4

Optical Instruments

[Including Eye and Its Defects]

MAGNIFYING GLASS (Simple Microscope)

A magnifying glass is used to see (examine) very small objects which cannot be seen clearly with naked eyes. For reading letters, small in size, we use a magnifying glass. To examine the skin of a patient, a doctor uses it. A watch repairer uses a magnifying glass so that an enlarged image of the smaller parts of the watch may be seen clearly. **A magnifying glass is also called a simple microscope**.

A magnifying glass or a simple microscope consists of a convex lens fitted in a round metallic frame with a handle (see Fig. 4.1).

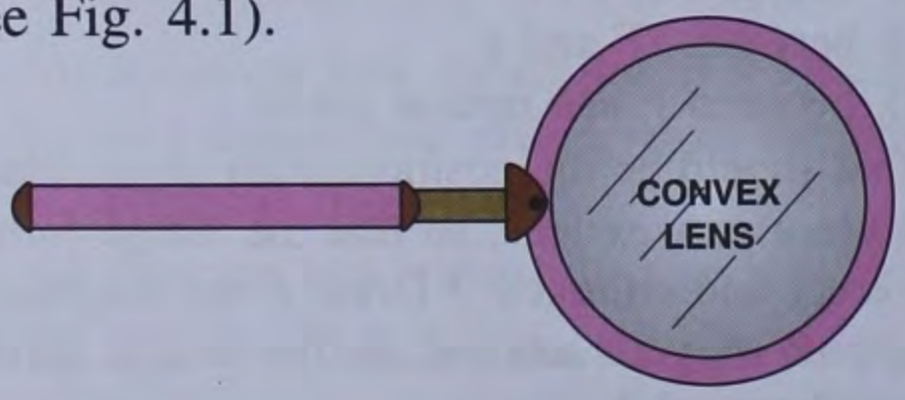


Fig. 4.1 Simple microscope (magnifying glass)

Suppose, AB is a very small object to be magnified by a magnifying glass with a convex lens of suitable focal length. The magnifying glass is so placed that the object AB falls within the focal length of its lens.

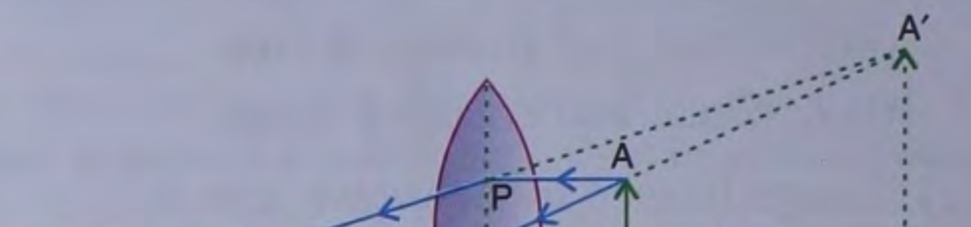


Fig. 4.2 Convex lens used as a magnifying glass

A ray AP from A, parallel to the principal axis, passes through the focus after refraction through the lens. Another ray from A, passing through the optical centre O, will be refracted without any deviation. When two refracted rays fall on the eyes of the observer, it appears to diverge from point A′. Then A′B′ is the image of the object AB. The image is virtual, erect and magnified. The eye will see a magnified image A′B′.

A convex lens of short focal length gives a greater magnification than lenses of long focal length.

CAMERA

A camera is an instrument which gives us a permanent image of the object. A photographic camera consists of a convex lens fitted in one face of a light proof box which is

painted black from inside. A strip of photographic film is placed at the other face of the box (Fig. 4.3). The distance of the lens from the film can be changed by turning the focusing ring. There is a diaphragm with an aperture behind the lens. The light reaching the film is controlled by changing the size of the aperture while using the diaphragm. There is a shutter behind the diaphragm. The shutter is opened for a while on clicking the camera. A view finder is also provided for setting the camera in a proper direction.

