designed to afford us information in reference to substances in a volatile or gaseous form. Invisible particles come from odorous bodies, and are brought by the respired air in contact with the terminal filaments of the olfactory nerve, upon which an agreeable or disagreeable impression is produced. The fineness of the particles that constitute odors is often so extreme, that they elude all attempts to measure or weigh them. A piece of musk, for instance, may be kept for several years, constantly emitting perfume, without any appreciable loss of weight. In other cases, a loss of substance is perceptible, such as the essential oils, which enter into the composition of the ordinary perfumes.

40. Smell, like taste, aids us in the choice of proper food, leading us to reject such articles as have a rank or putrid odor, and which are, as a rule, unfit to be eaten. The highest usefulness of this sense, however, consists in the protection it affords to the organs of respiration. Stationed at the gateways of the air-passages, it examines the current of air as it enters, and warns us of the presence of noxious gases, and of other and generally invisible enemies to health. Not all dangerous vapors are offensive, but almost all offensive vapors are unfit to be breathed. A number of small stiff hairs grow from the margin of the nostrils to prevent the entrance of dust and other atmospheric impurities, which would be alike injurious to the olfactory mucous membrane and to the lungs. The benevolent design of the Maker of our bodies may be observed in all parts of their mechanism; but, probably, in none is it more clearly displayed than in connection with the sense of smell.

41. The Sense of Sight.—Sight, or Vision, is the special sense by means of which we appreciate the color, form, size, distance, and other physical properties of the objects of external nature. Primarily, this sense furnishes us with information concerning the different shades of color and the different degrees of brightness: these are the simple sensations of sight, such as the yellowness and glitter of a gold coin. In addition to these, there are composite visual sensations, produced by the

joint action of the other senses and by the use of the memory and judgment; such as, in the case of the coin, its roundness, solidity, size, its distance and direction from us. So that many of our sensations, commonly considered as due to sight, are in reality the results of intellectual processes which take place instantaneously and unconsciously.

42. Light.—The Optic Nerve.—Unlike the senses previously considered—touch, taste, and smell—sight does not bring us into immediate contact with the bodies that are examined; but, by it, we perceive the existence and qualities of objects that are at a greater or less distance from us. In the case of the stars, the distance is incalculable, while the book we read is removed but a few inches. Light is the agent which gives to this sense its wide range. The nature of this mysterious force is not known, and it is not here to be discussed; since its study belongs more properly to the province of natural philosophy.

43. It is sufficient, in this connection, to state that the theory of light now generally accepted, and which best explains the facts of optics, is that known as the undulatory theory. This theory supposes that there exists an intangible, elastic medium, which fills all space, and penetrates all transparent substances, and which is thrown into exceedingly rapid undulations or waves, by the sun and every other luminous body, the undulations moving not less than 186,000 miles in a second.

44. These waves are thought to produce in the eye the sensation of light, in the same manner as the sonorous vibrations of the air produce in the ear the sensation of sound. That part of the eye which is sensitive to these waves is the expansion of the *optic nerve.* It is sensitive to no other impression than that of light, and it is the only nerve which is acted upon by this agent. The optic nerve, also called the "second pair" of cranial nerves, is the means of communication between the eye and the brain.

45. The Organ of Sight.—The Eye.—The proximity of the eye to the brain, and the important part it performs in

giving expression to the emotions, have given it the name of "the window of the soul." The exceeding beauty of its external parts, and the high value of its function, have long made this organ the subject of enthusiastic study. It is chiefly within the last twenty years, however, that this study has been successful and fruitful of practical results. Several ingenious instruments have been invented for the examination of the eye in health and disease, and new operations have been devised for the relief of blindness and of impaired vision. As a result, it is now a well-marked fact that, in civilized lands, the number of those who suffer from loss of sight is proportionally much less than in countries where science is less known and cultivated.

