Deep Sea Learning: Bioluminescence

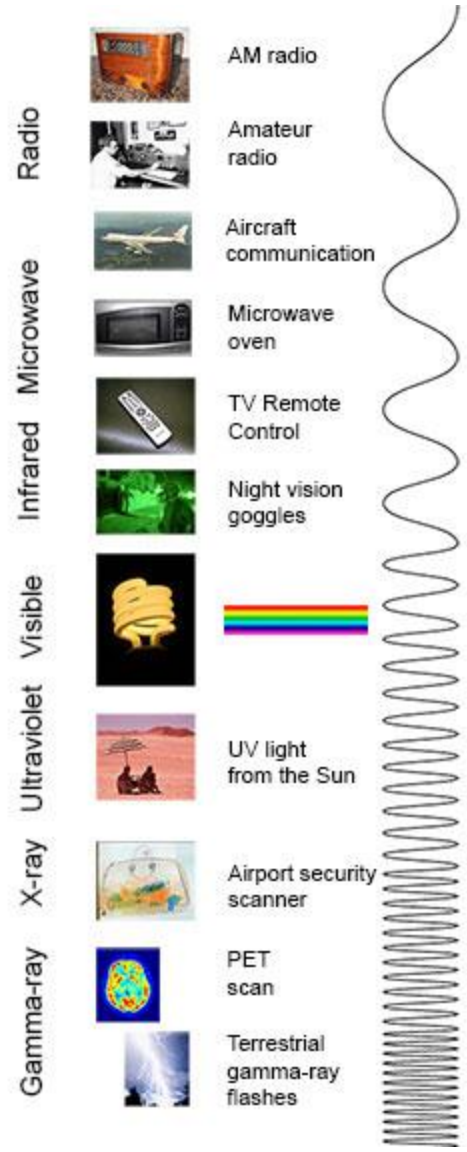
Electromagnetic Spectrum- The electromagnetic (EM) spectrum is the range of all types of EM radiation.

- Radiation is energy that travels and spreads out as it goes – the visible light that comes from a lamp in your house and the radio waves that come from a radio station are two types of electromagnetic radiation.
- The other types of EM radiation that make up the electromagnetic spectrum are microwaves, infrared light, ultraviolet light, X-rays and gamma-rays.

How to break it down for kids: We depend on it everyday. You can't feel it, touch it, hear it, taste it, and sometimes you can't even see it, but it is all around you.

- Similar to ocean waves in that ocean waves and EM waves are both energy.
- Travel through space at the speed of light.
- Our eyes can only see a small part of the spectrum (visible light)
- Watch this website to get a full, easy explanation and also see how the yarn experiment is going to work in the class : https://www.youtube.com/watch?v=cfXzwh3KadE

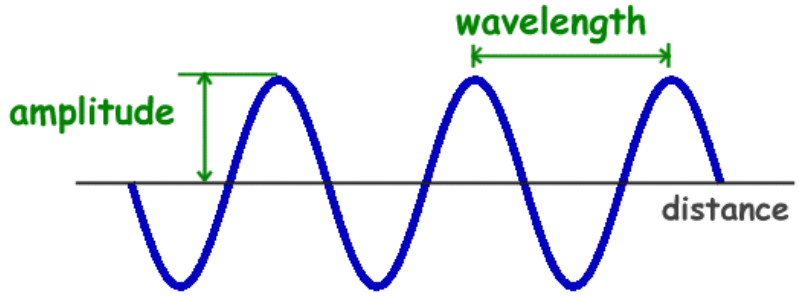
https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html



https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

Wavelength- The distance between adjacent peaks in a series of periodic waves. https://imagine.gsfc.nasa.gov/resources/dict_qz.html

Amplitude- The maximum displacement or distance moved by a point on a vibrating body or wave measured from its equilibrium position. https://www.britannica.com/science/amplitude-physics



https://www.ducksters.com/science/physics/properties_of_waves.php

Frequency- A property of a wave that describes how many wave patterns or cycles pass by in a period of time. Frequency is often measured in Hertz (Hz), where a wave with a frequency of 1 Hz will pass by at 1 cycle per second. https://imagine.gsfc.nasa.gov/resources/dict_ei.html#F