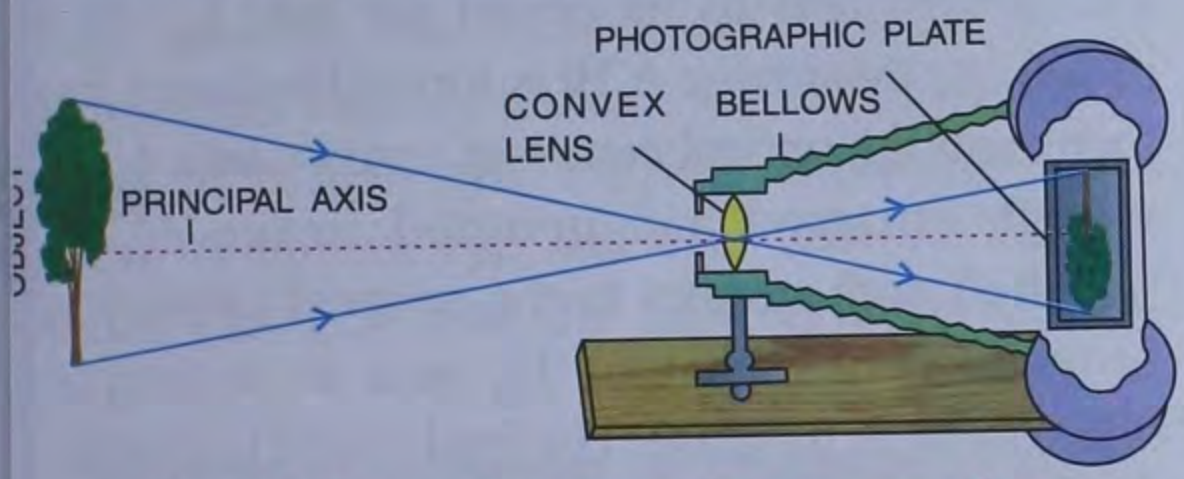


Fig. 4.3 Image formation in a camera lens

Working : The object to be photographed and the camera lens has to be kept at a distance usually greater than twice the focal length of the lens. The view finder has to properly focus the object before the camera is clicked. The photographs of the distant and near objects can be taken by the same camera by adjusting the distance of the camera lens from the film with the focusing ring. When the camera is clicked, light from the object enters into the camera and the lens forms an inverted, real and diminished image on the film. Figure 4.3 shows the ray diagram of the image formation.

After exposure, the film is treated with chemicals and a permanent image appears on the film. This is called a **negative**. The negatives are used to get the positives which are called **photographs**.

MICROSCOPE (Compound Microscope)

Sometimes we need huge magnification to see very minute objects distinctly. Since simple microscope could not give huge magnification, another microscope called the compound microscope was developed in which two lenses are used (Fig. 4.4).

