ELECTROMAGNETIC SPECTRUM

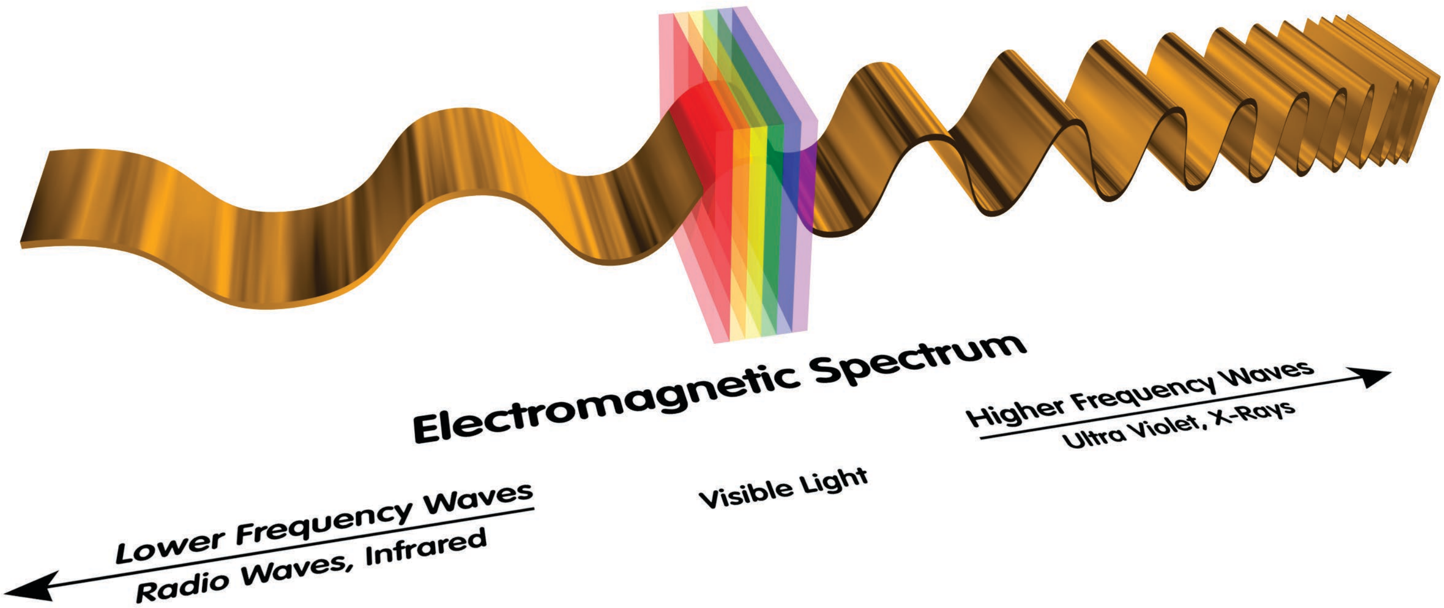
Supermarket science

Electromagnetic Spectrum

Radiating Energy, Photons, Waves, and Astronomy

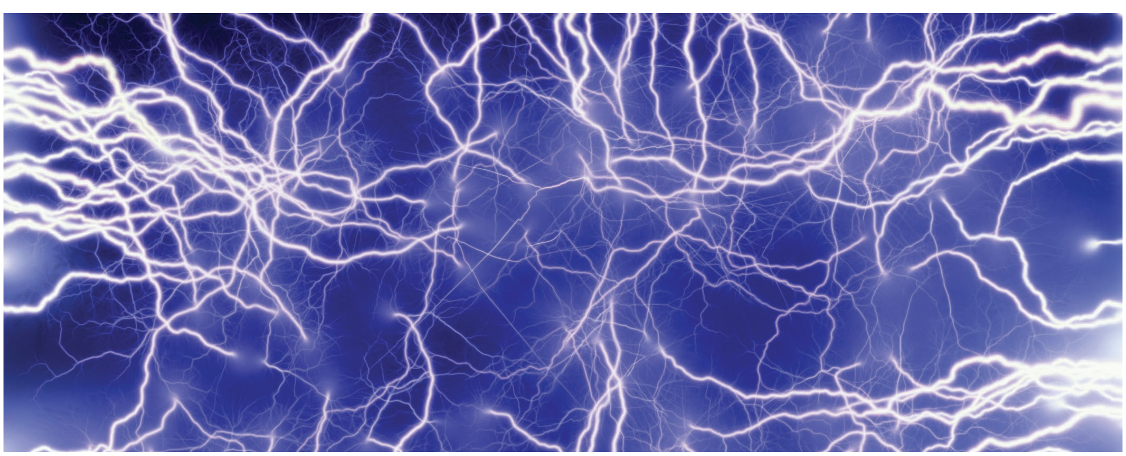
The Electromagnetic Spectrum is a term scientists use when they want to talk about radiating energy—radiation. All radiation is carried by photons, which are massless particles that travel at the speed of light. These photons can have greater or lesser amounts of energy.

Low energy photons carry things like radio signals. Radio signals can be generated by your favorite music station, but they can also be made by objects out in space. Radio telescopes "see" photons carrying energy in the radio part of the electromagnetic spectrum.



There are medium energy photons—these include visible light. Red is the same thing as blue, really. It's just that blue light has a little more energy in it than the red light. Then there are higher energy photons. You know how suntan lotion has "UV protection?" UV is ultraviolet light—it's just a little higher energy than what we can see with our eyes. And UV light can burn. When the photons carry even higher energies than that, you get x-rays, which can let doctors see broken bones. Photons with yet higher energies—gamma rays—are created by events which generate a huge amount of energy like exploding stars. Some gamma rays have such a large amount of energy that they can go all the way through the Earth and out to the other side. Gamma rays are not stopped by the walls of your home.

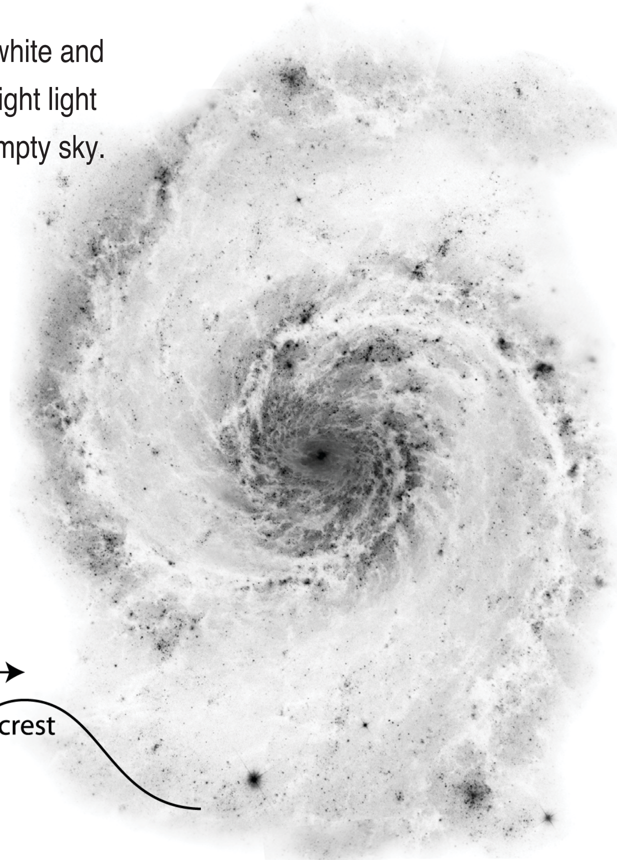
So the light that we can see is really only a small part of the electromagnetic spectrum. Our eyes just happen to be tuned to that one small part. If visible light is in the center, with red to the left and violet to the right, there are "colors of light" we can't see off to the left (deeper red than red) and colors off to the right (more intense violet than violet).



