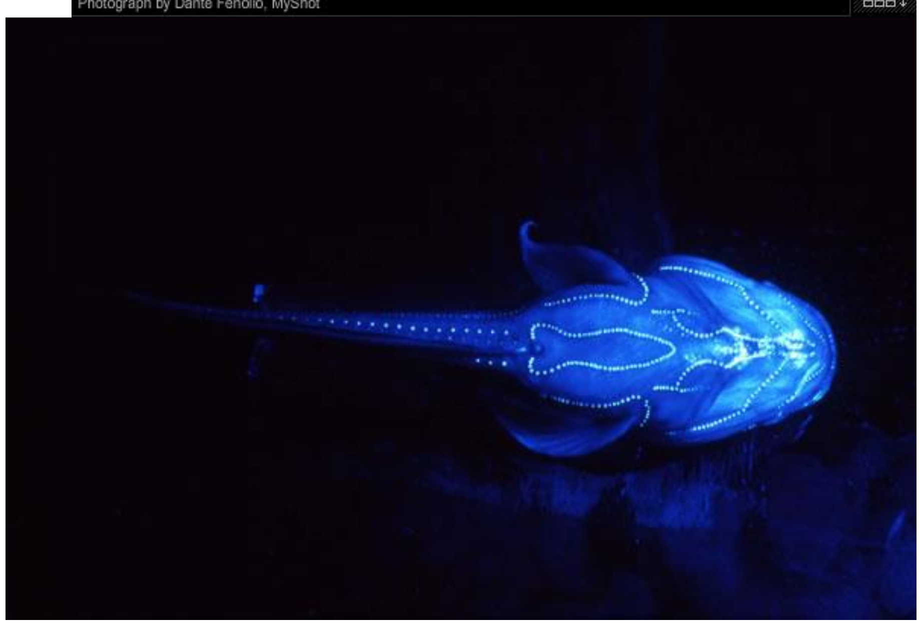
Photograph by Dante Fenolio, MyShot

Light Is Much Better,

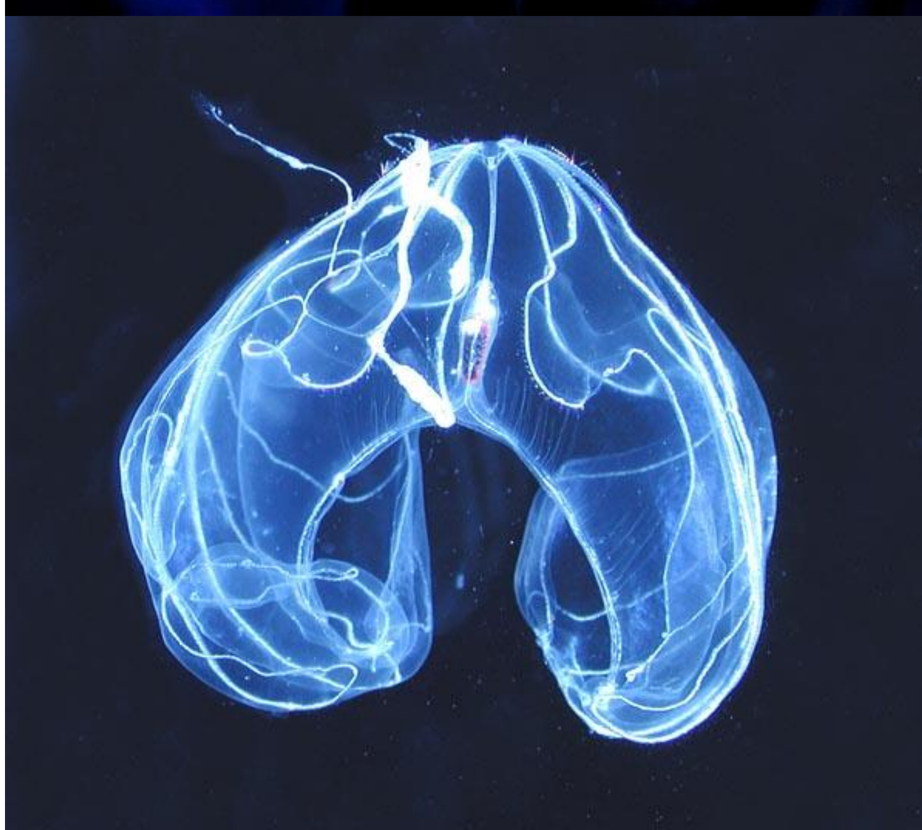
Down Where It's Wetter

What is the most commonly used language on earth?

Deep in the ocean, where sunlight can no longer penetrate in the aphotic zone, lies an incredible world of darkness. And against all odds, this just happens to be the location of one of nature's most impressive artificial light shows. The creatures here have evolved their own ways of dealing with the darkness. Through a process known as bioluminescence (bio = living,



luminescence = light), they have developed the ability to use chemicals within their bodies to produce light. It has been known for many years that all living creatures produce a small amount of light as a result of chemical reactions within their cells, but most of the time we can't see it. For example, humans glow in the dark. Ultra-sensitive cameras have revealed that our bodies emit tiny amounts of light that are too weak for the human eye to detect and at levels that rise and fall with the day
If you have ever seen a firefly then you have witnessed the same process in action. Descending 200 meters into the deep sea reveals some weird and wonderful creatures. Bioluminescence creates pyrotechnic displays deep in the ocean's darkness and is often used for attack and escape. Bioluminescence is mainly a marine phenomenon.



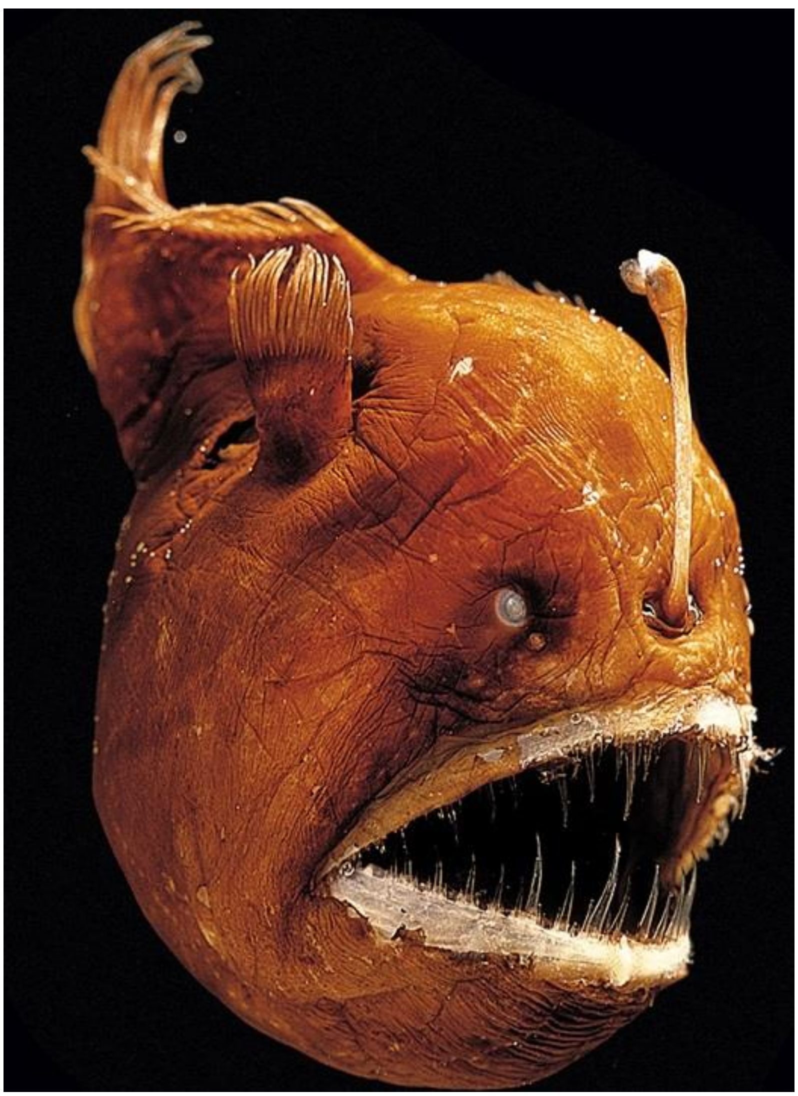
Only a tiny percentage of terrestrial (land based) life is bioluminescent—fireflies, most famously, but also some millipedes, click beetles, fungus gnats, jack-o'-lantern mushrooms and a few others. The one known luminous freshwater dweller is a lonely New Zealand limpet. Most lake and river residents don't need to manufacture light; they exist in sunlit worlds with plenty of places to meet mates, encounter prey and hide from predators. Sea animals, on the other hand, must make their way in the complete darkness of the deep ocean.