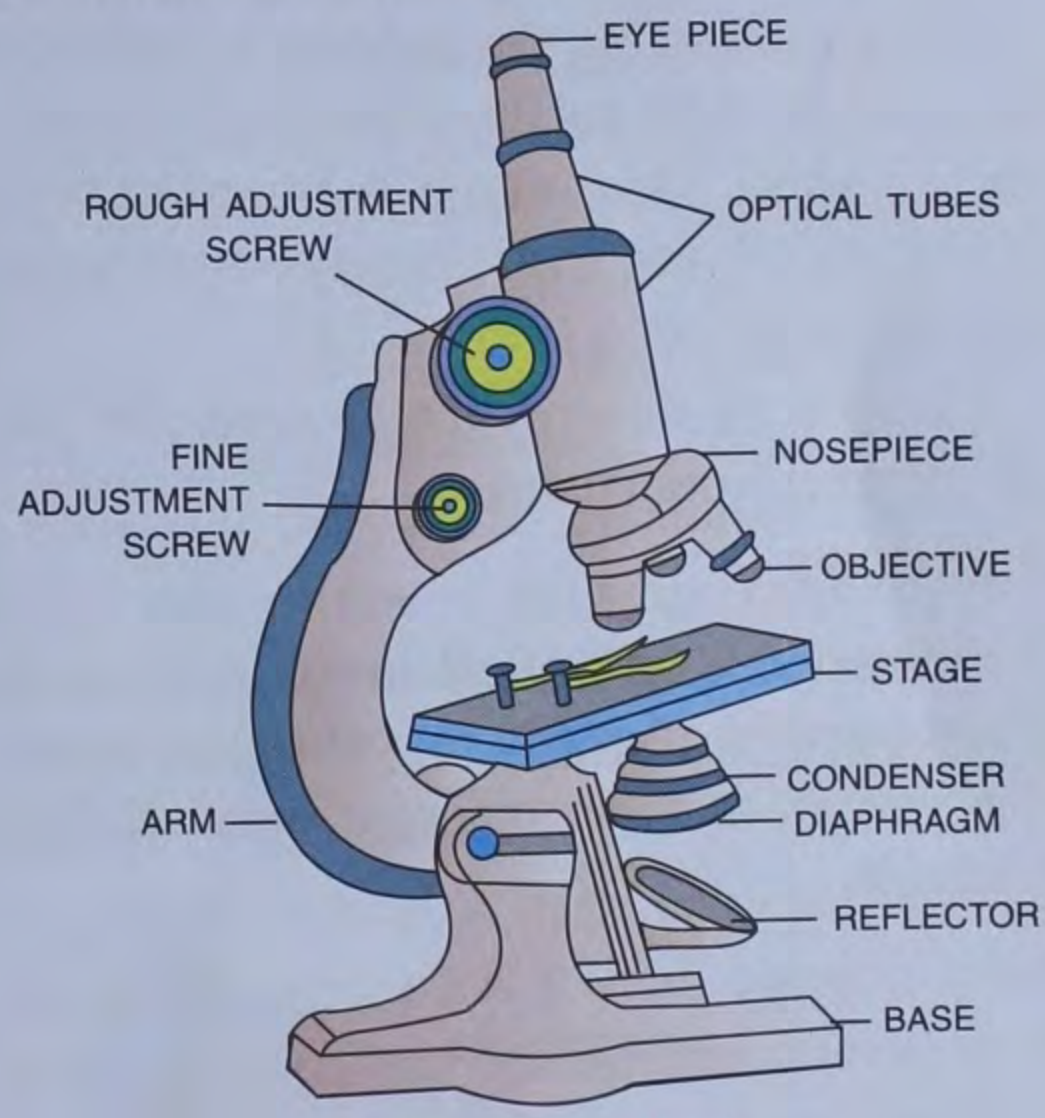


Fig. 4.4 A compound microscope

Principle : When an object is placed at a distance intermediate between F and 2F of a convex lens, a real, inverted and enlarged image is obtained. If this image falls within the focal

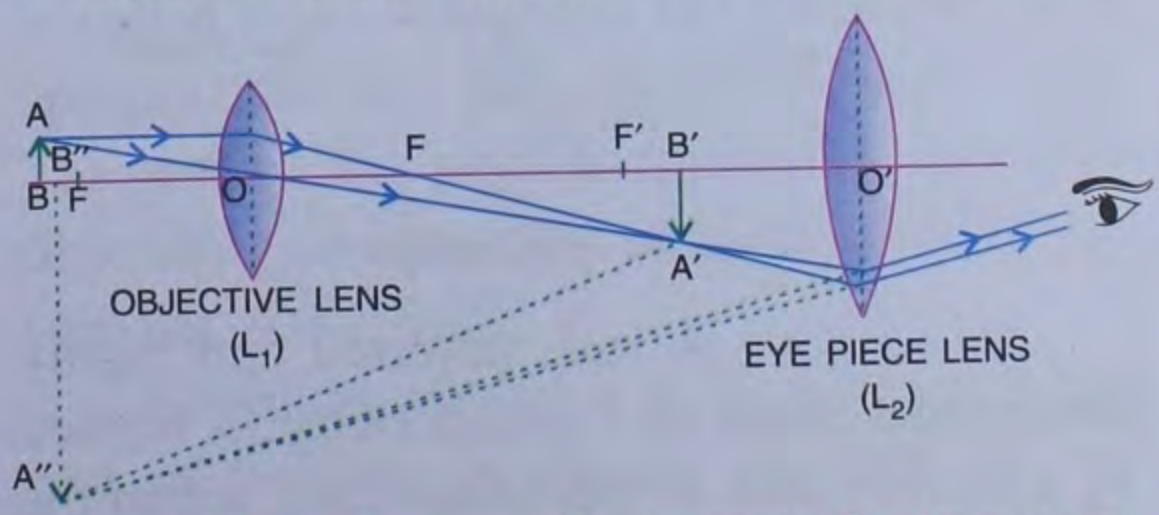


Fig. 4.5 Ray diagram of a compound microscope

length of another convex lens, an enlarged, inverted and virtual image of it is obtained.

