THE

ORGANS OF VISION:

THEIR STRUCTURE AND FUNCTIONS.

BY

G. J. WITKOWSKI, M.D.,
MEMBRE DE LA FACULTÉ DE MÉDECINE DE PARIS.

Translated by

HENRY POWER, F.R.C.S.,
SENIOR OPHTHALMIC SURGEON TO ST. BARTHOLOMEW'S HOSPITAL.

LONDON:
BAILLIÈRE, TINDALL, AND COX,
20, KING WILLIAM STREET, STRAND.

THE ORGANS OF VISION;

THEIR STRUCTURE AND FUNCTIONS.

THE SENSE OF SIGHT.

THE sense of sight, named by Buffon 'distant touch,' enables us to perceive light, and to distinguish such external qualities of bodies, as colour, form and distance, as well as their state of motion or repose.

Nor does the eye enable us to distinguish external objects alone, but it betrays the emotions of the mind, its feelings and its emotions; so that it has been properly regarded as the mirror of the soul. Indeed, as Victor Hugo has remarked, 'the eye of man is a window, through which the play of his thoughts can be clearly perceived.'

Apes, and birds of prey, like man, are capable of directing both eyes forwards, but in most other animals the axis of vision is inclined more or less outward; so that objects situated laterally or posteriorly are seen as clearly, or even more clearly, than those in front. This arrangement causes the hare to see clearly the dog in pursuit, while it neglects the sportsman in front; and we cover the eyes of a horse with blinkers, which suppress the vision of all that is behind it, to prevent its being startled with the movements of the garments of the rider.

The sense of sight, keen in man, is far more highly developed in some animals. At night, for example, the horse will avoid obstacles that a man is unable to perceive. Birds, again, have singularly long sight, and can distinguish the insects on which they feed at extraordinary distances.

Like the other senses, that of vision can be improved by exercise, sailors being able to distinguish the trim of a ship when the ship itself is scarcely perceptible to the ordinary passenger.

SECTION I.

STRUCTURE OF THE ORGANS OF VISION.

Regarded from a physiological point of view, the organ of vision is composed of a *receptive apparatus* and an *apparatus of transmission.* The *receptive apparatus,* represented by the two globes and their accessory parts, is contained in the orbit; the *apparatus of transmission,* which is composed of two nerves, is enclosed in the cranial cavity, and forms an integral part of the nerve centres. These nerves join and decussate in a point named the *chiasma.* They conduct those impressions of light which act on the receptive apparatus to the brain, and they consist, passing from before backwards, of the *optic nerves,* the *chiasma,* and the *optic tracts,* or *white roots of the optic nerves,* which are in direct continuity with the *corpora geniculata externa and interna.* A lesion of any part of these tracts interferes with the vision of one or the other eye, and if the lesion affects a part above the chiasma, vision may be lost in both eyes.

A description has elsewhere been given, under the head of *nerve centres,* of the *apparatus of transmission,* and those who desire to study this part of the organ of vision are referred to the plate in this series of drawings representing the *encephalon.* The following observations refer only to the *receptive apparatus.*

The apparatus for the reception of light, or the true visual apparatus, is composed in man of certain essential parts, the *eye-balls,* and of certain accessory parts by which these are moved and protected.

I.—GLOBE OF THE EYE.

The form of the globe of the eye is nearly spherical, the cornea, however, representing a segment of a smaller sphere.

The diameters of the eye vary but little in different individuals, and the differences that are observed are more apparent than real, depending on the size of the palpebral fissure, and the greater or less prominence of the globe. In myopes, however, the eyes are really larger, and consequently project more than those of hypermetropic persons. The eyes of women are a trifle smaller than those of men, but the eye of the infant is almost equal in size to that of the adult.

In considering the minute anatomy of the eye, we meet with a series of membranes enclosed one within the other, which serve as envelopes to fluids of greater or less density, known as the *media of the eye.*

The membranes are three in number, and are named respectively, proceeding from without inwards :

1. The *sclerotic* (55), and the *cornea* (120), which are fibrous membranes acting as protective envelopes.
2. The *choroid* (123), and the *iris* (130), which are muscular and vascular membranes presiding over the nutrition and the accommodation of the globe of the eye.
3. The *retina* (143), which is the nervous membrane that receives the impression of light.

The *media* of the eye are also three in number, and are named respectively, from before backwards, the *aqueous* humour, the *crystalline lens*, and the *vitreous* humour.

(A.) Membranes of the Eye.

1. Sclerotic. This is the most external of the membranes investing the eye, and is at once the thickest and the strongest, as is indicated by its etymology, the name being derived from the Greek word σκληρός, hard.

The sclerotic is inextensible, and its defective elasticity explains the intolerable pain that is experienced when the ciliary nerves (116) are compressed by intra-orbital effusion. The pain can be relieved by puncturing the sclerotic, or, still better, by removing part of the iris (131), an operation that is termed iridectomy.

The colour of the sclerotic is of a dull white, but in infants it is more transparent; and thus permitting the subjacent choroid (123) to be seen through, it presents a bluish tint. This peculiarity is still more marked in those who are phthisical and anæmic. In jaundice the sclerotic, like the tissues and humours of the body generally, assumes a yellow hue. Collyria containing nitrate of silver will stain the sclerotic of a more or less intense black.

Dr. Larcher has pointed out that the appearance of a livid spot on the sclerotic some hours after supposed death is a certain sign that death has really occurred. My own observations have demonstrated that this spot is to be regarded as the first apparent sign of putrefaction, but that it is only under certain conditions that it becomes manifest. Thus, I have never observed its occurrence when the eyelids have remained hermetically sealed ; whilst, on the contrary, it is rarely absent when they have remained open and exposed to the light. The discoloration takes the form of the palpebral fissure, and varies in size with the extent to which the lids are separated. The cause of its formation is unquestionably imbibition permitting the pigment-cells of the choroid to make their way into the narrow meshes of the scleral tissue. The practical conclusion to be drawn is that the face should never be covered nor the lids closed before the appearance of the discoloured spot. Precipitate inhumations might thus be avoided, especially in those countries where no certificate of death is required from a qualified man.

By its anterior surface the sclerotic gives attachment to the *recti* (98, 99, 100, 101) and to the *oblique* (102, 103) muscles, by which the movements of the globe of the eye are effected. Its internal surface is lined by the choroid, giving it a brown colour, especially in its posterior segment. By some anatomists this deposit of pigment has been regarded as a special layer, to which they have applied the name of *lamina fusca*.

The sclerotic is perforated by two apertures, one of which, posterior and circular in form, allows the passage of the optic nerve (110), whilst the other is anterior and of oval form. This last presents the appearance of receiving into the groove of its bevelled edge the transparent cornea, though it is in reality quite continuous with it. Near the point where the sclerotic blends and is continuous with the cornea, are certain channels termed the canal of Schlemm and of Fontana (117), from the name of the anatomists who discovered or described them.

2. The Cornea.—The cornea is a transparent membrane occupying the large anterior aperture of the sclerotic, into which it fits like a watch-glass into its case. Its anterior surface is convex and oval in form, with the long axis horizontal. The posterior concave face is perfectly circular. The exaggeration of its convexity constitutes a congenital or accidental vice of conformation known under the name of *staphyloma*, from *σταφυλή*, a grape. The several meridians of the cornea are equal to one another, though their curvature is sometimes irregular, as is seen in *astigmatism*.

Of all the coats of the eye the cornea is, by its position, most exposed to accidents from without, and it is no doubt with the object of protection that it has acquired so considerable a thickness. In point of fact, with the exception of burns, which are very serious in their results, injuries of the cornea are rare and comparatively trifling. The cornea possesses to a certain degree the power of imbibing fluids into, and transmitting them through its substance; hence the employment of collyria, a few drops of which are instilled between the lids with a view of acting on the deeper parts. To dilate the pupil, for example, it is sufficient to apply to the surface of the eye a drop of a neutral solution of sulphate of atropine, whilst its contraction can be induced by the application of a little eserine. In like manner, a dog can be almost instantaneously killed by instilling into the eye a single drop of prussic acid.

The tissue of the cornea is destitute of vessels, because they would produce shadows which would interfere with the clearness of vision, and they are only developed as a result of inflammation; but it possesses nerves the transparency of which presents no obstacle to the passage of light. They are derived from the ciliary nerves (116), are very numerous, and endow the cornea with its well-known and extreme sensibility. In *glaucoma*, a disease which receives its name from the sea-green tint that is presented by the dilated pupil, the cornea becomes insensible, owing to the compression of the ciliary nerves which run between the sclerotic and the choroid, a compression caused by the intraocular effusion which characterises this affection of the eye.

The photophobia, or exaggerated sensibility of the eye to light which accompanies keratitis, or inflammation of the cornea, results from the exposure to irritation of the extremities of the nerves.

The cornea presents three layers; a principal layer, composed of fibrous tissue, enclosed between two elastic lamellæ, each of which possesses, in addition, an epithelial investment.

The anterior elastic lamina, with the cells covering it, gives its smoothness to the convex surface of the cornea, and its inflammation, which is termed *keratitis superficialis*, is characterised by the temporary loss of this polish. If the inflammation attack the deeper layers, and becoming interstitial, propagates itself to the fibres and stellate cells which form the reticulated substance of the principal layer, opacity of the cornea results, and indelible spots, named leucomata, are formed.

It is possible, as M. Wecker has suggested, to tattoo these spots, and to give them the tint of the portion of iris or pupil over which they happen to be placed. In this way their presence is concealed, but they exist in another form, and equally interfere with vision.

The periphery of the posterior elastic lamina presents a thickening named the tendinous ring of Döllinger (129), which forms the posterior wall of the canal of Schlemm, and gives attachment to the ciliary muscle and to the iris. From this circular thickening spring the fibres which collectively constitute the *ligamentum pectinatum*, from the Latin word *pecten*, a comb. The epithelial layer which covers the anterior elastic lamina is a continuation of that of the ocular conjunctiva; whilst that which invests the posterior lamina is reflected with the ligamentum pectinatum upon the iris, and has received the name of the membrane of Descemet, or of Desmours.

