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# ON THE DEVELOPMENT OF THE ACCOMMODATIVE POWER OF THE HUMAN LENS.*

By E. Treacher Collins.

The accommodative power of the human lens was demonstrated by Helmholtz to be due to its elastic fibres being maintained in a state of tension, the relaxation of which brought about an increased convexity of its anterior surface. The way in which this state of tension of the lens fibres is developed forms the subject of this paper.

The relaxation of the tension of the lens fibres in accommodation was stated by Helmholtz to be effected by slackening of the suspensory ligament of the lens, and this theory, though contested by some, is supported by much clinical and experimental evidence. The development of the accommodative power of the lens must be looked for, therefore, in the development of its suspensory ligament.

In a paper on that subject published in vol. xiii, pt. 1 of these reports, I gave a table showing the diameter of a series of eyeballs and their lenses from the 4th to the 9th month of fœtal life.

At the 4th month the ciliary body is in contact with the

* This paper was read at the Tenth International Congress of Ophthalmology held at Lucerne. It is republished here, together with illustrations not previously reproduced. These illustrations are from photo-micrographs kindly taken for me by Mr. E. Collier Green, of Derby.

*b*

sides of the lens. At the 9th month the transverse diameters of the eyeball and the lens are double what they are at the 4th month, and in the adult they are treble what they are at the 4th month. As the eyeball and lens increase in size in this proportion, and as the eyeball is larger to begin with, it follows that as the eye develops there must be a gradual separation of the ciliary body away from the sides of the lens.

It is natural to suppose that the adhesions which join the lens to the ciliary body, viz., the fibres of the suspensory ligament, would be first formed while those structures are in contact, and that they would be stretched out and rendered tense as they become separated.

Sections of a human fœtal eye in which, what ultimately develops into the *pars ciliaris retinæ* is in contact with the lens, show, intervening and lying in contact with both, some tissue composed of spindle shaped cells of mesoblastic origin (Pl. II, Fig. 1).

In this tissue is subsequently developed the network of blood vessels which forms a vascular sheath to the lens.

In sections of fœtal eyes of a later date where the rudimentary ciliary body has become separated from the sides of the lens, in the situation of the suspensory ligament elongated cells may sometimes be seen, or fibres of the suspensory ligament with nuclei attached to them (Pl. IV, Fig. 1).

Similar elongated cells or fibres with nuclei on them are met with in congenital microphthalmic eyes in the situation of the suspensory ligament, evidently due to its arrested development. These malformations are referred to again more in detail at the end of this paper.

There seems then considerable evidence to show that the suspensory ligament of the lens is originally derived from cells which become lengthened out into fibres and lose their nuclei.

There are two possible sources of these cells:—

1. The mesoblastic cells already referred to as surrounding the lens capsule at a very early period of fœtal life.
2. The neural epiblastic cells composing the *pars ciliaris retinæ*.

*A priori*, seeing that the suspensory ligament is of the nature of a connective tissue it would be natural to suppose that it was derived from mesoblast. Its intimate association with the vitreous humour is also in favour of the two structures having the same genetic origin.

Schoen* and Terrien,† however, as the result of their histological researches, regard the fibres of the suspensory ligament as derived from the epithelial cells forming the *pars ciliaris retinæ*, *i.e.*, making them analogous to the fibres of Müller which form the supporting connective tissue of the retina.

I have myself been unable to arrive at any certain conclusion in favour of one or other of these views, and fortunately it is immaterial for the purpose of this paper which is ultimately found to be correct.

The most recent investigations‡ into the arrangement of the suspensory ligament in the human eye have shown that the bundles of fibres of which it is composed do not pass straight out from the sides of the lens to the ciliary body, but that they cross one another. Thus fibres which are most anterior in their attachment to the lens capsule pass to the hindermost part of the ciliary body, whilst those coming from the foremost part of the ciliary body pass to the posterior part of the lens capsule.

It has been possible to differentiate several groups of fibres and describe them by distinctive names. Thus, the fibres which pass from the non-plicated part of the ciliary body to the anterior part of the lens capsule, and which lie in the valleys between the ciliary processes, are called *the orbiculo-antero-capsular fibres.* Those which pass from the *ora serrata* and the hindermost part of the non-plicated part of the ciliary body to the posterior part of the lens capsule are *the orbiculo-postero-capsular fibres.* Those passing from the apices of the ciliary processes to the posterior part of the

* Anatom. Anzeiger, Bd. x, 1895.

† Archives d'Ophtal., T. xviii, 1898, p. 555.

‡ Garnier, Archiv f. Augenheilk., Bd. xxiv, 1892.

lens capsule, between the bundles of the orbiculo-antero-capsular fibres, are *the cilio-postero-capsular fibres;* and those running directly inwards from the ciliary processes to the lens capsules are called *the cilio equatorial fibres.* (Pl. I, Figs. 1 and 2).

Some writers have also described certain *accessory fibres* passing from the non-plicated part of the ciliary body to the ciliary processes, from one ciliary process to another, or from the ciliary body to adjacent fibres. It is very possible, however, that these so-called accessory fibres are really only some of the other bundles of fibres cut obliquely.

In order to understand how this interlacement of the different bundles of fibres of the suspensory ligament is brought about, it is necessary to examine the relation which the different parts of the ciliary body bear to the sides of the lens at different periods in fœtal life. When the lens vesicle is first formed and has become cut off from the surface epiblast there is no ciliary body and no iris. The anterior extremity of the optic vesicle at that time corresponds to what afterwards becomes the *ora serrata,* and it lies in contact with the antero-lateral portion of the newly formed lens vesicle. (Pl. II, Fig. 1).

As the iris and ciliary body bud out of the anterior extremity of the secondary optic vesicle and the anterior extremity of the rudimentary choroid, that part of the retina which corresponds ultimately to the *ora serrata* gets displaced backwards along the side of the lens, until, from being in contact with the anterio-lateral part of that structure it comes to lie in contact with the posterio-lateral part. (Pl. II, Fig. 2).

At first the ciliary body has no ciliary processes, at that time being represented only by a short straight unfolded area lying in close apposition with the sides of the lens.