Have students calculate where sunlight completely disappears. Sunlight decreases tenfold every 225 feet. When does it reach 0? Light disappears by 3,000 feet. It's pitch-black even at high noon, which is why so many sea creatures express themselves with light instead of color.

It is the oceans where this unique ability achieves its highest form. Hundreds of species of fish and invertebrates flash their colors in a light show that can sometimes rival the streets of Las Vegas. From bacteria to sea cucumbers to shrimp and fish, and even a few species of sharks, more than 50 percent of deep-ocean animals use light to holler and flirt and fight. They carry glowing torches atop their heads. They vomit brightness. They smear light on their enemies. Bioluminescence is the most common, and most eloquent, language on earth, and it's informing fields from biomedicine to modern warfare to deep-sea exploration. Bacteria, jellyfish, starfish, clams, worms, crustaceans, squid, fish, and sharks are just some of the groups of marine animals that have bioluminescent members.

Scientists estimate that half of the world's jellyfish species are bioluminescent. The deeper jellyfish live in the ocean, the more common it becomes. Some jellyfish startle predators with bright flashes, while others leave a glowing slime sticking to them. Other jellyfish can detach their glowing tentacles as decoys to help them escape from attacking creatures. A jellyfish's tentacles, which trail after its body, can be less than an inch to120 feet (30.48 meters) long.

Bioluminescence occurs when certain chemicals are mixed together. This effect is very similar to that in green light sticks. When the seal in the stick is broken, the two chemicals mix together and give off a soft, green glow. Most of the light created by marine organisms is blue-green in color. Colors are different underwater. Colors are really nothing more than different wavelengths reflected by an object. Underwater, waves travel differently, and some wavelengths are filtered out by water sooner than others. Lower energy waves are absorbed first, so red disappears first, at about 20 feet. Orange disappears next, at around 50 feet. Then yellow at about 100. Green stays longer and blue the longest, which is why things look bluer the deeper you go.



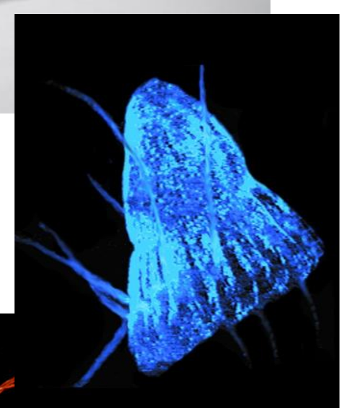
Blue light travels best in water, and because of this most marine organisms are sensitive to blue light. A notable exception is the Malacosteid family of fishes, also known as Loosejaws. These fish can produce red light and can see it when others cannot.

This gives them an advantage by allowing them to see their prey while without making their presence known. Marine creatures produce light with special organs called photophores. At least two chemicals are required to produce bioluminescence. The first is known as a luciferin. This is the chemical that actually creates the light. The second chemical is called a luciferase and is the substance that actually catalyzes the chemical reaction or makes it happen. When these chemicals are mixed together in the presence of oxygen, light is produced.

Some of these creatures give off light continually. Others flash their lights on and off by mixing their chemicals on queue or by covering their light organs with a flap of skin.

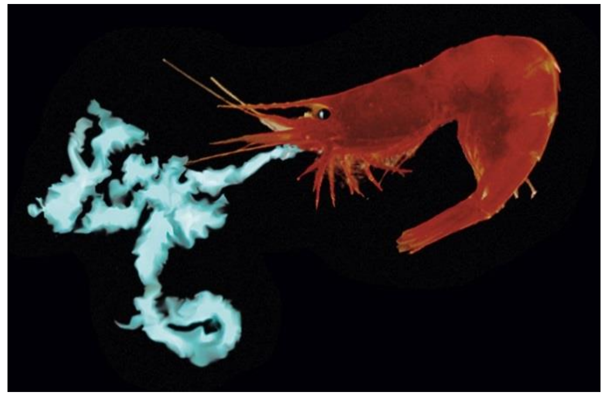
In front of its cruel jaws, the viperfish dangles a glowing bacteria-filled lure on the end of a mutated fin ray that resembles, to hungry passersby, a resplendent piece of fish poop—a favored deep-sea snack. (Rather than kindling their own light, some of these predators enjoy symbiotic relationships with bioluminescent bacteria, which they culture inside light-bulb-like cavities that they can snuff with sliding flaps of skin or by rolling the light organs up into their heads, “exactly like the headlights of a Lamborghini.”

The flashlight fish has a light-producing organ near its eyes that is covered with an eyelid-type flap. The fish can flash its light by opening and closing this f lap. These fish are so common off the Horn of Africa that they light up an area the size of Connecticut; the light can be seen by satellite.



These creatures produce light for a variety of reasons. Scientists today believe that bioluminescence is always a means of influencing other animals—a signal fire in the deep. The message must be important enough to outweigh the risks of revealing one’s location in the blackness. It’s the basic stuff of survival,” There’s incredible selective pressure on the visual environment, where you have to worry about what’s above you if you’re a predator and what’s below you if you’re prey. Often, you’re both.

For some, it is a warning to stay away. For others, it is a form of camouflage. Certain species of shallow water squid give off light to blend in with the moonlight. Some creatures use their light for navigation. Certain fish species use bioluminescence as a form of "night light". Some use it for communication. Certain species of crustaceans send out coded signals to others of their own kind during mating season. Other creatures use bioluminescence as a trap. The anglerfish uses a lighted "lure" on the top of its head to attract its prey. When the unsuspecting animal is within striking distance, the angler vacuums it down with a lightning-fast snap of its powerful jaws.



Bioluminescence can be used for defense, offense, or to attract a mate. Some species luminesce, or light up, to confuse or blind attackers. Many species of squid flash to startle predators, such as fish. With the fish caught off guard, the squid tries to quickly escape. In addition to activating their startle responses, hunted animals also use light as camouflage. Many mid-water predators have permanently upward-pointed eyes, scanning overhead for prey silhouetted against the down-dwelling sunlight. Viewed thus, even the frailest shrimp becomes an eclipse. So prey animals dapple (make spots on) their bellies with light organs called photophores. Activating these bright mantles, they can blend in with the ambient light, becoming effectively invisible. Fish can snuff out their stomachs at will, or dim them if a cloud passes overhead, one can even match moonlight.

One of these species is the hatchetfish. Hatchetfish use a fascinating technique called counter-illumination, a kind of camouflage, to protect themselves. Many predators hunt from below by looking above for shadows of prey against the light of the surface. Hatchetfish have light-producing organs that point downward. They adjust the amount of light coming from their undersides to match the light coming from above. Thus, they disguise their shadows and become virtually invisible to predators looking up.

Some animals, such as brittle stars, can detach body parts to distract predators. The predator follows the glowing arm of the brittle star, while the rest of the animal crawls away in the dark.

When some animals detach body parts, they detach them on other animals. When threatened, some species of sea cucumber can break off the luminescent parts of their bodies onto nearby fish. The predator will follow the glow on the fish, while the sea cucumber crawls away.

Another bottom-dwelling bioluminescent creature, the blackdragon fish has light-emitting organs arranged all along its belly to fool predators by changing its silhouette. The spooky fish also has bio-luminescencant "flashlights" next to each eye that it can flash on while on the look-out for prey or to signal potential mates. As you saw in the photo, the blackdragon fish is so toothy that even its tongue has razor-sharp teeth.

Finally, light is used to recruit mates. “We think they flash specific patterns, or have species-specific-shaped light organs,” one scientist says. Female octopods sometimes set their mouths ablaze with glowing lipstick; Bermuda fireworms enliven the shallows with glow-party like shows. Most romantic of all is the love light of the anglerfish. The female, a fearsome gal with a toothy under-bite, brandishes a lantern of glowing bacteria above her head. The male of her species, tiny and lantern-less but with sharp eyes, swims toward her and smooches her side; his lips become fused to her body until she absorbs everything but his testes/egg fertilizing parts. (You might say that she will always carry a torch for him.)

