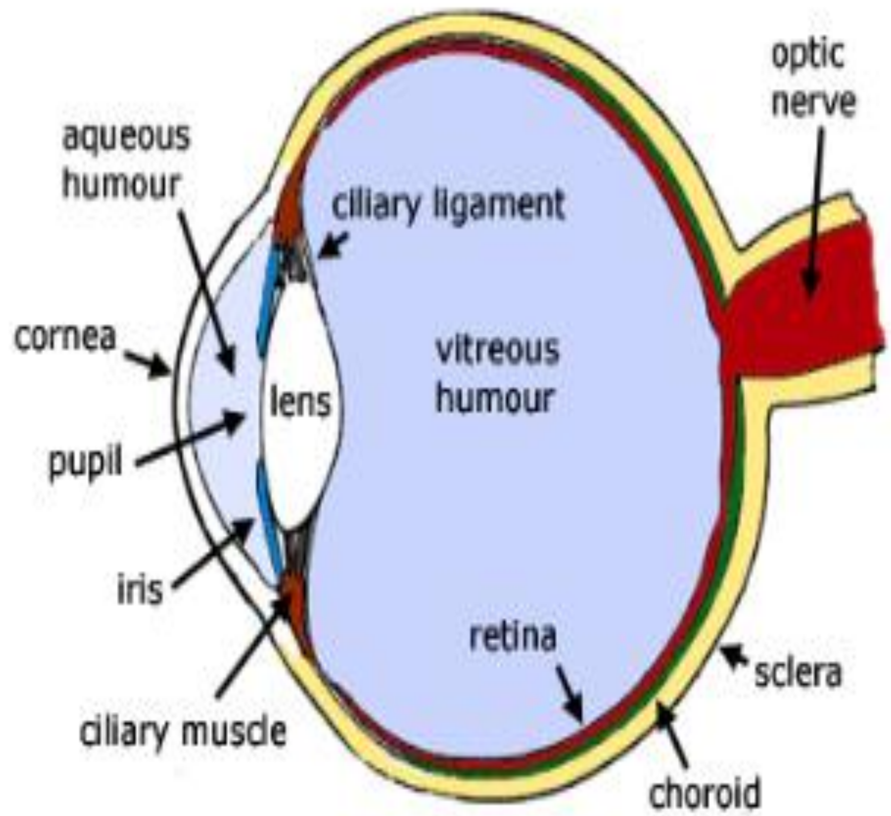
Defects of Vision

EYE

- Light entering the eye is focused by the cornea-lens system onto the back surface of the eye, called the retina. The surface of the retina consists of millions of sensitive receptors called rods and cones. When stimulated by light, these structures send impulses via the optic nerve to the brain, where a distinct image of an object is perceived.
- The eye focuses on a given object by varying the shape of the pliable crystalline lens through an amazing process called accommodation. An important component in accommodation is the ciliary muscle, which is attached to the lens. It is evident that there is a limit to accomodation, because objects that are very close to the eye produce blurred images. The **near point** is the smallest distance for which the lens will produce a sharp image on the retina. This distance usually increases with age.


optic
nerve
aqueous
humour
ciliary ligament
cornea
vitreous
humour
lens
pupil
iris
retina
sclera
ciliary muscle
choroid

retina - a light sensitive region on the rear of the inner surface of the eyeball.

accommodation - the ability of the eye to produce a focussed image on the retina. This is done by altering the shape of the eye-lens by muscle in the shape of a ring, called the **ciliary muscle**. The **ciliary ligament** transfers force between the muscle and the lens.

iris - a ring of muscle controlling the amount of light entering the eye.

lens - made of clear cartilage. In old age the lens can become opague. In a simple procedure it can be replaced with a plastic lens.