46. The most obvious fact in respect to the apparatus of sight is that there are two eyes, which may either act together as one, and be fixed upon one object, or one eye may be used independently of the other. In consequence of this arrangement the loss of one eye does not necessitate blindness, and, in fact, it not infrequently happens that the sight of one eye may be long impaired or lost before the fact is discovered. We next notice that it is placed at the most elevated part of the body, in front, and near the brain. It also commands a wide range of view, being itself moved with great rapidity, and being further aided by the free motion of the head and neck. The organ of vision consists essentially of two parts: the optical instrument itself—the eyeball—and its enveloping parts, or the case in which the instrument is kept free from harm. The latter, which are external, and which we shall first consider, are chiefly the *Orbits*, the *Eyelids*, and the apparatus for the *Tears*.

47. The Orbits.—The eyeball, which is a delicate organ, is well defended against external injury within the orbits or bony sockets of the head. These are deep conical hollows, bounded in part by the bones of the skull, and in part by those of the nose and cheek. The orbit juts out beyond the most exposed portion of the eyeball, as may be seen by laying a book over the eye, when it will be found that no part of the eyeball, unless it be very prominent, will be touched by the book; so that the only direction in which an injury is liable to be received is immediately in front of the eye. The overhanging brow is itself covered by a layer of thick skin, studded with short, stout hairs, which are so bent as to prevent the perspiration from running into the eye and obscuring vision. Through a hole in the bottom of the orbit, the nerve of sight passes outward from the brain. The orbit also contains a considerable amount of a fatty tissue, upon which, as upon an elastic cushion, the eye rests.

48. The Eyelids.—The eyelids are two movable curtains, or folds, which, when shut, cover the front part of the orbit, and hide the eye from view. The upper lid is the larger, has a curved margin, and moves freely, while the lower lid is comparatively short and straight, and has but a slight degree of motion (Fig. 36). Skin covers the exterior of the lids, while a fine mucous membrane lines their inner surface, and is likewise spread out over the entire front of the eyeball. This membrane, which is called the *Conjunctiva*, is highly sensitive, and thus plays an important part in protecting the eye against the lodgment of sand, ashes, chaff, and other foreign particles that are blown about in the air. This sensitive membrane will not endure the presence of these particles. If any find access, it causes a constant winking, a flow of tears, and other signs of irritation, until it is removed.

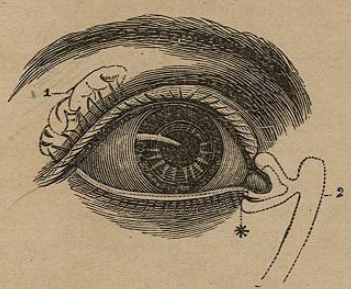

FIG. 36.—FRONT VIEW OF THE RIGHT EYE. (Natural Size.)
1. The Lachrymal, or tear gland, lying beneath the upper eyelid.
2. The Nasal Duct is shown by the dotted line. The * marks the orifice in the lower lid.
The central black spot is the *pupil*; surrounding it is the *iris*; and the triangular white spaces are the visible portion of the *sclerotic*.

49. The long, silky eyelashes, which garnish the edges of the lids, act like a sieve to prevent the entry of dust and the like; and together with the lids, they regulate the amount of light

which is permitted to enter the eye, so that it is shielded from a sudden flood or glare of light. The little points seen in the figure just within the line of the lashes, especially on the lower lid, represent the mouths of numerous little sebaceous glands (Fig. 37, D, D), such as are always found in the neigh-

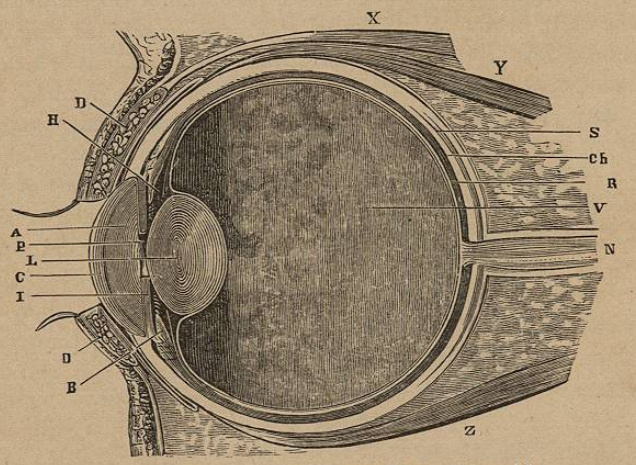

FIG. 37.—VERTICAL SECTION OF THE EYE. (Enlarged.)

