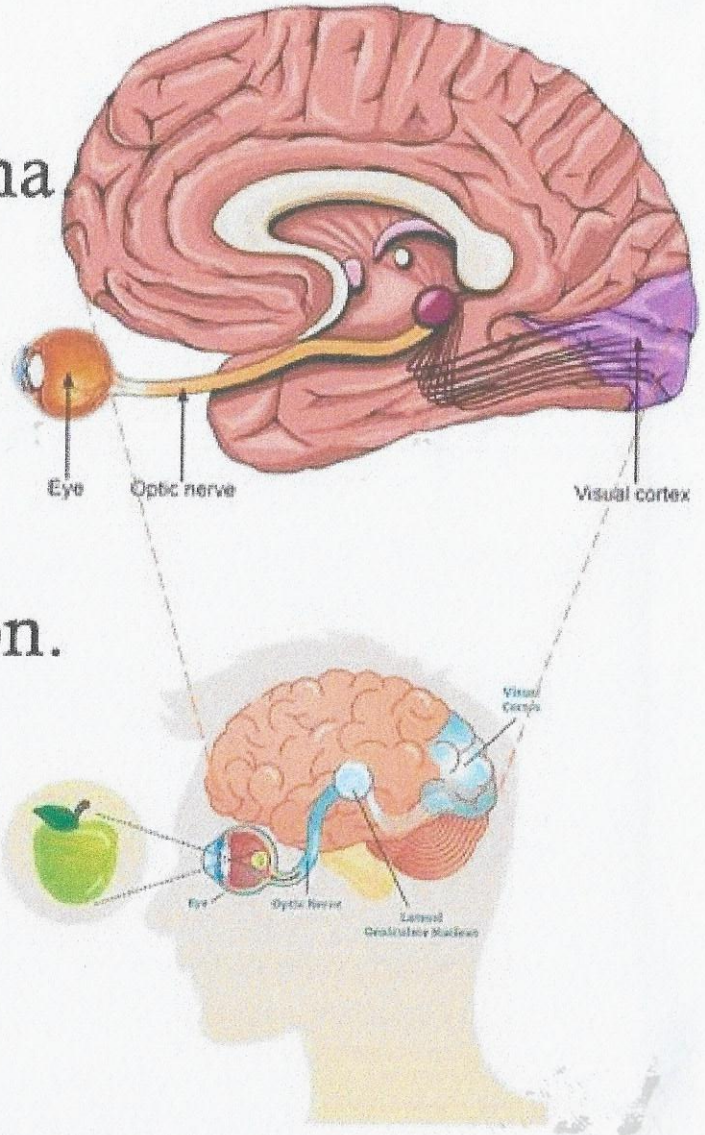
Physics of Eye and Vision

- The sense of **vision** consists of three major components:

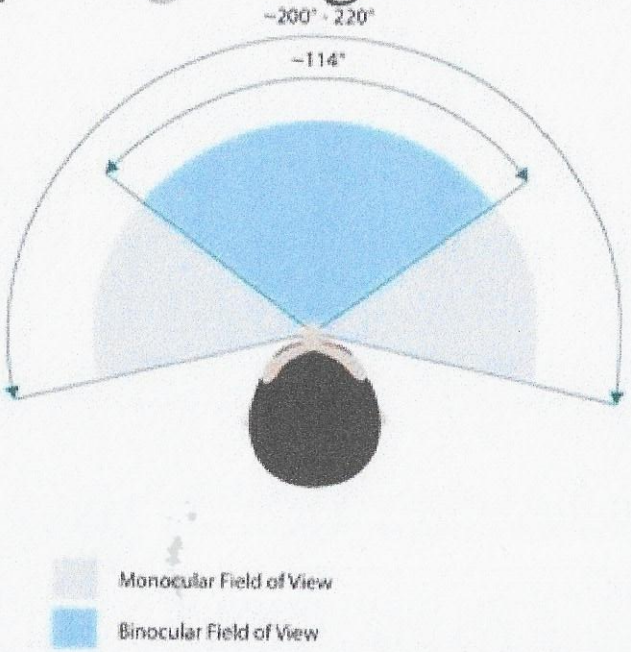
1. The **eyes** that focus an image from the outside world on the light- sensitive retina
2. The system of millions of **nerves** that carries the information into the brain.
3. The **visual cortex**– that part of the brain which processes visual information.