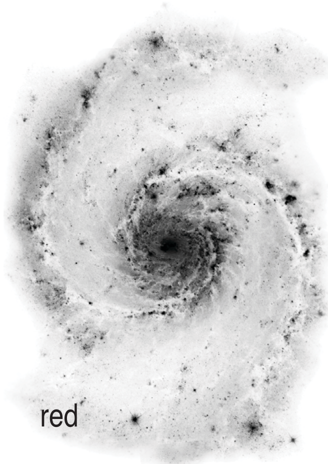
LEARN

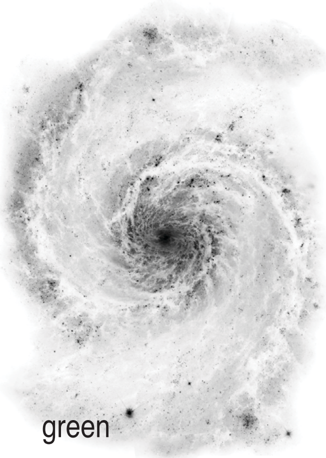
Wavelength

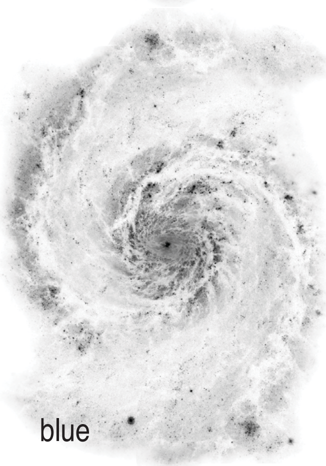
This galaxy is photographed in black and white and inverted—all black points correspond to bright light and stars, while white space is the dark, empty sky.

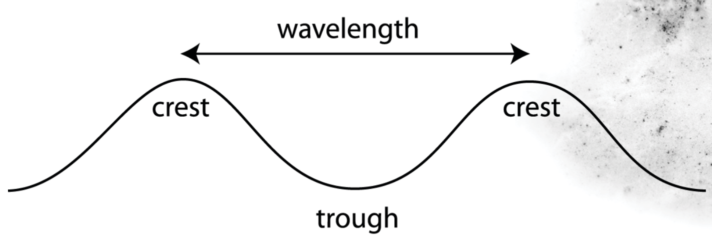


The three galaxy's images on the left reveal different information about its structure and the stars within it under three different wavelengths of visible light: red, green, blue. Take a close look and see if you can spot some differences.









One way to think about light is to picture its movement through space as a wave—something like the ripples on a pond. Light has a ***wavelength,*** which is the measure of distances between two adjacent crests. The more energy carried by light, the shorter its wavelength. So blue light has a shorter wavelength than red light. Visible light range from longer to shorter wavelengths is red, orange, yellow, green, blue, indigo, and finally, violet. There are higher and lower wavelengths than the small part of the spectrum that our eyes are adapted to see. X-rays carry a lot of energy; their wavelengths are millions of times closer together than the width of a human hair. Radio waves are less energetic and have wavelengths that can be spread apart longer than a football field.

While it's easy to image scientists measuring light wavelengths from crest to crest with rulers, the truth is that these ripples are moving at incredible speeds—the speed of light, in fact. So scientists stand at one spot and measure how many crests move past them during one second. That number is called the ***frequency:*** the shorter the wavelength, the more crests pass by. So radio waves have a low frequency and gamma rays have a very high frequency.

Higher frequency means more energy. If you're at a campfire, what color flame would cook your hot dog the fastest?

____

We can find out a lot of information about an object by studying the frequencies at which it radiates. Astronomers analyze stars and galaxies by looking at the information contained in different frequencies of light. By considering all wavelengths, they can build up a more accurate picture of what they're observing. In addition to telescopes that collect visible light, astronomers have built radio telescopes, x-ray telescopes, infrared imagers, and ultraviolet detectors.

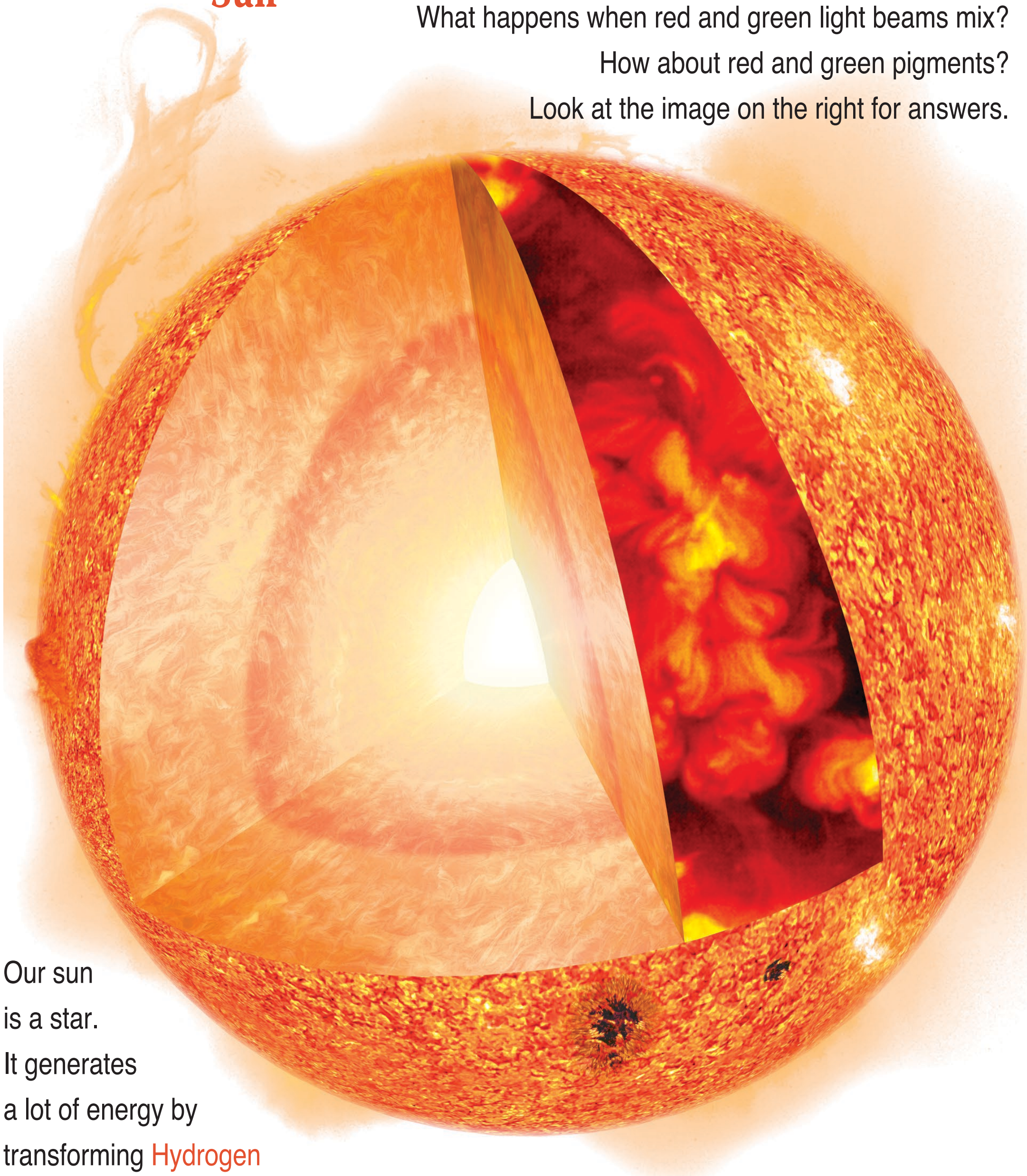
But there's a big a problem: the Earth's atmosphere blocks out a lot of these frequencies, stopping those photos from reaching the ground. X-rays from space, for example, are almost completely blocked out by the ozone layer. While that's good for our health, it poses a problem for viewing the universe in the x-ray spectrum. Telescopes have been sent into space to observe the universe from above the obscuring effects of the Earth's atmosphere. What we've seen has surpassed the wildest expectations of even the most optimistic astronomers. It's a great time to be interested in what's going on in the universe.

