UNIT 3 PERCEPTION OF LIGHT

Structure

3.1 INTRODUCTION

The sense of vision is one of our most prized possessions. It enables us to enjoy splendours of nature, stimulates our thinking and enriches our lives in many ways. We bccornc aware of the infinite variety of objects around us, especially their shapes, colours, textures and motion etc only due to our ability to see them. But have you cvcr thought: What makes us to see? It all begins with eyes but also depends on what happens behind the eye. Every object viewed is seen with light. Eye responds to illumination. We all know that all living species - from one celled amoeba to the great bald eagle - have developed special mechanisms for responding to light. Human perception of light, i.e. vision is a more developed process. It takes place almost spontaneously without any one, other than the perceiver, knowing what is happening. Perception of light involves formation of sharp images (in the visual apparatus) and their interpretation. Vision begins in the cyc, but light is sensed by the brain. In fact, what wc see is the world created by our visual apparatus inside our head. So we can say that vision involves a mix of physical and physiological phenomena. You are already familiar with some of the aspects about light and visual systems from your earlier classes. Therefore, you are advised to glance through NCERT physics text book. In this unit we will develop on what you already know. In Sec. 3.2 you will get an opportunity to review internal eye structure and know how light is sensed. Sec. 3.3 is devoted to colour vision where you will learn about dimensions of colour, the trichromatic and opponent-colour theories.

The amoeba reacts only lo extreme changes in light intensity such as light and darkness. The earthworms react to light through light sensitive cells present on their skin. This ability lo sense only general level of light intensity is termed **photosensitivity.**

Objectives

Alter studying lhis unit, you should be able to

- explain the functions of different parts of the eye
- list common cyc defects and suggest remedial measures
- describe how list common cyc defects and suggest remedial measures human cyc responds to colour, and
- explain trichromatic and opponent-colour theories of colour vision,

3.2 HUMAN VISION

Human vision also has a rich relationship with other senses. In fact, all our five senses cooperate and augment each other.

In medicine, the study of structure, functions and diseases of the eye is called **opthalmology**.

Vision involves a mix of physical phenomena and physiological processes. We can understand how the image of an object is formed within the eye purely in terms of physical principles and processes. But from image formation to its perception by the brain, the process is physiological. In this section our emphasis will be on the physics of vision. We shall also discuss very briefly the physiology of vision. Let us begin our study of human vision with the eyes - our windows to the external world. Our eyes are very versatile. They possess a staggering degree of adaptability and precision. They are capable of extremely rapid movement. That is why we can instantaneously shift the focus from a book in hand to a distant star, adapt to bright or dim light, distinguish colours, scan space, estimate distance, size and direction of movement. You may now ask: How vision begins in the eye? What is the internal structure of the eye? How brain interprets images? The answers to such questions have fascinated man for thousands of years. Physiologists say that human eye is an image-making device. (In a way, human eye has striking similarities to a camera of automatic intensity and focal control.) To know the details of mechanism of vision, some knowledge of the visual apparatus is necessary. You will now learn about the structure of eye and how it works as an optical instrument.

Human eyes are very versatile and highly accurate. Their overall visual horizon is broad. But they are less acute than a hawk's eyes and less wide-seeing than those of a deer. Moreover, human eyes are not ideally suited for seeing underwater, nor are they very efficient at night. Even in twilight, eyes lose all colour perceptions.

3.2.1 Viewing Apparatus: The Eye

Our eyes, as you know, are located in the bony sockets and are cushioned in fatty connective tissue. The adult human eye measures about 1.5 cm in diameter. Now refer to Fig. 3.1. It shows a labelled diagram of human eye.

