
DOMINE
UT VIDEAM

The Erasmus Wilson Lectures

ON

THE ANATOMY AND PATHOLOGY OF THE EYE.

Delivered at the Royal College of Surgeons of England on Feb. 12th, 14th, and 16th, 1900

BY

E. TREACHER COLLINS, F.R.C.S. Eng.

ASSISTANT SURGEON TO THE ROYAL LONDON OPHTHALMIC HOSPITAL

Reprinted from THE LANCET February 17 and 24, 1900.

The Erasmus Wilson Lectures

ON

THE ANATOMY AND PATHOLOGY OF THE EYE.

LECTURE I.

Delivered on Feb. 12th.

MR. PRESIDENT AND GENTLEMEN,—There is a law in biology to the effect that the various stages of development through which an individual passes typify to a great extent the history of the race. In the course of these lectures I shall have several opportunities of showing that in the study of the embryology of the human eye arrangements of parts are met with differing from what is present in the adult but simulating what is present in lower animals and, further, that when arrests of development occur conditions comparable to what are met with in lower animals, and not in man, sometimes persist.

THE EYELIDS OF ANIMALS AND THE HUMAN FŒTUS.

As an example I may first draw your attention to the development of the eyelids. In a human fœtus of six weeks no eyelids are present; the surface of the eye is directly continuous with the surface of the head. In eels and certain other fish there is no covering whatever for the eyes; the skin of the head is uninterruptedly continuous with the anterior layers of the cornea. In a human fœtus of about eight weeks the eyelids may be seen just commencing to bud out as little processes of mesoblast covered with epiblast above and below the eye. In most of the teleostean fish there is a little fold of projecting skin at the margin of the orbit, which varies in length in different species but does not usually reach the corneal margin. In a human fœtus the eyelids having budded out continue to grow over the front of the eyeball until they meet, when the epithelium along the margins becomes connected together, the conjunctiva being formed for a time into a closed sac. In the ophidia and some lacertilia the eyelids are permanently united in front of the eye; they are transparent and consist from without inwards of a continuous layer of laminated epithelium fibrous tissue and a single row of epithelial cells. The surface of the cornea is covered by but a single row of cells. The conjunctiva is a permanently closed sac through which the lacrymal secretion circulates. In the human fœtus the eyelids become separated again before birth. In many mammals of the feline tribe separation of the eyelids does not occur until some days after birth, so that their young are during birth protected from risks of infection of the conjunctival sac by secretion from the maternal passages—a protection which is unfortunately denied to man.

Cryptophthalmos.

Amongst the congenital malformations met with in connexion with the eyelids there is a condition of which I only know two cases that have been recorded in man, but of which I have met with one example in a chick. It is termed by Zehender[1] cryptophthalmos. In his case there was a total absence of the eyelids and their appendages, the eyebrows, the lacrymal glands, and the lacrymal ducts. The whole of the front of the eyes was covered by skin, continuous with that of the face, and connected with the surface of the eyeball by a subcutaneous cellular membrane. The absence of the lids had, as Zehender says, prevented the formation of a conjunctival sac. The eyeballs themselves, of which Manz made a pathological examination, presented several abnormalities; the chief of these were the imperfect development of the lens and the filling of the anterior chamber with vitreous. The optic nerve, retina, and its pigment epithelium were quite normal.

The second case, which was precisely similar as regards the absence of eyelids and the presence of skin over the

[1] Report of the Fourth International Congress of Ophthalmology, p. 86.

front of the eyes, has been described by Van Duyse.[2] There was also imperfect development of the parietal bone with meningo-encephalocele. The hen, the mother of the chick in which I found this condition of cryptophthalmos present, was the daughter of the cock which was the chick's father. The same cock had also been the father of a chick with two beaks, of one without any beak, and one with four legs. On removing the feathers from the blind chick I could not find a vestige of the eyelids. The skin passed continuously over the orbits and front of the eyes. These latter after removal were found to be of normal dimensions. Microscopical examination of them shows beneath the laminated epithelium on the surface a dense mass of fibrous tissue, amongst which, near the surface, are collections of round cells and blood-vessels, whilst deeper down it is less cellular and vascular, more regularly laminated like the substantia propria of the cornea. Attached to the posterior surface of this fibrous tissue and displaced backwards in the eye by it is the iris, there being no anterior chamber. The iris, the rest of the uveal tract, and the retina are very imperfectly developed. The pigment epithelium is much broken up and irregularly arranged. The lens is small but well formed.

It would appear that in these cases the eyelids and the conjunctival sacs having failed to develop and the individuals not living in a fluid medium like fish the epithelium covering the surface of the eyes became desiccated and a tissue similar in character to skin formed in front of them.

Congenital Ankyloblepharon.

Several cases of congenital ankyloblepharon have been recorded in man, but they are rare. The union of the lids may not only be due to a cementing together of the epithelium at the margins but there may be a real membranous union. It has most frequently been met with in cases of congenital absence or very extreme mal-development of the eyeball. Thus out of a series of 30 recorded cases of so-called bilateral congenital anophthalmos which I collected I found that a certain amount of ankyloblepharon was mentioned as being present in nine. Middlemore[3] says: "I have seen three cases in which the tarsal margins have been coherent from birth. The defect has occurred in both eyes; the eyelashes have not been formed and in the situa-

[2] Annales d'Oculistique, 1889, tome x., p. 69.
[3] Treatise on Diseases of the Eye, vol. ii., p. 842.

tion of the intertarsal slit there has been a narrow sulcus, lined by a delicate vascular portion of skin, which admitted of extension but not of absolute separation. In one of the cases the eyeball appeared to be imperfectly developed." Travers[4] mentions a case of co-adhesion of the tarsi in a full-grown boy whose eye was found perfect after the division though he had been thus blind from his infancy. De Haas[5] described an infant in whom the lids were united by several thin tracts of skin attached to the lid margins between the cilia and the mouths of the Meibomian glands. When these bands were divided the eyes were found to be normal.

Dermoid Growths of the Eye.

The cases of cryptophthalmos in which the whole surface of the eyeball is covered with skin, though rare, are interesting as offering an explanation of the much commoner malformation in which small patches of skin are found on the surface of the eye. Sometimes a portion of the upper eyelid fails to develop, a deep cleft or notch being left in it, which is spoken of as a coloboma of the eyelid. In many of such cases the surface of the eyeball opposite the gap presents some abnormality. In a case recorded by Manz,[6] in which the inner portion of the upper lid on each side was absent, bands of skin arose on the surface of each cornea where it was left exposed, and extended upwards in the region of the gaps to the skin of the forehead. In a case described by De Wecker[7] there was a small congenital notch in the border of the upper lid and on the surface of the globe was a small nodule of skin which when the eye was closed exactly filled the deficiency left in the lid. Little isolated patches of skin spoken of as dermoids are not very uncommonly met with on the surface of the globe apart from any deficiency in the lids. They occur most frequently at the sclero-corneal margin opposite the palpebral aperture, more often on the outer than the inner side and a little below the horizontal meridian of the eyeball—that is, in the region of the eye which would remain longest uncovered by the eyelids in their extension over it during fœtal life. Many years ago Ryba[8] suggested—and I think his observations are well borne out by the above cases—that the

[4] Synopsis of Diseases of the Eye, p. 104.
[5] Med. Weekblad., 1894, p. 489.
[6] Archiv für Ophthalmologie, 1868, Band xiv., Abtheilung 2, p. 145.
[7] Archives of Ophthalmology and Otology, vol. i., p. 91.
[8] Prager Vierteljahrschrift, 1853, Band iii.

reason skin formed on the surface of the eye opposite the gap left by a coloboma of the lid was that the lining membrane there not being covered over failed to become mucous membrane, and he further suggested that the dermoid nodules opposite the palpebral fissure probably resulted from an incomplete apposition and union of the margins of the lids, portions of the surface of the eye being left uncovered.

Xerosis of the Cornea and Conjunctiva.

The epithelium of the surface of the cornea and conjunctiva differs from that of the skin in the absence of a horny layer; the cells nearest the surface in these parts, unlike those in the superficial layers of the skin, are not shrunken and all possess nuclei. It is the presence of moisture and the constant friction of the lids over the front of the eye in the act of winking which accounts for this difference. That this is so is shown by what happens when their agents are absent. If a staphylomatous cornea protrudes between the lids and is so prominent that a portion of it is not covered by them during sleep, then the surface epithelium on the exposed part is not removed and layers of dry horny cells devoid of nuclei accumulate on the surface. In cases of severe granular ophthalmia or other destructive affections—such as pemphigus, when what is termed symblepharon posterior is formed—much of the retro-tarsal fold of the conjunctiva and its glands are destroyed by cicatricial contraction, and the lacrymal secretion is to a great extent cut off. Then the epithelial cells on the surface of the cornea and conjunctiva, instead of being removed, accumulate and form a dry horny layer on the surface. I have had the opportunity of examining microscopically the whole conjunctival sac and cornea of one such case and the cornea in two others.