Whatever the reason for producing this dazzling light show, it remains as one of the natural world's most bizarre and spectacular facts.

Watch the amazing clips of bioluminescence, “Light Lures,” and “Tricks of Light” at BBC Earth: http://www.bbc.co.uk/nature/habitats/Deep_sea#p006v47r Bioluminescence is light created by living organisms and it can create the most fantastic displays. As you watch these creatures, have students try to imagine the purpose of their bold displays. Although scientists are beginning to understand the mechanics of bioluminescent activity, much of the purpose of these living lights is still unclear.

Two videos comparing two species in artificial light and bio luminescing in darkness: http://oceanexplorer.noaa.gov/edu/learning/player/lesson06/l6la2.htm

The winking dinoflagellate blooms in the Indian River Lagoon on Florida’s east coast can be so bright that schools of fish look etched in turquoise flame. It’s possible to identify the species swimming in the lit-up water: Local residents call this guessing game “reading the fire.”

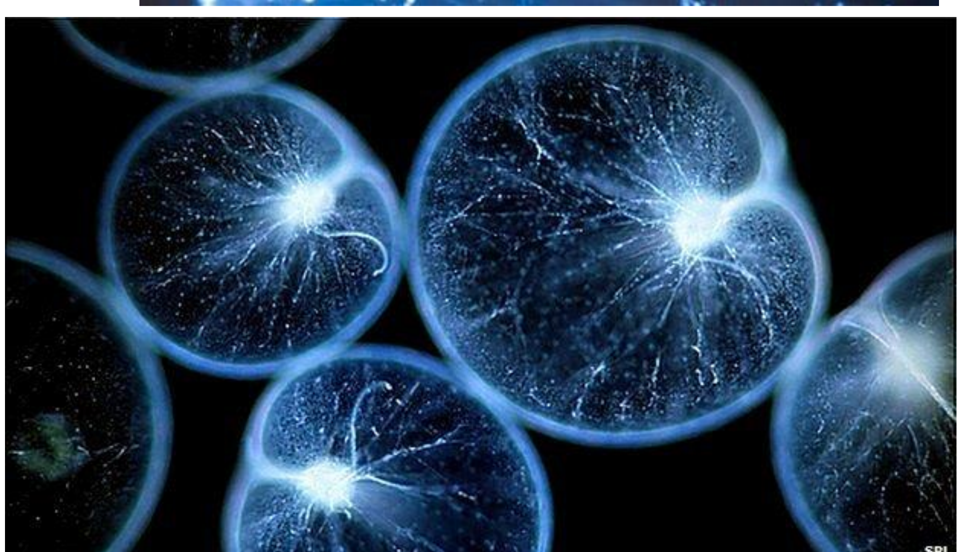
But there isn’t as much fire to read anymore. Pollution has thinned the lights. Animals once wreathed in blue fire are ailing, too. Many dolphins are afflicted by a flesh-eating fungus that corrodes their skin; others are infected by viruses and have severely suppressed immune systems. Luxurious sea grass beds grow bald, leaving conch and periwinkle snails without shelter. Mammoth algae blooms stink like rotting eggs. The shellfish industry is in shambles.

The sources of pollution here are discouragingly diverse: There’s airborne mercury from China, fertilizer and pesticide runoff from inland plant and animal farms, even the grass clippings from local lawns. There are literally thousands of chemicals being released into our environment and nobody is keeping track of them. It's hard to imagine a bright future for the deep sea lights if we keep flooding the seas with chemicals and wastes.

Searching for the Meaning of Light

Luminescence sheds light on the human adventure of science. Scientists and many others have explored the science and wonder of cold light--the chemistry of animals and things that make light but not heat. A 17th-century alchemist (early form of scientist, usually focused on trying to make gold) tried to turn a stone into gold. He failed, but the stone glowed in the dark instead. The alchemist began to mold the first luminescent objects.

A light also came on one night for the famous chemist Robert Boyle in the 1600s. One night his servants called for him to come and see something amazing in the pantry. There on a pantry shelf, Robert Boyle found some chicken that had been bought a week before. (No refrigeration in those days.) The meat was covered with about twenty spots of various sizes glowing with a greenish blue light. Boyle would later write that when it was picked up, the movement caused the meat to glow even more brightly, putting on what he called a "rather splendid show." After he saw a raw chicken glowing in his kitchen, he began his own research into luminescence, beginning with several experiments with that very chicken. One of them involved eating some of the meat! Luckily he survived his curiosity and went on to do other famous experiments with glowing mushrooms and other glowing things.



But what was it that made the chicken glow in Robert Boyle's pantry? The smallest of bioluminescent creatures, bacteria. These microorganisms show up in surprising places, from chicken or fish that's been left out on the counter too long to the pouches under the eyes of flashlight fish.

How could these bacteria be helpful to people? When could they be a negative or a hindrance? Think of challenges and helps on land and in the sea. Make a list on the board of your students' suggestions.

These scientists and many others have explored the science and wonder of cold light--the chemistry of animals and things that make light but not heat. Scientists are hotly pursuing modern applications for bioluminescent technology, particularly in medical research, where they hope it will change how we treat maladies from cataracts to cancer. In 2008, the Nobel Prize in Chemistry honored scientific advances in work with cells based on the crystal jellyfish's green fluorescent protein, a bioluminescent substance

Some sea creatures' use of light mystifies scientists. Why does the shining tube-shoulder fish shrug out light? Why does the smalltooth dragonfish have two headlights instead of one, in slightly different shades of red? How does the colossal squid use its light organ? These questions aren't just theoretical. Bioluminescent plankton (microscopic plants and animals) inhabit all of the world's oceans (but not its freshwater lakes.) **What problems might glowing creatures in the ocean cause? Think about our military, might they cause our ships any problems?** The light of just a single dinoflagellate (plankton) can be seen at night. When millions upon millions of tiny plankton give off their light at the same moment, the ocean can turn into a nearly indescribable light show.

The shining plankton often glow when they are physically disturbed and are very sensitive. The wake of a submerged submarine could cause this. This flash of light can be spotted from surface vessels, aircraft or even orbiting satellites. Tiny creatures that could highlight the shape of a hidden submarine are a national security concern. Bioluminescent algae can endanger military missions by illuminating incoming submarines, naval vessels, or even Navy SEALs swimming around covertly. The greenish wake of a ship can be seen from miles away as an ever-expanding trail on the surface of an absolutely flat and calm sea as billions of agitated plankton give off their light and the faster and more they move, the stronger the light! *Glowing plankton have a long history in naval warfare. On 9 November, 1918, the German submarine U-34 was destroyed in the Mediterranean after bioluminescent plankton betrayed its position.*

For this reason, the U.S. Navy asked for help from the scientists of the world to develop products that monitor bioluminescence. **What might need to be invented? Could ships or soldiers use bioluminescence as camouflage? How about using it for detecting enemy**

> Bonus fact: Glowing foxes were almost used by the U.S. military in World War II. But they weren't going to be covered with plankton — just slathered in paint. According to the book "Psychological Operations American Style" (excerpted here), foxes, "when illuminated," were considered a warning or bringer of bad times by many Japanese. The Office of Strategic Services (a CIA predecessor), as a test, painted thirty foxes with glow-in-the-dark paint and released them in Manhattan's Central Park. When New Yorkers reacted with fear and horror, the OSS decided to run a full-scale operation in Japan. But the war ended before the ghost foxes could be unleashed there.

or possibly hostile ships? *In 1998, Captain Michael McHugh, former manager of the US Navy's program for assessing strategic threats to ballistic missile submarines, admitted in the magazine Undersea Warfare that the US military had developed a way of using bioluminescence to detect submarines. Developing a system that can reliably detect submarine wakes means scientists will have to know a lot about the normal distribution and activity of the plankton in order to be able to tell what's normal, what's a fish, and what's a submarine.*

