YOUR EYES

Chapter 1

THE HUMAN EYE

THE human eye is built very much like a camera, actually, a TV camera. It is hooked up to the brain by a sort of coaxial cable, the ***optic nerve.*** The image received by the eye is relayed to the brain by an electronic impulse sent down the optic nerve. Several relay cables in the brain then transfer the image through the brain to the ***occipital lobes*** at the back of the brain, in which the picture is formed.

Three basic coats comprise the wall of the eye. The outer coat, the ***sclera,*** is of tough, firm fibrous connective tissue that gives durability and resistance to the wall of the eye. Just inside the sclera is a delicate vascular coat, the ***choroid,*** composed of many tiny blood vessels. The choroid's function is to nourish the inner, photosensitive coat of the eye, the ***retina.*** After an image is focused on the retina, which is very much like the film in a camera, it transforms the light impulses coming to it from the outside world into an electrical impulse that is transmitted by the optic nerve to the ***optic pathways*** of the brain.

The center of the eye is filled with a clear, jelly-like substance known as the ***vitreous humor.*** The front portion of the eye is covered with a perfectly clear watchglass structure, the ***cornea.*** The cornea serves as the window of the eye.

Just behind the cornea is a compartment, known as the ***anterior chamber,*** which is filled with a clear fluid, the ***aqueous humor.*** The ***iris,*** which gives the eye its color, forms the back portion of the anterior chamber. Basically, the iris serves as the diaphragm of the ocular ***camera.***

The hole in the center of the iris is the ***pupil.*** Under bright light, the pupil becomes small so that less light is admitted. In the dark, the pupil dilates widely, allowing the most possible light to reach the inside of the eye. Just behind the pupil is the ***lens*** of the eye. It is a clear tissue suspended from the rim of the eye by many little "guy wires" known as the ***zonules of Zinn.***

The zonules are attached to a little bulge in the choroid layer called the ***ciliary body.*** The ciliary body has some muscular fibers, the ***ciliary***

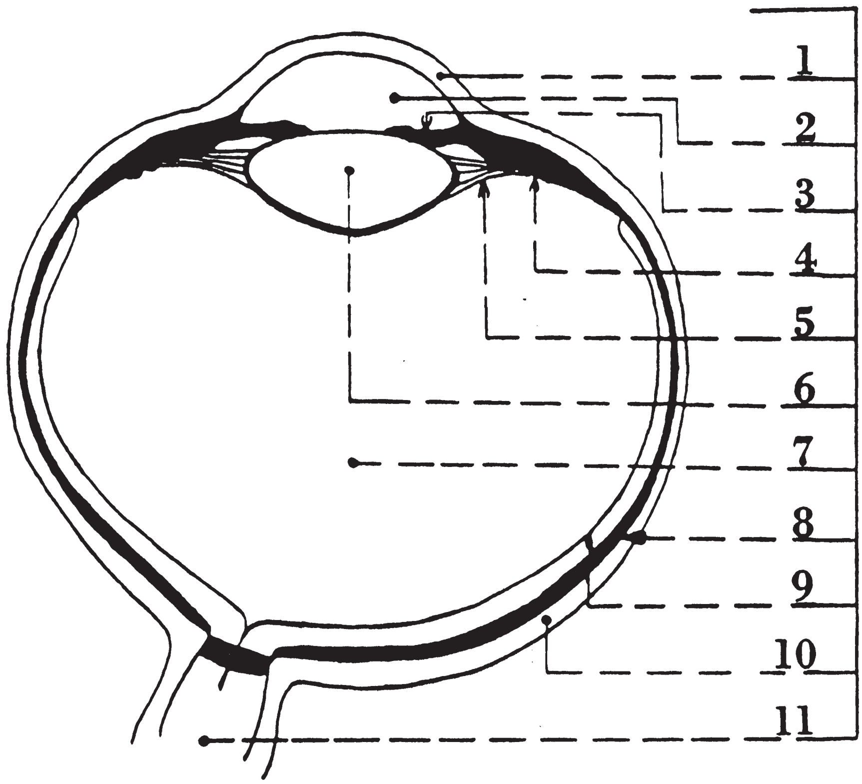

Figure 1. Simplified cross section of the human eye: 1. cornea, 2. anterior chamber, 3. iris, 4. ciliary muscle, 5. zonule fibers, 6. lens, 7. vitreous, 8. choroid, 9. retina, 10. sclera, 11. optic nerve.

muscle, which can change the tension on zonular fibers and cause the lens to become flatter or rounder. When the ciliary muscle is contracted, the lens, because it is elastic, becomes more spherical in shape. The ability to change the lens from more flat to more spherical is called the process of ***accommodation.*** This enables the eye to focus clearly on objects at greater or lesser distances.