- By similarity to TV system:
  - TV lens analogous to the eye lens.
  - The signal cable is the optic nerve.
  - Viewing monitor is the visual cortex.

- Our optical system has the following **special features**, most of which are not available on the most expensive cameras:

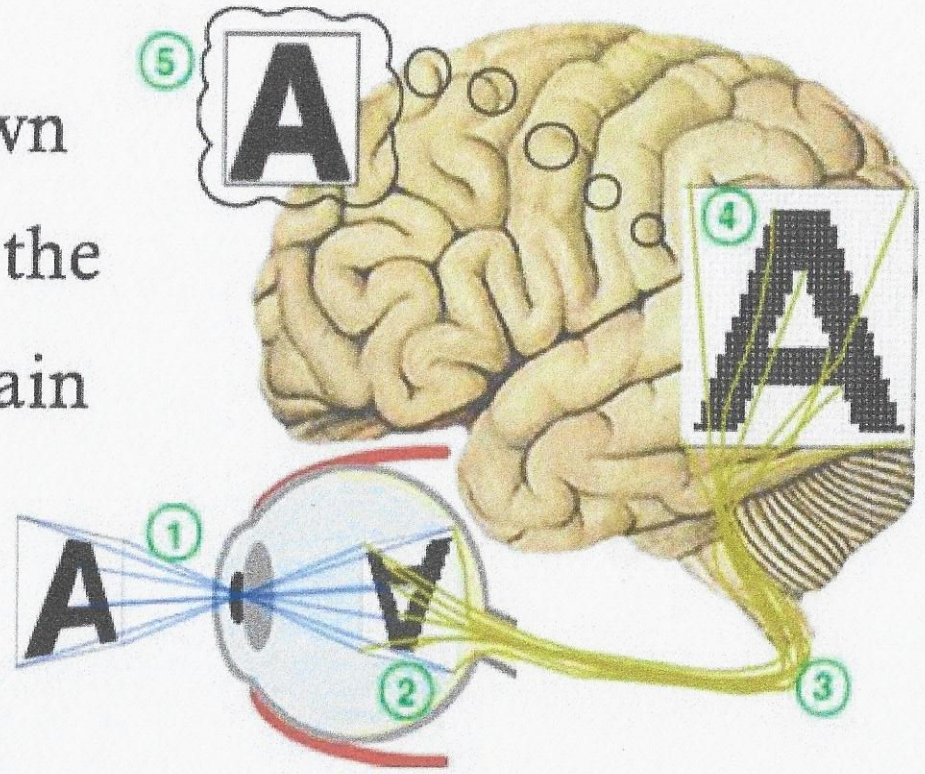
1. The eye can observe events over a very large angle while looking intently at an object directly ahead of it.



2. It is rapid automatic focusing system permits viewing objects as close as 20cm one second and distant objects the next.
3. The eye can operate effectively over a range of light intensity.
4. The eye has automatic aperture adjustment (the iris).

5. The eye has a self-regulating pressure system that maintains its internal pressure at about 20mmHg and thus keeps the eye in shape.

