Electromagnetic Spectra

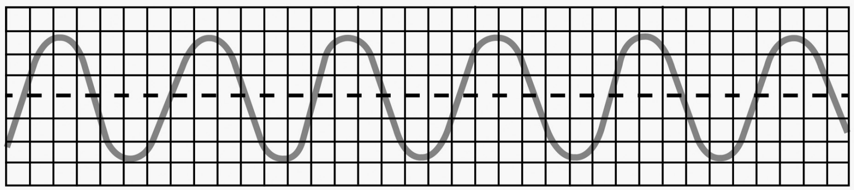
Light from the Sun may look white or yellowish, but it can be separated into a rainbow of colors.

You can see this when light passes through a piece of glass called a **prism**, an instrument called a **spectroscope**, or water droplets in the sky.

Light is packets of energy that move as waves of electricity and magnetism. It is very hard to imagine electromagnetic waves. It helps to use wave graphs as models that explain how they behave.

Electromagnetic waves do not require a medium. They travel through empty space at a constant speed of 300,000 kilometers (km) per second. If they pass through a medium like glass, water, or plastic, their speed slows down slightly.

Model of an Electromagnetic Wave



This wave graph helps us understand how electromagnetic waves travel.

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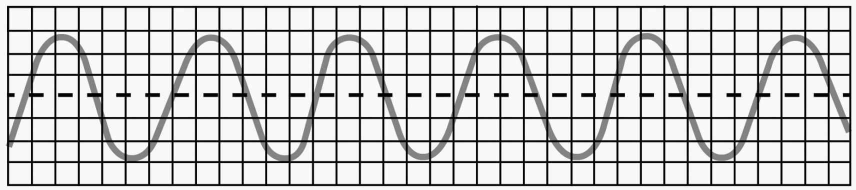

This wave graph helps us understand how electromagnetic waves travel.

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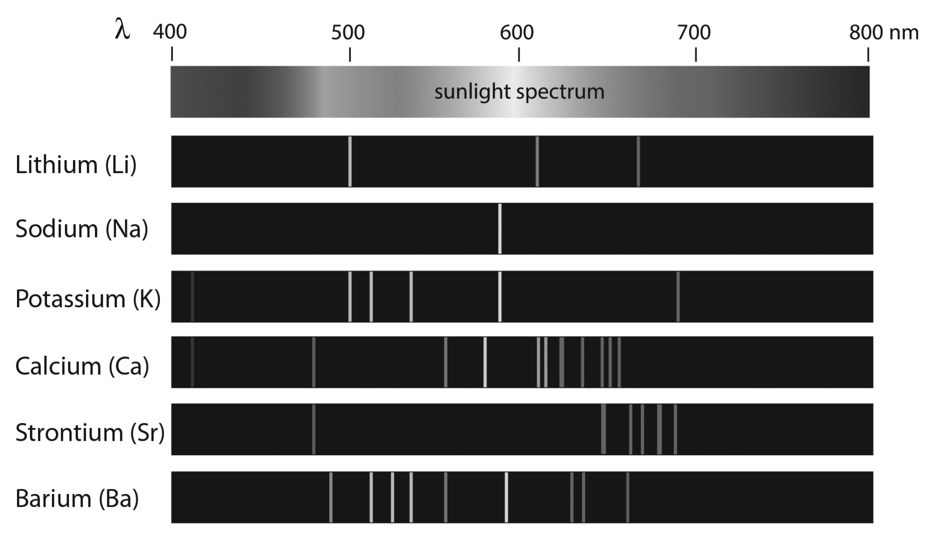
Spectroscopes

Spectroscopes can separate different wavelengths of electromagnetic **radiation**. Knowing the wavelengths lets you identify a light source. In class, you used spectroscopes to identify light sources. Waves of **visible light** have wavelengths between 400 and 700 nanometers (nm).

Spectroscopes also let you determine the chemical composition of the light source. How can you tell which substances are creating the light of the Sun or a lightbulb? When atoms' energy levels change, they absorb or give off certain wavelengths of electromagnetic radiation. The pattern (spectrum) of wavelengths can identify different atoms and molecules. These light spectra can be used to identify the chemical composition of the light source.

Take Note

Imagine that you used a spectroscope to look at an unknown lightbulb, and you observed one thin yellow band of light at about 590 nm. What conclusion could you make about the light source? Use evidence in your response.