Supermarket Science

SHOW

Sun

When red, green, and blue light beams intersect, the resulting color is white. But if red, green, and blue pigments were mixed together, the resulting color would be dark brown. What happens when red and green light beams mix? How about red and green pigments? Look at the image on the right for answers.



Our sun is a star. It generates a lot of energy by transforming Hydrogen into Helium via a nuclear fusion reaction. This energy is made at the center of the sun and needs to move all the way to the surface before it radiates through space and reaches the Earth. On the inside, the energy is first transported via radiation and then convection, creating multiple layers within the Sun.

Supermarket Science

A prism can divide white light into its components. When there is a lot of moisture in the air, small droplets of water act like a million little prisms and break down sun light into a rainbow. To look for a rainbow, you must stand with the sun right behind you.

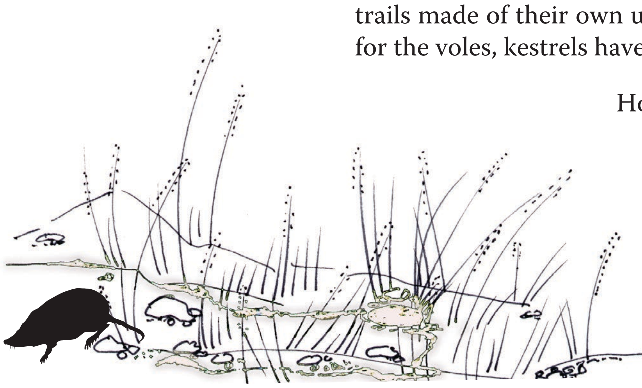
LEARN

The Pee and The Bee

Two Ultraviolet Stories

Kestrels are birds, a type of falcon. They are birds of prey that hunt and eat small animals. Kestrels rely on their keen eyesight. They can hover in the air and spot a small moving animal from a great distance. Scientists recently discovered that kestrels can even see in the ultraviolet part of the spectrum. But nobody could figure out how seeing in the ultraviolet would give kestrels any kind of advantage during hunting. It was a mystery.

Kestrels love to eat voles, small rodents that look something like rats. Voles burrow in the ground and they live in a world ruled by smell rather than vision. Voles move from place to place following scent trails made of their own urine. The scent trails lead right to their underground burrows. Fortunately for the voles, kestrels have no sense of smell.

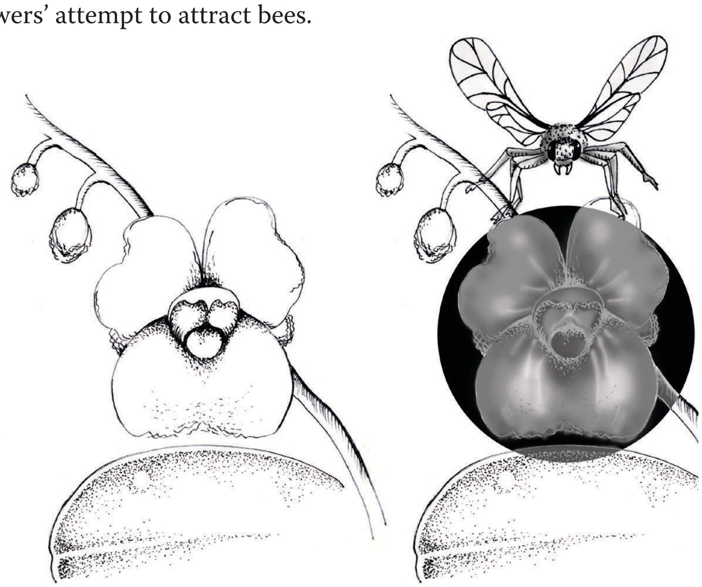


However, kestrels do have one advantage. It turns out that vole urine reflects ultraviolet light. In the voles' nesting area, eyes attuned to ultraviolet can see these bright trails of urine—and they lead right to the den of the voles. Kestrels hover above these dens waiting for the voles to come out. Then they strike.

Do kestrels really rely upon seeing vole urine to help them hunt or could it just be a coincidence? Scientista wanted to find out. They collected a bunch of vole urine (don't ask!) and marked trails in an area with no voles. Sure enough, kestrels came and hunted there.

Many flowers depend upon bees to transport their pollen from plant to plant. Bees unwittingly carry the pollen with them while they forage inside the flowers for their food. Flowers have evolved to maximize their attractiveness to bees. Bees have a highly evolved sense of smell, for example. Flowers probably smell good because bees like it. That humans also like the smell of flowers is an accidental by-product of the flowers' attempt to attract bees.

Bees can also see ultraviolet light that's invisible to us. Flowers have evolved a complex set of visual patterns only visible in the ultraviolet part of the spectrum. These patterns sometimes resemble an airport's runway lights and are designed to coax and guide bees towards the food rewards deep within the flower.