Besides the marked thickening of the epithelium and the dryness of its surface layers, I have found in each case numerous down-growing finger-like processes of epithelium, making the base line of the epithelium over the cornea, which is normally straight, very irregular, and so causing its appearance on section still further to resemble that of skin. The down-growths have a peculiar and definite arrangement, those in the centre of the cornea passing vertically downwards, those towards the periphery gradually sloping more and more outwards and downwards. These finger-like processes are probably first started by shrinking of the surface due to contraction of the cicatricial tissue in the subjacent structures. To quote another example of the readiness with which the conjunctiva will, under favourable circumstances, take on the characters of skin, I may refer to the operation for ectropion devised by Mr. Tweedy, in which after cutting out a flap of the whole thickness of the lid he utilises a portion of the conjunctival surface to fill up a gap left below the lid after it has been stitched into its required position. The transplanted and exposed piece of conjunctiva is found after a short time to take on all the appearances of skin.

The Influence of Friction of the Lids on the Surface of the Cornea.

The influence which the friction of the lids has in the preservation of the character of the surface epithelium of the cornea is well illustrated by some observations described by George Bull of Paris.[9] He examined the changes produced on the surface of the cornea by a method of entoptic observation in which he allowed the light from a small candle flame five metres distant to be thrown in circles of diffusion upon the retina by a convex lens of about five centimetres' focus, held within two centimetres from the eye. The field seen by this method is circular, more or less uniformly granular, and limited by the dark shadow of the iris. By the passage of the eyelids over the front of the eye Bull has pointed out that two sorts of bright bands bounded by darkened areas may be produced in the field. The first, which he calls temporary, are due to changes in the curvature of the lubricating fluid which the eyelids push before them over the front of the cornea. These temporary bright bands are seen to advance and recede with the movements of the lids, and a single sweep of the lids as in natural winking instantly effaces them. The second sort of bands are termed by Bull persistent; they are produced when stronger and more enduring pressure of the tarsal edge of the lid is made against the cornea and are due to a disturbance of the epithelial surface. These persistent bands are less bright than the temporary ones, indicating that when the disturbance of curvature is in the epithelium it is less in degree than the disturbance of curvature created by a wave of viscous fluid. The act of winking instead of making the persistent bands disappear makes them brighter

9 Transactions of the Eighth International Congress of Ophthalmology, 1894, p. 107.

as they tend to fade. Bull concludes from his observations, all of which I have repeated and am able to confirm, that the tarsal edge of the lid evidently acts as a kind of scraper over the front of the eye. By so doing it must constantly remove any epithelial débris from the surface of the cornea as well as provide fresh supplies of lubricating fluid.

Entoptic Examination of the Cornea under the Influence of Cocaine and Erythrophlæine.

I have further examined by this entoptic method the condition of the cornea after the application of certain drugs to the eye such as cocaine and erythrophlæine. As is well known, after the application of cocaine to the eye, unless the lids be kept closed the surface of the cornea becomes dry. That this is largely, if not entirely, due to the retraction of the eyelid from stimulation of the unstriated fibres of Müller is well shown by this method of examination. When the eye is well under the influence of the drug the bright temporary bands hardly ever make their appearance in the field, and when they do only at the extreme upper margin. After a while the whole of the field, instead of presenting a comparative uniform granular appearance, becomes irregularly mottled and marked out with a number of very irregular, bright, branching lines like the cracks seen in the glaze of china. Vision with an eye fully under the influence of cocaine, if the eyelids have not been kept closed, is, even for distant objects, somewhat misty, and a dim halo of colours can be seen round bright lights when viewed against a dark background.

The microscopical appearances of the cornea when under the influence of cocaine have been described by Wurdinger[10] who experimented on rabbits, dogs, and guinea-pigs. He found that there was an unevenness of the surface which was due to an irregular diminution of the thickness of the tissues. The anterior layers of the epithelium gradually became thinned and flattened, later the deeper layers began to shrink, and ultimately the external cells were in places cast off at the spots where the epithelium was most damaged. Wurdinger attributed the xerotic condition of the cornea partly to diminished lymph supply from contraction of the blood-vessels, as well as to the dryness produced by exposure. That diminished lymph supply from contraction

[10] Klinisches Monatsblatt für Augenheilkunde, 1886, Band xxiv., S. 140.

of blood-vessels alone will not produce the change in the cornea is shown by no alteration occurring after the application of the extract of suprarenal capsule to the eye, which gives rise to a more marked constriction of the conjunctival and scleral blood-vessels than cocaine. In ten normal eyes in which W. H. Bates [11] instilled this drug at short intervals for three hours no desquamation followed. The field examined by the entoptic method after its use shows no alteration whatever from its normal granular appearance.

Erythrophlæine is an alkaloid obtained from an African arrow-poison called "haya." In 1888, when experimenting with a 0·125 per cent. solution of the hydrochlorate to test its reputed local anæsthetic properties, I found that the instillation of a drop into the eye was followed by considerable smarting and irritation, lasting about from 10 to 30 minutes. Slight anæsthesia of the cornea was produced, but hardly any of the conjunctiva, never sufficient to obliterate the smarting caused by a 1 in 40 solution of carbolic acid. After about two hours the sight of the eye in which it had been put became very much blurred, everything appearing as if in a fog, and all lights having a pronounced circle of coloured rings around them, the red rays being the outermost. The position of the red rays was not altered by changes in the refraction of the eye. The nearer the light was to the eye the smaller were the halos, and *vice versâ*. The halos remained stationary whether the light was fixed by the eye or not. The blurring of vision was not due to any alteration in the accommodation of the eye. The cornea on careful examination was found to be slightly steamy. There was no increase in the tension of the globe. The first specimen of erythrophlæine that I used produced slight dilatation of the pupil. A second specimen produced slight contraction. After the use of both of these solutions the coloured halos were seen.

Examination of the cornea, when under the influence of the erythrophlæine by the entoptic method above described, shows it to be mapped out with a number of very dark branching lines bounded on each side by light ones, the field retaining its uniform stippled character in the spaces between the lines. These lines commence to appear about three-quarters of an hour after the application of a drop but are at first very faint, and do not reach their maximum intensity for two hours—i.e., until the coloured rings are also plainly visible. They last as long as these and are seen for

11 Archives of Ophthalmology, vol. xxviii., No. 3, 1899.

about 12 hours. Slight pressure on the globe so as to increase its tension causes the lines to change so that the part that was dark becomes bright and that which was bright becomes dark. If the pressure is increased they disappear altogether, the field becoming uniformly granular. I find it difficult to conjecture the nature of these lines. The cornea when they are present does not become stained with fluorescine. I made a drawing of them as they appeared in one of my eyes and a few weeks later after a fresh instillation I compared the drawing with their arrangement as then seen. So similar were the number, grouping, and branching of the lines on the two occasions that I cannot help thinking that they represent some definite anatomical structure.

Iridescent Vision.

The halos produced by erythrophlæine cannot be in any way connected with dilatation of the pupil, for they were seen equally well after the use of a specimen which produced slight contraction of the pupil. They cannot in any way be connected with the lens, for they were seen by a patient after a cataract had been extracted to whose eye I applied a drop. They cannot be due to pressure on the retina for there is no increase of tension. The irresistible conclusion is that they are due to the haze of the cornea.

Changes in the Surface of the Cornea in Glaucoma.

In glaucoma, too, when halos are seen, a haze or steaminess of the cornea is present. The changes which give rise to this haze were first pointed out by Fuchs[12] to be due to the collection of minute drops of fluid, which sometimes contain albumin and coagulate in the anterior part of the cornea, between the surface epithelium and the anterior limiting membrane, in the channels in the anterior limiting membrane through which the nerve fibres pass, and in the spaces between the anterior layers of the fibrous tissue forming the substantia propria. In eyes in which increased tension has existed for some time, what appear to the naked eye to be little vesicles may be met with on the surface of the cornea. Microscopically I have found these apparent vesicles to be composed of a loose network of fibres and branching cells with fluid in its mesh situated between the anterior limiting membrane and

[12] Archiv für Ophthalmologie, 1881, Band xxvii., Abtheilung 3, S. 66.

the epithelium. In some eyes, as these apparent vesicles form, great pain is experienced which is due probably to the stretching of the nerve filaments which pass to the epithelium. This pain lasts until the apparent vesicle collapses, when it is at once relieved. After a condition such as this has existed in an eye for some time a formation of dense fibrous tissue makes its appearance between the epithelium and the anterior limiting membrane, and the anterior limiting membrane in certain positions appears broken in its course by the extension through it from behind forwards of considerable collections of fibrous tissue.

The interpretation of these several changes seems to be that at first, as the result of the increased tension, there is a disturbance in the lymph flow in the cornea, a disturbance which results in œdema and which manifests itself naturally at the part where the pressure is least—namely, towards the anterior surface. The epithelium in places becomes separated from the anterior limiting membrane. The communications between the intercellular clefts within the anterior epithelium and the corneal spaces through the anterior limiting membrane become distended, and some of the spaces between the anterior layers of fibrous tissue are enlarged. At first the distended spaces are filled with the ordinary circulating lymph of the cornea, but if the œdema persists for some time cells find their way into it which proliferate, and a network develops. This loose network and cells later become transformed into dense fibrous tissue resembling that of the substantia propria, but much of it lying anterior to the limiting membrane and in the clefts formed by the immensely distended lymph spaces in it.

Transverse Films of the Cornea.