Spectroscopy can be used to identify the elements that make up a light source, such as a star. This is because each element—like the six shown in the chart—produces a unique pattern of lines, or spectra.

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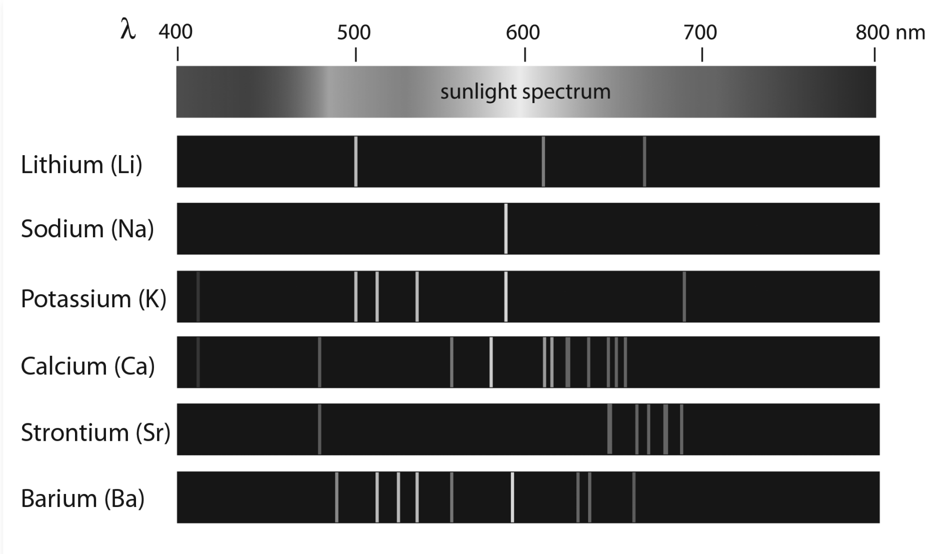

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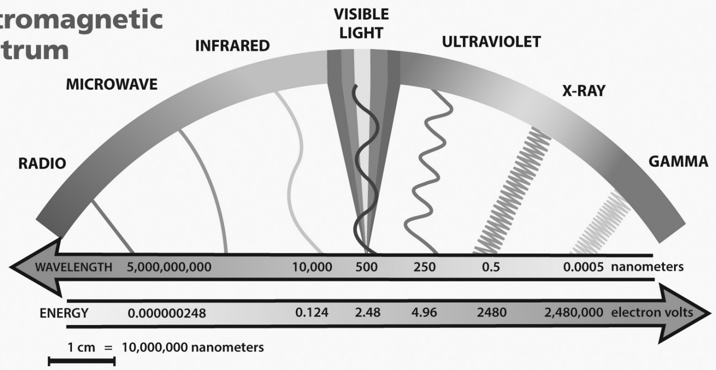
Spectroscopes are important scientific tools because it is impossible to see atoms and molecules directly. Using spectroscopes, scientists can determine the chemical makeup of stars and planets that are light-years away, or the composition of important molecules in cells and other structures.

Spectroscopy can reveal more than visible light. In fact, visible light is just a small portion of the millions of wavelengths that make up the **electromagnetic spectrum**.

Electromagnetic Spectrum



The waves in the electromagnetic spectrum have a wide range of wavelengths and frequencies. The wavelengths we can see make up visible light. The other wavelengths are forms of energy we cannot see.

Earth's atmosphere absorbs most of the invisible light from the Sun. This is good for life on Earth since exposure to too much ultraviolet, X-ray, and gamma radiation would be harmful.

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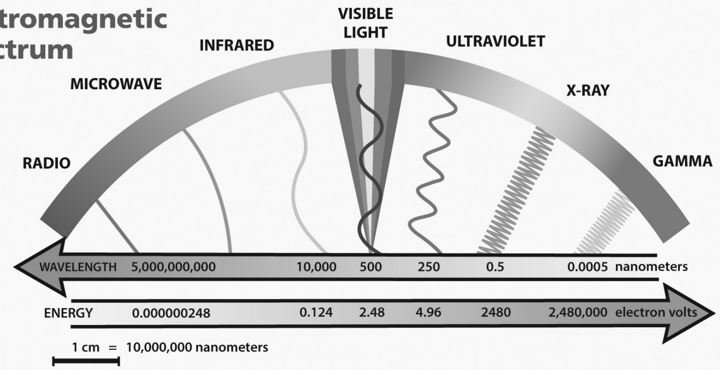

