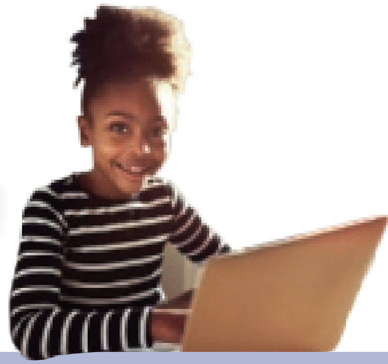
Core Knowledge® SCIENCE

Light and Matter:

Why do we sometimes see different things when looking at the same object?

Science Literacy



Science Literacy Student Reader

Transmission and Reflection

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Light and Matter

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Core Knowledge®

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Light and Matter

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Put Yourself in This Scene

It's 9:00 p.m. on a weeknight. You have brushed your teeth and turned off the lights in your room. You've just started to do some reading on your tablet when your dad walks in.

"Hey there," he says. "New rule. No more screens after eight o'clock on school nights. But you can use them until nine on Friday or Saturday because you can sleep in on weekends."

"What?" you exclaim. "I do this every night! It's my way of winding down, and I'm not even goofing off or playing games or watching videos. I'm reading! You guys always tell me you want me to read more. So . . . what's the deal?"

"The deal is we just heard something on the news about how these devices are bad for eyes, especially developing eyes like yours. Something about the blue light."

"Blue light? This screen isn't blue!"

"That doesn't mean it isn't emitting blue light. It just means the dominant color isn't blue. All these screens emit lots of blue light."

But this screen isn't blue! It's mostly white, like the page of a book!"

Your dad continues:

"Think about the sunlight that'll come in here in the morning. It probably will seem white or yellow, but it has all the different wavelengths of light, including blue. The screen of your tablet and my phone and Mom's phone and our computers and the screen on the dashboard of the car are all giving off a lot of light, blue included. And we just heard that it's bad for your eyes. It also makes it harder for you to get to sleep. So, the new rule is you turn off your tablet and other devices by eight on school nights so you have a better night's sleep and your eyes aren't shot by the time you get to be my age."

This doesn't seem fair. You ask, "What about you? Are you guys gonna stop watching TV and put down your phones at eight o'clock?"

"It is much more important when you are young."

"NO FAIR!"

"Sorry! Goodnight!"

You plan to get to the bottom of this. Just because your parents heard something on the news doesn't mean it was right or that they interpreted it correctly. You'll get on the internet to trace where they heard this . . . but you realize it'll have to wait until tomorrow, because you can't get on the internet without a screen.

That's what this book is about—scientific literacy, which means knowing how to think about science topics that you read or hear about. Our world has 24-7 news, social media, and too many websites to count. The amount of information we have to sort through is overwhelming, and all the information is not reliable. In the internet age, sources of information are often obscure or not trustworthy. It is good to process information with a healthy degree of skepticism. We will make our way back to this blue light topic by the end of the book. Along the way, the series of reading selections and the writing exercises that go with them will help you flex your mental muscles and sharpen your science literacy skills. The ability to read about science, understand the information, and tell truth from fallacy or misrepresentation is really important. Science literacy helps you as an individual and as a consumer, and it shapes the ways you affect the community in which you live.

Why Are We Talking about Waves?

You can't talk about light without talking about waves. We'll come back to why this is so. But first, back up . . . what is a wave, anyway? A wave isn't really a "thing," at least not the way objects are things. A wave is more of an event. Actually, it's more of a description of an event.

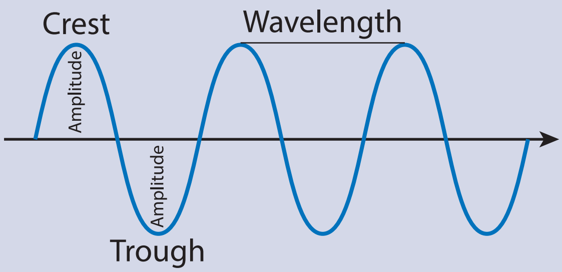
The event itself is the movement of energy from one place to another. Every such energy transmission can be described by certain features. Diagrams of waves are really models that describe the way energy is moving.

Energy transmission involves a regular, repeating pattern of variation or disturbance. The line drawing of a wave illustrates a repeating up-and-down pattern. Parts of the diagram represent properties of the wave.

The amplitude, wavelength, and frequency of a wave are properties that can be measured or calculated. Energy waves do not have mass, but they do have wavelengths, amplitudes, and frequencies. This is why we have to think about waves when we talk about light. **Light** is a form of electromagnetic radiation. And wavelength is what differentiates one type of electromagnetic energy or one type of visible light from another.

Words to Know

Transverse Wave



Wavelength, amplitude, and frequency are measurable properties of waves. *Wavelength* is the distance between wave crests. *Amplitude* is the height of the crest (or depth of the trough) of a wave from the flat line through the wave's middle (which represents equilibrium). A wave's *frequency* is the number of its wavelengths that travel past a reference point in a second, measured in hertz (Hz).

Electromagnetic radiation is energy that can travel through empty space. It can also move through certain kinds of matter.

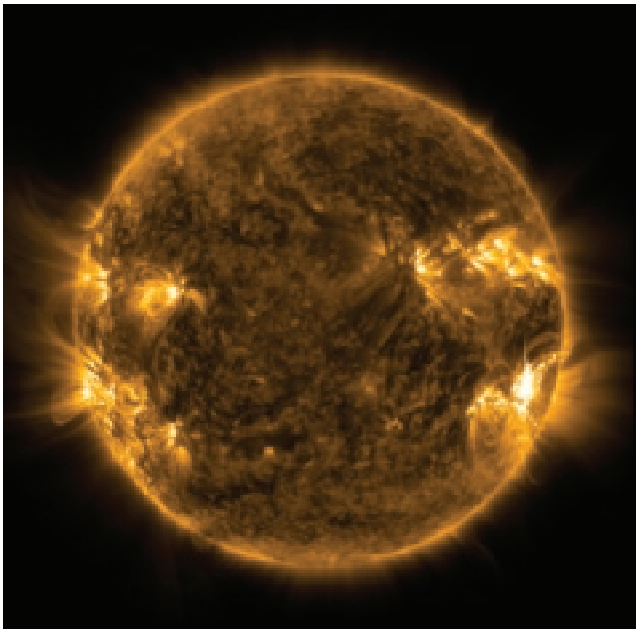
Vocabulary

light, n. visible electromagnetic radiation

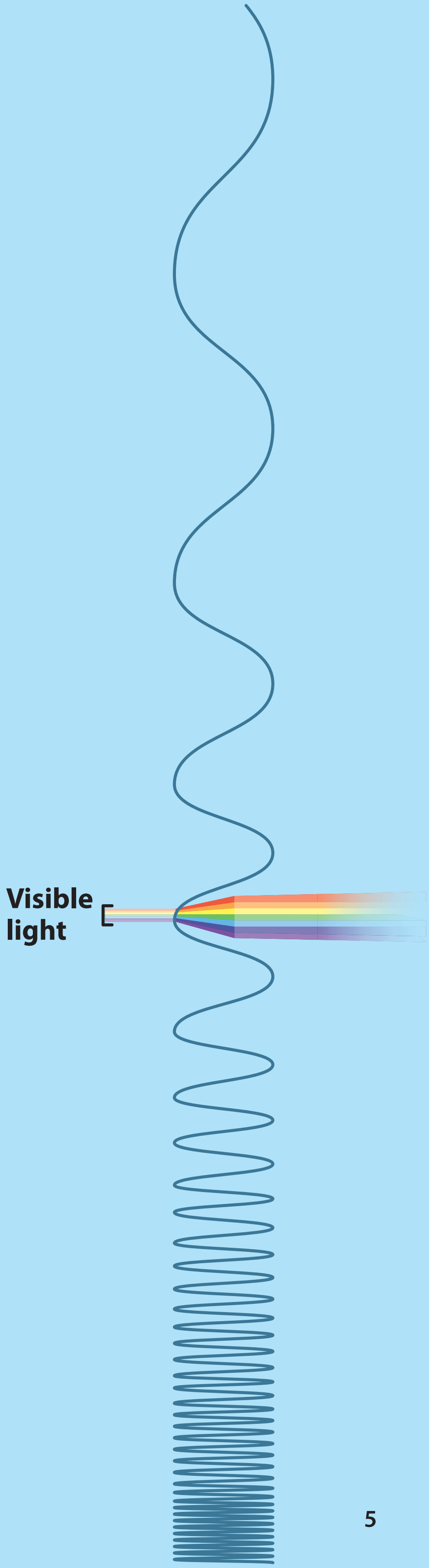
electromagnetic radiation, n. the flow of energy at the speed of light through empty space or through a material medium in the form of waves through electric and magnetic fields

Electromagnetic Radiation

So, light is a form of **electromagnetic radiation**. What does that mean? Radiation is the transmission of energy. This radiation can transmit through empty space as well as through some physical materials. The most notable source of electromagnetic (EM) radiation in human observation is the sun. It continuously emits radiation that travels through the void of space.



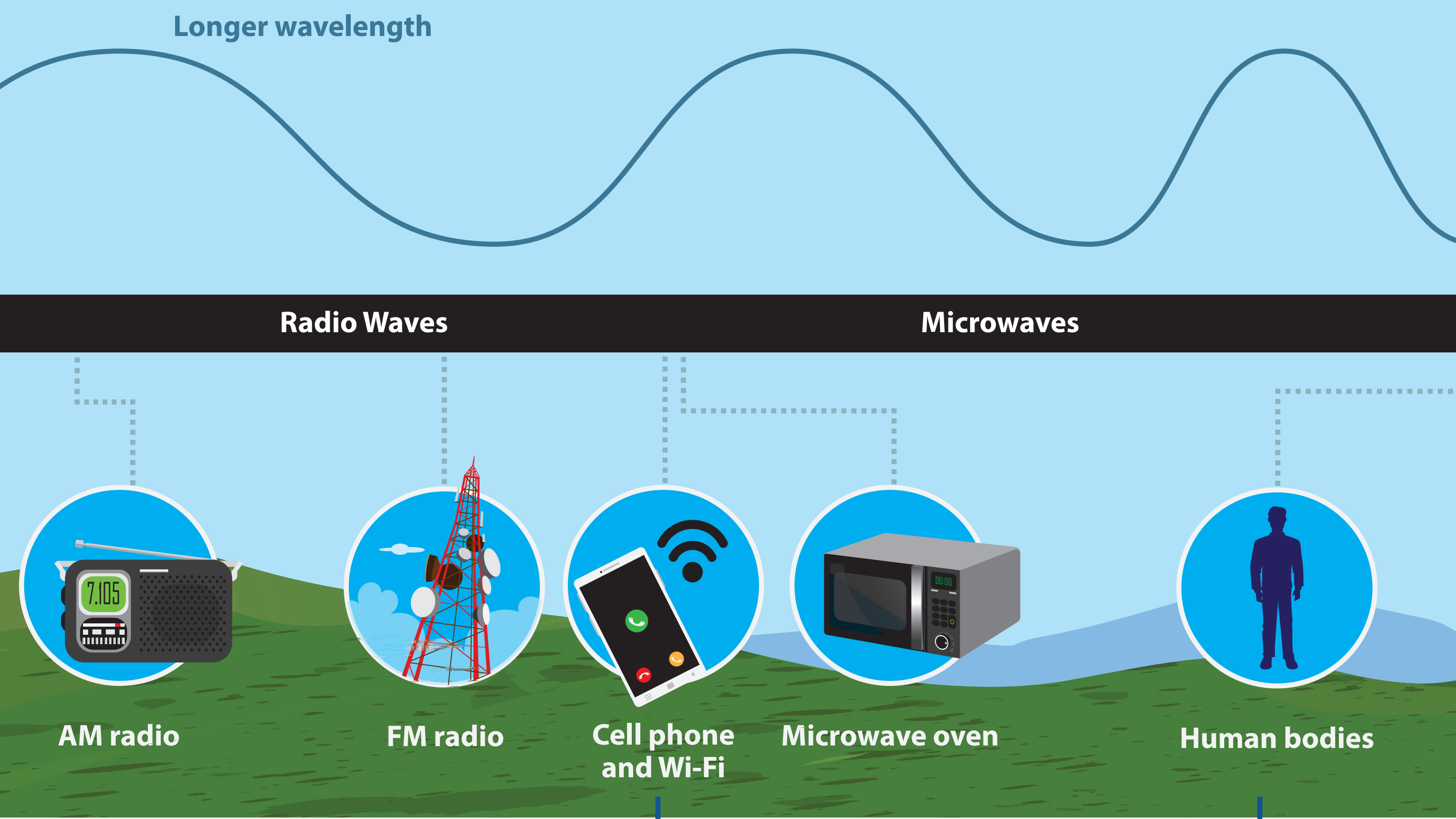
Waves of electromagnetic energy occur with different wavelengths. The full range of all the wavelengths, described on a scale, makes up the electromagnetic spectrum. Within the electromagnetic spectrum, only a narrow range of the wavelengths are visible light. This is the form of EM radiation that humans and many other animals perceive through the sense of vision. The sun also emits EM wavelengths that are not visible. Look at the next two pages to see examples of electromagnetic radiation that are not visible.



