THE

# ACCOMMODATION

OF

# THE EYE TO DISTANCES.

BY

WILLIAM CLAY WALLACE, M. D.



NEW YORK:
JOHN WILEY, 161 BROADWAY;
AND 13 PATERNOSTER ROW, LONDON.

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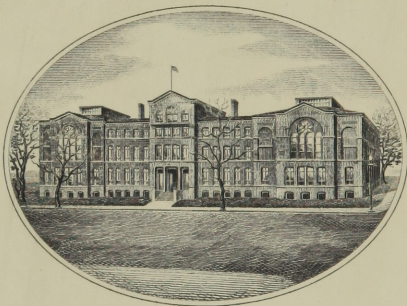

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The substance of the following essay has already appeared in Silliman's Journal for 1835; the London Medical Gazette for 1842; and the Boston Medical and Surgical Journal for 1844.

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Professor Mackenzie, in his Physiology of Vision, thus concludes the chapter on the Adjustment of the Eye to Distance: "Sir David Brewster observes, that 'there is no part of the physiology of the eye which has excited more discussion than the power by which it accommodates itself to different distances.' I fear we must also join with him in the following remark: 'Although the most distinguished philosophers have contributed their optical skill, and the most acute anatomists their anatomical knowledge, yet, notwithstanding all their combination of science, the subject is as little understood at the present moment as it was in the days of Kepler, who first attempted the solution of the problem.'"

Notwithstanding the assertion of one of the most eminent in the science of optics, and the apparent assent of one equally distinguished in the science of ophthalmology, I believe that the method by which the eye is adjusted can be demonstrated as clearly as any other truth in physiology.

The adjustment of the eye has been ascribed—1, to alteration of the form of the organ; 2, to alteration of the diameter of the pupil; 3, to muscularity of the crystalline lens; and 4, to alteration in the position of that lens.

1. *Alteration of Form.*—Kepler, who first pointed out the necessity of means of adjustment, ascribed it to the action of the ciliary processes, which acting *as* a muscle, and all contracting together like a diaphragm, produced an elongation of the eye. Although the central points of attachment are not sufficiently strong to effect an elongation of the axis of the organ, yet it will be shown that the theory of contractions of the diaphragm, by producing other changes, is nearer the truth than most of the theories which followed.

When the ciliary processes, which Kepler did *not* assert to be muscular, were proved to be vascular membranes, the alteration in the form of the eyeball by pressure of the recti muscles producing increased convexity of the cornea, or of the obliqui causing elongation of the axis of the organ, was supposed to be the means by which the effect is produced. In the seal and the green turtle there is a muscle for the purpose of compressing the eyeball, and accommodating the organ to distinct vision either in air or in water; but when no muscle for the specific purpose exists, the external muscles could effect adjustment only in one direction, and the focus would be altered with every motion. After the operation for cataract the muscles and cornea are as perfect as ever, yet the power of adjustment is lost; glasses of different powers being necessary to view near and distant objects. After the operation for strabismus, the eye can be adjusted as well as before it, even when one of the obliqui has been divided. Operations for the cure of myopia, by dividing the external muscles, are therefore barbarous and unscientific.

It is admitted, that the eyes of all animals are constructed in adaptation to the known laws of the refraction of light; that rays will deviate from straight lines and be collected in a focus only when they pass from rarer to denser media. Now granting that pressure of the external muscles produces increased convexity of the cornea, rays of light proceeding from an object under water to the eye of an animal immersed in the same fluid, would not by that means pass to a medium materially denser, and would not undergo sufficient refraction. Increased convexity of the cornea could not be produced in the eyes of some animals, for the sclerotica is sometimes so firm that no pressure of the external muscles could produce any alteration. In the sturgeon the sclerotica consists of unyielding cartilage ; and firmness is given to the sclerotica of the sword-fish by an osseous tissue within its lamellæ.

It is generally asserted that the osseous ring at the anterior portion of the sclerotica in birds can be so compressed by the external muscles, that the cornea may be made more convex, and that they are thus endowed with their extraordinary powers of near and distant vision. We should accordingly expect that where the ring is largest and strongest the muscles would be strong in proportion. The osseous ring in the owl is, compared with the size of the organ, larger than in any other bird, yet there is not a single muscle by which it can be moved ; consequently the ring cannot be drawn against the posterior part of the eye when there is nothing to draw it. It is difficult to conceive in what manner muscles for moving the eye could be adapted to an organ of such extraordinary form, as there is not room enough in the orbit to contain muscles of sufficient size to operate with such a disadvantageous lever. The most probable use of the osseous ring is to give firm attachment to the ciliary body.

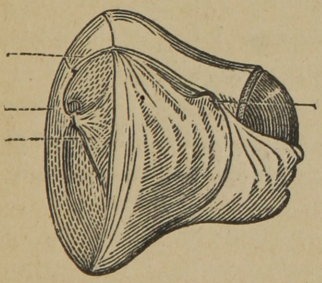


*Fig.* 1. Eye of the Owl.

The hypothesis of Crampton, that the form of the cornea could be altered by the contractions of a muscle at its circumference, cannot be maintained, for the fibres which he discovered in the eyes of birds are so arranged that the effect could not be produced.

2. *Alteration of the Diameter of the Pupil.*—As the eye is constructed on the same principle as the camera obscura, it is evident that alteration of the diameter of the pupil can have no more effect in producing in the eye a distinct image of objects at different distances, than alteration of the diameter of the aperture for the admission of light can produce a well-defined picture in a camera obscura. The diameter of the pupil is changed with every variation of light, yet the focus is not disturbed; and on looking through a pin-hole in a card, adaptation to distance is just as necessary as in vision with the naked eye.

3. *Muscularity of the Crystalline Lens.*—The fibres of the crystalline, prismatic in form and brittle in consistence, are totally different from muscular structure; and if they really did possess contractility, there is no point of attachment from which the fibres could act. In a certain species of hawk the crystalline is a plano-convex, and in all animals it is so exquisitely cut, if I may use the expression, that the irregular contraction of muscles would produce irregular refraction. In aquatic animals, in which the crystalline is very dense, the fibres are separated with so much difficulty that it is not probable they could slide over each other in such a manner as to produce the supposed effect. Sir D. Brewster has ascertained that in these animals the fibres of the crystalline are dovetailed into each other by a species of teeth, which would prevent any change in the configuration of the refracting medium.

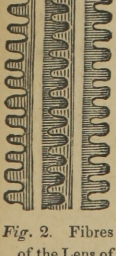


*Fig.* 2. Fibres of the Lens of the Cod. From Roget.

4. *Alteration of Position of the Crystalline Lens.*—The theory that the position of the crystalline is changed by the muscularity of the ciliary ligament, was supported by Porterfield and afterwards by Knox, yet they have neither shown how the fibres could be demonstrated nor detailed the method by which the change of position is effected.

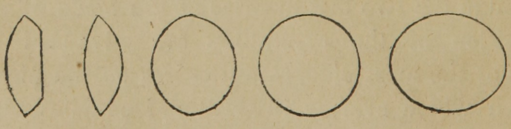
Hueck compares the ciliary body to the iris, of the contractility of which there is no doubt, but waives the question of its muscularity. He supposes that by contraction of the fibres of the ciliary body, the fluid contained in the upper angles of the ciliary zone is forced into the canal of Petit, the posterior wall of which yields so as to present a concave surface; by the pressure thus produced, the middle anterior portion of the vitreous body advances, and the lens is pushed before it, while the displaced aqueous humor finds room in the canal of Fontana.