Supermarket science

The Invisible Fingerprints of Heat

Hot Things Give Off Light—Even if the Light is Invisible to Us

Ever see coals in a barbecue? At their hottest, they glow white hot. As they cool, they glow red, and finally they stop glowing—they just look black. But they're still hot. If we were able to see infrared light, they'd still be glowing. Certain animals, like rattlesnakes and mosquitoes, can see infrared light. Since people are warmer than the air around them, they are easy to spot, glowing with heat in the dark. To female mosquitoes, we are like a beacon in the night.

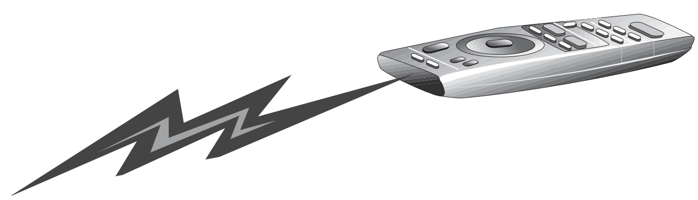
The police, the military, and scientists have devices called thermal imagers which can take heat and translate it into visible light.

But how do the police use thermal imagers? "Nightvision" goggles that look like binoculars are handy for seeing bad guys in the dark. Burglars who think they are totally hidden by the blackness stand out brightly on an infrared nightvision scope.

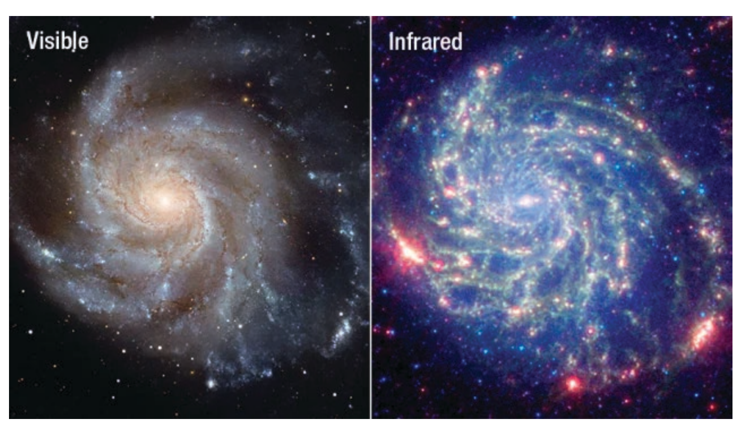
With just our eyes, the burglar is hidden by the darkness.

Under infrared light, the burglar's heat gives him away.

Ever wonder how a remote control works? Actually, it works in the infrared, sending coded light signals to tell the TV to change the channel. If you were wearing nightvision goggles, the remote control would shine just like a flashlight as you used it.



Astronomers can use infrared imaging devices to take pictures of objects which are hot but not hot enough to glow with visible light. For example, the big clouds of dust in space and the hot envelope of gas surrounding a supernova show up brightly on a thermal imager mounted on a platform in space.



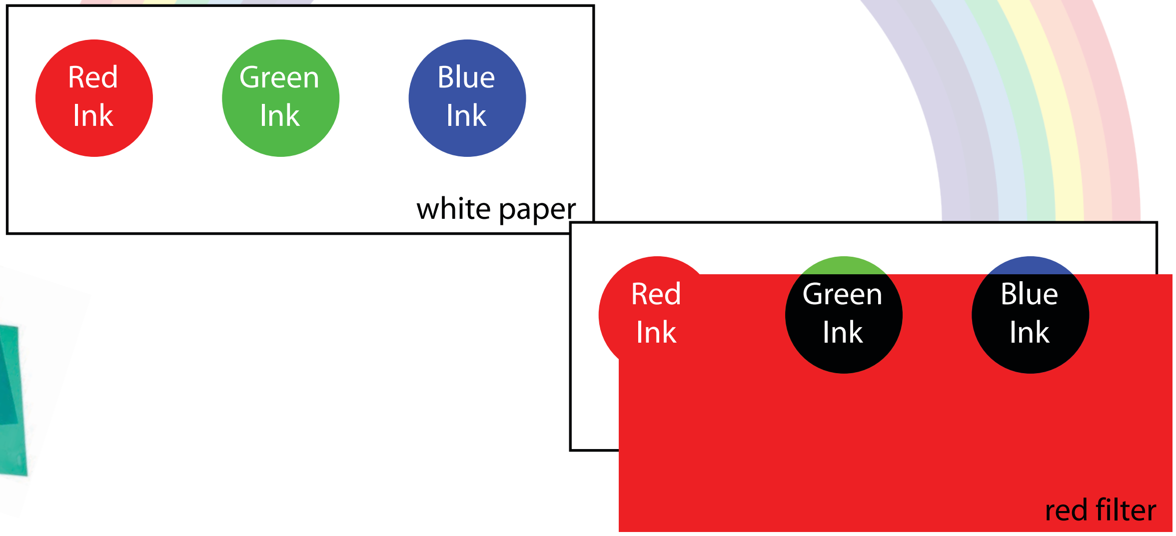
Supermarket Science

LEARN

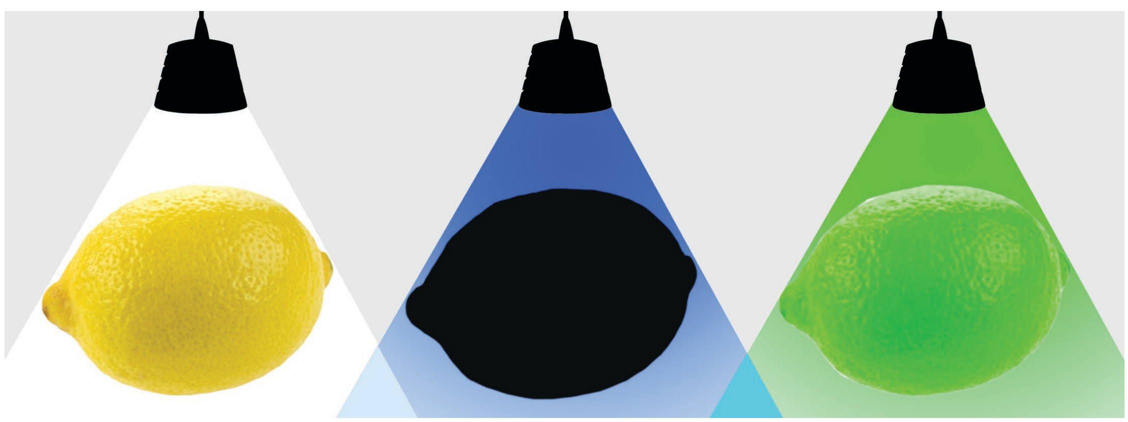
Color Filters & Reflected Light

White light is made out of all the colors of the rainbow. When white light passes through a prism, we can see it spread out on the other side into its different colored components. Red, green, and blue are colors of light which aren't a mixture of any of the others. We call them primary colors. Colors like yellow (a mixture of red and green light) are known as secondary colors.