An avascular development of fibrous tissue between the anterior limiting membrane and the epithelium, together with breaks in its continuity, through which pass bands of fibrous tissue, is met with, not only in eyes which have glaucoma, but also as a localised condition in what is spoken of as transverse films of the cornea. These transverse films are either primary—i.e., occurring in eyes apparently perfectly healthy—or secondary, occurring in eyes otherwise diseased, most frequently in eyes which have for some time been blind. It is probable, however, that both primary and secondary films have the same pathological characters. C. H. Usher, while working with me in the laboratory of the Moorfields Hospital, made a careful examination of the cornea of 13 eyes with secondary transverse films and published a description of them in the hospital's reports.[13] The results of his examinations may be summarised as follows: 1. The antero-posterior diameter of the cornea is increased in the situation of the film and this is usually the thickest part of the cornea. 2. A formation of laminated fibrous tissue is present at the anterior part of the cornea between the epithelium and the normal situation of Bowman's membrane, which in most cases contains a granular material. No blood-vessels are found in this new fibrous tissue. 3. Granular hyaline or entirely granular bands, frequently with a space in front of them, are found at the posterior part of the new tissue, in some cases forming a sharp line between it and the substantia propria. These bands vary much in length, shape, and arrangement. Their breadth varies only to a limited extent, being about equal to that of a normal Bowman's membrane. The number of granules in the bands varies considerably. 4. At parts where the hyaline granular bands exist Bowman's membrane is never found in contact with the epithelium. They may be found directly continuous with Bowman's membrane where it lies in contact with the epithelium. So that there can be no doubt that they are portions of Bowman's membrane which have become granular and divided up. 5. Degenerative changes are found in the epithelium in the situation of the film. 6. A portion of the film treated *en masse* (by cutting a piece off from the anterior part of the cornea), either with strong hydrochloric or acetic acid, showed by the evolution of bubbles that there was calcareous material present in every case in which it was tried.

As I have said in cases of glaucoma of long standing a formation of fibrous tissue similar in appearance to that met with in these films may be found between the epithelium and the anterior limiting membrane which appears to be the result of lymph stasis. The avascular formation of fibrous tissue in these films is probably brought about in the same way, but whilst the changes following glaucoma are comparatively acute the formation of the films is exceedingly slow, often extending over a period of several years. Hence the presence in these latter of calcareous granular-looking incrustations. In glaucoma the formation of vesicles or the later superficial development of fibrous tissue may be met

[13] Vol. xiii., 1893, p. 508.

with in all parts of the cornea. In the transverse films the change is confined to the portion of the cornea corresponding to the palpebral aperture and is usually a band situated a little below the middle line. The reason that this area is affected has been usually attributed to its being the part most exposed to irritation from external agents. There is, I would point out, another important cause which appears to have been overlooked and which accounts, moreover, for the way in which these films begin and extend. I refer to the effect of the pressure of the lids on the cornea. A transverse film is never seen to extend quite up to the margin of the cornea, a narrow band of clear tissue being always left between it and the extreme margin. The opacity usually commences to form in two places, on the outer and inner sides of the cornea, and then each patch gradually extends inwards until they meet and one complete horizontal band results. It always, however, remains thickest and densest at its two starting points. In a complete film the lower border is nearly straight whilst the upper is curved, the convexity being downwards.

We have seen from the observations of Bull that the pressure of the margin of the lid on the cornea may be such as to cause a lasting depression in the surface epithelium, and it is not difficult to understand that this sort of squeegee action of the lids in their passage over the surface of the cornea would tend to prevent the accumulation of œdematous fluid in spaces beneath the epithelium, unless the obstruction to flow of lymph in the cornea was fairly acute. The part of the cornea least affected by this lid pressure is opposite the palpebral aperture, and as the central portion of it projects most from the surface of the globe it is pressed on more than the sides, so that the peripheral portions of the cornea opposite the palpebral aperture are the least affected by lid pressure and are the parts in which the transverse film commence and are most intense. That a film does not extend quite up to the corneal margin is probably accounted for by that region being directly under the influence of the terminal vascular loops which tend to absorb any œdematous exudation in their immediate vicinity.

Vesicles in the Corneal Epithelium and Filamentary Processes.

Besides the vesicle-like formations at the anterior surface of the cornea, which are due to the separation of the epithelium from the anterior limiting membrane, others are met with which make their appearance in the substance of the epithelium itself. I published a drawing and description of these in the Moorfields Hospital Reports[14] for 1890. They are most frequently met with in glaucomatous eyes, but may occur where no increase of tension is present. J. P. Nuel,[15] who has more recently investigated this form of epithelial change, finds it to be due to a hyaline or mucoid degeneration of the cells. He has been able to trace all the stages in the gradual alteration of the cells, showing how they first become enlarged and then distended by the formation of a hyaline or mucoid substance in them, how several contiguous cells are often affected, their cell-walls ultimately becoming so attenuated that they break through into one another, little vesicles resulting. As these vesicles form the cells immediately surrounding them, from the pressure to which they are exposed, become flattened out. The ones in front and behind the vesicle become flattened so that their long axis is horizontal, whilst those at the sides have their long axis vertical. When two vesicles form close together a ridge of cells arranged vertically separates them. When, as ultimately happens, the vesicles open out this ridge of vertically placed cells remains as a filamentary process on the surface of the cornea. The way in which these vesicles tend to produce elevations of vertically placed cells helps us, I think, to understand how the filamentary formations met with in what is termed by Leber "filamentary keratitis" may be started. The filamentary formations in this disease have been shown by Nuel and Hess to be composed of a central core of twisted and much elongated epithelial cells, the long axis of which is for the most part vertical to the surface, and they have further shown that cells removed from the surface of the cornea in the neighbourhood of the filiform processes are frequently undergoing a hyaline change.

The Development of the Cornea and its Posterior Limiting Membrane.

The development of the cornea in the chick has been described as follows:[16] "The substantia propria corneæ first appears in the chick as a thin homogeneous layer lying immediately within this epithelium (the surface epithelium). Into this homogeneous layer mesoblastic cells pass from the

[14] Vol. xiii.
[15] Archives d'Ophtalmologie, October, 1893.
[16] Quain's Anatomy, tenth edition, vol. i., part 1, p. 87.

margin, greatly thickening it and producing eventually the regular layers of fibrous tissue which are characteristic of the cornea. No cells pass into the most anterior or into the most posterior stratum which remains homogeneous (anterior and posterior homogeneous lamellæ of Bowman). The epithelium of the posterior homogeneous lamella or membrane of Descemet is derived from mesoblast cells, which grow in like the corneal corpuscles from the margin and spread themselves over the posterior surface of the cornea, thus separating this from the iris and anterior surface of the lens." With regard to the origin of the homogeneous layer which first separates the lens vesicle from the surface epithelium in the chick and which remains ultimately as the anterior and posterior elastic laminæ two different views have been put forward. Kessler regards it as a secretion of the epidermis and Kölliker as of mesoblastic origin. In mammals this homogeneous layer has not been met with. Hertwig says [17]: " As soon as the lens vesicle in mammals is fully constricted off it is already enveloped by a thin sheet of mesenchyma with few cells, which separates it from the epidermis. The thin layer is rapidly thickened by the immigration of cells from the vicinity. Then it is separated into two layers, the pupillary membrane and the fundament of the cornea." He makes no mention as to the mode of origin of the anterior and posterior elastic laminæ in mammals.

In fœtal mice which I have examined I find at one stage the surface epithelium separated from the lens by a collection of round cells, but no vestige amongst them whatever of a hyaline membrane. In sections of a human fœtal eye of between the first and second months I find the cornea to consist from before backwards of the following layers. Epithelial cells in places appearing two rows thick; immediately in contact with them, and not separated by any homogeneous membrane, layers of cells with elongated nuclei and fibres. The nuclei of these cells are very much closer together than those of the corneal corpuscles in the adult cornea, the amount of fibrous tissue between them being very much less. Behind this laminated fibrous and cellular tissue is seen an extremely thin hyaline layer, posterior to which are closely packed cells with round nuclei, showing a tendency to arrangement into two layers, the anterior evidently being the lining endothelium of Descemet's membrane and the posterior

17 Text-book of Embryology, translation of the third German edition p. 477.

the commencement of the antero-fibro-vascular sheath of the lens. I am unable to find any blood-vessels amongst the round cells, though there are many already formed at the posterior part of the lens. In a specimen I have of a human fœtal eye of the fourth month blood-vessels are distinctly seen in the antero-fibro-vascular sheath. The posterior elastic lamina is still only seen as an exceedingly delicate line, and nothing of a homogeneous layer is yet visible between the anterior epithelium and the substantia propria of the cornea. In a human fœtal eye, said to be of the sixth month, Bowman's membrane, the anterior elastic lamina, is very distinctly seen, and the posterior elastic lamina is considerably wider than it was at the fourth month.

It is evident, then, from this that in mammals there is a stage in the development of the cornea where no elastic membrane is present. In man, when a very delicate rudiment of the posterior elastic lamina is just discernible, it is already lined by endothelial cells, and from this time onward it gradually increases in thickness. That there are physical and chemical differences between Bowman's and Descemet's membranes has been repeatedly pointed out, the former being similar in character to the substantia propria whilst the latter resembles closely elastic tissues. This difference I have lately further been able to emphasise by treating sections with acid solutions of orcein. After they have been allowed to soak in it for some hours Descemet's membrane can be made to stand out a reddish-brown colour, while the substantia propria and Bowman's membrane stains a dull pink. How then is Descemet's membrane formed? Is it the product of the endothelial cells lining it? In determining this point a study of the pathological changes observed in connexion with it are of considerable assistance. On the inner surface of Descemet's membrane in diseased eyes little hyaline nodules are sometimes seen indistinguishable in structure from the membrane itself. It seems unlikely that an inert basement membrane would give rise to such outgrowth and much more probable that the active endothelial cells lining it should undergo some change which results in their production. The nodules, moreover, are never met with except on the inner surface where the cells are situated. If they were simply thickenings of the membrane itself it seems reasonable to expect that they should sometimes be met with on both surfaces.