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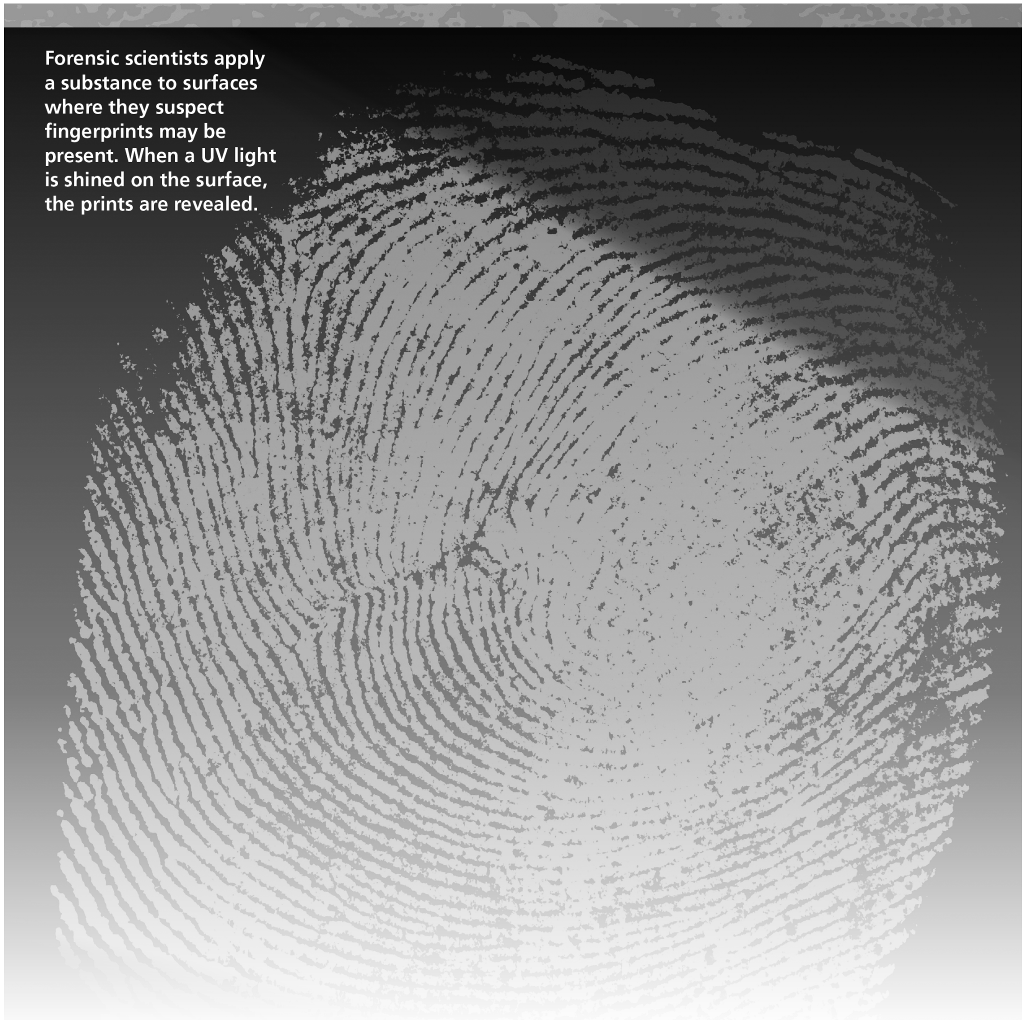

Forensic scientists apply a substance to surfaces where they suspect fingerprints may be present. When a UV light is shined on the surface, the prints are revealed.

Invisible Wavelengths Beyond Violet

What kinds of rays are in the electromagnetic spectrum? The shortest visible wavelengths are violet. Even shorter than violet light are ultraviolet light, X-rays, and gamma rays. As you know, wavelength and frequency have an **inverse relationship**. Short wavelengths are associated with high frequency and high energy.

Ultraviolet (UV) light has wavelengths shorter than visible violet light, from about 10 to 400 nm. Ultraviolet waves have higher frequency and higher energy than visible light waves. These properties are one reason that ultraviolet light can cause sunburn and skin damage. The energy is high enough to excite the electrons within a molecule.