Folds commence to bud out from the ciliary body at its anterior extremity, *i.e.,* where it joins the rudimentary iris. These folds extend inwards and backwards, passing between the side of the lens and the unfolded area of the ciliary body, which by that time have become somewhat separated. The apex of these folds extends so far back along the side of the lens as to reach its posterior lateral parts. (Pl. III, Fig. 1.)

In the later growth of the eye both plicated and non-plicated parts of the ciliary body become separated away from the sides of the lens. The development of the anterior chamber, and consequent displacement backward of the lens, tends still further to draw the ciliary processes away from a level with its posterior surface to a level with its anterior surface. (Pl. III, Fig. 2.)

The final stage in the development of the ciliary body, and one which is not complete until some time after birth, consists in the lengthening out of the non-plicated part of the ciliary body, and the further displacement backwards of it and of the *ora serrata* away from the lens. (Pl. IV, Figs. 1 and 2.)

It will thus be seen that different portions of the ciliary body are in contact with the sides of the lens at different times, and that adhesions which form between them must originate at different times.

The first to be formed are those passing between the anterior part of the lens capsule and the non-plicated part of the ciliary body, which as these structures grow apart become stretched out into the orbiculo-antero-capsular fibres of the suspensory ligament.

Next in formation are the adhesions between the posterior part of the non-plicated part of the ciliary body, together with the *ora serrata*, and the posterior part of the lens capsule which later result in the orbiculo-posterio-capsular fibres.

As the ciliary processes commence to form and grow, extending backwards between the rudimentary non-plicated part and side of the lens, they pass between the several bundles of the orbiculo-antero-capsular fibres, which latter come ultimately to lie in the valleys between the ciliary processes.

While the ciliary processes lie in contact with the sides and posterior lateral portion of lens, adhesions form, which on separation of those structures become lengthened out into cilio-posterio-capsular fibres and cilio-equatorial fibres.

The growth of the ciliary body away from the side of the lens, not only tends to stretch out and lengthen adhesions which have formed between them, but also causes considerable traction on the capsule of the lens.

We find that in early fœtal life, when the ciliary body is in contact with the lens the latter is round. As the ciliary body grows away from it, its lateral diameter increases considerably out of proportion to its antero-posterior diameter.

If this lateral traction on the lens is exerted to an abnormal extent, as it is in the expansion of the ciliary region in buphthalmic eyes, then the disproportion between its lateral and antero-posterior diameters becomes markedly increased.

The growth of the ciliary processes away from the posterior lateral portion of the lens, and the displacement of the lens backwards on the formation of the anterior chamber causes, through the cilio-posterior capsular fibres, considerable traction on the posterior capsule (Fig. *a* in text).

The growth backwards away from the sides of the lens of the non-plicated portion of the ciliary body causes, through the orbiculo-antero-capsular fibres, considerable traction on the anterior capsule.

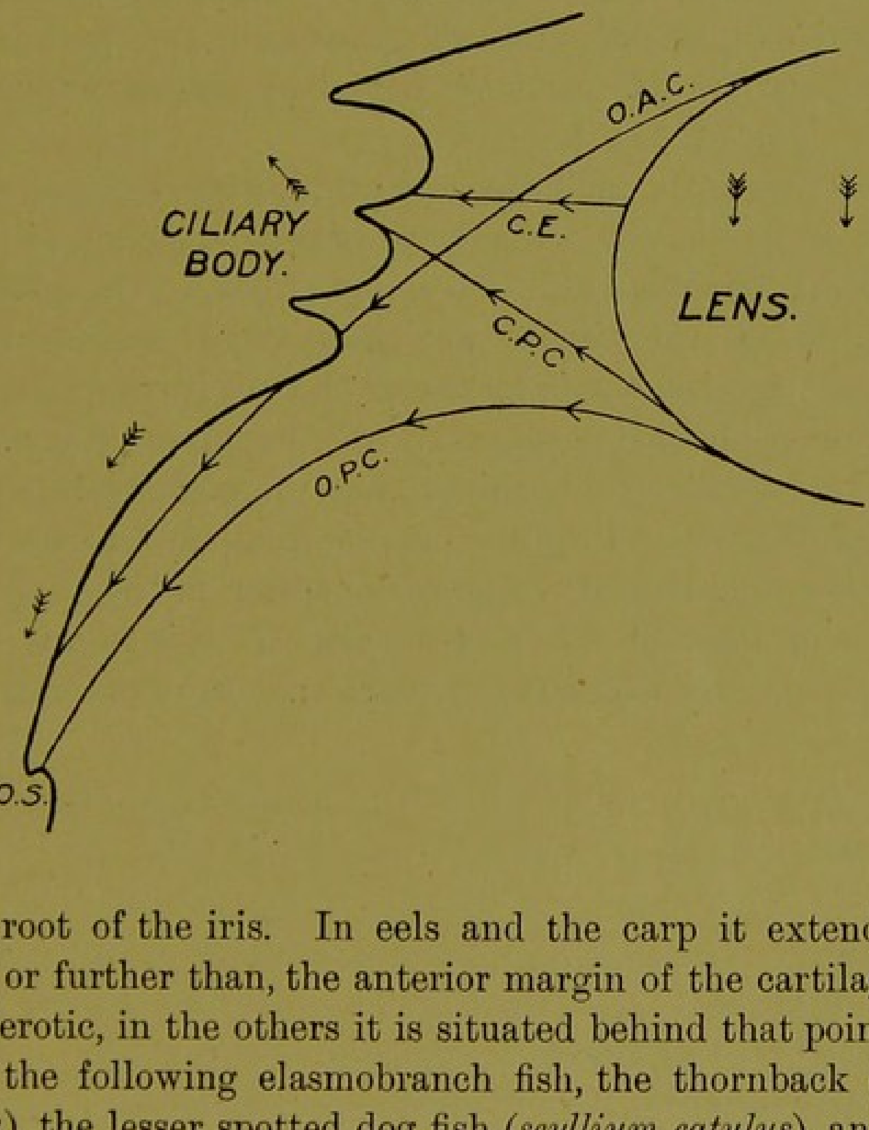
There are thus developed in the growth and expansion of the eye forces dragging on the posterior part of the lens capsule forwards and outwards, and on the anterior part of the lens capsule backwards and outwards.

