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COMMUNICATIONS

ON THE CEMENT SUBSTANCE OF THE INTRA-
OCULAR MUSCLES AND CHRONIC GLAUCOMA

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PART I

THE work here described, begun primarily as a research into the nature of the cement of the plain muscle of the eye, is of interest to ophthalmologists mainly in two of its results: (1) It leads up to and includes the demonstration of a complete glaucoma mechanism; and (2), it throws a good deal of light on the filtration angle and on the ciliary body, that is long overdue.

The Cement Substance and its Function

The evidence suggests that the cement of the muscles in the human eye differs somewhat in quality from that of smooth muscle elsewhere in the body, and from that of the eyes of animals below primates. It raises the question whether this particular cement should not be included among the recognised hyaline or glass membrane structures of the eye, with a definite rôle beyond that of a mere cement. In the ciliary body particularly it appears to be needed as part of the hyaline membrane system subserving man's highly developed accommodation.

The question seems to be merely one of degree of differentiation. It is a fact that the recognised hyaline membranes of the eye can be shown to vary considerably in grade of development.

The available evidence regarding the cement falls under three headings: (1) staining properties and appearance under the microscope; (2) direct continuity (*a*) of the cement with undoubted hyaline membrane, and (*b*) of the muscle fibres with the cells that secrete the hyaline membrane concerned; and (3) facts bearing on function.

The difference from the cement of unstriated muscle elsewhere may not be great. But the less this difference, the more must this evidence incline one to look for the properties of hyaline membrane—watch-spring type of elasticity, coupled with exceptional resistance—in the cement of unstriated muscle generally.

(I) Selective Staining and Texture

Hyaline membrane colours selectively with acid orcein, less deeply than elastic tissue, but considerably more so than white fibrous tissue (collagen) does. The cement of ordinary smooth muscle colours fairly well, but that of the ciliary muscle and of the pupillary sphincter has stained so strongly in some of my sections as to suggest glass membrane properties, when considered with the evidence given below under heading (II). But I believe that in all methods involving over-staining and subsequent differentiation, the personal equation is held to influence results so greatly that such observations have little absolute value.

Sections have been stained for one or two days in a freshly-made saturated solution of orcein, of a proved brand, in acid alcohol (hydrochloric acid 1, methylated spirit 100). Differentiation has been in spirit, both with and without the acid. The procedure has varied in detail. Following Unna's practice, the staining has sometimes been intensified by heating the dish in the incubator, or slowly over a spirit lamp. Considerably over one hundred eyes have been cut and stained by this and other methods.

FIG. 1.

Cement substance of portions of circular muscle bundles under oil immersion lens.

α = elastic fibres.

b = inter-fascicular fibrous tissue.

The differential colouring being relative only, much depends on the surroundings. The various orcein-staining tissues must lie fairly open, or must be separated by non-staining material, such as epithelial cells or muscle fibres, in order to give successful results.

In some of my most successfully stained sections there happen to be conjunctival blood vessels large enough to possess a definite tunica media. The cement of the muscle of these vessels is distinctly less coloured than that of the ciliary muscle in the same sections; but this difference may be an accident of position. It must be admitted that the staining of the thin films of cement is too uncertain to carry much weight. But it is in keeping with other evidence, and this is all that one can expect.

Apart from the staining the appearance of the cement of the circular bundles of the ciliary muscle is rather striking in some old people, forming honeycomb meshworks (see Fig. 1). Many of the spaces in the meshwork may appear by this staining empty, owing to vacuolation of the contained muscle fibres. The sharply defined dusky framework of homogeneous translucent material appears to stand out with a certain rigidity of its own, rather suggestive of a hyaline membranous structure.