The Electromagnetic Spectrum

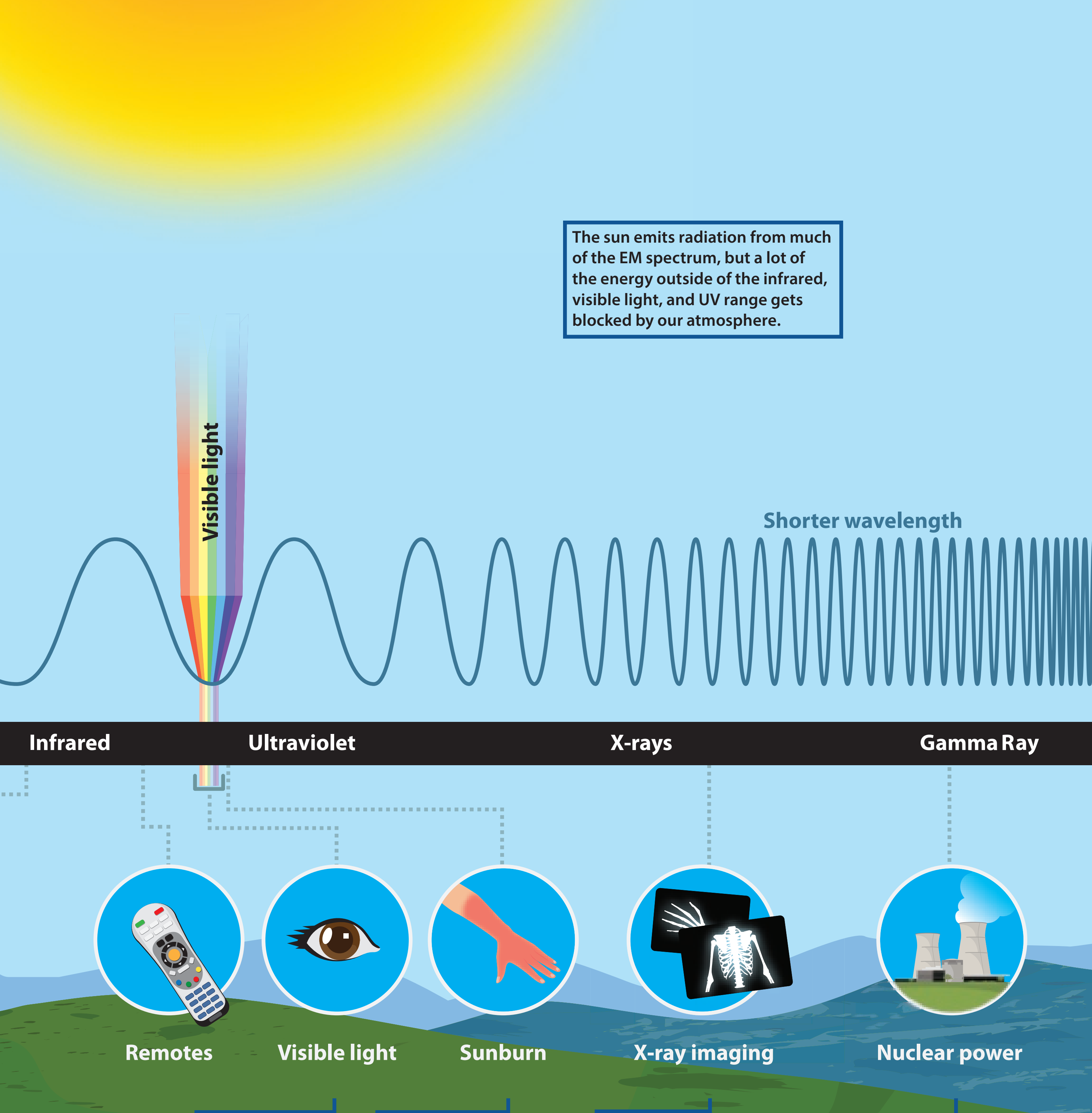
In addition to visible light, the sun also emits EM wavelengths that are not visible. Some examples are ultraviolet (UV) light, infrared light, radio waves, X-rays, and gamma rays. Some of these other forms of EM radiation are emitted by technologies that humans have developed, such as X-ray machines, radio towers, microwave ovens, and mobile phones.

The EM spectrum is based on wavelength, one of the properties of waves, measured in meters. The frequencies of waves are shown in hertz (Hz). A hertz is one wave cycle per second or how long it takes for two wave crests to pass the same point.



You are very likely surrounded by waves emitted by mobile phones, Wi-Fi routers, and cell phone towers. The wavelengths of these signals are about the width of a baseball.

If you have ever been in a crowded room, you might have experienced the infrared heat radiated by human bodies.



The relatively narrow band of EM radiation that falls within the visible light category is what we perceive with our eyes and brain.

Exposure to UV radiation can result in sunburn and increase the risk of certain skin cancers.

X-rays can penetrate a body. They pass less easily through dense tissues such as bones, so an image made by sending X-rays through an animal can be used to highlight bones and reveal injuries to them.

Nuclear power relies on particle reactions that release dangerous gamma radiation. The wavelengths of this energy are so small that they can knock particles out of position and alter the DNA of organisms.

Science Interviews Podcast

Special Summer Bonus Episode

(Begin transcript)

(Intro theme music)

Jordan: Welcome, friends; I'm Jordan, your science correspondent, and I want to thank you, as always, for listening to my Science Interviews Podcast. I've got a very special guest in the studio for today's pod. In today's episode, I'm pleased to bring you a conversation with a true ray of sunshine. I mean really, an actual beam of sunlight. Ray, thanks for joining us on the pod!

Ray: Happy to be here, Jordan! I always welcome the chance to illuminate the world of science.

Jordan: Ray, let's just jump right into some background about how you work. I understand that, as electromagnetic radiation, you don't need to travel through matter. So, what are you made of? What does a ray of sunlight contain? If you're not made of matter, how do you have energy?

Ray: Well, Jordan, human beings took a long time to figure this one out. Some scientists, such as Isaac Newton, thought light consisted of particles that had mass and shot through space like tiny, invisible cannonballs. Others thought light was made of waves. It turns out both sides of the debate have parts that are sort of right.

In 1905, Albert Einstein developed a theory that all EM radiation behaves like both a wave and a stream of particles called photons. Some scientists call the theory a "wave-particle duality," which says I am both a wave and a particle at the same time.

Jordan: Tell me something more about your energy.

Ray: Think about a really bright light source, such as the sun where I come from. When I run into matter, my energy can cause atoms to vibrate, which increases the temperature of whatever contains those atoms. In other words, things get hotter. My energy can also cause electrons, which are the negatively charged particles that are whizzing around the centers of atoms, to break free. The more intense my radiation, the more energy it has, which means particles that receive my energy will vibrate more and, in some cases, their electrons are knocked loose. Solar panels work by directing freed electrons to make a current of electricity.

Jordan: Okay, Ray, thanks for that explanation. Very interesting! So you, sunlight, and other forms of light are often thought of as both waves and particles, depending on how we describe the way you work. So, how do we know when to talk about or study a type of electromagnetic radiation as a wave versus as a bunch of photons?

Ray: Jordan, it really comes down to which sort of model better helps you understand how I behave and what I can do. Thanks to scientists who have studied waves, particles, and other aspects of physics, you have choices! There are lots of equations that can be used to measure different types of electromagnetic radiation and study how we work. I can be quite useful once you figure out how to work with me!

(laughter)

Jordan: Ray, I can’t thank you enough for coming into the studio today. It has been a pleasure to have you shed some light on your wave and particle duality. And truly, nothing brightens up our days like a ray of sunshine!

Ray: The pleasure was all mine, Jordan. Love your podcast. Keep spreading the science news.

Jordan: Shine on!

(Closing theme music)

(End transcript)

Light and Sight in Nature

The primary **light source** in our solar system is the sun. Other stars produce light, but the intensity of their light in our sky is fairly low. The moon was once thought of as a light source until humans determined that moonlight is in actuality reflected sunlight. On Earth's surface—and in some cases deep in the sea—there are some other natural sources of light.

And in nature, many organisms have sensory structures for detecting light. These organs in animals are typically called eyes. Eyes vary widely across different groups of organisms.

Vocabulary

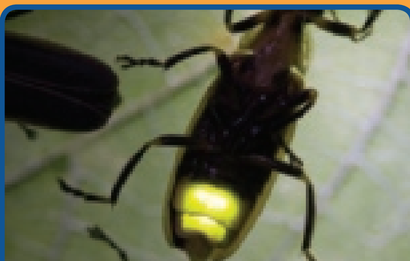
light source, n. something that emits visible light, typically through some kind of reaction occurring within it

Natural Light Sources

The sun is a star that bombards Earth with solar radiation. The intensity and color of the light that reaches Earth's surface depend on what's in the atmosphere. At sunrise, the sun's light passes through more air, which reduces its intensity and makes the light seem warmer.

Lightning and molten lava are two other natural sources of light. Lightning's light can be very intense, but it is momentary. Lava glows but cools quickly into solid rock that emits no light.

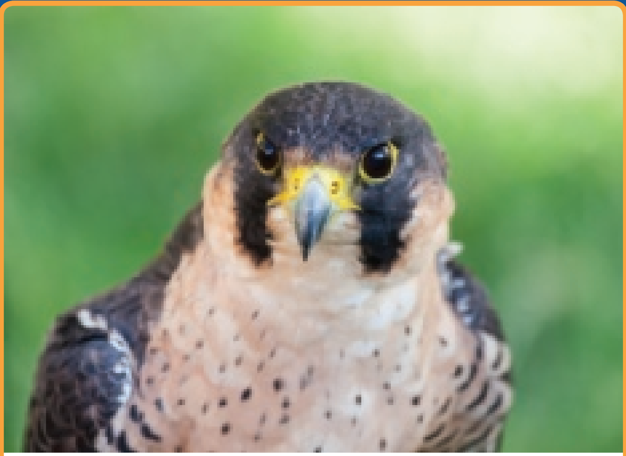
Fire, which can occur naturally due to lightning strikes and volcanic eruptions, can emit tremendous amounts of light and heat.



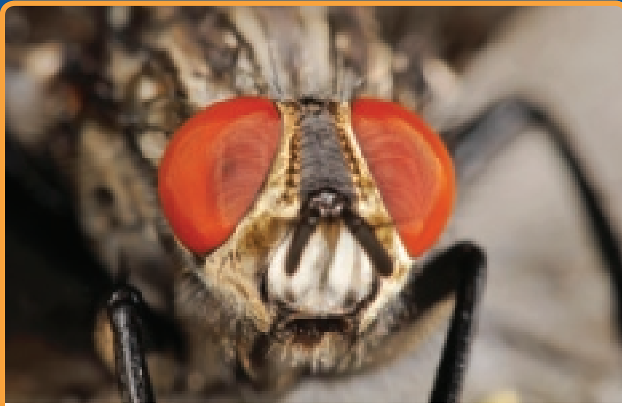
Fireflies and some other organisms can produce their own light through a chemical reaction. The light is not very intense, but it helps the fireflies communicate with each other.

Light from the moon comes from the sun. The moon's surface is very reflective, so much so that on a very clear night the reflected light can illuminate Earth's surface well enough for many organisms to find their way around.

Light-Sensing Organs



The peregrine falcon's large, complex eyes can focus on prey that is more than a mile away.