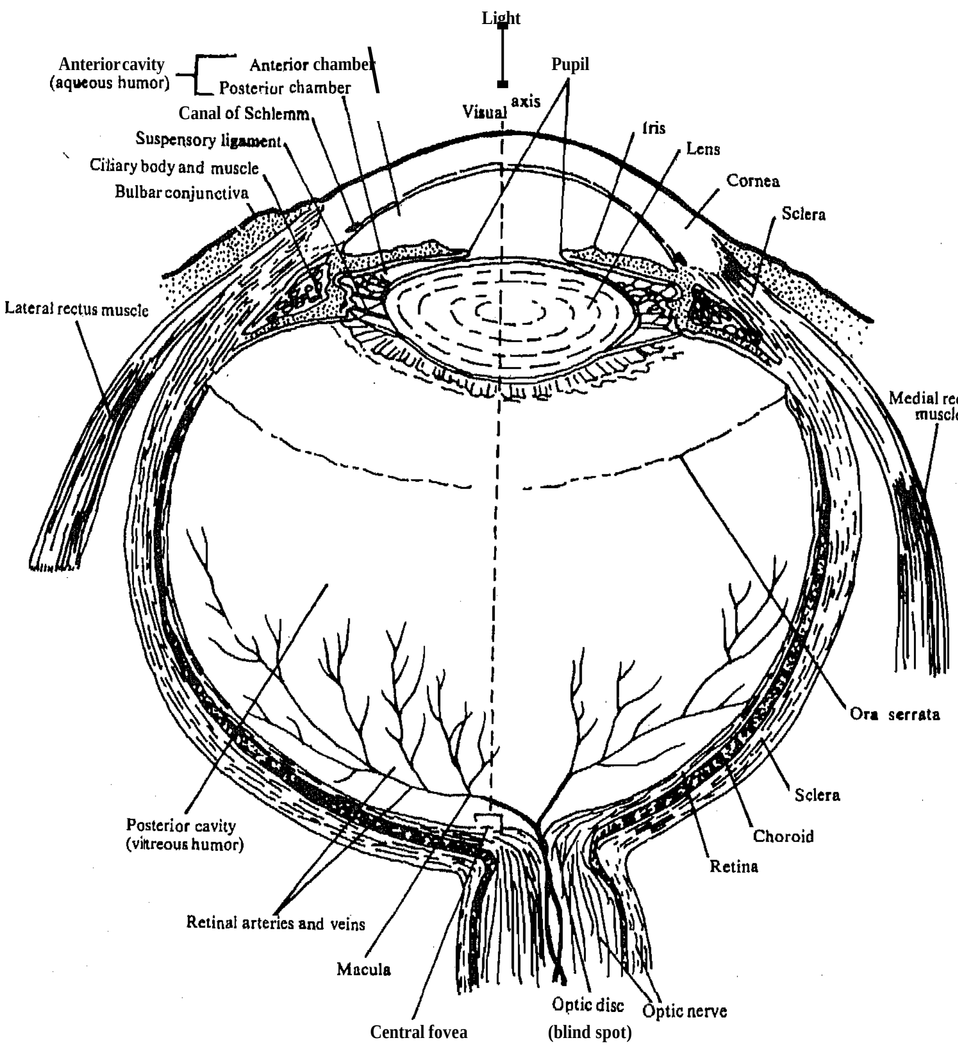


Fig.3.1: A schematic labelled diagram of human **eye**

The **sclera** or 'white' of the eyeball is an opaque, fibro-elastic capsule. It is fairly tough and gives shape to the eyeball, protects its inner parts and withstands the intraocular pressure in the eye. The muscle fibres which control eyeball movement are inserted on the sclera. The **cornea** is a tough curved front membrane that covers the **iris,** the coloured circular curtain in the eye. The cornea acts as transparent window to the eye and is the major converging element.

The cornea is followed by a chamber filled with a transparent watery liquid, the aqueous humor, which is produced continuously in the eye. It is mainly responsible for the maintenance of intraocular pressure. Besides this, aqueous humor is the only link between the circulatory system and the eye-lens or cornea. (Neither the lens nor the cornea has blood vessels.) The intraocular pressure maintains the shape of the eye, helps to keep the retina smoothly applied to the choroid and form clear images. Near the rear of this chamber is the iris. The iris is opaque but has a small central hole (aperture), called **pupil.** In our common observation, pupil appears more like a black solid screen. Why? This is because behind the opening is the dark interior of the eye. The size of pupil in normal eye is about 2 mm. The light enters the eye ball through this area. The iris is suspended between the cornea and the lens. The principal function of the iris is to regulate the intensity of light entering the eyeball. When the light is bright, the iris contracts and the size of the pupil decreases and vice versa.

The intraocular pressure maintains the shape of the eye, helps to keep the retina smoothly applied to the choroid and form clear images.

Thread-like suspensory ligaments hold the biconvex crystalline eye-lens, which is just behind the pupil and iris. The muscle responsible for changes in the shape of the lens for near as well as far vision is called the **ciliary muscle.** The cyc-lens is an elastic structure made of protein fibres arranged like the layers of an onion. It is perfectly transparent and its focal length is about 3 cm.

The crystalline lens is followed by a dark chamber, which is filled with **vitreous** humor. It is a transparent jelly-like substance. It augments the functions of aqueous humor and helps the eye hold its shape. The rear boundary of this chamber is retina, where the image of the object is formed. Microscopic structure of retina is shown in Fig. 3.2(a). It consists of a nervous layer and a pigmented layer. Apart from sensing the shape, and the movement of an object, the retina also senses its colour. The retina consists of five types of **neuronal cells:** the photoreceptors, bipolar, horizontal, amacrine and ganglion neurons. **A** magnified view of the arrangement of neuronal cells in the retina is shown in Fig. 3.2(b).

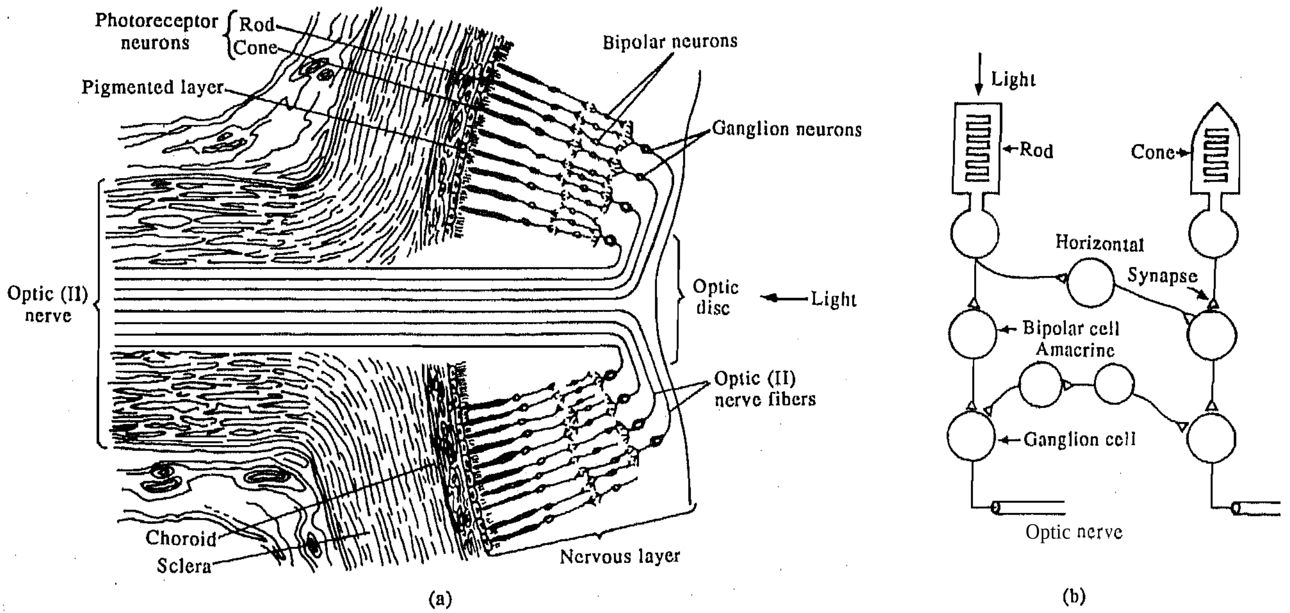


Fig.3.2: (a) Microscopic structure of retina (b) A Magnified view of arrangement of neuronal cells in the retina

The photoreceptor neurons are of two types: **rods** and **cones.** (This nomenclature is due to their geometrical shapes.) It is estimated that about 130 million rods and cones are found lining the retina. Of these, about six million are cones and about twenty times as many are rods. The light sensitive pigments of photoreceptors are formed from vitamin A.