C, The Cornea.
A, The Aqueous Humor.
I, The Iris.
P, The Pupil.
L, The Crystalline Lens.
H, The Ligament of the Lens.
B, The Ciliary Process.
V, The Cavity containing the Vitreous Humor.
S, The Sclerotic
Ch, The Choroid.
R, The Retina.
N, The Optic Nerve.
DD, The Eyelids.
X, The Levator Muscle of the Upper Lid.
Y, The Upper Straight Muscle of the Eye.
Z, The Lower Straight Muscle.

borhood of hairs. These glands supply a thick, oily material which greases the edges of the lids and prevents their adhering together, and likewise prevents the overflow of the tears upon the cheek.

50. The Lachrymal Fluid, or the Tears.—Just within the outer part of the bony arch of the brow, where the bone may be felt to be sharper than in other positions, is lodged a little organ called the lachrymal gland, the situation of which is indicated in

Fig. 36, 1. This is the gland whence flows the watery secretion, commonly called the *tears*, which is designed to perform an exceedingly important duty in lubricating the lids, and in keeping the exposed surface of the eyeball moist and transparent. For, without this or some similar liquid, the front of the eye would speedily become dry and lustreless, like that of a fish which has been removed from the water: the simple exposure of the eye to the air would then suffice to destroy vision.

51. Secretion of the Tears.—This secretion of the tears takes place at all times, during the night as well as the day; but it is seldom noticed, unless a person is under the influence of some strong mental emotion, when it is poured forth in excess, so as to overflow the lids. Strong light or a rapid breeze will, among many other causes, excite the flow of the tears. That portion of this secretion not used in moistening the eye is carried off into the nose by a canal, called the *nasal duct*, situated near the inner angle of the eye. This duct, shown in Fig. 36, 2, is connected with each lid by delicate tubes, which are indicated by dotted lines in the figure; the asterisk marks the little opening in the lower lid, by which the tears enter the nasal duct. By gently turning the inner part of that lid downward, and looking in a mirror, this small "lachrymal point" may be seen in your own eye. In old people, these points become turned outwards, and do not conduct the tears to the nasal cavity, so causing an overflow of tears upon the face.

52. Thus we observe that the gland which forms the tears is placed at the outer part of the eye, while their means of exit is at the inner angle of the eye; which fact renders it necessary for this watery fluid to pass over the surface of the eyeball before it can escape. This arrangement cannot be accidental, but evinces design, for it thus secures the perfect lubrication of the surface of the eye, and cleanses it from the smaller particles of dust which may enter it, in spite of the vigilance of the lids and lashes. The act of winking, which is generally unconsciously performed, and which takes place six or more times in a

minute, assists this passage of the tears across the eye, and is especially frequent when the secretion is most abundant.

53. The Eyeball.—The remarkable optical instrument called the eyeball, or the globe of the eye, upon which sight depends, is, as the name indicates, spherical in shape. It is not a perfect sphere, since the front part projects somewhat beyond the rest, and at the posterior part the optic nerve (Fig. 37, N) is united to it, resembling the junction of the stem with a fruit. In its long diameter, that is, from side to side, it measures a little more than an inch; in other directions it is rather less than an inch. In structure, the ball of the eye is firm, and may be felt by pressing the fingers over the closed lids.

54. The eyeball is composed chiefly of three internal, transparent media, called *humors;* and three investing coats, or *tunics.* The former are the *aqueous humor*, Fig. 37, A, the *crystalline lens* L, and the *vitreous humor* V. Of these the lens alone is solid. The three coats of the eyeball are called the *sclerotic* S, the *choroid* Ch, and the *retina* R. This arrangement exists in respect to five-sixths of the globe of the eye, but in the anterior one-sixth, these coats are replaced by the *cornea* C, which is thin and transparent, so that the rays of light pass freely through it, as through a clear window-pane.

55. The Cornea in shape is circular and prominent, resembling a miniature watch-glass, about $\frac{1}{25}$ of an inch thick. In structure, it resembles horn (as the name signifies), or the nail of the finger, and is destitute of blood-vessels. The *Sclerotic* (from *scleros*, hard) is composed of dense, white fibrous tissue, and gives to the eyeball its firmness of figure and its white color; in front, it constitutes the part commonly called "the white of the eye."