Professor Mackenzie assumes, "that the pupil and ciliary ring are antagonists; so that, while the pupil contracts, on our directing our attention to near objects, the ciliary circle expands, and when we look at distant objects the pupil expands, and the ciliary circle contracts around the lens. If it be asked what purpose could be served by such a motion of the ciliary circle, the answer must be merely hypothetical, and amounts to a conjecture, that as the ciliary circle expands, the crystalline is allowed to advance towards the pupil, but that by its contraction, the crystalline is made to retire towards the retina."

Although the two last theories of the mode of altering the position of the crystalline are advanced by the authors of the most elaborate treatises on the physiology of vision which ever were written, I cannot understand how the change of position of the crystalline could be thus produced.

That the crystalline advances when the eye is directed to near objects, is supported by the experiments of Hueck. After a hawk had fasted two days he placed it on his lap at the end of a table, on which he laid a piece of meat, fastened by two strings. When the meat was drawn towards the bill of the animal the iris was observed to become convex, especially at its upper portion; and when the meat was drawn back by an assistant, the iris immediately became flatter. Similar results were observed in the parrot, the fox, and the lynx. Dr. H. placed the recent eye of a pup in an opening made in a board, and observed on the posterior surface of the sclerotica, which in this animal is thin and nearly transparent, the distinct image of a window and the indistinct one of a key, which was nearer. He passed a needle at the distance of a line from the margin of the cornea into the middle of the lens, and when the latter was moved carefully forward the image of the key was well defined, whereas that of the window was indistinct. By looking in profile at the iris of an individual, who, with one eye shut, looked with the other at an object five inches distant, the iris was observed to project and become convex; but when the subject looked at a distant object, it again became flattened.

As the structure of the eye in the various classes of animals necessarily differs according to the medium in which they live, and the range of vision which they require, the mode of adjustment also varies. I shall now proceed to demonstrate the different methods by which the motions of the crystalline are produced.



*Figs.* 3, 4, 5, 6, 7.

The form of the crystalline is either, *a*, a plano-convex; *b*, a double convex; *c*, an oblate spheroid; *d*, a sphere;

or *e*, a prolate spheroid. (See *Figs.* 3–7.) When the crystalline is a perfect sphere there is no ciliary body, because the eye can be adjusted by a less complicated arrangement.

## ADJUSTMENT OF SPHERICAL LENSES.

**1, Campanula Halleri. 2, Falciform Membrane. 3, Membranes of Vitreous Humor. 4, Cartilages of Sclerotica.**

The spherical lens is suspended by a ligament which is formed by the membranes of the vitreous humor, and is sometimes covered with pigmentum nigrum. Beneath the crystalline there is a muscle (the campanula Halleri), which, though it varies in shape and size, is very conspicuous in the halibut, the dolphin, and the striped bass. In the halibut (hippoglossus vulgaris) the muscle is hatchet-shaped, and proceeds diagonally from the lower pole of the crystalline body to be attached slightly to the uvea, but firmly to the anterior and lateral portions of the membranes of the vitreous humor. In the dolphin, where

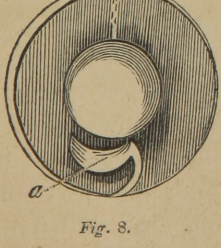



*Fig.* 8.

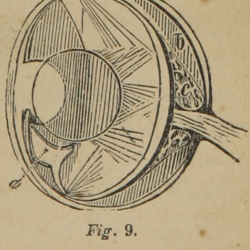



*Fig.* 9.

*Fig.* 8. Posterior view of the anterior segment, and *Fig.* 9, lateral section of the eye of the halibut. *a*, *a*, campanula Halleri. *b*, Gelatinous fluid.

the attachments are firmest, and in the striped bass (labrax lineatus), the muscle is triangular, and passes through a loop at the back of the iris before being inserted into the membranes of the vitreous humor. When

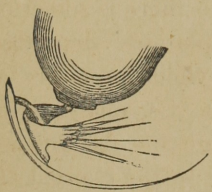


*Fig.* 10.

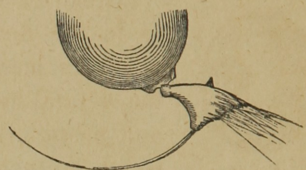


*Fig.* 11.

*Fig.* 10. Mode of attachment of the campanula Halleri to the lens and the vitreous humor, in the striped bass. *Fig.* 11. The same, with the campanula unfolded.

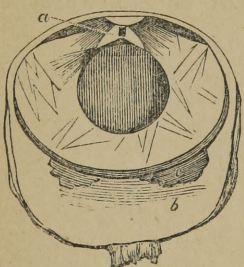



*Fig.* 12.

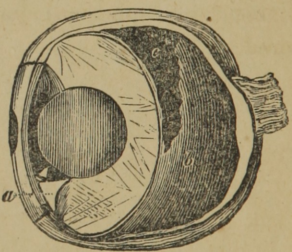



*Fig.* 13.

*Fig.* 12. Eye of the striped bass with the lens depending from the campanula, *a*. *Fig.* 13. Lateral view of the same in the natural position. *b*, Fat. *c*, Choroid gland.

the muscle, which is supplied by a large branch of the third pair of nerves, contracts, the crystalline approaches the cornea, and when it is relaxed the crystalline is drawn back by the elasticity of the membranes of the vitreous humor, some of which passing through the retina at a line that, in animals furnished with spherical lenses, divides the lower portion of the tunic, are firmly fixed to the choroid.

The campanula Halleri has, by some, been described as the ganglion of the crystalline; by others, as a cartilaginous body; but so far as I can ascertain, its muscular character, its passage through the loop at the back of the iris, its attachments and use, were unknown until 1834, when I pointed them out.

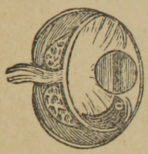


*Fig.* 14.
*a*, Falciform membrane.

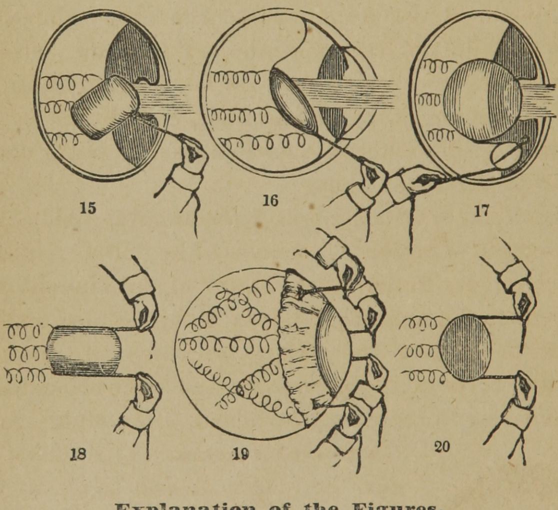
Instead of a muscle there is sometimes, as in the flounder (platessa dentata), a falciform membrane which proceeds from the crystalline to the iris, and inferiorly and posteriorly through the fissure in the retina, to be attached to the choroid. By contraction of the anterior portion the crystalline is brought nearer to the cornea, and it is drawn back by contraction of the posterior portion.

The elasticity of the cartilages in the scleroticæ of animals with spherical lenses will be afterwards considered.

# ADJUSTMENT OF LENSES WHICH ARE NOT PERFECT SPHERES.

**1, Ciliary Body. 2, Marsupium. 3, Membranes of Vitreous Humor.**

As the diameters of lenses of any other shape than spheres would be altered by applying the force necessary for adjustment at a single point, an arrangement is required by which it may be applied at more points than one. This arrangement is found in the ciliary body, which does not exist in animals possessing spherical lenses.