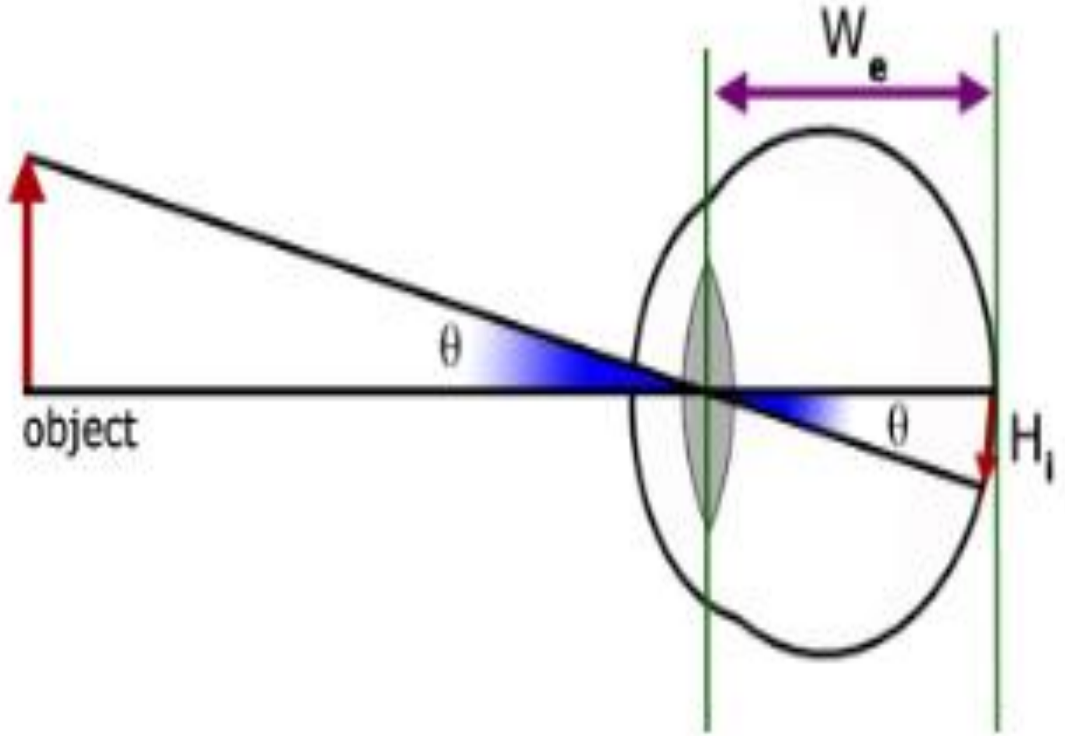
cornea - front part of the eye. Most of the deviation of light coming from an object occurs at the air/cornea boundary. Old age/disease can cause the cornea to become fogged, eventually causing blindness. Transplants from cadavers can remedy this.

pupil - the space inside the iris. This appears black because it leads into the eyeball. Inside the eyeball is caverness and dimly lit from light entering.

humours - the aqueous and vitreous humours are clear liquids within the eye with similar refractive indices.

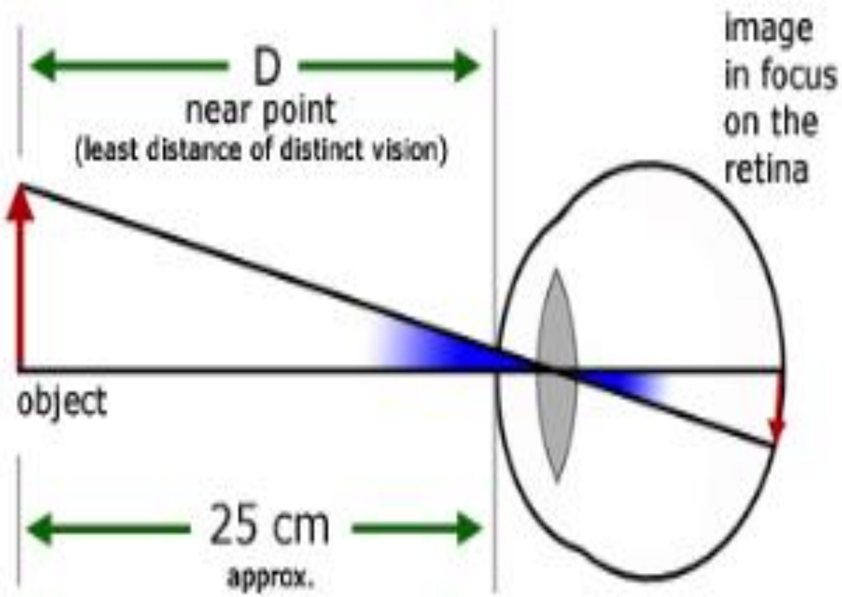
aqueous humour (1.33)
vitreous humour (1.34)
eye lens (1.41)
cornea (1.38)

