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 deep into the brain.

3. The visual cortex – that part of the brain. Blindness results if any one of the part does not function.

The eye has some striking similarities to camera (TV system).

1. The lens of TV camera is analogous to the lens of the eye.

2. The signal cable is the optic nerve.

3. Viewing monitor is the visual cortex.

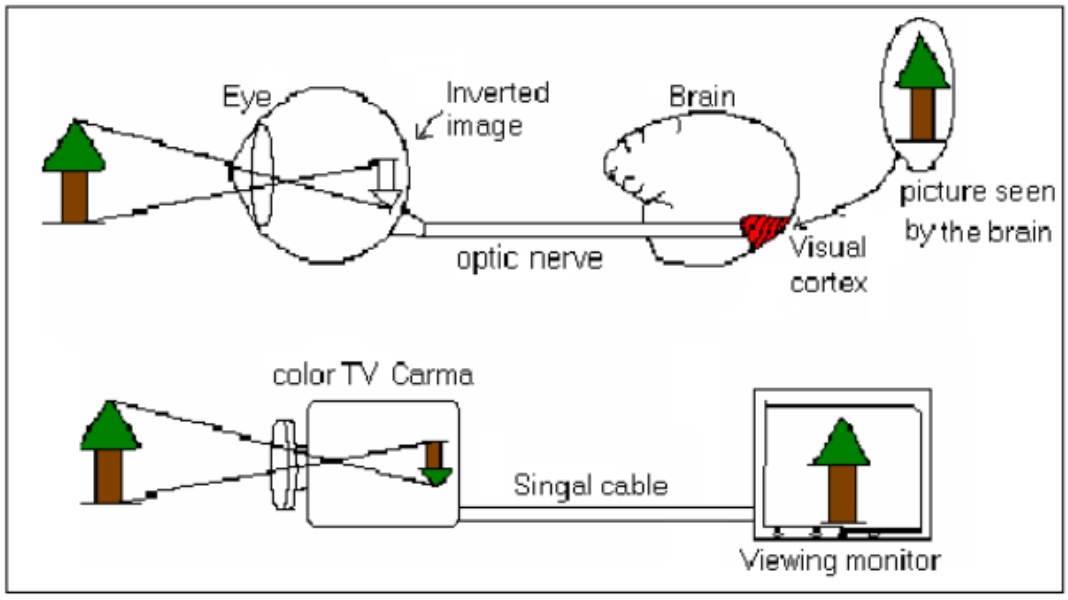


Figure. The sense of light is in many ways similar to a closed circuit TV system

a. Formation of the image on retina and its correction by brain
b. b. Formation of the image on camera and its correction by viewing monitor.

Specifications of the Optical System

1. Observation of events over **~180°** angle when looking intently at an object directly ahead of it.

2. Blinking to clean and lubricate the lens.

3. Clear distance viewing between**. ~25cm to infinity ∞.**

4. Operating effectively between the daylight and dark night (~1010 :1 intensity). Brilliant day light to a very dark night.

5. The eye has an automatic aperture adjustment (iris).

6. Cornea **(has no blood supply)** made of living cells and can repair the local damage.

7. The eye has a self-regulating pressure system that maintains the internal pressure of ~20mm Hg and thus **keeps the eye in shape.**

8. Mountain in a well-protected casing.

9. The image appears upside down on the light sensitive retain at the back of the eyeball, but **the brain automatically corrects for this**.

10. The brain blends the images from both eyes giving as good depth perception and the **3D viewing.**

11. The muscles of the eye (six muscles, the muscles work in pair) permit flexible movement up, down, side-ways and diagonally**. All six muscles are attached to the skull.**

One pair controls up and down movement.

= = = left and right movement.

= = = rotation.

After a little practice, the eye can even be made to go in circle.

Vision Elements of the Eye

1. **The cornea:** It is the clear transparent bump on the front of the eye that does about two-third of focusing of light.