Variation in quality among the several hyaline membranes of the eye is very noticeable when one compares Descemet's membrane with the outer limiting membrane of the ciliary body—the cuticular lamella—the basement membrane of the pigment epithelium. In some old people the limiting membrane may be thicker in parts than the central portions of Descemet's membrane, but it does not colour nearly as deeply. And that the relatively poor staining quality of the limiting membrane indicates a lower grade of differentiation is shown also by the fact that in texture it does not present the dense glassy appearance of Descemet's membrane, or of the lens capsule. It looks relatively dull and cloudy, without very sharply defined margins; and in some of my older sections it appears far from uniform in structure owing to uneven fading—quite different from the other membranes. And it does not resist inflammatory processes nearly so well as these membranes do.

Correspondingly defective quality is found also in the laminated chronic inflammatory formations in the anterior chamber, that are formed from migrated ciliary epithelial cells, contrasting with the very dense extensions of Descemet's membrane sometimes found on the iris, or on chronic inflammatory new tissue lying against the lower part of the cornea⁽¹⁾. But the cells from which the laminated accumulations in the anterior chamber are derived are probably mainly from the non-pigmented epithelium, and so belong to the inner—not the outer—limiting membrane.

(II) Direct Continuity

Continuity of the cement with recognised hyaline membrane, and of the muscle fibres with the cells that secrete the membrane, undoubtedly constitutes the strongest reason for regarding the cement as something out of the ordinary. The continuity occurs at two points—(1) at the base of the iris, and (2) at the origin of some of the ciliary muscle bundles.

(1) *At the base of the iris.* The finding of the section shown in Fig. 2 practically started the whole research. Its altogether exceptional value depends on a combination of three unusual features. There is (a) slight chronic inflammatory thickening of the cement of the periphery of the dilatator muscle of the pupil, (b) an offshoot of proliferated epithelial-muscle cells (x) conven-

FIG. 2. $\times 200$.

x = Offshoot from dilatator.
 x' = Connecting stalk.

y = Limitans externa.
 z = Cement meshwork of dilatator.

iently clear of pigment, and (c) exceptionally deep selective orcein staining.

The section happens to cut across the thickened periphery of the muscle between two of the well known radiations that pass back into the ciliary body. Thus the fibres are in cross section, and the dark cement forms a network that is only partly obscured by the pigment in the contained fibres. The hyaline outer limiting membrane (y) is clearly seen to end in this network. Minute examination under the microscope revealed no difference between the substance of the muscle-cement and of the limiting membrane. The thickened cement in parts of the proliferated group of cells (x) is

well shown, and under the microscope streaks of the same material were very noticeable also in the narrow connecting stalk (x^1).

There is, of course, no doubt about the direct continuity of the "epithelial muscle cells" of the dilatator with the pigment epithelium of the ciliary body, that secretes the limiting membrane. They represent the same layer of the optic vesicle. And except quite at the base of the iris, and to some extent beneath the sphincter muscle, the pigmented nucleated portions of the epithelial muscle cells of the dilatator muscle retain the appearance of the

FIG. 3. $\times 200$.

- a* = Proliferated epithelial cells enclosed in thin hyaline capsules.
- b* = Cement of dilatator pupillae.
- c* = Outer limiting membrane.
- d* = Abnormal gap, ? artefact or ? pathological.

ciliary pigment epithelium unaltered. In both positions the cement between adjacent cells is too thin to be stained. Practically the only difference is that in the iris, in place of the thick hyaline basement membrane of the ciliary body, the corresponding layer known as the "posterior border lamella" is mainly made up of unpigmented myofibril-containing expansions from the cells. It is by no means difficult, by orcein staining, to show the hyaline membrane still remaining between these contractile cell-expansions (see Fig. 3, *b*).

In other words, the forward prolongation of the outer layer of the optic vesicle, in taking on the additional function of muscular contractility does not entirely give up its primary function of forming hyaline membrane. It is what one would expect.