**Explanation of the Figures.**

*Fig.* 17 presents a diagram of the method by which the crystalline is advanced in the dolphin and the striped bass. When traction is made on a thread attached to the crystalline at a single point, and passing over a pulley behind the iris, the lens must be partially rotated on its axis, while it is drawn nearer the cornea. As the diameters of a sphere are always alike, the amount of refraction will not be affected by rotation. If we attempt to adjust a lens which is less or greater than a sphere (see *Fig.* 16, the human eye, and *Fig.* 15, the eye of the cuttle fish), by applying the force at a single point at the lower margin, the under half of the crystalline only advances, and the portion above the centre recedes; a distinct image, therefore, cannot be formed on the retina, because unequal diameters of the refracting medium are presented for the transmission of light. When adjustment is effected by applying the force at more points than one, uniformity of distance is maintained and irregular refraction avoided, as illustrated by the remaining figures.

## STRUCTURE OF THE CILIARY BODY.

The nature of the ciliary body cannot be understood until its component parts are examined separately. To inattention in this respect we may ascribe the discrepancy of opinion manifested in its description. Some term the whole arrangement the ligamentum ciliare; others the orbiculus, annulus, or circulus ciliaris; and others again have confined the term ligament to the white circle where the ciliary body is connected with the sclerotica. Some have described the ciliary body as muscular; and others as ligamentous, membranous, nervous, or vascular. All these tissues enter into its composition, but it does not consist of one tissue alone.

The ciliary body consists of, 1, the annulus albidus, at the anterior end of which it is connected by fibrous tissue with the sclerotica; 2, the outer lamina of the choroid, which proceeds to the annulus albidus; 3, the cellular and other tissues connecting the ciliary processes; 4, the ciliary muscles; 5, the ciliary processes; and 6, the orbiculus capsulo-ciliaris; to these may be added, 7, the ciliary zone.

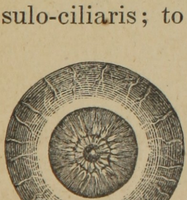


*Fig.* 21.

**External Lamina.** 1, *Annulus albidus.* 2, *Arachnoidea oculi.* — When we remove the anterior half of the sclerotica with the cornea, we bring into view a white ring, the anterior edge of which corresponds with the margin of the sclerotica to which it was attached. This ring receives the ciliary nerves, and is gradually blended with that portion of the choroid which invests the remainder of the ciliary body, whereas the inner lamina of the choroid ceases at the ora serrata. In birds, the continuation of the choroid seems to be a serous membrane, which is reflected on the inner surface of the sclerotica, for facilitating the extensive range of adaptation which is so necessary in this class of animals. This serous membrane has been called by Arnold the arachnoidea oculi, which, by analogy, he supposes to exist in the mammalia. At the inner margin of the annulus albidus there is a projecting lip, which is sometimes left on the second lamina when all the rest of the first is removed. This process of the ciliary body has been called by Hueck the ligamentum pectinatum iridis, which some have asserted to be muscular. It may be considered as a prolongation of the iris dividing into two lamina, of which the posterior receives vascular and nervous branches from the ciliary body, and the anterior probably permits the veins of the iris to pass into the canal of Schlemm. On the inner surface of the first lamina there is a series of muscular fibres radiating from the annulus albidus to the outer margin of the ciliary body.

**Second Lamina.** 1, *Cellular ring.* 2, *Inner ciliary muscle.* The second lamina may be demonstrated by dissecting off the annulus albidus and the above-mentioned continuation of the choroid from the preparation already described; but it may be more easily exhibited by taking another eye, and making a number of incisions radiating from the centre of the cornea through the anterior half of the sclerotica, without cutting the ciliary body. If we now turn over the flaps and split the annulus albidus, we may easily peel off the external lamina along with the outer ciliary muscle which adheres to its inner surface, and bring into view the second lamina, which I discovered in 1836.

The lamina thus exposed consists of two rings, the innermost of which is formed by the cellular membrane and vessels which connect the ciliary processes, and the other is composed of radiated fibres which possess all the characteristics of muscle. The muscular ring is of unequal breadth, being broader at the upper and outer than at the lower and inner portions. In some of the

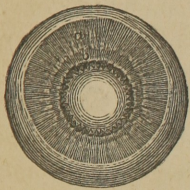


*Fig.* 22. Second Lamina of the Ciliary Body of the Human Eye. *a*, Ciliary muscle. *b*, Cellular ring.

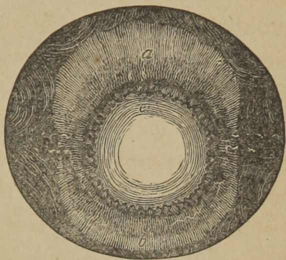


*Fig.* 23. Eye of the Ox. Letters as in the preceding cut.

mammalia the upper and lower portions form crescents, the horns of which meet at the horizontal diameter or equator of the eye. On the inner surface of the lamina the muscular fibres proceed from the greater circle of the external to the minor circle of the cellular ring.

**Third Lamina.** *Ciliary Processes. Orbiculus capsulo-ciliaris.* This may, with some difficulty, be seen by removing the second lamina, but its beautiful appearance behind may be more readily discerned by removing the posterior half of all the tunics, and viewing it through the vitreous humor. The ciliary processes, about seventy in number, consist of a series of membranes, which are arranged in a radiated manner around the crystalline body. They are covered with pigmentum nigrum, and like the iris, which they also resemble in other respects, are abundantly supplied with vessels and nerves. A corona of transparent elastic filaments proceeds from the inner surface of the ciliary processes to the anterior wall of the canal of Petit and the margin of the anterior capsule, constituting what has

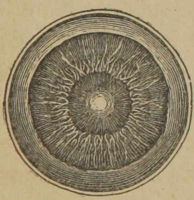


*Fig.* 24.

been termed by Ammon the orbiculus capsulo-ciliaris. These filaments fulfil to the ciliary processes an office

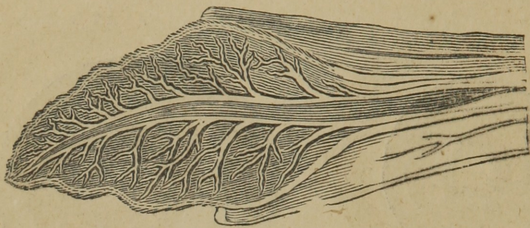


*Fig.* 25. Ciliary process of Ox magnified. From Bauer.

analogous to the tendons of muscles; but they are not muscular, as has been asserted by Home. The form of the ciliary processes varies in different animals: in man and the herbivora they resemble folded leaves, the apices of which float freely in the aqueous humor; in the carnivora they are triangular plates imbedded in the vitreous humor, with the edges directed forwards, but in birds they are muscular.

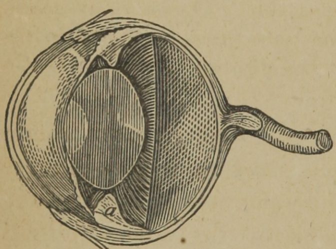


*Fig.* 26. Eye of Lynx.
*c*, Ciliary process. From Soemmering.

**Subjacent Lamina.** *Ciliary zone.*—This is also called the zonula Zinnii, the lamina ciliaris, and the corona ciliaris. It is a transparent membrane, continuous with the capsule of the crystalline, from which it extends to be attached to the vitreous humor at a line corresponding with the external or posterior margin of the ciliary body. This membrane lies upon the tunica hyaloidea, to which, besides the marginal attachment, there are several connections, so that the cavity between them, called the canal of Petit, when

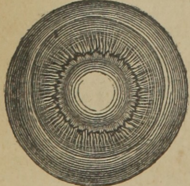


*Fig.* 27.

inflated, resembles a ruffle. Portions of pigmentum nigrum are frequently left on the ciliary zone, and form what is called the halo signatus. In the sheep, on the

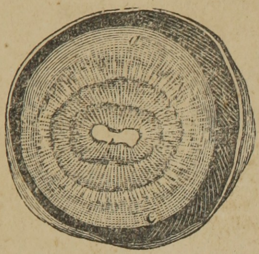


*Fig.* 28.