Part of the eye	Index of Refraction (μ)
Cornea	1.32
Aqueous humor	1.33.
Lens cover	1.35
Lens centre	1.41
Vitreous humor	1.35

2. **The Iris:** It is the colored part of the front eye. The function of iris is adaptation of vision from light to dark and vice versa.
It is believed that the iris aids the eye by increasing or decreasing incident light on the retina until the retina to adapted the new lighting condition.
In addition, under bright light conditions it plays an important role reducing lens defects.
3. **The Pupil:** It is the small opening in the center of iris where light enters the lens.
It appears black because essential all of the light that enters is absorbed inside the eye.
(Under average light conditions, the opening is about ≈4mm).
It can change from ≈3mm in diameter in bright light to 8mm in diameter in dim light. The physiologic reason form this change in size is not clear.

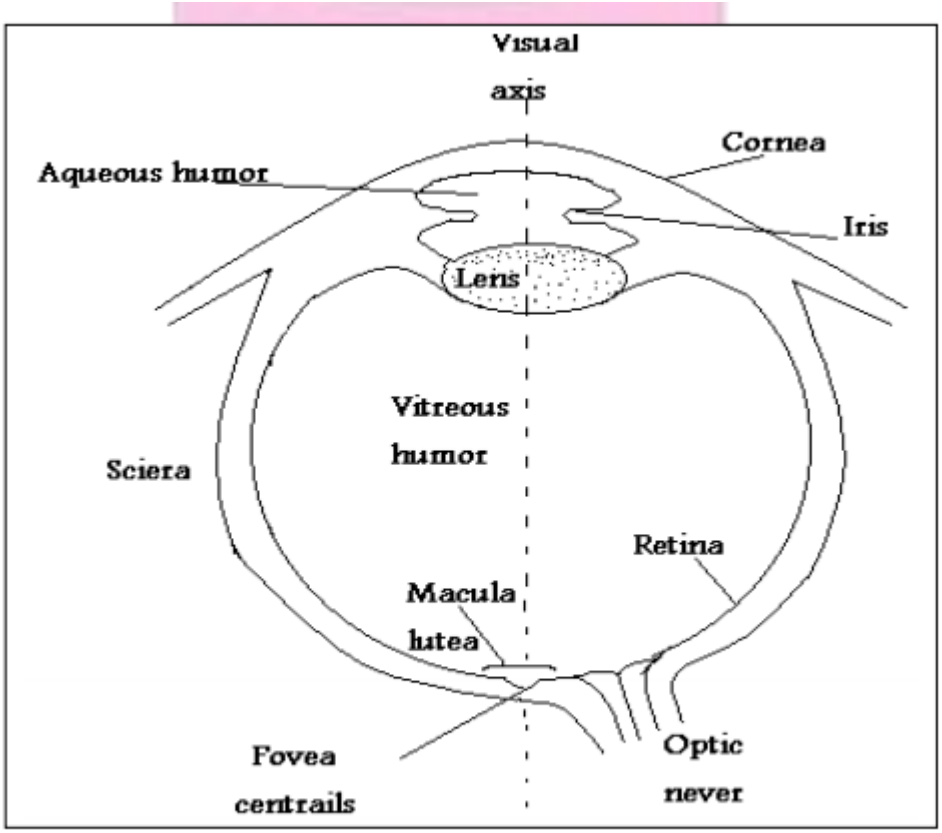


Figure. Cross section of the eye.

4. The lens: It is variable in shape and has the ability to focus objects at various distances at both its front and back surfaces. It is more curved in the back than in the front.
   The focusing power of lens is smaller than that of the cornea (1/3), because it is surrounded by substance that have indexes of refraction close to its own.
   The lens is made up of layers somewhat like onion and all layers do not have the same n.
5. **The aqueous humor:** It fills the space between the lens and the cornea. **This fluid mostly waters, n ≈1.33.**

   It is continuously being produced and the surplus escape through drain tube. "Canal of Schelemmt. Blockage of the drain tubes results in increased pressure in the eye. "Glaucoma".
   It maintains the internal pressure of the eye at about 20mm Hg.

It contains many of the components of blood and provides nutrients to the non vascularized cornea and lens.