Fig. 3, from a highly myopic eye, shows the same thing in simpler and less striking fashion. There has been chronic inflam-

matory proliferation of the pigment epithelium of practically the whole of the corona, the elevated portion of the ciliary body; and this has extended apparently to the periphery of the dilatator muscle of the iris. Proliferated epithelial cells (a) have moved a little away into the neighbouring tissues, carrying with them capsules of their hyaline basement membrane. The same process of separation of cells has reduced the ordinarily thickened end of the dilatator muscle to a single layer, enclosed in a single layer of hyaline membrane, representing the external limiting membrane (c), but separated from the latter by a small gap (d), which is either an artefact or pathological.

The evidence of these photographs seems conclusive as regards the *practical identity in substance of the dilatator cement and of the external limiting membrane*. The observation must be of considerable physiological interest, since it definitely raises the question of comparison with the cement of plain muscle elsewhere in the body. It stands out as a basal fact, strong enough to serve as a basis for deduction and speculation.

(2) The essentials, in this connection, of **the origin of the ciliary muscle** may be summarised thus: Direct continuity between hyaline membrane and muscle cement can be shown, though with difficulty, and not for the whole muscle. This fact, added to the information already gained with regard to the iris muscle and its cement, is sufficient to establish a *close relationship* in structure between the hyaline membrane of the pectinate ligament and the cement. But it does not go beyond this, to establish identity.

There is no aid obtainable here from chronic inflammatory thickening of cement, such as that shown at the base of the iris. And though the junction of hyaline membrane and cement necessarily implies continuity between the muscle fibres and the endothelial cells that secrete the hyaline membrane, this continuity cannot be seen, owing to the endothelium being too thin to be traced.

Also the relationship between the original endothelial cell and the fibrillated spindle cell of the ciliary muscle is less obvious than that existing between the ciliary pigment epithelium and its end result in the non-pigmented spindle cell of the iris, found in the pupillary sphincter muscle and in the bands connecting it with the dilatator, and in the peripheral radiations of the dilatator. In the iris the relationship is punctuated by the two intermediate phases—first, that in the greater portion of the iris, in which only a portion of the cell is fibrillated and elongated, and, secondly, that in the proximal portions of the peripheral radiations of the dilatator muscle, in which the whole spindle remains pigmented, though fibrillated.

This relative weakness of the histological evidence regarding the nature and connections of the ciliary muscle cement is made good

to some extent later under section No. III, Function. The histological evidence in detail, and its limitations, are as follows:

Fig. 4 shows clearly the tapering head (*a*) of a meridional muscle fasciculus encased in hyaline membrane. There is no possibility of error in this. The darker streak on each side of the tapering

FIG. 4. $\times 103$.

Orcein staining.

- a* = Tapering muscle head enclosed in hyaline membrane.
- b* = Posterior end of Schlemm's canal.
- c* = Pectinate ligament.
- d* = Spaces bordered by hyaline membrane.

muscle head is obviously composed of the same material as the broader hyaline bands continued back from the pectinate ligament. This being so, it is certain that the unseen cement of the muscle head must come into direct contact with the hyaline sheath, since every muscle fibre is always enclosed in cement. This is particularly noticeable in the sphincter of the pupil, ordinarily seen in cross-section.

In Fig. 5 a radial muscle head and its very thick sheath are well seen under an oil immersion lens. One of the difficulties in this work is here illustrated. The thin lines of cement between the

muscle fibres are seen, but the demonstration of their actual junction with the sheath fails, mainly, I think, owing to elastic tissue within the sheath. There is an unusual quantity of elastic tissue in this eye between the muscle heads also, seen as black, irregular blobs.

There is not the slightest doubt that these photographs illustrate a normal and typical mode of origin from the pectinate ligament. I believe that they represent the true origin in early life of all the radial (oblique), and frequently also of the inner meridional muscle

Very thick hyaline band dividing below
to enclose a muscle head.

FIG. 5.

Under oil immersion.

fasciculi—in some cases all except the outer few fasciculi that arise from the sclerotic. Yet in most eyes it is difficult to find any such tapering sheathed muscle head, and it is quite rare to find more than one in a section.