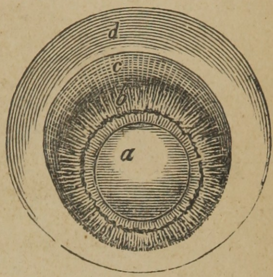



*Fig.* 29.

*Fig.* 28. Posterior view of the anterior segment of the eye of a sheep. *a*, Upper ciliary muscle. *b*, Ciliary processes. *c*, Lower ciliary muscle. *Fig.* 29. Crystalline and Vitreous bodies of the sheep. *a*, Crystalline lens. *b*, Portions of ciliary processes. *c*, Impressions from upper ciliary muscle. *d*, Vitreous humor.

upper portion of the zone corresponding with the unfimbriated portion of the ciliary processes the impressions are semicircular, as if occasioned by pigmentum collected in rugæ, produced by contractions of the ciliary muscle. The filaments of Ammon are so intimately connected with the ciliary zone, that separation can be effected only by laceration. Portions of the lacerated filaments may be seen floating on the zone, when the entire vitreous and crystalline bodies are immersed in water.

## CANALS OF THE CILIARY BODY.

The canals within and in the neighborhood of the ciliary body are: 1, The canal of Schlemm, or sinus for receiving the veins of the iris. 2, The canal of Fontana, which is that triangular space bounded by the ligamentum pectinatum iridis, the annulus albidus, and the upper anterior portion of the ciliary processes. Hueck supposes that this canal receives the aqueous humor and prevents undue pressure on the cornea when the crystalline advances ; but it is much more probable that the fluid is received through the furrows between the ciliary processes into the hyaloid cavity, though the former hypothesis would acquire plausibility from the presence of a canal in

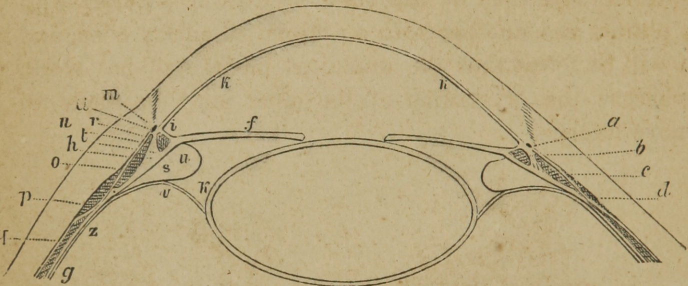



*Fig.* 30. Magnified section of the human eye, from Hueck. *a*, Canal of Schlemm. *b*, Anterior canal of Fontana. *c*, Middle canal of Fontana. *d*, Posterior canal of Fontana. *f*, Iris *g*, Posterior portion of ciliary body. *h*, Anterior portion of ciliary body. *i*, External margin of iris. *k*, Coat of Descemet. *m*, Ligamentum pectinatum iridis. *n*, *o*, Anterior junction of ciliary body with the sclerotica. *p*, *q*, Posterior junction. *r*, Orbiculus ciliaris. *s*, Ciliary process connected at *t* with the uvea. *u*, Fimbriated portion of ciliary process. *v*, Posterior wall of the canal of Petit. *z*, Junction of the hyaloid membrane with the ciliary zone.

the outer margin of the iris of the sword-fish (Fig. 40, p. 25), if a vacuum could exist in any part of the eyeball. Hueck describes two other canals in the ciliary body, which he names the middle and posterior canals of Fontana. The former of these seems to be the space between the ciliary muscles, and the latter, the cavity of Arnold's tunica arachnoidea. 3, The canal of Petit which is, as already stated, the cavity existing behind the ciliary zone, and between it and the tunica hyaloidea ; the term cavity being here, as well as in the preceding cases, applied in the same sense as when we say the cavity of the peritoneum, etc. In 1835, I announced, that when the cornea and iris are removed without disturbing the other structures of the organ, and the canal of Petit is then inflated, the crystalline advances. From this fact, which was afterwards published by Hueck in 1841, it is evident that the motions of the crystalline are facilitated by the existence of the canal. The utility of the plaiting of the anterior wall may be exhibited by making a model with a plaited and another with an unplaited ciliary zone, and it will be found that the unplaited model will not work, whereas the crystalline of the other may be made to move freely.

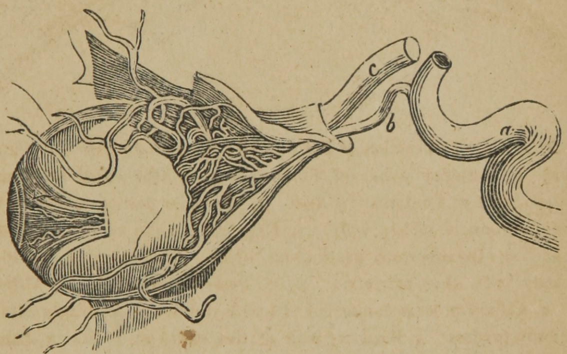



*Fig.* 31. *a*, Carotid artery. *b*, Ophthalmic artery. *c*, Optic nerve. From Soemmering.

VESSELS OF THE CILIARY BODY.

The anterior branches of the posterior ciliary arteries, which are branches of the ophthalmic, furnish to each of the ciliary processes one or two branches, which, with the returning veins, form the vascular tissue of which the processes consist. These veins proceed to the sinus of Hovius, and thence to the ciliary veins.

To govern arterial pulsation, the ophthalmic artery is given off after the curve of the carotid (Fig. 31, *a*). In the ruminantia the arteries, before entering the eyeball, form a rete mirabile, which is still more apparent in some of the carnivora, as the cat and the dog.

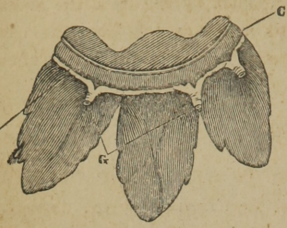



*Fig.* 32. C, Veins entering the circulus venosus. F, The circulus venosus. G, Veins passing from the circulus venosus to the sclerotica. From Hovius.

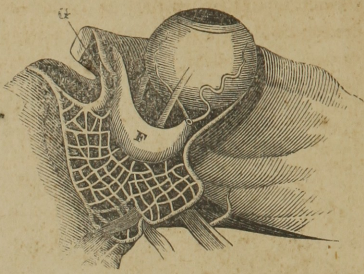



*Fig.* 33. G, Portion of the artery forming the rete mirabile. F, Venous sinus. From Hovius.

*The ciliary nerves* are from fourteen to twenty in number. Three or four of these proceed from the nasal branch of the fifth, and the remainder in two bundles from the lenticular ganglion, which is formed by a twig from the inferior oblique branch of the third pair, a filament from the nasal branch of the fifth, and a branch from the carotid plexus of the sympathetic.