Using easy-to-grasp applications of biochemistry, genetics, and electronics, today's scientists create amazing inventions and applications. It sounds like a child's riddle: What do you get when you cross a firefly with a tobacco plant? Answer: tobacco that lights itself. That is essentially what a team of scientists at the University of California at San Diego did in 1986. By outfitting a fragment of a plant virus with the gene that tells firefly cells to produce a protein central to generating light, the researchers created a plant that literally glows in the dark. In 2010, a company improved upon the experiment. Was their goal to help farmers? Nope. Red roses with glowing petals, poinsettias lit up for Christmas and shrubbery that illuminates communities at night, rendering street lights unnecessary — that's the vision behind the company BioGlow, Inc. Even so, the light of the leaves is not yet quite what the founders of BioGlow want it to be. "You have to be five minutes in the dark to see them with your eyes," the head scientist said, referring to the period humans' eyes typically need to adjust to the dark. But, "we are sure we are going to make them glow as bright as fireflies." And they promise there is no risk that the genes would be transmitted into the environment by pollen, **but what if nature found a way?** Although this project has the potential to bring new light to the floriculture industry, glowing flowers won't be showing up at corner florists' windows too soon, said Tal Eidelberg, cofounder of BioGlow, Inc. "This is more of a visionary thing," he said. **What might he have meant by that? What other "visionary things" might be done with glow?**

This wee green kitten not only glows, she's resistant to the feline version of HIV. Scientists exploring possible treatments for HIV have, purely as a byproduct of their methods made glowing kittens.

Researchers are interested in seeing how a certain monkey gene guards against FIV, which is the feline version of HIV, in hopes of transferring their insights to combating HIV/AIDS in humans.

But here's where things get wacky: The team also included in the virus a jellyfish gene that makes a glowing green protein, to act as a signal. The virus does not always succeed in transferring the genes entrusted to it, but by including the jellyfish gene, the team gave themselves an easy way to tell when the transfer took place: kittens that glow green under fluorescent light, showing that they carry the jellyfish gene, almost certainly carry the protective monkey gene as well.

The green kittens grew up into green cats, whose claws, in particular, show high levels of green proteins.

Scientists have also made glowing pigs, monkeys, and mice before as it's a handy way to tell if their work was successful and those genes they wanted were actually passed on to the next generation, allowing them to glow with pride.

Flying with Fire

Speaking of glowing, remember watching fireflies light up your yard on hot summer nights? Fireflies are beautiful, mysterious, and magical—and for many of us, catching and spotting them is an important part of summer. But firefly populations are dwindling all over the country—and all over the world. If you stop to really look, you might notice that there are fewer fireflies lighting up your lawn than there used to be. It's not your imagination; fireflies are actually disappearing from many locations around the country and world. "That's sad," you may be thinking, "but what does it have to do with science?" Well, that's where the Boston Museum of Science's Firefly Watch program comes in. Started 3 years ago by Don Salvatore in collaboration with local scientists, the program recruits citizen scientists to learn about the different colors that the insects display, what the various flash patterns mean, and how different fireflies act in different locations, help collect and analyze data around the country and do a census (count.) Citizen scientists collect data about the fireflies seen in their area as well as information such as light pollution, pesticide use, and other factors that may be affecting fireflies. Collected data will be cataloged and added to the observations of hundreds of other people around the country. Scientists and other researchers then use the compiled data to try to find patterns, possible causes, and potential solutions to the problem.

Why count fireflies?

Science is a powerful thing, but it's impossible for scientists to be everywhere at once. Especially with populations of insects such as fireflies that tend to thrive more in rural areas, it's incredibly helpful for scientists to get a broader picture of where those populations are, how they're behaving, and how they might be changing over time. Scientific research has been conducted on fireflies for many years. However, it is only recently that scientist have discovered many of the secrets of the firefly, including what controls their flashing. Hint: It involves controlling the flow of oxygen to special cells, just like bioluminescent bacteria need oxygen to glow.

Firefly Watch also makes all of the data it's collected available online, so if you've a penchant for number crunching and playing with charts, feel free to have your students take a stab at interpreting it themselves! *There's also a lot to explore and learn at www.firefly.org.*

There are a few things you can do to help fireflies make a comeback in your area.

- Turn off outside lights at night.
- Let some logs and tree litter accumulate.
- Create non-chemically treated water features in your landscape.
- Avoid use of pesticides.
- Use natural fertilizers.
- Plant Trees
- Don't over-mow your lawn
- Plant trees.
- Do NOT introduce earthworms into your land.
- Get your neighbors onboard.

Learn why & and a lot more at http://www.firefly.org/how-you-can-help.html

Lighting Up the Sea!

Our sub is reaching ever deeper depths in the ocean and we're observing new fascinating and brilliantly glowing behavior every time we peer outside the porthole. The scientists are going to want us to record each and everything we see. And in order to be able to describe it accurately, we need a closer look, and for them to trust us enough to not disappear into the dark we need to behave like the fish themselves! Come one, let's dive deeper and get our glow on!

Write the word "adaptation" on the board, and ask students if they know what this word means. Provide a definition from your classroom dictionary, or use this one: "an adjustment to conditions in the environment." For example, in order for us to survive the cold environments outside our submarine what would we need to do? Wear warm wetsuits that include heaters? How about oxygen? What else will we need. What is a whale or seal or polar bear's adaptation to its cold environment? It might includes a

very heavy coat of fur, thick layers of blubber, etc.

Ask students to think of other examples of animal adaptations. How are wild animals in our area adapted to the local climate or other conditions? Ex. hibernation, migration, growing thicker layers of fur (have they ever seen their dog do this? What about wild animals in other places, including the ocean?

When we and other scientists traveled below the seas trying to distinguish more precisely among the myriad lightmakers it sometimes looked like random flashing and chaos, but eventually it became apparent. Different species, it seems, have distinct light signatures. Some creatures flashed; others pulsated. Siphonophores looked like long whips of light; comb jellies resembled exploding suns. A kind of kaleidoscopic scream fest in the deep darkness. **(Go back to the fireflies- this something the kids know and could later look for. How do they think fireflies communicate?** Fireflies talk to each other with light. Also, fun fact, Adult fireflies aren't the only ones that glow. In some species, the larvae and even the eggs emit light. Firefly eggs have been observed to flash in response to stimulus such as gentle tapping or vibrations. **How could this be helpful or harmful? Might predators learn to look for glowing eggs?**)

What if we found a way on our expedition to identify animals just by the shape and duration of their glow circles? What might the benefits be? We could then conduct a bioluminescent census! (Scientists like to count animals, it helps them keep track of important data!) We could gather the sort of basic information that land-based biologists take for granted, such as whether, even in the ocean, certain species are territorial. Do certain animals hang back and vertically migrate at different times of day? How do you sort that out? The possibilities are endless!

Materials Required:

- Computer with Internet access or a book with pictures of bioluminescent creatures, ex. *Creatures That Glow* (Glow in the Dark Book) by Joanne Barkan
- Yardstick or meterstick
- Flashlights—enough that an even number of small groups (two to four students each) can each have one
- Glow sticks, glow straws, or glow bracelets
- Morse code strips, found at the end of this activity. Make 2 photocopies of the Morse code strips, and cut out each code, so that there are enough pairs for every student or group in the class to have their own Morse code strip, the same number as you will have groups so that every student or group in the has ONE partner in the class with a matching Morse code strip.
- Note: Petroleum jelly will glow or luminesce under a black light, like invisible ink. Have students use latex gloves if you don't want to get their hands messy (caution: some people are allergic to latex gloves!)

Turn off all the lights in the room and make it as dark as possible. Tell the students we are diving deeper into the seas. If we make too much noise in our submarine, the animals outside might get frightened and leave, making it so we lose all of our chances for observation! Have the students figure out how they could send a message to another scientist across the sub if they could not use their voice. Ask the students to imagine how they would find a snack in the dark or locate their friends in the sub. Turn on the lights, and have the students list their ideas.

Divide the class into small groups of two to four students each and let them know we're diving outside the sub to record our observations (and we're becoming what we observe). Make sure there is an even number of groups in the room, and ask groups to spread out around the room. Explain that each group represents one of the animals we've observed outside the portholes, an animal that lives in the deep ocean and that there are two of each kind of animal in the sea. Their goal will be to figure out where the other animal of their type is.

