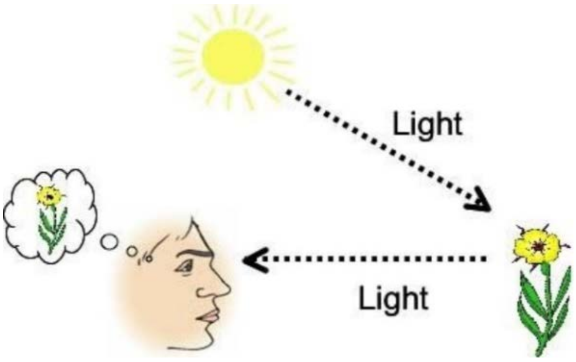
11.2 SIGHT AND IMAGE FORMATION

The bottom line is: without light, there would be no sight. The visual ability of humans and other animals is the result of the complex interaction of light, eyes and brain. We are able to see because light from an object can move through space and reach our eyes. Once light reaches our eyes, signals are sent to our brain, and our brain deciphers the information in order to detect the appearance, location and movement of the objects we are sighting at.



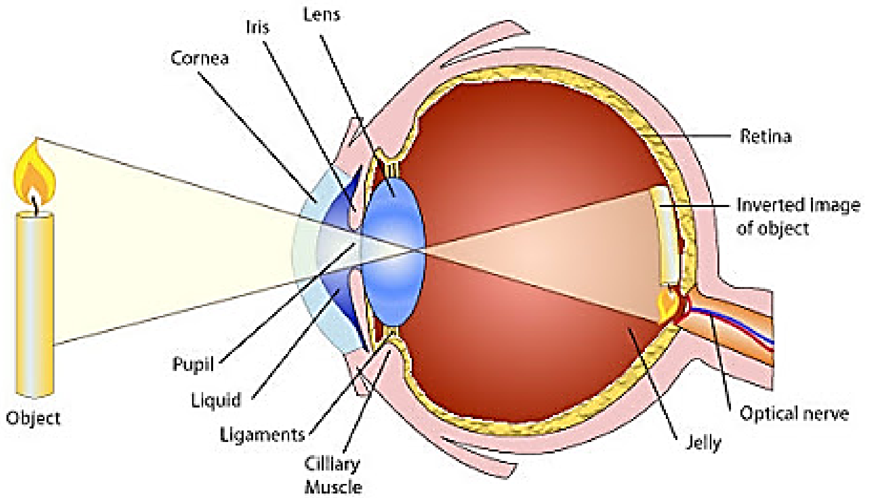
During the day, the sun generates sufficient light to illuminate objects on Earth. Without the light from the luminous objects, these illuminated objects would not be seen. During the evening when the Earth has rotated to a position where the light from the sun can no longer reach our part of the Earth (due to its inability to bend around the spherical shape of the Earth), objects on Earth appear black.

In order to view an object, you must sight along a line at that object; and when you do light will come from that object to your eye along the line of sight.

<u>Physics of the Eye</u>

The eye is perhaps the most interesting of all optical instruments. The eye is remarkable in how it forms images and in the richness of detail and colour it can detect. However, our eyes commonly need some correction, to reach what is called "normal" vision, but should be called ideal rather than normal.

The cornea and lens of an eye act together to form a real image on the light-sensing retina, which has its densest concentration of receptors in the **<u>fovea</u>** and a blind spot over the optic nerve. The power of the lens of an eye is adjustable to provide an image on the retina for varying object distances. Layers of tissues with varying indices of refraction in the lens.



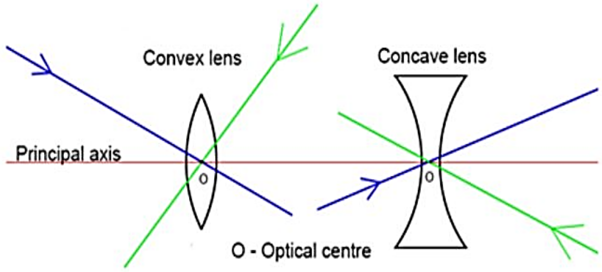
Refractive indices are crucial to image formation using lenses. The biggest change in the refractive index, and bending of rays, ***<u>occurs at the cornea rather than the lens</u>***.