Man and the greater number of animals have only one cornea to each eye. Insects, on the contrary, which possess multiple vision, have as many corneæ as they possess eyes. In the cock-chafer, for example, there are 8,820, whilst the butterfly has 34,650.

3. Choroid.—The name of this tunic is derived from its resemblance to the deep layer of the skin which is termed the chorion. It is composed of three layers of different texture. The superficial is areolar (134); the deep, pigmentary (139); and the intermediate, vascular (136).

i. The areolar layer, of brown colour and woolly aspect, presents whorl-like striæ, which correspond to the flexures of the veins of the subjacent vascular layers.

ii. The middle, or *vascular* layer, is composed of veins, arteries, and capillaries disposed in concentric layers. The veins, which are superficial, are named the *venæ vorticosæ* (112), because their rootlets describe parallel curves like a whorl; they unite to form four principal trunks. The capillaries, which form the innermost layer, are, like the veins, arranged in a stellate manner, with curved rays. This layer of capillaries, known as the *chorio-capillaris* (138), gives to the eye the deep red tint seen on ophthalmoscopic examination. The arterial ramifications (137) proceed from the short posterior ciliary arteries (114), and occupy the space between the two other vascular planes.

iii. The *pigmentary layer*, deeply placed, is very dark in tint, and owes its colour to the presence of a great number of pigment granules similar to those found in the skin of the negro. It serves to absorb the luminous rays which have acted on the retina, and which are no longer useful for vision. Were this layer absent, the light entering the eye would be reflected in all directions, and would render the retinal image indistinct. This is actually observed in Albinos, in whom the choroid is destitute of pigment-granules.

In old age the pigment-cells undergo fatty degeneration, and assume a grey colour, which renders the tint of the fundus of the eye of the aged less deep than that of the adult. This natural change is often mistaken by the inexperienced for incipient cataract. [In certain animals the internal surface of the choroid presents a beautiful iridescent appearance, or metallic lustre, named tapetum, which is due to a peculiar arrangement of the texture of this membrane.]

The choroid presents two apertures: a posterior one (140), which permits the passage of the optic nerve, and an anterior one, termed the *choroidal zone* (125), which surrounds the iris in a circular manner. The peripheric border of this zone has received the name of *ora serrata* (126), from its festooned appearance. The zona choroidea has a breadth of about five millimetres (one-fifth of an inch), and presents a single plane posteriorly, but is divided into two planes anteriorly. The more superficial of these two planes is the *ciliary muscle* (125), and the deeper is the *ciliary body* (164).

(1) The *ciliary muscle* is of grey colour, and is attached anteriorly to the tendinous ring of Döllinger, which constitutes the posterior wall of the canal of Schlemm. It is composed of two sets of fibres : a superficial, radially disposed set (158), and a deeper, circularly arranged set (159), which only occupies the anterior half of the ciliary muscle. This muscle either effects the compression of the lens, or causes relaxation of its suspensory ligament; in either case increasing its curvature and lessening its focal distance. It only contracts when attention is directed to near objects, and is, as we shall presently see, the essential agent in the accommodation of the eye for the vision of objects at different distances.

(2) The ciliary body, or ciliary ring (164), has the form of a membranous crown divided into sixty or more small rays, the apices of which are continuous with the choroid, whilst the base is free and floats in the fluid of the posterior chambers. These fleshy prolongations, or ciliary processes (from *procedo,* to advance) (165), grasp the periphery of the lens like the tags which secure a jewel in a ring. The ciliary processes (157) are white when the pigment investing them is detached; their base and posterior border always present a white colour, because they are not invested with pigment-cells. The ciliary body may be regarded as a small erectile apparatus formed by a plexus of intercommunicating veins, the action of which, however, is not accurately understood. It is probable that they secrete the aqueous humour, which explains the accumulation of fluid behind the iris in cases of complete posterior synechia.

iv. The iris (130) is a membranous circular septum placed vertically in front of the lens, and perforated by a central opening termed the pupil. The pupil in man is round, but in the greater number of animals it is elliptic. It is contractile, and has the power of dilating and contracting according to the therapeutic, physiological or pathological influence to which it is subjected. Light, opium, Calabar bean, and its extract, eserine, cause it to contract; its dilatation, on the other hand, is occasioned by darkness, the action of belladonna and its alkaloid atropine. It is also observed in cerebral diseases and in helminthiasis.

During an attack of epilepsy the pupils are generally dilated, though they are occasionally rather contracted, and are always insensible to the action of light. This last-named feature enables a true, to be distinguished from a simulated, attack of epilepsy.

The pupil is black in the adult, grey in age, red in the Albino, amber-coloured in hard cataract, and green in glaucoma. Its colour depends, therefore, on changes in the post-pupillary media and membranes.

The iris acts like the diaphragm in optical instruments, regulating the amount of light that can penetrate into the interior of the eye. Its normal contraction and dilatation are dependent on the intensity of the light and the sensitiveness of the retina. Cats, for example, like all nocturnal animals, possess so high a degree of retinal sensibility, that during the day their pupil is reduced to a mere slit, whilst in darkness it is strongly dilated. The pupil of a person afflicted with paralysis of the retina remains in a condition of permanent dilatation even when exposed to the brightest light. The immobility of the pupil of a healthy eye to which a light is alternately approximated and withdrawn, is generally considered a certain sign of death.

After death, atropine no longer possesses the power of effecting dilatation of the pupil, and hence M. Bouchut regards neutral sulphate of atropine as the 'test for death.' If, after a drop of its solution has been instilled into the eye, the pupil dilates, death is uncertain; but if it do not dilate, death is certain.

The iris is indebted for its name to the various tints presented by its anterior surface. Its colour is often in harmony with that of the hair; of a more or less brown colour in brunettes, it is of a livelier hue in blondes, rose-coloured in Albinos, and black in the negro. Its colour undergoes material modification in some forms of disease. Thus, in iritis it assumes a coppery tint, and in jaundice a slight yellowish hue overspreads it. The posterior surface of the iris is lined with a layer of pigment cells termed the *uvea* (162), the use of which is to absorb those rays of light which fall on the front surface of the iris, and those which have acted on the retina. Two sets of muscular fibres enter into the composition of the iris; one disposed circularly (132), the other radially (131). The circular fibres constitute the sphincter pupillæ, but the radial fibres form the greater part of the iris. The former effect the contraction of the pupil, and the latter, acting as antagonists, dilate it. Nerve-twigs are found in the interstices of these fibres, together with the ramifications of arteries and veins. The nerves are derived from the ciliary nerves (116), the veins form the rootlets of the *venæ vorticosæ* (163) of the choroid, and the arteries terminate in the substance of the sphincter pupillæ in a fine plexus termed the circulus iridis minor (160), in opposition to the circulus iridis major (127, 128), which is situated at the periphery of the membrane.

Occupying a deeper situation than the cornea, the iris is less exposed to injury; but, on the other hand, it is liable to very serious affections. The commonest disease of this membrane is inflammation, or, as it is termed, *iritis.* This affection is characterised by loss of definition of the markings of the iris, a change in the shape of the pupil, and by the appearance of whitish deposits which may obstruct the pupil and lead to the formation of adhesions between the iris and the capsule of the lens. These complications may be avoided by instilling a solution of atropine into the eye, the effect of which is to maintain the pupil in a state of dilatation. If in spite of these precautions the pupillary area becomes occluded, improvement in vision may be effected by making an opening or artificial pupil in some part of the membrane.

5. Retina.—The retina (143) is the most important of the membranes of the eye, since it is the seat of the visual impressions. It is applied to the choroid without being attached to it; but, at the same time, only separates from it when extravasations of blood or serum occur between the two membranes. The detached portion then loses its perceptive power, and the field of vision presents hiatuses which make objects appear deformed.

Transparent and smooth during life, the retina becomes opaque and crumpled after death.

According to some observers, it terminates at the festooned border of the ciliary body (155); others believe that it is continued as far as the periphery of the lens; whilst others again, whose opinion we adopt, consider that it ends at the posterior border of the *zonule of Zinn* (152).

The centre of the retina presents a yellow oval spot with depressed centre, named the *fovea centralis* (141). Three millimetres to the inner side, and one millimetre below the yellow spot, is a lenticular disc of rosy tint and slightly concave, from which the retinal vessels emerge. This is the *optic papilla* (144). Valuable deductions in establishing the diagnosis of various ophthalmic and even cerebral diseases may be drawn from the modifications of colour presented by the optic disc. Thus inflammation of the optic nerve, or *optic neuritis*, gives to it a more or less intense red colour, and renders its outlines indistinct, whilst in cases of atrophy of the nervous elements of the optic nerve it assumes a white aspect, the pearly aspect of which contrasts strongly with the deep red colour of the fundus of the eye. By physiologists the optic papilla has been named the *punctum cæcum*, or blind point of the eye, because it is insensible to the action of light. It is easy to demonstrate this insensibility by repeating the ingenious experiment of Mariotte, which consists in drawing two circles on a sheet of white paper. If one eye be closed and one of the circles be fixed with the other, and the book be then gradually removed from the eyes, on reaching a certain point, about a foot distant, the circle will disappear, because at this distance its image falls on the disc or punctum cæcum. At the distance of about two yards a human figure may thus be wholly lost sight of. This experiment was first shown by Mariotte at the court of Charles II., who demonstrated to the courtiers the mode of mutually seeing each other without a head.

The papilla is blind because it is unprovided with pigment, and reflects in all directions the rays of light that fall on its surface. As the images are formed on the retina at the posterior pole of the eye, this must necessarily be the most sensitive part to the impression of light; it is, in fact, the position of the yellow spot, and not of the optic nerve, which, owing to the insensibility of the optic papilla, enters the eye eccentrically.

The retina is not only impressionable to light, but luminous sensations, termed *phosphenes*, can be excited in it by mechanical stimuli. Everyone is aware that a severe blow in the eye causes the appearance of numerous phosphenes. 'We see,' it is said, 'a thousand stars.' The investigation of the production of phosphenes under the influence of slight pressure on the globe with the tips of the fingers, or some solid body, is a means in common use in ophthalmic surgery for appreciating the state of the retinal sensibility.