Pathological New Formations of Descemet's Membrane.

Sometimes after perforating wounds of the cornea a new formation of a hyaline membrane may be met with thus. B. Gepner, jun., described (in 1890[18]) the case of a man, aged 21 years, who had an iridectomy performed several years previously for iritis. The eye was removed on account of inflammation following a blow. A gap was found in Descemet's membrane in the region of the cicatrix, which was bridged across by a layer of hyaline membrane of the same structure as Descemet's membrane and lined by endothelial cells. Wagenmann (in 1891[19]) recorded the case of a patient, aged 57 years, who two and a half years previously had had a cataract extracted from his eye by the modified linear operation of von Graefe, and who while in the hospital for operation on his other eye died from pneumonia. The eye first operated on was removed shortly after death, and on microscopical examination of the seat of the wound the two cut extremities of Descemet's membrane could be seen, separated by a slightly protuberant film of tissue, posterior to which was a layer of newly formed hyaline substance lined by endothelial cells. Wagenmann has no doubt that the hyaline layer was derived from the endothelium. Alt mentions a case[20] in which there was a considerable new formation of fibrous tissue on the inner surface of Descemet's membrane, which was covered on the surface towards the anterior chamber by a newly formed secondary membrane of Descemet lined by endothelium, and he says: "I think that this case shows that Descemet's endothelium cannot only form lamellated connective tissue, similar to that of the corneal tissue, but that it can form, and, perhaps, originally forms, the vitreous membrane, which we call that of Descemet."

I have myself recorded two cases with a similar new formation and I have met with a third. My first case was that of a man, aged 46 years, who 26 years previously to excision had received an injury to his eye from a piece of steel. There was a faint scar at the lower part of the cornea and in the eye a small fragment of metal two millimetres square. Microscopical examination of sections of the cornea in the line of the scar showed on the posterior surface the two divided ends of Descemet's membrane turned

18 Archiv für Ophthalmologie, Band xxxvi., Abtheilung 4, S. 255.
19 Ibid., Band xxxvii., Abtheilung 3, S. 21.
20 American Journal of Ophthalmology, vol. xiii.

forwards and separated from one another by fibrous tissue, whilst a thin hyaline layer bridged over the gap posteriorly. This hyaline layer could be traced for a short distance in contact with, but distinct from, Descemet's membrane with which a little further on still it became blended. Endothelium continuous with that on Descemet's membrane lined its posterior surface.

The second case was that of a man, aged 44 years, who three years previously to excision had had an iridectomy performed for glaucoma. The divided ends of Descemet's membrane in the region of the scar were found to be widely separated; the more peripheral end was curved a little backwards. Between the two ends there projected backwards some new-formed fibrous tissue, which at one part was dense and laminated, resembling closely normal corneal tissue. Some of this new-formed fibrous tissue extended a short distance inwards towards the centre of the cornea behind Descemet's membrane. On the posterior surface of this dense new-formed laminated fibrous tissue was seen a thin hyaline membrane of the same structure as the posterior elastic lamina to which on the inner side it became united at an acute angle. It was lined by endothelium continuous with that on the posterior surface of the cornea elsewhere.

The third case was that of a girl, aged 16 years, the subject of congenital syphilis, who had had interstitial keratitis and in whom the eye had been operated on two and a half years previously to its enucleation. Two scars were found in the cornea; part of the iris and the lens had been removed. Extending backwards from each scar in the cornea to the lens capsule was a mass of fibrous tissue. At either side of each of these bundles of fibrous tissue the hyaline layer of Descemet's membrane seemed to divide into two. The anterior parts, of the same thickness as the membrane elsewhere, were continued on for a short distance lying embedded in the fibrous tissue and then terminated abruptly; they had no endothelial cells lining them. The posterior divisions which were thinner than the anterior, but lined by endothelial cells continuous with the endothelial cells of Descemet's membrane elsewhere, and ran for some distance along the margins of the bands of fibrous tissue connecting the lens capsule with the back of the cornea.

If, then, as seems to be shown by the above cases, under some abnormal stimulus the endothelial cells lining the posterior limiting membrane are capable of producing nodules or a layer of a substance indistinguishable in structure from that membrane, it seems fair to assume that it itself is originally developed from them.

Formation of Hyaline Membranes on the Anterior Surface of the Iris.

The anterior surface of the iris, like the posterior surface of the cornea, is covered by a single layer of flattened endothelial cells, but beneath the endothelial cells of the iris there is not, as beneath the endothelial cells of the cornea, a hyaline membrane. It is interesting, however, to note that under certain abnormal conditions a hyaline membrane like that of Descemet's may be developed immediately underneath the cells on the surface of the iris. I have met with it as what was probably a congenital abnormality and also as the result of a pathological change late in life. The eye in which this change was probably congenital was a buphthalmic one, which was removed from a girl, aged seven years. It had been noted as larger than its fellow since birth and there had never been any inflammation in it. There was an adhesion of the iris to the back of the cornea a little above its centre; where it was attached Descemet's membrane was thickened. The endothelium lining the latter turned round the edge of the synechia and was continuous with that on the surface of the iris, which was unusually well defined. On one side of the synechia starting from the thickened part of Descemet's membrane and extending for some distance beneath the endothelium on the anterior surface of the iris was a thin hyaline layer.

The eye, in which the formation of a hyaline membrane in the iris probably occurred late in life, was removed from a woman, aged 67 years, who had had absolute glaucoma of some years' duration. The angle of the anterior chamber was closed by adhesion of the root of the iris to the periphery of the cornea. The chamber itself was filled by a loose network of fibrous tissue in which blood-vessels had developed, and in the meshes of which were numerous cells of an endothelial type, probably derived from those on the back of the cornea, and cholesterine crystals. The whole of the surface of the iris was covered by a hyaline membrane, thicker in some parts than in others.

LECTURE II.

Delivered on Feb. 14th.

Relative Size of the Cornea to the Eyeball in Man compared with other Mammals.

Mr. President and Gentlemen,—The cornea in man's eye is smaller relatively to the size of the globe than in any other mammal. In all mammals below man the diameter of the cornea measures more than half the antero-posterior diameter of the globe. In the chimpanzee it is about half. In man alone is it considerably less than half. The following table (Table I.) shows the dimensions of the eyeballs and corneæ of a series of different mammals which I have had the opportunity of measuring :—

Table I.

—	Diameters of the eye-ball.		Diameters of the cornea.	
	Antero-posterior.	Lateral.	Lateral.	Vertical.
Man	24 8 mm.	24·4 mm.	11·6 mm.	11·0 mm.
Chimpanzee	19·0 ,,	18·0 ,,	10·5 ,,	—
Rhesus monkey (India)	19·5 ,,	19·0 ,,	12·0 ,,	11·0 mm.
Capuchin monkey (South America) ...	18·5 ,,	19·0 ,,	11·0 ,,	10·5 ,,
Rabbit	16·0 ,,	20 0 ,,	15·0 ,,	—
Mouse	4·0 ,,	5·0 ,,	3·0 ,,	—
Civet cat	11·0 ,,	17·0 ,,	13·0 ,,	—
Cat...	22·0 ,,	21·0 ,,	18·0 ,,	—
Horse	45·0 ,,	51·0 ,,	26·0 ,,	—
Sheep	27·0 ,,	28·0 ,,	19·0 ,,	15·5 mm
Ox	36·0 ,,	38·0 ,,	27·0 ,,	22·0 ,,
Pig...	23·5 ,,	24·0 ,,	17·0 ,,	14·0 ,,
Wallaby	18·0 ,,	19·0 ,,	14·0 ,,	—

It is this alteration in the relative size of the cornea to the eyeball in man which gives to him the characteristic feature of having a portion of the sclerotic and conjunctiva exposed to view in the palpebral aperture, and which renders him liable to two affections of the conjunctiva not met with in animals—namely, pinguecula and pterygium.

Relative Size of the Cornea to the Eyeball in Fœtal Eyes of Different Ages compared with the Adult Eye.

In the human eye during fœtal life the relation of the size of the cornea to the globe resembles what is met with in other mammals in the adult state. That is to say, the lateral diameter of the cornea is always more than half the antero-posterior diameter of the eyeball. This is shown in Table II., which gives the measurements of the eyeballs and corneæ from a series of human fœtuses of different ages.

Table II.

Age.	No. of eyes examined.	Measurements of the eyeball in millimetres.			Measurements of the cornea in millimetres.	
		Antero-posterior.	Vertical.	Lateral.	Vertical.	Lateral.
Fourth month	2	8·5	8·0	8·0	4·5	5·0
Sixth month ...	2	10·3	9·75	10·0	5·5	6·0
Seventh to eighth month	8	14·3	12·6	13·2	7·5	8·0
Ninth month...	1	17·0	15·5	16·0	10·0	10·5
Adult	—	24·8	24·0	24·4	11·0	11·6

Diminution of the size of the cornea in relation to the size of the eyeball lessens the space occupied by the filtration area relatively to the amount of contents in the globe.