Visible vs Non-visible Light- https://imagine.gsfc.nasa.gov/science/toolbox/emspectrum1.html

- **Radio:** Your radio captures radio waves emitted by radio stations, bringing your favorite tunes. Radio waves are also emitted by stars and gases in space.
- **Microwave:** Microwave radiation will cook your popcorn in just a few minutes, but is also used by astronomers to learn about the structure of nearby galaxies
- **Infrared:** Night vision goggles pick up the infrared light emitted by our skin and objects with heat. In space, infrared light helps us map the dust between stars.
- **Visible:** We perceive this radiation as colors ranging from red (longer wavelengths; ~ 700 nanometers) to violet (shorter wavelengths; ~400 nanometers.)
- **Ultraviolet:** Ultraviolet radiation is emitted by the Sun and are the reason skin tans and burns. "Hot" objects in space emit UV radiation as well.
- **X-ray:** A dentist uses X-rays to image your teeth, and airport security uses them to see through your bag. Hot gases in the Universe also emit X-rays.
- **Gamma ray:** Doctors use gamma-ray imaging to see inside your body. The biggest gamma-ray generator of all is the Universe.

Light Wave Absorption and Reflection- https://science.nasa.gov/ems/03_behaviors

- When a light wave encounters an object, they are either transmitted, reflected, absorbed, refracted, polarized, diffracted, or scattered depending on the composition of the object and the wavelength of the light.
- Reflection is when incident light (incoming light) hits an object and bounces off. Very smooth surfaces such as mirrors reflect almost all incident light
- Absorption occurs when photons from incident light hit atoms and molecules and cause them to vibrate.

- The color of an object is actually the wavelengths of the light reflected while all other wavelengths are absorbed.

Yarn Waves Game:

- Start by asking the students if they can list types of waves
- If they can't start your string at the microwave. If they come up with an example start at that. (ie cell phone/tablet/laptop/radio)
- Have a student hold the end of the string at the first item (microwave)
- Ask the students for another example or give them one (cell phone) Ask who has a cell phone and then roll the string out to that second item.
- Continue this for every item in the room that is giving off waves that you can think of.
- The end result should be a mess of strings all across the room, showing off how many waves surround us all the time.

Link for the Diver Video: https://www.scubadiving.com/video-shows-how-scuba-divers-see-colors-change-underwater

This is an article by NOAA on why so many deep sea fish are red: https://oceanexplorer.noaa.gov/facts/red-color.html

Ozone and UV Filtration-

- UV Water Purification systems use special lamps that emit UV light of a particular wavelength that have the ability, based on their length, to disrupt the DNA of microorganisms. These UV light waves are also referred to as the Germicidal Spectrum or Frequency. The frequency used in killing microorganisms is 254 nanometers (nm). https://www.espwaterproducts.com/understanding-uv/
- Ozone is one of the strongest disinfectants. It is generated onsite by an ozone generator that uses either dried air (requiring air dryers and compressors) or liquid oxygen. Different ozone dosages are required for different pH levels.
- Because of its high oxidation potential, ozone oxidizes (combines oxygen with) cell components of the bacterial cell wall. It enters the cell and oxidizes all essential components (enzymes, proteins, DNA, RNA). When the cellular membrane is damaged during this process, the cell will fall apart. This is called lysis. https://www.lenntech.com/library/ozone/disinfection/ozone-disinfection-mechanism.htm#ixzz5lwB2ig26

Color Spectrum and Waves

- Color is within the visible light spectrum on the electromagnetic spectrum. Each wavelength color sends out, our eyes perceive it as different colors.
- Colors like purple have shorter wavelengths
- Colors like red have long wavelengths.
- From short waves to long waves the colors go from purple to blue to green to yellow to orange and lastly with the longest waves are red.