Working : The object AB is placed between F and 2F of the objective lens L_1. A real, inverted and enlarged image A′B′ is formed by the lens L_1. This image A′B′ acts as the object for the second convex lens L_2 (eye piece lens). The image A′B′ lies between the optical centre O′ and the focus F′ of lens L_2 which acts as a simple microscope (magnifying lens). Thus, on looking through lens L_2 from the other side, the final enlarged and virtual image A″B″ is seen. This image is inverted with respect to the object, and is highly magnified as compared to the object (Fig. 4.5).

Compound microscope is used for the study of micro-organisms.

TELESCOPE

Telescope is an optical instrument which forms the image of a very far off object nearer to the eye so that the object is seen distinct and bigger.

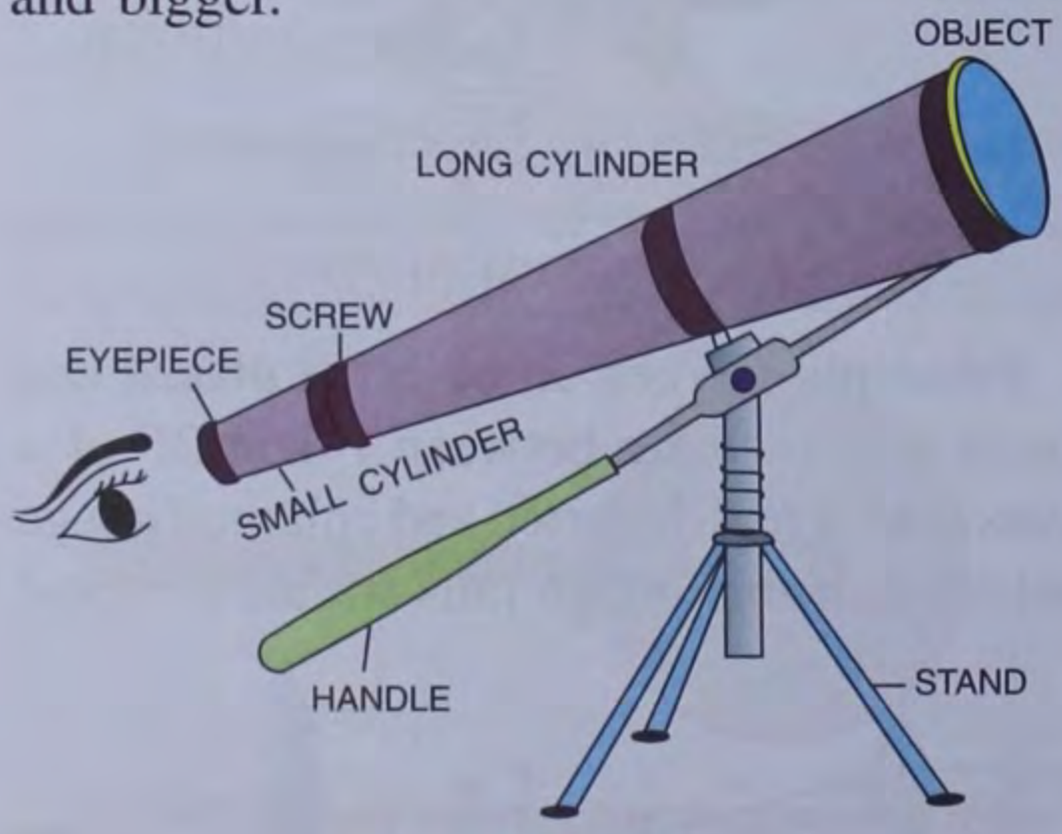


Fig. 4.6 A telescope

Principle : A real, inverted and highly diminished image of a distant object is formed by a convex lens. If this image falls within the focal length of another convex lens, an enlarged, erect and virtual image of this image is formed.