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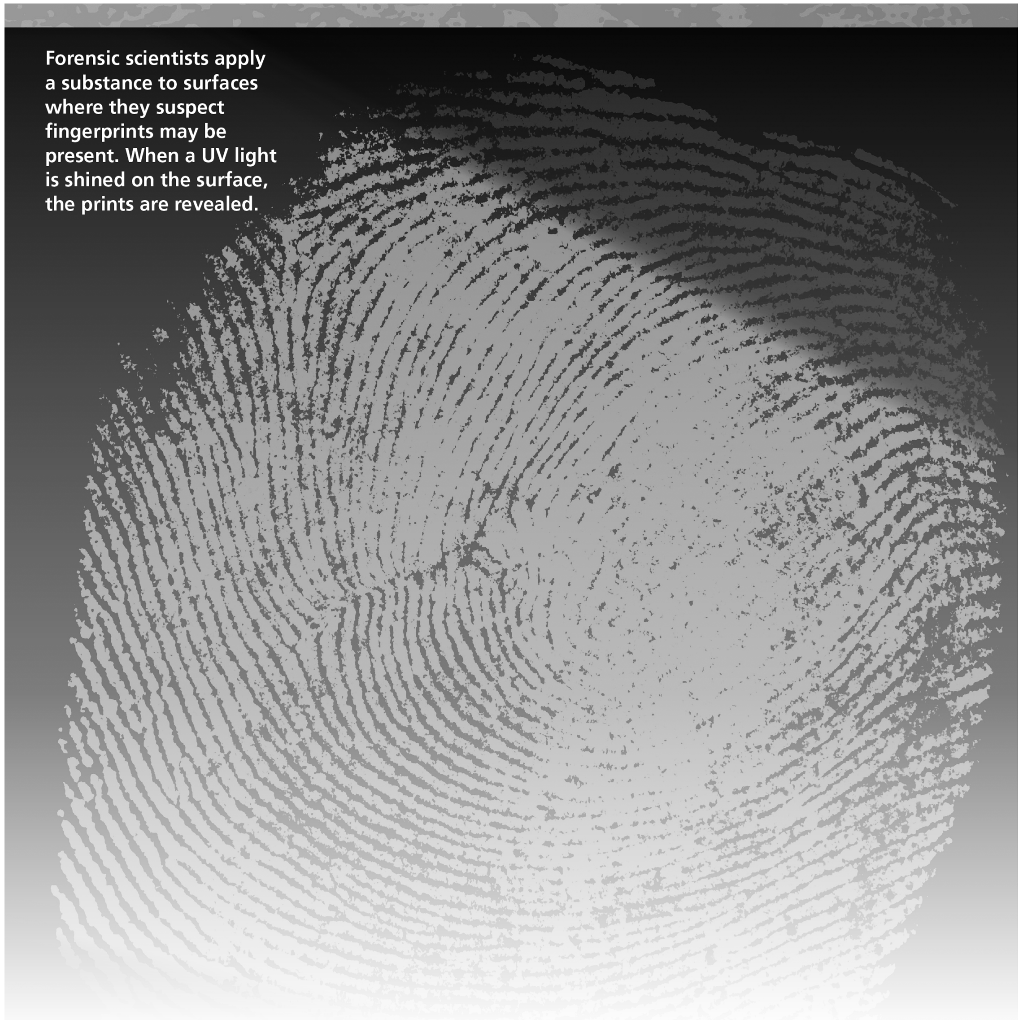