The Relation of Parts about the Angle of the Anterior Chamber in Man and Other Mammals.

I shall now proceed to show that this lessening of the space occupied by the filtration area in man's eye, as compared with other mammals, is accompanied by considerable alteration in arrangement of parts about the angle of the anterior chamber. In man the ligamentum pectinatum begins by the splitting up of the hyaline layer of

Descemet's membrane into a number of trabeculæ, which, lined by endothelial cells, are prolonged outwards. Some of the innermost of these turn round the angle of the chamber and pass to the root of the iris; others give origin to the ciliary muscle and the outermost are inserted into the sclerotic. The structure in antero-posterior sections has a laminated appearance and between the trabeculæ are narrow slit-like spaces. The distance between the point where Descemet's membrane begins to split up into the ligamentum pectinatum and the extreme angle of the anterior chamber measures on an average 0 8 of a millimetre. The canal of Schlemm overlies the ligamentum pectinatum and the extreme outer part of the angle of the chamber, so that if a line vertical to the surface of the eye were drawn backwards through the centre of the canal of Schlemm it would pass into the angle of the anterior chamber. If the same line were continued backwards it would almost pass through the large circular artery at the base of the iris and only a small portion of the ciliary processes would lie to its inner side.

The ligamentum pectinatum reaches its greatest development in the ungulata. Amongst them I have examined sections from the eyes of horses, sheep, oxen, and pigs. In these it is composed of an external laminated part with slit-like spaces having much the same arrangement as the ligament in man, and an inner part consisting of an irregular network of trabeculæ with large cavernous spaces between them, whilst in some sections on the side bounding the anterior chamber a prolongation of fibrous tissue, like that on the anterior surface of the iris, passes forwards to be attached to the back of the cornea. It is these fibrous tissue prolongations occurring at regular intervals which give the ligament its notched appearance. The angle of the anterior chamber in these animals does not extend outwards beyond the point where Descemet's membrane begins to split up, so that a line drawn backwards vertically to the surface of the eye through the centre of Schlemm's canal will not pass through the angle of the anterior chamber, but will be some distance outside of it, and the large circular artery of the iris together with a large portion of the ciliary processes will be to its inner side. In the kangaroo the arrangement is very similar to that in the ungulata, the cavernous part of the ligamentum pectinatum, however, not being quite so extensive.

In the carnivora, amongst which I have examined the eyes of dogs, cats, and foxes, the trabeculæ of the ligamentum pectinatum are very delicate, the laminated portion small, but the cavernous portion very extensive, extending backwards a considerable distance beyond the termination of Descemet's membrane and having very large spaces in it. The angle of the chamber, as in the ungulata, ends where Descemet's membrane begins to split up, and the line drawn back through the canal of Schlemm would be some distance outside of it and have the circular artery of the iris and a large part of the ciliary processes to its inner side. The same applies to the eyes of rodents, in whom the laminated portion of the ligament is still less marked than in the carnivora, while the space between the trabeculæ of the cavernous portion are very large.

Among the quadrumana I have examined sections of the eyes of a South American monkey (capuchin) and Indian monkeys (rhesus) and a chimpanzee. In them the arrangement of parts about the angle of the anterior chamber has a much closer resemblance to that met with in human eyes than that in other mammals. There are, however, slight differences to be observed. In them, and especially in the chimpanzee, the innermost trabeculæ of the ligamentum pectinatum are more widely separated, bend down sooner to be attached to the root of the iris, and have larger spaces between them than in the human eye. They form a modified cavernous zone.

No prolongation forwards of fibrous tissue from the anterior surface of the iris to the back of the cornea on the anterior chamber side of the ligamentum pectinatum is met with in them as in other mammals. The angle of the anterior chamber is not so rounded as in man A line drawn vertically backwards through the canal of Schlemm would, as in man, pass into the extreme angle of the anterior chamber and leave the greater part of the ciliary processes external to it.

Development of the Ligamentum Pectinatum in the Human Eye.

The fibres of the ligamentum pectinatum when treated with reagents and stains behave in precisely the same way as the hyaline layer of Descemet's membrane. In sections stained with acid orcein I have found them picked out a reddish-brown colour like Descemet's membrane. As I have shown, there is considerable evidence to prove that Descemet's membrane is the product of the endothelial cells lining it. It would seem probable, therefore, that the fibres of the ligamentum pectinatum are the products of the endothelial cells lining the spaces of Fontana. In sections of a human fœtal eye in which the iris is just beginning to bud out from the ciliary body and to insinuate itself between the cornea and lens I find that the site of the ligamentum pectinatum is occupied by a collection of round cells radiating from the single row lining the back of the cornea and blending, without any line of demarcation, with others which form the basis of the ciliary muscle. Schlemm's canal can be distinguished as a ring of cells. In a human fœtal eye of about the fourth month the ligamentum pectinatum and ciliary muscle are distinctly differentiated; the former consists of very delicate fibres with cells lining them and spaces between. Though the parts are small there is a portion of the ligamentum pectinatum comparable to what I have described as the cavernous zone in lower mammals. The angle does not extend outwards beyond the termination of Descemet's membrane, and a vertical line drawn backwards through the canal of Schlemm is external to the angle of the anterior chamber, while the large circular artery of the iris and the ciliary processes are internal to it. In a fœtal eye of the seventh month the trabeculæ of the cavernous zone are more spaced out, but a line drawn vertically backwards through Schlemm's canal still passes externally to the angle of the anterior chamber. In the sections of a human fœtal eye at birth I have found delicate trabeculæ of fibres stretching across what would have ultimately become the angle of the anterior chamber, much in the same way as I have found fibres of the ligamentum pectinatum bend down to the root of the iris in the eye of the chimpanzee.

It will be seen, then, that the diminution in the relative size of the cornea to the globe in man's eye, as compared with other mammals, is accompanied by a simplification of the structure of the ligamentum pectinatum and a prolongation of the anterior chamber outwards. Further, in the process of development the human eye passes through stages in which the relative size of the cornea to the globe and the relation of parts about the angle of the anterior chamber resemble that met with in animals.

Congenital Abnormalities of the Ligamentum Pectinatum and their Relation to Congenital Glaucoma.

The congenital abnormalities which are met with in connexion with the ligamentum pectinatum are of special interest in the connexion which they have with some forms of buphthalmos. It must be borne in mind that the condition of buphthalmos is simply a manifestation of increased tension in a child's eye, and that as there are many causes which may give rise to increase of tension, so buphthalmos may be brought about in a variety of ways. As can be easily understood, congenital defects in the network of fibres at the angle of the anterior chamber, through which the aqueous humour filters out of the eye, would be exceedingly liable to cause some obstruction to its exit resulting in increase of tension. In a congenitally buphthalmic eye, removed from a boy, aged 14 years, I have found the ligamentum pectinatum to be completely absent. The posterior limiting membrane, instead of splitting up into a number of fibres at the angle of the anterior chamber, continued round it and extended for a short distance along the anterior surface of the iris as a hyaline structure lined by endothelial cells which terminated rather abruptly. Externally to the angle of the chamber in this eye there was a broad adhesion of the root of the iris to the sclerotic, to which also the ciliary muscle was attached, but neither fibres of the ligamentum pectinatum nor a canal of Schlemm could be detected.

Out of six congenitally microphthalmic human eyes which I have measured (Table III.) I have found four in which the lateral diameter of the cornea was more than half the antero-posterior diameter of the globe, one in which it was exactly half, and one in which it was slightly less than half. So that in all except one of these eyes the relation of the size of the cornea to the globe resembled the pre-natal or pre-human condition.

TABLE III.

No.	Eyeball.			Cornea.	
	Antero-posterior.	Lateral.	Vertical.	Lateral.	Vertical.
1	19·0 mm.	18·0 mm.	18·0 mm.	9·5 mm.	8·5 mm.
2	17·0 ,,	18·0 ,,	16·5 ,,	8·25 ,,	7·5 ,,
3	15·5 ,,	—	14·0 ,,	9·0 ,,	—
4	13·5 ,,	12·0 mm.	12·0 ,,	8·5 ,,	5·5 mm.
5	19·0 ,,	20·0 ,,	20·0 ,,	11·5 ,,	10·5 ,,
6	20·0 ,,	20·0 ,,	20·0 ,,	11·0 ,,	10·5 ,,

No. 2 in the above table was an eye which had coloboma of the iris, displacement of the lens backwards, and other congenital defects (a full description of it is published in the Transactions of the Ophthalmological Society of the United Kingdom, vol. xiii., p. 116). In sections of it the extreme angle of the anterior chamber is seen to be almost on a level with the termination of Descemet's membrane. Directly this membrane has split up into the ligamentum pectinatum some of the fibres of the latter curve back almost at a right angle and pass to the root of the iris. Between the trabeculæ of the ligamentum pectinatum nearest the angle of the anterior chamber the spaces are large. A line drawn vertically backwards through the canal of Schlemm passes through the ligamentum pectinatum, not through the angle of the anterior chamber. The position of the ciliary processes is much distorted owing to the faulty position of the lens.

No. 3 in the table was an eye with a congenitally persistent and patent hyaloid artery and fibrous tissue formation in the vitreous chamber (a detailed description of it is given in the Royal London Ophthalmic Hospital Reports, vol. xiii., p. 92). In sections of it the canal of Schlemm is seen some distance externally to the angle of the anterior chamber. The ciliary processes and large circular artery of the iris are well external to a line drawn vertically backwards through it. There is a well-marked cavernous zone to the ligamentum pectinatum.