Give each group a flashlight and a card with a Morse Code light pattern. Morse code can be transmitted in a number of ways: originally as electrical pulses along a telegraph wire, but also as an audio tone, a radio signal with short and long tones, or as a mechanical or visual signal (e.g. a flashing light). Explain that a dot (or the word "short") means they'll put the flashlight on, or uncover their glow stick, for just a count of one, or a flash, while a dash (or the word "long") means they'll hold it on for about one to three seconds. You might want to demonstrate this concept to the class with your own flashlight or glow stick first.

Hand out the Morse code strips. Advise the students that their code needs to be kept secret, so that their neighbors don't know what their code is. ***(This rule can be changed later in order to incorporate the behavior of mimicry.)*** Have them look at their code briefly, before hiding it in their hands or under their notebooks.

Explain the Morse code briefly to the students. Dashes are LONG, and Dots are SHORT. Draw several examples of brief Morse codes on the board, and have the students recite the code out loud. For example, draw .._._ on the board, and all together, have the students recite "short short loooooong short looooooong".

Ex. SOS SOS (which does not actually stand for anything) is used as a warning or distress signal and s the only 9-element signal in Morse code, making it more easily recognizable.

· · · – – – · · · = short, short, short, looooooong, looooooong, looooooong, short, short, short…

Continue practicing until the students understand how to read the code.

Next, have students look again at their Morse code strip, and have them figure out (silently) what their Morse code signal is. They need to commit it to memory for the activity. Give them enough time to do so.

Variation: Give students the Morse Code Alphabet and have them create their own short code.

Stand in front and demonstrate to the students how to use the Morse code with the flashlights or glow sticks. Cover the glow stick with your hand (this is why the short sticks need to be used). Then, remove your hand very briefly, and cover the glow stick again, to demonstrate "short". Then, remove your hand for 3 or 4 seconds before covering the glow stick again to demonstrate "long". Use the codes that you practiced on the board earlier to demonstrate how you use the glow stick to transmit the code through the dark. After showing the students how to do it a few times with the lights on, turn the lights off and demonstrate it again, so that the students can see what it will look like.

When all groups are ready, turn off the lights and ask them to begin emitting their patterns with their flashlights. While one student in each group beams the light, the others in the group should look carefully around the room for the same signal.

Once every group has found its "match," have students return to their own seats. Discuss how the activity they have just done relates to bioluminescent deep sea animals. Students should realize that, just as they used their lights to find other animals of the same species, deep sea animals use lights to locate others that are like them. Why would they want to do this? Generally, to find a mate!

Variation: As an extension, predators and prey in the deep sea may mimic other animals' signals. The teacher can stand up front with the students, and transmit 2 or 3 made-up codes to the class that mimic the codes of other students in the class. Then, when some students come up to the teacher to be "partners", explain that you are a predator, and that you mimicked their signals to attract them to you so that you could eat them!

Who Glows There?

Prepare the students for the glow stick activity. The classroom should be arranged so that there are not any obstacles in the center of the room.

Check students' comprehension. Ask:

- *What is bioluminescence?* (an animal's ability to emit its own light)
- *What causes bioluminescence?* (chemical reactions in an animal's body)
- *What do animals use bioluminescence for?* (to confuse or blind attackers; to communicate)

1. Give each student a glow stick (or make patterns with petroleum jelly on their hands or gloves and use a black light in the room to make them glow). With glow sticks it is necessary to bend them so that the chemical reaction is activated and the stick begins to glow. Explain that these accessories give off light in a way that's very similar to how many marine animals emit light. There's a chemical reaction inside these glow sticks that produces light, much like there's a chemical reaction inside the animals' organs that creates the light.

2. Choose a couple of students who will get to be the predators the number of predators will depend on the size of the class. For a class of 25, there should be about 3-4 predators.

3. Divide the other students into groups. Each group represents a different species of bioluminescent organisms.

4. The students can come up with secret flashes on their stick so that they know their group from another group using the Morse Code alphabet. The goal is to not get eaten by the predator.

5. Send the predators to another part of the sea (hallway) and given a chosen prey's code.

6. The groups should be broken up. The groups should try and find each other so that they can reproduce or get points! The students should try and find the other members of their group based on their secret flashing code.

7. Turn all the light off and let the predators into the room. The predators are going to tag anyone they can. If a student gets tagged, then they must they are out and must wait until the next game starts or until 2 members of their species set them free.

8. Predators will be assigned prey fish of a specific kind of fish with a specific code. **This can bring in an interesting discussion of mimicry, will other fish use that signal? Will the chosen prey be allowed to use mimicry of another type of fishes' signal one time? How could that help them? How could that harm them?**

9. Up the challenge by have multiple types of predators going after different specified prey. **Would mimicry help you then? What if you tricked your predator, but looked like food to another predator?**

10. If two members of the same group find each other, then they can go release another member of their group that has been tagged.

11. The game will end if all predator groups tag all members of the chosen prey species.
    This can be done a number of different times and the different people can play the predators.

Did the bioluminescence help or hurt their communication? What did the predators think? Ask 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.

Discuss with the students how bioluminescence is used in the deep sea. Discuss why this is a necessary adaptation for organisms living in the deep sea, and discuss limitations that were encountered, and relate the difficulties to difficulties that organisms in the deep sea might encounter.

••••	→•_••	→_•_•	→••_ _	_ _ _ _
••••	→•_••	→_•_•	→••_ _	_ _ _ _
→•••_	→_•••	_••_	→•_ _ _	→_ _ _•
→•••_	→_•••	_••_	→•_ _ _	→_ _ _•
→••_•	→•_•_	•_ _•	→_ _••	**→=** read the code this direction (if you flip it upside down, it's a different code
→••_•	→•_•_	•_ _•	→_ _••	

••••	→•_••	→_•_•	→••_ _	_ _ _ _
••••	→•_••	→_•_•	→••_ _	_ _ _ _
→•••_	→_•••	_••_	→•_ _ _	→_ _ _•
→•••_	→_•••	_••_	→•_ _ _	→_ _ _•
→••_•	→•_•_	•_ _•	→_ _••	**→=** read the code this direction (if you flip it upside down, it's a different code
→••_•	→•_•_	•_ _•	→_ _••	

Morse Code Alphabet

A	•-	N	-•	0	-----
B	-•••	O	---	1	•----
C	-•-•	P	•--•	2	••---
D	-••	Q	--•-	3	•••--
E	•	R	•-•	4	••••-
F	••-•	S	•••	5	•••••
G	--•	T	-	6	-••••
H	••••	U	••-	7	--•••
I	••	V	•••-	8	---••
J	•---	W	•--	9	----•
K	-•-	X	-••-	.	•-•-•-
L	•-••	Y	-•--	,	--••--
M	--	Z	--••	?	••--••

Morse Code Alphabet

A	•-	N	-•	0	-----
B	-•••	O	---	1	•----
C	-•-•	P	•--•	2	••---
D	-••	Q	--•-	3	•••--
E	•	R	•-•	4	••••-
F	••-•	S	•••	5	•••••
G	--•	T	-	6	-••••
H	••••	U	••-	7	--•••
I	••	V	•••-	8	---••
J	•---	W	•--	9	----•
K	-•-	X	-••-	.	•-•-•-
L	•-••	Y	-•--	,	--••--
M	--	Z	--••	?	••--••

Morse Code Alphabet

A	•-	N	-•	0	-----
B	-•••	O	---	1	•----
C	-•-•	P	•--•	2	••---
D	-••	Q	--•-	3	•••--
E	•	R	•-•	4	••••-
F	••-•	S	•••	5	•••••
G	--•	T	-	6	-••••
H	••••	U	••-	7	--•••
I	••	V	•••-	8	---••
J	•---	W	•--	9	----•
K	-•-	X	-••-	.	•-•-•-
L	•-••	Y	-•--	,	--••--
M	--	Z	--••	?	••--••

Morse Code Alphabet

A	•-	N	-•	0	-----
B	-•••	O	---	1	•----
C	-•-•	P	•--•	2	••---
D	-••	Q	--•-	3	•••--
E	•	R	•-•	4	••••-
F	••-•	S	•••	5	•••••
G	--•	T	-	6	-••••
H	••••	U	••-	7	--•••
I	••	V	•••-	8	---••
J	•---	W	•--	9	----•
K	-•-	X	-••-	.	•-•-•-
L	•-••	Y	-•--	,	--••--
M	--	Z	--••	?	••--••