The muscle fasciculi to the inner side of the one showing the sheathed head have all retracted more or less from their sheaths (See later, in Part II of this Paper.) And the empty sheaths do not remain open. They lie mixed with wavy elastic fibres, forming the zone of tissue bounding the angle of the chamber. And it is impossible to stain the empty hyaline sheaths selectively, except when they are pulled open by some abnormal lateral traction, such as that seen in Fig. 6, due to a shrinking lens and organizing exudate, following a recent penetrating wound.

The meridional muscle heads are also too closely packed normally for clear differential staining of their hyaline sheaths. I have sections, however, of an eye in which two fasciculi have been widened and separated by inward traction like that of Fig. 6, so that the sheaths can be clearly seen enclosing the muscle heads, and faintly, here and there, the inter-muscular cement reaching up to the sheaths, in spite of poor staining. But there are certainly exceptions to this mode of origin of the meridional muscle. See, for example, the tendon, quite free from hyaline substance, shown in the photograph, *Brit. Jl. of Ophthalm.*, 1923, p. 470, and *Trans. Ophthalm. Soc. U.K.*, XLV (1925), i, p. 341. And in some eyes, more especially, perhaps, those in which the lamellae of the pectinate ligament are thin, the lamellae

FIG. 6.

- a* = Hyaline band dividing below to form a sheath, containing only streaky elastic tissue.
*a*¹ = Muscle head retracted from the sheath.
b and *b*¹ = Similar band, sheath and muscle head.
c = An unretracted muscle fasciculus.

continue on to the meridional muscle fasciculi unchanged, with white fibrous centres, and hyaline coverings.

Part of the difficulty experienced in tracing the change from the Descemet endothelium to ciliary muscle fibres is doubtless due to the rearrangement of the tissues, whereby the muscle fibres lie within the glass membrane sheaths, while in the pectinate ligament the endothelium lies outside the glass membrane bands. But there need be little hesitation in affirming a direct relationship between the cells and the fibres, since there are no other cells from which any but the outer meridional muscle fasciculi can have developed. The white fibrous centres of the ligamentous trabeculae are entirely without nuclei (Salzmann⁽²⁾). Collagenous centres of quite the innermost bands of the ligament may extend backwards well beyond the level of some of the radial muscle heads. But such bands have no direct connection with the ciliary muscle; they go to the "elastic ring" (see later, Part III) and are connected through it with the dilatator muscle of the pupil.

The Scleral Origin of the Muscle. Since the whole ciliary muscle is held to form a continuous meshwork, the origin of one portion of it from hyaline membrane should serve in some degree as a hyaline connection for the whole. But this conception becomes at least somewhat strained for the outer meridional bands that commonly arise from the sclera behind the scleral furrow.

This limited purely fibrous tissue origin undoubtedly tends to discount somewhat heavily any inference that may be drawn from the much wider hyaline connections of the muscle. But it seems to be the only serious objection to the suggestion of

hyaline qualities in the muscle cement; and it is largely overcome by the fact that the direct scleral attachment is morphologically a late development, and therefore perhaps secondary in influence, a scleral spur being confined to primates.

Morphology

A cursory examination of the eyes of the more readily available domesticated mammals serves further to reduce the scleral attachment of the muscle in man to relative unimportance, in this connection. It is necessary here to utilize one general deduction that may be drawn from such examination. It may be formulated thus: Fibrous bands of uvea attached to the periphery of the cornea, forming part of the "uveal meshwork of the iris angle," tend to become enclosed in hyaline sheaths—outgrowths from Descemet's membrane—in proportion to the intermittent pull placed upon the bands in accommodation. This is shown in the following comparison: In the horse, representing ungulata, a short thick tube of hyaline membrane surrounds for a moderate distance the exceptionally thick band of uveal meshwork that passes across to the iris at the mouth of the sinus of the chamber. In some sections an additional band of the meshwork of the sinus is found similarly enclosed in hyaline substance, a little further back. But that is all. See illustrations in Graefe-Saemisch.⁽³⁾

