Physics of Eyes and Vision

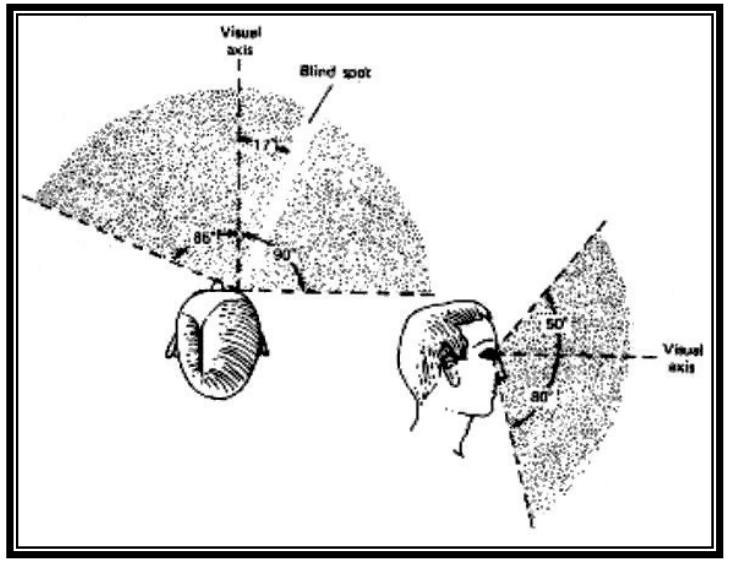
Most of our knowledge of the world around us comes to us through our **eyes**. The helplessness we feel when caught in the dark in unfamiliar surroundings is a good indication of our dependence on **vision**.

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 where "**it is all put together**".

Blindness results if any one of the parts does **not function**.

Our optical system has the following **special features**, most of which are not available on even 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. Blinking provides the front lens (**cornea**) with a built-in lens cleaner and lubricator.

3. A rapid automatic focusing system permits viewing objects as close as **20cm** one second and distant objects the next. Under relaxed conditions the focus for normal eyes is set for "**infinity**" (**distant viewing**).

4. The eye can operate effectively over a range of light intensity of about **10 billion** to one (**10^{10}:1**)-brilliant daylight to very dark night.

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

6. The cornea has a built-in scratch remover; even though it has no blood supply it is made of living cells and can repair local damage.

7. The eye has a self-regulating pressure system that maintains its internal pressure at about **20mmHg** and thus keeps the eye in shape. If "**dented**", the eye rapidly returns to its original shape.

8. The eyes are mounted in a well-protected casing almost completely surrounded by bone, and each eye rests on a cushion of fat that reduces sharp shocks.

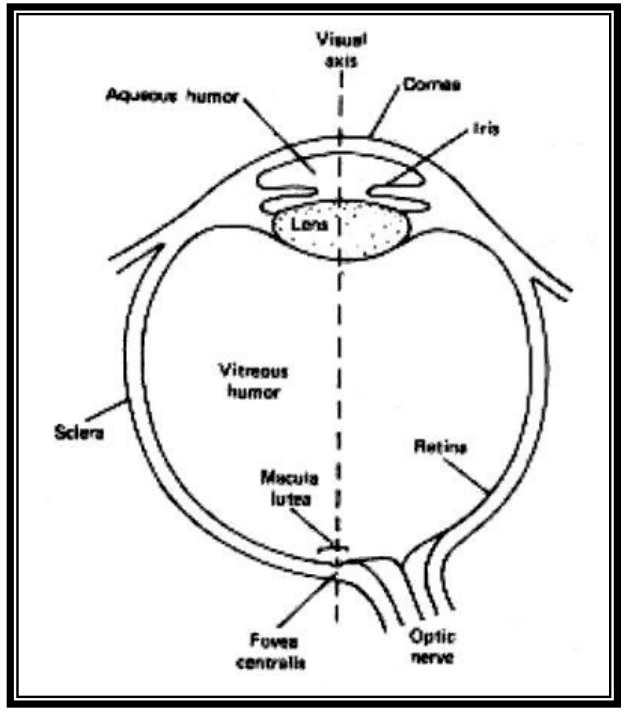
9. The image appears upside down on the light-sensitive retina at the back of the eyeball, but the brain automatically corrects for this.

10. The brain blends the images from both eyes, giving us good depth perception and true **three-dimensional** viewing. If vision from one eye is lost, the vision from the remaining eye is adequate for most needs.

11. The muscles of the eye permit flexible movement up and down, sideways, and diagonally. After a little practice, the eyes can even be made to go in circles.

Focusing elements of the eye

The eye has **two** major focusing components: the **cornea**, which is the clear transparent bump on the front of the eye that does about **two-thirds** of the focusing, and the **lens**, which does the **fine** focusing. 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 and the **speed** of light in the lens compared with that in the surrounding material (**relative index of refraction**).

When the **cornea** is under-water it loses most of its focusing power **because** the **index of refraction** of the water (**1.33**) is close to that of the cornea (**1.37**). Fish have a similar problem out of the water. Divers keep air around the cornea by wearing a face mask.

Nearly all of the focusing by the cornea is done at the front surface since the **aqueous humor** in contact with the back surface has nearly the same **index of refraction** as the cornea.

Since the living cells in the **cornea** are not supplied with oxygen by the blood, they must get their oxygen from the air. Having blood vessels in the **cornea** would not help our vision! The nutrients for the cells in the **cornea** are supplied by the **aqueous humor** that is in contact with its back surface. The **aqueous humor** contains all of the blood components except blood cells.

If the **cornea** is scratched it will heal itself, but some other types of damage are more permanent. Some types of radiation (**ultraviolet, neutrons, X-rays, etc.**) can cause **opacities** to develop in the **cornea** that will block out light.

The **lens** has focusing properties at both its front surface and its back surface. The **lens** is more curved in the back than in the front. It changes its focal strength by changing its curvature. The focusing power of the **lens** is considerably less than that of the **cornea** because it is surrounded by substances that have **indexes of refraction** close to its own. The **lens** is made up of layers somewhat like an **onion**, and all layers do not have the same **index of refraction**.

The **lens**, like the **cornea**, can be damaged by **ultraviolet** and other forms of radiation. It can develop **cataracts**, which destroy its clarity.

Some other elements of the eye

The **pupil** is the opening in the center of the **iris** where light enters the lens. It appears black **because** essentially all of the light that enters is absorbed inside the eye. Under average light conditions, the opening is about **4mm** in diameter. It can change from about **3mm** in diameter in bright light to about **8mm** in diameter in dim light.

It is believed that the **iris** aids the eye by increasing or decreasing incident light on the retina until the retina has adapted to the new lighting conditions. In addition, under bright light conditions it plays an important role in reducing lens defects.

The **aqueous humor** fills the space between the **lens** and the **cornea**. This fluid, mostly water, is continuously being produced, and the surplus escapes through a drain tube, the **canal of Schlemm**. Blockage of the drain tube results in increased pressure in the eye; this condition is called **glaucoma**.

The **aqueous humor** contains many of the components of blood and provides nutrients to the nonvascularized **cornea** and **lens**. It maintains the internal pressure of the eye. If you press on the eye, you find it is fairly stiff; you cannot indent it much. The reasons are that the fluids in the eye are incompressible at the pressure you use and that the covering of the eyeball does not stretch easily. When you rub your eyes, you greatly increase the internal pressure.

The **vitreous humor** is a clear jelly-like substance that fills the large space between the **lens** and the **retina**. It helps keep the shape of the eye fixed and is essentially permanent. It is sometimes called the **vitreous body**.