Visual Angle



Near Point

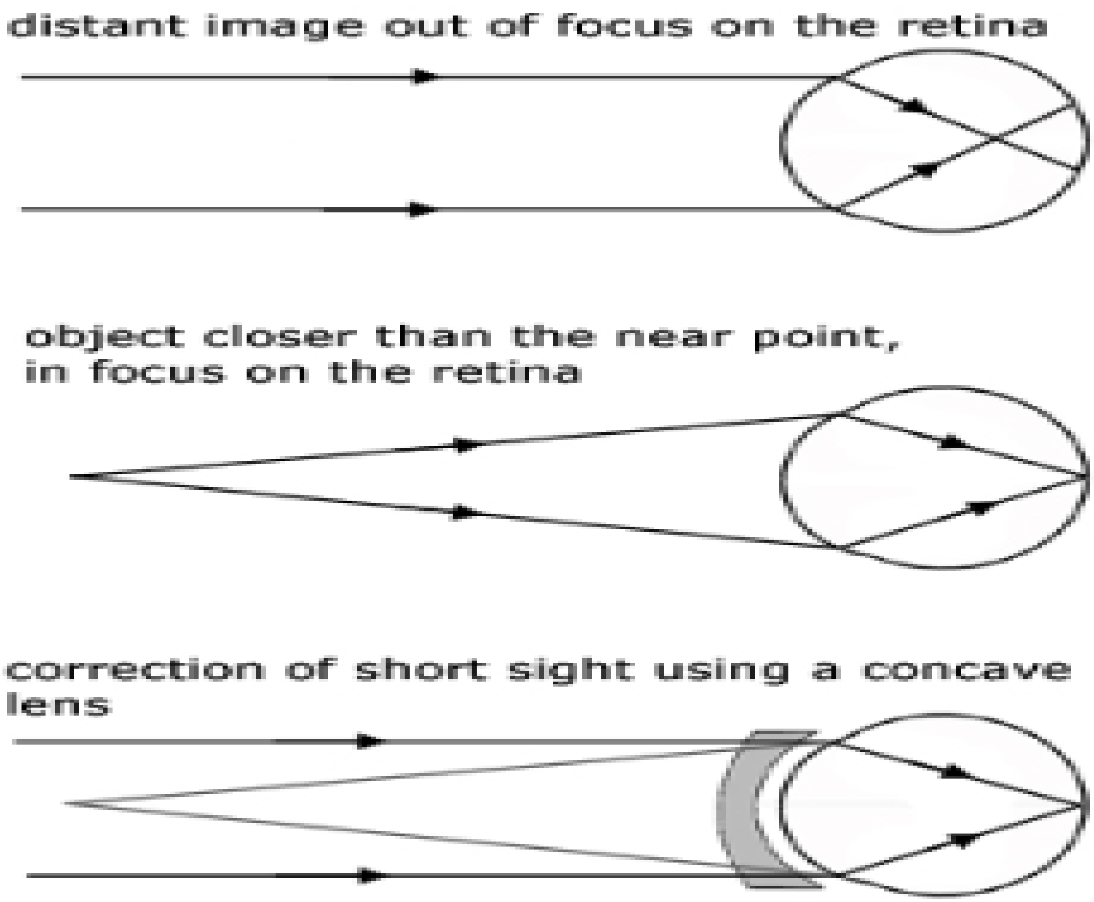
The **near point** (**D**) is the closest distance infront of the eye where a positioned object is in focus. It is sometimes referred to as '**the least distance of distinct vision**'.



Short Sight (Myopia)

As the name implies, a person with 'short sight' can see objects close up, but not in the distance.

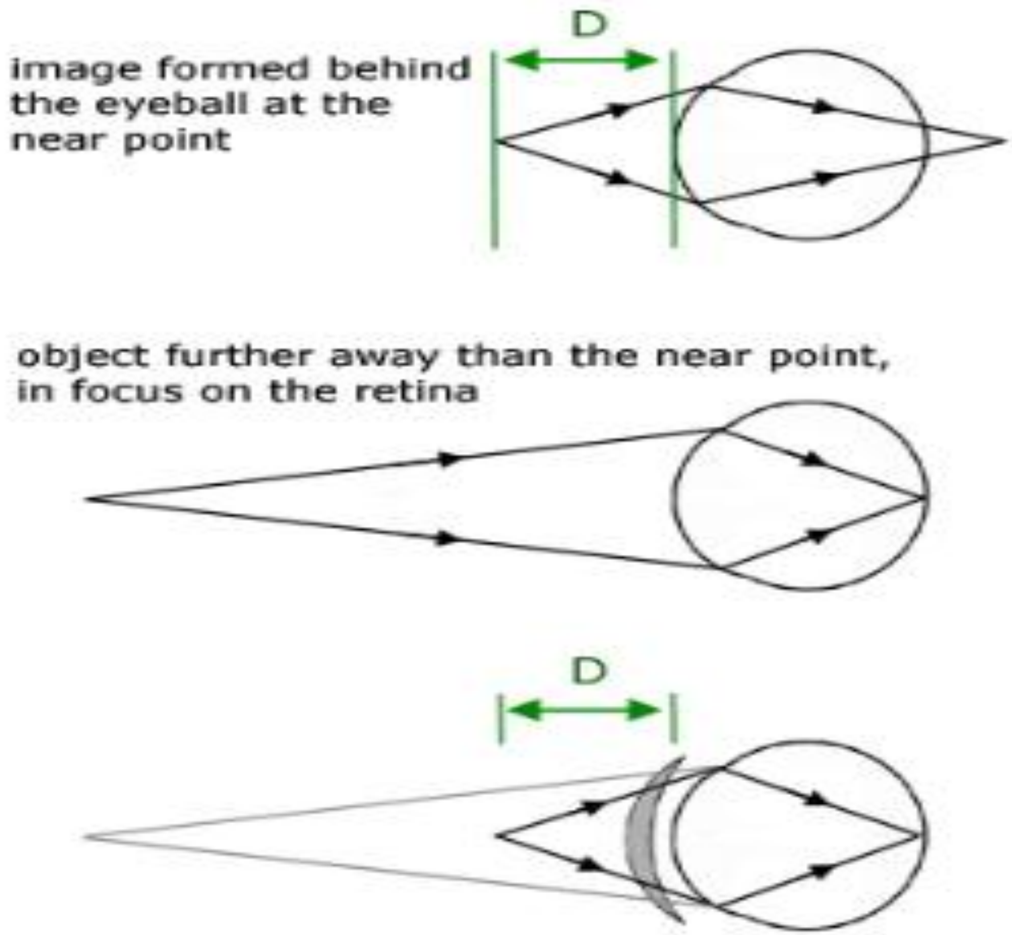
Short sight is a result of an abnormally long eyeball or the eye lens being too strong. The consequence is that the image of a distant object is formed infront of the retina. The resulting image actually reaching the retina is therefore out of focus.