The aqueous humor is secreted by the ciliary body into the posterior chamber, which is located between the iris, which makes up its front surface, and the zonules and the lens, which make up its posterior surface. The aqueous humor circulates from the posterior chamber through the pupillary opening into the anterior chamber. It then flows out of the eye through the trabecular meshwork–at the angle of the anterior chamber–into the Canal of Schlemm and then on out through the aqueous veins into the veinous circulation on the surface of the eye. Except for

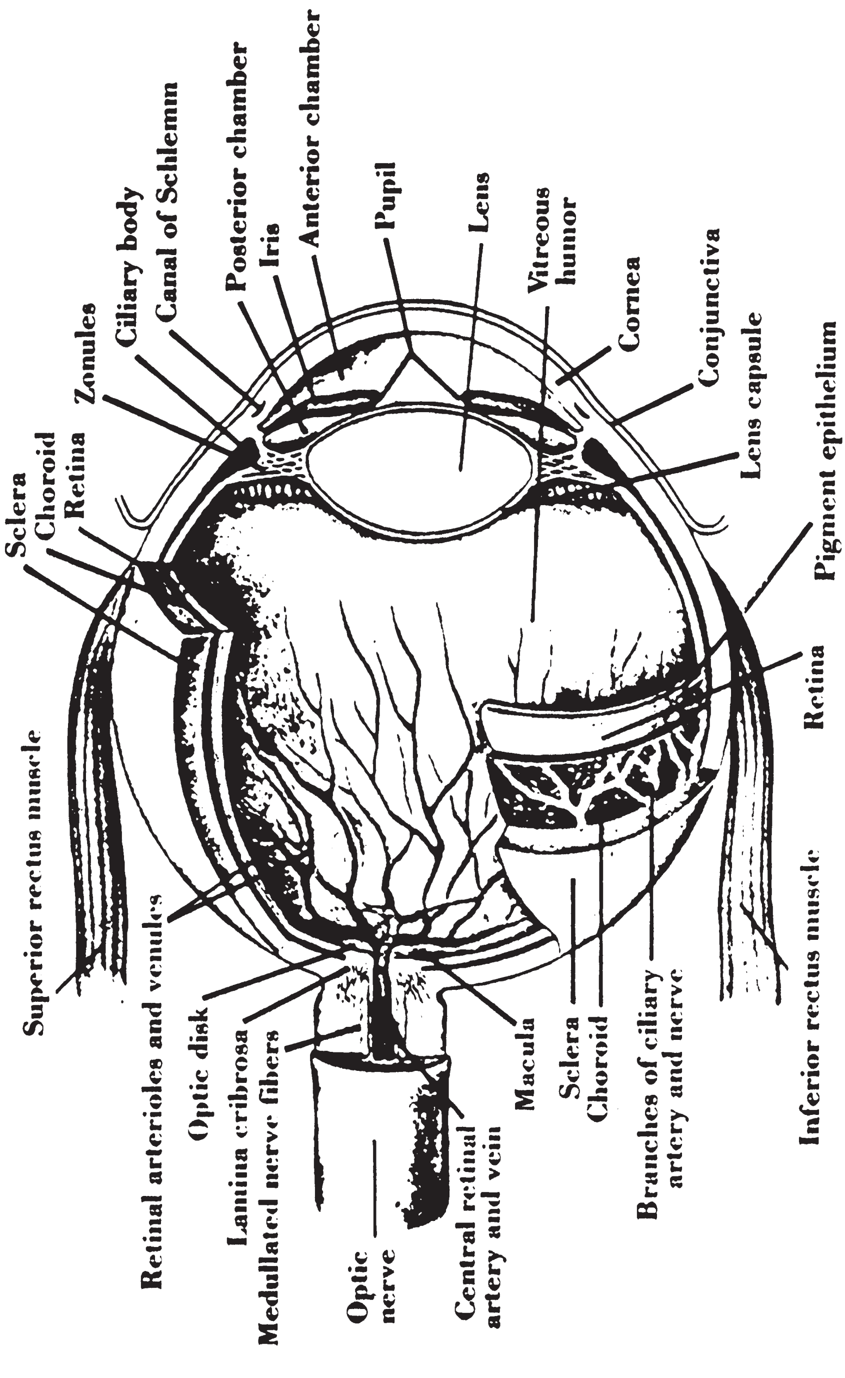

Figure 2. Internal structures of the human eye.

the little bulge in the front caused by the cornea, the eyeball itself is an almost perfect sphere. It is embedded in fat that is surrounded by the bony ***orbit*** formed by several bones of the skull. The fat cushions the eye. The hard bones of the orbit protect it from injury.

Six ***extraocular muscles*** move the eyeball in its compartment. They are the lateral rectus, medial rectus, superior rectus, inferior rectus, superior oblique, and inferior oblique. These extraocular muscles are responsible for the motility of the eye. All of them are attached at one end to a point on the bony orbit. The muscles' other end is attached to the sclera, the outer coat of the eye.

The optic nerve leaves the back of the eye and runs through a hole in the skull, the ***optic foramen,*** into the brain cavity. At the ***chiasm*** (Greek for X), some fibers from the optic nerve cross to the other side of the brain and some fibers continue on the same side of the brain. After making an additional connection in the ***lateral geniculate body*** of the brain, the fibers run back along the optic pathway to the occipital lobe of the brain.