A fly has compound eyes. Each eye consists of thousands of individual lenses. Flies can detect wavelengths of light that humans cannot. Their keen sight enables them to detect movement very well—such as that of a flyswatter.

The bigeye thresher shark has large eyes that can peer both out and up. These help the shark pinpoint prey in the relatively dark ocean waters. By looking up toward the surface, the shark can detect the silhouette of prey against the somewhat brighter background when there is sunlight or moonlight from above. At night, the large size of the eyes helps gather what little light there is, including brief flashes of moonlight off the scales of prey.

Some corals, which are marine organisms that have limited access to sunlight, reproduce when the moon is full. They have sensory organs that receive moonlight, though they are not considered eyes. The corals release a blizzard of sperm and eggs that mingle and produce a new generation of coral.

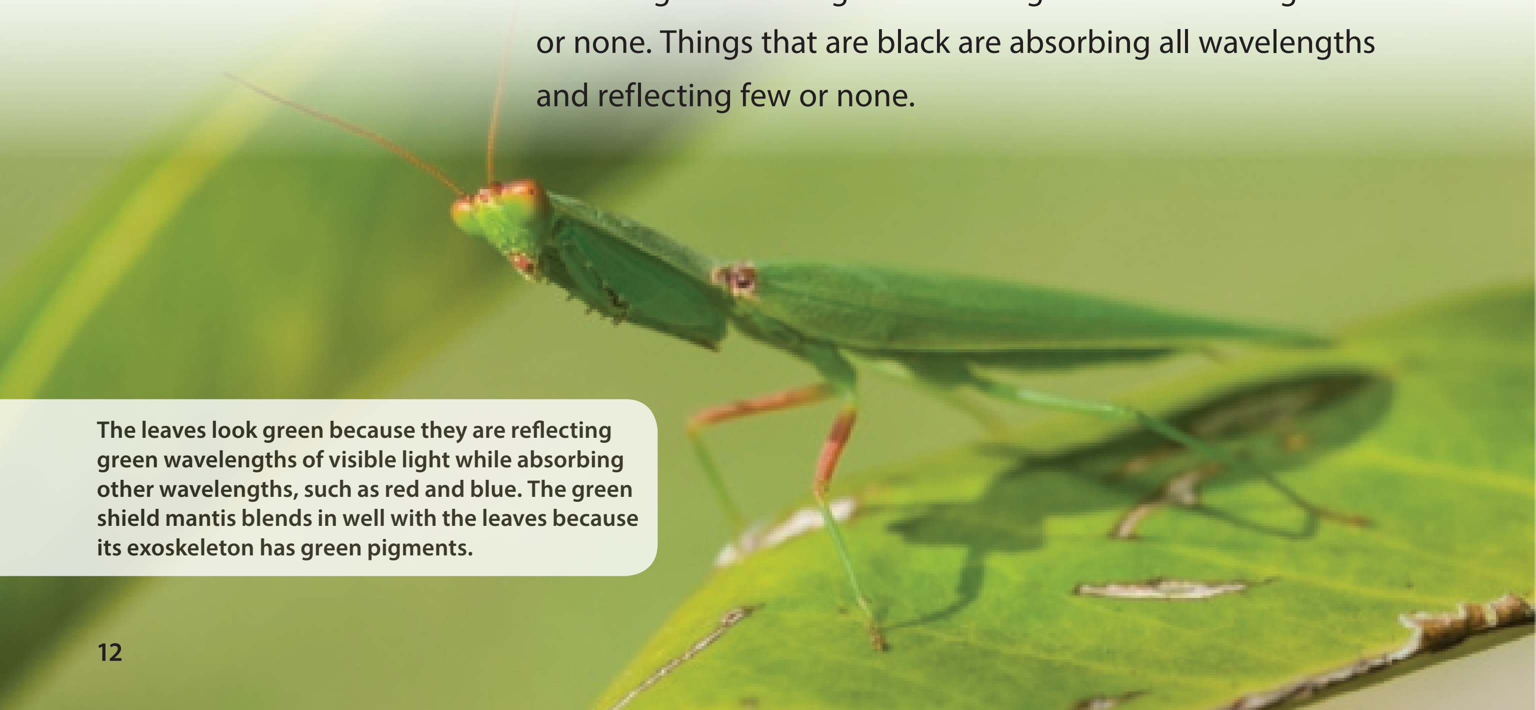
This scallop has several dozen simple eyes that detect light, mainly to help the animal avoid being eaten. The scallop can squeeze its shells together, producing a jet of water that thrusts the scallop several feet away.

Color

Isaac Newton observed a narrow beam of sunlight passing through a glass prism. The prism scattered the visible, white light into bands of different colors. A prism separates light according to wavelength. The result is a rainbow of different colors of light. Red, orange, yellow, green, blue, indigo, and violet—which you can remember by the name "ROY G BIV," which broadly names colors of light in order from the longest wavelength to the shortest.

When light shines on an object, the color of the object that you see is the light that the object has reflected instead of absorbed. For example, grass reflects more green light than other colors, which it absorbs. So, grass looks green.

That is the somewhat counterintuitive thing about color: Something appears red because it is actually reflecting red light while absorbing other colors. Things that are white are reflecting the full range of wavelengths and absorbing few or none. Things that are black are absorbing all wavelengths and reflecting few or none.



The leaves look green because they are reflecting green wavelengths of visible light while absorbing other wavelengths, such as red and blue. The green shield mantis blends in well with the leaves because its exoskeleton has green pigments.

Why Do Plants Reflect So Much Green?

These aspen trees have lost their green pigments, revealing yellow pigments that were there all along but were visually overpowered by the green pigments.

Plants' and other photosynthetic organisms' pigments tend to be green. But why? What is it about green light and those particular wavelengths of electromagnetic energy that make them less useful than other wavelengths? Why aren't more plants red or indigo?

Scientists now think that the answer to this question lies in photosynthesis, the reaction that plants use to convert the energy in sunlight into chemical energy in the form of the sugar glucose. If plants were black, this would mean maximum absorption of sunlight, but it would make them too hot and they would cook on clear, sunny days. But why reflect green? It turns out that the blue and red portions of sunlight are the ones that react with chlorophyll. Green light is not needed for the process and is reflected.

There are other pigments present in green plants. These can be revealed when the green chlorophyll breaks down. In autumn, the loss of green-reflecting chlorophyll reveals orange, red, and yellow pigments in the leaves.

Red Fish, Blue Fish

Some fish appear in vivid hues of red when reeled to the surface or displayed on ice in a fish market. But most of these fish are not red at all in water. A red snapper at a depth of 100 meters is colorless unless you shine a light on it. In deep water, a red snapper absorbs all light, making it dark and difficult to spot. It is hard for a predator to see it. Many fish species that live in deep water are colorless for this reason. Red is the first color to be filtered from the sunlight as it moves from atmosphere to seawater. But when red light is available, such as when the fish is brought to the surface, the fish's pigments reflect the red light now present.

Vivid red at the surface, these fish would blend into the dark blue of the deep sea because red light is filtered out by the top few meters of seawater.

Light Cooking

Welcome back, readers! In today's blog post, I want to tell you about some light cooking. And by that I don't mean low-calorie. I mean SUNlight cooking!

It's mid-July here in New York City, and as my favorite band put it in song, it's "hot as a hair dryer in your face." Restaurants like mine are cranking up the air conditioning. My daughter wanted to see if we really could fry an egg on the sidewalk. So, we ventured out during the afternoon to crack open an egg. In the park we targeted a metal sewer cover that had been roasting in the sun for a few hours. As you can see from the photo, it worked.

It didn't fry as quickly as an egg in a stovetop frying pan, but it did cook. Did we eat it? No, but it was a cool experiment. It got us thinking about how sunlight makes some things so hot but others not so much. My memory of science classes isn't so great, and my daughter hasn't gotten to lessons on light and thermal energy yet. To get some answers, we hopped on the phone with my college roommate Erin, who's now a materials scientist.

Erin explained that, of the sunlight that reaches Earth, about 71 percent of the solar energy gets absorbed in Earth's systems and warms things up. The rest of the light's energy is reflected. Color is a big factor in how much radiation gets reflected. The sewer cover got hot enough to fry our egg partly because it's dark. Same with asphalt, tar rooftops, outdoor basketball courts, and even the dark green slide at the playground. The closer something is to black, the more it **absorbs** sunlight. That absorbed light energy of the infrared type gets converted to heat. Erin mentioned that we could make these scorching cities of ours just a little bit cooler by painting some things white so they would **reflect** more sunlight and absorb less.

Erin knows I'm a chef, so she threw down a challenge when we were talking about cooking the egg with sunlight. She inspired me to build a solar oven. What is a solar oven? It's really just a box for trapping sunlight. It is designed to transmit, reflect, and absorb sunlight in ways that contribute to cooking.

This design is a plastic-roofed box with large reflective panels sending sunlight into the dark-bottomed oven.

A solar oven needs a clear roof, like glass or acrylic, that **transmits** light in. The walls need to be solid to trap heat, and if their inside surfaces are reflective, that can direct sunlight toward the dish to be cooked. Walls coated with aluminum foil do the trick, but mirror glass would be even better. If the bottom of the oven is black, it will absorb lots of sunlight. And a dark cooking vessel, such as a cast iron pan, can also help.

Here's what I learned from the challenge: solar ovens do work, but they usually don't work very quickly. If you try it, you'd want to give yourself a full afternoon to cook chicken or fish. Stews seem ideal for solar cooking, especially if it's a recipe that you would normally put in a slow cooker. For those campers out there, look for portable solar ovens that will fit in your hiking packs! It's amazing what you can do just managing the direction of light!

Vocabulary

absorb, v. to take in or soak up by chemical or physical action

reflect, v. to throw back without absorbing

transmit, v. to cause or allow something, such as light or force, to pass or be conveyed through space or a medium

Light in the Atmosphere

The Springfield Banner

Scientists Encourage Geoengineering to Slow Climate Change

A distinguished panel of scientists published a report suggesting that the world's governments and scientific agencies should invest more in geoengineering to combat climate change. Specifically, the report says that releasing aerosols into the upper atmosphere could help counter the heat-absorbing effect of carbon dioxide, which industrial activity has been emitting at high levels for nearly two centuries. This will effectively increase something that is already occurring, just as our emissions of greenhouse gases have enhanced the natural greenhouse effect.

Not all aerosols are alike. Some, like black carbon, absorb heat. Sulfates and nitrates reflect sunlight. When Mount Pinatubo erupted in 1991, it released 20 million tons of sulfur dioxide, which reacted with other substances to become sulfate aerosol high in the atmosphere. This layer of sulfate reflected sunlight, causing Earth's atmosphere to be cooler near Earth's surface for more than a year.

If manufactured sulfate aerosols could be released into the upper atmosphere, this could provide a similar cooling effect to counteract some of the warming that has already occurred and is likely to continue for decades, according to the report. However, tweaking the atmosphere in this way could have other effects on climate and weather, such as altering where and when clouds form and, therefore, where and when precipitation falls to Earth. Critics of so-called geoengineering think the top priority should be drastically reducing carbon emissions, not coming up with new ways to alter the chemistry of Earth's atmosphere.

Mount Pinatubo emitted ash and sulfur dioxide into the atmosphere in 1991.

Letter to the Editor

Study Is Warranted, Not Action

The *Banner's* recent article on a report on geoengineering made a crucial error in its reporting. The panel, of which I am a member, did not recommend that we "should invest more in geoengineering to combat climate change." The panel recommended that we invest *in more research* on geoengineering approaches to mitigating climate change. This is a key distinction, and I am concerned that the headline and that particular line will be the takeaway for many readers—and also for television viewers who will hear similar language when newscasts lift their talking points from your article.

There is a big difference between government-funded action and government-funded research. Our panel does agree that geoengineering approaches such as introducing sulfate aerosol into the upper atmosphere *could eventually be* a last-resort tactic as part of a larger strategy to reduce global warming, but we are far from ready to actually take this action. We need to know the other likely impacts of this approach well before we start loading tanks of compressed sulfate aerosols onto balloons or high-altitude aircraft.

I ask that you fix your headline and, ideally, publish a new article to clarify what our panel recommended lest the world moves on thinking that this is the best approach, or the one the world is taking, in lieu of reducing our emissions of greenhouse gases. We cannot afford to give the public the idea that all we need to do is put more of a different kind of stuff into the atmosphere and magically all will be fine.