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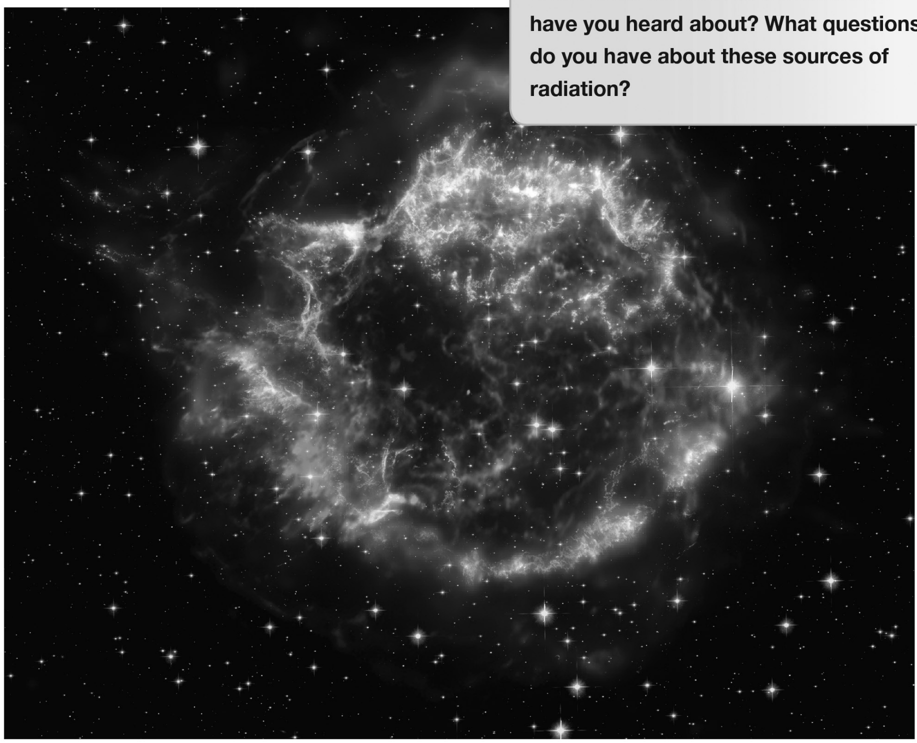
X-rays have wavelengths in the range of 0.01 to 10 nm, smaller than ultraviolet light. X-rays are used to study crystal structure. Ultraviolet and X-ray lights are not visible to our eyes, so their spectra are usually displayed as a wave graph. This information can also be interpreted by computers to display X-ray images.

Gamma rays are the highest-energy electromagnetic waves. Sources of gamma rays include radioactive substances, nuclear reactors, and lightning strikes. Astronomical processes, such as nuclear fusion in stars and supernova explosions, also create gamma rays.

Take Note

Think about the three kinds of electromagnetic radiation with higher frequency and energy than visible light: ultraviolet, X-rays, and gamma rays. What other sources of this radiation have you heard about? What questions do you have about these sources of radiation?



A supernova is an immense explosion that can occur during the last stages of a massive star's life. It may release an intense flash of gamma radiation that can outshine other stars in the universe. A gamma-ray burst is the most energetic form of electromagnetic radiation known.

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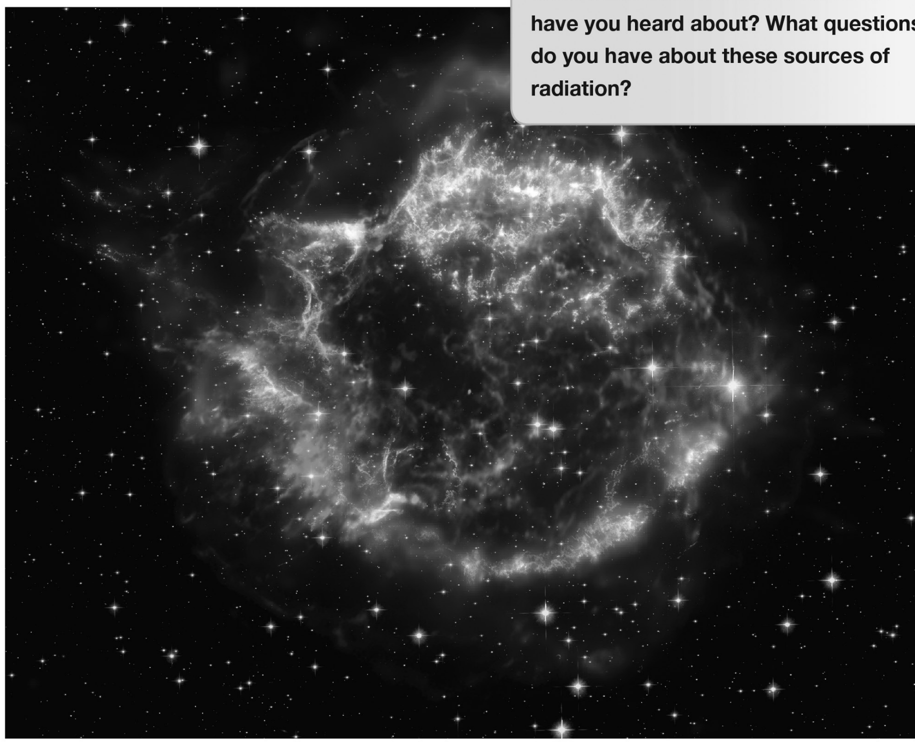