TAKE-HOME EXPERIMENT: THE PUPIL
Look at the central transparent area of someone's eye, the pupil, in normal room light. Estimate the diameter of the pupil. Now turn off the lights and darken the room. After a few minutes turn on the lights and promptly estimate the diameter of the pupil. What happens to the pupil as the eye adjusts to the room light? Explain your observations.

11.3 IMAGE FORMATION BY MIRRORS

➢ *PRINCIPAL AXIS (optical axis) AND OPTICAL CENTRE (vertex/pole)*

The straight line passing through the geometrical centre of a lens and joining the two centres of curvature of its surfaces is called the principal axis. Rays passing through the mirror/lens that are parallel to the principal are called secondary rays. The path of a light ray along this axis is perpendicular to the surfaces and, as such, will be unchanged.

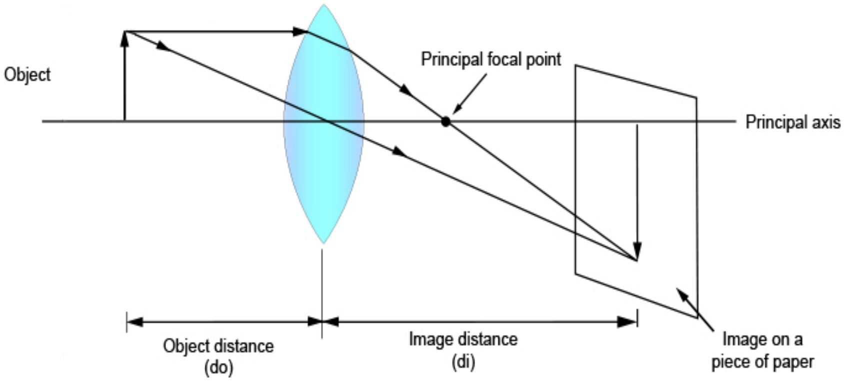


The optical centre of a lens is a point inside the lens on the principal axis. A ray of light passes through without any change in its direction.

➢ *OBJECT AND IMAGE DISTANCE*

The object distance d_o is the distance of the object to the centre line of the mirror/lens.

The image distance d_i is the distance of the image to the centre line of the mirror/lens.



➢ *OBJECT AND IMAGE HEIGHT*

The object height h_o is the height of the object to the principal axis.

The image height h_i is the height of the image to the principal axis.

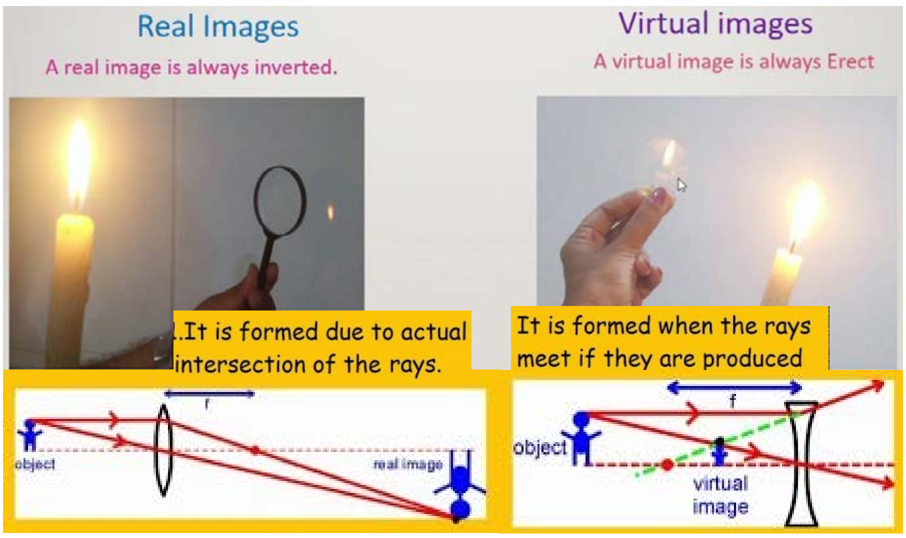
➢ *MAGNIFICATION*

Magnification M is defined as the ratio of the height of an image to the height of an object.

