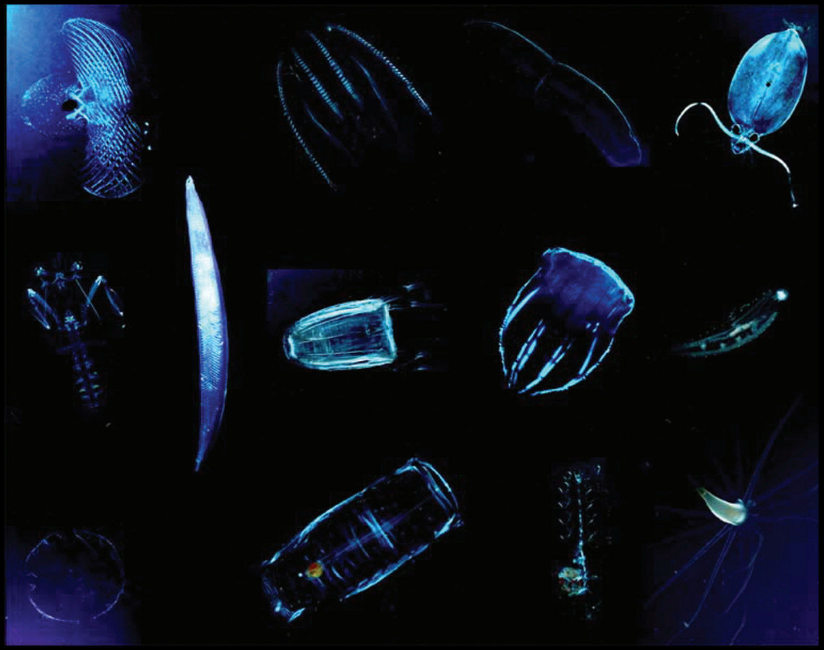
Do You Have Twisted Vision?

Now you see them, now you don't!

Some marine animals are nearly invisible to the human eye, but become much easier to see if viewed through a polarizing filter. If you have ever put on a pair of polarized sunglasses to reduce glare, you have first-hand knowledge about how a polarized filter can make things easier to see.

Many animals, including fish, insects, birds, crabs, and shrimp have built-in polarized vision that helps them find food, avoid predators, navigate, and communicate with mates. Scientists know very little about how animals see in the deep ocean, and it's quite possible that many animals have been able to avoid being seen by deep ocean explorers. Maybe some animals can't be seen at all with ordinary human vision, even if they are right in front of us!

The Ocean Explorer Deep Scope Expeditions looked into the deep ocean with new eyes, including high-tech cameras that can see animals under extremely dim light, as well as instruments to observe animals that make their own light (bioluminescence) or use various types of polarization vision. Here are some simple experiments you can do to start exploring with polarized light.



A gallery of images of plankton viewed between two polarizers. In this particular setup, a normal transparent object would still be invisible. However, if the object, or animal, contains any birefringent (doubly refractive) substance, it will appear quite bright. Tissues such as muscle and tendon can be highly birefringent and are responsible for almost all the bright areas on these images. Photo composite: S Johnsen using images from E. Widder.

What You Will Do

Experiment with polarizing filters, and find out whether you have polarization vision

What You Will Need

- ❒ Two pieces of polarizing filter material from an old pair of polarizing sunglasses, or you can buy polarizing filters from educational supply companies (*https://www.teacher-source.com*; about $65 for a 15 inch x 17 inch sheet). The material will be marked with an arrow that shows the "polarization axis." If you cut the filter into pieces, use a felt tip marker to draw an arrow pointing the same way on each of the pieces.
- ❒ Plastic protractor, drafting triangle, and/or clear plastic fork

Warning

NEVER look directly at the sun, even through polarized filters!