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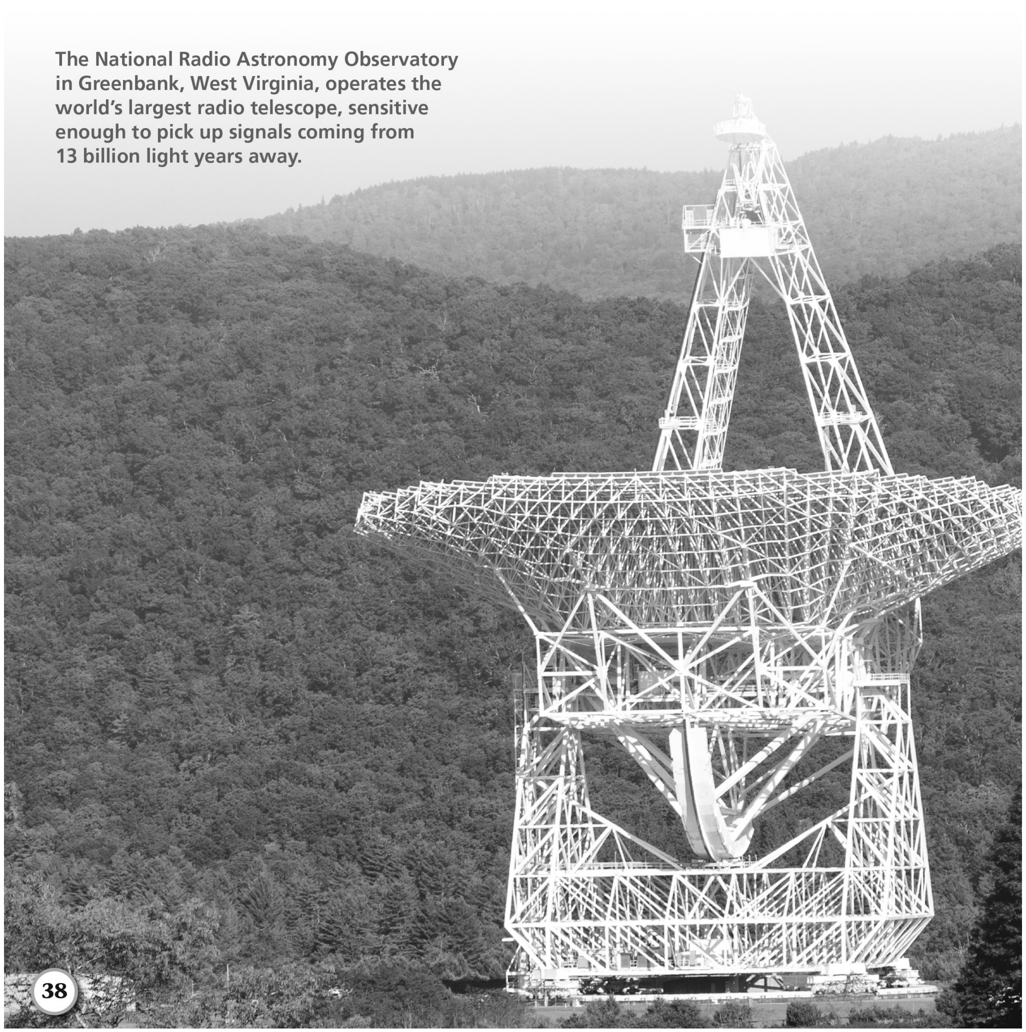
Invisible Wavelengths Beyond Red

Some waves are longer than the longest visible wavelengths (red). They include infrared waves, microwaves, and radio waves. As you know, long wavelengths are associated with low frequency and low energy.

Infrared (IR) waves range from 700 nm to about 1 millimeter (mm). As with all spectra, infrared spectra can be used to identify and study chemicals.



The National Radio Astronomy Observatory in Greenbank, West Virginia, operates the world's largest radio telescope, sensitive enough to pick up signals coming from 13 billion light years away.