Long Sight (Hypermetropia)

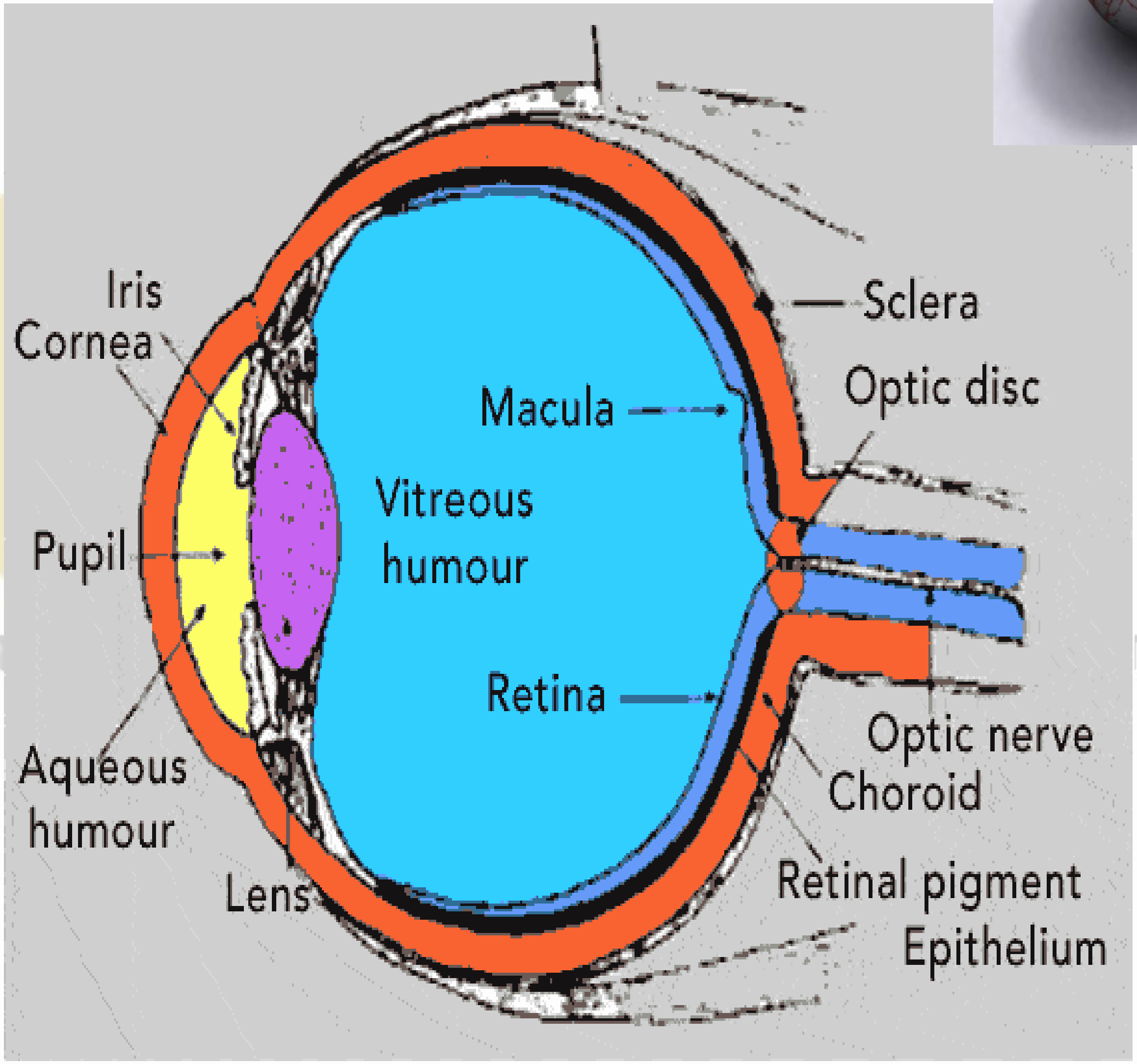
As the name implies, a person with 'long sight' can see objects far away , but not close up.