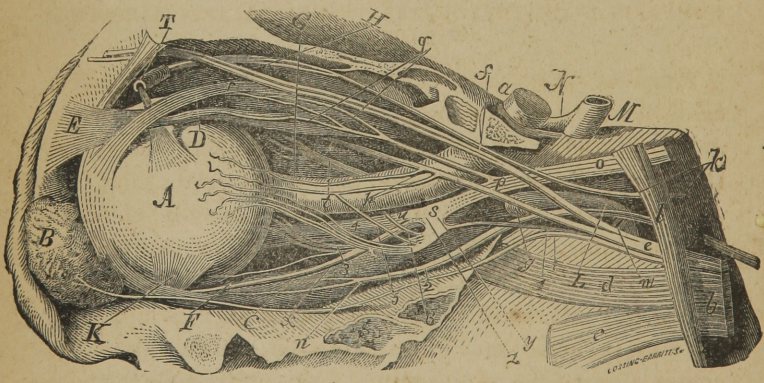


*Fig.* 34. Nerves of the eye. From Zinn. *a*, Optic nerve. *b*, 5th pair. *c*, 3d branch of 5th. *d*, 2d branch. *e*, 1st branch. *f*, Frontal branch. *g*, Nasal branch. *h*, Ciliary branches. *i*, Lacrymal branch. *k*, 4th pair. *l*, 6th pair. *m*, Intercostal. *n*, Insertion of 6th in abducens. *o*, 3d pair. *p*, Superior branch of 3d. *q*, Branches to attollens. *r*, Branch to levator palp. *s*, Inferior branch. *t*, Branch to adducens. *u*, Branch to depressor. *x*, Branch to inferior oblique. *y*, Lenticular ganglion formed by *z*, the shorter branch from the inferior oblique; and 1, the longer branch from the nasal branch of the 5th. 2, Superior fasciculus of ciliary nerves. 3, Inferior fasciculus.

MARSUPIUM.

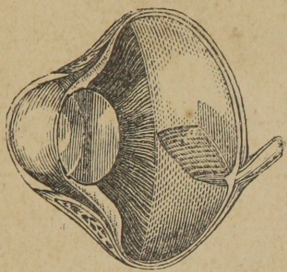


*Fig.* 35. *a*, Marsupium of Eagle.

In birds and some reptiles a fan-like membrane analogous in structure to the ciliary processes, proceeds from the choroid through a slit in the retina, and through a portion of the vitreous humor, to be attached to the membranes proceeding from the posterior crystalline capsule. By means of this retracting membrane these animals are furnished with the extraordinary power of distant vision which their necessities require.

COMPARISON OF THE CILIARY PROCESSES AND MARSUPIUM WITH THE IRIS.

Each of these structures consists of a rete mirabile of vessels animated by nerves from the same ganglion, and their position and attachments show that they are intended for motion, and demonstrate their use. A better idea of the structure of the iris may be obtained by examining it in the living subject rather than in the dead. If the observer looks at his own iris in a concave mirror of short focus, such as the speculum of a telescope, he will perceive that the dilatations which follow the contractions of the pupil resemble in every respect the contractions of elastic bodies. He will also observe on the annulus minor a series of projections in form and number resembling the ciliary processes; and fibres passing into elevations near the annulus minor, as the ciliary nerves pass into the annulus albidus. If he now examines the iris in the dead eye, he can compare the radiating fibres on the posterior surface with the ciliary muscles, and the sinus of Schlemm with the sinus of Hovius. In short, he will observe a miniature ciliary body. If he stimu-

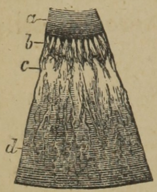



*Fig.* 36.

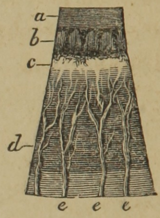



*Fig.* 37.

*Fig.* 36. Portion of the iris. *a*, Pupil. *b*, Annulus minor. *c*, Irregularities on the surface. *d*, Situation of radiating fibres on the posterior surface. *Fig.* 37. Portion of the ciliary body. *a*, Lens. *b*, Ciliary processes. *c*, Annulus albidus. *d*, Ciliary muscle. *e*, Ciliary nerves.

lates the radiating muscles of the iris to contraction by applying veratria to the neighborhood of the living eye, the pupil contracts, and the eye is at the same time adjusted to near objects ; whereas if he relaxes the muscles by belladonna, the elasticity or contracting force of the tissues becomes greater than the extending, the pupil dilates, and the eye is adjusted to distant objects. As the vascular power is not necessarily diminished by relaxation of the muscles, the annulus minor continues to act when the pupil is expanded ; and as that elasticity of the tissues which may be observed after stretching the skin of a healthy forearm ceases with life, we cannot expect that the dead iris will be in any other condition than that of medium contraction. The pupil is contracted during sleep, but sleep facilitates the extension of other structures the erectibility of which is unquestioned. The iris and ciliary body are both excited to action through the medium of the retina. The one obeys the demand for the requisite degree of light, and the other for the requisite distinctness of the image ; but the one is involuntary, and the other is under the control of the will. Although their offices are distinct they seem to act simultaneously, for the pupil contracts when we look at a near object, and expands when we look at one which is distant. On the other hand a stimulus to the iris affects the adjusting organs, as a presbyope can see more distinctly by increased illumination.

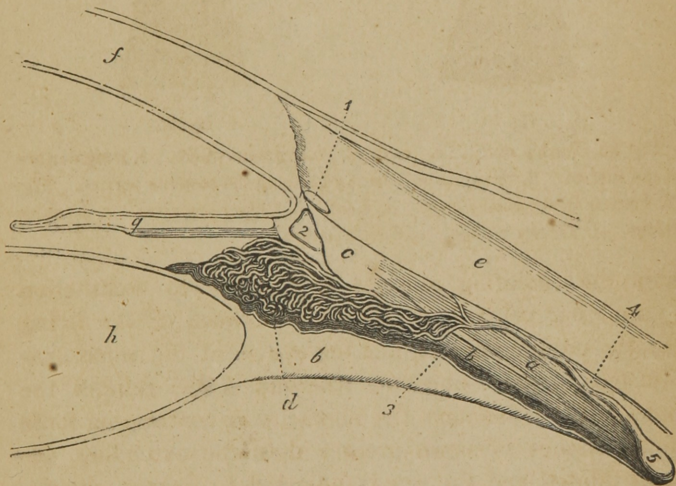



*Fig.* 38. Diagram of the ciliary body. *a*, External muscle. *b*, Internal muscle. *c*, Annulus albidus. *d*, Ciliary process with the vein lifted out of place. *e*, Sclerotica. *f*, Cornea. *g*, Iris. *h*, Lens. 1, Canal of Schlemm. 2, Canal of Fontana. 3, Middle canal of Hueck. 4, Posterior canal of Hueck. 5, Sinus of Hovius.

## FUNCTIONS OF THE CILIARY BODY.

We have, then, the ligament by which the ciliary body is attached to the sclerotica; the outer ciliary muscle to contract the vessels returning from the ciliary processes; the ciliary processes, which are attached by the filaments of Ammon to the ciliary zone and crystalline capsule, to become erect and draw forward the crystalline body; and the inner ciliary muscle, aided by the elasticity of the membranes of the vitreous humor, to draw it backwards.

The functions of the various parts of the ciliary body are evident from, 1, its entire absence when there is another instrument for adjustment; 2, its structure; 3, there is no other arrangement by which adjustment can be explained, or by which we can account for the sudden occurrence of near and far-sightedness.

If, when the eye is adjusted to a remote object, we direct it by the external muscles to one which is near, an indistinct image of the latter is formed on the retina; the impression is communicated to the sensorium by the optic nerve; a reflex affection of the third, from which the ciliary nerves in part proceed, causes the ciliary muscle to contract, the processes to become erect, and the crystalline body to be drawn forward until a distinct image of the object is formed on the retina.