The connections are such that the left occipital lobe receives all the visual impulses coming from the left side of each eye, and the right occipital lobe receives all the visual impulses coming from the right side of each eye. As a result, if the occipital lobe or the area just in front of the occipital lobe on the right side of the brain is injured, that portion of the vision routed from the right half of each eye will disappear. This is called ***homonymous hemianopsia.*** The right side of each eye "sees" things to the left, and vice versa. If the right side of the brain is injured, left homonymous hemianopsia will result and the person will be unable to see to the left.

The upper and lower ***eyelids*** protect the front of the eye. They have an outer layer of skin, some deeper muscle fibers that enable them to close and open, and a deep connective-tissue plate called the ***tarsus.*** The many ***lashes*** along the margins of the eyelids provide additional protection to the eye.

Lining the inside of both eyelids is a thin, essentially clear, vascular membrane, the ***conjunctiva.*** It reflects back over the front surface of the sclera and continues down to blend with the ***epithelium*** of the cornea.

Another function of the eyelids is to push the tear film across the cornea with each blink. The ***tears*** themselves are secreted by the ***lacrimal gland,*** which is located just behind the lateral portion of the upper eyelid. The tear film not only helps protect the eye but also assists in keeping the cornea transparent.

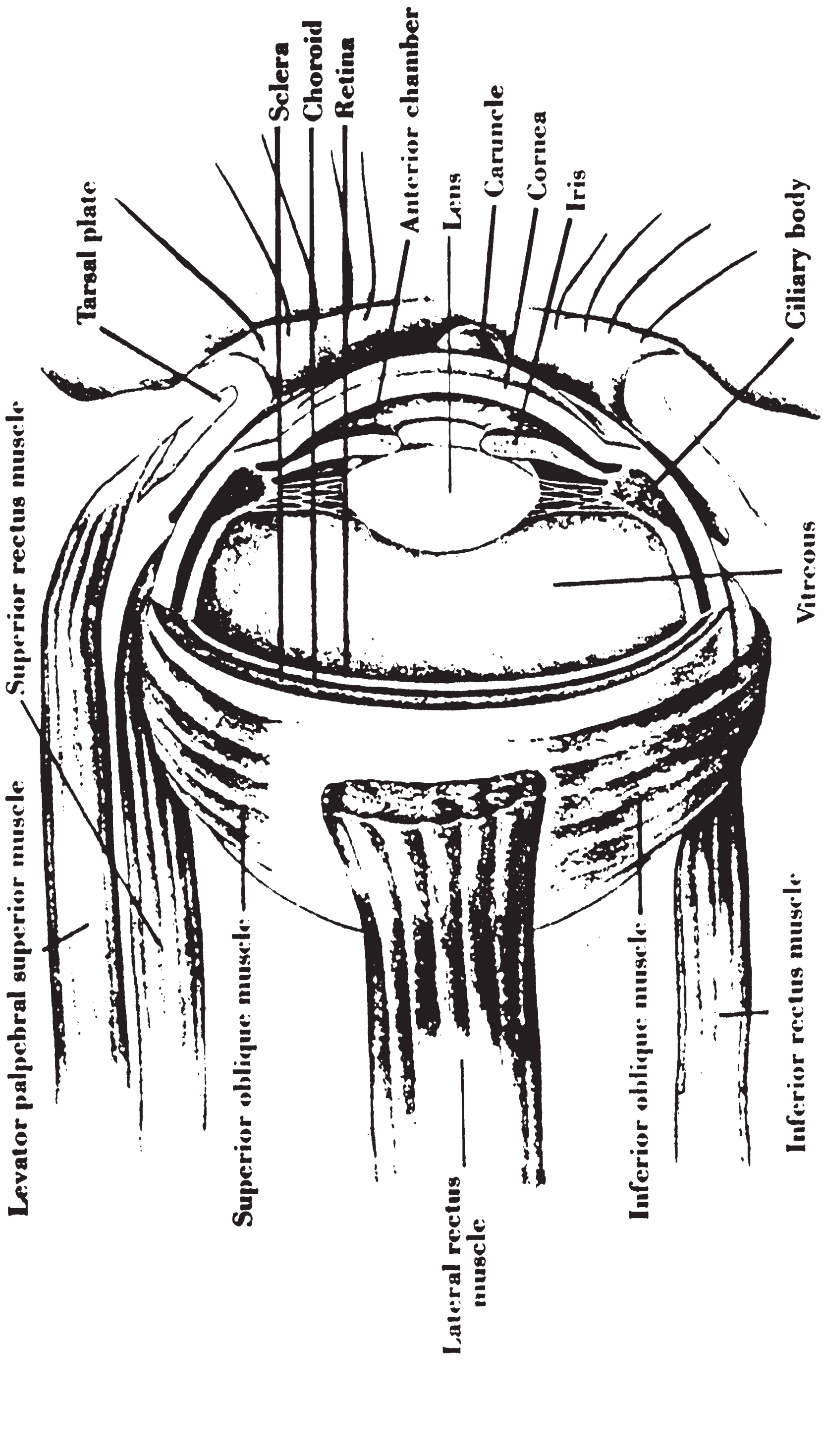

Figure 3. Side view cross section of the right eye.