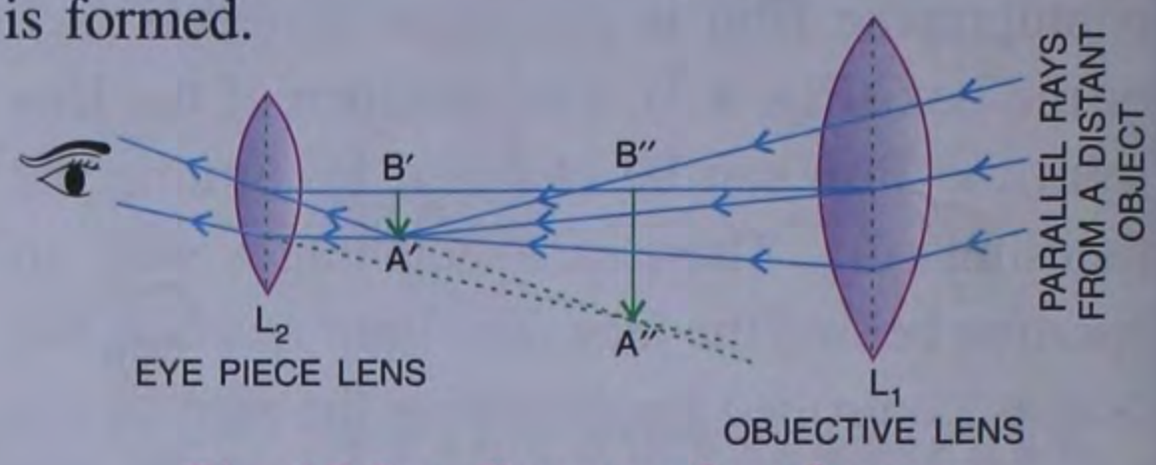


Fig. 4.7 Ray diagram of a telescope

Working : When the parallel rays from a distant object are incident on the convex lens L_1 (objective), a real, inverted and highly diminished image A′B′ is formed at the focus of lens L_1. This image acts as an object for lens L_2 (eye piece). As this image A′B′ is formed between the focus and the optical centre of convex lens L_2, a virtual, enlarged and inverted image A″B″ (inverted with respect to the original object) is formed. Thus, the lens L_2 acts as a simple microscope in this case. The final image is smaller than the object itself, but it is much larger than the object as seen by the naked eye.

The telescope is used to observe celestial objects like the moon, planets, stars, *etc.*

HUMAN EYE — A REMARKABLE OPTICAL INSTRUMENT

The human eye is like a camera having a lens on one side and a sensitive screen called the **retina** on the other. The essential parts of a human eye are shown in Fig. 4.8.

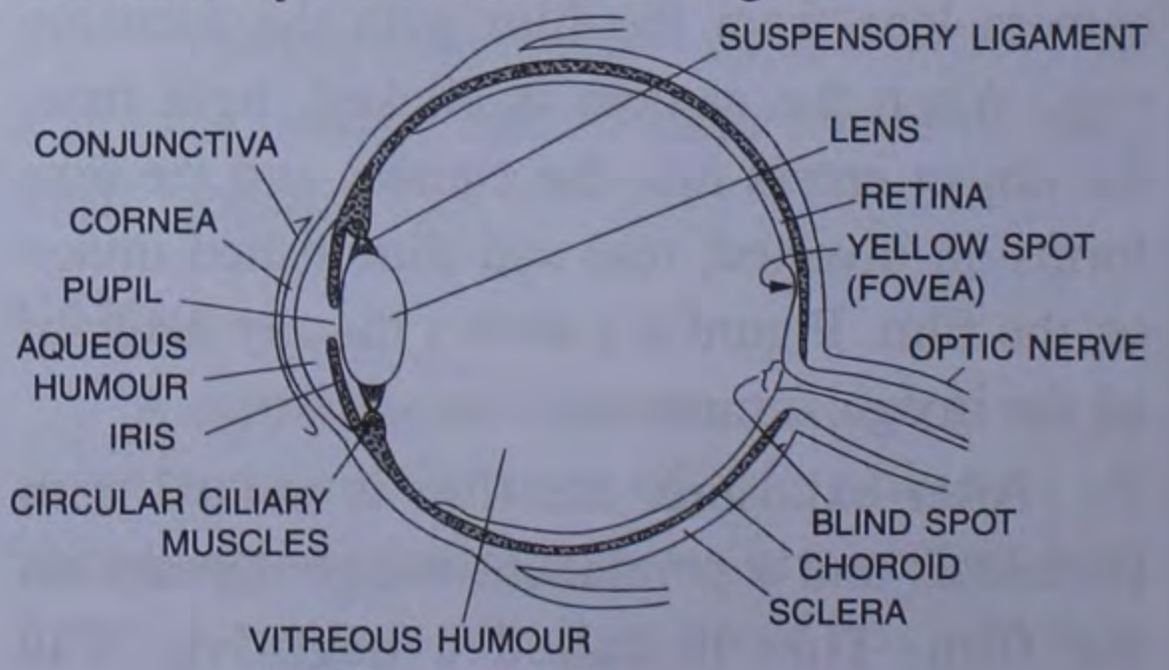


Fig. 4.8 The human eye

ACTIVITY 1

Take a torch and stand in front of a mirror. In the mirror see the image of your eye. You will find the pupil of both eyes to be of the same size. Now keep looking at the mirror, throw torch light to one of your eye. What change do you observe in the image of that eye? You will observe that the size of the pupil in the image of that eye becomes smaller.