- Insects can see colors that humans cannot. They can see ultraviolet waves, waves that are just before purple on the spectrum. Insects cannot see colors like red.
- A lot of light that we see like the light coming from a light bulb is a mixture of all the visible light waves. This is called white light. When mixed, it becomes very difficult for our brains/eyes to be able to separate the different colors.
- When light passed through materials such as water droplets, the light can bend where each color wave can be differentiated. When this occurs, it creates what we call a rainbow.

https://idahoptv.org/sciencetrek/topics/light_and_color/facts.cfm

Vet Services

X Ray machine:

- As waves of light decrease, they increase in energy. X-rays have smaller wavelengths making them have more energy.
- The x-ray was accidentally discovered in 1895 by Wilhelm Conrad Roentgen, who was a scientist living in Germany. It got the name "X" ray because at the time they were unaware of how much radiation an x-ray was giving off.
- X-rays show the shadows left behind by the things that an x-ray cannot travel through. X-rays cannot see skin or clothes, only bone or metal-like material.
- When you get an x-ray, an x-ray sensitive film is put on one side of your body and the x-ray is shot through you. You cannot feel x-rays at all.
- Bones and teeth are dense and absorb x-rays and a silhouette will be left behind on the film after the x-ray is taken. Metal can be seen even more on an x-ray.
- Things in space give off x-rays. Black holes, neutron stars, binary star systems, supernova remnants, stars, the sun, and some comets. These things in space emit very high temperatures and when something is heated to over a million degrees it will give off x-rays

https://www.nasa.gov/audience/forstudents/5-8/features/F_X_Rays.html

Ultrasound machine: the ultrasound image is produced based on the reflection of waves that bounce off the body and what's inside the body.

Fluorescing Laundry detergent Activity

Set up - prep will need educators to fill cup with hot water or microwave water from seaside classroom sink. After water is heated up, put a small amount of laundry detergent (couple drops or ½ oz) in the cup. Will need one cup prepped this way per route running. (4 routes running, 4 cups)

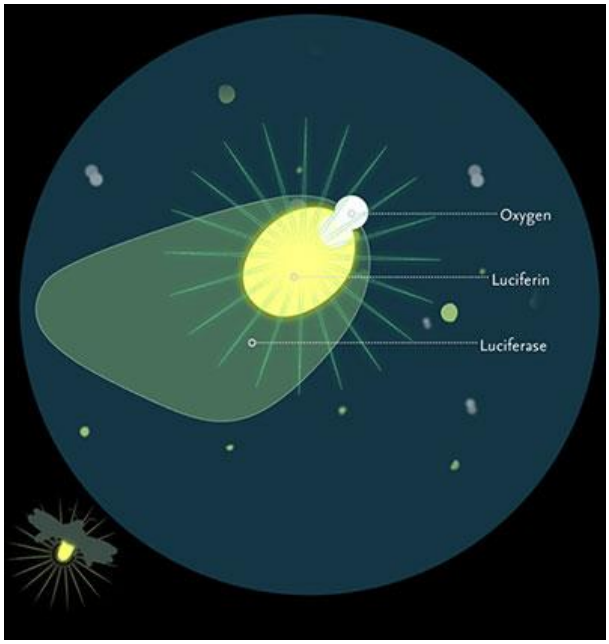
Activity-

- Instructor will take a prepped cup with detergent and tell the students what is inside.
    - Laundry detergent with a whitening agent : bleach
    - Hot water

- Have students take turns to hold the cup under the black lights.
- Observe the change in light.
- Remove the cup from the light and observe if the detergent continues to glow.
- Have students stand under the light and observe what changes occur under the light.

Light and Organisms

- Bioluminescence:
    - Bioluminescence occurs when an organism produces light through chemical reactions, either on its own or with the help of symbiotic bacteria.
    - Is the production and emission of light by a living organism.
    - Very unique because it requires input from no other form of energy source other than the food organisms may be consuming or the organism itself.
    - There are proteins called luciferins that store energy in the form of excited electrons. The electrons are freed from their bonds by the enzymes called luciferases.
    - Generates almost zero heat.
    - It is referred to as a 'cold reaction' because nearly 100% of the energy consumed during bioluminescence is the reaction given off as 'cold light' of the glowing organisms.
    - Possible uses for bioluminescence: lure prey, attract a mate, counter-illumination for camouflage
        - examples: fireflies, angler fish