56. The Choroid is the second or middle coat of the eyeball, and lies closely attached to the inner surface of the sclerotic. Unlike the latter coat, its structure is soft and tender, it is dark in color, and possesses a great abundance of blood-vessels. Its dark color is due to a layer of dark brown or chocolate-colored cells spread out over its inner surface. This dark layer serves

to absorb the rays of light after they have traversed the transparent structures in front of it; if the rays were reflected from side to side within the eye, instead of being thus absorbed, confused vision would result from the multitude of images which would be impressed upon the optic nerve.

57. The Iris.—Continuous with the choroid, in the front part of the globe of the eye, is a thin, circular curtain, which occasions the brown, blue, or gray color of the eye in different individuals. On account of the varieties of its color, this membrane has received the name *Iris*, which is the Greek word for "rainbow" (See Fig. 37, I). A front view of it is shown in Fig. 36. The iris is pierced in its centre by a round opening, called the *pupil* (P), which is constantly varying in size. In olden times it was spoken of as the "apple of the eye." The hinder surface of the iris has a layer of dark coloring matter resembling that of the choroid. The iris is a muscular organ, and contains two distinct sets of fibres; one of which is circular, while the other radiates outward from the pupil. The action of these sets of fibres regulates the size of the pupil; for when the circular set acts, the pupil contracts, and when the other set acts, the opening expands. Their action is involuntary, and depends on the reflex system of nerves, which causes the contraction of the pupil when a strong light falls upon the eye, and its expansion when the illumination is feeble.

58. The iris, accordingly, serves a very useful purpose in regulating the admission of light to the eye. It, however, does not act instantaneously; and hence, when we pass quickly from a dark room into the bright sunlight, the vision is at first confused by the glare of light, but as soon as the pupil contracts, the ability to see becomes perfect. On the other hand, when we enter a dark apartment, such as a cellar, for a short time we can see nothing clearly; but as soon as the pupil expands and admits more light, we are enabled to distinguish the surrounding objects. Animals of the cat species, and others which prowl around after nightfall, are enabled to see in the dark by having

the iris very dilatable. The size of the pupil affects the lustre of the eye. When it is large, as it usually is during youth, the eye appears clear and brilliant; while in old age the pupil is small and the eye is dull.

59. The Retina constitutes the third and inner coat of the globe of the eye. This, the important part of the eye that is sensitive to light, is a kind of nervous membrane, formed by the expansion of the optic nerve. Its texture is soft, smooth, and very thin; it is translucent and of a grayish-white color. It is sensitive to light alone; and if any form of mechanical irritation be applied to it, the sensations of touch and pain are not experienced, but flashes of fire, sparks, and other luminous appearances are perceived. Too intense light occasions a feeling of pain, but it is of a peculiar kind, and is termed "dazzling."

60. Impressions made upon the retina are not at once lost, but remain a measurable length of time, and then gradually fade away. Thus, a bright light or color, gazed at intently, cannot be immediately dismissed from sight by closing or turning away the eyes. A stick lighted at one end, if whirled around rapidly in the dark, presents the appearance of an unbroken luminous ring; and the spokes of a rapidly revolving carriage-wheel seem to be merged into a plane surface. If an object move too rapidly to produce this sort of lasting impression, it is invisible, as in the case of a cannon-ball passing through the air in front of us.

61. If a card, painted with two primary colors—as red and yellow—be made to rotate swiftly, the eye perceives neither of them distinctly; but the card appears painted with their secondary color—orange. The average duration of retinal images is estimated at one-eighth of a second; and it is because they thus endure, that the act of winking, which takes place so frequently, but so quickly, is not noticed and does not interrupt the vision. The retina is easily fatigued or deprived of its sensibility. After looking steadfastly at a bright light, or at a

white object on a black ground, a dark spot, corresponding in shape to the bright object, presents itself in whatever direction we look. This spot passes away as the retina resumes its activity. In some persons the retina is incapable of distinguishing different colors, when they are said to be affected with "color-blindness." Thus, red and green may appear alike, and then a cherry-tree, full of ripe fruit, will seem of the same color in every part. Railroad accidents have occurred because the engineer of the train, who was color-blind, has mistaken the color of a signal.