Regards,

Amanda Michaels, PhD

Department of Geoscience
Springfield Institute of Technology

Words to Know

An *aerosol* is a liquid or solid that is dispersed in a gas.

Consider the Source

The writer of the letter is a professor and a member of the panel mentioned in the original article. The original article may have been written by an experienced science reporter, but it's clear that the panel's report was not accurately translated for the paper's readers. This could be due to the reporter's work or revisions made by an editor. Note also that headlines, meant to catch attention, are rarely written by the reporters who research and write news stories.

Photography and Light Metering

There's much more to photography than snapping pictures with your phone. An artist would say that photography is painting with light. Photojournalists capture realistic images that look very much like what another person would see with the naked eye. Artistic photographers use slow or fast shutter speeds, various lenses, artificial lighting, and other techniques and tools to create images that could never be seen by the naked eye.

Today's digital technology makes the art of photography nearly limitless. People can now create images that would astound history's great film-based photographers. What remains fundamental to photography is having a basic understanding of light and some tools to make sense of it. Light metering, which simply means measuring light, is key.

Today's digital cameras can do light metering automatically and adjust the camera's settings to suit the light. For example, a setting called *evaluative metering* collects light measurements from the entire area that a camera is aimed at. The setting called *spot metering* measures the light reflecting off whatever is in the very center of the frame. There are times to use one or the other. To shoot a bright, reflective subject in an otherwise dimly lit area, spot metering tells the camera to adjust exposure and control the lens so the reflective subject's details will be captured. If the camera uses evaluative metering in that situation, it will try too hard to capture details in the dark areas, and the bright subject will be "blown out"—too bright to show details.

Built-in metering can tell a camera how to adjust several variables that effect how the camera uses light. Shutter speed is how long the camera lets light in. Another adjustable variable is aperture, how wide or narrow the lens opening is when the photo is taken. A wide-aperture lens lets in more light. This can be very handy for shooting in low light, allowing the lens to grab as much of the available light as it can.

Lens aperture also affects how deep or shallow the depth of field is. This means how much of the subject will be in focus, from front to back. A wide aperture means a shallower depth of field. If a photographer isn't aware of how shallow that actually is, they might end up with a portrait that features a very clear nose and cheeks but slightly out-of-focus eyes and very out-of-focus hair. A narrow aperture is appropriate for shooting landscapes or other subjects that a photographer wants to be sharp and in focus from corner to corner.

Another variable is ISO. This is how light-sensitive the recording medium (either digital sensor or film) is when the photo is taken. In the film days, ISO was usually 100, 200, 400, or 800. Now, sensors can reproduce those sensitivities and well beyond—even over ISO 100,000. These high-ISO settings mean digital photographers can basically shoot in the dark.

A wide aperture puts the flower above in focus but not the background. A narrow aperture allows all the plants in the photograph below to be in focus.

Words to Know

A *variable* is something that can be adjusted to produce a different effect.

Clarity of Water

An Analysis of Turbidity in Muddy Creek

By Clark Cunningham, Ella Newbold, and Gabby Trivedi

Mr. Snow's Grade 10 Biology Class, Harwich H.S.

Introduction

Turbidity is a measure of how clear water is. When turbidity is high, like in muddy lakes, light transmits poorly through water. Some bodies of water are naturally turbid. For example, the lower parts of the Mississippi River are very muddy and almost opaque. This high turbidity is caused by suspended sediment in the water. Other bodies of water can become turbid when phytoplankton populations rapidly grow, or "bloom." Phytoplankton blooms fill the water with green-pigmented organisms that absorb light and reduce light transmission to lower depths.

Given the plans to further develop the land around Muddy Creek, we think it is important to study the factors that affect turbidity. Muddy Creek is a tidal river that feeds into Pleasant Bay. We began our investigation with the following hypothesis: Turbidity is higher following heavy rainfall, due to the flow of sediment from developed land along the creek. The dependent variable is turbidity, and the independent variable is rainfall.


Muddy Creek as the tide goes out

Words to Know

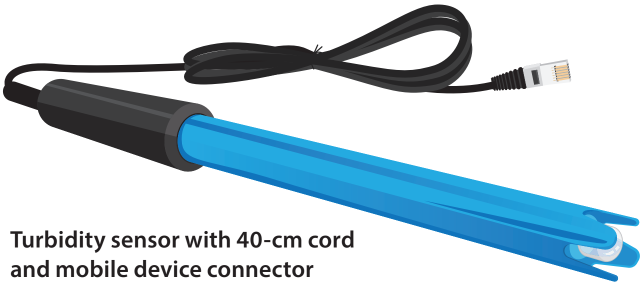
Turbidity is a measure of the clarity of water.

Methods and Materials

Our investigation involved measuring Muddy Creek's turbidity with a sensor that emits a beam of light and then measures how much light is reflected back by suspended particles in the water. The sensor provides measurements in NTUs, or nephelometric turbidity units. NTU is the widely used unit for measuring turbidity. The higher the reading, the greater the turbidity.

The sensor has an LED that emits a light with a wavelength of 890 nanometers. We used a smartphone and turbidity-reading app to log results. The sensor was lowered to a depth of 30 cm,

- at the same location in the creek,
- at the midpoint of the outgoing tide,
- between the hours of 8 a.m. and 8 p.m.,
- across two five-day periods in April and May.



Turbidity sensor with 40-cm cord and mobile device connector

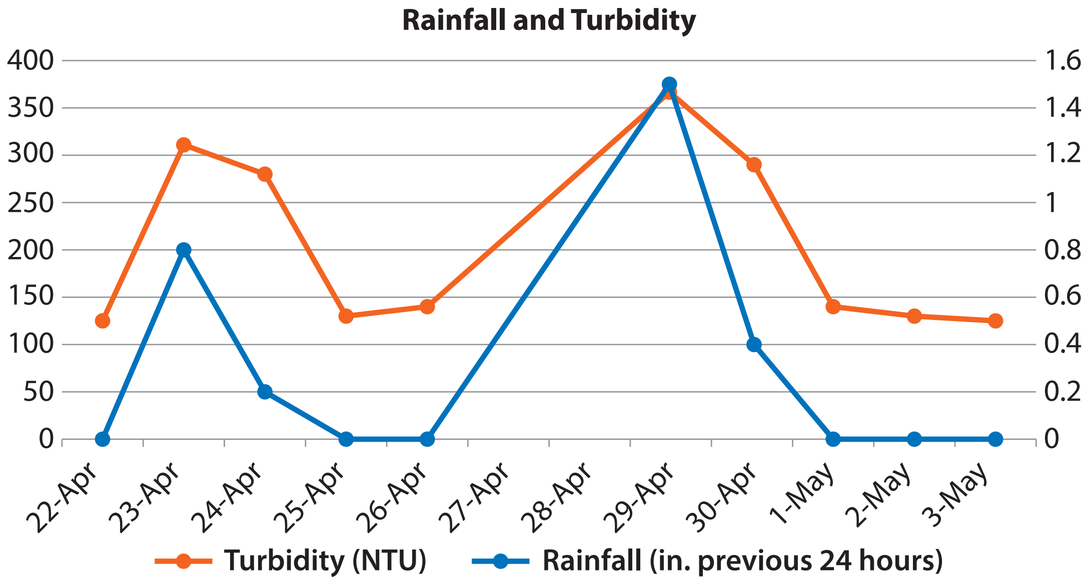
We recorded rainfall in the Muddy Creek area in the 24 hours leading up to each visit to the creek. For this we used a standard rain gauge anchored in the sand of the creek bank, away from trees. We also collected data from the local weather service as backup.

Results

The data table contains our results. The rain gauge was knocked over by wildlife on one day, so we relied on the weather service for rainfall data for one of the ten days. As shown in the table, all ten of our turbidity testing sessions fell during daylight hours. The tide shift caused a shift in our schedule of approximately 50 minutes from day to day. We took one weekend off halfway through the investigation.

Date	4/22	4/23	4/24	4/25	4/26	4/29	4/30	5/1	5/2	5/3
Time (midpoint ebb tide, daytime)	8:20 a.m.	9:12	10:14	11:08	12:02	3:55	4:50	5:45	6:40	7:30
Rainfall prev. 24 hours (in.) as measured by rain gauge/ reported by weather service	0.0/ 0.0	**0.8/ 0.9**	**0.2/ 0.2**	0.0/ 0.0	0.0/ 0.0	**0.0*/ 1.5**	**0.4/ 0.5**	0.0/ 0.0	0.0/ 0.0	0.0/ 0.0
Turbidity	125	310	280	130	140	370	290	140	130	125

*Rain gauge had been knocked over, we think by a heron.



Discussion

The data show a clear correlation between rainfall and turbidity, with periods of rain followed by periods of high turbidity and then drop-offs to lower turbidity. In general, turbidity doubles following rainfall and then settles to a range around 125 NTU when there isn't rainfall. This supports our hypothesis that rainfall increases turbidity in Muddy Creek.

Our investigation did not investigate exactly how rainfall increases turbidity. We think that suspended sediment increases as soil is washed off the land adjacent to the creek, including properties that recently were developed. Further investigation could track and measure the flow of sediment from those specific properties toward or into the creek.

It would also be worthwhile to measure turbidity during the incoming tide, as it is possible that suspended sediment and other factors such as plankton blooms are coming in with the tide and increase the turbidity in the creek through the full cycle of the tide. To investigate this, we could measure turbidity at multiple sites along the full length of the creek. It is possible that turbidity could be increased mostly by rainfall at upstream, inland parts of the creek while areas downstream, where the creek meets the bay, are influenced more by tidal flow and plankton.

Words to Know

A *correlation* is a perceived connection or relationship between two things.

An *independent variable* is a factor that is deliberately adjusted, or varied, in an experiment or investigation.

A *dependent variable* is a factor that is studied for effect by the independent variable in an investigation.

The graph shows a correlation, but correlation is not causation. Causation means cause and effect, with one factor directly influencing something else. Correlation can occur without a direct causal relationship.

Human Eyes

The human ability to perceive light is vision. Human vision begins with two eyes set to the left and right sides of the front of the head.

In the center of the front of the eye is the slightly raised cornea, which is a glass-like window through which light enters.

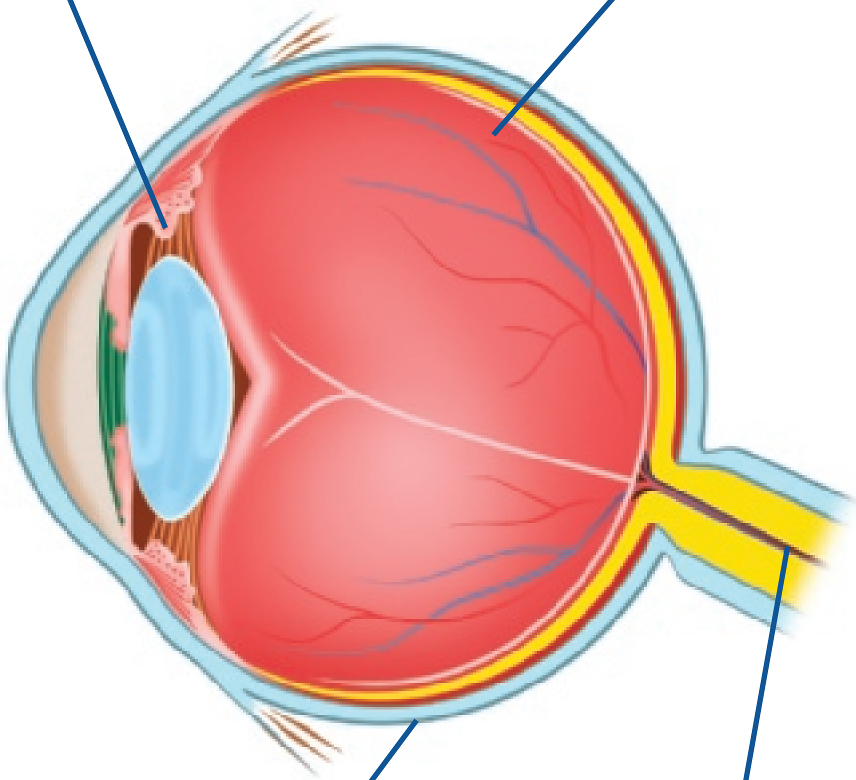
Muscles of the iris (which is similar to the aperture in a camera lens) cause the iris to contract or relax. This controls how much light enters the eye.