L•O•S•T art of Image Description			
Location	**Orientation**	**Size**	**Type**
At C (or 2F) *Beyond* or *Behind* C Between C and F Between F and mirror	Upright Inverted	Magnified Same Size Reduced	Real Virtual

➢ *REAL IMAGE*

It is the image in which light rays from one point on the object actually cross at the location of the image and can be projected onto a screen, a piece of film, or the retina of an eye.



➢ *VIRTUAL IMAGE*

It is an image that is on the same side of the lens as the object and cannot be projected on a screen. A screen placed at the location of a virtual image will receive only diffuse light from the object, not focused rays from the lens. Additionally, a screen placed on the opposite side of the lens will receive rays that are still diverging, and so no image will be projected on it.

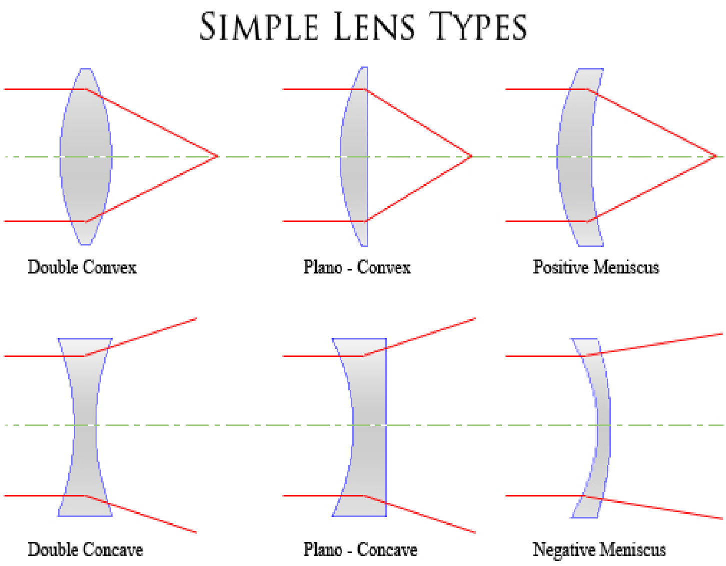
11.4 IMAGE FORMATION BY LENSES

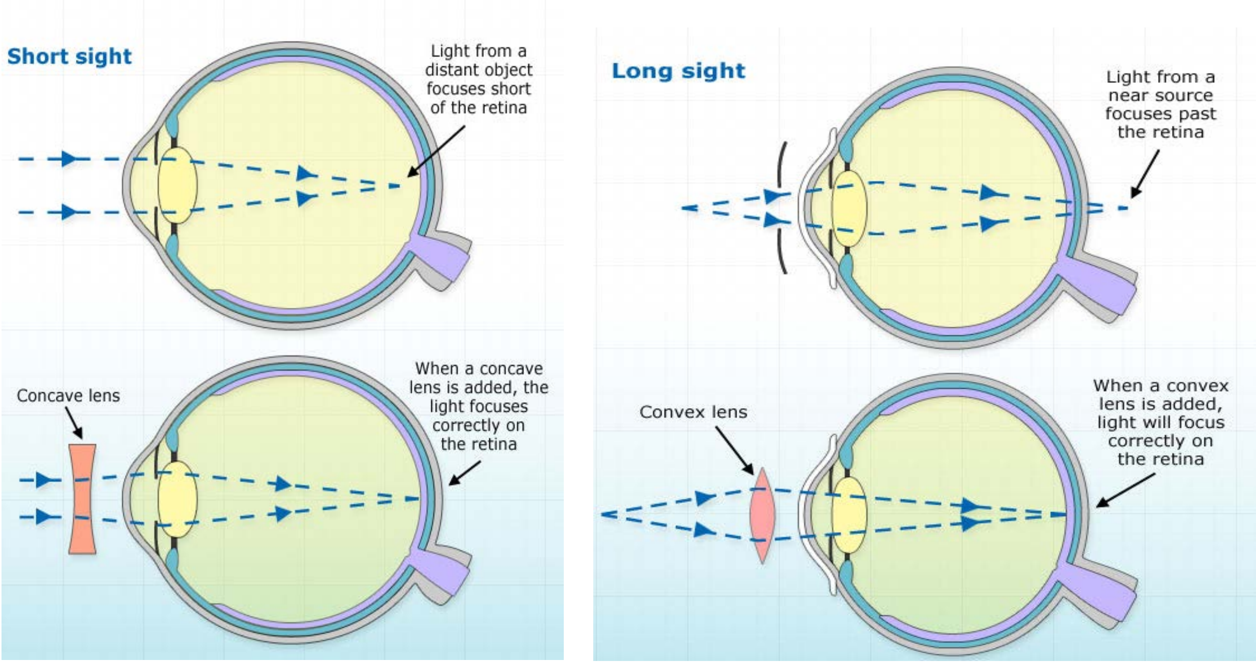
Lenses are found in a huge array of optical instruments, ranging from a simple magnifying glass to the eye to a camera's zoom lens. The word *lens* derives from the Latin word for a **lentil bean**, the shape of which is similar to the convex lens.