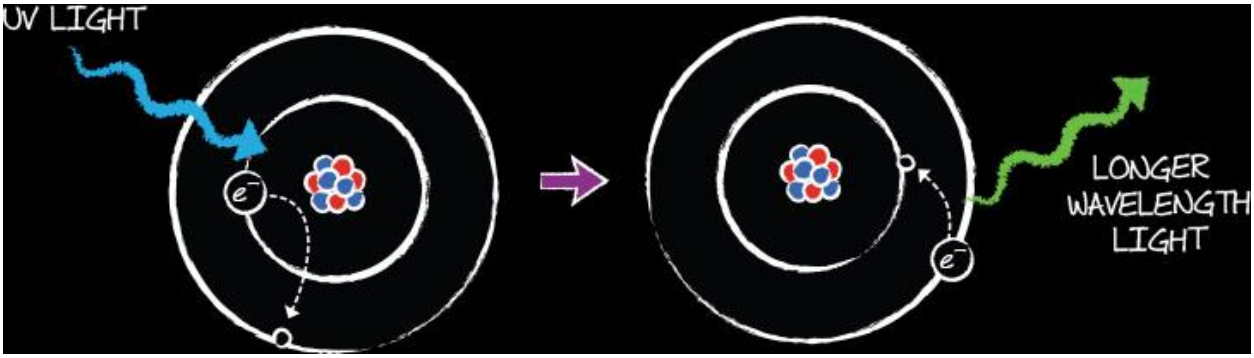


https://www.newsdeeply.com/oceans/articles/2018/07/13/inside-the-frenzy-for-japans-mysteriously-glowing-firefly-squid

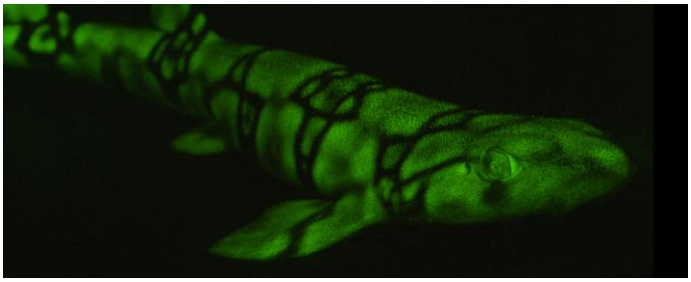
Biofluorescence:

- Biofluorescence occurs when an organism reflects invisible UV light back at a slightly lower frequency, making it visible to the human eye. These animals appear to glow in the dark because they are reflecting invisible light in a way that makes it visible, while the surrounding environment seems dark.
- Not a chemical reaction because it is not the animal producing their own light or creating a power source.
- Instead, they absorb light and transform it to re-emit it as a completely different color.

- When the specialized fluorescent molecules are ‘excited’ by high energy UV or blue light, they lose some of their light energy and release the rest as a low-energy wavelength. This is the green color that humans will see.
- On an atomic level, the fluorescent molecules absorb photons (very small light parcels) given off by the external or added light. The photons getting excited is the reaction of them colliding with the fluorescent molecules and bumping its electrons to a higher energy state.
- Once in their excited state, the electrons relax to their original state, but in the process of relaxing, they release all the extra energy as new light. This emits longer wavelengths of light and it's all happening between a trillionth and a millionth of a second. Humans cannot see this, but can see the photons changed state which is the visible color change of shiny green or even a rainbow.



- Many organisms have only been recently discovered to be biofluorescent because it takes certain specific conditions for this effect to be visible to humans. Because it’s a fairly new area of study, not much is known about why some organisms might possess this trait.



https://www.the-scientist.com/image-of-the-day/image-of-the-day--fluorescent-sharks-66263
http://www.luminescentlabs.org/science.html

- Important Note:
  - Sometimes a Google search for “bioluminescence” will bring up a lot of images of iridescence or fluorescence instead because many publications that don’t specialize in biology incorrectly use the terms interchangeable, so watch out when looking for examples!
- Bioluminescence can happen in complete darkness because the organism *creates* the light. In contrast, biofluorescence and iridescence only cause changes to existing environmental light, so they cannot occur in complete darkness.

Make your Own Light Activity (Triboluminescence)

Wintergreen lifesavers & triboluminescence

- Similar to the electric charge build up that produces lightning
- Triboluminescence: the emission of light resulting from something being smashed or crushed. It is similar to the build-up of electric charge that produces lightning. It occurs when molecules (such as the crystalline sugar molecules in a Wintergreen Lifesaver) are crushed and force some electrons out of their atomic fields. The free electrons bump into nitrogen molecules in the air and when they collide, the electrons deliver energy to the nitrogen molecules, causing them to vibrate. In this excited state and in order to get rid of extra energy, the nitrogen molecules emit light. This light is mostly ultraviolet (non visible) – but with this activity you can see some of the visible light produced by this chemical reaction!