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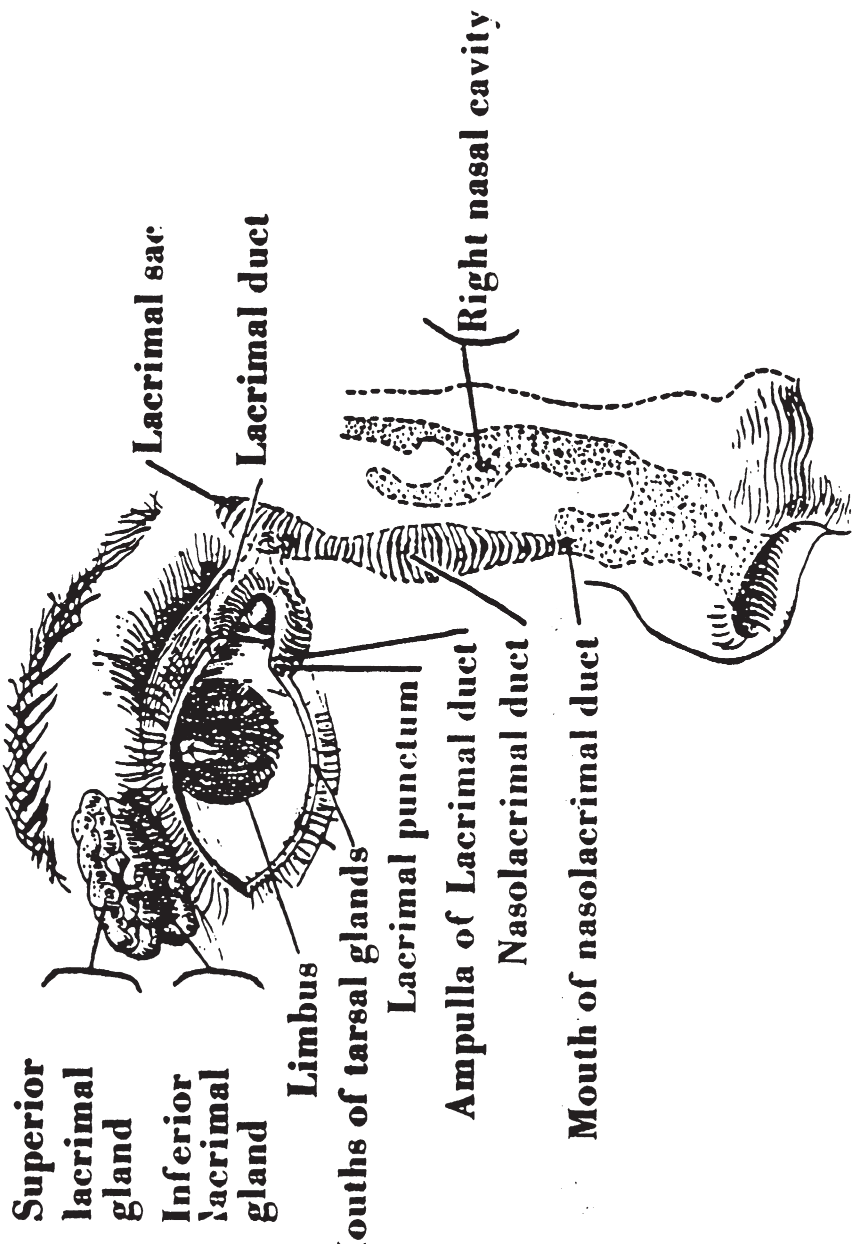

Figure 4. Lacrimal apparatus of the eye.