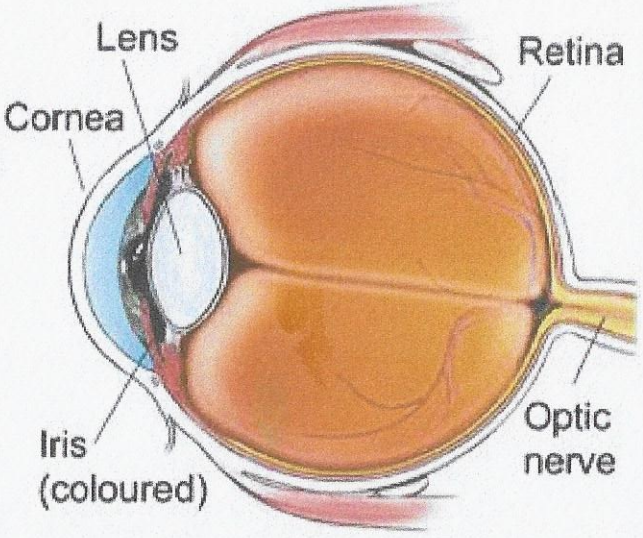
6. The image appears upside down on the light-sensitive retina at the back of the eyeball, but the brain automatically corrects for this.



7. The brain blends the images from both eyes, giving us good depth perception and true three dimensional viewing.

Focusing Elements of The Eye

- The eye has two major focusing components: The **cornea**, that does ~2/3 of the focusing, and the **lens**.
- The cornea is a *fixed* focus element; the lens is *variable* in shape and has the ability to focus objects at various distances.
- The cornea focuses by *bending* (*refracting*) the light rays.
- The amount of bending depends on:
  - The curvatures of its surfaces
  - The speed of light in the lens compared with that in the surrounding material (index of refraction).



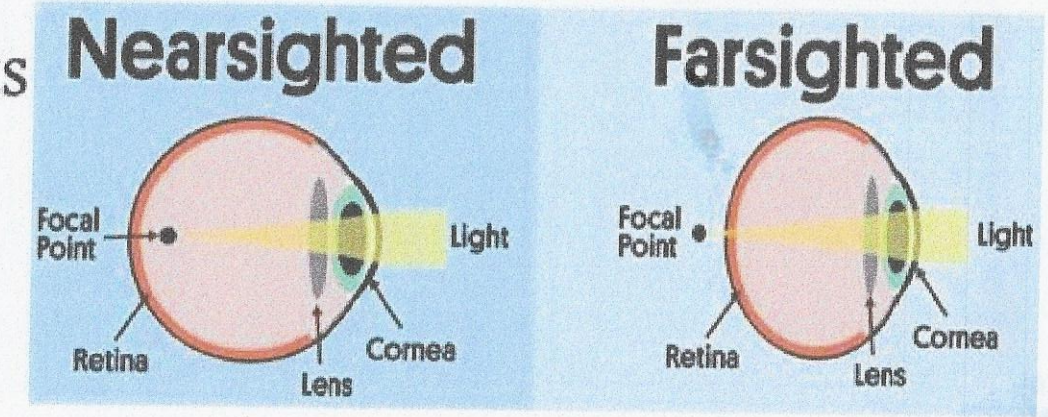
- The index of refraction is nearly constant for all corneas, but the curvature varies considerably from one person to another and is responsible for most our **defective vision.**

Part of the eye	Index of Refraction (μ)
Cornea	1.37
Aqueous humor	1.33
Lens cover	1.38
Lens center	1.41
Vitreous humor	1.33

a) If the cornea is curved too much the eye is nearsighted.