Long sight is a result of an abnormally short eyeball or the eye lens being too weak. The consequence is that the image of a distant object is formed behind the retina. The resulting image perceived on the retina is therefore out of focus.

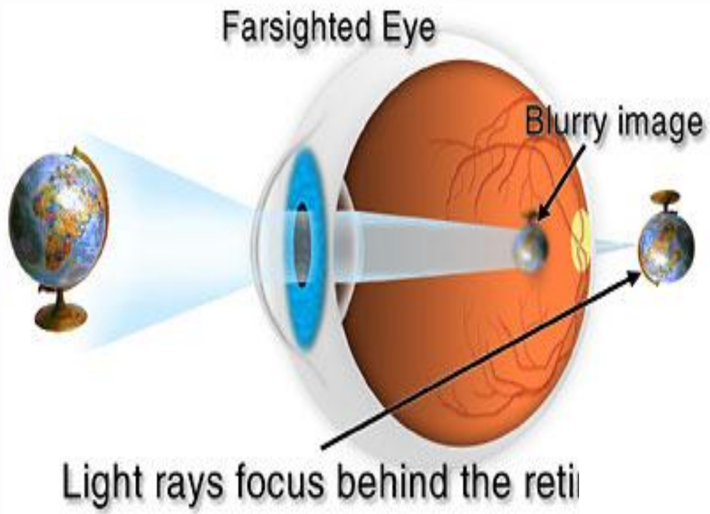


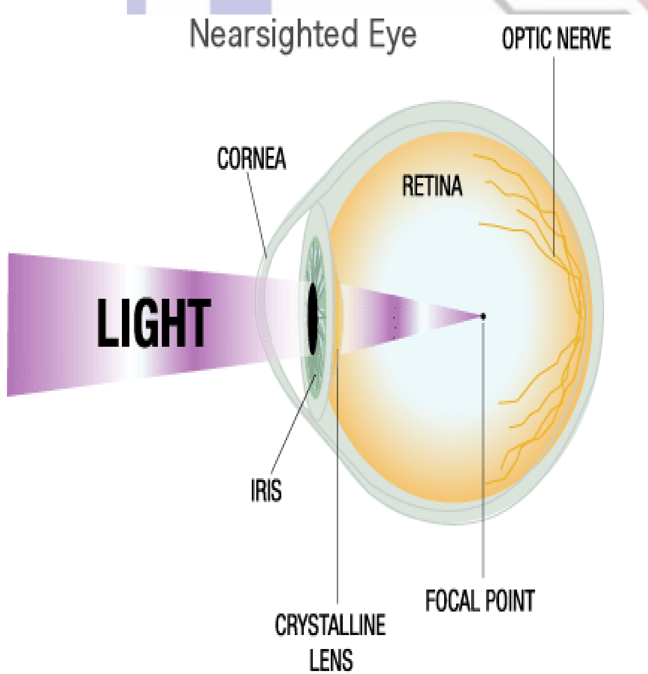
correction of long sight using a convex lens

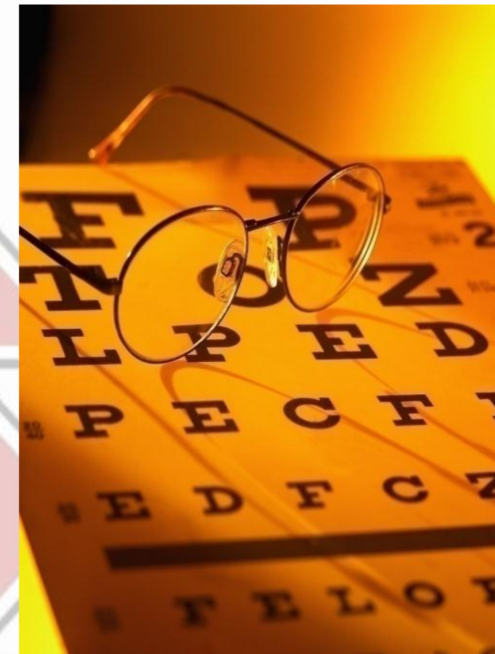
The Human Eye



Farsighted vs. Nearsighted







- The human eye is sensitive to electromagnetic waves that have wavelengths in the range from 400 nm to 700 nm. What range of frequencies of electromagnetic radiation can the eye detect?