The number of layers entering into the structure of the retina varies according to different authors. We shall admit five, namely, from without inwards, 1. The layer of rods and cones, or Jacob's membrane. 2. The granule layer, or nuclear layer. 3. The cellular layer, or layer of the grey substance. 4. The fibrous layer, or layer of medullary substance. 5. The internal, or limiting layer. Anatomists are unanimous in recognising the existence of the external layer, or membrane of Jacob. This layer is the most important in a physiological point of view, since it constitutes the recipient surface for visual impressions. It is formed by the juxtaposition of an infinite number of small cylinders named *rods*, disposed like the several elements in a mosaic. One extremity of each is in contact with the choroid, and the other with the hyaloid membrane. The general aspect of the extremities, the sectional area of each of which is about 3-1000ths of a millimetre, resembles a mosaic with microscopic tesseræ. Some of the rods present a dilated extremity like a club, and are then termed *cones*. At the yellow spot cones alone are present. These microscopic bodies, the rods and cones, may be compared in their functions to the nervous papillæ of the organ of touch. The central artery of the retina presides over the nutrition of the several layers of this membrane, and breaks up into an infinite number of capillaries in front of the layer of rods and cones, which explains the fact that under certain conditions they may be perceived.

6. Zonule of Zinn.—This fibrous membrane has the same form and general direction as the iris. The festoons of its periphery (152) give attachment to the retina, whilst the radii of its inner margin (151) surround the lens like a collar. This fibrous zone constitutes an organ of support which, on the one hand, stretches as far as the retina, and on the other maintains the lens in its vertical position, from which circumstance it has been termed the *suspensory ligament*. Its anterior surface presents a series of elevations and intermediate depressions, which interdigitate with the *ciliary processes* (153). If a small opening be made through the zonule of Zinn, an entrance is made into an annular and prismatic canal, bounded in front by this zone, behind by the hyaloid membrane, and internally by the border of the lens. If a little air be blown into this canal through the artificial opening, elevations are produced, according to Petit, resembling those in silver ornaments, to which the term 'godronné' has been applied. Hence the term of 'canal godronné,' or frilled canal of Petit (154).

(B.) Media of the Eye.

1. Aqueous Humour.—This limpid and transparent fluid occupies the space between the cornea in front and the lens behind, a space that is divided into two chambers by the iris—an *anterior* and a *posterior*. The quantity of aqueous humour is very small, being estimated at only eight drops; it can, however, if evacuated, be reproduced with great rapidity. The aqueous humour loses its transparency and becomes turbid in various diseases of the eye; it may also contain fibrinous flocculi, and blood or pus. Foreign bodies which have perforated the cornea are sometimes found in the anterior chamber, as are also tumours, or condylomata implanted on the iris, a dislocated lens, or cysticerci. The function of the aqueous humour is to refract the luminous rays which traverse it, and to maintain the regularity of the corneal curvature. After death the aqueous humour evaporates, and the cornea becomes flaccid.

2. **Crystalline Lens.**—The lens (147) has the form and dimensions of an ordinary hand lens. Anteriorly it is in contact with the aqueous humour, and its posterior surface is lodged in a hollow of the vitreous. It is contained in a transparent and elastic envelope named the *capsule of the lens*, which is attached by its deep surface to the hyaloid membrane (148). This capsule has the property of reproducing the lens, just as the periosteum has the power of reproducing bone, and it therefore presides over the nutrition of this organ. Galen has compared the capsule to the skin of an onion, but this comparison is more appropriate to the lens itself, which, like this bulb, is composed of laminæ concentrically disposed. The imbrication of these lamellæ can easily be demonstrated in the large and spherical lens of a boiled fish. Each lamella is formed by the apposition of a large number of prismatic, tubular, and dentated longitudinal fibres, the cavity of which is filled with a viscous fluid.

When the lens loses its transparency, it is said to be affected with *cataract* (from the Latin *cataracta*, a fall of water, because the ancients attributed its production to the descent of a humour upon the eyes). This alteration is the result of age, heredity, of certain diseases like cataract, or of wounds of the eye. Cataract is not, therefore, due to the formation of a skin over the eye, as is generally thought, but to an opacity of the lens. The operation of cataract consists in extracting this opaque body, which obstructs the entrance of the rays of light to the fundus of the eye.

3. **Vitreous Humour.**—The vitreous humour is a transparent fluid of gelatinous consistence analogous to that of raw white of egg, which occupies the posterior two-thirds of the cavity of the globe. It is contained in a special envelope named the *hyaloid membrane* (148, 149). The membrane and its contents together constitute the *vitreous body*. Numerous filaments spring from the internal face of the hyaloid membrane, which decussate in all directions, and limit areolar spaces, which freely intercommunicate with one another, as may be shown by making a puncture through any point of the hyaloid membrane. The vitreous humour may then be seen to flow away till only a delicate, sponge-like framework remains. In the fœtus the vitreous humour is traversed from behind forwards by the *capsular artery*, which disappears after birth.

Some anatomists incorrectly regard the zonule of Zinn (153) as a process of the hyaloid. It is true that these two membranes are adherent at the periphery of the zone (152), but they soon separate to enclose the festooned walls of the canal of Petit.

Diseases of the vitreous humour are rare; its fluidification, or *synchysis*, however, has been observed. Fibrinous flocculi may float in it, and give rise to subjective sensations named *muscæ volitantes*, but these more frequently proceed from disease of the retina or choroid. Digitalis taken in a certain dose produces similar troubles; hence its common name of *berlue.*

II. APPENDAGES OF THE EYE.

There are certain additional organs which enter into the formation of the visual apparatus and serve to protect and move the globe. These appendages are the eyebrows, the lids, and lacrymal apparatus; the muscles, and suspensory apparatus; and lastly, the cavity of the orbit in which they are contained.

1. The Eyebrows.—These are formed of two more or less projecting hairy arches, the function of which is to protect the visual apparatus from too intense light, and to prevent the entrance into the eye of irritating sweat descending from the brow.

Phrenologists are much in error in considering prominence of the supraciliary arch (14) a sign of intelligence. The bony projections on which the eyebrows are implanted have not, in point of fact, any relation with the development of the anterior lobes of the brain, since their size is entirely dependent on that of the cavities situated in the anterior part of the frontal bone, named the *frontal sinuses.*

The eyebrows owe their extreme mobility to the supraciliaris (22) frontalis and orbicularis palpebrarum (4, 5) muscles, the numerous fibres of which are inserted into the deep surface of the skin in this region.

Wounds of the eyebrows are sometimes followed by amaurosis, or loss of vision, though no explanation can be offered of this result. The sensory nerve of the skin of the frontal region and of the upper lid, is the supra-orbital, which emerges from the orbit by the fissure or foramen of the same name. Excision of this nerve has been recommended and practised in cases of neuralgia which have proved rebellious to other means.

2. Eyelids.—The eyelids are situated in front of the orbit, and are destined to protect the eyes in the same way as the eyebrows. They serve to favour sleep, and to facilitate the flow of tears over the ocular surface. Each eye possesses two eyelids, an upper and a lower. They are separated by the *palpebral* fissure, the extremi ties of which form the *commissures*, or *angles*, of the eye (canthi). The internal angle (7) is situated upon a lower plane than the external angle (6), and this disposition forms an inclined plane, by means of which the tears are directed towards the *lacus lacrymalis*, as the space between the internal commissure and the globe of the eye is named.

The free border of each lid has two lips, an anterior or cutaneous lip, into which the cilia are implanted, and a posterior or conjunctival lip, on which the Meibomian glands open (35).

The *cilia* (8), the principal function of which is to strain the air and prevent the entrance of foreign particles into the eye, are irregularly implanted into the border of the lids. Their roots, or bulbs, are each connected with two sebaceous glands named *ciliary glands*. In *blepharitis*, or inflammation of the free border of the lids, these glands secrete a large quantity of a yellowish, oily fluid, commonly known in France under the name of *chassie*. This affection, so common in infants of lymphatic temperament is further characterised by the falling out of the cilia, and by increased thickening and redness of the palpebral borders. If the inflammation become chronic, the border of the inferior lid is liable to become everted or inverted, in the former case constituting the affection known as *ectropion*—in the latter case, *entropion*. The lids are formed of five superimposed layers, which are in succession from before backwards: the *skin*; the *orbicular muscle* of the eyelids; the *tarsal fibro-cartilages*, with their *broad ligaments*; the *orbito-palpebral muscle*; and, lastly, the *conjunctiva*.

i. Cutaneous Layer.—The skin of the lids is fine and transparent. It is thickened by a layer of loose connective tissue, which is capable of being infiltrated with air, blood, or serum. The areolæ of this tissue never enclose fat cells, even when the subject is fat. The lid contains also in its substance *sudoriparous* and *sebaceous glands*. The abnormally abundant secretion of the former of these glands causes *ephydrosis*, or excessive sweating; that of the latter *seborrhœa*, and the lids are then coated with a layer of oil.

Hordeolum is the result of inflammation of the subcutaneous areolar tissue, and appears in close proximity to the cilia. Its common name of *compère loriot* has, no doubt, been applied to it on account of the yellow discoloration of the skin it produces, which calls to mind the tint of the plumage of the bird so named. Leeches should never be applied to the eyelids, both on account of the suffusion that takes place in the loose subcutaneous connective tissue, and because of the difficulty of stopping the flow of blood by pressing the wound against a resistant surface, the globe of the eye yielding to any pressure applied to it.

ii.—**Orbicularis Palpebrarum Muscle.**—This muscle is composed of two sets of fibres, the excentric, or orbital (4), and the concentric (5), or ciliary, which are paler, and situated in the lid itself. These fibres are attached to a fibrous cord named the tendon of the orbicularis (24), situated at the internal angle of the eye, and directed outwards to be inserted into the deep surface of the skin. The tendon of the orbicularis is bifurcated, the anterior branch, or *direct* portion, being that which is seen through the transparent skin, especially in a black eye; and it may also be made prominent by drawing the external commissure outwards. Its posterior or *reflected branch* (44) is attached to the crest of the *os unguis*, behind the *lacrymal sac* (37). There is yet another muscle, described as an appendage of the orbicularis muscle, and to which the name of Horner's muscle has been applied. This little muscle springs also from the *os unguis*, and terminates in two elongated processes, or tongues, in the substance of the lids, and near their ciliary border.