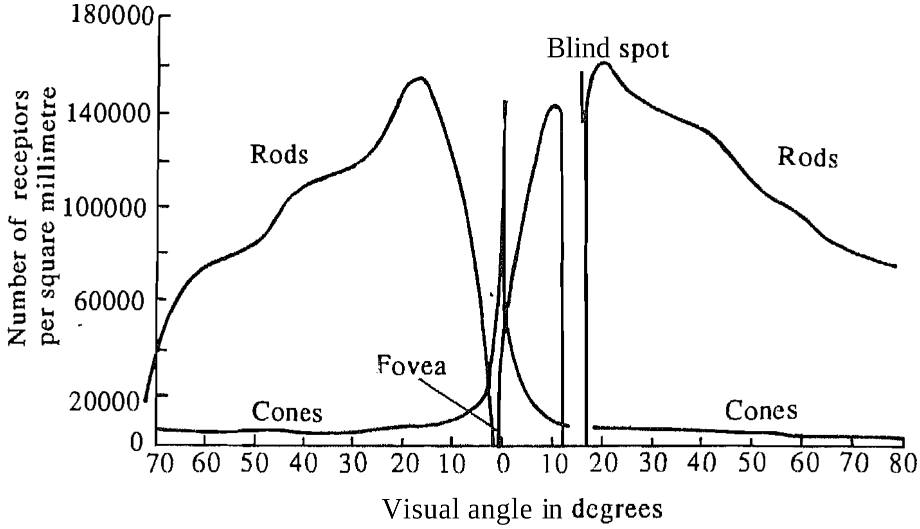


Fig. 3.3: Distribution of rods and cones in the retina of human eye

At the very centre of the retina is a small yellowish depression, called **fovea.** This small valley (of about 5mm diameter) contains a large number (~110,000) of cones and no rods. The distribution of rods and cones across the human retina is shown in Fig. 3.3. The horizontal axis shows the distances in degrees of visual angle from the fovea located at 0°.

Rods are highly specialized for vision in dim light. They enable us to discriminate between different shades of dark and light, see shapes and movements. That is, rods provide a high sensitivity. Cones contain light sensitive pigments which make colour vision and sharpness of vision (high visual acuity) possible.

When light is absorbed by photoreceptor cells, the light sensitive pigments arc broken up by specific wavelengths of light. The bipolar nerve cells carry nerve impulses generated by rods and cones to the ganglion cells. The axons of the ganglion cells converge on a small area of the retina. It is lateral to the fovea and is free from rods and cones. Can you say anything about its ability for vision? Since this area contains only nerve fibres, no image is formed on it. That is, it is devoid of vision. For this reason, it is called the **blind spot.** You may be tempted to ask: Is there a spot in the eye for maximum vision? Certainly yes, the fovea is the valley of the sharpest vision. This remarkable perceplivc ability is provided by the cones. Muscles for moving the eye spring from the sclcra. The conjunctiva - a supple protective membrane - joins the front of the eye to the inside of the eyelids.

3.2.2 Imnge formation

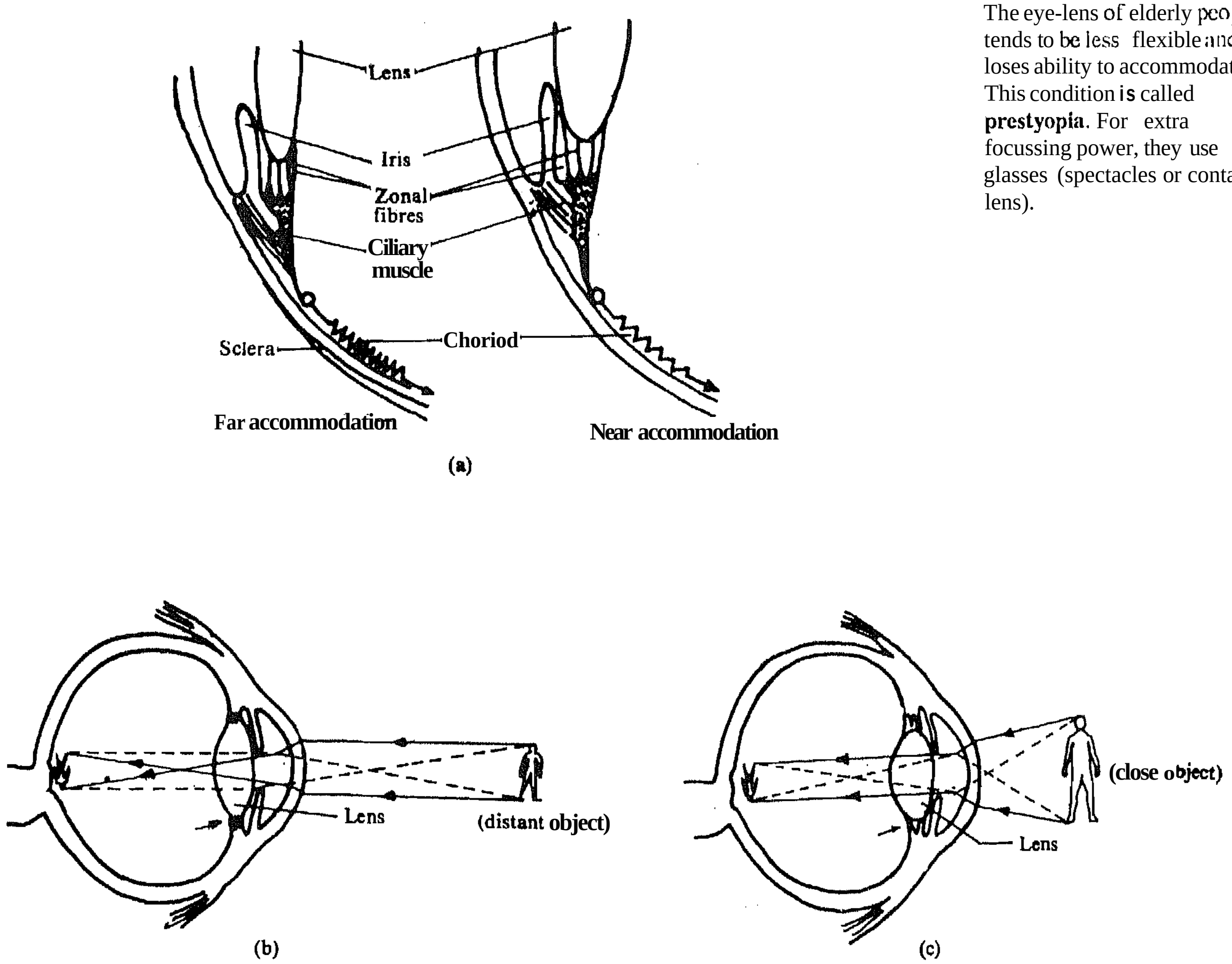
Before stimulating rods and/or cones, light passes through the cornea, aqueous humor, pupil, eye-lens and vitreous hurnor. For clear vision, the image formed on the retina should be sharp. Image formation on the retina involves refraction of light, accommodation of eye-lens, constriction of pupil, and convergence of the eyes. We will now discuss these.