No. 4 in the table was a microphthalmic eye, a description of which I will give later. In it the condition of the ligamentum pectinatum and the relation of parts about the angle of the anterior chamber are seen to be similar to that in No. 3.

No. 5 in the table had considerable defect in the development of the iris in its whole circumference, which led to its being described clinically as a case of irideræmia (a detailed description of it is published in the Transactions of the Ophthalmological Society, vol. xiii., p. 128). The condition of the ligamentum pectinatum in this case closely resembles that met with in the ungulata. In some sections portions of the fibrous tissue from the anterior part of the iris seem to pass forwards to the posterior surface of the cornea in the position where Descemet's membrane ends and the ligamentum pectinatum begins. Externally to this prolongation forwards of iris tissue are some irregular trabeculæ with large spaces between them, and anteriorly and externally to this cavernous zone are the laminated fibres of the ligamentum pectinatum with slit-like spaces between them.

In these eyes the structure of the ligamentum pectinatum and the relation of parts about the angle of the anterior chamber seem to have remained in their fœtal condition and to have simulated that met with in lower mammals. Probably on account of the smallness of the eyeballs these abnormalities in the filtration area did not cause sufficient obstruction to the exit of the aqueous humour to give rise to increase of tension. In several congenitally buphthalmic eyes bands of adhesion have been seen stretching across the angle of the anterior chamber between the root of the iris and the periphery of the cornea. These sometimes consist of delicate fibres only and are sometimes quite broad adhesions. As the eyeball enlarges and the anterior chamber becomes deepened these adhesions may break through, then loose tags of fibres are met with. Mr. Richardson Cross[21] published the description of a careful microscopical examination which he had made of three congenitally glaucomatous eyes. Speaking of the filtration area in these eyes he says: "There was in No. 1 a definite adhesion of the root of the iris to the ligamentum; No. 2, no definite adhesion, but strands of tissue suggestive of a former contact of iris and cornea which has given way; No. 3, distinct block of considerable width occluding the angle." I have elsewhere described these adhesions as due to a congenital failure in the complete separation of the anterior surface of the iris from the posterior surface of the cornea. This they certainly are, but the more extended examination which I have recently made of the eyes of animals leads me to think that some of them are better spoken of as an abnormal persistence of the pre-human or pre-natal condition of the ligamentum pectinatum.

Arrangement of Parts about the Angle of the Anterior Chamber in Birds, Reptiles, and Fish.

Before passing from the consideration of the arrangement of parts about the angle of the anterior chamber I wish to refer briefly to the examinations of this region of the eye which I have made in animals other than mammals. In birds, in whom the cornea is very convex, the front portion much prolonged forwards, and the anterior chamber very

21 Transactions of the Ophthalmological Society of the United Kingdom, vol. xvi.

deep, the ligamentum pectinatum is an extensive structure. Thus in a pigeon's eye I find it to consist of a number of radiating delicate fibres and branching cells. Starting at the sclero-corneal margin a little anterior to the level of the root of the iris it extends backwards a considerable distance between the striated muscle of Crampton and the portion of the ciliary body connected with the ciliary processes. The canal of Schlemm is large and in the sections remains widely open. In a snake's (coluber natrix) eye the ligamentum pectinatum is seen as a definite collection of fibres stretching from the back of the cornea to the rudimentary ciliary body and the canal of Schlemm is a channel of considerable size. In fish, in which the anterior portion of the eye is much flattened and the anterior chamber very shallow, the arrangement of parts about its angle is of a much simpler character, though they vary considerably in different species. Thus in a carp (carassius auratus) I find at the angle of the anterior chamber, filling a considerable part of the space between the iris and posterior surface of the cornea, a mass of large endothelial cells. No canal of Schlemm is present, but at one part of the circumference of the chamber large blood channels on the surface of the choroid extend forwards between this mass of cells and the iris, and their lumen is only separated from the chamber by a thin vessel wall. In the other teleostean fish which I have examined this mass of cells at the angle of the chamber is much less extensive, the cells themselves being elongated, sometimes branching and forming a network. In none have I met with any regular canal of Schlemm, only the prolongation forwards of a choroidal vessel as above described. In the elasmobranch fish the cells at the angle of the chamber branch more and form a more pronounced network. In the lesser spotted dog fish (scyllium catulus) in the portion of the chamber in the neighbourhood of the campanula and of the ocular cleft, there are some fibres lined by cells which present an arrangement much like the ligamentum pectinatum in mammals, and external to it is a large channel which can be traced back to communicate with the choroidal and anterior perforating vessels.

The Ciliary Body the only Source of Intra-ocular Nutrient Fluid in Mammals.

In man and other mammals anatomical, clinical, and experimental evidence goes to show that the fluid which circulates in the vitreous and aqueous chambers, and which gives nutriment to the lens, is secreted by the ciliary body. In them it would seem that this is its only source and that the other vascular structures in the eye play no part in its production, for we find that each of them may be absent without any diminution of the intra-ocular tension taking place. In cases where the iris is absent congenitally or as the result of traumatism normal tension is as a rule fully maintained. So also is it when the retinal circulation is completely blocked by embolism of the central artery, or when there is almost complete congenital absence of the choroid, as in a remarkable case shown at the Ophthalmological Society by J. Tatham Thompson last year.[22] In it ophthalmoscopically the fundi presented throughout the appearance of dazzling white sclera, with retinal vessels coursing over it as seen in coloboma of the choroid, no chorio-capillaris or red reflex being seen except at the macular region. The following is a case in which as the result of the operation of optico-ciliary neurectomy, performed for the relief of pain in glaucoma, the retina and choroid became completely atrophied and yet the tension remained increased.

The patient was a man, aged 44 years, who had had an iridectomy performed on the eye for acute glaucoma which did not, however, relieve the tension. The eye became blind and the pain continued but he refused to have it removed, so five months after the iridectomy an optico ciliary neurectomy was performed. The pain was then for a time relieved, but two years later it had again become so severe that he consented to have the eye excised. The tension at that time was noted as + 3. On pathological examination of the eyeball the lens, which was clear, appeared to be healthy. The vitreous was only slightly shrunken. The choroid and retina, as far forwards as the equator of the globe, were most extremely atrophied. Microscopically no blood-vessels could be detected in the former, its elastic lamina being the only part of it that could be made out, while the latter was represented by a strand of fibrous tissue with a few scattered pigment epithelial cells in it. In front of the equator the atrophy of these structures was less marked; a few blood-vessels were present in the choroid, while in the retina the two nuclear layers could be differentiated though just behind the ora serrata it had some cystic spaces in it. The ciliary body was not more atrophied than was to be expected in a case of glaucoma of such long standing.

22 Transactions of the Ophthalmological Society of the United Kingdom, vol. xix., p. 140.

Comparative Anatomy of the Ciliary Body.

In other animals than mammals and in the human fœtal eye there are other sources for nutrient supply to the intra-ocular structures in place of, or in addition to, the ciliary body. In eels both the common and conger (anguilla anguilla and conger vulgaris) and in a species of carp (carassius auratus) I find there is no ciliary body, no pars ciliaris retinæ. The retina proper ends at the base of the iris and is then continued, on the back of that membrane, as a single row of cells which are at first unpigmented and only become pigmented a short distance from where they turn round at the tip to join the outer deeply pigmented layer of the secondary optic vesicle. In the other teleostean fish, of which I have examined sections—viz., whiting (gadus merlangus), cod (gadus morrhua), mackerel (scomber scombrus), and plaice (pleuronectis platessa)—the termination of the retina does not extend quite so far forwards, it does not quite reach up to the root of the iris, and whereas in the former it extends as far as, or farther than, the anterior margin of the cartilage in the sclerotic, in these latter it is situated behind that point. The pars iridis retinæ has, however, the same arrangement. Amongst the elasmobranch fish I have sections from the thornback (raja clavata), the lesser spotted dog-fish (scyllium catulus) and the spring dog-fish (acanthus vulgarus). In them I find the displacement backwards of the anterior termination of the retina still more marked. The area which exists between it and the root of the iris is thrown into shallow folds laterally and has some slight elevations and depressions antero-posteriorly. The inner row of cells which line this area, which may be regarded as the pars ciliaris retinæ, are unpigmented, whilst both layers of the secondary optic vesicle on the back of the iris are pigmented. Immediately outside the pigmented layer of the rudimentary ciliary body large blood-vessels are seen. In sections of the spring dog-fish passing across the campanula elevations and depressions much more pronounced and closely resembling the ciliary processes in a mammal's eye are met with.

I have sections of the eyes of the following reptiles: the land tortoise (testudo Græca), the slow worm (anguis fragilis), the sand lizard (lacerta agilis), and the common ringed snake (coluber natrix). In all except the last the ciliary body is represented by a short area, without any elevations or depressions, situated between the termination of the retina and the root of the iris, which is lined by a single row of unpigmented cells inside the pigment epithelial layer. In the snake there is a well-marked fold protruding inwards in the ciliary region lined by columnar-shaped unpigmented cells.