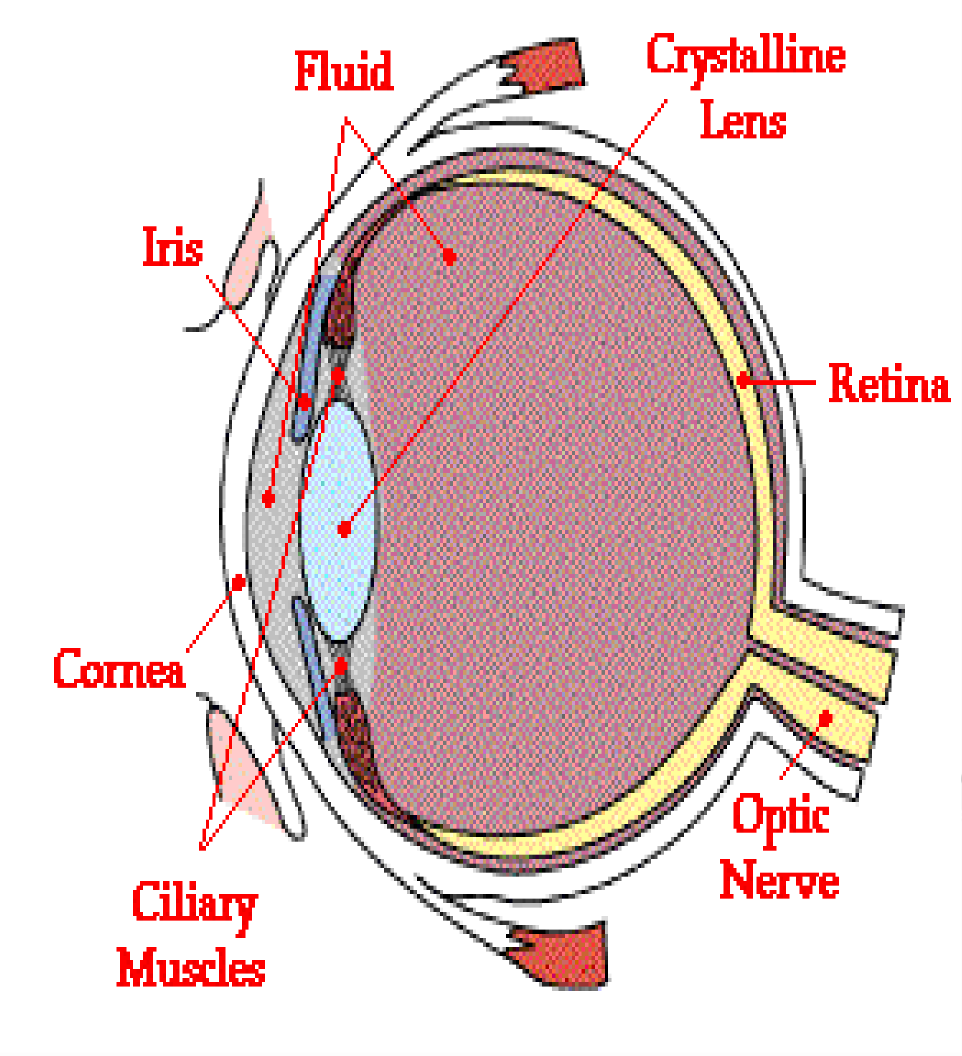
$$f_1 = \frac{c}{\lambda_1} = \frac{3 \cdot 10^8 \text{ m/s}}{700 \text{ nm}} = 4.3 \cdot 10^{14} \text{ Hz}$$

$$f_2 = \frac{c}{\lambda_2} = \frac{3 \cdot 10^8 \text{ m/s}}{400 \text{ nm}} = 7.5 \cdot 10^{14} \text{ Hz}$$

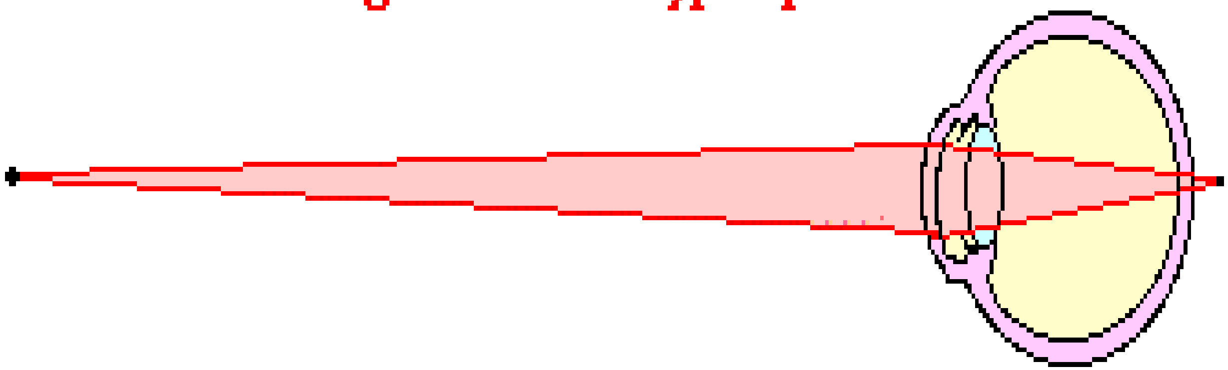
- What are the wavelength ranges in the FM (frequency modulation) radio band, 88 – 108 MHz

$$\lambda_1 = \frac{c}{f_1} = \frac{3 \cdot 10^8 \text{ m/s}}{88 \text{ MHz}} = 3.4 \text{ m}$$

$$\lambda_2 = \frac{c}{f_2} = \frac{3 \cdot 10^8 \text{ m/s}}{108 \text{ MHZ}} = 2.8 \text{ m}$$