62. The Crystalline Lens.—Across the front of the eye, just behind the iris, is situated the *Crystalline lens*, enclosed within its own capsule. It is supported in its place partly by a delicate circular ligament, and partly by the pressure of adjacent structures. It is colorless and perfectly transparent, and has a firm but elastic texture. In shape it is double-convex, and may be rudely compared to a small lemon-drop. It is only one-fourth of an inch thick.

63. When this little body becomes opaque, and no longer affords free passage to the rays of light, as often happens with the advance of age, an affection termed "cataract" is produced. Between the crystalline lens and the cornea is a small space which contains the *aqueous humor* (See Fig. 37, A). This humor consists of five or six drops of a clear, colorless liquid very much like water, as its name implies. That part of the globe of the eye lying behind the lens is occupied by the *vitreous humor*, so called from its fancied resemblance to melted glass (Fig. 37, V). This humor is a transparent, jelly-like mass, enclosed within an exceedingly thin membrane, and constitutes fully two-thirds of the bulk of the eyeball.

64. The Uses of the Crystalline Lens.—A convex lens has the property of converging the rays of light which pass through it; and the point at which it causes them to meet is termed its focus. If a lens of this description, such as a magnifying or burning-glass, be held in front of an open window, in

such a position as to allow its focus to fall upon a piece of paper, it will be found to depict upon the paper a miniature image of the scene outside of the window. It will be further noticed that the image is inverted, or upside down, and that the paper at the place upon which the image is thrown is much brighter than any other part. All the transparent structures of the eye, but especially the crystalline lens, operate upon the

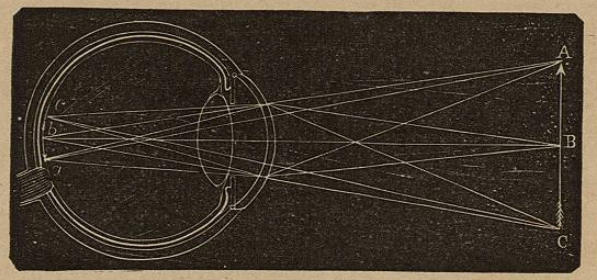

FIG. 38.—THE RETINAL IMAGE

retina, as the convex lens acts upon the paper; that is, they paint upon the retina a bright inverted miniature of the objects that appear in front of the eye (Fig. 38).

65. The form and structure of the crystalline lens endow it with a remarkable degree of refractive power, and enable it to converge all the rays of light that enter it through the pupil, to a focus exactly at the surface of the retina. When this lens is removed from the eye, as is frequently done for the cure of cataract, it is found that the rays of light then have their focus three-eighths of an inch behind the retina; that the image is four times larger than in the healthy eye, that it is less brilliant, and that its outline is very indistinct. From this we learn that one of the uses of the crystalline lens is to make the retinal image bright and sharply defined, at the same time that it reduces its size. Indeed, the small size of the image is a great advantage, as it enables the limited surface of the retina to receive, at a glance, impressions from a considerable field of vision.

66. As the image upon the retina is inverted, how does the mind perceive the object in its true, erect position? Many explanations have been advanced, but the simplest and most satisfactory appears to be found in the fact that the retina observes no difference, so to speak, between the right and left or the upper and lower positions of objects. Consequently, our knowledge of the relative location of external objects must be obtained from some other source than the retina. The probable source of this knowledge is the habitual comparison of those objects with the position of our own bodies: thus, to see an elevated object, we know we must raise the head and eyes; and to see one at our right hand, we must turn the head and eyes to the right.