Refraction and Accommodation

The light entering the eye through the transparent window - cornea - undergoes refraction four times. This is because the eye has four optically different media: cornea ($n = 1.38$), aqueous humor ($n = 1.33$), eye-lens ($n = 1.40$), and vitreous humor (n = 1.34). Most of the refraction occurs at the air-cornea interface. Can you say why? This is because the cornea has a considerably larger refractive index than air (n = 1.0). Moreover, due to the curved shape, the cornea bends the light towards the retina. Additional bending is provided by the eye-lens, which is surrounded on both sides by eye- fluids (Fig. 3.1). However, the power of the lens to refract light is less than that of the cornea. So the main function of lens is to make fine adjustments in focussing. The focussing power of eye lens depends on the tension in the ciliary muscle. When the ciliary muscle is relaxed, the lens is stretched and thinned. When a visual object is 6m or more away from the eye, cornea receives almost parallel light rays. When the eye is focussing an object nearer than 6m, the ciliary muscles contract. As a result, the lens shortens, thickens and bulges and its focussing power increases. These features are illustrated in Fig. 3.4. The great value of the lens lies in its unique ability to automatically change its focal control. This ability is called

While a healthy cornea is transparent, disease or injury may result in blindness. But eye surgeons have now acquired competence in replacing damaged cornea with clear one from human donors. **Any** imperfection in the shape of the cornea may cause distortion in visual images.

The eye-lens of elderly people tends to be less flexible and loses ability to accommodate. This condition is called **prestyopia**. For extra focussing power, they use glasses (spectacles or contact lens).



Pig. 3.4: Far and near accommodation (a) In the diagram on the left, the ciliary muscle is relaxed. This causes the eye-lens to curve less. In the other diagram, the ciliary muscle is contracted. This causes the lens to curve more. (b) Accommodation for far vision (6m or more away). (c) Acommodation for

accommodation. Since accommodation means work for the muscles attached to the eye lens, viewing an object nearer than 6m for a long time can cause eye- strain.

Constriction of Pupil

Constriction of the pupil means narrowing down of the diameter of the hole through which light enters the eye. This action occurs simultaneously with accommodation of the eye-lens and prevents the entry of light rays through the periphery of eye-lens, which can result in blurred vision. The pupil also constricts in bright light to protect the retina from sudden or intense stimulation. (When the level of illumination is low, the pupil dilates so that the retina can receive enough light.)

Convergence

Human beings have single binocular vision. This signifies that both eyes focus on only one set of objects. When we stare straight ahead at a distant object, the incoming light rays are directed at both pupils, get refracted and are focussed at identical spots on the two retinas. Suppose that we move close to the object and keep our attention on the same stationary object. Our common sense suggests that even now images should form on the same points (in both retinas). It really does happen and our eyes automatically make adjustments by radial movement of two eyeballs. This is referred to as **convergence.**

Refer to Fig. 3.4 again. You will note that the images formed on the retina are inverted laterally as well as up-side-down. But in reality we do not see a topsy-turvy world. You may now ask: How does this happen? The solution to this apparent riddle lies in the capacity of the brain which automatically processes visual images. This suggests that though vision begins in the eye, perception takes place in our brain. Its proof lies in that severe brain injury can blind a person completely and permanently, even though eyes continue to function perfectly.

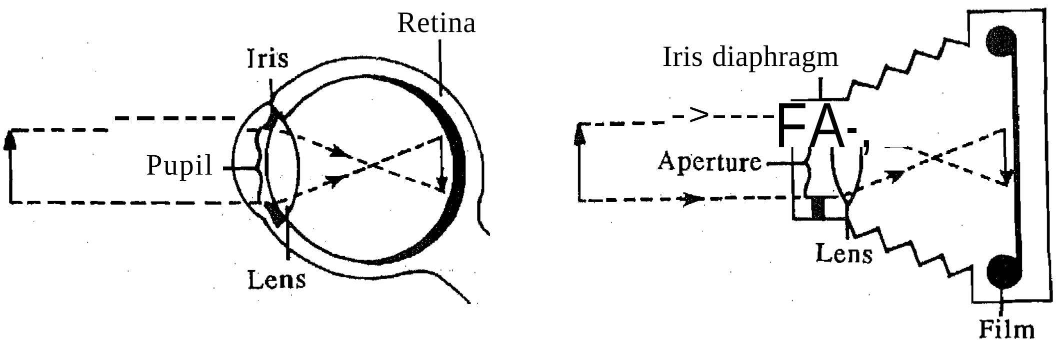
You may now like to reflect on what you have read. So you should answer the following SAQ before you proceed.

Spend 5 min

SAQ 1

Human beings are unable to see under water. Discuss why'?