The effect of this on the elastic curved lens fibres is to cause them to become more bent and kept in a state of tension. A state of tension which is only relaxed when by the contraction of the ciliary muscle the suspensory ligament is slackened and the pull on the capsule relieved.

It is interesting to note, in connection with the development of the ciliary body in the human eye, that the different temporary stages through which it passes are formed as permanent conditions in lower animals. In the lowest fish, eels, and also in some species of carp, there is no ciliary body, the retina ends at the base of the iris. (Pl. V, Fig. 1).

In the following teleostean fish, whiting (*gadus merlangus*), cod (*gadus morrhua*), mackerel (*scomber scombrus*), and plaice (*pleuronictis platessa*), the termination of the retina does not extend quite so far forwards, it does not quite reach up

Fig. *a*.




to the root of the iris. In eels and the carp it extends as far as, or further than, the anterior margin of the cartilage in the sclerotic, in the others it is situated behind that point.

In the following elasmobranch fish, the thornback (*raja clavata*), the lesser spotted dog fish (*scyllium catulus*), and the spring dog fish (*acanthus vulgaris*), the displacement backwards of the anterior termination of the retina is still more marked. The area which extends between it and the root of the iris is thrown into shallow folds laterally, and has some slight elevations and depressions antero-posteriorly. It is lined by a single row of unpigmented cells, the *pars ciliaris retinæ*.

In the eyes of the following reptiles, the land tortoise (*testudo Græca*), the slow worm (*anguis fragilis*) and the sand lizard (*lacerta agilis*), the ciliary body is represented by a short area lined by a single row of unpigmented cells, situated between the root of the iris and termination of the retina without any elevations or depressions in it. (Pl. V, Fig. 2). In the common ringed snake (*coluber natrix*) there is a well marked simple fold protruding inwards and backwards in the ciliary region, lined by columnar shaped unpigmented cells. (Pl. VI, Fig. 1.)

All mammals, including the ornithorrynchus and echidna, have well marked ciliary processes showing in antero-posterior sections well developed folds. The amount of plication of the ciliary processes varies considerably in different species, but in all except the quadrumana the extent of the non-plicated area is markedly less than in man.

The following table shows that the distance between the root of the iris and the *ora serrata* compared to the antero-posterior diameter of the globe is greater in the quadrumana and man than in other mammals. That is to say, that in those mammals who have greatest amount of accommodative

| | Antero posterior diameter of eyeball. | Distance between root of iris and ora serrata. |
|---|---|---|
| | mm. | mm. |
| Man ... ... ... ... | 24·8 | 6 |
| Chimpanzee ... ... ... | 19 | 4·25 |
| Rhesus monkey (India) ... ... | 19·5 | 5 |
| Capuchin monkey (South America) | 18·5 | 4·25 |
| Cat ... ... ... ... ... | 22 | 3·5 |
| Sheep ... ... ... ... | 28 | 6 |
| Bullock ... ... ... ... | 35 | 6·5 |
| Pig ... ... ... ... ... | 22 | 4 |
| Rabbit ... ... ... ... | 19 | 2 |

power, there is the widest separation of the *ora serrata* from the anterior surface of the lens and consequently the greatest amount of drag on the anterior capsule.

In the examination of sections of human microphthalmic eyes it is frequently found that there has been an arrested development of the ciliary body and suspensory ligament.

Relations of the ciliary body to the sides of the lens which are only temporary phases in fœtal life are found, and evidence of the cellular origin of the fibres of the suspensory ligament is met with.

In one microphthalmic eye of which I have recorded a description, the vascular system of the vitreous and lens, which exists during fœtal life, had failed to become obliterated, a complete network of blood-vessels encircled the lens. The ciliary processes had failed to develop, the *pars ciliaris retinæ* and *ora serrata* were in contact with the sides of the lens. In the expansion of the globe their adhesion to the lens had remained so firm, that the two layers of the secondary optic vesicle became torn apart in the ciliary region, instead of its inner layer growing away from the lens. In other microphthalmic eyes, where the central hyaloid artery has remained patent and where the anterior part of the vitreous has developed atypically, I have found the ciliary processes passing backwards and adherent to the posterior lateral part of the lens.

I have also found that the retina at the *ora serrata* has failed to grow backwards away from the back of the lens, a fold having become formed in it in that position. An abnormally short non-plicated area of the ciliary body is a frequent accompaniment of microphthalmia.

I have sections of microphthalmic eyes in which the apices of the ciliary processes are in close proximity to the lens capsule, and where some elongated cells join the two structures. Also sections of several eyes in which stretching between the ciliary body and the lens capsule are fibres, like those of the suspensory ligament but with nuclei on them. Some of these at their insertion into the ciliary body are seen to pass definitely into elongated cells (*vide* Figs. 1 and 2, pp. 84 and 85, vol. xiii, of the R.L.O.H. Reports).

In one specimen in which the lens was congenitally displaced, in the interval between the ciliary body and lens on the opposite side to which the latter was drawn, there were no fibres of suspensory ligament, but lying in the circumlental space in front of some atypically developed vitreous were some elongated cells and nucleated fibres. (Pl. VI, Fig. 2.)

## Description of Plates I—VI.

Plate I, Figs. 1 and 2.—Show the suspensory ligament of the lens in sections of a normal human eye. The foremost fibres shown in Fig. 2 are the orbiculo-antero-capsular fibres, the prolongation of which backwards to the non-plicated part of the ciliary body is shown in Fig. 1. The hindermost fibres shown in both figures are the orbiculo-postero-capsular fibres. The cilio-equatorial fibres can be seen in Fig. 2 crossing the orbiculo-antero-capsular fibres, and passing direct from the ciliary processes to the equator of the lens. The cilio-postero-capsular fibres are shown in Fig. 2 and at their commencement in Fig. 1. They cross the cilio-equatorial and orbiculo-antero-capsular fibres, and pass to the back of the lens.