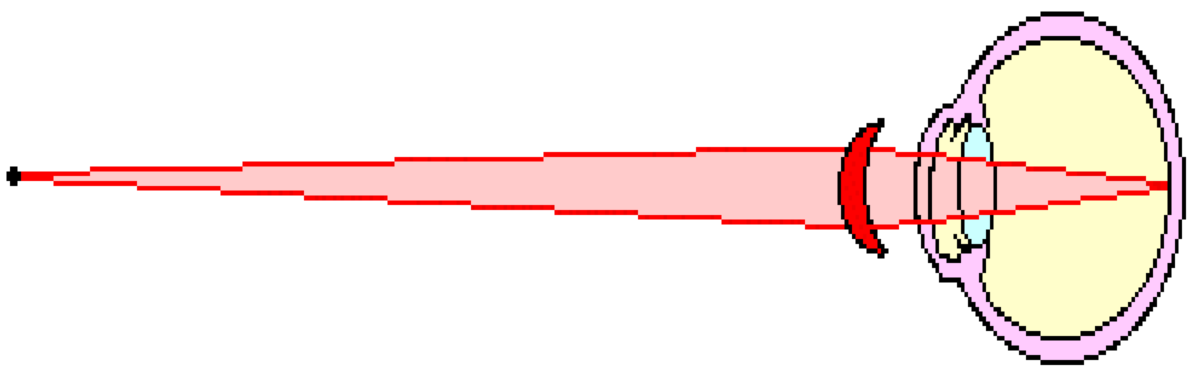

Fluid
Crystalline
Lens
Iris
Retina
Cornea
Optic
Nerve
Ciliary
Muscles

Farsightedness or Hyperopia



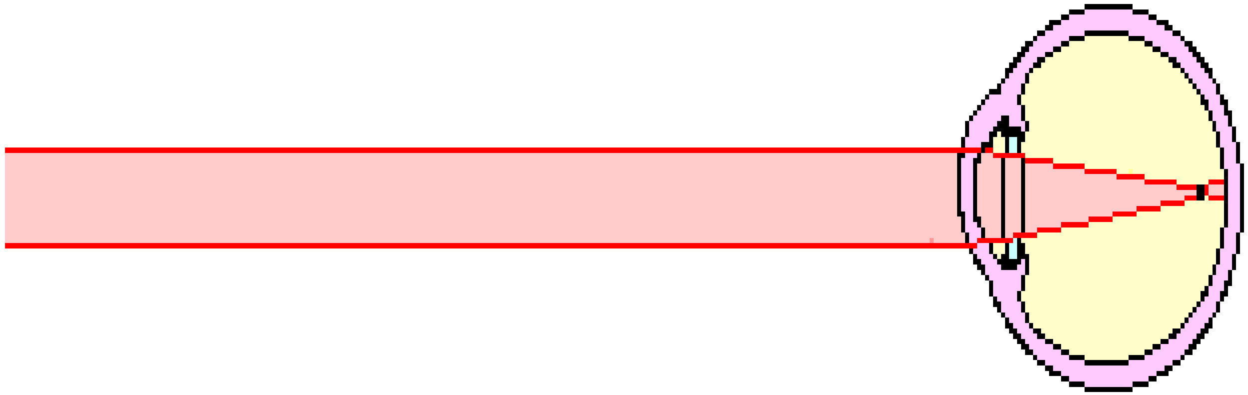
The inability of the lens to assume a high curvature and a short focal length leads to the formation of an image located behind the retina.

Correction for Farsightedness



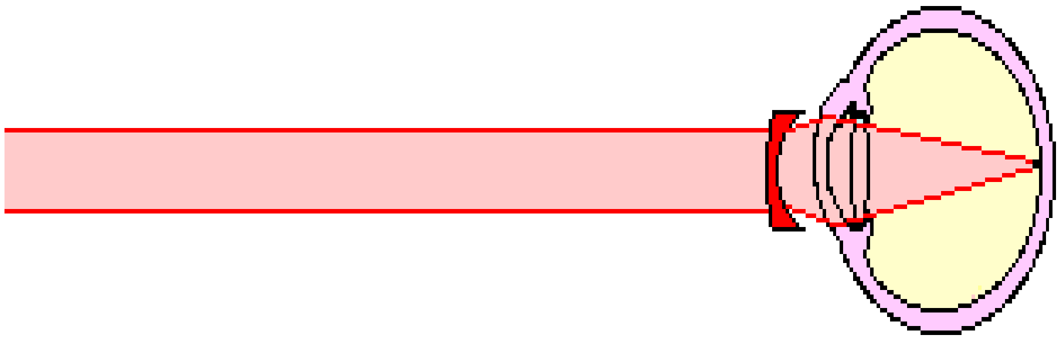
Farsightedness can be corrected by the use of a converging lens. Light refracts before reaching the cornea and is subsequently focused on the retina of the eye.