Hence we conclude that the pupil becomes smaller in size when the light falling on our eyes is brighter.

Human eye : It is one of the most remarkable optical instruments. Human eye has various parts and each part has an important function. Fig. 4.8 shows various parts of human eye. Fig. 4.9 shows the front view of human eye and also how the size of pupil changes with the light available to the eye.

(a) Size of pupil is smaller when person is outside a room (Brighter region)

(b) Size of pupil is bigger when person is inside a room (Darker region)

Fig. 4.9 Comparison of size of the pupil when light recieved by the eye is (a) Brighter (b) Dimmer

Following are the important eye parts and function of each part :

Sclerotic : It is the outermost covering of the human eye from inside. It protects the eye from internal damage. It is opaque.

Cornea : It is the outermost covering of the human eye from outside. It protects the eye from external damage. It is colourless so that light may enter through it.

Choroid : It is the layer which is just inside the sclerotic. It is generally dark brown in colour. It provides nutrition to the eye and also helps to check internal reflections if any, due to its dark colour.

Retina : It is the most sensitive part of our eye in which the image is formed. The image formed here is real diminished and inverted.

There is a slight elevation on the retina at its central region. It is known as the **Yellow spot**. To get maximum clarity, the image has to be formed on the yellow spot.

There is a slight depression at the centre of yellow spot which is known as **Fovea centralle**. For very minute observation, image has to be formed on the fovea centralle. *For example* when we are threading a needle, the image must form on the fovea centralle; retina is made up of two types of cells — cylindrical and conical cells. One group of cells are responsible for distinguishing black and white colours. The other group is responsible for distinguishing the rest of the colours.

Iris : Iris is a dark coloured muscular diaphragm which has a small circular opening in its middle. This regulates the amount of light entering the eye by adjusting the size of the pupil. It provides colour to the eye. Generally it is brown, blue or even light green. This can expand or contract.

Pupil : The central circular aperture of iris is called pupil. The pupil is transparent but it appears black due to the black colour of retina. The size of the pupil increases or decreases depending on the light available to the eye (see Fig. 4.9(a)&(b)).

Crystalline lens : It is the most important part of the eye. It refracts the light for the formation of image on the retina. Eye lens is a

convex lens made of a transparent jelly-like material.

Suspensory ligaments : To hold the **crystalline lens** at its proper place, suspensory ligaments are attached.

Ciliary muscles : Alongwith the suspensory ligaments ciliary muscles are also attached to the lens. It helps to change the size of the lens and thereby its focal length. Depending on the distance between the **eye** and the object to be seen, the focal length of the lens automatically changes in order to obtain the image always on the retina.

Aqueous humour : In between cornea and lens there is a fluid which helps the eye meet for its proper function. This is called aqueous humour.

Viterous humour : Between lens and retina there is a fluid which keeps the eye wet. This is called vitreous humour.

POWER OF ACCOMMODATION

The human eye is a wonderful instrument provided by nature. The eye in its normal condition is able to see objects from a nearby distance upto objects at a far off distance. This phenomenon is due to the ability of the ciliary muscles to change the focal length of the eye lens. This change in focal length brings the images of nearby or distant objects on the retina.

The ability of the eye-lens to change the power of lens to accommodate the near and far off distances on the retina is called the power of accommodation of eye.

The power of accommodation takes place by the contraction and relaxation of the ciliary muscles. When a distant object is to be seen, the curvature of the lens decreases, thereby increasing its focal length and in the case of nearby objects, it is vice-versa. Thus, by changing the curvature of the lens and its focal length, the image of nearby or distant objects can be brought in focus on the retina.

But there is a limit to the power of accommodation of the eye. It may accommodate to see distant objects clearly, but if the object is too close to the eye, it is not clearly visible.

If an object is at a distance less than 25 cm from the eye, it cannot be seen clearly without a strain on the eye. This distance of 25 cm is the least distance of distinct vision.