The following facts show that the eye, in a perfectly passive state, is adjusted for the discernment of distant objects: 1, an effort is necessary to look at near objects, and that effort, when long continued, becomes painful; whereas we can look at distant objects without fatigue: 2, as age advances, the ability to see near objects becomes lessened, while distant objects can be seen as plainly as ever: and 3, when under the relaxing power of belladonna, the eye loses the power of seeing near objects distinctly.

By the graduating power of the ciliary processes and ciliary muscles, together with the elasticity of the membranes of the vitreous body, the crystalline may be drawn not only backwards and forwards, but its inclination may be changed so as to throw the image on another part of the retina. As the upper and outer portion of the ciliary body is the broadest, that margin of the crystalline will advance the furthest, and thus facilitate the vision of near objects with both eyes at the same time.

## ADJUSTMENT OF THE RETINA.

**1, Choroid Gland. 2, Pneumatic Pressure. 3, Hydrostatic Pressure. 4, External Muscles. 5, Central Foramen.**

As the campanula Halleri is sometimes so small that, by its contraction alone, sufficient motion of the crystalline could scarcely be expected, there seems to be another arrangement for the adjustment of spherical lenses. Between the sclerotica and choroid there is a rete mirabile of vessels forming a crescent-like body, over and nearly around the optic nerve. This body, which has been called the choroid gland, can be split into two portions, the anterior of which can be injected from the ophthalmic artery with quicksilver, but the injection cannot be forced into the portion connected with the choroid. If capable of being erected, the cellular bands, by which the vascular body is connected with the sclerotica, prevent its advancing and producing irregularity in the form of the retina. By enlargement of the choroid gland, the fat or gelatinous fluid, which lies between the choroid and sclerotica (Fig. 9, p. 9), will be pressed against the choroid, and the retina will advance, and when it is diminished in size the retina will recede. The elastic cartilages which exist in the sclerotica, of most animals furnished with a choroid gland will, by yielding, prevent compression of the retina, and by resuming their position, prevent the formation of a vacuum. In the sword-fish, in which there is an unyielding osseous sclerotica, the fluid thus displaced can be received through the trian-

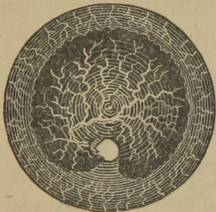


*Fig.* 39. Choroid gland of the Halibut.

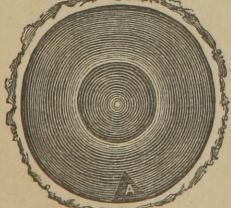


*Fig* 40. A, opening to cavity in the iris of the Sword-fish, diminished half the diameter.

gular opening at the under portion of the anterior lamina of the iris, into a canal at its circumference. If a similar congestion occurs in the walls of the iris, which is also a rete mirabile, the fluid effused into the anterior chamber will assist in forcing the crystalline backwards when the opposing force is removed.

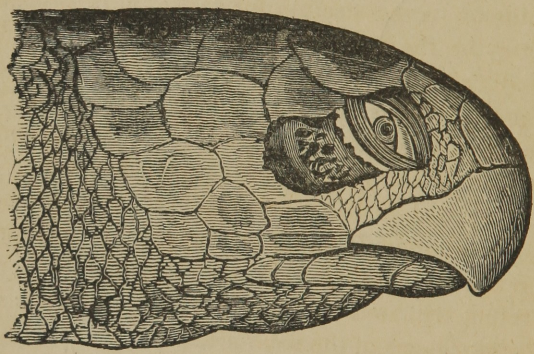


*Fig* 41. *a*, Air cavity behind the eye of the Green Turtle.

Behind the eye of the green turtle there is an air cavity which is intersected by numerous tendons, somewhat resembling the tendinous chords of the heart, and in the posterior wall of the singularly formed sclerotica there is a foramen communicating with the cavity. When air is forced between the laminæ of the elastic sclerotica the retina will advance, and the distance between the latter membrane and the cornea will be still more diminished by the action of the muscle, which, in this animal, as well as in the seal, compresses the eyeball anteriorly.

In 1835 I discovered that the orbits of several fishes are not filled up with fat, but that the cavity in which the muscles play is occupied by fluid. In the halibut a portion of the under surface of the membrane in which the fluid is contained is, in the right orbit, traversed by fibres somewhat similar to the musculi pectinati of the heart, and in the left orbit there is a foramen which leads to a cavity beneath the organ. This cavity also contains fluid, and is intersected by numerous irregular bands. It was at first supposed that by contraction of the fibres in the orbit and additional cavity, the eyes were, by the pressure of the fluid, elevated and partially rotated, so as to change the direction of the organs, and enable the animal to see straight forward. It is probable that this may be the true explanation, as the given direction is produced by injecting water into the orbit; yet it is also probable that the apparatus may assist in adjustment to distance, by producing on the posterior portion of the sclerotica a certain amount of pressure, which will be communicated to the gelatinous fluid between the sclerotica and choroid, (Fig. 9, *b*,) and by this medium cause the retina to advance. When the pressure is removed, the retina will resume its former position by the elasticity of the cartilages of the sclerotica.

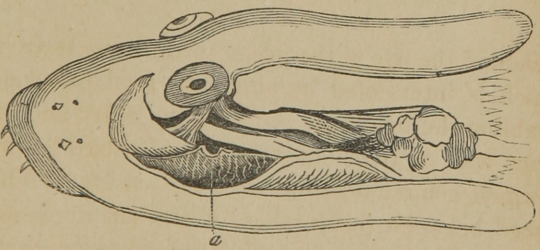



*Fig.* 42. *a*, Cavity beneath the left orbit of the Halibut.

Dr. Jacob observes: "A single lens remedies, in a great degree, the defect arising from want of power of adaptation, but no single lens will confer on a landsman the distant vision of a sailor, nor on a long-sighted person the power of distinguishing minute objects enjoyed by some near-sighted persons." It is possible, that when the eye is maintained in one direction nicer degrees of adjustment may be effected by contractions of the obliqui increasing, or of the recti diminishing the curve of the retina; it is also possible that the central portion of the retina has, as supposed by Blumenbach, a motion of its own—an hypothesis which will be better understood by a brief examination of its structure.

The anatomical composition of the retina may be more easily demonstrated in the eyes of fishes than in those of other animals. When the anterior hemisphere of the eye of a fish which has been immersed for a few days in alcohol is cut off, and the humors removed, we observe in the cup-like cavity which remains a number of fibres radiating from the entrance of the optic nerve, and distributed over the entire cavity, with the exception of the lower portion, where there is a fissure, (*a*,) to permit attachments of some of the membranes of the vitreous humor to the choroid. Beneath the fibres there is a lamina of granules which may be removed, to exhibit another granular lamina.

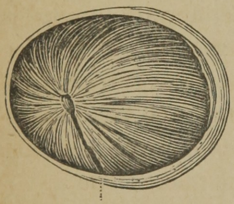



*Fig.* 43. *a*, Fissure in the retina of the Halibut.

In summer, or at a temperature of 80° F., the fibres of the retina may be demonstrated in the eyes of young ruminantia just as distinctly as in fishes, by preparing them in the same manner, and filling the cup-like cavity first with a weak aqueous solution of corrosive sublimate, and in a minute afterwards with diluted alcohol. The vascular membrane may be lifted in the liquid with forceps, and, by a camel's hair pencil or piece of pointed wood, the fibres may be separated from each other in bundles, or removed to show the granular lamina beneath them. In the human eye some of these fibres commence at the foramen of Soemmering, and of these the filaments nearest the optic nerve proceed in nearly straight lines; whereas the more distant sweep around the more central like notes of interrogation facing each other and placed horizontally. Those which do not commence at the centre, proceed from the margin of the ciliary body and from every point of the cavity to the optic nerve. The fibrous lamina is consequently much thinner at the inner posterior portion than it is at the circumference or at the centre. This course of the fibres of the retina in man and the quadrumana, which I discovered in 1834, explains the loop-like filaments said to be observed under the microscope.