By now you must be convinced that mechanically speaking, human eye is an optical instrument resembling a camera. **(A** better analogy exists between the eye and a closed circuit colour TV system.) The eye-ball has a light focussing system (cornea and lens), aperture (iris) and **a** photographic screen (retina). This is shown in **Fig.** 3.5. There are of course very important differences between our eye and a camera. The engineering sophistication of human eye is yet to be achieved even in the costliest camera. The camera-man has to move the his camera lens for change of focus, whereas the eye-lens has automatic intensity and focal control. (The brain constantly analysis **and** perceives visual images. This is analogous to the development of a photograph.) The image on the retina is not permanent but fades away after 1/20th of a second and overlaps with the next image. This gives the impression of continuity. There is of course no film in the eye that records the images permanently as a photo film does.



kYg.3.5: The similarity between the *eye* and *the* camera

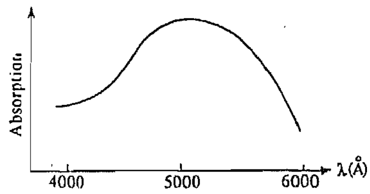
3.2.3 Information Processing

As soon as light impulses impinge on the retina (and an image is formed), these are absorbed by rods and cones, which contain four kinds of photosensitive substances. These visual pigment molecules undergo slructural (chemical) changes. It is believed that each rod cell contains about seventy million molecules of a purple-coloured photosensitive pigment, **rhodopsin.** Like rods, cones contain violet - coloured photosensitive pigment, iodoysin.

Each pigment molecule consisls of two components: a colourless protein, opsin, and a coloured chromophore, **retinene**. Opsin is different lor each of the four visual pigments and determines thc frequency of light to which each pigment responds.

Let us now understand as to what happens to rhodopsin in rods. (The same basic

Rhodopsin has **a** molecular weight of about 4×10^4 dalton. It consists of the **scotopsin** protein and the chromophore retinene, a derivative of vitamin **A** in the form called cis-retinene. **Any** deficiency of vitamin **A** causes **night-blindness.** Fig. **3.6** shows the absorption **curve** of rhodopsin.



Pig. 3.6 The absorption curve of rhodopsin

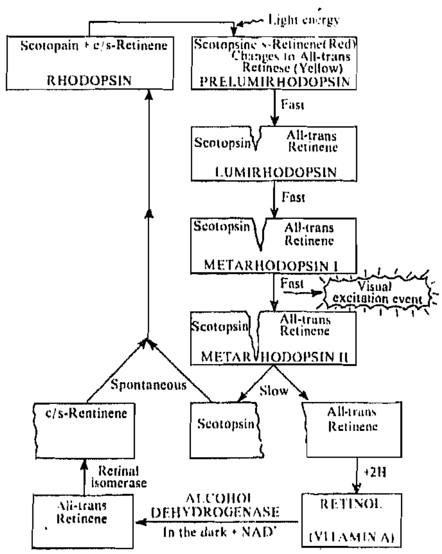
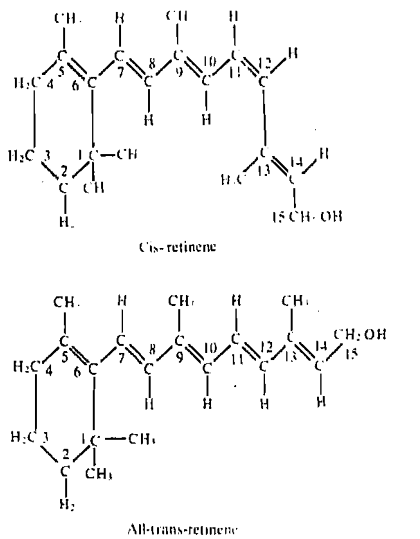


Fig. 3.7: The rhodopin cycle: Bleaching action

changes occur in the visual pigments in cones.) Reler lo Fig. **3.7** which depicts the rhodopsin cycle. The first slep in this process is the absorption of photon by rhodopsin, which then undergoes a chemical change. Its cis-retinene portion changes to **all-trans-retinene** On referring to Fig. **3.8** you will note the rotation that occurs around the carbon numbered 12. This change triggers decomposition ol rhodopsin (into scotopsin and all-trans-retinene) by a multi-stage process known as bleaching action. The pigment loses colour and the visual excitory event is believed to occur. Then rhodopsin is resynthesized in the presence of vitamin A. In this process, an enzyme, **retinene** isomerase, plays the most vital role.



Pig.3.8: Structures of cis-retinence nnd all-trans- retlnence

The rods respond even to poor illumination such as twilight. Rhodopsin is highly sensitive to even small amounts of light. Their responses to light generate colourless images and objects are seen only in shades of grey. It is for this reason that you see a red flower black in the evening. On the other hand, the pigments of the cones are much less sensitive to light and require bright illumination to initiate decomposition of chromophore. Visual acuity or ability to see clearly and to distinguish two points close together is very high and their responses produce colouredimages.

The information received in terms of light is converted into electrical signals in the retina. The potential of the cell membranes of the photoreceptor cells undergoes a change even on brief illumination. This occurs through a complex chemical process involving a flow of calcium ions and sodium ions across the membrane. The change in membrane potential, ΔV_m, is governed by the following equations in time and space:

$$\Delta V_m(t) = I_m R(1 - e^{-t/\tau}) \quad (3.1)$$

and

$$\Delta V_m(x) = V_0 e^{-x/L} \quad (3.2)$$

where I_m is the membrane current, R the membrane resistance, τ is the membrane time constant. V_0 is the change in the membrane potential at $x = 0$ (x being the distance away from the site of current injection) and L is the length constant. **As** can be seen, the spread of ΔV_m in space is governed by L (whose values fall in the range of about **0.1** to **1** mm), It is important to note that while slow potentials are generated in most cells, action potentials are produced only in the ganglion cells. The signals generated in the retina are further transmitted to the higher centres in the visual pathway of the brain such as lateral geniculate nucleus and visual cortex. In this way, precise information about the image projected on the retina is conducted accurately to the brain. The transfer of visual information in a typical retinal circuit is shown (Fig. **3.9).**