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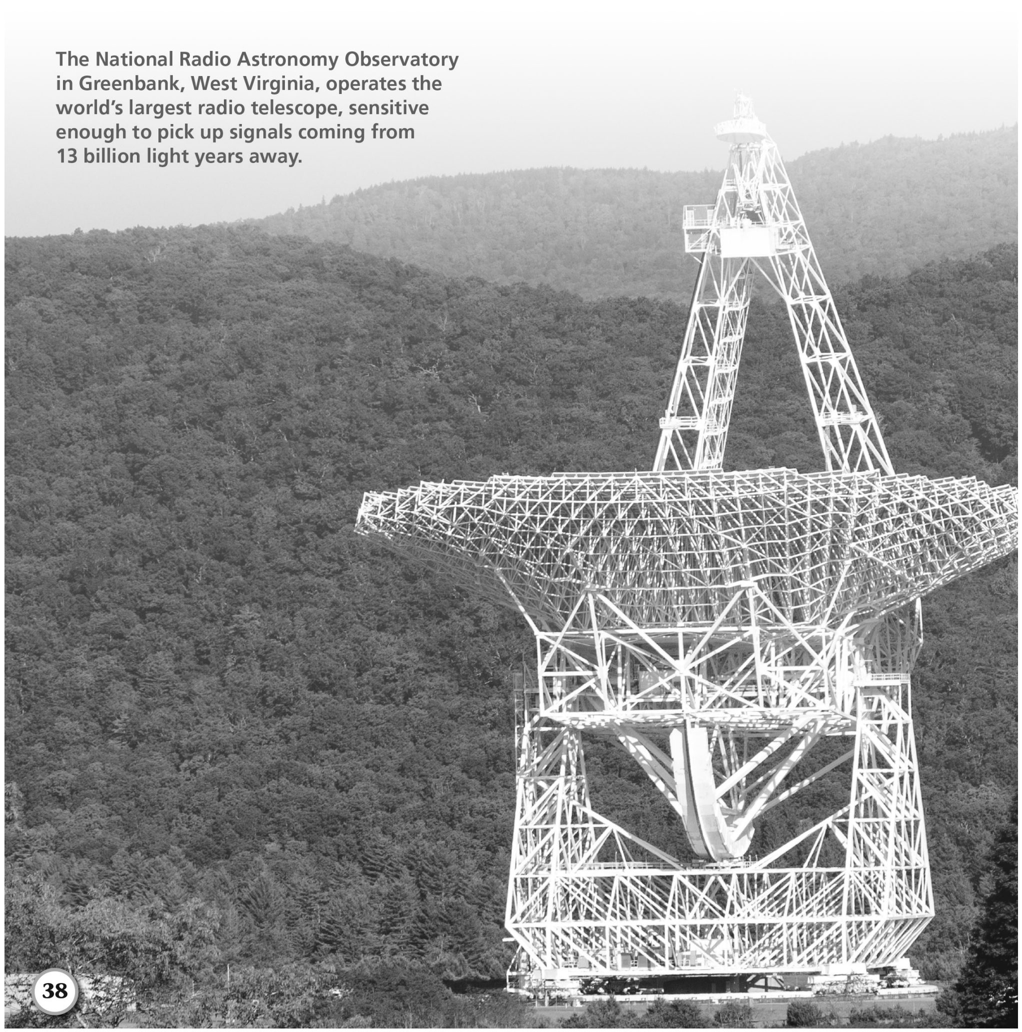

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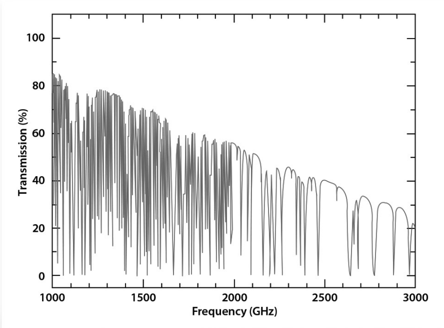
Microwaves have wavelengths ranging from 1 mm to 1 meter (m). Microwave spectra can be used to analyze the energy of molecules in gases.

Radio waves range from 1 m to 100 km long. Large radio telescopes observe radio waves. The radio telescope in Greenbank, West Virginia, is used to study radio waves coming from galaxies and gas clouds in space. More than 140 different molecules have been observed in space based on their radio wave spectra.



This graph shows a microwave spectrum for water vapor in the atmosphere at Mauna Kea, Hawaii.