67. Long-sight or Hyperopia, and Short-sight or Myopia. The eye is not in all cases perfectly formed. For example, persons may from birth have the cornea too prominent or too flat, or the lens may be too thick or too thin. In either of these conditions sight will be more or less defective from the first,

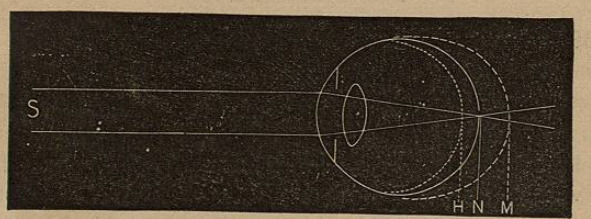

FIG. 39.—THE DIFFERENT SHAPES OF THE GLOBE OF THE EYE.
N, The Natural Eye. M, The Short-sighted Eye.
H, The Long-sighted Eye. S, Parallel Rays from the Sun

and the defect will not tend to disappear as life advances. The most common imperfection, however, is in the shape of the globe; which may be short (Fig. 39, H), as compared with the natural eye, N, or it may be too long, M.

68. When the globe is short, only objects that are at a distance can be clearly seen, and the condition of the vision is known as "long-sight," or hyperopia. It will be observed, by

reference to Fig. 39, that the focus of the rays of light would fall behind the retina of this eye. When the globe is too long, only objects that are very near to the eye can be clearly seen; and the condition resulting from this defect is termed "short-sight," or myopia. The focus of the rays of light is, in this case, formed in the interior of the eye in front of the retina.

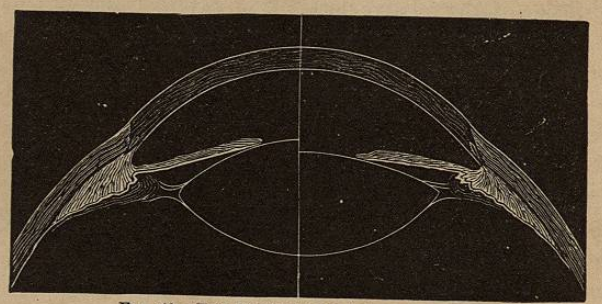

FIG. 40.—THE FUNCTION OF ACCOMMODATION.

The right half of the diagram shows the eye at rest. The left half shows the lens accommodated for near vision.

69. The Function of Accommodation.—If, after looking through an opera-glass at a very distant object, it is desired to view another nearer at hand, it will be found impossible to obtain a clear vision of the second object unless the adjustment of the instrument is altered; which is effected by means of the screw. If an object, like the end of a pencil, be held near the eye, in a line with another object at the other side of the room, or out of the window, and the eye be fixed first upon one and then upon the other, it will be found that when the pencil is clearly seen, the further object is indistinct; and when the latter is seen clearly, the pencil appears indistinct; and that it is impossible to see both clearly at the same time. Accordingly, the eye must have the capacity of adjusting itself to distances, which is in some manner comparable to the action of the screw of the opera-glass.

70. This, which has been called the function of accommodation, is one of the most admirable of all the powers of the eye, and is exercised by the crystalline lens. It consists essentially in a change in the curvature of the front surface of the lens, partly through its own elasticity, and partly through the action of the ciliary muscle. When the eye is at rest, that is, when accommodated for a distant object, the lens is flatter and its curvature diminished (see Fig. 40); but when strongly accommodated for near vision the lens becomes thicker, its curvature increases, and the image on the retina is made more sharp and distinct. Since a strong light is not required in viewing near objects, the pupil contracts, as is shown in the left-hand half of the diagram.

71. Old-sight, or Presbyopia.—But this marvellously beautiful mechanism becomes worn with use; or, more strictly speaking, the lens, like other structures of the body, becomes harder with the approach of old age. The material composing the lens becomes less elastic, the power to increase its curvature is gradually lost, and, as a consequence, the person is obliged to hold the book further away when reading, and to seek a stronger light. In a word, the function of accommodation begins to fail, and is about the first evidence that marks the decline of life. By looking at the last preceding diagram, and remembering that the increased curvature of the lens cannot take place, it will be at once understood why old-sight is benefited in near vision by the convex lens, such as the spectacles of old people contain. It acts as a substitute for the deficiency of the crystalline lens.

72. The Sense of Hearing.—Sound.—Hearing is the special sense by means of which we are made acquainted with *sound*. What is sound? It is an impression made upon the organs of hearing, by the vibrations of elastic bodies. This impression is commonly propagated by means of the air, which is thrown into delicate undulations, in all directions from the vibrating substance. When a stone is thrown into smooth water, a wave of circular form is set in motion, from the point where the stone