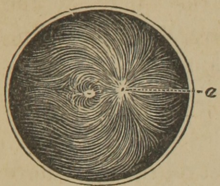



*Fig.* 44.

*Fig.* 44. Fibres of retina. *a*, Entrance of optic nerve.

By the microscopical observations of Treviranus, Hannover, Pacini, and others, the minute structure of the retina has been elucidated. The outer lamina has been found to consist of rods arranged side by side, and interspersed at regular intervals with bulbs. On this is arranged a lamina of granules which I presume are the terminations of the fibres lying before them, as each granule is supplied with one or two filaments. On the fibres there is another lamina of granules, on these another series of fibres, and on these again there is the vascular membrane. Pacini regards the transparent granules between his two fibrous laminæ as the terminations of the fibres; but when the retina is prepared as formerly described, the bundles appear much larger than the representation he gives of the lamina towards the hyaloid surface, and some force is necessary to separate their apices from the granular lamina. There is reason, there-

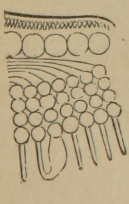


*Fig.* 45.

fore, to believe, that the fibres have a direction (*Fig.* 45) opposite to that given by Pacini in *Fig.* 46. The microscope has become an indispensable assistant to the anatomist, but it cannot be depended upon alone.

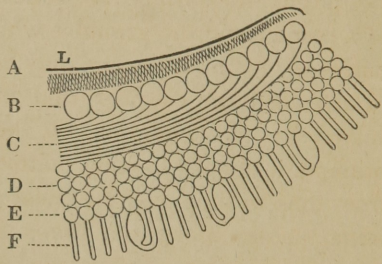



*Fig.* 46.

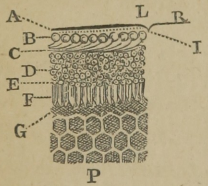



*Fig.* 47.

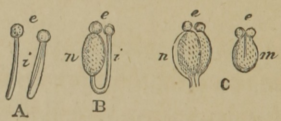



*Fig.* 48.

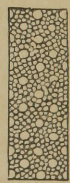


*Fig.* 49.

*Fig.* 46, Diagram, and *Fig.* 47, Lateral view of the retina. From Pacini. A, White nervous fibres. B, Nerve cells. C, Gray nervous fibres. D, Nerve granules. E, Supplementary stratum of nerve cells. F, Rods of Jacob's membrane. G, Pigment cells of the choroid. *Fig.* 48. A, Simple rods of Jacob's membrane; *i*, the rod, to the inner end of which adheres *e*, a nerve cell of the adjoining lamina. B, Associate rods, or cones, of the human retina; *n*, the rod enlarged. C, The same in the mullet. *Fig.* 49, View of the ends of the rods, interspersed with the bulbs in Jacob's membrane.

As there is no communication between the retina and the neighboring tunics except at the ciliary body and the entrance of the optic nerve, and as no vessels have been seen to pervade this delicate texture, it may be presumed that the granules near the hyaloid surface are a medium of nutrition to the other laminæ. The granules of the liquor Morgagni eliminate from or through the capsule what is necessary for the nutrition of the lens, and the granules of the torula cerevisiæ decompose the fluid by which they are surrounded; we may consequently conclude that chemical changes are also effected by living cells.

If we consider the outer lamina of the retina as a daguerreotype plate, the surface of which is removed every sixth of a second, and the granules which lie upon it as the extremities of the fibres, the eye may be regarded as an organ of touch; or if we consider that the electricity which is evolved by the oxidation of the phosphorus probably contained in the oily looking matter in the bulbs, and spread from time to time over the inner surface of the external lamina, passes along the fibres and the optic nerve, the organ of vision may be regarded as a telegraph by which a secondary series of undulations passes to the brain.

By means of the microscope, we may observe what appears to be some of the fibres with granules at the extremity, as if endeavoring to feel the picture. Some of these, as if paralysed and contracted upon themselves like intestines, seem either nearly stationary, or moving at different perspective distances and laboring to expand. When we repeat Sir David Brewster's experiment of looking at the flame of a candle through a powerful convex lens, held at such a distance from the eye and the object that the whole surface of the glass appears illuminated, we perceive a beautiful mosaic which rises and falls with respiration, and which resembles the drawing of the external lamina of the retina. On this mosaic a number of granules may be seen, which, as Sir David has stated, appear double when two candles are employed. We also observe a number of fibres, but their motions are not so distinct as when looking at the field of the microscope.

It has been often asserted that the nerves have a motion of their own. Serres supposes that the motions of the pupil depend upon nervous contraction and elongation. Other eminent physiologists state that the filamentous pencils of the organs of touch and taste become erect when excited. If, therefore, the power of motion is possessed by one series of nervous filaments, it may likewise be granted to the fibres of the retina.

In the cuttle fish the fibres of the optic nerve perforate the sieve-like lamina of pigment, the anterior surface of which is covered with an infinite number of separate retinæ united into one, and each of these is supplied with a granule to receive the impression, and fibres to convey it to the sensorium.

It is evident that if the fibres possess motion, they will be less impeded at the central foramen than at those portions of the retina where they are crowded over each other, and vision will be more distinct. Should the granular lamina follow the terminations of the fibres when the latter become excited, the central foramen, which is the only place where they are free, will advance, and adjustment will be facilitated.

# APPENDIX.

## 1. Campanula Halleri.

" Piscibus nempe etiam pecten est sed dissimilis. In trocta et lucio ex ingressu nervi optici prodit arteria nigro pigmento obducta, cujus alter ramus vitreum corpus adit, alter circumductus circa vitreum humorem cellulosa tela sensim altiori augetur, et denique de interiori quasi iridis facie in plumulam abit, quæ mucrone suo capsulæ lentis crystallinæ adhæret. Sed in cyprino, et in altero viliori cyprino capitone, etiam pulchriora vasa vitrei corporis ostenduntur. Huic nempe arteria de Ruyschiana tunica cum sustentaculo lentis crystallinæ prodit, eademque in duos ramos fissa totum humorem vitreum in speciem circuli ambit, qua retina anterius finitur."—*Halleri Elementa Physiologiæ, Tom. V., p.* 391.

" Il y a de plus dans un grand nombre de poissons un ligament en forme de faux qui passe par un sillon de la rétine et pénètre dans le vitré, dont il est le seul lien. Ce ligament commence à l'entrée du nerf optique, et suit la concavité intérieure en descendant vers le bas de l'œil ; il contient des vaisseaux et des nerfs : sa pointe inférieure, la plus voisine de l'uvée, s'attache à la capsule du crystallin par sa face inférieure, tantôt au moyen d'un simple proéminence ou d'une lame un peu plus opaque."—*Cuvier.*

"That the existence of this body is unknown, in England at least, is, I think, borne out by the fact that the learned professor of comparative anatomy at King's College, Mr. Owen, and Mr. Yarrell so well known by his beautiful work on the ichthyology of Great Britain, were both unacquainted with the circumstance when I mentioned it to them."—*Dalrymple, Lond. Mag. Nat. History*, 1838.