The colored iris surrounds the pupil, which appears black in most human eyes and is the hole through which light enters the lens. When the iris causes the pupil to dilate, more light enters the eye. Pupils dilate when the intensity of light is low. They will contract when intensity is high, to prevent damage.

The white part of the eye is the sclera.

The ciliary body produces a fluid called aqueous humor, which is behind the cornea and around the lens.

At the back of the eye is a layer of tissue called the retina. The retina has specialized cells that convert light—electromagnetic radiation—into electrical signals that are then sent to the brain along the optic nerve.



The cells that perceive light intensity are called rods. These are clustered mostly around the sides of the eye.

Cells called cones perceive different wavelengths of light, or color. There are several types of cones. If someone lacks a type of cone, they will be color-blind for the colors that the missing cone perceives. In humans, 1 in 12 males and 1 in 200 females are color-blind in some way.

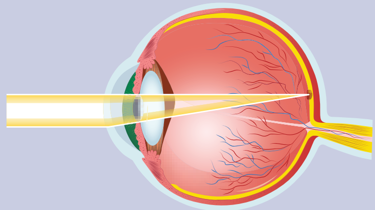
Conditions that cause focal points to miss the retina can be treated with corrective lenses, meaning eyeglasses or contact lenses.

The image produced on the retina is inverted. What is at the top of an object in front of you is at the bottom of the image that reaches your retina. The image is also flipped horizontally, meaning something that is physically on your left projects onto the right of your retina. Different parts of your brain process the information sent from the retinas and "unflip" the images so that you see objects in their true orientation.

The brain also processes the signals from the two different eyes to give you depth perception—a feel for how far away objects are from your eyes. Someone without two functioning eyes is likely to have difficulty with depth perception.

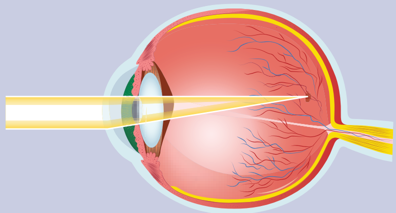
The vitreous humor in the back part of the eye gives the eye much of its mass and volume. If there is too much pressure in the vitreous humor, the optic nerve can be damaged, leading to a condition called glaucoma.

Another condition that affects human eyes, especially in older people, is cataracts. This produces cloudy or blurred vision. Proteins in the lens break down, giving the lens a slightly yellow, cloudy appearance that affects the light passing through the lens. This condition can be corrected with surgery.



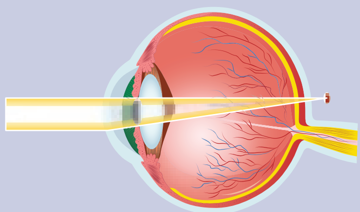
Normal vision

Light rays enter the lens. The convex shape of the lens causes the light to refract, focusing rays at focal points across the retina.



Myopia

If the eye is too long from front to back, the focal points do not quite reach the retina. This causes things that are far away to be out of focus, or blurred. This condition is called myopia, or nearsightedness.

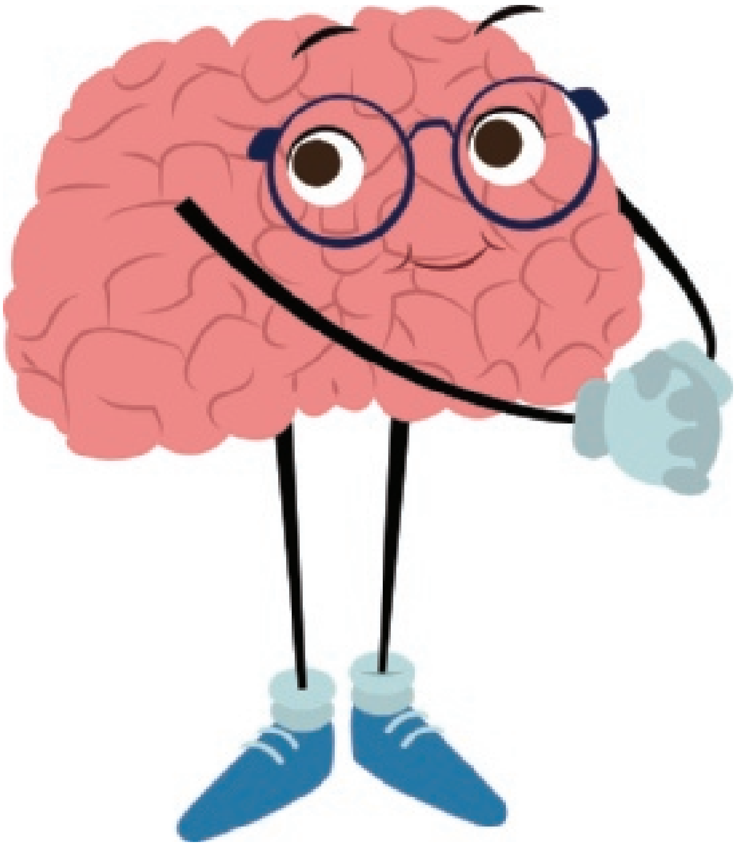


Hyperopia

If the eye is shorter than normal from front to back, the opposite condition occurs. The focal point is slightly behind where the retina is, causing objects that are near the eye to appear out of focus. This is farsightedness, or hyperopia.

The Brian, Visual Decoder

Vision involves much more than detecting light with the eyes. Reading is one example of what your brain can do with the detection of differences of black lines on a white background. The process of reading this sentence involves your eyes and your brain—along with other systems that help keep those organs functioning. Some years ago, you learned to read letters, then words, and then different sequences of words. All of that required memory. Your brain can even make sense of data that arrive in a jumbled or incorrect form. Take this, for example:



Tehre si a cahnce oyu aer rdeanig htis esenetce wiht esae evne htouhg mnya elettrs aer otu fo oderr.

Were you able to decode that? If so, you can credit your brain with being able to recognize familiar patterns among the different jumbled words. Your eyes did their job as usual when reading. They scanned from left to right and top to bottom. Your brain perceived the spaces between jumbled bunches of letters as the usual spaces that separate words while recognizing clusters of letters that your brain has seen together before. All of this requires memories: learning the letters of the alphabet, learning to spell words, learning how words fit together into sentences. These are things your brain got started on years ago and has been practicing ever since. You will continue to read with more ease the more you practice, too.

Your brain can recall patterns. After you have read or heard thousands of sentences, your brain becomes accustomed to certain patterns in language. For example, the forms of verbs ending with –*ing* are often found with other words or phrases.

He is going to the store.

What are you doing?

Are you running today?

You are making me laugh.

Your brain learns to anticipate words based on context, the surrounding situation. In this case, it has to do with the other words your brain is processing. The jumbled "oyu aer" set up your brain to expect some kind of –*ing* word, because of how often it encounters –*ing* words after "you are" and similar phrases.

Then, the actual appearance of the letters *ing* in proximity to each other most likely led your brain to decode "reading" very quickly, which provided confirmation that your brain was on the right track. Your brain was also set up to decode the jumbled sentence by the context of the first paragraph. In fact, it is very likely that you felt more confident that you were decoding the sentence correctly because the sentence made sense in the context of this reading!

However, if too many letters are scrambled in a truly random way, your brain cannot decode as quickly. In the example, most of the letters that began and ended the words were not moved very far if they were moved at all. For example, "cahnce" had just two letters moved out of place, and by just one space, and the first and last letters were left alone. The two-letter "si" and "fo" could only be decoded to "is" and "of," so these were easy. The easily decoded words allowed your brain to quickly move on to others, making it more likely that your brain would process the rest of the sentence. If your brain had been slowed down by more-jumbled words, it might have lost the context. Try reading this:

Itsh esntcne iwll eb ermo ifdfilcut ot edcdoe ebuaces het elterts era eryv csasbmdle.

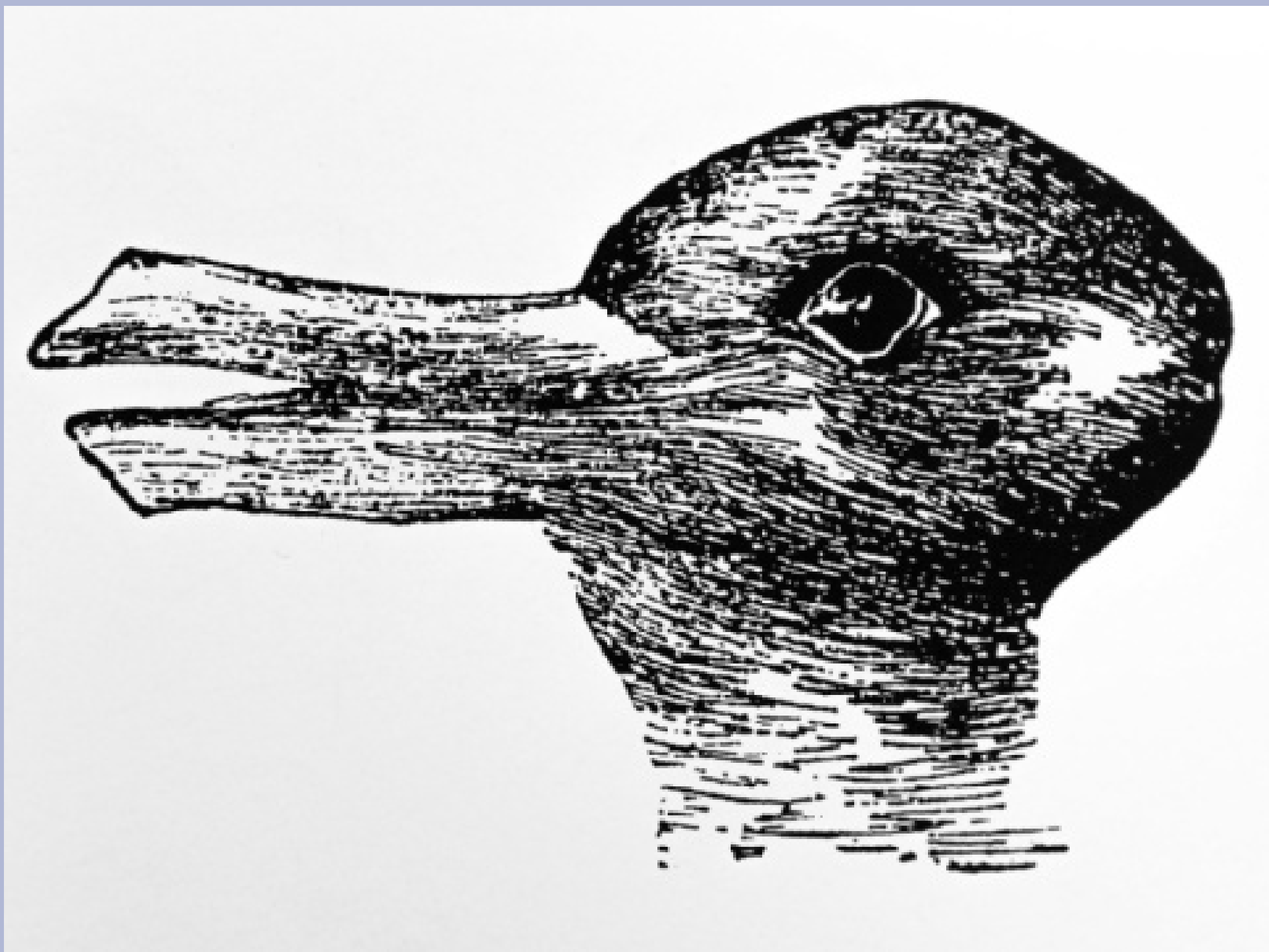
Longer words, with letters more displaced, add up to a trickier puzzle for your brain.

