toward your face, with your right eye still fixed upon the circle, you'll reach a position about 20 to 25 cm from your eye where the X disappears. To establish the blind spot in your left eye, close your right eye and similarly look at the X with your left eye so that the circle disappears. With both eyes opened, you'll find no position where either the X or the circle disappears because one eye "fills in" the part of the object to which the other eye is blind. It's nice to have two eyes.

Figure 30.19 ▲
For the blind spot experiment.

In both the camera and the eye, the image is upside down, and this is compensated for in both cases. You simply turn the camera film around to look at it. Your brain has learned to turn around images it receives from your retina!

A principal difference between a camera and the human eye has to do with focusing. In a camera, focusing is accomplished by altering the distance between the lens and the film. In the human eye, most of the focusing is done by the cornea, the transparent membrane at the outside of the eye. Adjustments in focusing of the image on the retina are made by changing the thickness and shape of the lens to regulate its focal length. This is called *accommodation* and is brought about by the action of the *ciliary muscle,* which surrounds the lens.

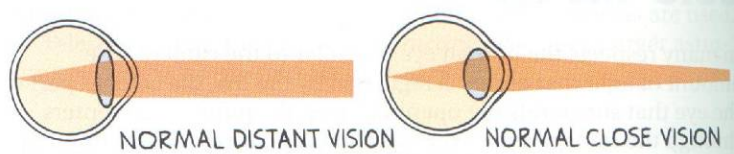
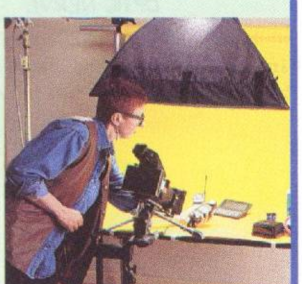


Figure 30.20 ▲
The shape of the lens changes to focus light on the retina.

PHYSICS ON THE JOB

Photographer

Photography blends art with physics. A photographer's ideas are based on artistry, but their execution relies on a savvy use of physics technology. A photographer knows that camera film seldom is able to record what our eyes see. Our eyes can discern detail simultaneously both in dark shadows and in light that is millions of times brighter; camera film can't. Hence, the photographer is concerned with and experiments with contrast. The photographer who has knowledge of the physics of light and optics is better able to understand and keep up with the changes provided by an expanding technology—newer films and newer imaging techniques.



30.7 Some Defects in Vision

If you have what is called normal vision, your eye can accommodate to clearly see objects from infinity (the *far point*) down to 25 cm (the *near point,* which normally recedes for all people with advancing age).

The eyes of a **farsighted** person form images behind the retina (Figure 30.21). The eyeball is too short. Farsighted people have to hold things more than 25 cm away to be able to focus them. The remedy is to increase the converging effect of the eye. This is done by wearing eyeglasses or contact lenses with converging lenses. Converging lenses will converge the rays that enter the eye sufficiently to focus them on the retina instead of behind the retina.

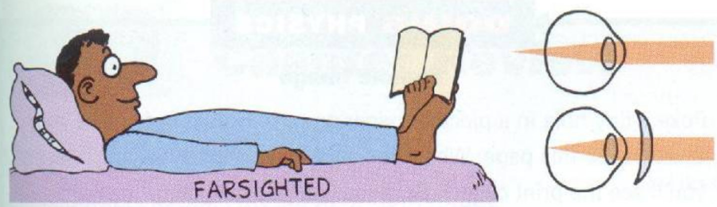


Figure 30.21 ▲
The eyeball of the farsighted eye is too short. A converging lens moves the image closer and onto the retina.

A **nearsighted** person can see nearby objects clearly, but does not see distant objects clearly because they are focused too near the lens, in front of the retina (Figure 30.22). The eyeball is too long. A remedy is to wear corrective lenses that diverge the rays from distant objects so that they focus on the retina instead of in front of it.

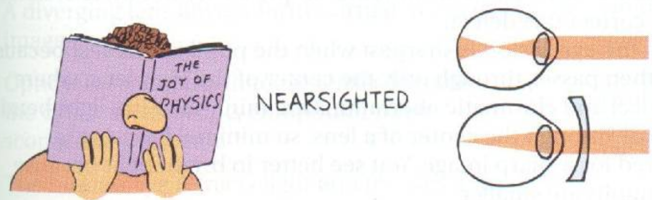


Figure 30.22 ▲
The eyeball of the nearsighted eye is too long. A diverging lens moves the image farther away and onto the retina.

Astigmatism of the eye is a defect that results when the cornea is curved more in one direction than the other, somewhat like the side of a barrel. Because of this defect, the eye does not form sharp images. The remedy is cylindrical corrective lenses that have more curvature in one direction than in another.

30.8 Some Defects of Lenses

No lens gives a perfect image. The distortions in an image are called **aberrations.** By combining lenses in certain ways, aberrations can be minimized. For this reason, most optical instruments use compound lenses, each consisting of several simple lenses, instead of single lenses.

Spherical aberration results when light passes through the edges of a lens and focuses at a slightly different place from light passing through the center of the lens (Figure 30.23). This can be remedied by covering the edges of a lens, as with a diaphragm in a camera. Spherical aberration is corrected in good optical instruments by a combination of lenses.

Figure 30.23 ▲
Spherical aberration.