The use of the orbicular muscle is to close the lids. It plays an important part in effecting the act of *winking*, and in *sleep*. It is the antagonist of the *levator palpebræ superioris* muscle, or elevator of the upper lid (66), the name of which indicates its action, and its paralysis is characterised by an inability to close the lids, from which circumstance the name of lagophthalmus (λαγὼς, hare, ὀφθαλμὸς, eye) has been applied to this affection.

In contracting the orbicularis, it drags upon the skin of the temple and throws it into folds that have received the name of *crow's feet.* With age the skin becomes flaccid, and the folds are permanent.

iii. **Tarsal Fibro-Cartilages.**—These thin, long, and narrow laminæ (18, 21) occupy the free border of the lids, and form, so to speak, the skeleton of the palpebræ, the form of which they serve to maintain. They may be compared, as Cruveilhier has pointed out, to the pieces of wood that are placed beneath tables to prevent them from doubling up. They are kept in position by the *broad suspensory ligaments* (17, 19) of the lids which are attached to the borders of the orbit.

Imbedded in the posterior surfaces of the cartilages of both lids are small sinuous elongated canals, constricted here and there, which are named the Meibomian glands (35). These glands are more numerous in the upper lid, where from thirty to forty may be counted and are destined to secrete an oily matter which coats the edge of the lids and prevents the tears from flowing over the cheeks. The orifices of these glands are sometimes obstructed, and the products of their secretion accumulate in the excretory ducts, which become greatly distended, and may ultimately proceed to the formation of a cyst named chalazion.

iv. **Orbicularis Palpebrarum Muscle.**—Behind the broad ligaments each upper lid presents a membrane of fibrous aspect, that all authors have hitherto described under the name of *tendinous expansion of the elevator muscle of the upper lid* (36). Sappey considers this membrane to be muscular, and has called it the orbito-palpebral muscle. It extends from the palpebral conjunctiva (1) to the upper border of the tarsal fibro-cartilage. Invested by the conjunctiva in its two inferior thirds, it receives in its upper third the upper expansion (50) of the *orbital aponeurosis,* still called the *capsule of Tenon,* which we shall describe with the *suspensory apparatus* of the eye.

v. **The Conjunctiva** is a transparent mucous membrane uniting the globe of the eye to the eyelids. After having lined the deep surface of the lids for two-thirds of their height, it is reflected upon the globe of the eye, forming a circular groove named the oculo-palpebral *cul-de-sac.* The conjunctiva, therefore, may be regarded as composed of two parts, the *palpebral portion* (1) and the *ocular portion* (2). The *palpebral portion* is adherent to the tarsal cartilages; it presents numerous papillæ, which give to the free surface a rugous, or velvety aspect. The papillæ increase in size in *conjunctivitis,* and give to the patient the sensation of small grains of dust beneath the lid. The *ocular portion* is not directly adherent to the sclerotic, but is separated from it by connective tissue with large meshes, which permits it to glide over it. According to some authors, the ocular conjunctiva covers the anterior segment of the eye with the exception of the cornea, to the borders of which it is attached. Others, on the contrary, consider that it is continuous over the cornea, but is reduced to its epithelial layer.

The ocular conjunctiva of a horse, instead of being colourless and transparent like that of man, is of a deep brown colour, which makes the eye of this animal appear dark.

At the inner angle of the eye the conjunctiva is reflected upon itself, and forms a fold named the *plica semilunaris* (3), which disappears when the eye is directed outwards, as may be observed by experiments on one's self, or by an examination of the plate. This fold is the remnant of the third eyelid, or nictitating membrane of birds.

On the inner side of the semilunar fold is a mass of sebaceous glands, surmounted by small white hairs, the *caruncula lacrymalis* (43).

The conjunctiva contains follicles which secrete a peculiar fluid destined to facilitate the reciprocal movements of the eyes and eyelids. Some physiologists believe that these glands aid to some extent in the production of the tears, since this secretion persists even after the ablation of the lacrymal glands, and because, in *xerophthalmia* the conjunctiva becomes dry and sere, though the glands remain intact.

3. Lacrymal Apparatus.—The tears are chiefly secreted by the *lacrymal gland* (46), which lies in the lacrymal fossa (32), and is prolonged for some distance into the upper lid, on which account it has been divided into two parts, an *orbital* and a *palpebral* motion. This gland possesses from three to five ducts, which open by as many minute orifices into the upper and outer part of the oculo-palpebral *cul-de-sac.* During the action of winking the tears are distributed uniformly over the surface of the eye, and then accumulate in the internal angle of the orbit, in the triangular surface named lacus lacrymalis. From this reservoir the tears escape by capillary orifices, the so-called *puncta lacrymalia* (39), which perforate the cartilaginous tubercles that are found at the inner part of the free border of each lid. The muscle of Horner (45), which is inserted into these tubercles, is destined to make the puncta lacrymalia dip into the lacrymal sac by drawing them backwards and inwards. After having entered the orifices of the puncta the tears successively traverse the *lacrymal canals* (40), the *lacrymal sac* (37), the *nasal duct* (38), and are finally discharged into the inferior meatus of the nasal fossæ, or undergo evaporation in the double current of expired and inspired air.

If the secretion of tears undergo augmentation, owing to any psychical or physical influence, the excess flows over the cheeks, and the remainder passes by the ordinary channels into the nasal fossa. When too abundant to be evaporated, they flow away by the nose, and render the use of a handkerchief necessary, as may be observed in any theatre during an affecting representation.

According to M. Richet, the lower orifice of the nasal duct is often occluded by a fold of membrane, which plays the part of a valve and prevents the entrance of air into the lacrymal passages. This valve is far from being constant, and its absence explains the power that some people possess of making the smoke of tobacco escape by the eyes, or, more properly speaking, by the *puncta lacrymalia*.

Permanent overflow of the tears, or *epiphora*, is the consequence of more or less complete obstruction of some part of the lacrymal passages. This stoppage is occasioned in some instances by the presence of small calcareous deposits analogous to vesical calculi. It is remarkable, as Dr. Chéreau tartly observes, that all the instances that have been recorded are of women, the disposition of whom to shed tears is well known. Small rods of silver, termed Bowman's probes, are employed to restore the permeability of obstructed ducts, and are introduced into the nasal ducts through the previously slit-up canaliculi. This operation constitutes catheterism of the lacrymal passages. Dr. Gorecki has discovered a means of materially shortening the treatment, by combining catheterism with the passage of an electric current, the probe traversing the nasal duct acting as the negative electrode, and the positive being formed by a canula introduced through the nostril.

Inflammation of the lacrymal sac is generally the result of the accumulation of muco-purulent fluid in its interior forming *lacrymal tumour.* The description that we have given of the disposition of the lacrymal passages explains how it is possible that a woman cured her child affected with this disease by simple suction of the nose.

When suppuration is established in the lacrymal tumour, pus makes its way to the surface near the inner angle of the eye by an artificial course, which constitutes *fistula lacrymalis*, a disease difficult to cure, and sometimes incurable, in which case it has been proposed to alter the natural course of the tears, and to enable them to pass directly from the lacus lacrymalis into the nasal fossæ, by perforating the *os unguis* (79), which corresponds to the middle meatus (74).

The tears are colourless and saline, but in certain cases have been observed to be bloody. According to Professor Tillaux the secretion of tears is not continuous, and does not serve, as is generally imagined, to lubricate the surface of the eye, but has, as its principal function, to carry away particles of dust that fall upon the eye.

4. The Motor Apparatus.—The muscles which effect the movements of the eye are seven in number, *viz.*, the *elevator of the upper lid*, the *four recti*, and the *two oblique*.

i. The Elevator of the Upper Lid.—This muscle (66) arises at the bottom of the orbit, and terminates in the upper lid by an aponeurosis (36), named by M. Sappey the *orbito-palpebral muscle*, though authors generally regard it as the tendinous expansion of the elevator of the upper lid. In its action it is antagonistic to the orbicular muscle, and its paralysis is characterised by the drooping of the upper lid.

ii. Recti Muscles.—The recti muscles (54) are four in number, and are named respectively, in accordance with their position, the superior, inferior, external, and internal. They arise from the bottom of the orbit, the superior from the sheath of the optic nerve, and the three others from the tendon of Zinn, and, passing forward, are attached to the anterior segment of the sclerotic, near the margin of the cornea. Each muscle in contracting draws the pupil to its own side, the superior upwards, the inferior downwards, the internal inwards, the external outwards. The movement of circumduction of the pupil results from the successive action of these muscles. Paralysis of either of them determines a permanent deviation of the pupil in the opposite direction to the muscle paralysed, whilst its shortening draws the pupil to its own side. In these cases the subject is said to suffer from strabismus, or to squint, an affection that may be cured by the total, or partial, division of the muscle which draws the pupil to its own side.

iii. **Oblique Muscles.**—These muscles are two in number, and are termed the *great* and the *small*, or *superior* and *inferior*. They preside over the movements of rotation of the eye on its antero-posterior axis, and tend to draw the globe forwards, whilst the recti muscles act in an opposite direction. These two opposed forces neutralise each other, and tend to keep the globe of the eye in equilibrium. The *great*, or *superior oblique* (52), arises, like the recti, from the bottom of the orbit, and is directed forward to the *cartilaginous pulley* at the internal angle of the orbital margin, where it is reflected to be inserted into the posterior and upper segment of the sclerotic. The *small*, or *inferior* oblique (58), arises from the floor of the orbit near the lacrymal sac, and is inserted into the sclerotic below the insertion of the superior oblique. When acting it directs the pupil upwards and outwards, and aids in giving to the face a peculiar expression, which has led to the name *pathetic* being applied to it, in opposition to the name *contemptuous*, which has been applied to the superior oblique, the action of which is to direct the pupil downwards and outwards. The term *pathetic*, which has been applied to the nerve supplying the superior oblique, is therefore incorrect. By their combined action the oblique muscles prevent the eyes from rotating in accordance with the different movements of inclination of the head.