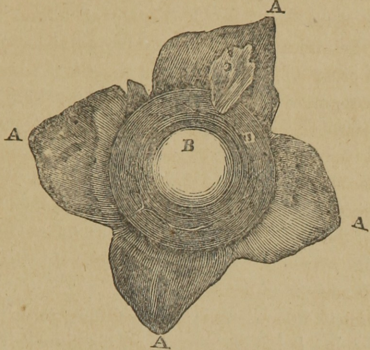
" Durch diese Spalte der Retina dringt bei vielen Knochenfischen eine von der Membrana Ruschiana gebildete pigment- und gefässreiche Falte (Processus falciformis), welche von der Hyaloïdea umfasst, durch den Glaskörper zur Linse tritt und meistens vermittelst eines anscheinend knorpelartigen Knotchens, der Campanula Halleri, an den Rand der Linse sich befestigt."—*Von Siebold und Stannius Lehrbuch der vergleichenden Anatomie.*

## 2. Ciliary Muscle.

P. 4. " Nam isti radii nigri, processus ciliares dicti, videntur ideo sic pectinatum esse distincti, ut quilibet pro se esset veluti peculiaris quidam musculus, quibus universis simul recurrentibus in sese et sic brevibus effectis, hoc veluti diaphragma oculi angustius redditum, contractis lateribus oculi, facit oculi figuram nonnihil oblongam seu elipoidem, ubi fundus seu retiformis tunicæ cavitas recedat ab humore crystallino."—*Kepler, Dioptric, Prop.* LXIV.

P. 6. "The organ to which I allude is a distinct muscle, which arises from the internal surface of the bony hoop of the sclerotica, and is inserted by a tendinous ring into the internal surface of the cornea about one line within its circumference. In order to demonstrate this muscle it is necessary only to remove the anterior segment of the eye just behind the bony hoop, and then the pigmentum nigrum being carefully washed away, the iris is to be gently detached from the ciliary circle, and the choroid coat from the sclerotica. Some delicacy is necessary in performing this part of the operation, for the muscular fibres adhere to the internal surface of the choroid coat, as well as to the bony hoop: if the choroid, therefore, be not slowly and carefully detached, many of the muscular fibres will be separated from the bone, and confounded with the membrane and its pigment.

"When the muscle is thus exposed, its descending fibres will be seen terminated in a well-defined tendinous ring, which advances a little beyond the circumference of the cornea, to which it firmly adheres. The thickness of the muscle as well as the manner of its insertion may be most conveniently demonstrated by cutting the anterior segment of the eye through its diameter. The fibres will then be seen upon that part of the cut edge which corresponds with the bony hoop. To complete the demonstration, a pin, or thin probe, may be passed between the muscle and the sclerotica. The nerves which are seen branching in a singularly-beautiful manner through the substance of the muscle, are derived from the lenticular ganglion. A mere inspection of the attachments of this muscle will be sufficient to suggest its action; for since the bony hoop, from which the fibres arise, must be considered as a fixed point, the cornea into which they are inserted must be drawn inwards by their contraction; but the matter admits of demonstration. By means of the galvanic influence, the action of the muscle may be excited in the eye of a turkey, a few minutes after the head has been separated from the body, when it may be observed that every contraction of the fibres is attended with a corresponding motion of the cornea; or if the fibres be drawn upwards by means of a forceps, the cornea may not only be flattened, but its convexity may be made to *respect* the iris. Since then it may be demonstrated that this muscle is in its action a depressor of the cornea, it seems scarcely necessary to add that its influence must tend to diminish the convexity of the eye. It seems probable, therefore, that the eyes of birds are in the ordinary state possessed of a high refractive power; and an eye so constituted seems peculiarly well adapted to the uses of the animal while it rests upon the earth, but when it soars into the middle regions of the air the rays proceeding from objects below must arrive at the eye in lines which may be considered as parallel; consequently to form anything like a distinct image, the focal length of the organ must be increased as the divergency of the rays decreases. This adjustment may be perfectly effected by diminishing the convexity of the cornea, and it has been shown that there is in the eye a muscle to which this function may be assigned."—*Crampton, Thomson's Annals of Philosophy, Vol.* 1, 1813.




A, The sclerotica, cut and thrown back. B, The cornea. C, The marsupium. D, The muscle of the cornea.

P. 7. " I had already remarked during the course of my dissections, that the annulus albus assumed a variety of appearances, but that it resembled a ligament, in a very few animals only: that in still fewer did it bear any resemblance to a nervous ganglion; which resemblance I speedily satisfied myself was a complete deception. At last, having discovered that in birds and in the deer, the so named ligament received numerous nerves, that its texture bore no resemblance whatever to ligament, and that it became rudimentary in those animals whose sight was feeble, which would not necessarily happen were it simply a ligament for the suspension of the tunics and humours of the eye; the conclusion was irresistible; that the annulus albus is a muscle, that it is the muscle by which the eye adapts itself to the perception of distant objects, and that by it in conjunction with the iris, all the changes which take place in the interior of the eyeball are effected.*

" It were desirable that I should bring forward ample collateral proofs of the presence of this great central muscle of the eyeball, and which I shall henceforward call the ciliary muscle; but I am by no means prepared for so extended an enquiry. * * * * * *

" But I do not suppose that the whole of the phenomena of the adjustment

* " The opinion that the annulus albus is muscular has been often maintained, but so far as I know, no proofs derived from anatomy of its muscularity have ever been laid before the public.

" In compliance with the wish of some of my friends, small sections of the annulus albus were submitted to the microscope. The result of this investigation was, that it had no resemblance to a ligament; that it contained comparatively large branches of nerves; that it did not resemble any of the textures of the eyeball except the iris, but that here the resemblance was so close that they could with difficulty be distinguished."

of the eye to the perception of objects placed at various distances, depend entirely on the ciliary muscle. I have every reason to believe that the perception of objects placed at very short distances, depends altogether, or nearly so, on the contractions of the pupil or iris. * * *

"When belladonna has been applied to the eye, near objects cannot be perceived, and the eye is said to have changed its focus and to have become long sighted. These expressions are incorrect, the eye has lost its power of viewing very near objects, because the iris can no longer contract. * * *

"When the iris is drawn backwards, after having removed the cornea, and allowed the aqueous humour to escape, the anterior edge of the ciliary processes may be seen projecting into the posterior chamber of the aqueous humour, and on drawing these also backwards, a number of parallel fibres are seen proceeding from the marginal or equatorial edge of the capsule of the lens, to be inserted between each of the ciliary processes. These fibres" [the orbiculus capsulo-ciliaris of Ammon?] "lie immediately over the canal of Petit, and contribute with the perfectly transparent membrane lying immediately beneath them, to form a portion of the parietes of this canal. If we now examine the eye in the opposite direction, *i. e.*, by dissecting off the sclerotic and choroid tunics and the retina, we may perceive a similar range of fibres proceeding from the anterior edge of the vitreous humour, and from the point where the retina terminates, forwards and upwards, to be in like manner connected with the ciliary processes, by passing in between each. If a lateral view be taken, by making a very delicate section of the eye and gently raising the cut edges of the ciliary body, there is still the same appearance, viz.: of anterior and posterior fibres which have a common insertion between the ciliary processes near the base, and which form, in conjunction with a transparent membrane, the external paries of the canal of Petit." * * *
*Knox, Ed. Phil. Trans., Vol. X.*

### 3. Retina.

P. 31. "It belongs to physics and chemistry to commence where the anatomist ends. He describes the parts, they tell the use. They show how the images of external objects form, on optical principles, on the dark pigment, and how, under this influence, the nerve globules of the retina are oxydized by the arterial blood, which, through thousands of vessels, finds its way all over the choroid coat. How, wherever this oxydation goes on, the temperature rises, and the optic nerve transmits the impression to the brain; and we thus discover, that though in a certain sense the action of that nerve is special, yet in reality it is like that of any other sensory nerve, which, in like manner, transmits the impressions of heat."—*Draper's Introductory Lecture on Phosphorus.*