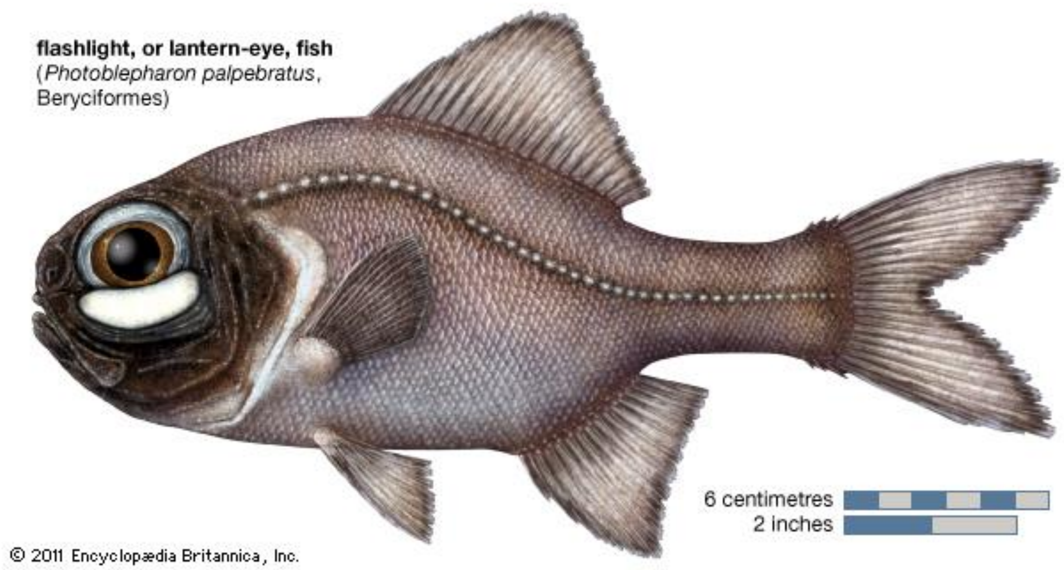
Flashlight Fish and "Glowing" Bacteria?

Myth: Most bioluminescence comes from bacteria.

Truth: As we've explored we've seen (and taken samples!) that bacteria can be luminous and some organisms like flashlight fish and squid do have bacteria in their light organs. However, most bioluminescent animals are able to produce light with chemicals they have stored in their own bodies.

Most animals make their own living light. Yet, some marine animals are not bioluminescent and still "glow." How is this possible? We need to dive in and find out!

Some animals, such as the flashlight fish, have a special chamber to store bioluminescent bacteria. The aptly named flashlight fish sweeps the darkness with its intense cheek lights, looking for tasty neighbors. Bacteria need a home and nutrients, and the flashlight fish and other creatures need a light source. It is a mutually beneficial relationship. **In order to best observe, we need to become like the observed. There's a group flashlight fish ahead! Hurry, get your gear, it's time to blend in!**



Using blindfolds, students will work together to understand this amazing occurrence, learn and understand bioluminescent bacteria, understand that symbiosis is when two unlikely organisms work together in a mutually beneficial relationship, and identify the reasons behind this arrangement so that we can report back what we learned to our researchers back home who won't get to observe the flashlight fish in the wild like we do.

Materials:

For teacher demonstration:

- Flashlight

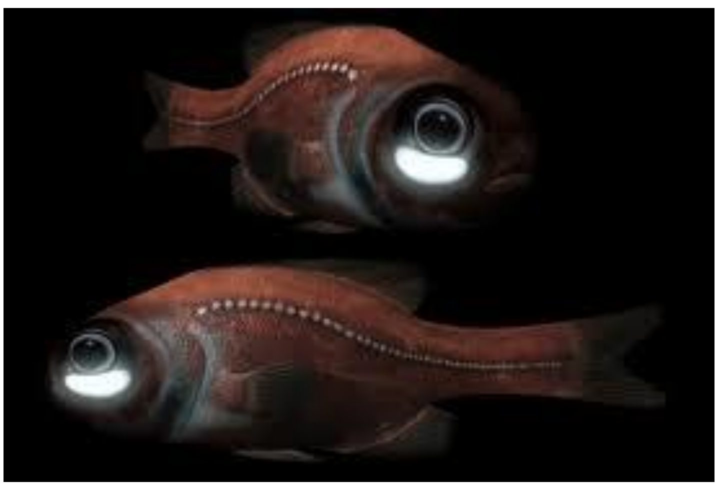
One for each pair of students:

- Blindfold

- 2 plastic cups
- Assorted flavored jelly beans (1/4 cup per student) Option: use dry beans or macaroni instead, don't allow students to eat the dry beans or macaroni.
- Non-injury causing obstacles (nothing too dangerous) Tip: An outdoor setting with some obstacles (but nothing too dangerous!) is ideal, or a properly prepared classroom.

Some ocean animals do not produce their own living light. They "borrow" bioluminescent bacteria as a light source. "To borrow" means to get something from another person with the understanding that it will be returned. However, a "borrower" as in the case of the flashlight fish, does not return its light. The flashlight fish and bioluminescent bacteria develop a permanent partnership.

Flashlight fish (about 6 inches in length) live in the Indian Ocean and the South Pacific. They live in reefs and rocks near shore where they hide during the day. When it becomes dark, they come out to feed. Flashlight fish use their light to find prey. Also, many of the plankton that they eat are attracted to their lights similar to the way moths are attracted to a flame.



Flashlight fish also use their light for defense. They swim up to a predator, flash their lights, and then zig-zag away to confuse it.

In the flashlight fish, bioluminescent bacteria are located in the light organ underneath its eyes. The size of a kidney bean, the light organ is home to about a billion bacteria.

The "glowing" light is crucial for the flashlight fish's survival, and the fish provide the bacteria a home and nutrients. This mutually beneficial arrangement is known as symbiosis.

Procedure:

1. Introduction to a "Borrower"

a. Inquire to your students if they can define the term, "borrow." Describe the difference between "borrow" and a "borrower" as it relates to symbiosis.

b. Ask your students- but isn't bacteria usually harmful? Some bacteria, which are so tiny that most can only be seen through a microscope, can make us sick, but certain other ones can be really helpful, like in this case.

2. Why are flashlight fish linked with bioluminescent bacteria?

a. Describe the symbiosis relationship. Link the flashlight fish and bioluminescent bacteria. Using the flashlight, demonstrate this arrangement. (put the flashlight beneath your eye.)

Like a flashlight, the bioluminescent bacteria helps the fish find food or attract food to come to the fish. In return, the fish provides the bacteria with a home and food which they need to grow.

b. Explain how to most creatures, being eaten is not a good thing, but for the bioluminescent bacteria, it gets them a safe and comfortable home inside the fish's body. The glow of these bacteria can also work to attract fish to eat them in the first place.

c. Explain symbiosis as a mutually beneficial relationship and explain the symbiosis relationship activity.

d. Pair students. One student will be the "flashlight fish." (with the cup) and one student will be the "glowing" bacteria (with the assorted beans.) Pass out materials. Blindfold the "flashlight" fish. Once the blindfolded partner is ready, slowly spin the person around a few times so that they are unsure which direction they are headed.

e. Explain the rules. Guide the participants to the seabed, littered with obstacles (ex. cardboard boxes, balloons, etc). From this point on, the guide should not touch their bacteria guide at all, but rely solely on verbal cues (e.g. "In approximately five steps ahead, there is an octopus. Go ahead and step to the right three steps, slowly.") Remind them that the guide is solely responsible for his or her partner's safety. He or she try their best to steer their partner away from obstacles and their partner will have their own chance to guide.

As the light for flashlight fish to "see" as they travel through the water in search of prey, bioluminescent bacteria must verbally guide the fish where the food is located, pick up a bean with one hand, hold it at a distance from the fish, and guide the fish to their hand with the beans is: ex. an inch more, higher, etc, as they travel through the seas. When they complete the activity and safely finish getting food from all locations in the sea, they will switch places.

f. The pair who can complete the route the fastest wins.

Challenge: Incorporate predators (students) who are either mobile or must stand still for the flashlight fish to have to avoid, with the help of their bacteria.