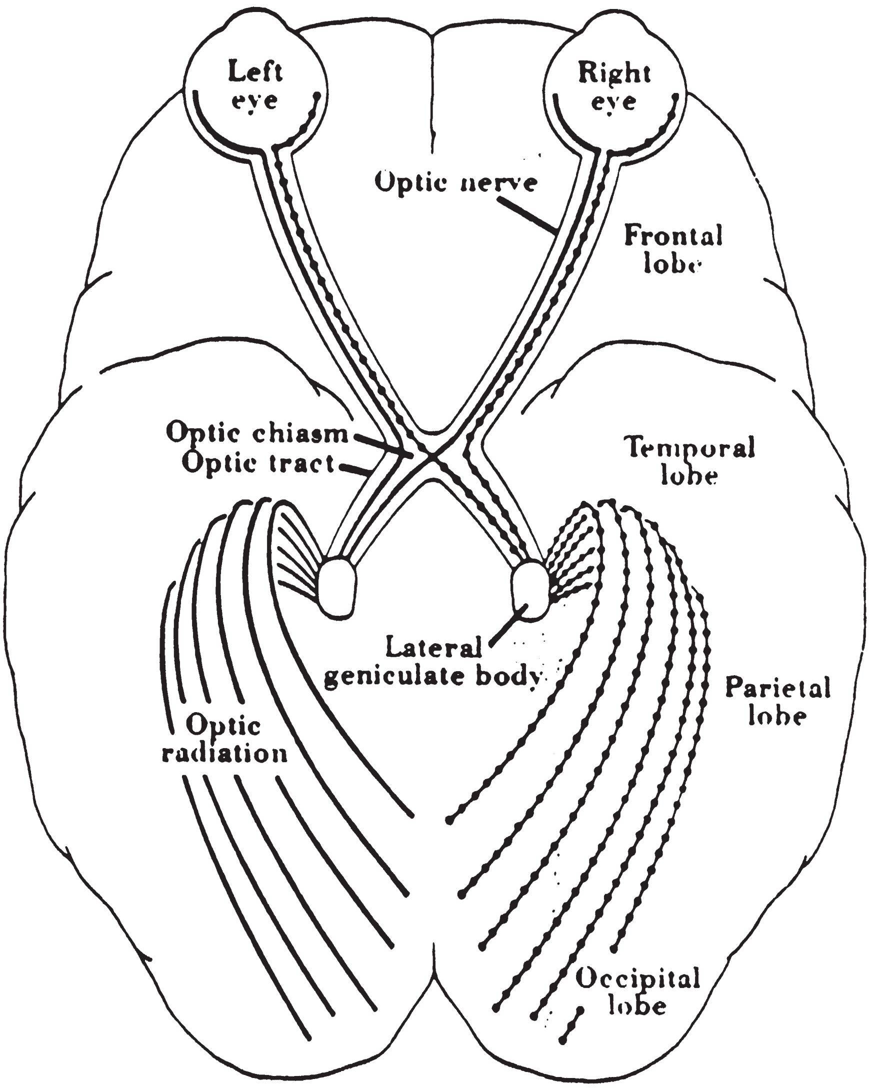

Figure 5. Optic pathways in the brain.

The tears contain an enzyme called ***lysozyme,*** which inhibits the growth of bacteria. Irrigation of the surface of the eye by the tears and their drainage down the ***lacrimal canal*** to the ***lacrimal sac*** provides further protection from infection.

The lacrimal sac, located just below the medial junction of the upper and lower eyelids, drains into the nose. When one cries, or peels an onion, the nose begins to drip. One can feel the tears run from the eyes to the nose.

If any part of the drainage system is overwhelmed–as in moments of crying or excessive tearing–the tears spill over onto the cheeks. If the tear drainage system becomes blocked by a foreign body or disease, infection is likely to occur in the stagnant pool of tears (just as mosquitoes breed in stagnant water). It will be necessary to reopen the lacrimal apparatus.

Thus the human eye, in spite of the fact that it performs a terribly intricate and complex function, is built very simply. It is merely a spherical camera attached to the brain via a relay cable. The eye is obviously the invention of a creative genius.

QUESTIONS

1. What are the three coats of the wall of the eye?
2. What is the anterior chamber?
3. What substance comprises most of the volume of the eye?
4. Describe the cornea.
5. What is the pupil and what is its function?
6. What muscle is used for accommodation?
7. List the six extraocular muscles.
8. What is the chiasm?
9. What are the functions of the eyelids?
10. Describe the conjunctiva.
11. What purpose do the tears serve?
12. What is the function of the occipital lobes of the brain?

Chapter 2

LIGHT AND VISION

LIGHT is energy emitted in pulses or waves from a natural (sun, stars) or artificial (candles, electric light, laser) source. Light travels from the sun through the vacuum of space at 186,282 miles per second. Light will also pass through transparent objects, for example, the cornea and lens of the eye. The phenomenon of vision requires that light stimulate the retina of the eye, very much as light activates a chemical reaction in a photographic film.

The rays of light emitted from a distant source, such as the sun, travel in all directions in a formation that is essentially parallel. To provide a sharp, well-defined image in the eye, these rays of light must be bent and focused on the retina. The curved cornea, along with the lens, carries out this function.

Materials that permit the passage of light–such as glass or plastic–can bend the rays of light. The denser the transparent material in comparison with the surrounding air, the greater its ability to bend the rays of light, because light travels more slowly through dense materials than through air. Light slows down when it hits the surface of the transparent material. It regains its speed after it passes into less dense air or water.

To illustrate, let us imagine a regiment of soldiers parading across a grassy field. The column reaches a large, wide, sticky mud puddle. The puddle lies at an angle to their direction of march. As the first rank of soldiers wade into the puddle, the oozy mud sticks to their feet. They continue marching, but more slowly than the soldiers behind. As a result, the troop formation will bend in toward the mud puddle. As more and more soldiers wade into the mud puddle, the entire troop slows down (a typical traffic jam). When the soldiers in the first ranks come to dry grass, they again march at normal speed away from the mud puddle through which their comrades are still struggling. Now the column of troops bends back in the original direction.