When you look at anything, what you're seeing is the light that bounces off of the object and into your eyes. Imagine you're looking at a white sheet of paper with big colored dots on it. The white parts of the paper are reflecting all the colors which fall on it—so they look white. A red dot on the page reflects only the red light. The other colors are absorbed into the paper. So only red light bounces off and hits your eyes—it looks red. Green dots only reflect green and blue dots only reflect blue.



Use some colored pencils to draw a picture. Consider drawing a self-portrait and make sure to add many colorful details. When you've finished carefully coloring everything in, look at your drawing through the different gels. Notice the difference?



An object is a particular color because of the color of the light it reflects. So lemons look yellow because they reflect red and green light and absorb blue light. If you shine only green light on a lemon, it will look green.

Why? Because lemons (yellow) reflect red and green light. If you shine only blue light on a lemon, it will look black.

Why? Because the lemon absorbs the blue light and there's nothing to reflect back. When an object looks black, it means that it absorbs all of the colors in the light and doesn't reflect any back.

A white object reflects all of the colors in the light that strikes it. So when you're reading the words on this paper, you're not actually seeing any light from the words themselves. You're really seeing light reflected from the white spaces which surround the black ink letters.

Supermarket science

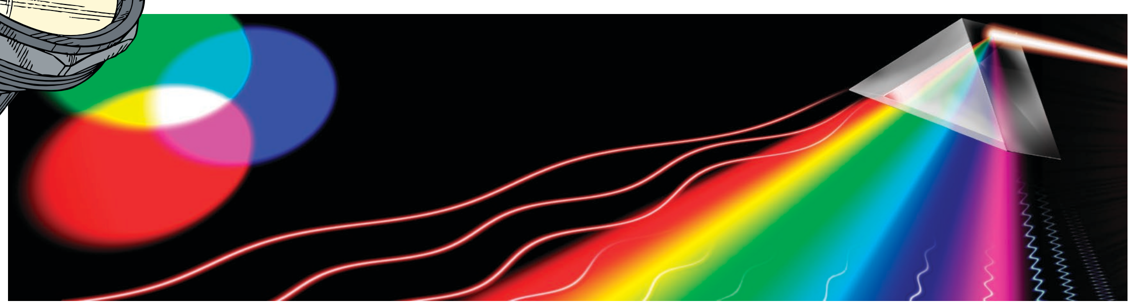
LEARN

Color & Light

Color the image of the zebra as if it was standing under a blue light. You can use your color gels to see what the image would like like if you shine different colored light on it.

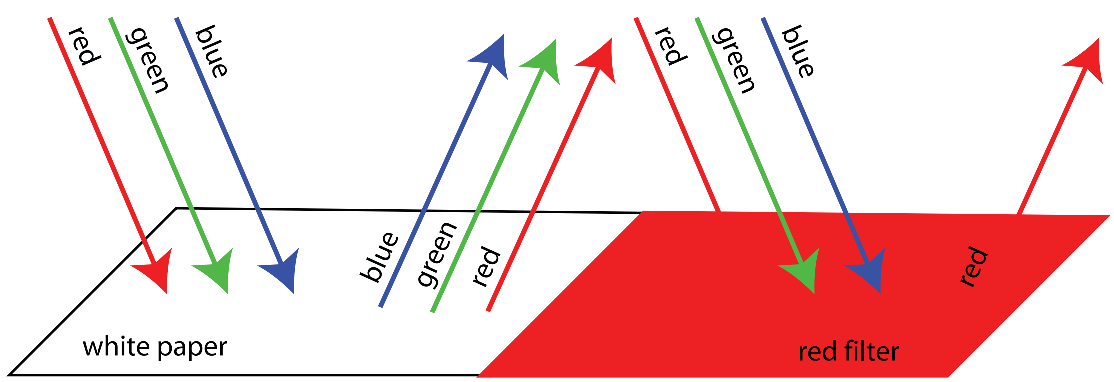
What happens when you're looking at a zebra? What colors will a zebra be if you only shine red light onto it?

Let's go back to the white paper with colored dots. What's happening when we put a red filter over the paper with red, green, and blue dots? The red filter rejects all colors of light except red. So the white paper looks red. The blue dot looks black—there isn't any red color reflected from the blue dot to pass through the filter. Similarly, the green dot looks black. What about the red dot? The red dot's color passes through the filter as red. But the dot becomes invisible. *Why?* Because it is now swamped by the red color reflected from the white paper around it.



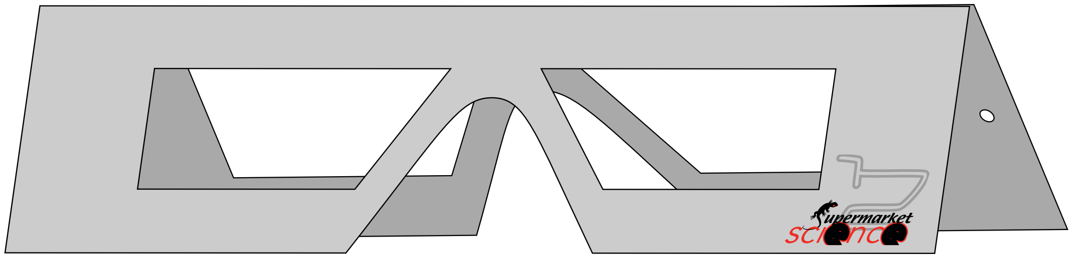
What would happen to a red dot on a black background if you looked at it under a red filter?

By the way, if yellow is a mixture of red and green light, how come you get an ugly brown color if you mix red and green paint? Colored light mixes differently than colored pigment. Paint has a color because of the light which reflects from the pigment, while light has a color because it is of a certain wavelength. If you add colored lights together, you're combining those different wavelengths. Add all the colored lights together and you get white light. Mix all the colors of a paint set, however, and you're going to get a dark, muddy brown color.