DEFECTS OF VISION AND THEIR REMEDY

When you have a healthy eye, the muscles surrounding the lens automatically adjust the curvature of the lens which enables it to form a sharp image of the object on the retina, whether the object is near or far away from the eye. Thus, the object can be seen clearly.

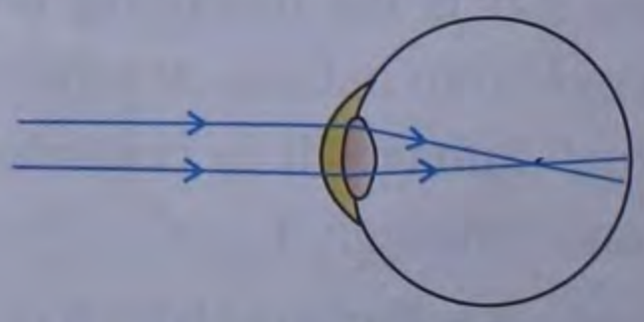
Sometimes, the curvature of the lens cannot be adjusted to the required value for formation of sharp images due to some reason. This is called the **defect of vision**.

There are *two* types of defects in the human eye :

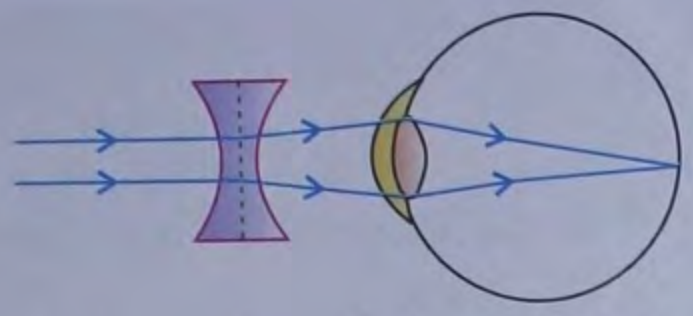
(1) Myopia or short-sightedness

(2) Hypermetropia or long-sightedness

Short-sightedness or myopia



(a) Short-sightedness



(b) Correction of short-sightedness

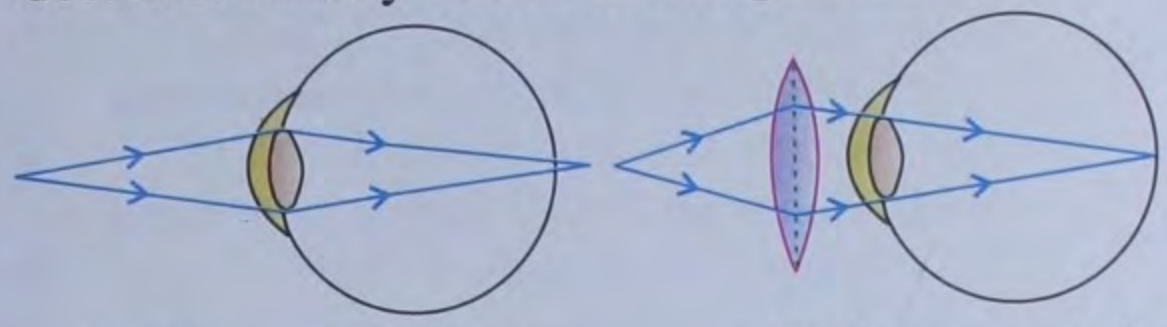
Fig. 4.10

A person who suffers from myopia can only see the nearby objects clearly, but he cannot see the distant objects clearly. This defect arises due to the eye-ball becoming too long or if the distance of retina from the eye lens has increased. This defect is usually found in young people.

This defect can be rectified by using spectacles with concave lens of appropriate focal length.

Long-sightedness or hypermetropia

A person who suffers from hypermetropia can clearly see the distant objects but he cannot see the nearby objects clearly. In this case, the image of the object falls behind the retina. This defect is mostly found in old persons.



(a) Long-sightedness *(b) Correction of long-sightedness*

Fig. 4.11

This defect can be corrected by using spectacles with convex lens of appropriate focal length.