Word to Know

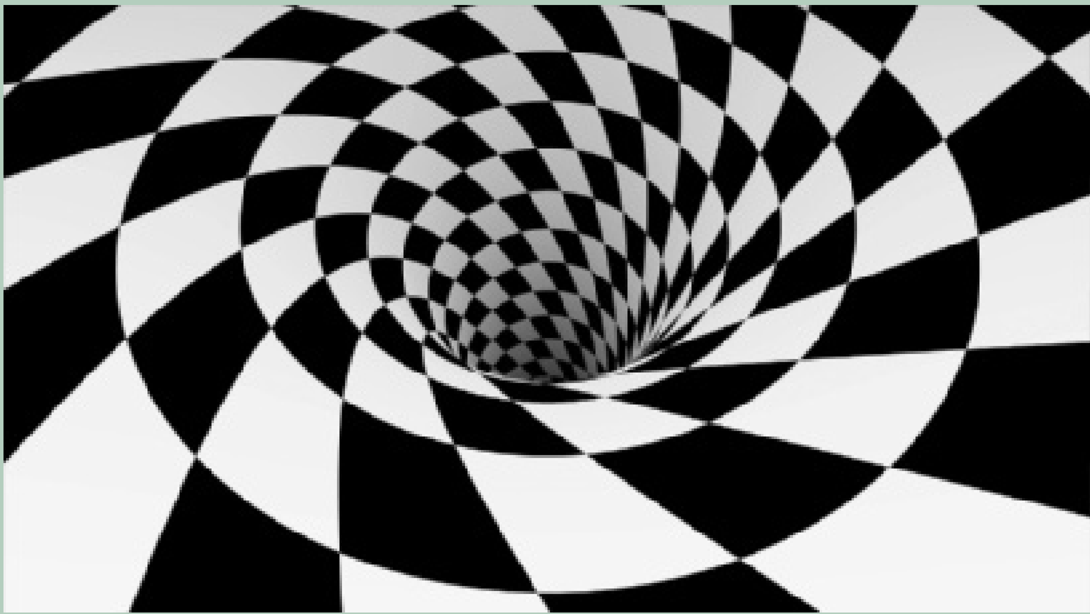
Context is all of the words and ideas that surround an individual word or passage and can shed light on its meaning.

Illusions and Mirages

Your eyes and brain work together to produce images of the world around you and make sense of them. Depending on your prior experiences, your memories, and even how you look at or read things around you, what you "see" might be very different from what someone else sees, even though you both detect the same reflected light.



This famous illustration, which first appeared in a German humor magazine in 1892, was designed to look like two different animals at the same time. Whether someone first sees a duck or a rabbit depends on their memories, their perspective, and even whether they tend to look at things on a page from left to right or right to left. If you tilt your head slightly to the left and look at the right side of the illustration first, you might see a rabbit. If you focus more on the left side, you might see the duck very clearly. Of course, if you have never seen a rabbit before, you won't see one here. Likewise, someone who has never seen any kind of bird but has seen plenty of rabbits will insist that this is clearly a rabbit.



This is a two-dimensional pattern that is designed to suggest some kind of hole. The white diamonds in the center are smaller and a darker shade, and the way the diamonds seem to disappear behind what looks like a slope in the foreground of the image adds depth. This illusion also depends on your prior experience with encountering three-dimensional tunnels or holes in the real world. To an infant, there might not be any sign of a tunnel.

The camera and woman are positioned relative to the kneeling person to make it look like she is a giant. This image works as an illusion on paper or on a screen because it is a two-dimensional image. Your eyes' ability to perceive depth is useless with 2-D images. In the real, three-dimensional setting, it would be easier to tell that the kneeling person is several yards away from the woman and the two are close in actual size.

This mirage is caused by light above the surface of the water bending. To the viewer's eyes—or the camera's sensor—objects that are on the sea surface appear to be above it. This is called a superior mirage. The brain assumes light rays are straight, but in this case they are being bent in a way that puts the image well above the actual position of the object. This is due to air masses of different temperatures sitting on top of each other just above the water.

A similar phenomenon occurs over very hot surfaces, such as desert sand or asphalt. Air masses of different temperatures sit on top of each other just above the sand. The light rays are being bent in a way that puts the image well above the actual position of the object.

Vocabulary

mirage, n. an optical illusion in which light bends through one or more layers of air, altering a subject's apparent position or orientation

Factoring in Refraction

Let me tell you my fishing story. I see this nice brown trout twenty yards downstream. I execute a perfect cast to drop the fly right in front of the fish's face . . . but then the fish splashes away. (*Argh!*) And its movement reveals that its actual position was about a yard closer than I thought. Is there something wrong with my prescription sunglasses? Is my brain playing tricks on me? I've since learned that it's a function of how light behaves when it moves through different media.

Let's start with the basics. Light transmits through any medium if the medium is **transparent**. Think of the water a few miles off the Bahamas on a calm day. You could hop in the water with a mask and see fish hundreds of feet away.

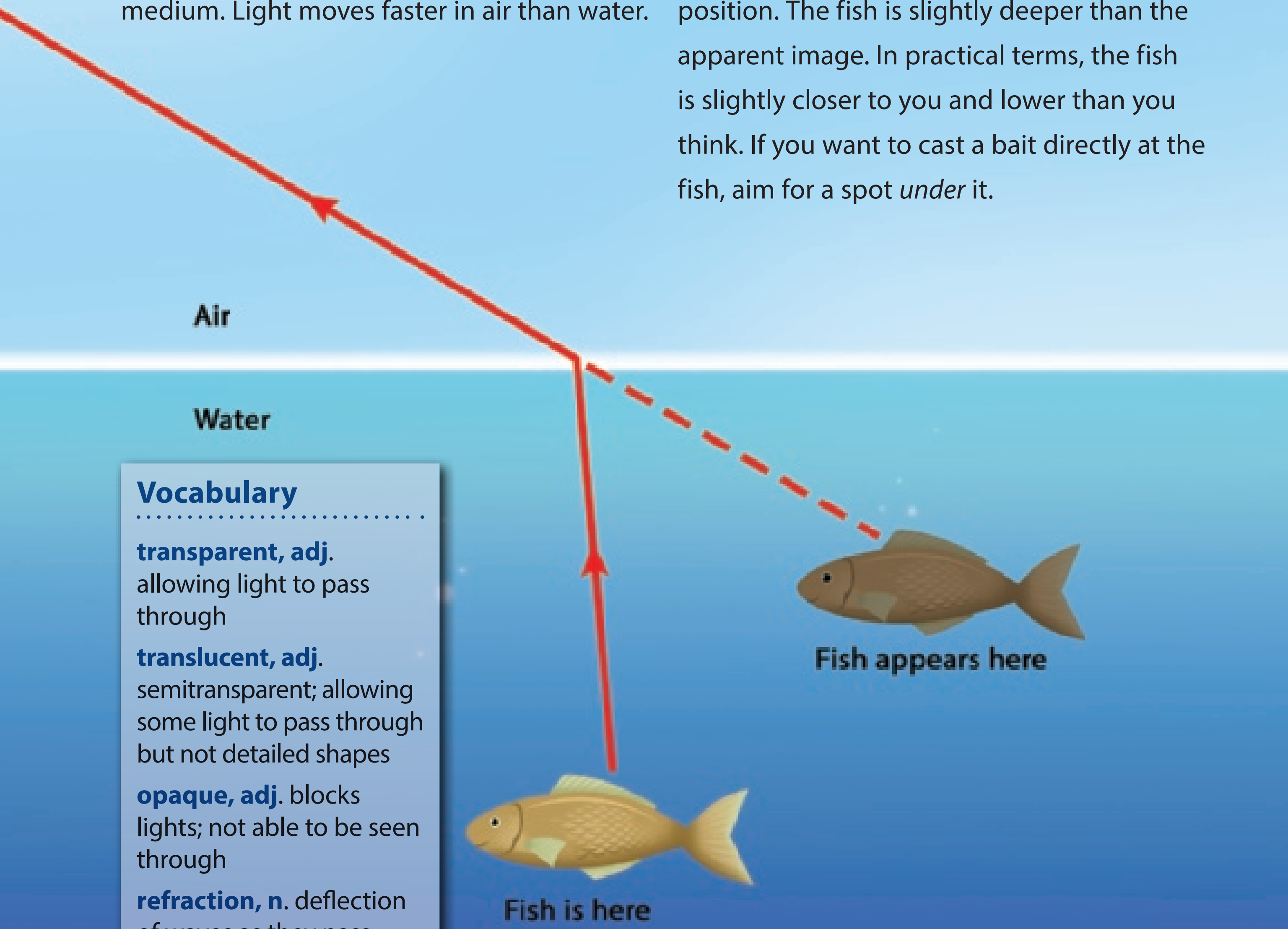
Translucent means the light doesn't pass through as easily. Some of it is absorbed or scattered by particles in the material. Think of the waters in a lake in the late summertime, a little cloudy. **Opaque** means light does not get through at all. Think of the muddy Mississippi in April. All of these terms describe how light does or does not transmit through a medium such as water.

But another variable is at play when you look at things in the water without being in the water yourself. That factor is **refraction**. This is the deflection of wave energy due to a change in media. In short, the light bends.

Light rays reflecting off the fish move in straight lines from the fish toward the surface, but then they leave the water and move into the air, which is a different medium. Light moves faster in air than water.

When those reflected rays of light reach the air, they speed up and bend at an angle slightly more toward you.

Your brain assumes the light is moving in straight lines, so it places the fish at the end of what it assumes is a straight line between your eyes and the fish. However, because the light bends when it reaches the air, that line of sight is actually above the fish's actual position. The fish is slightly deeper than the apparent image. In practical terms, the fish is slightly closer to you and lower than you think. If you want to cast a bait directly at the fish, aim for a spot *under* it.



Vocabulary

transparent, adj. allowing light to pass through

translucent, adj. semitransparent; allowing some light to pass through but not detailed shapes

opaque, adj. blocks lights; not able to be seen through

refraction, n. deflection of waves as they pass from one medium to another

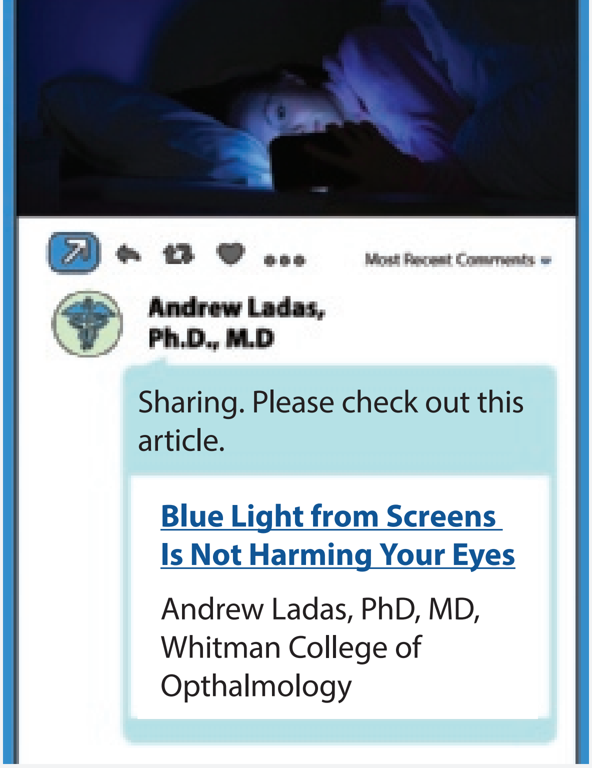
Blue Light and Eye Health

Consider the Sources

One of the social media posts is written by someone who appears to be a physician who specializes in opthalmology, or the study of eyes and eye diseases. The other features unsubstantiated claims and heresay.

Spot the BS

Heads up! There's some **bad sensemaking** on this page. Can you detect some unreliable information about light?



Blue Light from Screens Is Not Harming Your Eyes

Andrew Ladas, PhD, MD, Whitman College of Opthalmology

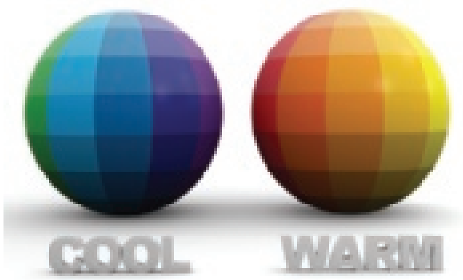
As with many topics that get discussed on the internet, concern about our use of electronic devices bearing bright screens for hours a day has triggered some thoughtful discussion as well as an avalanche of outright hooey. Contrary to what your mom's cousin might have posted on social media, there is no conclusive evidence that blue light from a phone screen, computer screen, or television screen is or is not doing lasting damage to your eyes or increasing your risk of developing age-related macular degeneration or blindness.