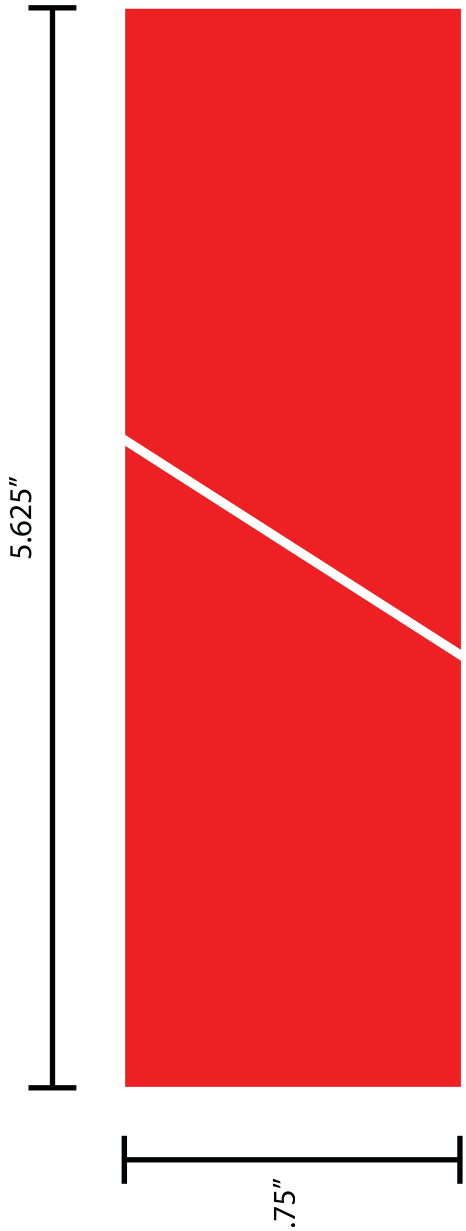


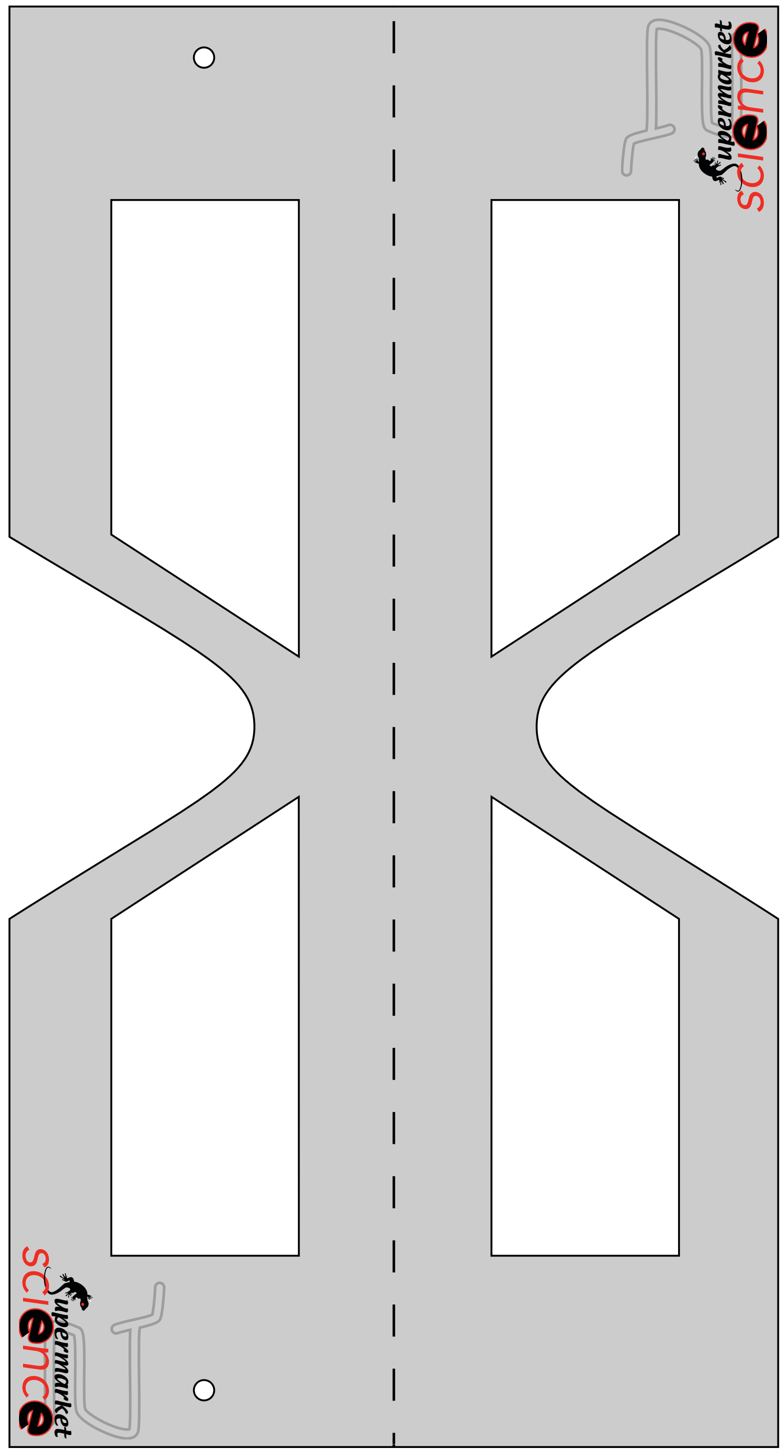
USE

A Template for Making Colored Lens out of Paper and Red Gel



These eyeglasses let you look at the world through different colored filters. Use this page as a pattern to make glasses from paper and different colored plastic sheets. Use a thumbtack to punch out the small white holes at the temples. Note that the holes need only be on one side.





What You Need:

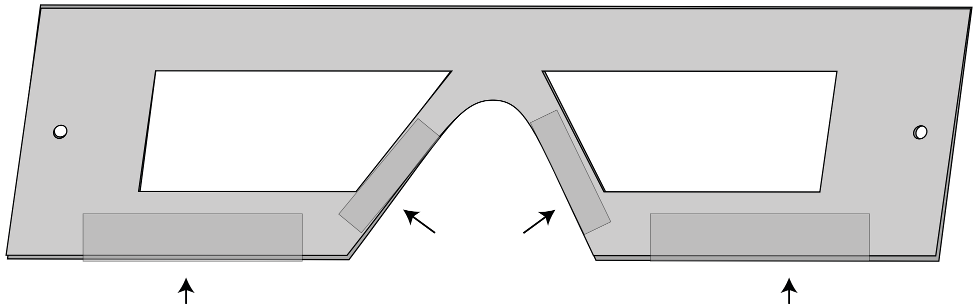
DO

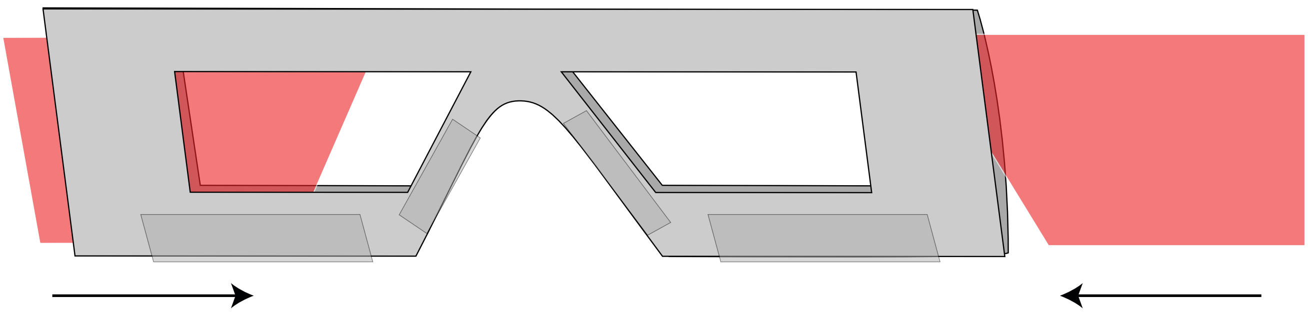
Make Colored Filter Glasses

What You Need:

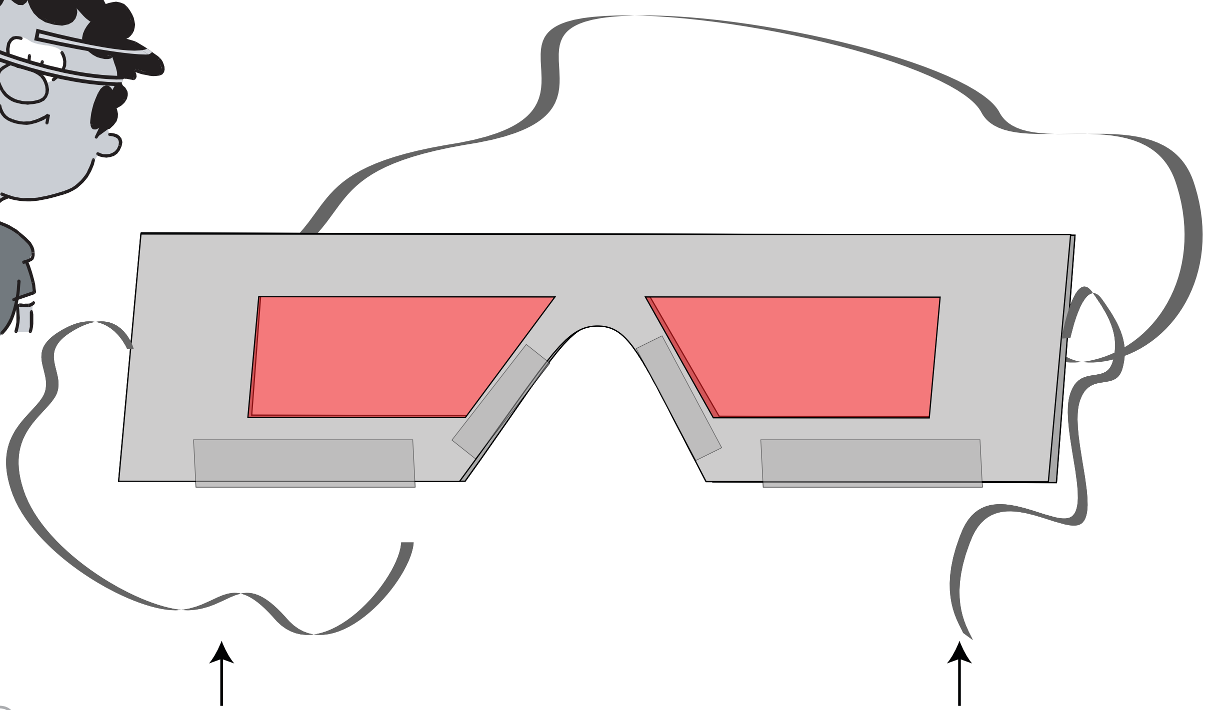
Parent Helpers

Fold the glasses and then tape them shut as shown in the illustration. Be especially careful when taping around the nose so that the tape doesn't block the eye holes.





Measure a length of ribbon by wrapping it around your head twice. Then cut it.



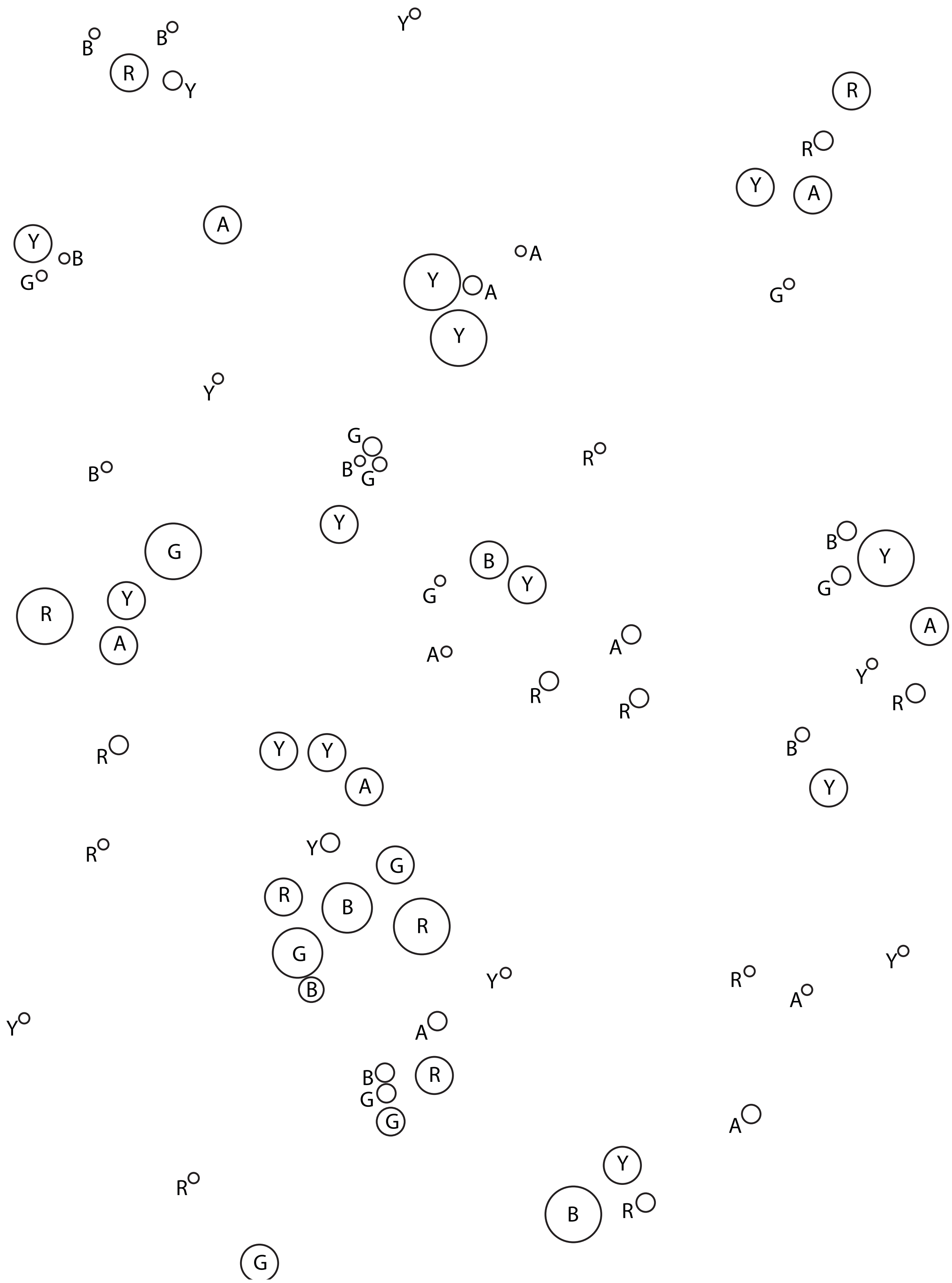
Put the glasses on and tighten the ribbon headband by pulling on the ribbon ends at the front of the glasses. The filter can be changed by slipping out the old filters past the ribbons and then slipping in the new filters.