- **THIN LENS.** A thin lens is defined to be one whose thickness allows rays to refract but does not allow properties such as dispersion and aberrations. An ideal thin lens has two refracting surfaces but the lens is thin enough to assume that light rays bend only once. A *thin symmetrical lens* has two focal points, one on either side and both at the same distance from the lens. Another important characteristic of a thin lens is that light rays through its centre are deflected by a negligible amount. (The axis is defined to be a line normal to the lens at its centre.)

- **CONVERGING OR CONVEX LENS.** The lens in which light rays that enter it parallel to its axis cross one another at a single point on the **opposite side** with a converging effect is called converging lens.

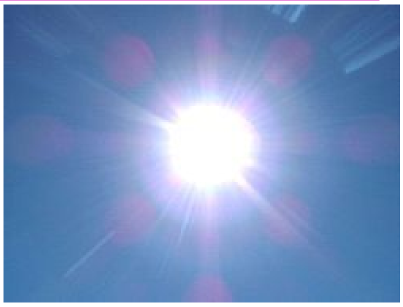
- **DIVERGING OR CONCAVE LENS.** A lens that causes the light rays to bend away from its axis is called a diverging lens. The dashed lines are not rays—they indicate the directions from which the rays appear to come. The focal length f of a diverging lens is **negative**.





TAKE-HOME EXPERIMENT: A VISIT TO THE OPTICIAN
Look through your eyeglasses (or those of a friend) backward and forward and comment on whether they act like thin lenses.