The same thing happens when rays of light traveling through air enter a piece of glass at an angle. The rays bend inward as they are

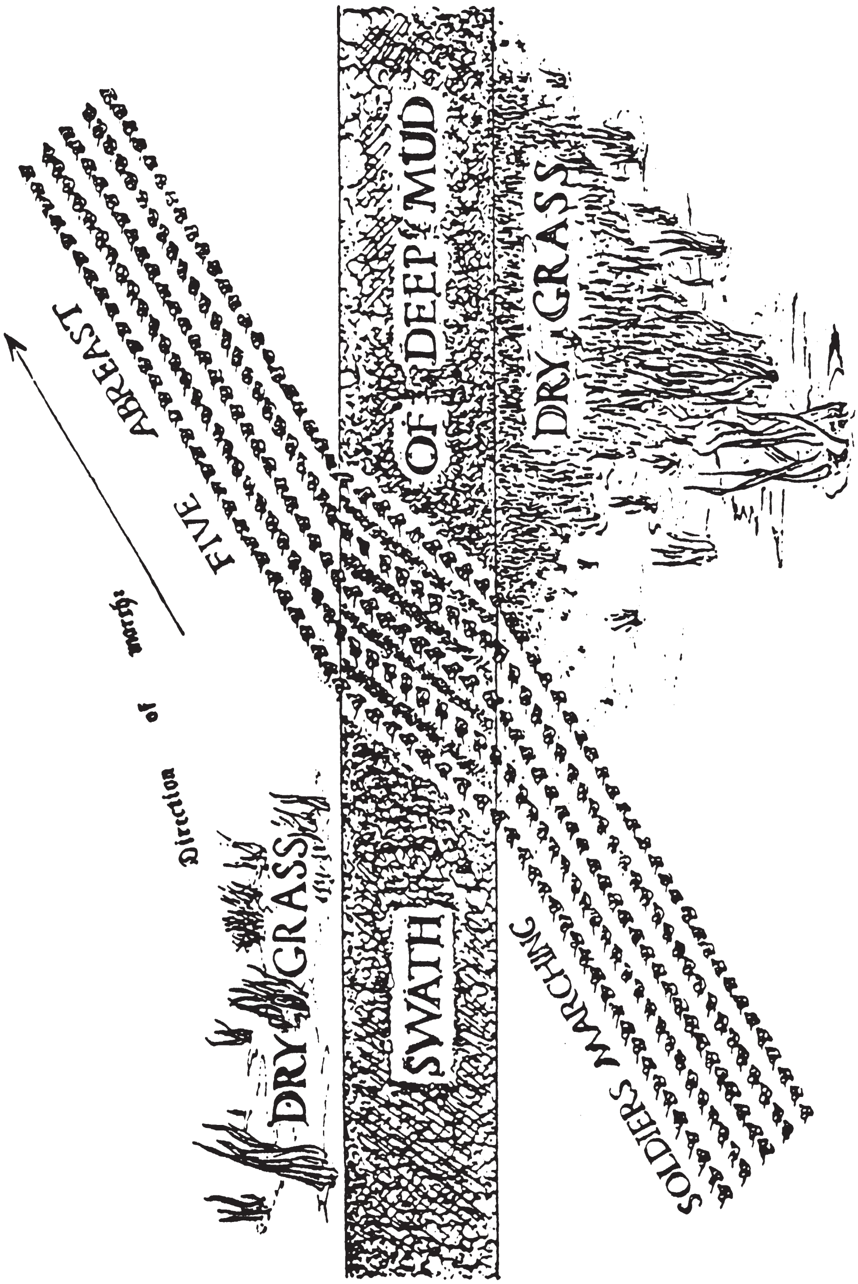

Figure 6. Illustration of analogy between column of soldiers marching through a swath of mud and the way light bends going through a glass.

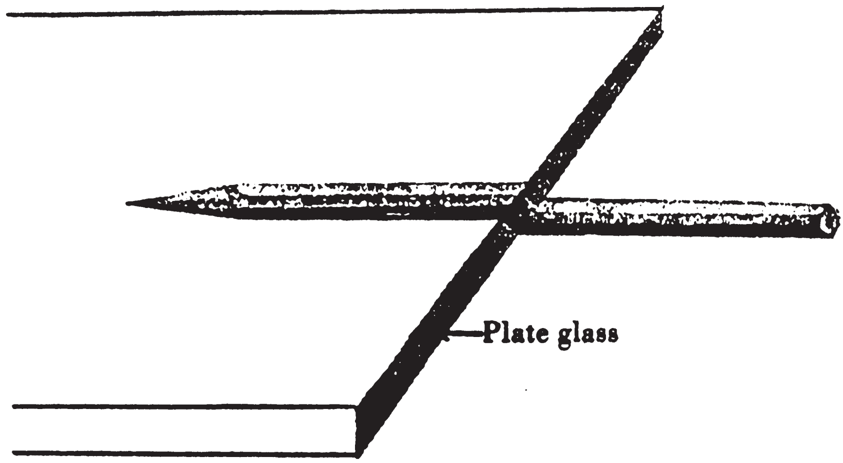

Figure 7. A pencil held behind plate glass shows refraction of light.

slowed down. When they exit, they bend outward. A prism of glass affords the best example of this effect. Light rays striking a triangular-shaped piece of glass, which is called a ***prism,*** first bend into the glass, then as they leave the prism they bend away from its surface. The phenomenon suggests to the person who is looking at an object through a prism that the image is moving toward the point of the prism.