6. The Vitreous humor: Is a clear jelly-like substance that fills the large space between the lens and the retina. It helps to keep the shape ***of the eye fixed and is essentially permanent.***

7. The sclera: Is the tough, white, light .. tight covering over all of the eye except the cornea. The sclera is protected by a transparent coating called the conjunctive

8. The Retina: The light sensitive part of the eye. It converts the light image into electrical nerve impulses that one sent to the brain. "It's lining the most of sclera".

The physical aspects of the Retina:

Energy of photon ⇒Retina ⇒Photochemical reaction in the photoreceptors ⇒ initiates the action potential.

Energy of photon = hf ≈ 3 ev.

The energy of photon must be >3 ev to cause photochemical reaction in the receptors.

Most vision is restricted to small area called "Yellow Spot" (all detailed vision take place in a very small area in the Yellow Spot ~0.3 mm in diameter. Called the "Fovea centralize".

The characteristics of the image on retina are **(i) Real (ii) inverted (iii) small** size because of the short image distance of about 2cm.

There are two general types of photoreceptors in the retina: the **cons and rods**. Throughout most the retina, **the cones and rods are not at the surface of the retina but behind several layers of nerve tissues through which the light must pass.**

Rods & Cones

The Rods and Cons are distributed symmetrically in all directions from the visual axis except in one region the blind spot.

A. Cones: The Cones **(~ 6.5 million in each eye)**

1. Are primarily used for **daylight or photopic vision.** With the cones, we can see fine details and recognize different colors

2. The cones are primarily found in the **fovea centralize** although some are scattered **throughout the retina.**

3. Each of the cones in the fovea **has its own telephone lines to the brain**. In the rest of the Retina several cones share one nerve fiber.

4.The cones are not uniformly sensitive to all color but have a maximum sensitivity at **about 550mv in the yellow-green region.**

5.The cones adapted most rapidly (**dark adapt)** at the ~5min in the fovea centralize has reached its best sensitivity.

B. Rods:

The rods **(~120 million in each eye and covered most of the retina)**.

1. Are used for **night or scotopic vision** and for peripheral vision.

2. They are **not uniformly distributed over the retina** but have a maximum density at an **angle of about 20˚**.

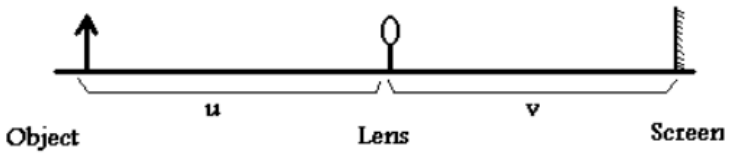
3. Hundreds of rods send their information to **same nerve fiber**.

4. The rods are most sensitive to **the blue-green light (~510-nm)** which has a wavelength shorter than the optimum for the cones (~ 550 nm).

5. The rods continue **to dark adapted for 30-60 min** although their adaptation occurs in the **first 15min.**

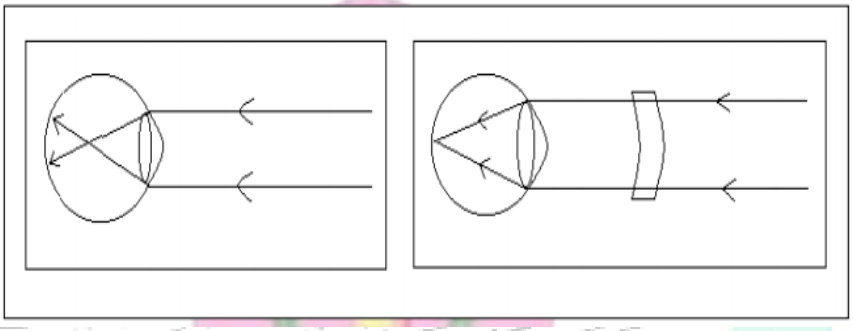
The power of Accommodation

1. The object distance (near point) for normal eye:
   u = 25cm = 0.25m.
   Image distance: V = 20mm = 0.02 m.
   Focal length of the lens = f.
   Power of lens : Pn = 1/f (m) = 1/u + 1/υ (diopter)
   = 1/0.25 + 1/0.02 = 4 + 50 = 54D
2. The far point of normal eye = ∞.
   Image distance: V = 20mm = 0.02 m.
   Power of lens : Pf = 1/f(m) = 1/u + 1/υ (diopter)
   = 1/∞ + 1/0.02
   = 0 + 50 = 50D.
   Power of accommodation = Pn – Pf
   = 54 – 50 = 4D
   The range of accommodation of the eye decreases with age as a result of loss in elasticity of lens