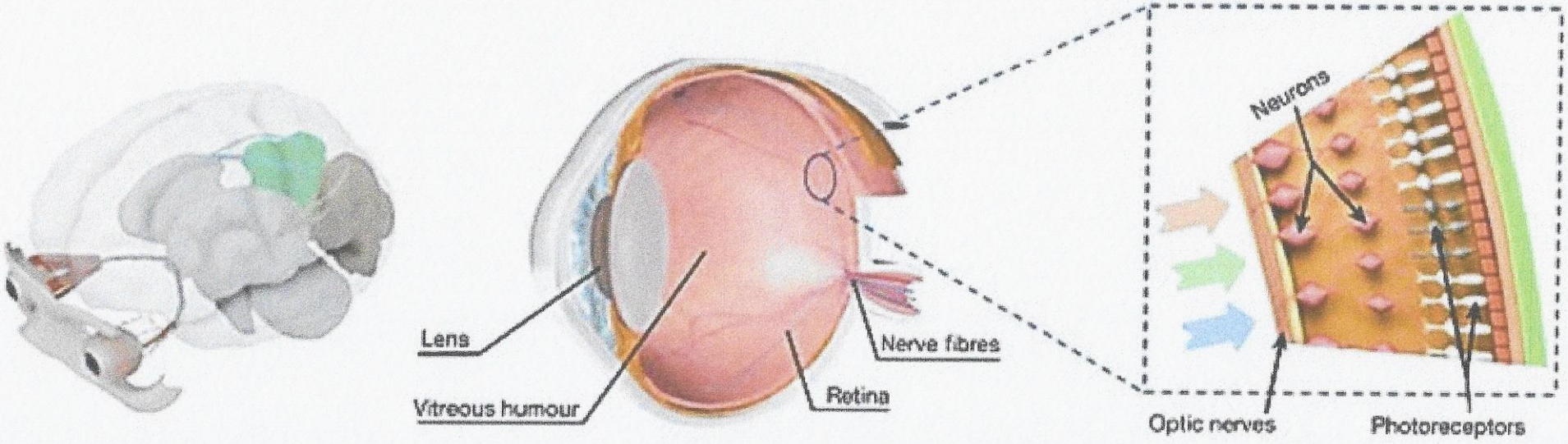
b) Not enough curvature results in farsighted.

a) Uneven curvature produces astigmatism.



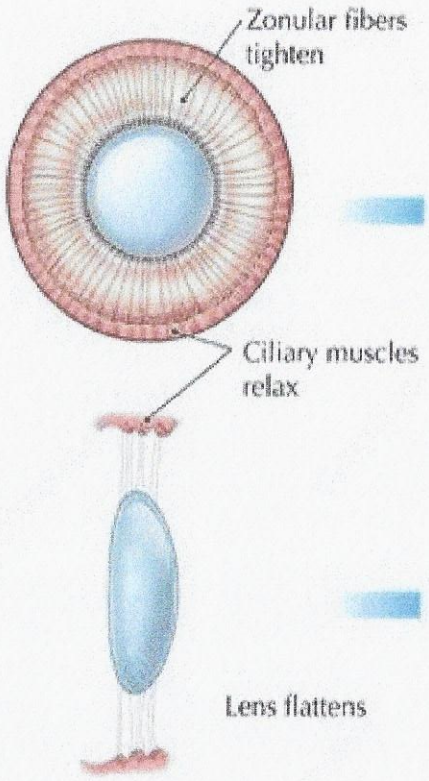
The Retina

- The retina (the light-sensitive part of the eye) converts the light images into electrical nerve impulses that are sent to the brain.



- The absorption of a light photon in a **photoreceptor** causes a *photochemical reaction* in it, which in some way initiates the **action potential** then produce electrical nerve impulses that are sent to the brain.

- The shape and the focal length of the crystalline lens are controlled by the **ciliary muscles**.
- When this **muscles**
  - **relaxed** the front surface of the lens is kept relatively flat and light from distant objects is focused on the retina.
- **contract** the lens assume more rounded shape and its focal length decreases binging the nearby into focus on the retina.



- The ability of the lens to adjust its focal length is called **accommodation.**

Defective vision and its correction

- Our eyes often need some **correction** to reach what is called "**normal**" vision.
- There is a simple relationship between the **focal length** f, the **object distance P**, and the **image distance Q** of the lens