1. This activity works best with wintergreen flavored candy because of the oil fluorescence that enhanced the light.
2. Brighter light is produced by this type (methyl salicylate)
3. It is fluorescent, meaning it absorbs light of a shorter wavelength and then emits light of a longer wavelength.
4. Ultraviolet light has a shorter wavelength than visible light.
5. When the lifesavers are crushed, the methyl salicylate absorbs the ultraviolet light (shorter waves) by the excited nitrogen and readmits it as visible light. (blue light in this case)

Activity for students to do at home;

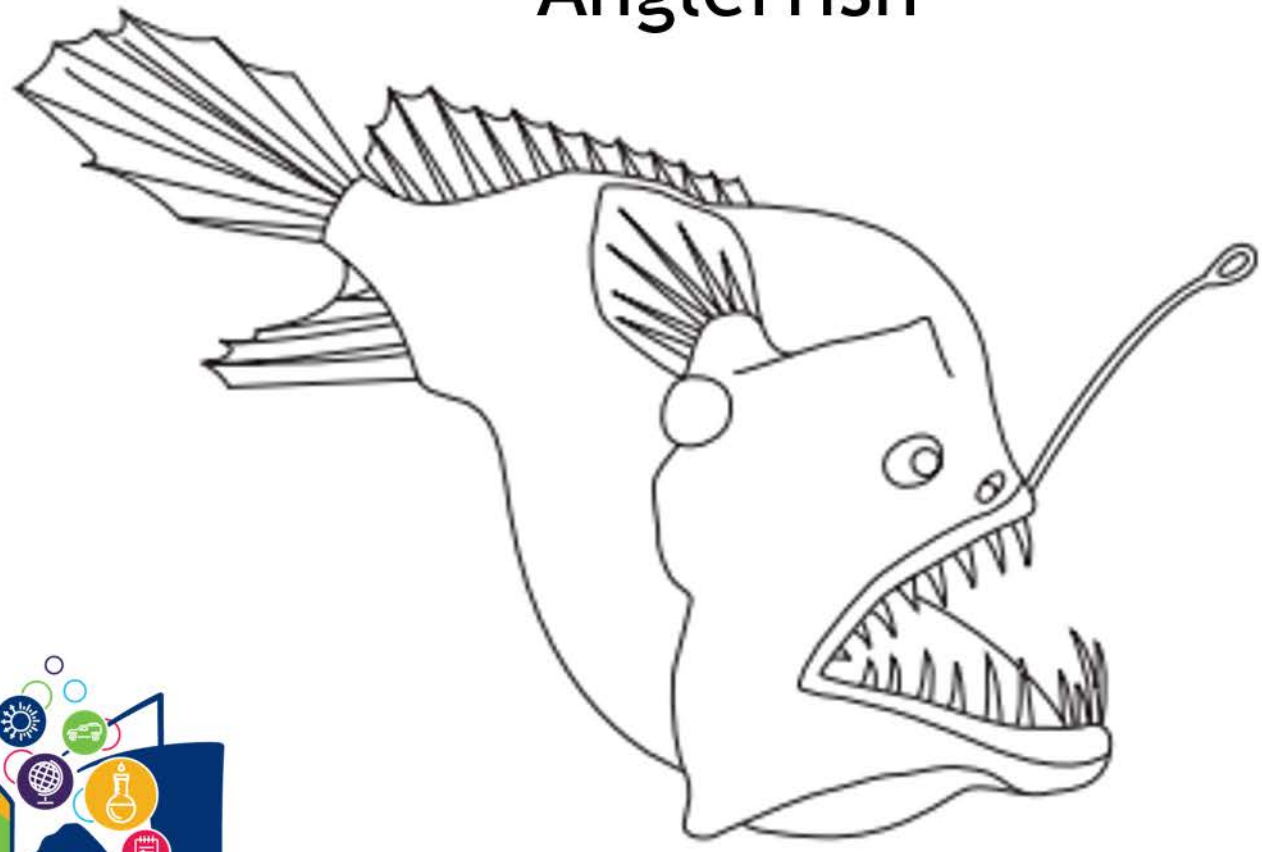
Materials:
Paper towel
A dark room
A mirror, or do the activity with a friend
Wintergreen Lifesavers