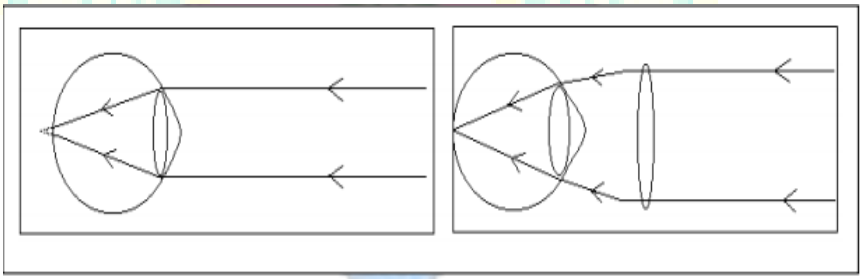


Optical Defects of the Eyes

1. **Myopia (Short sight):** The eyeball is too long and parallel ray is focused in front of the retina. Therefore only near objects can be seen clearly. Near point < 25cm, far point ≤ ∞.
   The defect can be corrected by use of spectacles, which employ **diverging spectacle lenses (negative lens).**

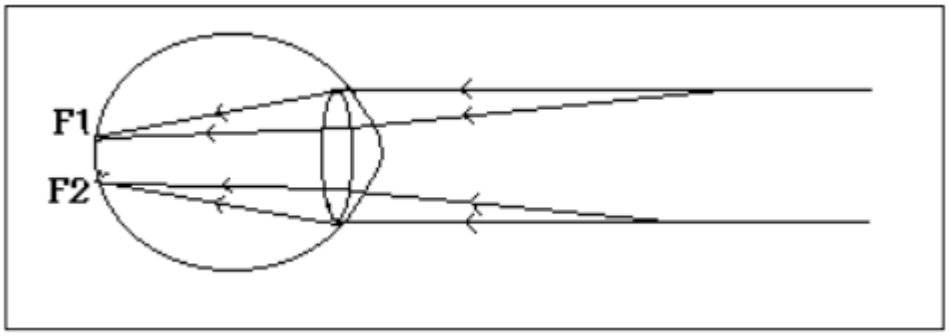


2. **Hypermeteropia (Long sight): The eyeball is too short**, and parallel rays are focused to a point **behind the retina**. Therefore the near point is much further from the eye than normal. **Near point > 25 cm, far point =** ∞**.**The defect can be corrected by using **converging spectacle lenses (Positive lens).**



3. **A stigmatism:** 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. (25 ⇒** ∞**).** The defect is corrected by

the use **of cylindrical spectacle lenses (- ve or + ve) with axes about 0 ⇒180.**



4. **<u>Presbyopia (old sight):</u>** as people get older, **the ciliar muscles weaken and the lens losses some of its elasticity. In order to compensate, converging spectacle lenses are employed a the case of hypermeteropia.**

If you wear corrective lenses, you should carry copy of your prescription.

	Sphere	Cylinder		Axis	Add
O.D	-1.25	-1.25	X	180	+1.25
O.S	-1.75	-1.45	X	163	+1.25

This means:

The right eye (O.D) ⇒ needs a spherical lens of – 1.25D + cylindrical lens of – 1.25D in the horizontal plane of 180° + (+1.25D) for reading.

The left eye (O.S) ⇒ same way.

<u>Snellen chart :</u>

a) Normal eyes test**: 20/20 ft or 6/6 m**

That means good vision can read detail from 20 ft or 6m

b) If eye test **20/40 ft, 6/12m.**

c) That mean, you can just read from **20 ft** the line that appears with good vision from **40 ft.**