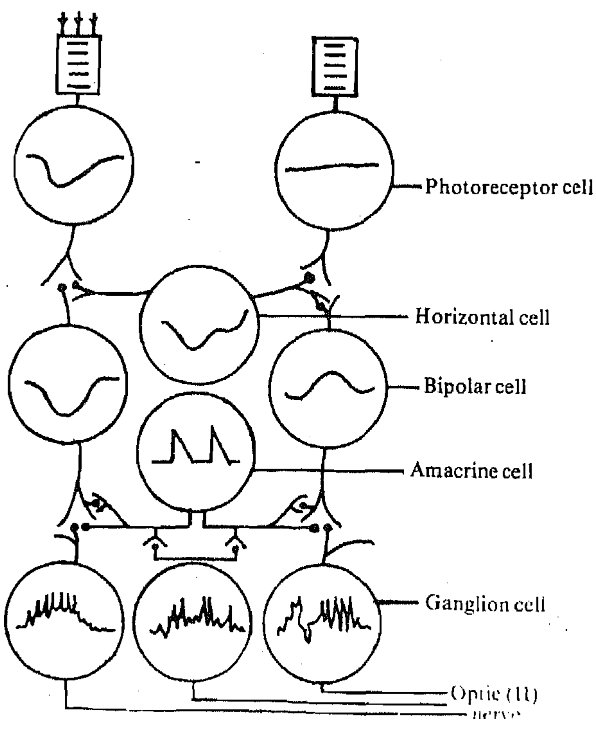


Fig.3.9: Retinal circuit showing the electrical link. between cells of the retina: Action potential

We hope that now you have a reasonable idea of how we perceive the world around us. You may now like to know the factors that hamper vision.

3.2.4 Defects of Vision

Sometimes the eye loses its power of accommodation. When this happens, we are unable to see objects clearly and vision becomes blurred. These are corrected by using contact'lenses or spectacles.

In one kind of such a defect, human beings can see nearby objects clearly but it is difficult to see objects at long distances. In such a (defective) eye, the image of distant objects is formed in front of the retina (Fig. 3.10a) rather than on the retina. This defect of the eye is known as **shortsightedness** or **myopia.** It is frequently observed in children and its occurrence is fast increasing in our country. In shortsightedness, the eyeball gets elongated. It can be corrected by using a concave (divergent) lens (Fig. 3.10b) of appropriate focal length which moves the image on to the retina.

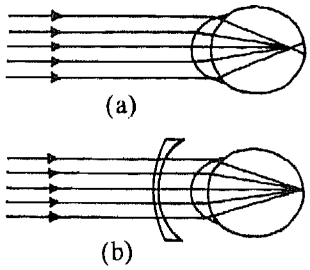


Fig.3.10: (a) Shortsightedness (b) its correction

In another eye defect, eyeball gets shortened. Though distant objects are seen clearly, nearby objects look blurred. In this case the image is formed behind the retina (Fig. 3.11a). This defect is known as **longsightedness** or **hypermetropia.** It is normally observed in elderly people. It can be corrected by using a convex (convergent) lens of appropriate focal length (Fig. 3.11b).

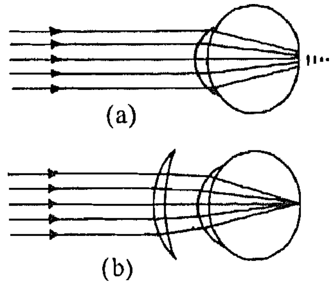


Fig. 3.11: (a) Long sightedness (b) its correction

Sometimes a person may suffer from both myopia and hypermetropia. Such people often use bifocal lenses, in which one part of the lens acts as a concave lens and the other part as a convex lens. The third type of defect of vision is called **astigmatism,** wherein distored images are formed. The corrective lenses are used to restore proper vision.

3.3 COLOUR VISION

You all know that human beings have remarkable sense lo adore the varied creations of nature. This is particulary because colour is an automatic part of our perception. In fact, the phenomenon of colour vision has added real charm in life. Can you now realize what vision is like without colour? You will learn that the colour is a perceptual experience; a creation of the eye and the mind.

One of the earliest observations about colour perception was made in 1825 by Purkinje. He observed that at twilight, blue blossom on flowers in his garden appeared more brilliant than the red. To understand this you must know the mechanism of colour vision. The process of colour perception is influenced by the physiology of the eye and the psychology of the person. Before wc plunge into these details, it is important to know the dimensions of colour, i.e., the parameters with which colour may bc defined.

3.3.1 The Dimensions of Colour

The most important physical dimension of colour is the wavelength of light. For most light sources, what we perceive is the dominant colour, which we call tlie **hue.** It is hue to which we give the names like red, blue or greenish yellow. In fact, the terms colour and hue are frequently used inlerchangeably. You may therefore conclude that **hue is the perceptual correlate for variations in wavelength.**

The second dimension relevant to colour vision is **illuminance,** which refers to the amount of light reaching the eye directly from the source. Illuminance, therefore, characterizes the perceived brightness of a colourcd light. This relationship (between illuminance and brightness) is fairly complex because perceptual sensitivity varies with the wavelength of light. Every individual with normal eye possesses maximum sensitivity to light between the green and yellow parts of the spectrum (500nm - 600 nm). And the sensitivity to predominantly blue light (400 - 500 nm) is rather low.

Intensity is defined as the amount of energy reaching a receiver of given cross-sectional area every second.

Another physical dimension associated with colour is the degree of purity of spectral composition. That is, purity characterises the extent to which a colour (hue) appears to be mixed with white light. This is responsible for variations in the perceived saturations of the colour. For example, when we add white light in a spectrally pure blue, the light begins to look sky- blue. On progressive addition of white light you may eventually observe it as white.

We may therefore conclude that

> **Colour, as a perceptual phenomenon, is three dimensional and is characterised by hue, saturation and brightness.**

Thinking logically, you may now ask: Is there any other alternative expression for the dimensions of colour ? The answer to this question is: Yes, there is. It is based on the observation that colour depends on intensity of light. Let us now learn about it in some detail.

Trichromacy

You must have realised sometimes that when intensity of light is low, we see no colours. You also know that by varying the wavelengths and/or intensities of lights of different colours, it is possible to produce light of a desired colour. In your school you must have learnt that all the colours of the visible spectrum can be produced by mixing lights of just three different wavelengths: red, green and blue. These are known as primary colours. The explanation for this trichromacy lies in the mechanism for colour vision. You will learn about it in the next sub- section.