Paralysis of any one of the muscles produces *diplopia*, or double vision, as the patient inclines the head in a mode which varies with the muscle paralysed.

5. **Suspensory Apparatus.**—As a chestnut is contained in its capsule, the globe of the eye is enclosed in a fibrous shell, which permits movements of rotation, but prevents those of translation. All authors designate this envelope the *capsule of Tenon*. M. Sappey, however, who has made a special study of it, names it the orbital aponeurosis. It completely invests the

eye with the exception of the cornea, at the border of which it terminates. It furnishes a complete sheath to the muscles of the eye, and each sheath, except that of the superior oblique, presents near its anterior third a ligamentous expansion, or wing (50), which the old anatomists termed the orbital tendon, or tendon of arrest. The expansion of the sheaths of the superior and inferior recti terminate in the corresponding eyelid; those of the external and internal recti, which from their size are the most important, are attached to the orbital border by a terminal fasciculus of smooth muscular fibres named by M. Sappey *internal and external orbital muscles.* The expansion of the obliquus inferior is triangular, its inferior surface is in contact with the floor of the orbit, its upper surface blends with the sheath of the muscle, and its external surface is attached to the edges of the spheno-maxillary fissure, which is covered by the inferior orbital muscle.

The adhesions presented by this aponeurosis throughout its whole extent, says M. Sappey, have the effect of rendering it to a great extent immovable, and of maintaining it in a state of permanent tension, thus preventing the folds which would otherwise form in its walls if these accompanied the globe of the eye in its various movements. They have an additional advantage of which the surgeon may avail himself. For, in the operation of extirpation by the method of Bonnet the orbital aponeurosis in the act of cicatrisation folds in upon itself, and ultimately forms a small bulb, the movements of which are identical with those of the eye which has rested intact. The movements of an artificial eye adapted to this bulb are, in point of fact, so perfect, that they materially aid in concealing the defect; and, in one case which was shown to a group of students, no one was able, from its movements alone, to distinguish the true from the false eye.

6. **Cavity of the Orbit.**—This cavity is hollowed out of the face, and contains all the organs we have described. Its form is that of a four-sided pyramid, the base of which looks forwards and outwards, the summit backwards and inwards. The superior, inferior, and internal walls are represented by thin osseous lamellæ, which may be easily broken down, and separate the orbit from the cerebral maxillary and nasal cavities. This anatomical disposition explains the facility with which a wound of the orbit may affect the brain, and how tumours, polypous or others, which take origin in one of the neighbouring cavities, may break through the walls, and even destroy them, and invading the orbital cavity, lead to projection of the eye—that is to say, to exophthalmos.

On the outer side the eye projects beyond the base of the orbit, a disposition which augments the field of vision, but exposes the eye to injury on this side.

The cavity of the orbit contains, in addition, small masses of fat, which occupy the interspaces left between the organs of vision. This fat serves as a soft cushion for the globe of the eye to rest upon, and enables it to bear severe shocks without injury. Its absorption is very rapid in debilitated patients, and in those who suffer from cholera, which is the cause of the brown tint of the lids, and that sinking in of the eyes which gives their peculiar facial aspect to such patients.

SECTION II.

FUNCTIONS OF THE ORGANS OF VISION.

Of the Exciting Agent of Luminous Impressions.

ALTHOUGH the study of the laws of light belongs rather to physics than to physiology, it is indispensable, before describing the mechanism of vision, to state some of the chief points in optics.

Of Light.—Light is an imponderable agent, which renders objects visible. Two hypotheses explain the mode of its transmission. The oldest, termed the *emission theory*, suggested by Newton, has been rejected by the greater number of physicists; the other, named the *undulatory theory*, proposed by Huyghens, and supported by Descartes, holds undisputed sway at present in science. This hypothesis supposes that light emanates from luminous bodies, and that it reaches us by a series of undulations resembling those by which sound is propagated.

The transmission of light takes place in straight lines, and it is propagated with inconceivable rapidity. The astronomer Roemer demonstrated by observations made upon the satellites of Jupiter that light occupies about eight minutes in traversing the distance which intervenes between the earth and the sun; it must, therefore, travel at the rate of about 200,000 miles a second. It appears, nevertheless, that three years would elapse before the light emanating from the nearest fixed star would act on our retina, and thus, if such a star were obliterated from the heavens, it would still remain visible for the same space of time. It is not, therefore, astonishing that there are stars that have never yet been seen, a sufficient time not having elapsed for their light to reach us. The light reflected from the moon takes less than a second to reach the earth.

Reflection and Refraction.—Opaque bodies *reflect* luminous rays, the angle of reflection being equal to the angle of incidence. Transparent bodies, on the other hand, allow of their transmission, whilst at the same time they *refract* them—that is to say, change their direction, inclining them towards a perpendicular struck from the surface at their point of emergence. The law of refraction is demonstrated by the following experiment: Place a coin at the bottom of an opaque vase, and remove the vase from the eye till the coin can no longer be seen; if now water be poured into the vessel, the coin will reappear. To reach the eye of the observer the luminous rays proceeding from the coin must be broken, or refracted, in passing from the water into the air. For the same reason, a stick plunged into water appears broken at its point of immersion, and to shoot a fish we must fire below the point at which it appears to be. Similarly, the iris appears to be less deeply situated than it really is, since it is placed at the bottom of the aqueous humour.

Biconvex Lenses.—When luminous rays traverse a convergent lens—that is to say, a transparent body terminated by two spherical surfaces—they are refracted, and meet in a common centre termed the *principal focus* of the lens. They form at this point a *small and inverted* image of the object from which the rays emanate. Tinder placed in the principal focus is set on fire. In a well-formed eye, the retina is situated in the principal focus of the lens. If the retina lies behind this point, the eye is too elongated, and is rendered *myopic.* If, on the contrary, this membrane lies in front of the principal focus, the eye is too flat, and becomes *hypermetropic.* In order to make the principal focus coincide with the retina, divergent or biconcave glasses are supplied to myopes, whilst convergent or biconvex glasses are required by hypermetropic patients.

Decomposition of Light.—When a ray of direct sunlight is made to traverse a prism of glass, it is decomposed into a multitude of tints, amongst which *seven* principal colours may be distinguished, which, passing from above downwards, are in succession violet, indigo, blue, green, yellow, orange, and red. The *violet, indigo, green,* and *orange* colours are said to be *mixed colours,* because they are produced by the combination of two of the three *principal colours—yellow, blue,* and *red.* The term *complementary* is applied to two colours, one of which is a *principal* colour, the other *mixed,* the combination of which corresponds to that of the three principal colours, that is to say, to *white*. For example, *violet*, which is formed of *blue* and *orange*, is *complementary* to *yellow*, since if it be mingled with this principal colour, it produces white. For the same reason green is *complementary* to *red*, and *orange* to *blue*.

These colours are the same as are seen in the rainbow, which meteorological phenomenon is due to the decomposition of the solar rays in the drops of rain. A similar decomposition occasions the tints of twilight and morning. The varied hues of gems are due to the decomposition of light by their numerous facets.

The yellow and orange rays are by far the most stimulating, the blue and green, on the contrary, are the most agreeable to the eye, and hence glasses of the latter tints should be recommended to those whose eyes are impaired by disease. The green, however, still contains yellow rays, whilst the blue rays with the yellow reflex of artificial light give a greenish tint to all objects. It is preferable, on the whole, to employ lightly smoked glasses, which simply diminish the intensity of light. It may be observed, in passing, that those colours which are most widely distributed in nature—the green, the blue, and the grey—are precisely those that least fatigue the eye.

Hypothesis to Explain the Colour of External Objects.—In order to explain the colours of bodies, it has been suggested that they possess the power of absorbing or of reflecting certain colours; a blue material, for example, owes its colour to the fact that it reflects the blue rays and absorbs all the others. Bodies which appear black are those which absorb all the rays of light, whilst bodies which appear white, on the contrary, are those which reflect them all.

Aberration of Refrangibility of Lenses—Iridisation.—Solar light is not homogeneous. It is composed of rays of different kinds, which do not undergo refraction in the same manner, and which separate from each other in traversing a refracting medium. This dispersion is the cause of objects appearing with a fringe of iridescence when they are looked at through a prism, or, better still, through a glass lens. This inconvenience, due to the unequal refrangibility of the simple colours, is termed chromatic *aberration*. The optical instruments, lenses, and prisms termed *achromatic* (from ἀ, negative, and χρῶμα, colour), are employed to avoid this defect. The crystalline lens is not an achromatic lens, but the iridescent halo which surrounds retinal images is so small as to be almost imperceptible.

Aberration of Sphericity of Lenses.—*Aberration of sphericity* is another imperfection of lenses, and is due to the circumstance that the luminous rays do not unite into a single point or focus, a difference being observable according to whether the rays traverse the lens near its axis or near the periphery. Those which traverse the central part converge to nearly the same point; the others form so many distinct foci which interfere with the sharpness of any one image. In optical instruments the rays which fall on the periphery of the lens are suppressed by the use of a diaphragm pierced with a central opening. The same result is obtained in the eye by means of its natural diaphragm, the iris.

Course Pursued by the Rays of Light in the Eye.—Amongst the rays which are emitted by any luminous body, some fall on the sclerotic, by which they are reflected, whilst others fall on the cornea, which they traverse. The latter undergo here their first refraction towards the optic axis, and then continue their course through the aqueous humour without further change of direction, because the refracting index of this medium is almost identical with that of the cornea. When they have arrived at the bottom of the anterior chamber, those rays which strike the iris are reflected, and those which traverse the pupil—the only ones that are subservient to vision—fall on the crystalline lens, which refracts them anew; then, having undergone a final refraction in the vitreous humour, they form on the retina an inverted and very small image of the objects from which they emanate.