The source of the intra-ocular nutrient fluid in animals, in which there is no ciliary body or in which it is only very rudimentary, can only definitely be determined by experiment. The following anatomical points are, however, very significant. In fish the anterior chamber is comparatively very shallow and the amount of aqueous humour very small. In all those of which I have examined sections the blood-vessels in the iris situated immediately external to the pigment epithelium are large and numerous. In eels I find blood-vessels attached to and forming a network in the hyaloid membrane of the vitreous humour. The main trunk from which these vessels are derived passes in from the choroid along the lower border of the optic nerve through a cleft in the two layers of the retina. In the other teleostean fish which I have examined the line of the ocular cleft in the retina is discernible in its whole length. Blood-vessels pass through it, forming a vascular process which projects slightly into the vitreous chamber. These vessels start from a rete mirabile which is met with in the choroid of these fish surrounding the optic nerve, and which has been termed the choroidal gland. In the elasmobranch fish in which ciliary processes are met with there is no rete mirabile in the choroid and no persistent cleft with a projecting vascular process.

In many reptiles a collection of blood-vessels termed the falciform process protrudes into the vitreous chamber which in birds is modified into the pigmented plicated structure called the pecten. I have bleached sections of the pecten from a cock's eye. I find it composed of some large main blood-vessels and many very small ones the latter having entirely cellular walls. In fact, it closely resembles in structure the choroidal coat of which it is a prolongation, having, however, a rather finer capillary plexus. Birds, therefore, not only possess well-formed ciliary processes but also a special vascular arrangement in the vitreous chamber. In neither of the two lowest and very exceptional mammals the ornithorrhynchus and the echidna is any trace of a pecten to be found. The ciliary processes in these animals, though not so markedly convoluted as in other mammals, show in antero-posterior sections many well-developed folds. The length and amount of plication of the ciliary processes vary considerably in different mammals, but in all except the quadrumina the extent of the non-plicated area of the ciliary body is markedly less than in man.

Development of the Ciliary Body in the Human Eye.

In a human fœtal eye of the sixth week no iris or ciliary processes can be detected. The cells composing the outer layer of the secondary optic vesicle are not pigmented and the inner layer, which is composed of undifferentiated round cells with large nuclei, is as thick at its anterior termination near the sclero-corneal margin as elsewhere. Even at this early age a blood channel is to be detected passing through the cleft in the secondary optic vesicle into the rudimentary vitreous humour. At the tenth week the anterior termination of the secondary optic vesicle, which lies for some distance in close contact with the sides of the lens, has begun to insinuate itself between the lens and cornea to form the posterior layers of the iris. It has also a little further back, where it lies in contact with the sides of the lens, become slightly corrugated, forming the commencement of the ciliary processes. Its outer layer is by this time deeply pigmented and its inner layer, from the point where it first touches the lens forwards is much thinner than elsewhere, though it apparently consists of more than one row of cells. It remains unpigmented until just before it begins to turn round to join the outer layer. The blood-vessels in the posterior part of the fibro-vascular sheath of the lens are by the tenth week well developed, but I am unable in my sections to detect any in the anterior part of the sheath. By the fourth month the ciliary processes have considerably grown; their apices still touch the sides of the lens. The inner layer of the secondary optic vesicle covering them, as in the adult, consists of a single row of unpigmented cells, while on the inner surface of the iris they are pigmented, not, however, so deeply pigmented as they become later. The ora serrata of the retina is situated where the ciliary processes end posteriorly, there being no non-plicated area to the ciliary body. The non-plicated portion of the ciliary body commences to form after the fourth month, gradually lengthening, and the ora serrata gradually being displaced further and further back until the eyeball reaches its full dimensions. The plexus of blood-vessels around the lens I have found still patent in sections of the fœtus at the sixth month: by the seventh month they have quite disappeared. In many congenital microphthalmic eyes which I have examined the non-plicated portion of the ciliary body is seen to be relatively smaller than the rest of the structure.

10th wk Mesoblastic tissue which is subsequently to form ciliary muscle can be differentiated from that to form [illegible]. Can see blood vessels in ant. fibro-vascular sheath [illegible] ciliary body. 4th adult. Cil. muscle composed of a considerable mass of undifferentiated closely packed cells with deeply staining nuclei. After 4th month cells become lengthened out

into longitudinal fibres of ciliary muscle at posterior part of the body. At this time the ciliary muscle extends a long distance posterior to the ora serrata & the ciliary processes are almost entirely anterior to it.

Microphthalmic Eye with Persistent Fœtal Vascular System and Absence of Ciliary Processes.

I have only met with one human eye in which there was anything approaching complete absence of the ciliary processes, and in it the vascular system of the vitreous and lens which exists during fœtal life had failed to become obliterated, its vessels remaining patent and carrying blood. It was a congenitally microphthalmic eye removed from a child two months old by Dr. Hector Mackenzie of Torquay, to whom I am indebted for the specimen. It measured only 12 millimetres antero-posteriorly and 11·5 millimetres vertically and transversely. The cornea was clear but small, measuring six millimetres transversely. No iris could be seen through it. The lens appeared opaque and calcareous. Microscopical examination of sections of the eye show an exceedingly small rudimentary iris, better formed on one side than on the other. Where best developed it does not measure more than one millimetre in length but possesses a sphincter muscle. On the opposite side no sphincter muscle is to be seen; the pigmented epithelium turns forward at the tip to form a nodulated mass. Extending from the anterior surface of the rudimentary iris on one side across the pupil in contact with the anterior surface of the lens to the anterior surface of the iris on the other side is a thin membrane composed mainly of flattened cells with large nuclei. Extending also from the anterior surface of the iris round its pupillary margin and backwards to the sides of the lens is a membrane composed in part of the same flattened cells but having in it besides a plexus of blood-vessels. These vessels in the sections are seen to be patent and to contain blood corpuscles; they can be traced forwards to the stroma of the iris, where they join the blood-vessels in that structure. Continued backwards they are seen to start from the posterior pole of the lens, where an artery, passing through the centre of the vitreous, breaks up in a thin membrane into numerous branches. The lens is very small and presents a very irregular outline; its nucleus is the only part in which the lens fibres appear well formed; in the cortical portions there is much irregularly arranged hyaline substance. Cells line the whole of the posterior as well as the anterior part of the capsule. At the anterior pole the capsule is much corrugated and on its inner surface is some dense laminated tissue with flattened cells between the laminæ and calcareous deposit, like what is usually met with in anterior polar cataracts. A ciliary muscle is present composed entirely of longitudinally arranged spindle-shaped cells. Its inner surface forms an even curve lined by pigment epithelial cells. On either side of the sections only one small knob-like projection is seen to protrude inwards from it.

The unpigmented layer of cells forming the pars ciliaris retinæ, together with some pigmented cells and the anterior extremity of the retina in the region of the ora serrata, are seen to be in great part in contact with the fibro-vascular sheath surrounding the lens. The sides of the lens, owing to its small size, are separated some distance from the ciliary body. Nowhere is the unpigmented layer of the pars ciliaris retinæ seen in contact with the pigmented layer. The retina at the ora serrata is also separated from the choroid ; it is well formed but has several rucks in it radiating from the optic disc. The choroid shows no abnormality. The central artery of the vitreous starts from that in the optic nerve ; it is for a short distance surrounded by a sheath composed of long spindle-shaped cells, but anteriorly lies without any sheath in a canal separated only by a hyaline membrane from the vitreous. The detached folds of the pars ciliaris retinæ and the retina itself at the ora serrata where they lie in contact with the fibro-vascular sheath of the lens have cellular connexions with it, while in places very much elongated cells can be seen, apparently partly developed fibres of the suspensory ligament.

The probable explanation of the appearances of the ciliary body in this eye is that at the stage of fœtal life when the portion of the secondary optic vesicle which comes to line the ciliary body lay in contact with the sides of the lens adhesion formed between them which should later have developed into fibres of the suspensory ligament. Owing, however, to the persistence of the blood-vessels in the sheath these adhesions became of a tougher character than usual ; consequently when the ciliary body in the process of growth became separated from the sides of the lens, instead of these adhesions stretching out into fibres, a part of the inner layer of the secondary optic vesicle became torn from the outer layer and remained in contact with the lens.

I have previously had the opportunity of examining and recording the appearances of several eyes in which the central artery of the vitreous had remained persistent and patent, but in none of these have I been able to trace the branches into which it broke up round the sides of the lens to join the vessels of the iris, as in this case. In the specimens which I have previously examined, so far as I could make out, the vessels terminated in a mass of fibrous tissue in the anterior part of the vitreous. In the present case there is none of this abnormal fibrous tissue formation in the vitreous.

Microphthalmic Eyes with Cystic Protrusions.

The case just recorded is an example of a microphthalmic eye without any defect in connexion with the fœtal cleft; in it the choroid and sclerotic were complete and well formed. In many microphthalmic eyes there is an imperfect closure of the cleft, accompanied by a protrusion of a portion of the retina through the gap. Sometimes the protuberant retina becomes distended into a cyst. Such a cyst may be so large and the eyeball with which it is connected so small that the latter is clinically completely concealed from view. The apparent absence of the eyeball in such cases has led to some of them being described as cases of anophthalmos, a title which, strictly speaking, is not applicable. Of recent years quite a number of records have been published of the microscopical appearances of microphthalmic eyes with protrusions of retinal tissue. I have myself recorded the details of seven such eyes, and Kundrat, Rindfleisch, De Lapersonne, Gallemaerts, Czermak, Mitvalsky and Hess have recorded others. A study of the descriptions of all these specimens shows that though they are alike in being microphthalmic eyes with a protrusion of retinal tissue through a gap in the choroid and sclerotic, they present considerable variations, both as regards the character of the protrusion and as to the state of development or mal-development of the other structures of the eyeball. The protuberant portion of retina consists of varying amounts from simply a knuckle of tissue to quite two-thirds of that membrane. In some cases it forms a solid mass surrounded and intermixed with bands of fibrous tissue. In others folds of retina have become distended into one or more fluid-containing cystic protrusions which are bounded externally by a fibrous-tissue coat and have a lobulated outline.