Another important phenomenon associated with colour vision is complemantarity of colours i.e. pairs of colours, when mixed, seem to annihilate one another. For example, when we mix suitable proportion of a monochroniatic blue light (A– 470 mm) with a monochromatic yellow light (A– 575 nm), we obtain a colourless grey.

Reflecting on this observation, Hering suggested that complementary pairing is an indicator for pairing in the mechanisms responsible for signalling colour in the visual system. The complementary relationships among pairs of colours can be well represented as shown in Fig. 3.12. To locate the complementary colour in this figure all that you have to do is to choose any point and draw a line passing through the centre of the circle. A suitably adjusted mixture of two complementary colours will appear grey.

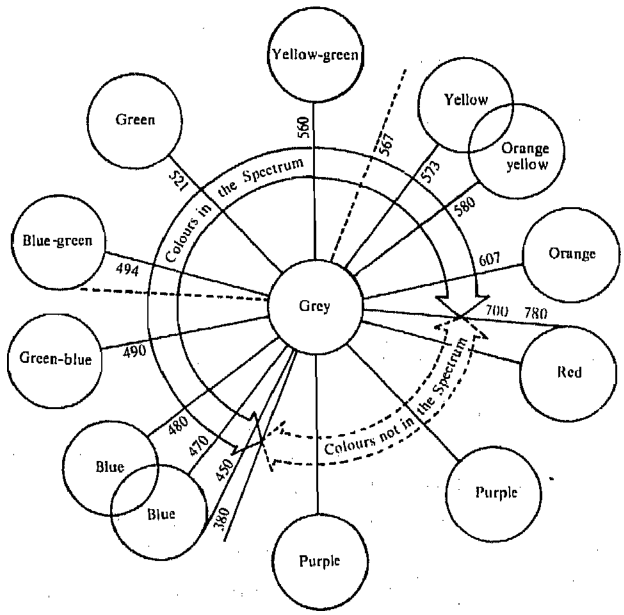


Fig. 3.12: The complementary colour circle

Before you proceed further, we want you to pause for a while and answer the following **SAQ.**

SAQ 2

Spend 5 min

How would you indicate brightness and saturation in Fig. 3.12?

Note the presence of 'purple' hues. You may recall that dispersion of white light by a prism does not reveal this hue. Then the question arises: What is their significance in the colour circle? The complementary circle will remain incomplete without them.

You may also note that though colour circle represents colours as a continuum, primary colours are perceptually quite distinct. The phenomena of primary colours and trichromacy led Young to propose three different types of receptors (cones) for colour vision. You will learn the details as you proceed.

Colour Blindness

You now know that a single monochromatic light can be produced by combining two primary colours. The measurements made to know the amounts of these colours required to match a given monochromatic colour gave fairly standard results. That is, when we ask a group of people to match a test colour, experience tells that they mix the same proportions of primary colours. But colour-mixing requirements for some individual may be anomalous. In fact, some individuals may need only two, rather than three, primary colours to match all the inonochromatic hues. These anomalies are indicative of varying degrees of colour blindness. People who show anomalous colour-matching requirement do not see the same colours as individuals having normal vision. The most common defect is in the proportions of red and green lights required to match a monochromatic yellow. The manifestation of this in everyday life is a limited ability to distinguish between red and green.

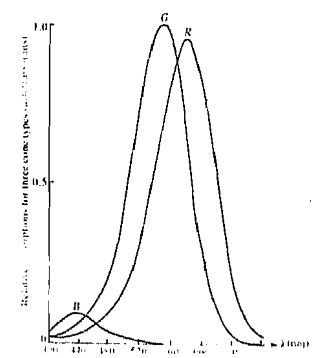


Fig. 3.13: Spectral absorption curves for three different cone pigments

3.3.2 Colour Receptors

In the above paragraphs you have learnt that trichromatic theory led Young to propose that eye possesses three types of cones, each containing a different pigment. And three types of pigments in the cones correspond to three primary colours (three- dimensional colour vision). The absorption curves for these pigments are shown in Fig. **3.13.** You will note that the curves show substantial overlap. Moreover, the blue mechanism is markedly less sensitive than the other two.

The argument leading to this conclusion is rather subtle and needs closer analysis. To understand this, let us ask: How do humans distinguish such a large number of colours? Do we need a different type of receptor to discriminate each colour? Since the colours are numerous, the number of receptors available for a particular colour will be a small fraction of the total number of colour receptors. When monochromatic light reaches our eye, only the corresponding class of receptors will respond. And since the total number of responding receptors is comparatively small, the ability to see a monochromatic light will be much less than the ability to see white light. But in practice, this is not true. This led Young to conclude that only a few different types of receptors are present, which by working in combination give rise to all the different colours we perceive. His experience with colour mixing led him to conclude that the number of receptor types is only three.

This theory was proposed even before very little was known about the physiology of the visual system. The outputs from the three types of receptors are transmitted separately to the brain which combines the information and constructs certain abstractions to which we give names like hue, saturation, yellow, blue etc.

We all know that yellow gives a sensation independent of red, blue and green, **i.e.** it seems as much of a primary colour. But no coding system is postulated for yellow in the trichromatic theory. Such feelings, though subjective, led Hering to propose an alternative theory of colour based on four colours: red, yellow, green and blue. This is known as **opponent-colour theory.** These colours are associated in pairs: red-green and blue-yellow. The members of a pair are thought to act in opposition adding upto white. Hering also specified a third pair of black and white to represent the varying brightness and saturation of colours. (The perception of brightness of the colour also depends on the mood of the perceiver.) You must appreciate that the most important difference between this theory and the trichromatic theory lies not in the number of postulated receptor types, but in the way their outputs are signalled to the brain. Fig. 3.14 depicts a simple version of the opponent-process theory. Three basic receptor types are indicated by X, Y and *Z*. Mixture of Y and *Z* is perceived as yellow. White is obtained by mixing X, Y and *Z*.