Inverted Images at the Fundus of the Eye.—The inversion of the images may be demonstrated by the following experiment. If the eye of an ox, the sclerotic of which has been thinned or removed at the posterior pole, be fixed in a hole in the shutter of a dark chamber, the inverted images of bodies placed in front of the eye may be actually seen. Magendie employed the eyes of white or Albino rabbits, because their sclerotic is extremely thin, and the choroid is destitute of pigment.

Physiologists have not as yet given a clear explanation of that optical illusion which makes us see objects not as they impress the retina, but upside down. The following explanation, however, appears to be the most rational. We localise the visual sensations in accordance with their relative position, without paying attention to the organic condition, which is of little importance to us. But that which is the top of the image upon the retina is, in regard to its external condition, below; and that which is the bottom of the image has its external condition above. Yet since these conditions alone govern the localisation, we place our sensations in the inverse order of the image, and in the same order as the external conditions. It is for this reason, therefore, that when we produce *phosphenes* by pressure with the fingers, the luminous circle appears to be external to the eye, and on the opposite side to that on which the pressure is applied.

The eye may be compared to that part of a photographic apparatus known under the name of the *dark chamber*. The iris is the diaphragm, the pupil is the aperture, the crystalline the convex lens, the choroidal pigment the blackened walls, and, lastly, the retina the screen on which the images of external objects are thrown. The analogy of the eye to a photographic apparatus is, however, pushed a little too far when it is suggested that the portrait of a criminal can be found fixed, after death, in the eye of his victim. Such an idea is to be found only in the pages of a novel.

Adaptation of the Eye for different Distances.—In order that an image may be sharply formed on the dull plate of a photographic apparatus, it is necessary, as has been already stated, that the screen should be situated in the principal focus of the biconvex lens. If the position of the object be changed, the focus will also alter, in accordance with the law of optics, that the closer the object approximates the apparatus, the more distant is the focus from the lens. With each variation of distance, therefore, the position of the screen must be altered to make it coincide with the corresponding principal focus. Photographers obtain this result by the aid of a rack and pinion, which approximates or removes the screen from the mobile object. But the eye is provided with a special apparatus—the ciliary muscle—which enables it to adapt itself or to be accommodated to all distances. This muscle plays the part of the rack and pinion; but, instead of causing the crystalline lens to alter its position, it modifies its power of convergence either by compressing the periphery, or, as appears to be more probable, by drawing forward the choroid coat and relaxing the suspensory ligament of the lens, and thus allowing it to become, by the action of its own elasticity, thicker. On this account the ciliary muscle is named the *muscle of accommodation*. It is not brought into play when distant objects are regarded, because the eye is so constructed that under these circumstances the images of external objects are naturally thrown with clear definition upon the retina.

The ciliary muscle only begins to act when attention is paid to an object that is about sixty-five metres distant from the healthy eye. The nearer the object is placed the greater is the amount of muscular effort that is exerted. The examination of near objects is consequently accompanied by more or less fatigue; that is, it is said, that such work 'draws the eyes.'

Eyes that have been deprived of the lens by a cataract operation are necessarily deprived of the power of accommodation, and such persons supply the want of the lens by using biconvex lenses of various power, some of which are adapted for near, others for distant vision.

Range of Accommodation.—The most distant point of distinct vision is called the *punctum remotum*, which, for the normal eye, is infinity; and the nearest point, that is to say, that point at which ordinary type can be read, is named the *punctum proximum*. M. Giraud-Teulon fixes this point at one metre, whilst the greater number of authors estimate it arbitrarily at twenty-five to thirty centimetres (twelve inches). The distance which separates the *punctum proximum* from the *punctum remotum* is termed the *range of accommodation*, because it is owing to the accommodation that the eye can traverse this distance. The *range of accommodation* of the myope is very limited; that of the presbyope and that of the hypermetrope differ but little from that of the normal eye.

Presbyopia.—As age advances, the lens loses its elasticity and becomes more rigid; it no longer obeys the action of the ciliary muscle, and loses by degrees its power of accommodation. This change commences about the age of forty. From this period the vision for distant objects, for which no accommodation is required, is still sharp, but that for near objects is obscured. In other words, the *punctum proximum* retreats several centimetres.

The attitude of a presbyopic person in reading is characteristic. He holds his book at a great distance from him, and seeks the light to compensate for distance by superior illumination. Presbyopia, therefore, properly regarded, is a disturbance of accommodation dependent on the age of the visual apparatus. The term, in fact, is derived from πρέσβυς, an old man.

Presbyopia is corrected by the use of convex lenses, which, however, are only serviceable for seeing near objects.

Sharpness of Vision.—In order to measure the acuteness of vision, ophthalmic surgeons employ letters of a definite size. A given letter or character of this scale, with sufficient illumination, ought to be seen by a normal eye at a certain distance. But if, in any case, those letters can only be seen at four metres which ought to be seen at eight metres with a normal eye, the acuteness of vision is said to be diminished one-half. It has been shown, with the aid of these scales, that the sharpness of vision diminishes with age, as well as in certain pathological conditions, such as anæmia, and in patients suffering from the toxic influence of lead, uræmia, the abuse of tobacco, etc. The diminution of visual acuteness constitutes *amblyopia* and its entire abolition, *amaurosis*. It is not true, as is generally stated, that persons have lost their vision by intently regarding lights; nevertheless, if they are very strong and close to the eye, they may cause temporary blindness, which, however, soon passes away.

Amongst other troubles of sharpness of vision, *hemeralopia*, or inability to see after sundown, may be mentioned, as well as *hemiopia*, characterised by inability to see more than one-half of objects looked at with the diseased eye; and lastly, *scotomota*, which are blanks in the continuity of the field of vision.

Size of Objects.—Each nervous element of the retina transmits to the brain one impression, and one impression only; and thus, in order that two objects, or two points of the same object, may be seen, their images must not fall on a single element, as happens in the case of blue powder mixed with grains of yellow powder, which collectively appear green. Each element of the retina has a diameter of from three to four thousandths of a millimetre; and thus, in order that the details of an object should be visible, its retinal image must measure more than three to four-thousandths of a millimetre. But physicists have calculated that at a distance from the eye of twenty centimetres (eight inches), the image presenting these conditions will proceed from an object measuring about a *twentieth of a millimetre* (1-500th of an inch). Below this limit, recourse must be had to the microscope, which, as everyone is aware, is an optical instrument intended to improve vision by enlarging objects.

Persistence of Impressions on the Retina.—It has been demonstrated by experiment that the momentary stimulus of a luminous body produces an impression on the retina which only lasts one-sixth of a second. If the body be moved with such rapidity that it only affects a given part of the retina for this period of time, the successive impressions are fused together, and appear to be continuous. The luminous train of the meteor and the circle caused by the rotation of a burning stick are thus explained. The persistence of impressions on the retina, again, is the reason that vision is not interrupted during the act of winking. The thaumatrope, the phenakistiscope, which under the name of zootrope has been recently so widely circulated; the wheel of Faraday, the kaleidoscope, the stroboscopic discs of Stampfer, are all optical apparatus which occasion illusions of the same kind.

Consecutive or Secondary Images.—The persistence of luminous impressions is proportionate to the duration and to the intensity of the stimulus. It is easy to demonstrate this by looking steadily for a certain period at a vividly illuminated object, and then suddenly closing the lids; the image of the object will be found to remain visible for several minutes. Images thus produced are named *secondary images.* If the object happens to have been coloured, the secondary image will appear of the colour *complementary* to that of the object; that is to say, if the colour of the object be *blue*, its image will be *orange*, and will be *green* if the colour of the object be *red.*

Secondary images and illusions of colour may still appear when the eyes are open. If a red wafer be fixed on a sheet of paper, and steadily regarded for some time, it will be found, on looking at another blank sheet, that a bright green image of the wafer appears.

The synthesis of this experiment may be made by looking into a stereoscope, one of the compartments of which is coloured *red* and the other *green.* In this case we perceive only one impression, that of *white.* Railway signals are red and green; and if the guard receive in each eye a fasciculus of light proceeding from one of the two signals, he will have the perception of white light, an error that might be followed by very serious consequences.

Irradiation.—When the source of light is very vivid, it constitutes a stimulus which becomes diffused around the portion of the retina impressed by it, and the object from which it emanates appears larger than it in reality is; and hence, of two circles having the same diameter, of which one is white and the other black, the white appears the larger. The application of the same principle leads thin and tall people to select tints of a bright colour, which adds to their apparent size.

On looking at the sun through a darkened glass, its contours appear more sharply and more clearly defined. The dazzling sensation experienced in passing from a brilliantly illuminated room into darkness, is also a phenomenon of irradiation.

Of two luminous impressions, the more brilliant alone is perceived by the retina. Hence the phosphorescence of the glow-worm, the light from metal at a dull red heat, and that of stars, are abolished by the light of day, and are only visible at night. Stars may be seen at midday, either during an eclipse of the sun or on inspecting a limited area of the sky from the bottom of a well, for the rays emanating from these stars strike the eye of the observer directly, whilst those of the sun fall upon it obliquely, and more or less weakened by successive reflections.

Perception of Colours—Daltonism.—Physiologists, supported by the facts of comparative anatomy, have assigned to the *rods* the duty of measuring the quantity of light, and to the *cones* that of appreciating its quality, that is to say, of determining shades. It appears that the *fovea* of nocturnal birds is composed of rods alone, whilst that of man is provided with cones alone.

Certain persons find it impossible to distinguish one or several colours, and red is that which is most frequently at fault. All red objects appeared green to the chemist Dalton, whence the name of Daltonism given to this affection. The historian, Sismondi was affected in a similar manner, and cherries appeared to him as green as the leaves of the tree. Daltonism is incompatible with certain occupations. Thus, D'Hombres-Girmas cites the case of a painter, who, in depicting a blue object, believed the colour of his composition coincided with that of an article of furniture coloured red. Marion reports the case of a tailor, of Plymouth, who inserted a piece of scarlet into a pair of black breeches. The disastrous consequences that may result from an incapacity to discern certain signals at sea, and on railways, may easily be conceived. The perception of sailors and railway guards and officials for colour ought, therefore, to be carefully tested. Daltonism may be transitory, as is especially the case when it owes its presence to some accidental cause, such, for example, as jaundice or the action of santonine. In such cases objects appear very yellow.