In the eye of a retriever dog, of which I have sections, representing the higher domesticated carnivora, there is a definite step onwards, showing, I think, the mode of development of the middle and inner trabeculae of man's pectinate ligament, some of which give origin to the radial muscle bundles. In the dog's eye, the sheaths of the uveal bands at the mouth of the sinus are much thinner than in that of the horse. But there are, in addition, some very long sheathed bands running back through the outer part of the long sinus towards the middle portion of the more developed ciliary muscle. The sheaths cannot be traced as far as the muscle. But it is only a step onwards from this stage to the sheathed muscle-heads that I have shown above in the human eye.

I do not suggest that this endothelial product, hyaline membrane, actually extends onwards further, still unchanged, into the muscle in man, to constitute the muscle cement. But I do suggest that the same influence that stimulates the endothelium of Descemet's membrane to proliferate, extending backwards and forming new hyaline sheaths, serves also to stimulate the morphological equivalents of the Descemet endothelium—the muscle fibres—to the formation of something closely allied to hyaline membrane.

In support of this suggestion is the fact that only in primates apparently do the fibres of the inner and middle portions of the muscle remain grouped in clearly cut bundles anteriorly, entirely free from admixture with white fibrous tissue, as they are further back. The clearly cut circular and radial fasciculi in man, separated by solid blocks of fibrous tissue, form a great contrast to the condition in the animals

above mentioned. In the horse, particularly, the intermingling of muscle fibres and of connective tissue fibres anteriorly is very marked, many of the muscle fibres becoming lost individually in the areolar tissue of the sinus of the anterior chamber. In the horse, it is the shortest outermost portion of the muscle only that has any direct connection with hyaline membrane. These fibres disappear in the strongly developed "scleral meshwork" of the sinus, which, stretching backwards from Descemet's membrane, forms a broad area of closely set thick cords, cut across transversely in meridional sections, each formed largely of a thick hyaline shell.

The cement of the ciliary muscle is comparable with the outer limiting membrane in two respects. Relatively poor quality in the case of both structures may be attributed to the fact that, regarded as hyaline membrane, they are *late developments* morphologically, and, in a sense, *end developments*. That the somewhat rudimentary hyaline quality of the external limiting membrane in man, already discussed, is a late development, is seen on searching for its representative in the horse, for example. In the latter, I have found it very difficult to demonstrate any continuous basement membrane beneath the pigment epithelium. There is certainly no selective staining.

The glass membrane quality of the muscle cement, if admitted, is obviously an end development of the mesodermal glass membrane of the eye, comprising also Descemet's membrane, the pectinate ligament sheaths and their backward extensions.

And if it be true, as I feel sure it is, that the inter-cellular cement of the two layers of ciliary epithelium, pigmented and unpigmented, consists of hyaline substance⁽⁴⁾, the external limiting membrane may be regarded as the end development of a continuous ectodermal system, including lens capsule and zonule with the two limiting membranes and their intercellular connecting cement.

And the vessel-containing gap left between the outer limiting membrane and the ciliary muscle is *the only gap left in the hyaline multiple loop system that stretches across the eye from the periphery of Descemet's membrane on each side, enclosing the lens, and drawn tight posteriorly by the extension of the ectodermal section of the system to Bruch's membrane in the choroid.*

(III) Function

(1) *Of the cement of the pupillary dilatator.* There is apparently need for some resilient material, when the dilatator muscle is relaxed, to bring the base of the iris back into position automatically after each act of accommodation (see later, Part II). Fig. 4 is interesting in this connection, showing unusual evidence of slackness in the base of the iris—very uneven width and surfaces. The dilatator muscle, with its cement, does not extend peripherally as far as is usual; and there is an almost complete absence of the normal peripheral radiations of the muscle into the ciliary body. The result of the lack of the support normally afforded to the base of the iris by the muscle and its cement, and by its radiations, is seen in the photograph.