Putting two prisms together base to base results in a simple convex (or plus) lens, which, if smoothed to a spherical shape, becomes a biconvex spherical lens. This is merely a fancy term for a lens that is fat in the middle, thin at the rim, and rounded at the front and back. If the two points of the triangle of glass touch each other, the crude lens that results is called a biconcave (or minus) lens, which, when smoothed until it has a spherical surface, is called a biconcave spheric lens. This simply means that its surface slopes inward toward the thin center and outward toward the thick rim. The effect is similar to that seen when two round soup spoons are placed back to back, their bottoms touching.

Convex or plus lenses tend to bend the rays of light in on themselves and focus them at a point. The lens of the eye is of this type. Concave or minus lenses bend the rays of light away from their former axis; they do not focus the light at a point, and so make the observer feel that everything is smaller and farther away.

If construction is imperfect and either type of lens is not completely spherical, but warped–with more slope in the touching, horizontal direction and less slope in a perpendicular direction (like a teaspoon)–

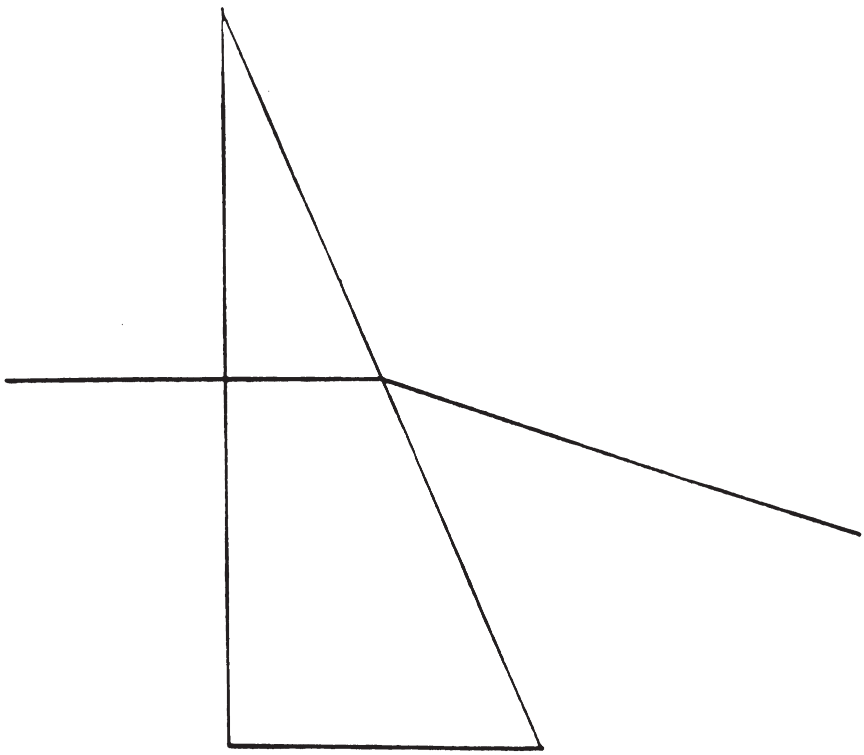

Figure 8. How a prism bends a ray of light.

the lens is astigmatic. This means that the light will not be focused on a point but rather on a line. The object observed through such a lens becomes distorted, just as a person strolling in front of the mirrors of a funhouse sees an image in one mirror that is a grotesquely tall and thin caricature, and in the next one that is abnormally short and fat.

Placing a cylinder of glass perpendicular to the axis will correct this defect and eliminate the distorted image. The results will be equivalent to a smooth, spherical lens, which gives clear vision.

The lens of the normal eye changes its focus automatically without conscious effort on the part of the viewer. This property is called the act of accommodation. Accommodation is the function of the ciliary muscle attached to the inside of the sclera just behind the rim of the iris. It surrounds the lens of the eye by 360 degrees. The ciliary muscle is comprised partly of choroidal material. Some retinal elements that cannot perceive light cover it. If the ciliary muscle contracts, it causes the elastic lens of the eye to relax and become spherical in shape. Because