Single Vision with Two Eyes.—All objects form a distinct image at the bottom of each eye. We therefore see everything double; yet everything appears single to us. In this matter of appreciation of number, as in that of the position of objects, a mental operation founded on the sense of touch takes place, and rectifies the impression of sight. In the same way, insects which have compound eyes, have yet only simple or single vision.

In order that this vision of an object should appear single, it is necessary that the apex of the *optic angle* formed by the meeting of the two optic axes coincides with the object. This is proved by the fact that if an object be fixed with the two eyes, on one of them being displaced by pressing lightly upon it with the tip of the finger, the optic axes will not converge on the object, and this will appear doubled. Hence all who squint ought to see double if they look at any object with both eyes; but, in order to avoid this unpleasant diplopia, they pay attention to the impressions received from one eye alone. Wheatstone made the synthetic demonstration of this law of optics, by proving that the view of two bodies exactly alike produces only one sensation. In order to repeat his experiment, we must look through two hollow cylinders at two billiard balls placed in juxtaposition, when it will be found that only one is seen, which appears more distant than either alone, and which occupies virtually the point of intersection of the two prolonged optic axes.

Sensation of Relief.—When the same object is regarded fixedly with either eye, the images may be observed to be dissimilar. It is from the simultaneous perception of two different images that the sensation of 'relief' is obtained, a sensation that is impossible in monocular vision. The ingenious mind of Wheatstone founded the *stereoscope* on these considerations, the object of which is to make images represented on a plane surface appear in relief.

Appreciation of the Size and Distance of Objects.—Rays which emanate from the opposite extremities of a distant object, and converge upon the fundus of the eye, limit an angle termed the *visual angle*, the summit of which corresponds to the optic centre. The more remote the object and the more acute the visual angle, the smaller appears the object, notwithstanding that its size has in no way altered. It is well known that the trees at the end of an avenue appear less high than those near at hand. In the same way the moon, subtending a wider visual angle, appears to be of much larger size than the stars, which, however, are very far superior to it in magnitude.

When several objects are placed at an equal distance from the eye of the observer, the size of each will be estimated by him according to the size of the angle which each subtends. If the same objects be placed at different distances, the estimation of their size and of their distance from the eye will be essentially founded on a comparison with objects in their vicinity with the size of which we are familiar.

In order to estimate the size of a ship, we must see the men on board. If the sun and moon appear much smaller to us when in the zenith than on setting or rising, it is in part due to the fact that in the former case we are unable to compare it with any object in their vicinity, the real size of which is known to us. That which shows clearly enough that habit plays a very essential part in our estimates of size and distance, is that those who are born blind and who have been made to see, consider all objects to be upon the same plane, and take their apparent for their real magnitude.

Sanson's Images.—If a lighted candle be placed in front of a healthy eye, three reflections of the flame may be perceived, of which *two* are *erect*, and *one* is *inverted*. This last is produced by the posterior concave surface of the crystalline lens, whilst of the two former one is formed by the cornea, and the other by the anterior convex surface of the lens.

These images were discovered by Purkinje, but Sanson's name has been applied to them, because this physiologist was the first who employed them as a means of diagnosis in ophthalmic diseases. A defect in the curvature of the cornea will be revealed by the distortion of the large anterior erect image, and the presence of deposits on the capsule of the lens will interfere with the production of the two others. The inverted image alone will be obliterated if the opacity affects the proper substance of the lens.

Troubles of Refraction.—We have seen that the normal, or emmetropic (from ἔμμετρος, having a limit), eye is an optical apparatus so constructed that the images of distant objects are thrown with sharpness on the retina. But all eyes are not so constructed. In some the eye is too flat, and the images are formed behind the plane of the retina. Such eyes are termed *hypermetropic* (from ὑπὲρ, beyond, μέτρον, measure, and ὤψ, the eye). In others the eye is too long, and images are formed in front of the plane of the retina. In such cases the eye is said to be *brachymetropic* (from βραχὺς, short). This anomaly of construction has always been termed *myopia.* We shall immediately refer to the cornea. It is not unusual to observe, in the same subject, one eye myopic, and the other hypermetropic. It is even possible for the eye to be hypermetropic in one diameter, and myopic in the other, which constitutes *astigmatism.*

1. **Hypermetropia.**—This anomaly of vision must not be confounded with presbyopia. Presbyopia only occurs in elderly persons. It depends on advancing age, when the lens loses its elasticity and thus occasions progressive diminution of the faculty of accommodation. This is the reason that, in presbyopia, vision for near objects becomes gradually impaired, whilst vision for distant objects, for which accommodation is not required, remains normal. Hypermetropia, on the contrary, is a congenital affection, and as the image, even for distant objects, falls behind the retina, the muscle of accommodation is brought permanently into play to augment the convergence of the lens, and to cause the image to fall on the retina. The closer the object is to the eye, the greater is the muscular effort that is demanded; hence persons who are thus affected are incapable of working at near objects for any length of time. Congenital hypermetropia does not, as a rule, become apparent till about the age of twenty to thirty; because it is only at this period that the essential agent of accommodation, the ciliary muscle, begins to be fatigued after some moments of sustained exercise. To sum up. The presbyopic person sees well at a distance, and not at all near at hand, whilst the hypermetrope sees well both distant and near objects, but his vision is rapidly fatigued.

Convex glasses are employed to correct hypermetropia, as well as the weakness of the power of accommodation, or *accommodative asthenopia*, which results from it. And after what has been said, it will be understood that glasses are chiefly serviceable for the vision of near objects.

2. Myopia.—Myopia is the opposite condition to hypermetropia. The vision of the myope is confused, or absolutely defective, for distant objects, whilst it is very clear for near objects, a fact that accounts for the small handwriting of myopic patients. The eye of the myope being, as we know, preternaturally elongated, it is necessary that objects should be very closely approximated to it in order that their images should fall on the retina. Hence the position assumed by them in reading. The *punctum remotum*, or most distant point of distinct vision, is therefore no longer, like that of the normal eye, infinity, but often only a point at some yards distant, or even less, from the eye. The *punctum proximum*, or near point of distinct vision, is, on the contrary, only some centimetres distant from the eye. As the myope grows old, his eyes have a tendency to become presbyopic; but the change that this state induces in the conditions of vision consists only in causing the *punctum proximum* to retreat a few centimetres from the eye. The vision of the myope, therefore, does not, as is usually imagined, undergo any noticeable improvement with age.

The myope, only being able to see near objects quite clearly, is obliged to keep the optic axes in such a degree of convergence, as soon causes fatigue of the recti interni, which is termed *muscular asthenopia*. When the eyes are no longer in use, the internal recti muscles, fatigued, yield to the action of their antagonists, the recti externi, which draw the eye to their own side, and thus produce an external squint.

The pupil of the myope is almost always in a permanent state of dilatation. This disposition is somewhat troublesome, since it allows too large an amount of light to enter the eye, which interferes with clearness of vision by occasioning circles of diffusion. To remedy this inconvenience, those who are affected with that vice of accommodation constantly wink their eyes; hence their name of myopes, from the Greek *μύειν*, which means to wink. We now understand why the myope sees more distinctly objects at which he looks through a pin-hole in a card, since he in this way diminishes the intensity and the quantity of light. It is with the same object that myopic women instil into each eye, before going to a *soirée*, a drop of eserine collyrium, which has the property of contracting the pupil.

Contrary to the hypermetrope, who only employs spectacles to look at near objects, the myope ought to follow the advice of

V. Gräfe, and only use his glasses when looking at distant objects.

The remedy for the condition of myopia is the employment of biconcave or dispersing glasses; and a myope is said to be myopic to one-tenth, if his myopia is neutralised by a concave glass of ten inches focus.

Young French conscripts, by habituating the eye to become adapted for short distances, and thus inducing myopia, endeavour to obtain exemption from military service; but the degree required for exemption by law can only be reached with difficulty, and in general any attempts to do so result only in enfeebling the vision.

In order to be exempted from *active service*, letterpress must be read very near the eye, or at a distance of twelve inches (thirty-five centimetres), with a No. 6 or 7 biconcave glass; or he must be able to distinguish distant objects with a No. 4 concave, or read with these glasses, at a minimum distance of five metres, large type (No. 20 of Jäger's test types). Exemption from active service then can only be obtained when there is a marked degree of myopia, a degree that has been satisfactorily ascertained to amount to one-fourth.

The myope is considered to be admissible to the *auxiliary service* when the impairment of his vision does not reach the degree which effects exemption, but which is sufficiently pronounced to require the use of glasses, such, for example, as amounts to from one-fifth to one-fourth. The use of glasses has its inconveniences, because objects appear larger in proportion to their proximity, and the myope seeks willingly this enlargement, which he, however, can only obtain at the expense of his sight. A myope should not, therefore, hold his work at a less distance than from fourteen to fifteen inches, and should stoop as little as possible, to avoid congestion of the vessels of the head, and consequently of the membranes of the eye.

3. **Astigmatism** is also a trouble of refraction which is usually characterised by asymmetry in the curvature of the cornea in different meridians. The most frequent alteration is in the vertical meridian. Astigmatism may be myopic or hypermetropic, according to the degree of curvature in the defective meridian. When an eye affected with astigmatism looks at a plate on which horizontal and vertical lines are drawn, only one set can be distinctly seen. This anomaly of vision is corrected by the employment of convex, or concave, cylindrical glasses, according to the nature of the astigmatism.

Illusions and Hallucinations of Vision.

Illusions of sight are errors of judgment in regard to certain phenomena of light seen by all, whilst *hallucinations* are subjective sensations of vision which are peculiar to the individual.