Plate II, Fig. 1.—Shows a section through the eye of a human fœtus of the 6th week. The lens vesicle has become shut off from the surface epiblast. There is no iris or ciliary body. The termination of the secondary optic vesicle touches the antero-lateral part of the lens. The ciliary body and iris grow out from it, and what is at this stage its termination ultimately corresponds to the *ora serrata*. Some tissue, composed of spindle-shaped cells which becomes the fibro-vascular sheath of the lens, lies between the sides of the lens capsule and the inner layer of the secondary optic vesicle.

Fig. 2.—Shows a section of fœtal pig's eye. The lens is in contact with the back of the cornea. The iris and ciliary body have commenced to grow out of the anterior part of the secondary optic vesicle. The part which would have ultimately corresponded to the *ora serrata* lies opposite the equator of the lens.

Plate III, Fig. 1.—Shows a section through the anterior part of a human fœtal eye of about the 10th week. The eyelids are seen united over the front of the cornea. The lens is in contact with the back of the cornea. The iris is beginning to grow and insinuate itself between the lens and cornea. The ciliary process is seen beginning to grow out with a direction backwards towards the postero-lateral part of the lens. In the preparation of the specimen the pigmented layer of the ciliary body has become slightly separated away from the *pars ciliaris retinæ*; the latter lies in close contact with the side of the lens.

FIG. 2.—Shows a section through a portion of a human fœtal eye of between the 4th and 5th month. The lens is separated away from the cornea, and the ciliary processes from the side of the lens. The most anterior of the ciliary processes points backwards in the direction of the posterior lateral part of the lens. A piece of a cellular adhesion, which stretched between them, is shown attached to the postero-lateral part of the lens. There is no non-plicated part of the ciliary body.

PLATE IV, FIG. 1.—Shows a section through a portion of a human fœtal eye of between the 4th and 5th month. The lens is separated from the back of the cornea. The ciliary processes have grown a short way away from the side of the lens; stretching between them can be seen the fibres of the suspensory ligament with a few nuclei faintly showing on them. There is no non-plicated part of the ciliary body. The retina, in preparing the specimen, has become detached; the *ora serrata* is situated at the termination of the ciliary processes.

FIG. 2.—Shows a section through the ciliary body and suspensory ligament in a normal adult human eye. The wide separation of the *ora serrata* from the ciliary processes and from the side of the lens is seen. It is due to the lengthening out of the non-plicated part of the ciliary body.

PLATE V, FIG. 1.—Shows a section through the angle of the anterior chamber and anterior termination of the retina of the eye of an eel. The posterior layers of the cornea, in the preparation of the specimen, have become spaced out. The anterior chamber is very shallow. There is no ciliary body. The anterior termination of the retina extends up to the root of the iris, almost as far as the angle of the anterior chamber.

FIG. 2.—Shows a section through the eye of a sand lizard. There is a small non-plicated area seen between the root of the iris and the anterior termination of the retina.

PLATE VI, FIG. 1.—Shows a section through the angle of the anterior chamber and ciliary region of the eye of a common ringed snake. The anterior chamber is very shallow. Between the root of the iris and the anterior termination of the retina one simple fold protrudes inwards, constituting the ciliary body.

FIG. 2.—Shows a section through ciliary region of a human eye which had a congenitally displaced lens. Between the ciliary processes and the side of the lens, instead of the fibres of the suspensory ligament, some elongated cells and nucleated fibres are seen.

## Description of Fig. *a* in Text.

This diagram is to represent the direction of the different forces which come into play in the development of the suspensory ligament. The letters are the initials of the names of the different sets of fibres in the suspensory ligament, which are here each represented by a single line. The arrows and arrow heads show the direction in which traction is exerted on the lens. The arrows on the lens itself indicate that on the formation of the anterior chamber it is displaced backwards.

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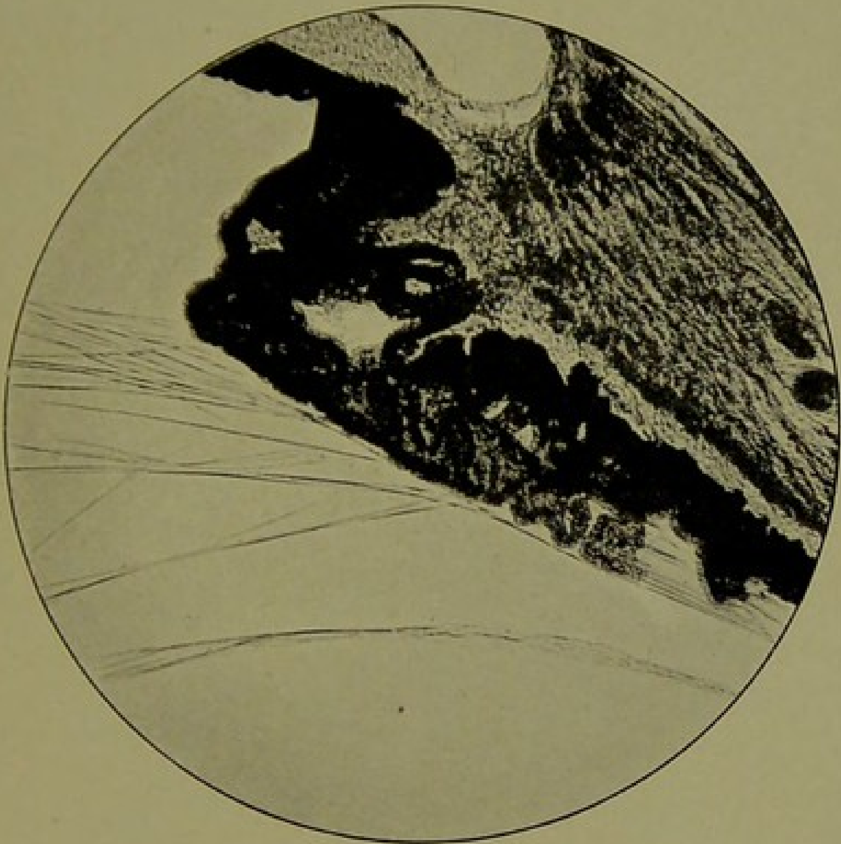