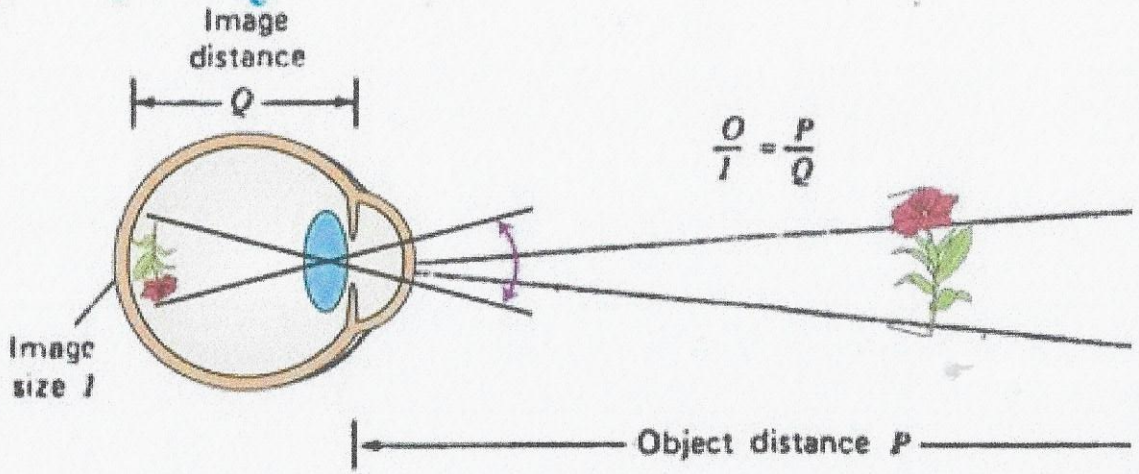
$$\frac{1}{f} = \frac{1}{P} + \frac{1}{Q}$$

I: is image size

Q: is image distance

O: is object size

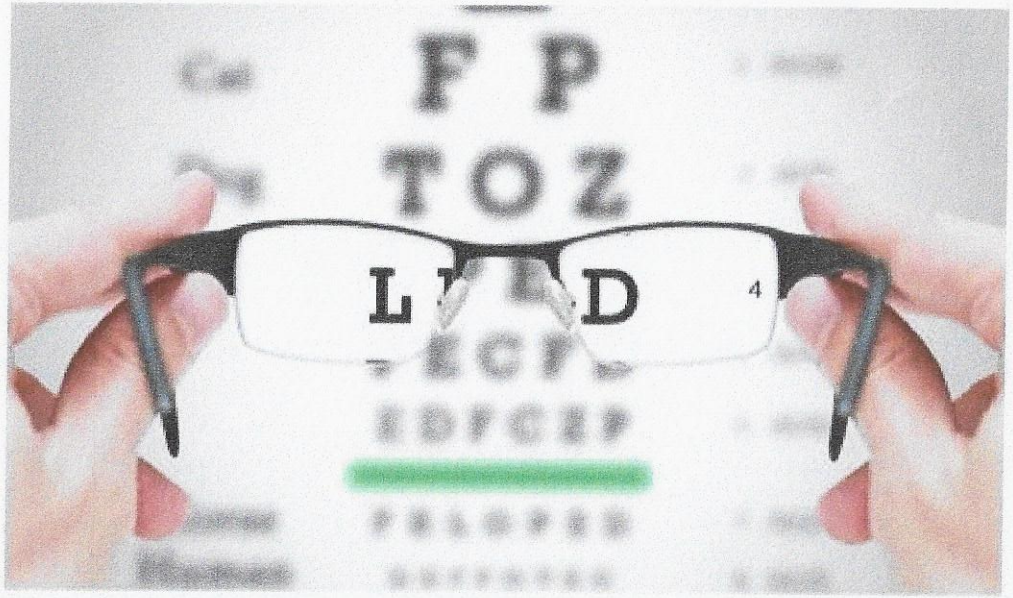
P: is object distance.