Amongst optical illusions we shall cite the "relief" produced by the stereoscope; the perspective of tableaux; the effects obtained with various amusing optical instruments, such as the zootrope, and the magic lantern; illusions due to refraction of light, such as the mirage, the giant of the Brocken, the fata Morgana, the rainbow, the thaumaturges of antiquity and of the middle ages, and even by the physicist Robin in the present day—in all of which cases apparitions and spectres are invoked by an application of the laws of the reflection of light. Thus Nostradamus made Marie de Medici see that the throne of the Bourbons was destined for her.

Hallucinations, or visions, are frequent amongst the insane, but, like those of hearing, may occur without any serious mental disturbance. The labarum that Constantine the Great saw in the sky; the apparition of St. George aux Croises; the phantom which appeared to Brutus on the night before the battle of Philippi; the apparition of Apollo to Galen when the god directed him to give himself up to the study of medicine; the celestial visions of St. Geneviève; the apparition of St. James to Charlemagne in the Milky Way; that of the angel Gabriel to Joan of Arc; the visions of Mahomet; the lighted torches of Luther; the armies that Ravaillac saw rising in the air many days before the assassination of the king; the angel who presented himself to Jacques Clement, desiring him to kill the tyrant of France; the scorpions that the Cardinal de Brienne saw in his bed; the gigantic woman who appeared to Oliver Cromwell, predicting to him that he would one day be the greatest man in England; the visions of Charles XI., which prophesied to him the death of Gustave III. and the judgment of Ankarstroem, his assassin; the spectres which surrounded the bed of Richard III.; the hideous faces covered with blood which appeared unceasingly to Charles IX. after the massacres of St. Barthélemy; the visions of Tasso; the abyss that Blaise Pascal saw ever open before his feet; the spectre which presented itself to Spinoza in his retreat at Rheinbourg; that which sometimes visited Byron; the old woman who appeared to Bernadotte, king of Sweden; and, finally, the star that Napoleon I. showed to General Rapp in 1806, are all so many visual hallucinations that are compatible with reason.

Certain substances, like datura, stramonium, hyoscyamus, solanum somniferum, belladonna, opium, haschisch, alcoholic liquids, chloroform, and the protoxide of nitrogen have the power of inducing the transient appearance of hallucinations to the sight. The water of Lethe, the water of Mnemosyne, the Ciceion, and other mysterious beverages that have been composed and taken when prophetic dreams have been invoked as an initiation into the mysteries of Eleusis were probably prepared with these substances.

Hallucinations of vision occur in some forms of disease, such as catalepsy, hypochondriasis, chlorosis, chorea, and rabies.

GENERAL REFERENCES TO THE NUMBERS CONTAINED IN THE PLATES.

1. Palpebral conjunctiva.
2. Ocular conjunctiva.
3. Semilunar fold of the conjunctiva (plica semilunaris).
4. Periorbital portion of the orbicularis palpebrarum muscle.
5. Palpebral and ciliary portion of the orbicularis palpebrarum muscle.
6. Outer angle of the palpebral fissure (external canthus).
7. Internal angle of the palpebral fissure (internal canthus).
8. Ciliary border and cilia.
9. Zygomaticus minor muscle of the left side.
10. Fibres of the corrugator supercilii decussating with those of the orbicularis palpebrarum.
11. Superior maxillary bone.
12. Infra orbital nerve.
13. Malar bone.
14. Supraciliary arch.
15. Frontal bone.
16. Temporal fossa.
17. Superior broad ligament.
18. Superior tarsal fibro-cartilage.
19. Inferior broad ligament.
20. Orifices of the Meibomian glands on the ciliary border of the lid.
21. Inferior tarsal fibro-cartilage.
22. Corrugator supercilii muscle.
23. External palpebral ligament.
24. Straight tendon of the orbicularis.
25. Nasal bones.
26. Lateral cartilage of the nose.
27. Septal cartilage.
28. Supplemental cartilaginous lamellæ.
29. Nasal cartilage.
30. Ala nasi.
31. Ascending process of the superior maxillary bone.
32. Fossa for the lacrymal gland.
33. Nasal fossæ.
34. Maxillary sinus.
35. Meibomian glands.
36. Orbito-palpebral muscle, with the expansion of the levator palpebræ superioris.
37. Lacrymal sac.
38. Nasal duct.
39. Lacrymal papillæ, at the apices of which are the puncta lacrymalia.
40. Lacrymal canaliculi.
41. Antero-internal wall of the nasal duct.
42. Antero-external wall of the nasal duct.
43. Caruncula lacrymalis.
44. Reflected tendon of the orbicularis palpebrarum.
45. Horner's muscle.
46. Principal lacrymal gland.
47. Accessory gland and excretory ducts of the lacrymal gland.
48. Capsule of Tenon, with the orbital aponeurosis.
49. Fasciæ of the recti muscles or prolongations of the first order of the capsule.
50. Tendinous fasciculi or prolongations of the second order.
51. Internal and external unstriated orbital muscle terminating in a tendinous expansion.
52. Fascia of the tendon of the superior oblique muscle.
53. Internal surface of the anterior segment of the capsule of Tenon.
54. Insertions of the recti muscles into the sclerotic.
55. Anterior segment of the sclerotic.
56. Iris.
57. Posterior segment of the globe of the eye.
58. Inferior oblique muscle.
59. Internal surface of the posterior segment of the capsule.
60. Tendon of the superior oblique.
61. Cartilaginous pulley of the superior oblique.
62. Orifice for the passage of the optic nerve.
63. Fascia of the inferior oblique.
64. Superior oblique muscle.
65. Optic nerve.
66. Levator palpebræ superioris muscle.

67. Fasciæ of the recti muscles.
68. Fascia of the superior oblique muscle.
69. External surface of the posterior segment of the capsule.
70. Infra-orbital nerve.
71. Os planum of the ethmoid.
72. Os unguis.
73. Crista unguis.
74. Middle meatus and middle turbinal bone.
75. Inferior meatus and inferior turbinal bone.
76. Superior nasal spine and fissure.
77. Sphenoid bone.
78. Malar bone.
79. Infra-orbital groove.
80. Spheno-maxillary fissure.
81. Sphenoidal fissure.
82. Optic foramen.
83. Orbit.
84. Lacrymal fossa.
85. Pterygoid process.
86. Posterior aperture of the nasal fossæ.
87. Clinoid process.
88. Sella turcica.
89. Frontal sinus.
90. Sphenoidal sinus.
91. Sphenoidal fissure.
92. Optic foramen.
93. Cribriform plate of the ethmoid.
94. Crista galli.
95. Decussation of the fibres of the orbicularis and corrugator supercilii.
96. Points of attachment of the internal and external recti muscles to the sclerotic.
97. Openings for the passage of nerve fibres springing from the ciliary nerves and distributed to the cornea.
98. Internal rectus muscle.
99. Inferior rectus muscle.
100. Superior rectus muscle.
101. External rectus muscle.
102. Inferior oblique muscle.
103. Reflected tendon of the superior oblique muscle.
104. Anterior and superior ciliary arteries.
105. Anterior and internal ciliary arteries.
106. Anterior and external ciliary arteries.
107. Anterior and inferior ciliary arteries.
108. Branches of the anterior ciliary arteries penetrating the sclerotic to supply the ciliary muscle.
109. Branches of the posterior ciliary arteries.
110. Optic nerve.
111. Arteria and vena centralis of the retina.
112. Superior choroidal veins.
113. Inferior choroidal veins.
114. Short posterior ciliary arteries.
115. Long posterior ciliary arteries (external and internal) accompanied by a ciliary nerve.
116. Ciliary nerves.
117. Anterior opening of the sclerotic, the bevelled edge of which appears to project over the cornea for about two millimetres below, one millimetre above, and half a millimetre on the sides.
118. Venous canal of Schlemm, or of Fontana.
119. Posterior aperture of the sclerotic for the passage of the optic nerve.
120. Transparent cornea.
121. Openings for the passage of the ciliary nerves and for the branches of the posterior ciliary arteries.
122. Internal surface of the sclerotic tinted owing to the presence of pigment cells detached from the choroid. Some authors make a special layer of these cells, and name it the lamina fusca.
123. Choroid.
124. Cellular layer of the choroid.
125. Choroidal zone of the ciliary muscle.
126. Ora serrata.
127. Circulus arteriosus major iridis.
128. Anterior ciliary arteries.
129. Tendinous ring of Döllinger, from which the ligamentum pectinatum arises.
130. Iris.
131. Radiated fibres.
132. Circular fibres.
133. Apertures through which the trunks of the superior and inferior choroidal vessels pass.
134. Superficial or cellular layer of the choroid.
135. Openings through which the branches of the short posterior ciliary arteries pass.
136. Middle or vascular layer of the choroid.
137. Branches of the posterior short ciliary arteries, which are distributed beneath the venous plane of the middle or vascular layer of the choroid.
138. Deep layer of the choroid, or chorio-capillaris.
139. Choroidal pigment.
140. Opening for the optic nerve.
141. Yellow spot and fovea centralis.

142. Bifurcation of the arteria and vena centralis retinæ into an ascending and descending branch.
143. Retina.
144. Optic papilla or disc.
145. Superior and inferior branch of the arteria centralis retinæ.
146. Superior and inferior branch of the vena centralis retinæ.
147. Crystalline lens.
148. Anterior hyaloid membrane.
149. Posterior hyaloid membrane.
150. Zonule of Zinn. Anterior wall of the canal of Petit (canal godronné).
151. Anterior or radiated border of the zonule of Zinn.
152. Posterior or festooned border of the zonule of Zinn.
153. Ciliary processes of the zonule of Zinn.
154. Canal of Petit.
155. Festooned border of the choroid.
156. Layer of pigment covering the ciliary processes.
157. Ciliary processes deprived of their pigment.
158. Superficial or radiated plane of the ciliary muscle.
159. Deep or circular layer of the ciliary muscle.
160. Circulus arteriosus iridis minor.
161. Termination of the ciliary arteries in the iris.
162. Uvea.
163. Origins of the venæ vorticosæ.
164. Ciliary body.
165. Base of a ciliary process; the apex, which is sometimes bifurcated, is at the opposite extremity.

THE END.

LONDON: BAILLIÈRE, TINDALL, AND COX, PRINTERS.