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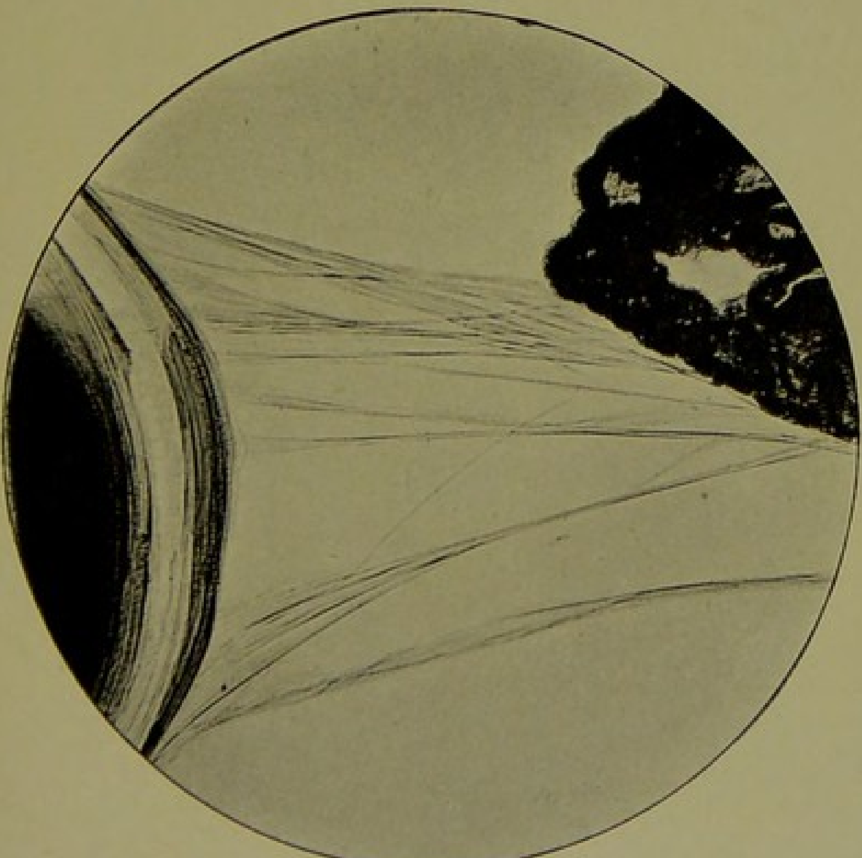

Fig. 2.

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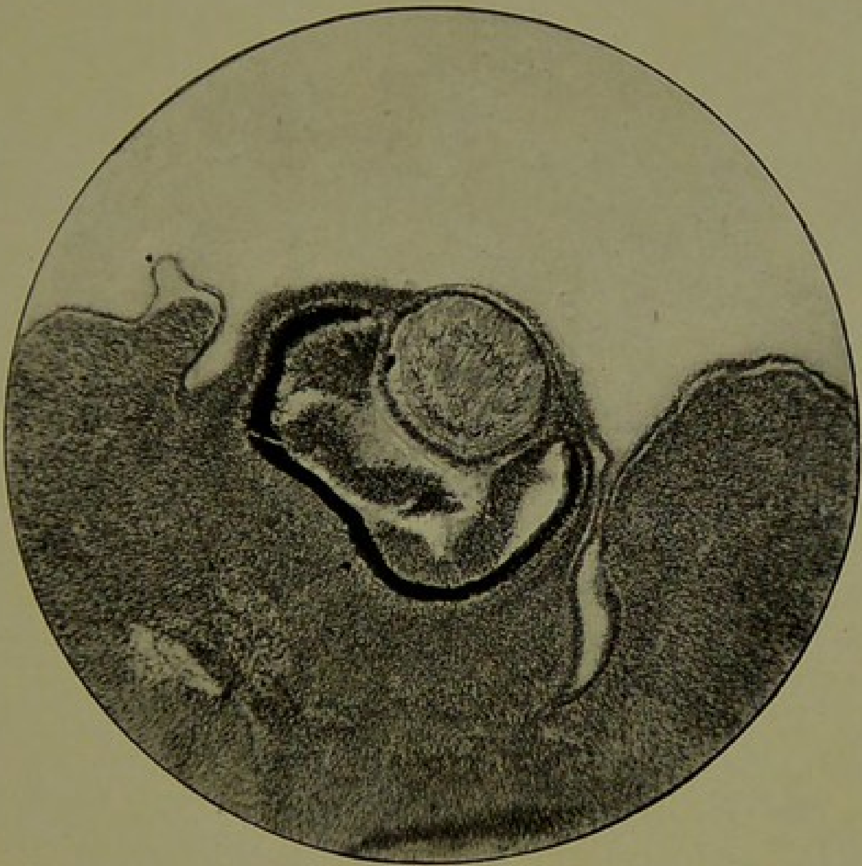