Thus we can write $\frac{P}{O} = \frac{Q}{I}$

Defective vision and its correction

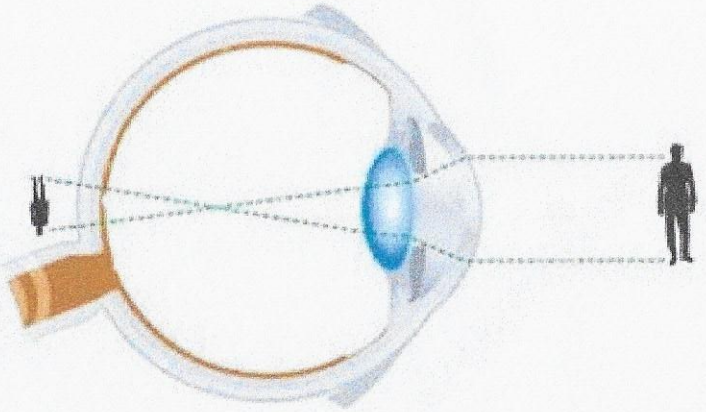
- Four common optical defects of the eye can be corrected by use of eyeglasses:
  1. Hyperopia,
  2. Myopia,
  3. Presbyopia,
  4. Astigmatism.



- In three of these defects the glasses are used to shift the apparent position of an object , so that the defective eye is able to focus properly.
- In the last (astigmatism) the glasses are used to correct the distortion produced by the eye.

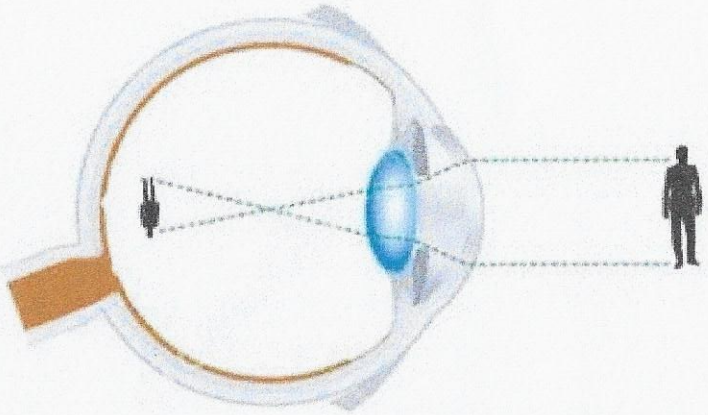
Hyperopia (farsightedness):

- In this defect parallel light from a distant object is focused by relaxed eye at a point **behind** the retina.
- This problem arises because the eyeball is too short,
- Therefore closer objects are blurred.
- The defect can be corrected by using **converging** lenses (Positive lens).



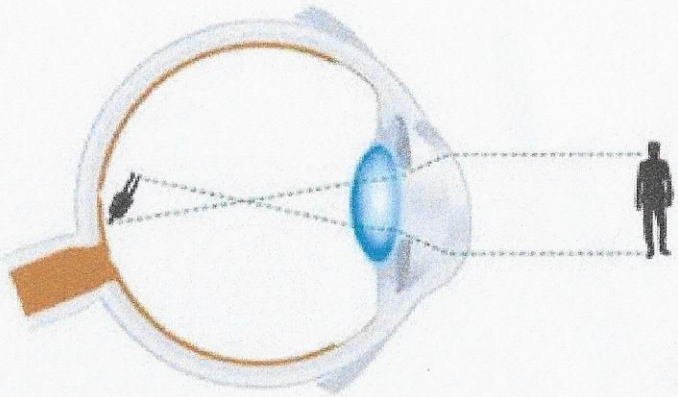
Myopia (nearsightedness):

- In this defect parallel light from a distant object is focused by relaxed eye at a point **before** the retina.
- This problem arises because the eyeball is too long,
- Therefore only near objects can be seen clearly.
- ✓ The defect can be corrected by use **diverging** lenses (Negative lens).



Astigmatism:

- When a stigmatism is present, point objects do not form clear point images on the retina.
- This is normally due to the corneas having an equal curvature in different directions.
- ✓ The defect is corrected by the use of cylindrical (- ve or + ve).



Presbyopia: Due to reducing accommodation with age, Converging lenses are needed for closer work or reading much like person with hyperopia