1. First, make sure your mouth is dry by putting a paper towel in your mouth.
2. Find a room that can be made very dark, with a friend or a mirror (a bathroom without windows is a great place!)
3. Turn out the lights and make the room as dark as possible.
4. Chew a piece of Wintergreen Lifesavers candy with your back teeth.
5. Open your mouth and look in the mirror; or show your friend.
6. Watch closely for the blue sparks that should emit!
7. Watch closely for the blue spark that will admit.

Helpful Resources:
Fluorescence: https://www.youtube.com/watch?v=O9og_we5EZM

Fluorescence: https://gpb.pbslearningmedia.org/resource/nvcol-sci-biofluore/wgbh-nova-creatures-of-light-how-biofluorescence-works/#.XXFrVyhKiM9
Fluorescent sharks: https://owlcation.com/stem/Biofluorescence-Colored-Light-Emission-by-Marine-Animals
Luminescence: https://www.youtube.com/watch?v=oKjFVBVGad0
http://www.luminescentlabs.org/science.html

Anglerfish

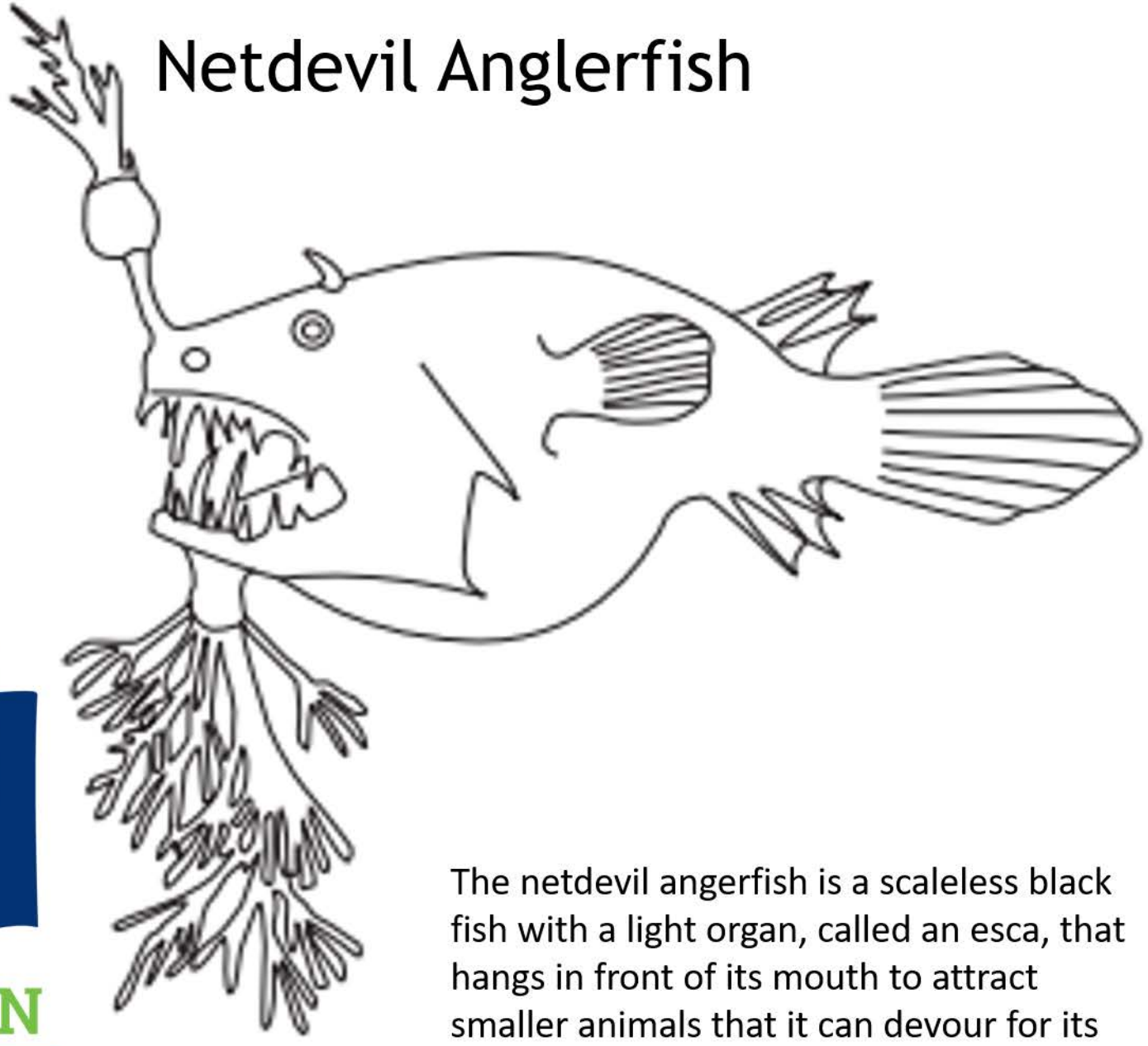


EDUCATION