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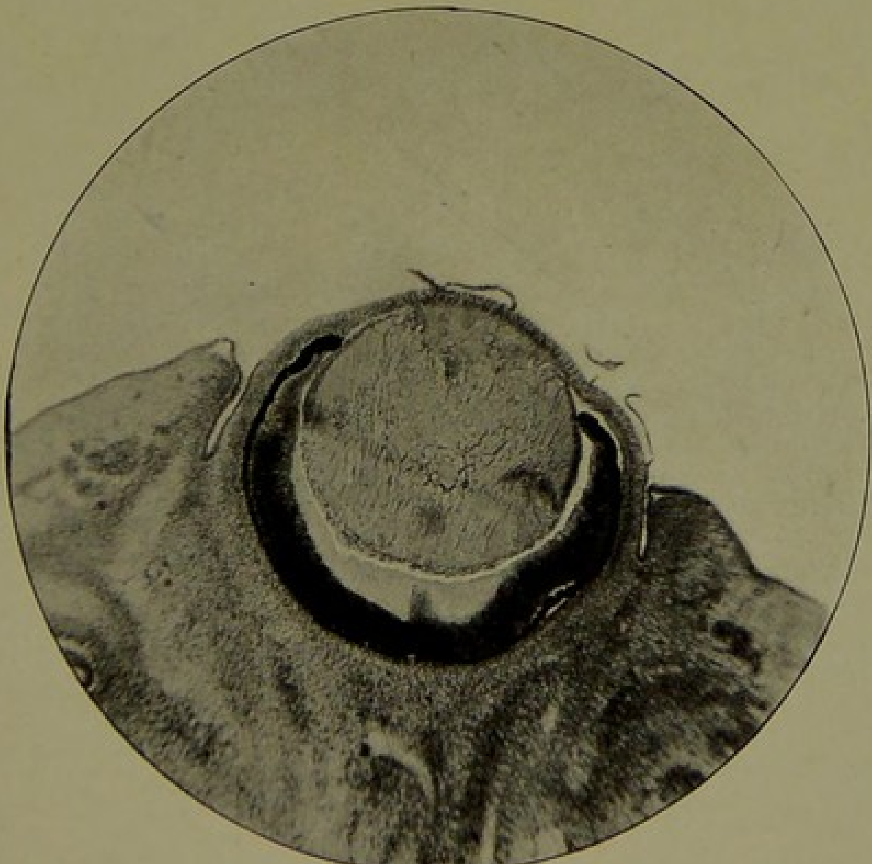

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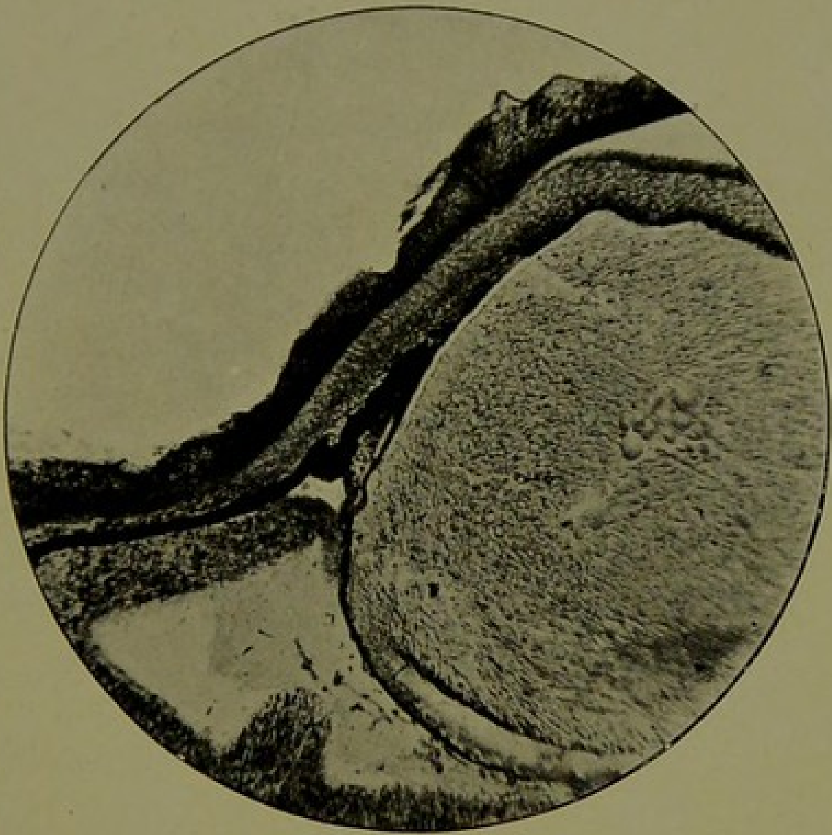

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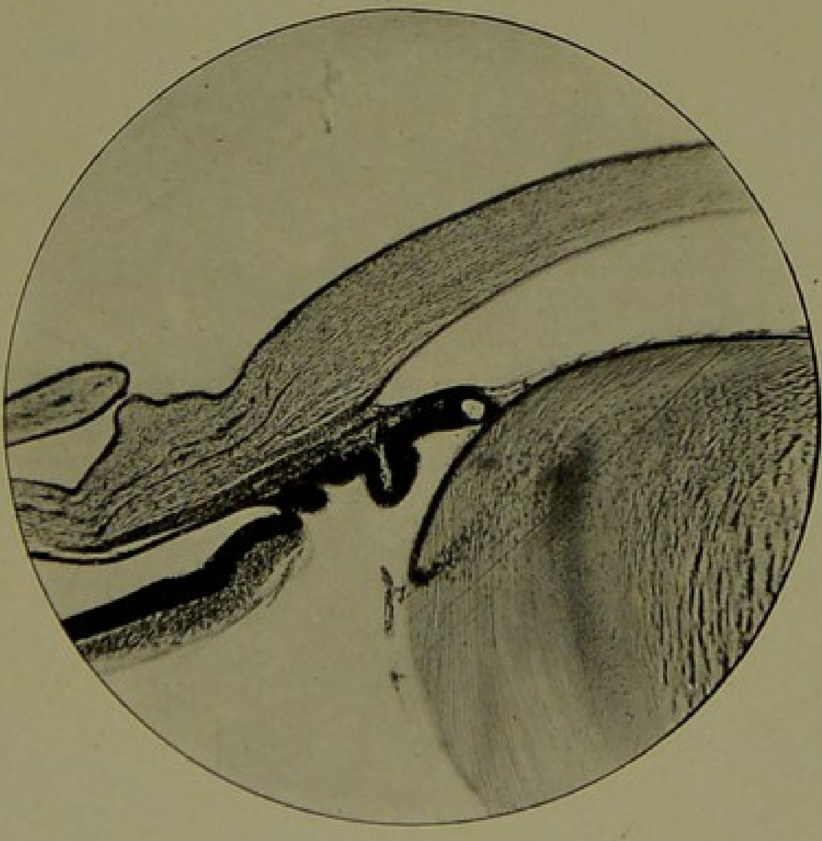