Welcome Code-Breaker

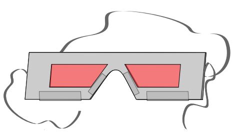
Use your Red Filter Glasses to identify the "real" constellation. Which one is it?

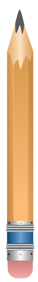
Below is an image of a star map. Some stars are real and some are fake. Use green, yellow, blue, red, and orange "watercolor" markers (pastel shades) to color in the stars on the map. Follow the color code directions about which colors to use on which stars.

Hidden Constellation Star Map



What You Need:





- green
- yellow
- blue
- red
- orange

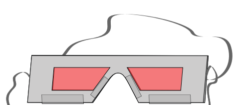
G = green
Y = yellow
B = blue
R = red
A = orange

Supermarket science

DO

Looking for Secrets

What You Need:



There are hidden words in the picture above. It's hard to find them with a "naked" eye. But if you use your color glasses, you might discover the secrets within. You will need blue, red, and green filters for your glasses. Look at the picture through these three colors. What are the words you found:

Blue Filter: ______________________________

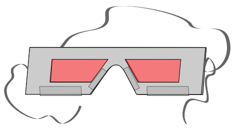
Red Filter: ______________________________

Green Filter: ______________________________

DO

Secrets Messages

What You Need:



green
yellow
blue
red
orange

Secret messages can be hidden among multi colored drawings. For example, color blue and color green become black when viewed through a red colored glasses. But any spot of red color becomes completely invisible when seen through a red filter. And the more "red" it is, the more invisible it becomes—orange, which is made by combining yellow and red colors, becomes less visible through a red filter than by observing it with a naked eye. These color-change rules can be used to create secret messages that only become visible through a red colored glasses.

For example, use green, yellow, blue, red, and orange "watercolor" markers (pastel shades) and color the letters in the sentence below so that:

letter "a" is green
letter "m" is blue
letter "e" is green
letter "d" is yellow
letter "i" is orange
letter "c" is red
letter "r" is blue
letter "a" is red
letter "n" is orange
letter "i" is green
letter "n" is yellow
letter "t" is orange
letter "o" is yellow
letter "a" is red
letter "c" is blue
letter "a" is green
and letter "b" is red.

a medic ran into a cab

Now look at the colorful sentence above through your red glasses. What is the hidden word:

What is the hidden word?

all a's are yellow
all i's are red
m, t, y, d, n, and s are orange
f is green
first l is blue and second l is red
o is green
w is blue
first e is green and second e is yellow
r is blue

family on a water slide

What is the hidden word?

you may open your test at one

all e's are yellow
all u's are red
p is orange
first y is blue, second y is red, and last y is orange
m is green
first o is red, second o is green, third o is blue, and last o is orange
first a is yellow and second a is green
first n is blue and second n is red
first t is blue, second t is red, and last t is yellow
s is green

Read backwards. What is the hidden word?

Now on the back on this page or on a seperate piece of paper, use green, yellow, blue, red, and orange "watercolor" markers (pastel shades) to create your own secret message in such a way that it is ONLY visible through a red filtered glasses. Can yout freinds and family figure it out?

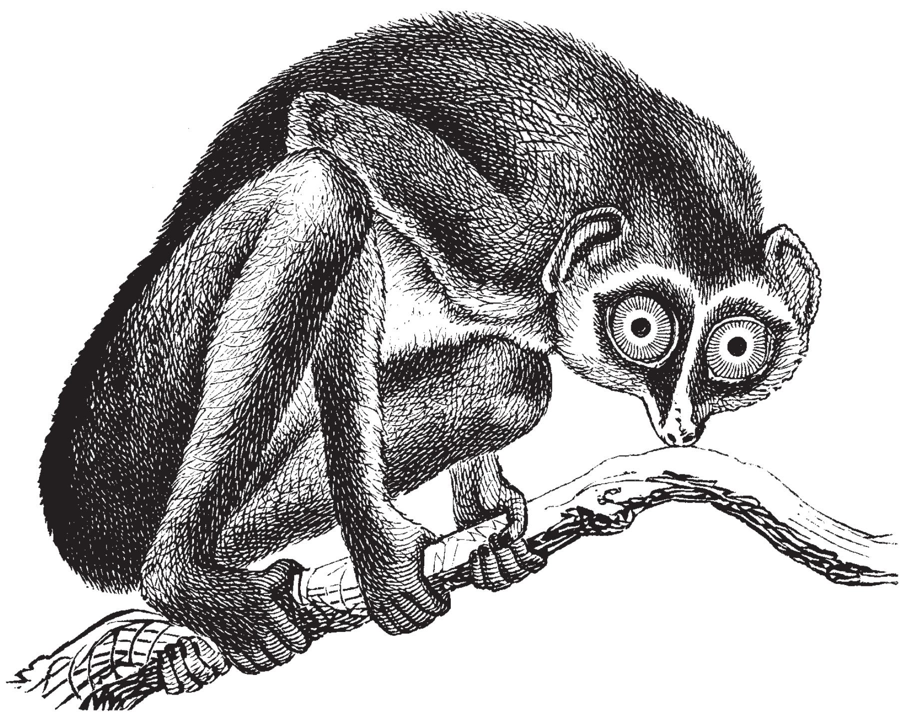
Supermarket Science

DO

Word Puzzle

electromagnetic
spectrum
photons
radio
signals
visible
light
UV
ultraviolet
gamma
rays
frequency
astronomers
stars
galaxies
ozone
layer
telescopes
atmosphere
universe
hydrogen
helium
nuclear
fusion
reaction
nightvision
binoculars
infrared
supernova
primary
colors

I	N	F	R	A	R	E	D	S	C	E	S	R	R	E
F	A	N	M	M	L	O	I	N	R	O	E	S	A	L
V	U	M	O	B	U	G	I	E	J	S	P	E	Y	E
H	A	S	I	I	N	I	H	D	U	N	O	I	S	C
G	Y	S	I	A	S	P	L	P	A	U	C	X	F	T
N	I	D	L	O	S	I	E	E	L	R	S	A	R	R
V	H	S	R	O	N	R	V	T	H	F	E	L	E	O
S	R	E	M	O	N	O	R	T	S	A	L	A	Q	M
H	O	T	J	O	G	A	P	A	H	S	E	G	U	A
U	A	E	V	Q	V	E	Y	H	E	G	T	O	E	G
Y	R	A	M	I	R	P	N	V	O	L	I	Q	N	N
B	I	N	O	C	U	L	A	R	S	T	C	N	C	E
V	D	L	M	U	R	T	C	E	P	S	O	U	Y	T
M	E	U	N	I	V	E	R	S	E	W	I	N	N	I
T	H	G	I	L	N	O	I	T	C	A	E	R	S	C



Supermarket science