Challenge: Create difficulty by selecting certain "bacteria" not to "glow." Inform certain "flashlight fish" they are "in the dark" and will not get instructions as to where the beans are, but must find their own way. Set a time limit.

1. Inform certain "bacteria" and "flashlight fish" that the glowing bacteria are not available and they must find the mixed beans on their own.

2. Set a time limit.

3. Discuss the advantages and difficulty in having or not having their "glowing light."

BBC Nature Online Game: Dive to the Abyss

Exploring the Three Light Zones

Materials:

- Computer Access
- Game site: http://www.bbc.co.uk/nature/blueplanet/alien/flash/main_game.shtml

Reiterate to your students that *we* are going down, this is our dive, our mission!

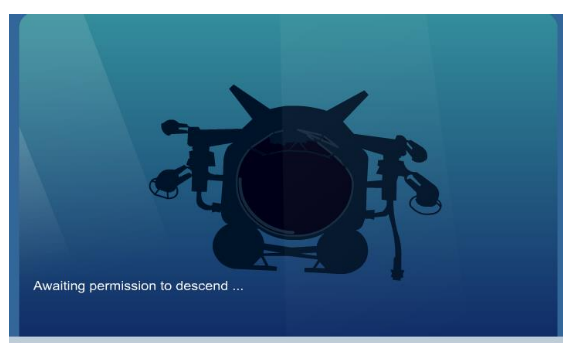
Divide students into pairs or groups and have them access the website. Positioned at the edge of the mid-atlantic ridge, the Abyss team (your students) must prepare to dive in one of the world's only submersibles capable of diving into the pitch black deep ocean. At 2,300 meters down, the pressure begins to build and our team is keen to discover if there is any life down in the unknown underwater world. *Watch video from the real-life BBC Wildlife Abyss team:*

- Preparing to dive at https://www.youtube.com/watch?v=evrlnLAvOhI
- This second clip includes brilliant footage of the Grenadier fish, the Caimira fish and the Dumbo Octopus. https://www.youtube.com/watch?v=utELpCi7ywI.
- Watch as a huge rare 6 gilled shark appears in front of the submersible vessel https://www.youtube.com/watch?v=sQhuWlCltrc
- Sir Leonard gets up close and personal with a giant octopus. Would you be happy to get this close to an Extreme Animal with giant eys and pale blue blood? Find out now as you take a dive into this beautiful aquatic environment. http://www.youtube.com/watch?v=lwAqhThd_EQ

Instructions for Students

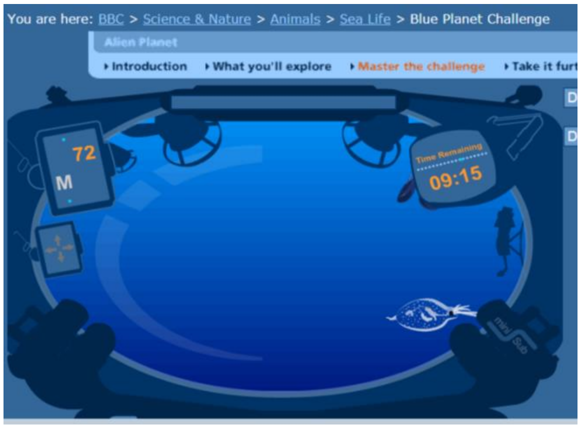
Our goal is to explore three main zones as we descend into the deep ocean: the twilight zone between 200m and 1000m, the dark zone between 1000m and 4000m and the abyssal plain at 4000m.

As we descend, we only have 10 minutes to collect a total of nine deep sea animals, as outlined in the list of dive objectives provided by Captain Fothergill. We'll be awarded points for each one we correctly sample and label.



To drive your sub and find the animals, drag your cursor up, down, left and right and you'll be able to move around the screen. You can click on the animals to find out more about them.

If you think they're relevant to your dive objectives, press the 'Take sample' button and add them to your selection. Then identify the correct label by picking one from the 'Select Category' option.

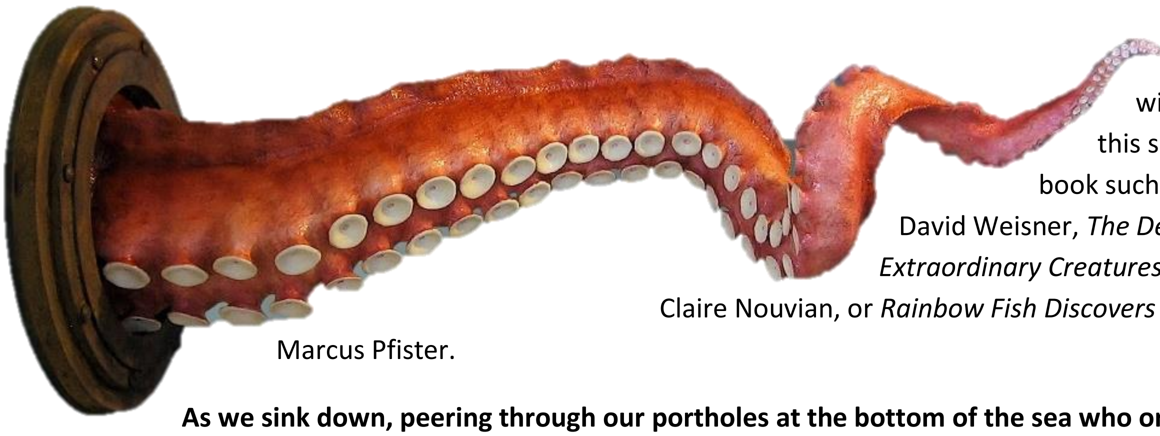


You can check your dive objectives and re-read the instructions at any time by clicking on the appropriate button.

After 10 minutes, you'll be transported back to the surface for a debrief by Captain Fothergill, and a chance to top up your score.

You can take the dive again and you'll have a different selection of objectives. The team with the highest score at the end of their dives wins the title of Lead Expeditioners!

Portholes: Windows to the Deep



You might wish to introduce this section with a book such as *Flotsam* by David Weisner, *The Deep: The Extraordinary Creatures of the Abyss* by Claire Nouvian, or *Rainbow Fish Discovers the Deep* Sea by Marcus Pfister.

As we sink down, peering through our portholes at the bottom of the sea who or what might be looking back? Have you seen only suckers as the giant squid tries to take over our ship? The giant eye of a whale? Sunken ships and vast treasure? The curious eyes of a passing mermaid? Blue lights dancing from bioluminescence? A lost city under the sea? What else could there be?

One scientist described what she saw this way. What she saw in the darkness rivaled Van Gogh's Starry Night—plumes and blossoms and flourishes of brilliance. "There were explosions of light all around, and sparks and swirls and great chains of what looked like Japanese lanterns," she remembers. Light popped, smoked and splintered: "I was enveloped. Everything was glowing. I couldn't distinguish one light from another. It was just a variety of things making light, different shapes, different kinetics, mostly blue, and just so much of it." Sometimes, the mystery animals outside were so bright that Widder swore the diving suit was releasing arcs of electricity into the surrounding water. Once, "the whole suit lit up." What she now believes was a 20-foot siphonophore—a kind of jellyfish colony—was passing overheard, light cascading from one end to the other. "I could read every single dial and gauge inside the suit by its light," Widder remembers. "It was breathtaking." It went on glowing for 45 seconds.

Have students use new art techniques and hair gel to make their own amazing 3-dimensional artwork where their image appears to be under water! Kids go crazy for this technique as it is quite fun to squish around!

Materials:

- Cheap **clear** or very light blue hair gel (Clear or light blue works best, it will make whatever image they place behind it seem as though it's floating in water!)
- Zipper-seal sandwich or other appropriate sized bags (needs to fit inside porthole opening)
- Double sided tape, craft glue, or flat glue dots
- Glue
- Scissors
- Art materials (ex. watercolors, construction paper, colored pencils, pastels, etc.)
- Fine Glitter

Have students use art materials to create a multimedia or single medium artwork demonstrating their vision of what they might see in the deep blue sea if they looked out a porthole.

Tip: Visually write the instructions out on the white board using symbols and have the students try to solve or decode what the next step is. A student gets to erase a step as the group completes them. This technique can help keep everyone engaged and at the same pace.