(2) *Of the cement of the pupillary sphincter.* There is a very obvious and serious objection to be met here: The extremely wide range of movement possible in the

pupil indicates a much higher degree of elasticity—the elasticity of rubber—in the cement of the sphincter muscle than one associates with hyaline membrane. But it is largely a question of degree, rather than of kind. The property of watch spring recoil is that required in an intermuscular meshwork of cement to bring back the pupil to a medium position of rest, either from pin-point contraction or from extreme dilatation.

(3) *Of the ciliary muscle cement.* There seems to be a *real need* for hyaline tissue in close association with the muscle. Apparently it has two uses, (a) and (b), varying with the state of the muscle :

(a) The primary need is to facilitate the action of the circular muscle bundles.

The strong but elastic attachment of the more mobile section (inner two-thirds) of the ciliary muscle, provided by the glass membrane meshwork of the pectinate ligament, is needed to allow the circular muscle bands to move inwards towards the lens, as a ring muscle, and to draw them back after their contraction. If the heads of the radial muscle bands were attached to rigid immovable fibrous tissue, the circular muscle fibres on contraction would tend to be drawn outwards by the shortening radial bundles, and they would soon cease to exist as circular bundles.

And if the extensile and resilient pectinate ligament bands have developed largely to provide freedom of movement to the inner muscle fibres, it must be agreed that there is an exactly similar need for extensile and resilient tissue extending throughout the connecting radial muscle bundles, to link up the inner fasciculi with the pectinate ligament. This need should supply the necessary stimulus. Given the stimulus, some attempt at the secretion of a muscle cement with hyaline qualities must follow unless the homology between the muscle fibres and the endothelium of the pectinate ligament and of Descemet's membrane means practically nothing; or, in other words, unless the presumptive potentialities of the endothelial derivatives, the muscle fibres, remain for some obscure reason in abeyance.

(b) *When the ciliary muscle is at rest*, there is constant tension of the lens capsule and zonule, flattening the lens⁽⁵⁾. And the portion of this tension that is not borne ultimately by the choroid (Bruch's membrane and elastic tissue) must be transmitted to the cornea and sclera through the attachment of the ciliary body.

As shown later (Part III) by the process of exclusion, the *only tissues found to be available* in the muscle area to transmit this zonular tension, converging to the pectinate ligament, are the cement meshwork of the muscle and such elastic fibres as are to be found mixed up with the cement (Fig. 1). The total bulk of the elastic fibres is insignificant compared with that of the cement substance, and there is nothing so well suited to support the continuous pull of glass membrane as a meshwork of glass membrane itself, with its watch spring qualities.

If the muscle cement has this quality it must serve, not only for transmitting the pull of lens capsule and zonule, but also to distribute and equalize this pull in rapid changes of accommodation of the eye.

It is true that there is nothing to transmit the zonular tension from the external limiting membrane to the muscle cement except ordinary elastic tissue supplemented by loose collagenous fibres. There are three remarks to be made concerning this :

(1) On the whole there is less tension to be borne in this space between limiting membrane and muscle than in the muscle area, since there can be no tension at all here when the zonule is relaxed in accommodation.

(2) The elastic fibres crossing the space, connecting the ciliary muscle with the external limiting membrane, are much thicker, or more numerous (see Part III), than those found closely associated with the muscle, except possibly in the case of some circular muscle fasciculi (Fig. 1) that are so placed that they can bear no portion of the tension of the zonule.

But (3) in spite of this, in many eyes there is evidence that *this hyaline-free gap constitutes a weakness, a serious defect.* The gap throughout the corona, the elevated zone of the ciliary body, and in quite the anterior portion of the orbiculus, *tends to widen throughout life*, and this stretching may have a bearing on the origin of glaucoma in either of two quite different ways. (It is taken for granted that in estimating the width of this space in the ground-plate of the ciliary body, between the ciliary processes, oblique sectioning is avoided, and the measurements are taken quite in the depth of the valleys between the processes.)