Blue light is visible light with a wavelength of 400 to 450 nanometers. We perceive this light as blue, and it is most obvious when looking at the midday sky (away from the sun) or the ocean, as both air and water scatter blue light in all directions. Blue light can also be present in light that is dominated by other colors. For example, white light reflected off freshly fallen snow contains blue and other wavelengths, but for our eyes it all adds up to "white." The concern with blue light is it has more energy and therefore has more potential to cause damage to cells than, say, red or green light.

However, devices that emit quite a bit of blue light do not pose a threat to our eyes because they simply aren't bright or intense enough. A phone screen, or an LED light in a living room ceiling, is not going to be intense enough to emit a dangerous level of blue light. Only an industrial-strength blue light, such as a military-grade flashlight, would pack enough blue-light energy to pose a threat to your eyes, but you would not voluntarily stare into such a light as you stare at a screen.

However, this is not to say that blue light cannot do harm. Heavy use of screens can cause eyestrain, which is essentially fatigue and dryness; but these can be remedied with breaks from the screen and eye drops to treat the dryness. Blue light can also activate your natural circadian clock, meaning excess exposure to blue light can disrupt your sleep patterns. For that reason, we do recommend limiting use of screen-based devices before bedtime. Some devices have bedtime settings that cut out some of the blue light from the screen.

Color Temperature



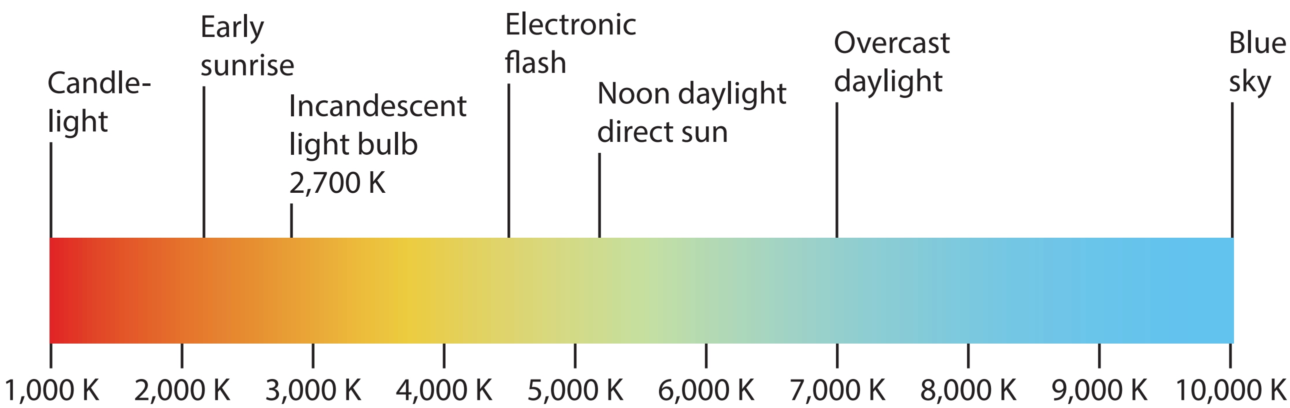
When we perceive color, it's because of the interactions between different pigments and the wavelengths of light that the pigments either absorb or reflect. Our brains add meaning to what our eyes detect. Context, experience, and memories lead us to associate different colors, or ranges of colors, with thoughts and feelings. For example, in an art class you might have heard different hues referred to as "cool colors" or "warm colors" before.

But do warm and cool colors really have different temperatures?

There is a characteristic of light defined as its temperature. The Kelvin scale is used to describe the temperature of light sources, from searing stars to tiny, touchable light bulbs. The scale ranges from 1000K to 10,000K, but a narrower version from 2000K to 6500K is used for human-made light sources.

The way we talk about light on the Kelvin scale is, confusingly, the opposite of what one would expect. Light sources that are described as "warm" are lower on the Kelvin scale, or cooler, and sources that look "cool" are hot on the Kelvin scale. For example, the blue light of the daytime sky on a clear day is as hot as color temperature can get. The "warm" glowing light of a candle is as cool as it gets. To the left of the candle, if the scale were extended, is infrared light. To the right of the blue sky would be UV light.

Color Temperatures in the Kelvin Scale



In the digital age of photography, processors in cameras and computers allow photographers to record images and edit them to make them look as if they were taken in entirely different light conditions than they were. This allows for creativity and can also make better photographers out of people with little experience metering light and adjusting camera variables.

A camera will let you set the temperature on the Kelvin scale based on the type of light you are shooting in—sunlight, overcast/cloudy, fluorescent lighting, incandescent lighting, and more. This is done through the white balance (WB) function. You basically tell the camera how to register the color white, and then it either warms or cools the other colors accordingly from that set point. But a digital photo is simply a computer file. If you forget to pick the correct WB setting, you can correct it later on using photo processing software.

Here's an example. The images of the swan shown below are the same digital file with different color temperature settings. In the left version, the original file, the camera wasn't set for bright sunlight. So, it recorded the image with a higher temperature ("cooler" in appearance—in fact, it appears blue and icy in the extreme!). To make the image look closer to what it looked like in real life, the temperature was adjusted from 6018K down to 3421K. Counter to intuition, to "warm up" the image requires a decrease in the light temperature—because "warm" in art and photographer-speak actually means "cool" on the Kelvin light temperature scale. So, just keep in mind that "cooling" a photo (toward a bluer appearance) means *raising* the color temperature, and vice versa.

Scattered Light

Why Is the Sky Blue?

The sun radiates light in all directions. Earth is very far from the sun, so it is on the receiving end of a very tiny fraction of the rays of light the sun emits. And these rays strike Earth and its atmosphere in one direction, almost like the beam from a flashlight. The intensity and other properties of sunlight when it reaches Earth's surface depend on what happens to light as it passes, or is transmitted, through the atmosphere.

The atmosphere is a thin blanket of gases and other particles around Earth's solid and liquid sphere. A lot of sunlight passes through the atmosphere, but some light is absorbed and reflected by the atmosphere. The atmosphere consists of particles of oxygen, nitrogen, water, argon, carbon dioxide, dust, and other substances. These particles, like any other matter, receive waves of electromagnetic energy and can absorb or reflect them.

Opposite the sun but up and away from the atmosphere, the daytime sky is a deep blue on a clear day. Near the horizon, it tends to be light blue or almost white. The snow reflects sunlight that reaches the surface. The reflected light can be scattered by the atmosphere, too.

Atmospheric particles reflecting energy in all directions **scatter** the light. It is this scattering of light that gives the sky its colors. Otherwise, the daytime sky would appear black, and the sun would appear as a bright disc surrounded by black and stars.

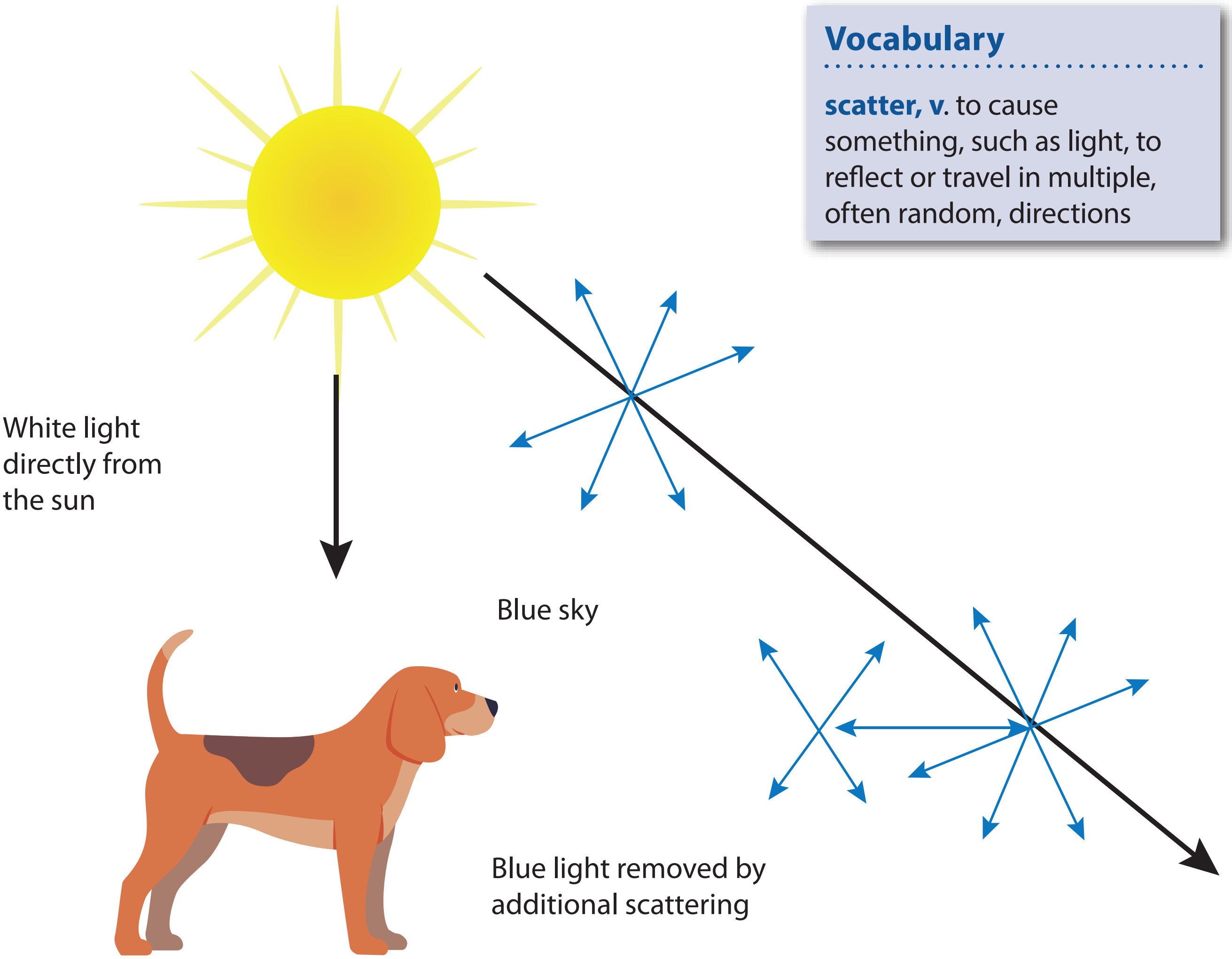
When the sky is clear, meaning not particularly cloudy or hazy, the sky looks blue because, of all the colors within visible light, blue is the wavelength that is the most scattered.

Other colors are scattered as well, but blue dominates the visual data that our eyes take in. So we cannot perceive the scattered rays of red, green, violet, and other colors.

You might have noticed that the sky is less blue near the horizon at midday, when the sun is high. The light has been scattered and rescattered so much by the air and by things on Earth's surface that the light is more washed out and almost white.