11.5 VISION AND THE LIGHT SPECTRUM

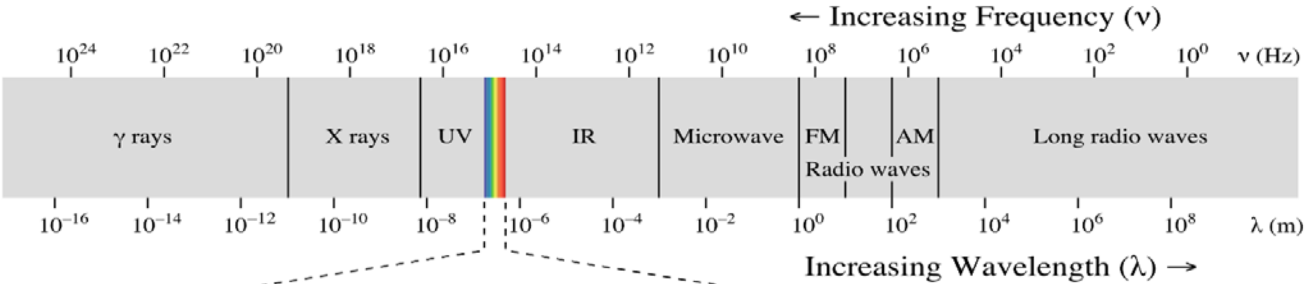


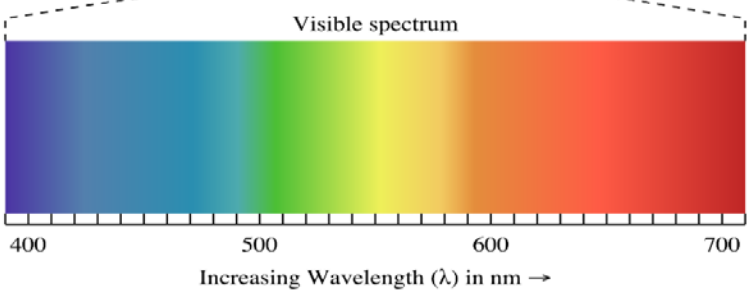
The main source of light on Earth is the Sun. Sunlight provides the energy that green plants use to create sugars mostly in the form of starches, which release energy into the living things that digest them. Historically, another important source of light for humans has been fire, from ancient campfires to modern kerosene lamps. With the development of electric lights and power systems, electric lighting has effectively replaced firelight.

11.5.1 Visible Light Spectrum

Though electromagnetic waves exist in a vast range of wavelengths, our eyes are sensitive to only a very narrow band. **Light** is electromagnetic radiation within a certain portion of the electromagnetic spectrum. The word usually refers to **visible light**, which is the visible spectrum that is visible to the human eye and is responsible for the sense of sight.

The primary properties of visible light are intensity, propagation direction, frequency or wavelength spectrum, and polarization, while its speed in a vacuum, 299,792,458 metres per second (3×10^8 m/s), is one of the fundamental constants of nature.

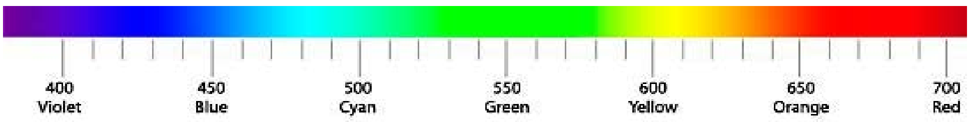




This narrow band of visible light is affectionately known as **ROYGBIV**.

When all the wavelengths of the visible light spectrum strike your eye at the same time, **white light** is perceived. The sensation of white is not the result of a single colour of light, rather result of a mixture of two or more colours of light. Technically speaking, white is not a colour at all - at least not in the sense that there is a light wave with a wavelength that is characteristic of white.

If all the wavelengths of the visible light spectrum give the appearance of white, then none of the wavelengths would lead to the appearance of black. Once more, black is not actually a colour. Technically speaking, **black is merely the absence of the wavelengths of the visible light spectrum**. So, when you are in a room with no lights and everything around you appear black, it means that there are no wavelengths of visible light striking your eye as you sight at the surroundings.

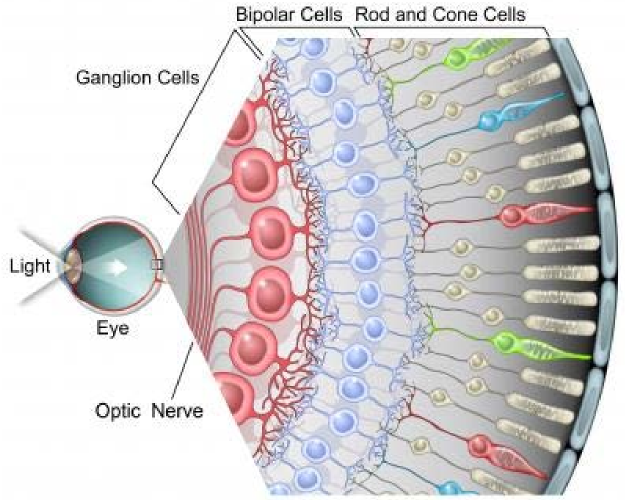


Additive color system: The combination of red, green, and blue light produces all other colors, and white light at the center

11.5.2 Colour and Colour Vision

We have already noted that colour is associated with the wavelength of visible electromagnetic radiation. When our eyes receive pure-wavelength light, we tend to see only a few colours. These are the rainbow of colours produced when white light is dispersed according to different wavelengths. There are thousands of other *hues* that we can perceive.