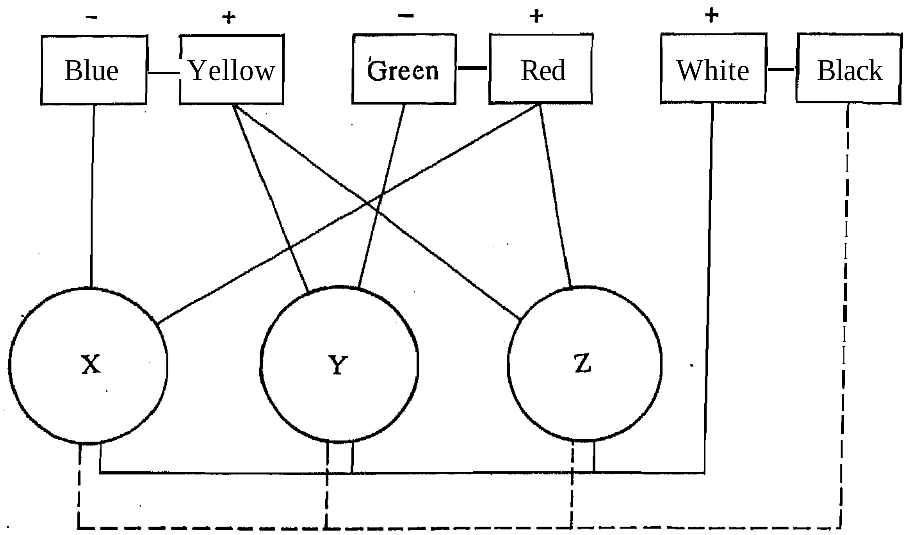


Fig.3.14: Opponent-process theory based on Hering's postulate. *X*, *Y* and *Z* denote basic receptor types.

According to the model shown in Fig. 3.14, three different receptor types are each sensitive to a range of wavelengths. The mode of operation is such that the activity level increases in response to a predominant input about one colour. You may ask: What happens in response to the input about the complementary colour? We expect it to decrease. To illustrate it, let us consider that the input to the blue-yellow system is predominantly in the yellow region of the spectrum. Then, there is an increase in activity (over a spontaneous level) about yellow colour. On the other hand, if the input is predominantly blue, there is a decrease in activity. Activity in the black-white mechanism is based on outputs from all three receptor types.

Even though trichromatic theory and the opponent- process theories appear conflicting, recent studies show evidences that they are compatible. Researches at the Johns Hopkins University (US) provide evidence in favour of trichromatic theory. However, the cones do not send 'color signals' directly to the brain. Cone signals pass through a series of neurons which are colour specific.

Vision is an endlessly fascinating area . We here conclude saying: Eye is not merely an instrument for survival; it is a means for enrichment of life.

We will now like you to answer the following SAQ.

SAQ 3

Spend 5 min

Name the regions of retina specialized for (a) colour and detailed vision at high levels of illumination and (b) non-colour vision at low levels of illumination.

3.4 SUMMARY

- Perception of light involves formation of sharp images in the eye and their interpretation in the brain. That is, vision involves a mix of physical and physiological phenomena.
- Human eyes are image making devices. They have striking similarities to a camera of automatic intensity and focal control. There are however differences in details.
- Cornea is the major converging element in the eye.
- The image of an object is formed on the retina. It consists of five types of neuronal cells: photoreceptors, bipolar, horizontal, acrine and ganglion neurons.
- The photoreceptor neurons are of two types: rods and cones. Rods are specially suited for vision in dim light and provide high-sensitivity. Colour vision and sharpness are possible due to cones.
- Image formation on the retina involves refraction of light, accommodation of eye-lens, constriction of pupil and convergence of the eyes.
- Information processing involves structural changes in photosensitive pigment rhodopsin by bleaching action.
- Two common defects of eye are Myopia (short sightedness) and hypermetropia (long sightedness). These are corrected by using a concave and a convex lens respectively.
- Colour, as a perceptual phenomenon, is three dimensional: hue, illuminance and purity.

  According to Young's trichromacy theory, colour vision requires three types of receptors (cones) for three primary colours.

  According to Hering's opponent - colour theory, colours are associated in pairs: red-green, blue-yellow and add up to white. The brightness and saturation are determined by a black-white pair.

3.5 TERMINAL QUESTIONS

1. List the differences between the human visual system and a camera.
2. When we enter a dark room, we feel blinded. Gradually we become dark adapted. The dark adaptation curve shown here shows a kink. Can you suggest an explanation in terms of rod and cone-adaptation ?

3.6 SOLUTIONS AND ANSWERS

SAQs

1. The refractive indices of water and cornea are 1.33 and 1.38, respectively. Due to small difference in these values, cornea is unable to bend light towards the retina. This is why humans are unable to see under water.
2. An arrow originating at the centre and directed towards the circumference would indicate increasing colour saturation. Brightness does not depend on hue and saturation. So a line drawn normally out of the page (towards you) would represent increasing brightness.
3. The first description applies to the fovea whereas the second description applies to the peripheral regions.

TQ's

1. Some of the main differences are tabulated below. You can add more if you have thought of others.

Camera	Eye
Lens is responsible for focussing.	Cornea as well as lens is involved in focussing; lens is responsible for fine adjustments
Lens is rigid and fixed. Fine focus is achieved by changing lens and/or by changing distance between lens and film.	Lens is soft and flexible. Fine focus is achieved by alterations in convexity of lens.
Only sophisticaled cameras have automatic aperture adjustments.	Pupil adjustment is an automatic response.
The brightness of a photograph depends directly on the level of illumination.	The brightness of a perceived scene depends on prevailing illumination as also the lighting level to which the eye has been previously exposed.
Light-sensitive substances do not regenerate once film has been exposed.	Light-sensitive substances are constantly regenerating.
Image is fixed.	Image is in constant motion (owing to eye movements).
Information stored in photographic form is not immediately transmitted.	Information on retina is automatically processed and the results are immediately transmitted to the brain.

2. The principal mechanism for dark adaptation is regeneration of bleached visual pigments, in partcular rhodopsin. So, the first part of the curve signifies the foveal adaptation, due to cone cells. It levels off at the kink. And the second part of the curve represents the contribution of rods.