Tendencies towards Congestive Glaucoma

(1) *The widening along the inner side of the ciliary body* can only form part of the mechanism of glaucoma production indirectly through secondary enlargement of the ciliary processes. That widening of the space must lead to secondary enlargement of the ciliary processes seems highly probable from the detailed anatomy of the region, given in Part III of this paper. The veins in the ground-plate (between and beneath the ciliary processes) lie suspended between two lines of elastic network in loose areolar tissue. The separation of the two lines of support must tend to dilatation of the veins, and this again to secondary dilatation of the offshoot veins in the ciliary processes, directly enlarging the processes.

(2) Widening of the space immediately behind the iris may act also directly, since it means an advance of the ground-plate of the ciliary body towards the lens, directly narrowing the circumlental space.

These two influences lead to nothing very new in glaucoma causation. The subject, as regards primary congestive glaucoma, has been sufficiently worked out by Priestley Smith⁽⁶⁾. There are, however, some minor points of interest in the mechanism of the widening of the space :

(1) The widening along the inner side of the ciliary body may apparently be produced in two ways :

(a) The long zonular bundles (of fibres) and those of medium length, lying along the curved surface of the ciliary body, held in position possibly by the

FIG. 7.

FIG. 8.

multiple origins of individual fibres and by the "orbiculo-ciliary" fibres (Fig. 8), and in the region of the ciliary processes by a few circular fibres, must ordinarily exert a slight inward traction on the ciliary surface. The elasticity of the zonule must tend to pull the ciliary surface to the position of a straight line drawn between the extreme ends of the zonule—a line drawn from the ora serrata to the mean attachment of the zonular fibres to the lens capsule. The direction of the pull on the ciliary body as a whole must be somewhere near that of the arrow in Fig. 7.

The degree of traction must be in proportion to the height of the curve of the surface of the ciliary body. Therefore in eyes with a very thick prominent ciliary body, due to bulky muscle, this indirect inward pull may be *nil* in parts; and therefore in these eyes there may be little widening of the space.

(b) But in those eyes with prominent muscle there may be very obvious direct traction of the orbiculo-ciliary fibres, each stretched like the string of a bow, and inserted at various points on the elevated corona, as in Fig. 8. The direct pull of these fibres must tend to draw the points of attachment inwards and backwards. This is emphasized by the fact that elastic fibres crossing the widened vessel-containing space of the ciliary body may be found continuing exactly the direction of some of these orbiculo-ciliary zonular fibres, clearly extending the traction of the latter onwards to the ciliary muscle.

Exceptional widening of the space in a few people seems to be partly attributable to narrowing of the ciliary muscle from senile wasting. But usually inward displacement of the two limiting membranes and their contained epithelium appears to be the chief, or the only means by which the stretching is produced.

In old people it is common to find the fasciculi in the middle of the muscle much thinned, while those seen in cross section along the inner border of the muscle, forming the "inner net" or "plate" may possibly have actually increased in thickness at the expense of the middle bundles. And this relative development at the inner border of the muscle may reasonably be attributed, in part, to traction of the zonule transmitted to the muscle by the elastic tissue seen in Figs. 17 and 19. Thus senile shrinkage of the total muscle area may be prevented or diminished.

In a few old eyes the space has been found quite narrow, from compression in advanced glaucoma, or from obvious meridional traction of varying origin. But in one or two cases the explanation has not been found.

(2) In many eyes the space between muscle and limiting membrane is widest immediately behind the iris. Reasons are given later for attributing this largely to traction of the short fibres of the zonule. The pull of these fibres is direct, towards the lens, and may therefore be sufficiently effective, in some eyes, apparently to extend through the tissues to the ciliary muscle, influencing that also.

(To be continued.)