Take Note

Think about the three kinds of electromagnetic radiation with lower frequency and energy than visible light: infrared waves, microwaves, and radio waves. What other sources of this radiation have you heard about? What questions do you have about these sources of radiation?

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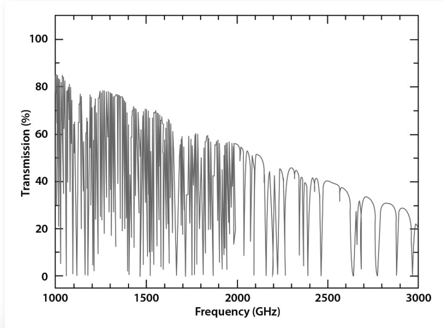

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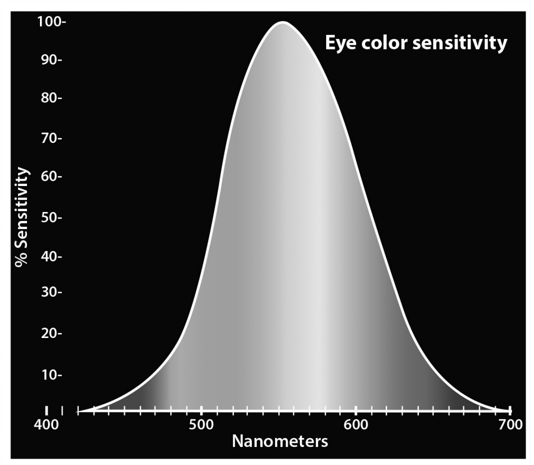
Animals and Vision

Your eyes can respond only to light with wavelengths in the visible range. Thus, you can see blue, red, green, and all the other **colors** of the rainbow. But try as you might, your eyes cannot see colors beyond the visible spectrum. But what about other animals?

Almost all animals have between one and five color receptors. The receptors let animals see fine differences in colors. Most humans have three, but a rare genetic mutation gives some people four. Does this extra color receptor let people see ultraviolet or infrared or even X-rays? No, but it does let those people see fine differences between colors more easily.



This graph shows how well humans can detect each wavelength of the visible spectrum. What range of colors are we most sensitive to—that is, which do we perceive best?

Some snakes are capable of sensing prey with infrared waves. This green tree python has infrared receptors on its lips that let it find prey by detecting the animal's body temperature.

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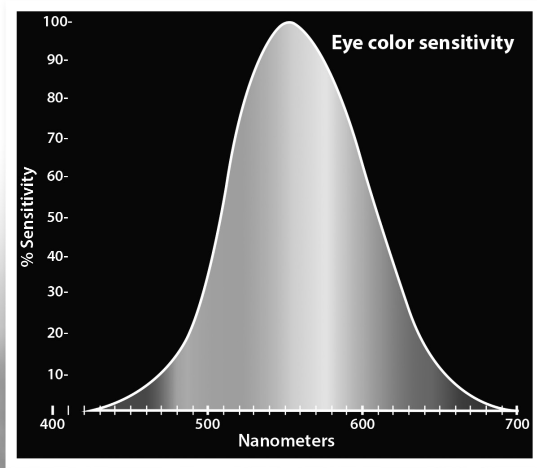

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Bees and other pollinating insects can detect light in the ultraviolet range of the spectrum. They can detect special markings on flowers that have nectar. Some birds can also see ultraviolet. Their feathers can have patterns that reflect ultraviolet rays. These patterns help birds locate mates. Many animals that see ultraviolet light do not see the red end of the spectrum.

Some animals can detect infrared waves. For example, rattlesnakes, pit vipers, boas, and pythons have infrared-sensing pits on their heads. Some vampire bats have three infrared-sensing pits on their nose. This sense helps them find the best place to attack.

Some insects also can detect infrared. Blood-sucking bedbugs have infrared-sensing organs on their antennae that help locate their prey. Some species of beetles have evolved infrared sensing for detecting forest fires, so that they can lay their eggs in newly burnt wood.

Both photos show the same cluster of flowers, but the bottom view, showing ultraviolet light, is more similar to how a bee sees them. The bee finds nectar-rich blossoms, and the flowers attract an effective pollinator.

Think Questions

1. **What waves are in the electromagnetic spectrum, besides visible light?**
2. **How do light spectra help identify light sources?**

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