The two major types of light-sensing cells (photoreceptors) in the retina are ***rods and cones***. Cones are most concentrated in the fovea, the central region of the retina. There are no rods here. The fovea is at the centre of the macula, a 5 mm diameter region responsible for our central vision. The cones work best in bright light and are responsible for high resolution vision. There are about 6 million cones in the human retina. There are three types of cones, and each type is sensitive to different ranges of wavelengths.

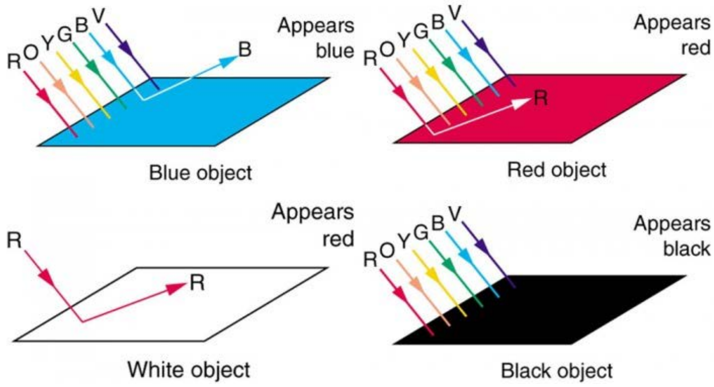


TAKE-HOME EXPERIMENT: RODS AND CONES

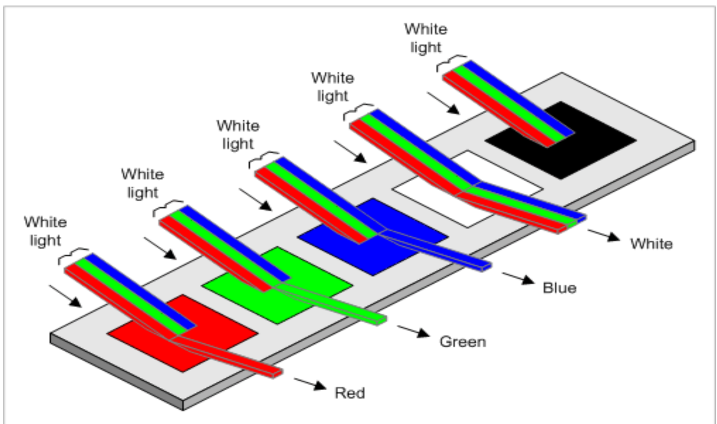
1. Go into a darkened room from a brightly lit room, or from outside in the Sun. How long did it take to start seeing shapes more clearly? What about color? Return to the bright room. Did it take a few minutes before you could see things clearly?
2. Demonstrate the sensitivity of foveal vision. Look at the letter G in the word ROGERS. What about the clarity of the letters on either side of G?

The *true colour of an object* is defined by its **absorptive** or **reflective** characteristics.

Absorption characteristics determine the true colour of an object. Here, three objects are illuminated by white light, and one by pure red light. White is the equal mixture of all visible wavelengths; black is the absence of light.



Similarly, *light sources have colours* that are defined by the wavelengths they produce. A helium-neon laser emits pure red light. In fact, the phrase "pure red light" is defined by having a sharp constrained spectrum, a characteristic of laser light. The Sun produces a broad yellowish spectrum, fluorescent lights emit bluish-white light, and incandescent lights emit reddish-white hues. As you would expect, you sense these colours when viewing the light source directly or when illuminating a white object with them. All of these fits neatly into the simplified theory that a combination of wavelengths produces various hues.



Shining white light on different colored paints

https://phet.colorado.edu/sims/html/color-vision/latest/color-vision_en.html