RECAPITULATION

- Simple microscope is a convex lens used to see small objects as it gives an enlarged and erect image. For this reason, it is also known as a magnifying glass.
- While using a simple microscope, the object is kept between focus and optical centre of the lens used.
- In a camera, the image formed on the film is real, inverted and diminished.
- In order to get a sharp image of an object, the distance between the lens and the film of the camera is adjusted (increased or decreased).
- Microscope is an optical instrument used to see very minute objects distinctly.
- Telescope is used to get the image of large distant objects at smaller distances.
- In a telescope and in a microscope, the objective is the lens closer to the object. Both the optical devices make use of two convex lenses.
- Functions of an eye and a camera are similar. Both form real, inverted and diminished images. The image formed by an eye is temporary whereas the image formed by a camera is permanent.
- A healthy normal eye can see the object clearly at distances greater than 25 cm. This distance of 25 cm is called the least distance of distinct vision.
- An eye has the ability to focus the image of objects at different distances. This is called the power of accommodation of the eye.
- The two common defects of a human eye are : short-sightedness (myopia) and long-sightedness (hypermetropia).
- A person suffering from myopia can clearly see the nearby objects, but cannot see the distant objects clearly. Whereas a person suffering from hypermetropia can clearly see the distant objects, but cannot see the nearby objects clearly.
- The defect of myopia is corrected using a concave lens and the defect of hypermetropia is corrected using a convex lens.

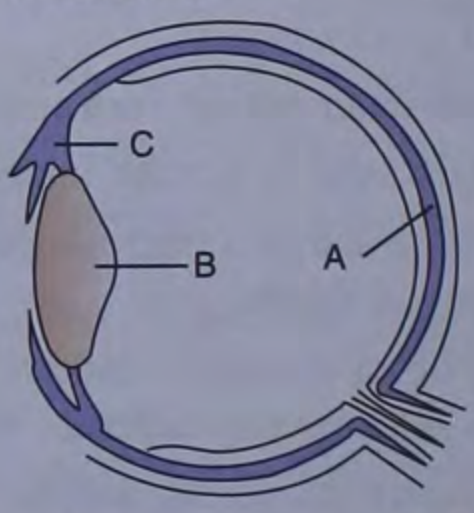
TEST YOURSELF

A. Short Answer Questions

1. State, *true* or *false* :
   (a) A simple microscope is sometimes known as a reading glass.
   (b) The image formed by a magnifying glass is real and enlarged.
   (c) While using a simple microscope, the object is kept between F and O.
   (d) Compound microscope is used to see the objects at large distances.
   (e) Image formed in a compound microscope is virtual and enlarged.
   (f) To observe celestial objects like moon, stars, *etc*., we use a telescope.
   (g) A telescope gives an inverted and diminished image of distant objects.
   (h) To get sharp images of objects at different distances, the focal length of the eye-lens changes on its own.
   (i) To get sharp images of objects of different distances, the distance between the lens and the film of a camera is adjusted.
   (j) Short-sightedness means, that the eye cannot see the nearby objects clearly and long-sightedness means, that the eye cannot see the distant objects clearly.
2. Fill in the blanks :
   (a) The image formed by a magnifying glass is .....
   (b) The image formed by a camera is .....
   (c) The image formed by an eye is .....
   (d) In a simple microscope, object is placed between ..... and .....
   (e) The image formed in an eye is ....., whereas image formed in a camera is .....
   (f) Compound microscope is used to see .....
   (g) A telescope is used to see .....
   (h) The least distance of distinct vision is .....
   (i) ..... lens is used to correct myopia and ..... lens is used to correct hypermetropia.
   (j) The lens used in a camera is .....
   (k) Both the lenses used in a telescope are .....
3. Answer the following questions :
   (a) What is the power of accommodation of an eye?
   (b) What are the common defects of vision of a human eye ? How can these defects be removed by spectacles ?
   (c) Write one similarity and one dissimilarity between an eye and a camera.
   (d) What is meant by least distance of distinct vision ? What is its value ?
   (e) What controls the time of exposure ?
   (i) In eye (ii) In camera

B. Long Answer Questions

1. In a camera, what is the function of each of the following ?
   (a) Focusing ring (b) Film (c) Lens
2. Write short notes on :
   (a) Simple microscope (b) Telescope
   (c) Camera (d) Human-eye
   (e) Compound microscope
3. Name the parts marked A, B and C in the following diagram. What is the function of each part marked.



4. Write the characteristics of the final image formed in a :
   (a) Magnifying glass (b) Telescope
   (c) Compound microscope
5. Write the function of (a) iris and (b) ciliary muscles in the eye.
6. Compare the focusing in a camera with the focusing in a human eye.
7. Write short notes on the two defects of the human eye.