GEORGIA AQUARIUM

Most anglerfish live at depths below 1,000 meters in the ocean. They are not streamlined, have huge mouths and expandable stomachs. Instead of using their energy to find food, the female anglerfish has an elaborate, glowing lure that acts as a fishing rod. The glowing bait attracts small fish and shrimp to her mouth.

Netdevil Anglerfish



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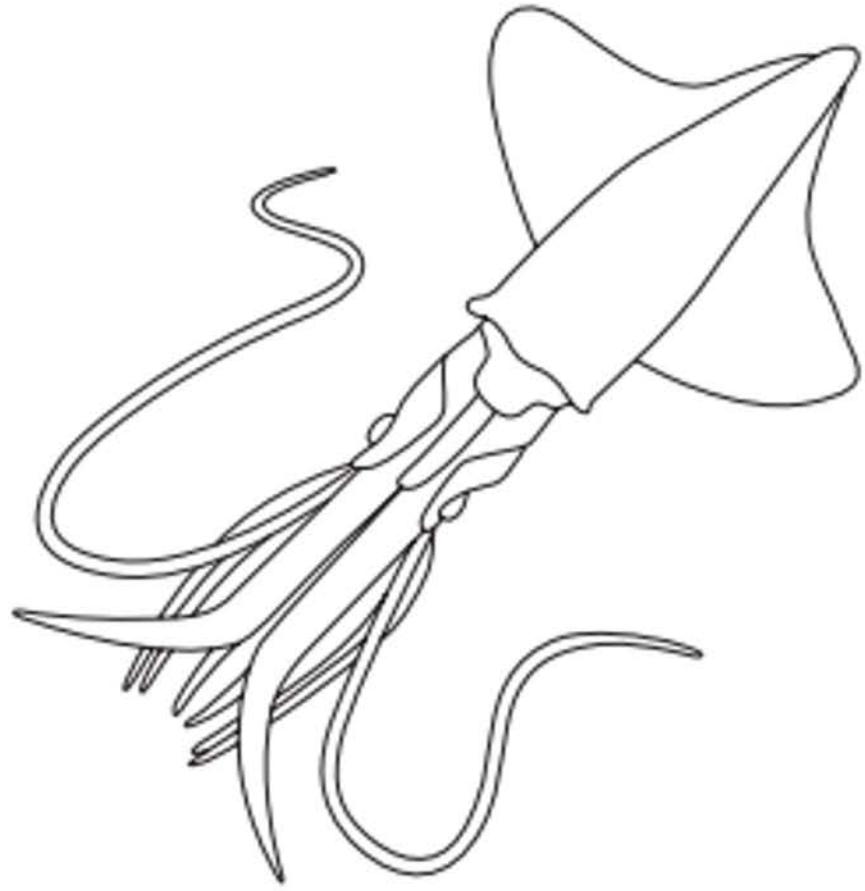
The netdevil angerfish is a scaleless black fish with a light organ, called an esca, that hangs in front of its mouth to attract smaller animals that it can devour for its dinner. It also has a light organ that dangles from its chin.

Bioluminescent Squid



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Squids are closely related to octopus and have eight arms and two long tentacles. Some species of squid are bioluminescent. One type squirts a cloud of glowing ink, confusing predators by the sudden glow and giving the squid the chance to escape.