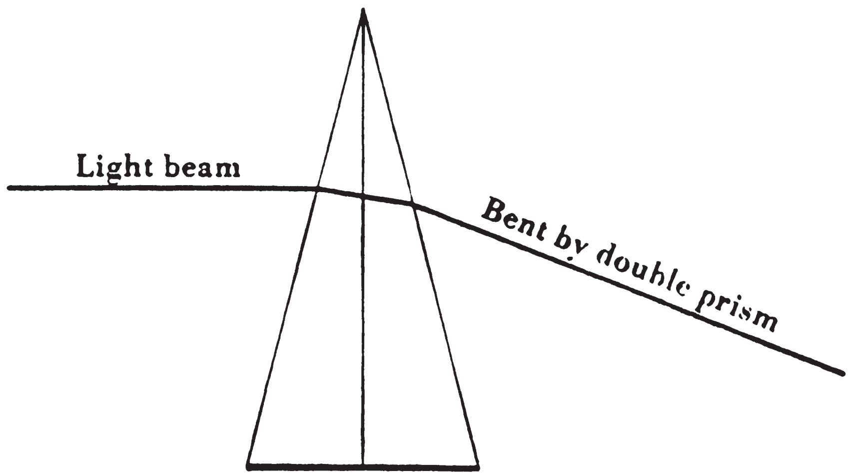

Figure 9. How two prisms back-to-back form the basic shape of one-half of a convex lens.

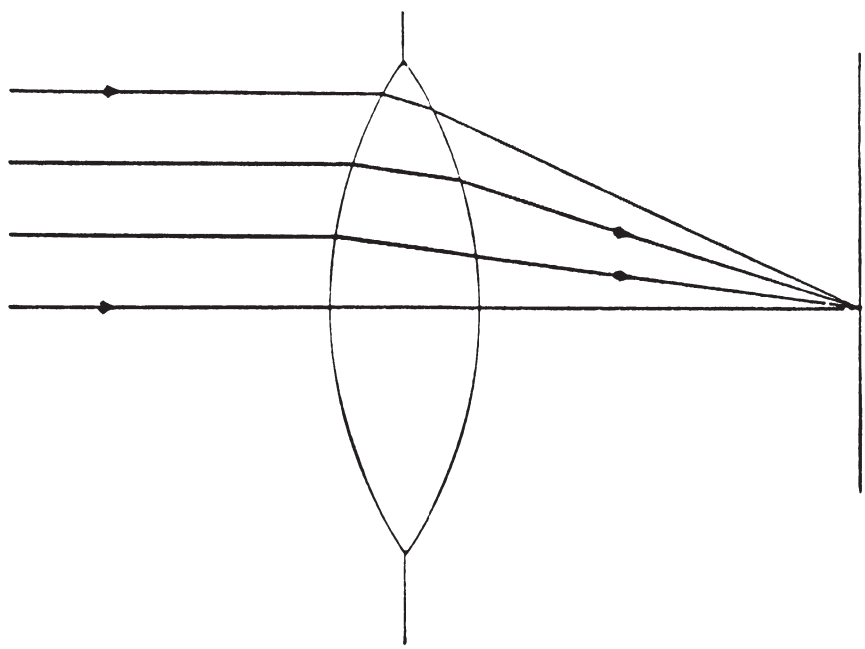

Figure 10. Prismatic power of a convex (plus) lens.

its surfaces are more convex, it has become a stronger plus lens, with the ability to focus light at a point closer to its back surface. This enables one to see objects that are closer to the eye, because the rays of light emitted by close objects are no longer parallel to but are divergent from each other.

When the ciliary muscle relaxes, the suspensory fibers become taut and the lens becomes flatter, allowing a distant object to come into focus. The rays of light coming from the far object's surface are almost completely parallel. In the normal eye, the lens is in the position of rest. No further lens action (accommodation) is needed to keep a distant object in focus.

During aging, new lens fibers constantly develop. They compress, pushing more and more fibers in toward the center of the lens. This decreases the lens's elasticity and, therefore, its ability to accommodate. Distant objects remain in focus, but it becomes more and more difficult to focus near objects. When this happens, one needs to wear reading glasses with more convex, or plus, lens strength. This typically occurs after age forty and is called ***presbyopia.*** Presbyopia generally progresses past the age of fifty, requiring stronger and stronger glasses. Finally the lens is inelastic and stabilizes.

The eyes of young persons are still growing in length. When they observe close objects, light may be focused back on the retina because the rays of light are divergent. Gradually, however, it may become impossible to focus distant objects clearly, because as the eyeball grows the retina becomes more and more widely separated from the lens and the lens cannot flatten sufficiently to focus light on the distant retina. Such individuals need to wear concave or minus lenses so that the light rays reaching the eye will be divergent instead of parallel, thus allowing the relaxed, flattened lens to focus them on the retina.

A person who is farsighted has the mechanism for focusing on distant objects but requires a plus lens to focus on close objects. The nearsighted individual, whose eyeball is too long for the focusing apparatus, requires a minus lens to observe something at a distance.

Most nearsighted (***myopic***) persons develop myopia in their young years while they are still growing. Their basic problem is that their eyes become too long for the focusing mechanism. On the other hand, the farsighted individual is more likely to be troubled later in life when the aging process of the lens itself no longer permits his eyes to adjust (accommodate) to close material. Farsightedness (***hyperopia***) affects some persons throughout their entire life, making glasses necessary