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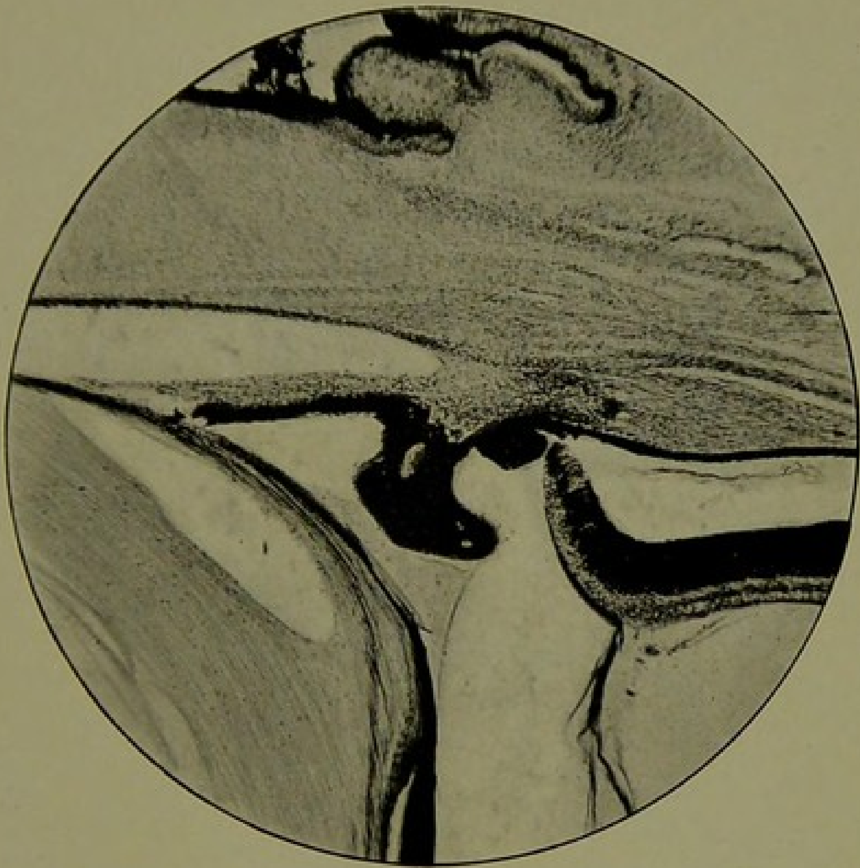

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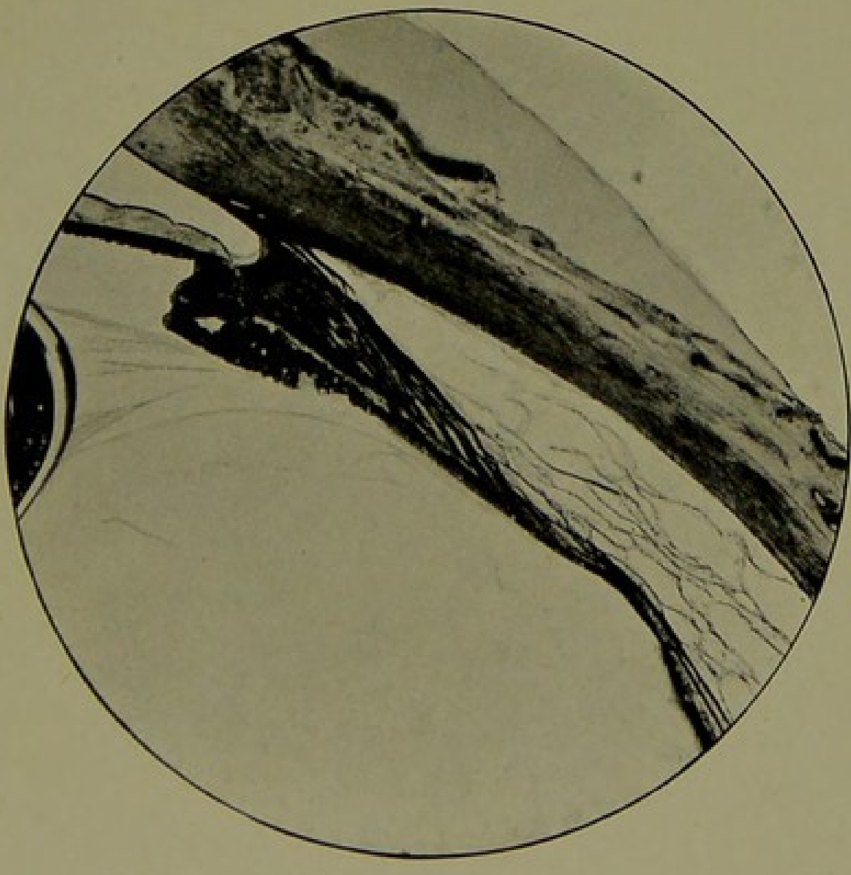

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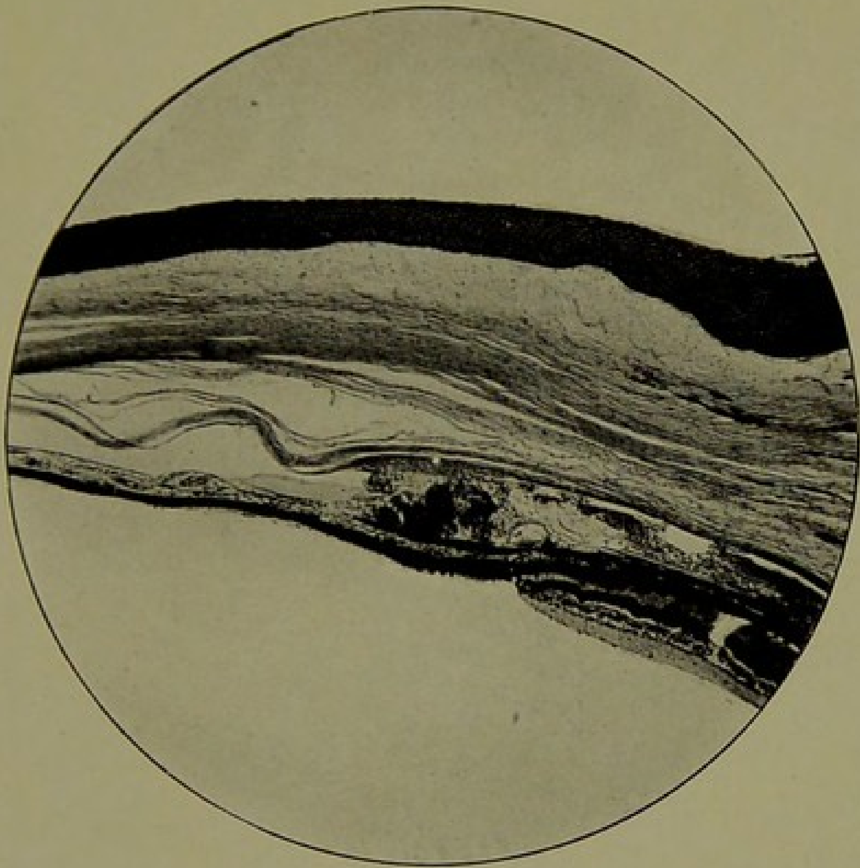