Vocabulary

scatter, v. to cause something, such as light, to reflect or travel in multiple, often random, directions

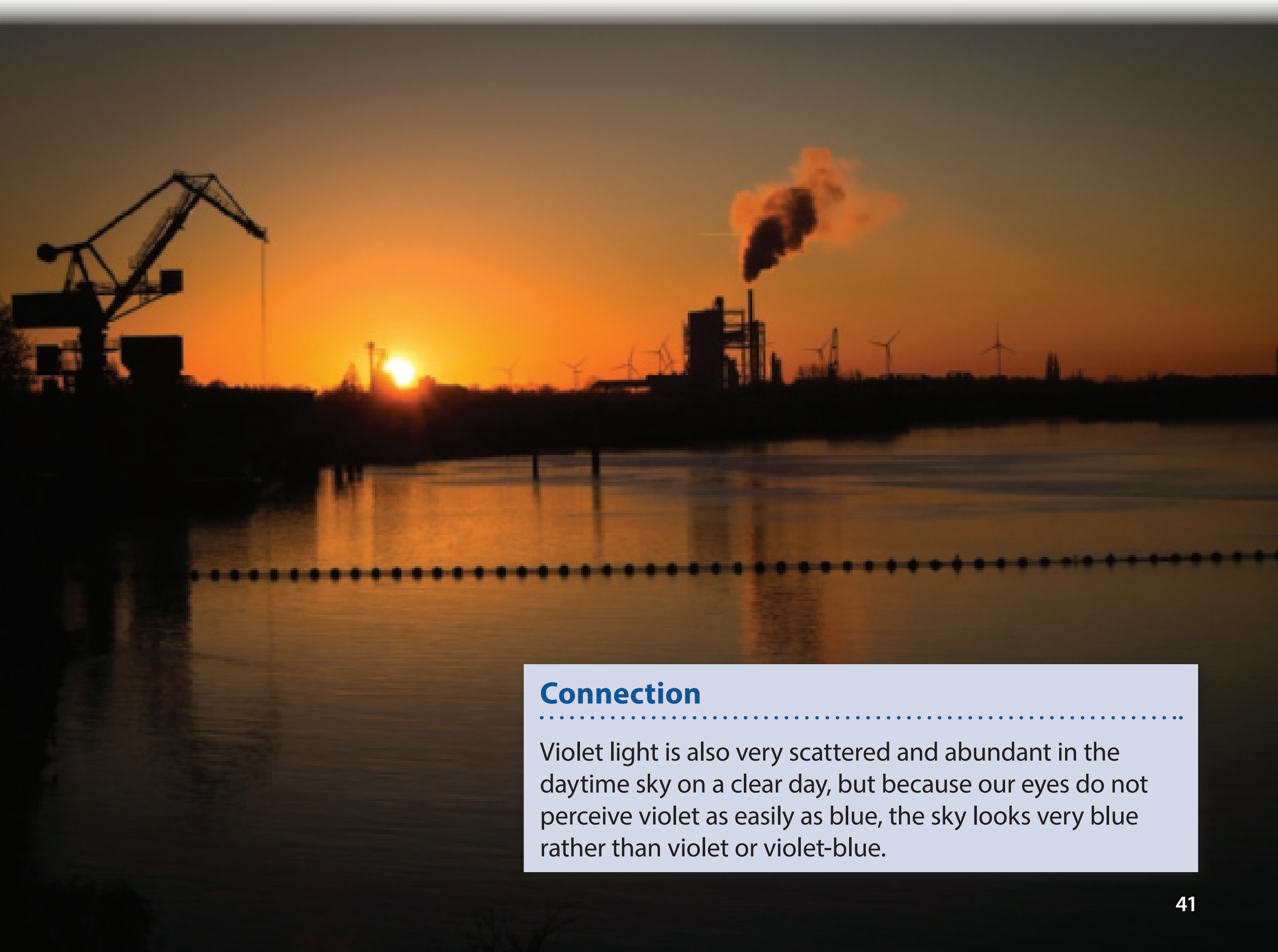


The ocean and other large bodies of water also look rather blue because blue wavelengths of light are scattered more than other wavelengths by the molecules of water. The short waves of blue light penetrate deeper while also being scattered in all directions. This makes the ocean appear blue from below the surface as well as above. If the ocean looks green, it is due to the presence of phytoplankton, which reflect green light. If the sky is very cloudy, ocean blues and greens will appear less vivid, as the light is less intense.

Red is the first color to be filtered out by water, but if certain organisms with red pigments are close to the surface they can reflect red light and give the ocean a red hue.

The red pigments of this sponge are visible because the water is shallow enough to let some red wavelengths of light arrive at the sponge, and the sponge's red pigments reflect that light to the camera.

The unclouded atmosphere in the daytime typically is full of intense blue, but at the beginning and end of the day there can be many other colors. Light is still being scattered when the sun is low in the sky. The difference is the light is passing through a thicker span of atmosphere. Sunlight's path to Earth's surface when the angle of the light is low involves passing through more molecules of water vapor, dust, oxygen, and other components of the atmosphere. The blue light that dominates when the sun is high is so scattered that blue is filtered out, letting the longer wavelengths be visible in your perception. This is why sunsets and sunrises can be full of reds, oranges, and yellows. The sun itself can appear red and its intensity is much lower because its light is passing through so much more atmosphere. The sunlight is getting absorbed and scattered by that many more particles. Pollutants can make sunsets even more intense and vivid, as they add up to more particles that can reflect and scatter light.



Connection

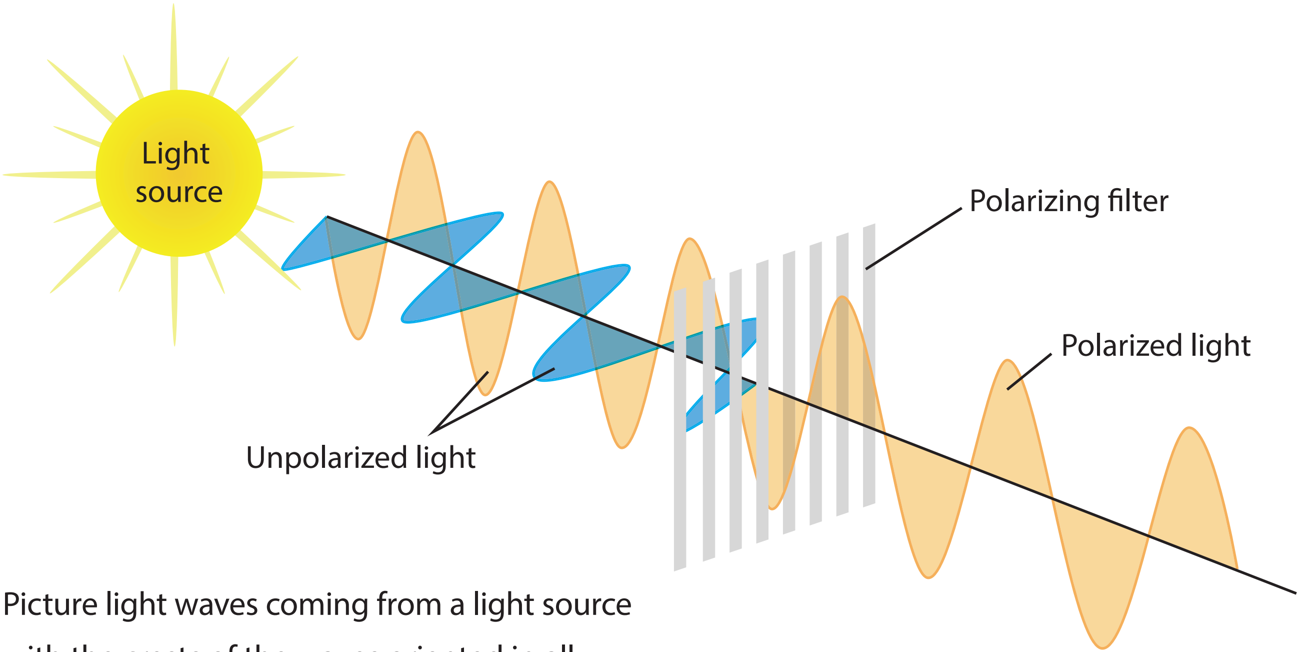
Violet light is also very scattered and abundant in the daytime sky on a clear day, but because our eyes do not perceive violet as easily as blue, the sky looks very blue rather than violet or violet-blue.

Polarization

A circular polarized filter brings out the color of both the tree and sky.

When I was a young travel photographer, I took a trip through national parks to shoot scenery. While sorting through my gear at the airport on one trip, I got to chatting with an older photographer who was also on my flight. We talked lenses and film speeds, and then he asked, "You do have a polarizing filter packed, right?" My stomach sank as I realized I had left my set of circular polarizing filters at home in Brooklyn. I muttered a few cross words. Then my soon-to-be savior unzipped his backpack and pulled out a filter. "You can borrow this one," he said. "Just send it back to me when you get home from the trip." That lucky encounter saved my trip and allowed me to do what I was hired to do. For big skies, a polarizer really is a game changer. Why?

When light reflects off nonmetallic surfaces such as water or even the molecules in the air, the light gets polarized. This means that most of the light is now lined up to arrive at the eyes of the beholder, or the lens of a camera, in a single plane. Here's a model of what I mean by that.



Picture light waves coming from a light source with the crests of the waves oriented in all directions (not just upward). Now, imagine trying to make these all-directions waves fit through narrow vertical slats somewhat like a picket fence. It won't work unless the waves are all aligned parallel, along a vertical plane that fits neatly through the slats.

A polarizing filter is essentially a very fine picket fence that sits in front of your camera lens to control the polarized light. Depending on the orientation of the reflected light waves that are going into your camera and the orientation of the polarizer, reflected light can pass through, be completely blocked, or be partially blocked.

To better illustrate what the polarizer brings to the game, look at these images of a bridge in Portugal. The top photo has a polarizer oriented to cut out the reflected light from the sky and water. The bottom photo does not.

Years later, I still sell a lot of photos that would be dull and full of unwanted highlights were it not for the circular polarizer. The only downside to using a polarizer is it does reduce the intensity of light getting into the camera, so you need to adjust your exposure or other variables to account for this.

Top image taken with polarizer; bottom without.

Glossary

absorb, v. to take in or soak up by chemical or physical action

aerosol, n. a liquid or solid that is dispersed in a gas

amplitude, n. the height of a wave's crest or depth of its trough from the baseline

context, n. all the words and ideas that surround an individual word, passage, event, or situation and can shed light on its meaning

correlation, n. a perceived connection or relationship between two things

dependent variable, n. a factor that is studied for how it is effected by the independent variable in an investigation

electromagnetic radiation, n. the flow of energy at the speed of light through empty space or through a material medium in the form of waves through electric and magnetic fields

frequency, n. the number of waves that pass a fixed point in a unit of time

independent variable, n. a factor that is deliberately adjusted, or varied, in an experiment or investigation

intensity, n. the quality of strength or magnitude, as in the brightness of light or the loudness of sound

LED light, n. a light source that emits light when current flows through a light-emitting diode

light, n. visible electromagnetic radiation

light source, n. something that emits visible light, typically through some kind of reaction occurring within it

mirage, n. an optical illusion in which light bends through one or more layers of air, altering a subject's apparent position or orientation

opaque, adj. blocks lights; not able to be seen through

photon, n. a quantum (minimum amount) of the electromagnetic field, also described as a particle of light (though massless)

pigment, n. a substance that imparts color to other materials

polarize, v. to restrict oscillations partly or completely to a limited direction

radiation, n. the transmission of energy that can travel both through space and through physical media

reflect, v. to throw back without absorbing

refraction, n. deflection of waves as they pass from one medium to another

scatter, v. to cause something, such as light, to reflect or travel in multiple, often random, directions

system, n. a set of interconnected things working together

translucent, adj. semitransparent; allowing some light to pass through, but not detailed shapes

transmit, v. to cause or allow something, such as light or force, to pass or be conveyed through space or a medium

transparent, adj. allowing light to pass through

turbidity, n. a measure of the clarity of water

variable, n. a factor that can change or be changed from one occurrence to another

visible light, n. the range of wavelengths of electromagnetic energy that can be detected by human vision

wave, n. a propagating disturbance that transfers energy outward from a source

wavelength, n. the distance from one crest of a wave to the next crest (or from one trough to the next trough)

Key Sources

"Why Are So Many Deep-Sea Animals Red in Color?" NOAA Ocean Explorer, 2017. https://oceanexplorer.noaa.gov/facts/red-color.html

Ferris Jabr, "The Lunar Sea." *Hakai Magazine*, June 3, 2017. https://www.hakaimagazine.com/features/lunar-sea/

Vivaine Callier, "What Scallops' Many Eyes Can Teach Us About the Evolution of Vision." *Smithsonian Magazine*, May 6, 2019. https://www.smithsonianmag.com/science-nature/what-scallops-many-eyes-can-teach-us-about-evolution-vision-180972099/

"Introduction to the Electromagnetic Spectrum." Science Mission Directorate, NASA Science, National Aeronautics and Space Administration, 2010. http://science.nasa.gov/ems/01_intro

Celia Vimont, "Should You Be Worried About Blue Light?" The American Academy of Opthalmology, March 10, 2021. https://www.aao.org/eye-health/tips-prevention/should-you-be-worried-about-blue-light.

G.E. Cordy, "A Primer On Water Quality." United States Geological Survey, 2001. https://pubs.er.usgs.gov/publication/fs02701

Todd Vorenkamp, "Understanding White Balance and Color Temperature in Digital Images." B&H Photo, 2015. https://www.bhphotovideo.com/explora/photography/tips-and-solutions/understanding-white-balance-and-color-temperature-digital-images

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