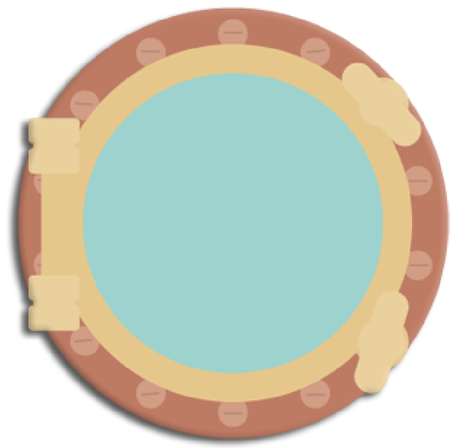
Variation: What might a fish-eye-view of you through a porthole look like?

How to make the "water"

Have students squeeze a little hair gel into their zipper seal bag, approximately a teaspoon or so for a very small bag (make sure to use a bag without a gusset down the middle because it will show through the gel). Only add enough to cover the inside of the bag. Too much gel might cause the bag to "pop" later on. Also, too much hair gel will make your artwork too thick and will make it difficult to glue your frame to the rest of the card

Option: Add a little bit of small glitter for sparkle.

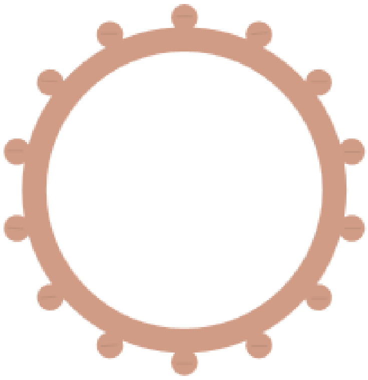
Press excess air out of the bag, close it and spread the gel evenly over the entire inside of the bag. Be sure to remove ALL of the excess air from the bag before you zip it closed. Don't try to avoid air bubbles - they look pretty and they're what makes it look like water!



Make a porthole:

1. Paper: Have students use construction or craft paper, measure, and cut out thick circles to go around their artwork. This can be put over a rectangular sheet of construction paper or cardstock with the same sized hole cut out of it as the porthole. This will make it easier to attach the bag. Either way, make it large enough to leave about a 3/4" of an inch all around your image, or the part of the image you want to show.

2. Add screws and metal work



3. Add rivets and “brass” details with additional paper shapes in another color, ex. Add rivets to the bottom of the plate with a marker pen. Just draw small circles at intervals around your porthole.

4. To create weathering, shading, fine details, etc. have students use a marker pen, and/or or oil pastel.

Putting it all together:

Turn your porthole around and add double-sided tape or other adhesive around the back of your porthole opening. Adhere your gel bag over the opening. The gel bag should be attached securely so that none of edges show around your frame.

Adhere your scene behind the window so it faces out through the porthole. Make sure to place the image in the center and check that it lines up when covered. This is a wonderful touch and feel art technique. No one can resist playing with it for a bit!

Samples of Porthole Art

Image Credit: Jasmine Ann Becket-Griffith. http://www.ebsqart.com/Artist/Jasmine-Ann-Becket-Griffith/56/Art-Portfolio/Portholes-to-Fantasy-5-ORIGINAL-PAINTING/677034/. All Rights Reserved. Copyright 2011.

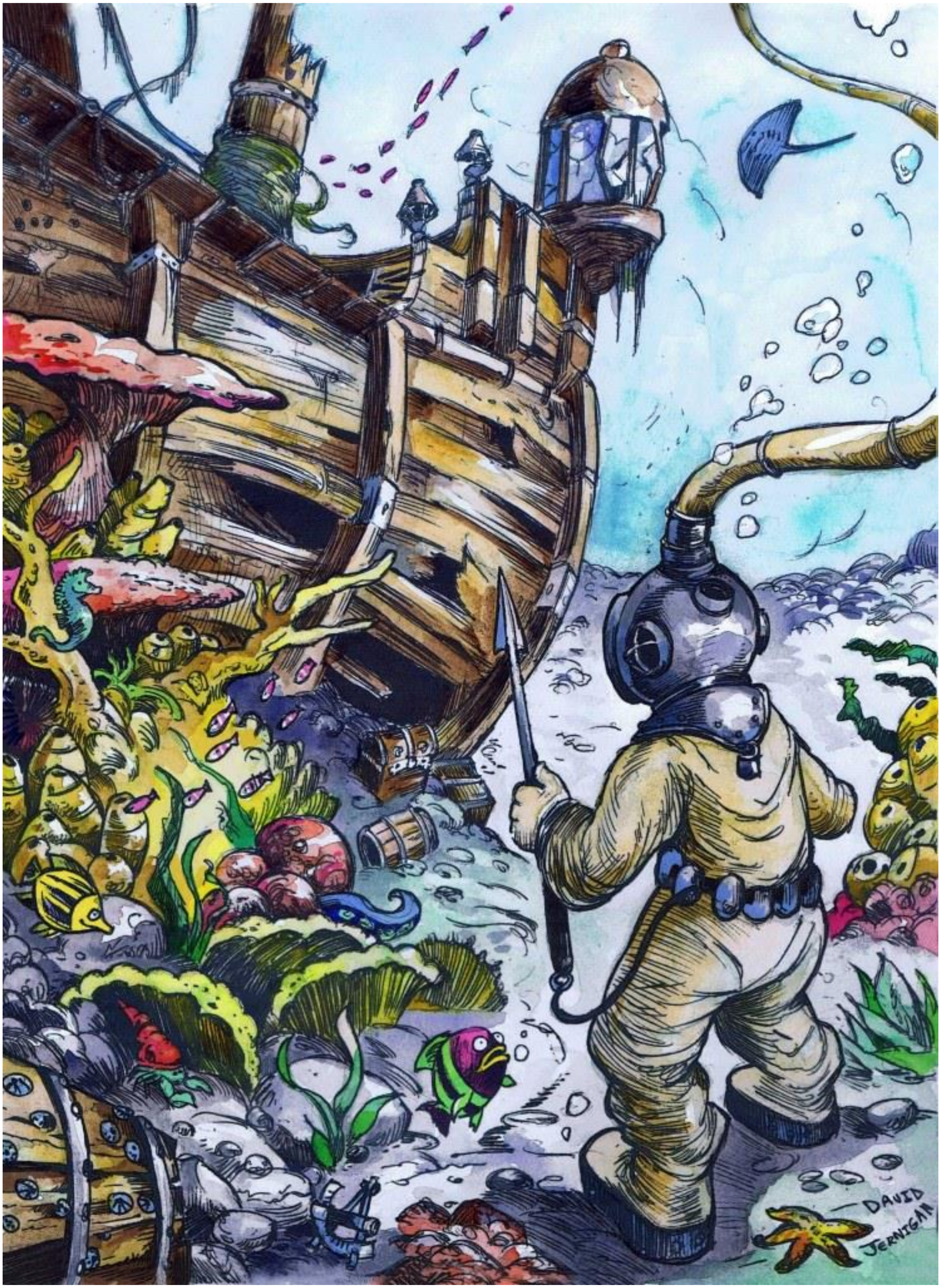


Image Credit: Dave Jernigan. Copyright 2011. http://sketcharound.wordpress.com/category/under-the-sea/

Image Credit: Dave Jernigan. Copyright 2011. http://sketcharound.wordpress.com/category/under-the-sea/

Samples of Sources and Resources

- BBC Ocean http://www.bbc.co.uk/nature/habitats/Deep_sea#p00hn502
- Bioluminescent Learning: http://education.nationalgeographic.com/education/activity/bioluminescence-living-light/?ar_a=1
- BBC Ocean http://www.bbc.co.uk/nature/adaptations/Bioluminescence#p0039dhx
- Ocean Zones http://howtosmile.org/record/13888
- Deep Sea Geysers http://education.nationalgeographic.com/education/activity/deep-sea-geysers/?ar_a=1
- http://www.guardian.co.uk/science/blog/2009/jul/17/human-bioluminescence
- http://kimiachemyst.blogspot.com/2010/05/chemistry-home-experiment-make-things.html

Read more: http://www.time.com/time/magazine/article/0,9171,962873,00.html#ixzz2Q5uI6JsL