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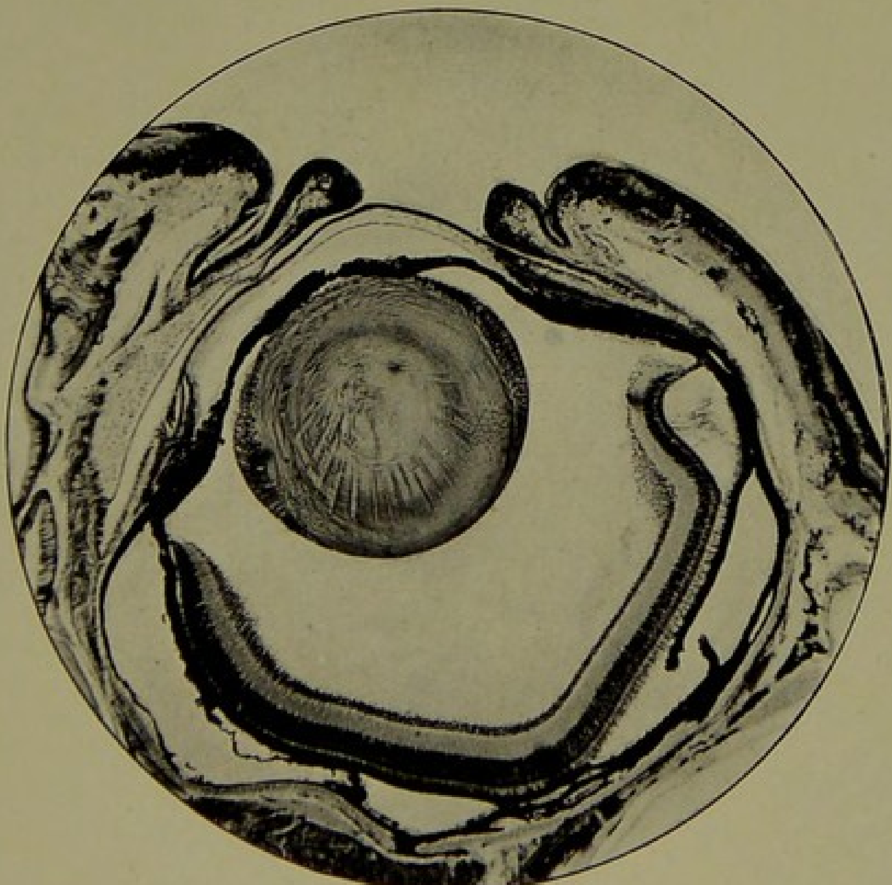

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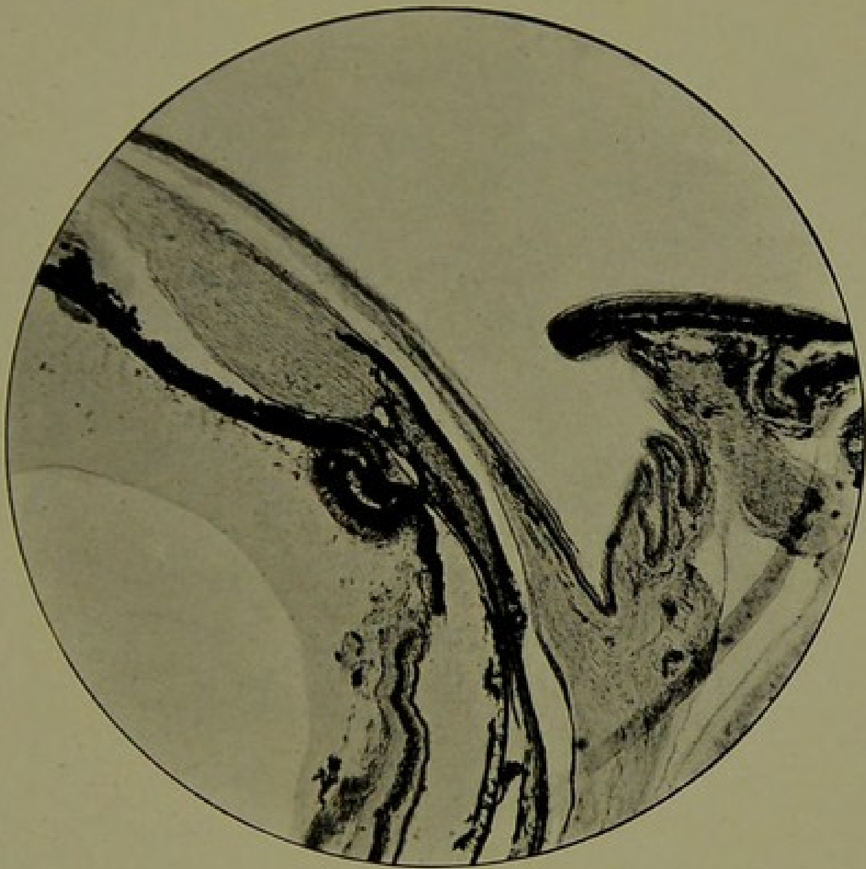

FIG. 1.

FIG. 2.

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