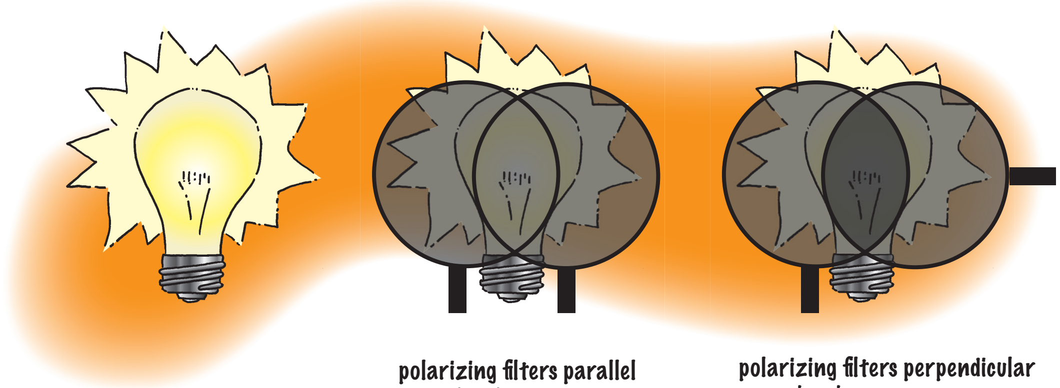
How to Do It

1. Shine a light through a single piece of polarizing filter material. Some of the light will be absorbed by the filter, but it probably won' t matter very much how the filter is rotated. Take the filter outside, and look at blue sky, away from the sun. Now, if you rotate the filter the sky will appear darker and then lighter. Most light passes through when the filter is lined up with the direction of the polarized light.
2. Put a second piece of polarizing filter material on top of the first filter and shine a light through the combined filter. When one of the filters is rotated, you will see that most light comes through when the polarization axes of the filters are pointing in the same direction (parallel). Less and less light passes through as the angle between the polarization axes increases, to a point at which almost no light is transmitted when the polarization axes are perpendicular to each other.

This is an example of birefringence, which is what happens when materials bend polarized light in different directions. Birefringence occurs in many living tissues, and can make food organisms much more visible to marine animals with polarized vision.

Note: Not all plastic objects show birefringence. If some of your plastic objects don't work, try some others!

The Effect of Polarizing Filters



3. Place a plastic protractor, drafting triangle, or clear plastic fork between two sheets of polarizing filter material and shine a light through the stack. When one filter is rotated, bands of color will appear and move over the surface of the plastic object. Flexing the object may reveal stress lines in the material.
4. If human eyes could detect polarized light, you wouldn' t need the second filter in these demonstrations. But some humans do seem to have very limited polarization vision. To find out if you are one of them, try this: Face blue sky, away from the sun, and concentrate on the center of your visual field (the area

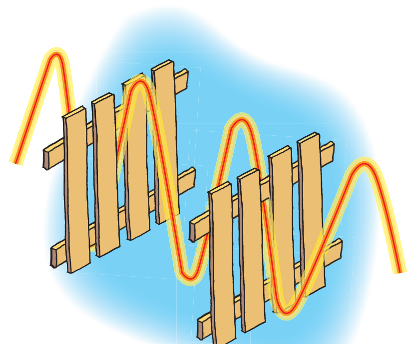
of sky that you can see). If you see a fuzzy yellowish horizontal bar or bow-tie shape, you are seeing "Haidinger's brush," and you have a limited form of polarized vision! You can also try to see Haidinger's brush by looking at a bright background (such as a well-lit white wall) through polarized sunglasses.

5. Why do you suppose so many invertebrates have polarized vision while humans do not? Part of the answer is that the human eye consists of a single lens that focuses an image onto light-sensitive cells in the retina that transmit nerve signal to the brain. Many invertebrates have compound eyes made of hundreds (or thousands) of "simpler" eyes called ommatidia. Each ommatidium has a lens, crystalline cone, and visual cells containing rhodopsin. In vertebrates, the visual pigment molecules are randomly oriented, but in many invertebrates these molecules are lined up in the same direction. This makes it possible for these animals to detect polarized light.

What's Happening

We can imagine light as vibrating particles of energy moving in a series of waves, sort of like the particles of water that make ocean waves. In some light waves, the energy particles are vibrating in many different directions. These light waves produce unpolarized light. If the energy particles are all vibrating in the same direction, the light is said to be polarized. Most light, including light from the sun, from ordinary light bulbs, and from candles is not polarized. Unpolarized light can be transformed into polarized light in several ways, including passing light through a filter that only transmits light waves that are vibrating in a single direction. Light waves vibrating in other directions are blocked.

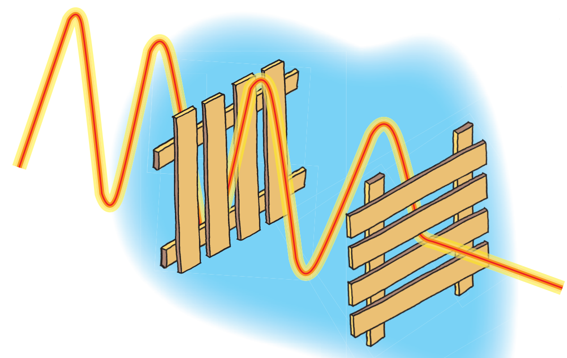
It may be easier to understand this kind of polarization by imagining a picket fence with a rope passing between the pickets. If we raise and lower one end of the rope to make a wave, it' s easy to understand that the wave can only pass through the fence if the wave is parallel to the pickets, like this:



"rope" wave passing through parallel picket fences

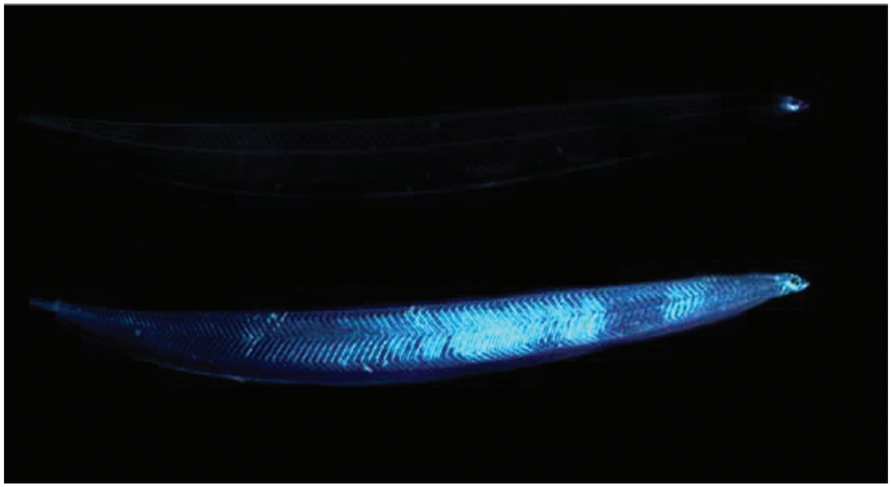
A wave in any other direction would run into the pickets and be stopped. The same thing happens in a polarizing filter, except the molecules of the filter material are lined up instead of the pickets in the fence.

The picket fence also helps understand what happens when light is passed through two polarizing filters. If the rope passes through two picket fences, a wave in the rope will only be transmitted if the pickets in both fences are parallel. If one of the fences is rotated, the wave will be blocked, like this:



"rope" wave blocked when one fence is rotated

So, if we hold two polarizing filters in front of a light source, and then rotate one of the filters, we will see the light grow brighter as the molecular "pickets" in the two filters become parallel. Light can also be polarized by reflection from non-metallic surfaces such as roads, snow, and water. The amount of polarization depends upon the type of surface and the angle at which the light approaches the surface. Glare from these surface can be reduced or eliminated by polarizing filters (such as sunglasses) whose molecular "pickets" are not parallel to the vibration direction of the reflected light waves. Light can also be partially polarized when it is scattered off of particles in the atmosphere.



Two images of the same leptocephalus eel larva. The top image is viewed under unpolarized, transmitted light. The bottom image is viewed under polarized, transmitted light by a camera with a polarizing filter. The increased visibility of the bottom image is due to the presence of birefringent muscle and connective tissue fibers. Photo composite: S Johnsen using images from E. Widder.

Want to Do More?

One of the most famous examples of polarization vision is the discovery by Karl von Frisch that bees detect patterns of polarized light in the sky, and communicate directions to each other by dancing in a specific pattern.

- For more information about Karl von Frisch and his bees, visit polarization.com/bees/bees.html.
- For more information about Haidinger's brush and polarization vision in humans, visit polarization.com/haidinger/haidinger.html and theconversation.com/polarised-light-and-the-super-sense-you-didnt-know-you-had-44032
- For more information about the Ocean Explorer Deep Scope Expeditions, visit:
  - oceanexplorer.noaa.gov/explorations/05deepscope/welcome.html

–"Secret Communication Channels in the Ocean: Polarization Vision"
oceanexplorer.noaa.gov/explorations/04deepscope/background/polarization/polarization.html

–"Hiding in Plain Sight: Birefringence"
oceanexplorer.noaa.gov/explorations/04deepscope/logs/aug15/aug15.html

–"Measuring Vision in Crustaceans"
oceanexplorer.noaa.gov/explorations/04deepscope/background/vision/vision.html

This Caranchid squid, about four-inches across, uses transparency to hide from potential predators. Open-water divers can more easily observe these creatures with polarizing filters. Compare the polarized and unpolarized images to one another. Images courtesy Edie Widder.

This activity is adapted from "Twisted Vision," a lesson from the Ocean Explorer Operation Deep Scope 2005 Expedition (oceanexplorer.noaa.gov/explorations/05deepscope/background/edu/media/twisted.pdf); by Mel Goodwin, PhD, Marine Biologist and Science Writer, Mt. Pleasant, SC.