Nearsightedness or Myopia



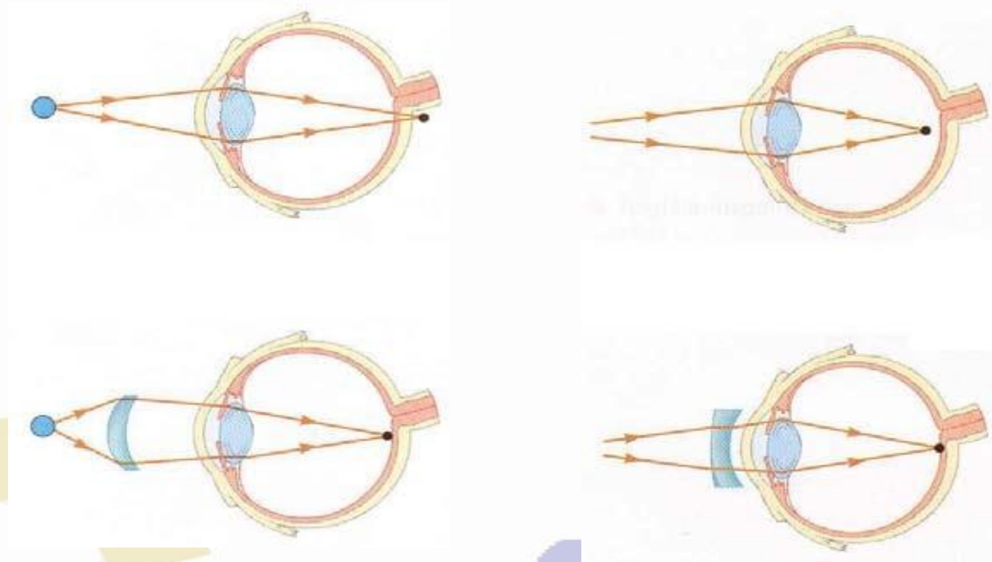
A bulging cornea or an elongated eyeball often increases the refracting power of the eye, leading to the formation of images in front of the retina.

Correction for Nearsightedness



Nearsightedness can be corrected for by the use of a diverging lens. Light diverges before reaching the cornea and is then converged to a location on the retina.

- An eye can have several abnormalities that keep it from functioning properly. When the relaxed eye produces an image of a nearby object behind the retina, the abnormality is known as **hyperopia**, and the person is said to be **farsighted**. With this defect, distant object are seen clearly but near object are blurred. Either the hyperopic eye is too short or the ciliary muscle cannot change the shape of the lens enough to focus the image properly. The condition can be corrected with a converging lens.
- Another condition, known as **myopia**, or **nearsightedness**, occurs when a distant object is focused in front of the retina. This can be corrected with a diverging lens.
- A common eye defect is **astigmatism**, in which light from a point source produces a line image on the retina. This occurs when the cornea or the lens are not perfectly spherical. A cylindrical lens is used to correct this.



- The **power, P**,of a lens in diopters equals the inverse of the focal length in meters. That is, **P=1/f**.
- For example, a converging lens whose focal length is +20 cm has a power of 1/(+0.2 m)=+5 diopters, and a diverging lens whose focal length is –40 cm has a power of 1/(-0.4 m)=-2.5 diopters.

- The near point of an eye is 50 cm. What focal length must a corrective lens have to enable the eye to see clearly an object 25 cm away? What is the power of this lens?

  The thin-lens equation enables us to solve this problem. We have placed an object at 25 cm, and we want the lens to form an image at the closest point that eye can see clearly. This corresponds to the near point, 50 cm.

$$\begin{aligned}
\frac{1}{p}+\frac{1}{q} &= \frac{1}{f} \\
\frac{1}{25\ \mathrm{cm}}+\frac{1}{-15\ \mathrm{cm}} &= \frac{1}{f} \\
f &= 50\ \mathrm{cm} \\
P &= \frac{1}{f}=\frac{1}{0.5\ \mathrm{m}}=2\ \text{diopters}
\end{aligned}$$

- A particular nearsighted person cannot see objects clearly when they are beyond 50 cm (the far point of the eye). What focal length should the prescribed lens have to correct this problem?

For an object at infinity, the purpose of the lens in this instance is to place the image at a distance at which it can be seen clearly.

$$\begin{aligned}
\frac{1}{p}+\frac{1}{q} &= \frac{1}{f} \\
\frac{1}{\infty}+\frac{1}{-50\ \mathrm{cm}} &= \frac{1}{f} \\
f &= -50\ \mathrm{cm} \\
P &= \frac{1}{f} = \frac{1}{-0.5\ \mathrm{m}} = -2\ \text{diopters}
\end{aligned}$$