The degree of development of the protuberant retina is also very different in different cases. When folds of it have become distended in the form of cystic protrusions it may be so atrophied as merely to be represented by a few groups of nuclear bodies and a little retiform tissue. On the other hand, it may remain so well developed that some of its different layers are easily distinguished. In the latter cases it is found that sometimes the inner surface of the retina is turned towards the interior of the cyst, and at other times just the reverse, the inner surface of the retina being directed towards its fibrous outer wall. The region of the globe in which the protrusion is situated is nearly always its lower and posterior part, sometimes a little further forwards than others. In one case, besides the gap in the sclerotic there was a considerable deficiency in the outer sheath of the optic nerve.

Speaking generally, the larger the amount of the retinal protrusion the smaller and more imperfectly developed is the eyeball. When the protrusion is not very extensive the eyeball may present little external evidence of malformation beyond its defect in size. The lens and vitreous may also appear quite normal. On the other hand, there are numerous congenital defects which may be met with in association with it, such as vascularity of the cornea, formation of cartilage in the sclerotic, coloboma of iris, persistent pupillary membrane, displacement of ciliary processes, cataract, persistence of blood-vessels in the vitreous and formation of fibrous tissue in it, detachments of the retina elsewhere than at the protrusion, and hyaline nodules in the choroid.

In considering the causation of this congenital malformation I would first like to point out that in none of the seven specimens which I have examined is there anything which would lead me to suppose that the changes shown were inflammatory in origin. In one case there were some collections of round cells found in the cyst wall which might have been inflammatory ; if so they were of recent production, and as the eye was not removed until the patient was 18 years old they cannot be considered as having had anything to do with the causation of the congenital defect. I lay stress on this point because Deutschmann in 1881, from his investigation of a case of bilateral coloboma of the iris and choroid in a rabbit, advanced the theory, which has been widely accepted and quoted, that so-called arrests of development were only changed developments of the eye the result of intra-uterine inflammation. Hess brought forward several cases which, like those which I have examined, go to show that inflammation has very much less to do with the production of congenital malformations than has generally been supposed. The difference in the position of the retina in these cases suggests that they are not all produced in precisely the same way. When the normal outer surface of the retina is external in the cyst it is possible, as Alt has suggested, that part of the lower wall of the globe, where there was a defect in the choroid and partial defect in the sclerotic, may have been stretched before the intra-ocular pressure and the lining retina pushed into the depression formed. Where, however, the normal outer surface of the retina is towards the interior of a cyst and where the amount of retina which protrudes is very large, such an explanation cannot be accepted, and Kundrat's view, that the cystic formations are due to the projection during development of a portion of the retinal tissue through the fœtal cleft into the subjacent mesoblastic tissue, would seem more applicable. The retina in the human fœtal eye is normally thrown into folds and it is not difficult to understand how, as the result of some imperfect development of the vitreous humour or delayed closure of the cleft, one or more of these folds of the inner layer of the secondary optic vesicle might become extruded through the fœtal ocular cleft into the surrounding mesoblast, and subsequently become expanded into one or more fluid-containing cysts.

LECTURE III.

Delivered on Feb. 16th.

Elastic Tissue of the Human Sclerotic.

Mr. Vice-President and Gentlemen,—The human sclerotic, consisting chiefly of white fibrous tissue, contains also a number of delicate yellow elastic fibres. The distribution of these is well shown in sections stained with acid orcein by which they are picked out a bright red. They may be seen cut transversely when they appear as little dots, and longitudinally when for the most part they run parallel with the bundles of white fibrous tissue and have a wavy course. The outer layers of the sclerotic contain more elastic fibres than the inner, and they are more numerous posteriorly than anteriorly. Around the entrance of the optic nerve there is quite a dense plexus of them. The lamina cribrosa is largely composed of elastic fibres which extend across the nerve fibres from the plexus in the sclerotic on each side. From the lamina cribrosa a delicate network of elastic fibres extends backwards around the central blood-vessels of the optic nerve. In both the pial and the dural sheaths of the optic nerve there are numerous elastic fibres. In the former they are like those in the sclerotic, fine and delicate, but they run a more tortuous course. In the dural sheath the elastic fibres are thicker than are those in the sclerotic, but they have the same wavy character, and they run parallel to the bundles of white fibrous tissue. In the tendons of the recti muscles, where they are inserted into the sclerotic, thick elastic fibres are deeply stained by the acid orcein; they are especially numerous in the sheath around the muscles. This arrangement of the elastic fibres in the sclerotic which I have described corresponds very closely to that which was demonstrated by Professor Salter at the twenty-fifth Ophthalmological Congress at Heidelberg in 1896, who employed what he terms Spaltenholz's method of staining which he says shows up the elastic fibres black against a yellow background.

Structure of the Sclerotic in Different Animals.

The structure of the sclerotic presents several variations in the different species of the animal kingdom. In elasmobranch fish it consists of hyaline cartilage from the sclero-corneal margin right back to the optic nerve with only a small amount of fibrous tissue on its outer surface. In most teleostean fish there is hyaline cartilage anteriorly extending up to the margin of the cornea, but posteriorly there is only fibrous tissue, or fibrous tissue with scattered patches of cartilage in it. In birds and in some reptiles there is a cup of hyaline cartilage posteriorly extending forwards beyond the level of the ora serrata and anterior to it are plates of bone. In other reptiles the sclerotic is fibrous throughout. In all mammals, with the exception of the ornithorrhynchus and the echidna, the sclerotic is entirely fibrous. In the two exceptional mammals it contains a cup-shaped piece of hyaline cartilage at the posterior part extending forwards as far as the ora serrata and having fibrous tissue on its inner and outer surfaces.

Hyaline Cartilage in the Sclerotic of Congenitally Malformed Human Eyes.

In some congenitally microphthalmic human eyes which have presented several malformations and had cystic protrusions connected with them pieces of hyaline cartilage have been found in the fibrous tissue of the sclerotic. I have met with one such case myself. The eye was removed from a child aged 14 weeks, and was noted to have been defective since birth. The cornea and the whole globe were exceedingly small. Attached to its lower part in front of the optic nerve was a thin-walled lobulated cyst lined with retinal tissue. At the upper part of the globe, lying in front of a large portion of the cornea, partly embedded in it and partly in the sclerotic, was a broad plate of hyaline cartilage which ended anteriorly in a rounded extremity amongst the fibrous tissues beneath the epithelium of the conjunctiva. Posteriorly it also ended in a rounded extremity surrounded by fibrous tissue and projected as a sort of spur from the sclerotic about the equator of the globe, there being fatty tissue in the recess left between the spur and the sclerotic. There was a second piece of hyaline cartilage in the sclerotic on the opposite side of the globe which commenced posteriorly in a rounded extremity a short distance from the optic nerve and the anterior termination of which was not shown in my sections. In some sections this last piece of cartilage was seen as a circular patch lying in the fibrous tissue between the eyeball and the cyst.

Mitvalski,[23] in the description of a somewhat similar microphthalmic eye with a cystic protrusion, says: "Where the scleral tissue passes over into the fibrous wall of the sac there is on each side in the entire length of the ball a mass of cartilage." Dr. Lapersonne[24] also mentions and figures a piece of hyaline cartilage embedded in fibrous tissue lying between a microphthalmic eyeball and a cystic formation connected with it.

Various Forms of Cystoid and Bulging Scars met with after Operations.

The peculiar bulging translucent form of scar which is met with sometimes after operations on the eye, most frequently after iridectomy for glaucoma, was first described by von Graefe and termed by him "cystoid cicatrix." I have previously demonstrated how microscopical examination of such cicatrices shows them to consist of a gap in the sclero-corneal tissue covered by conjunctiva and lined by a piece of atrophied iris. That these cystoid cicatrices are produced by the prolapse of a fold of iris does not, from their clinical appearances alone, appear obvious and has been doubted. Pathological examination of a large number of cicatrices has, however, convinced me that for a permanent fistula to become established in the fibrous tissue tunic of the globe it is necessary that the two edges of the wound should become lined by cells of an epithelial character, otherwise plastic exudation is sure to be thrown out and to lead to their union. When a fold of iris becomes incarcerated this epithelial lining is supplied by the pigment epithelium on its posterior surface. I have found in some cases the lining also in part furnished by the most anterior of the ciliary processes and a turning forward of one of the divided ends of Descemet's membrane with its endothelial cells. I have had recently to examine a glaucomatous eye in which a short time previously to excision the operation for incision of the iritic angle, in the way suggested by Valude, had been performed. It is interesting in two ways. First, it shows how difficult it is to know when the point of the knife is passed into the iritic angle, for though the operator, a most experienced ophthalmic surgeon,

[23] Archives of Ophthalmology, vol. xxii., p. 355.
[24] Archives d'Ophtalmologie, tome xi. p. 207.

aimed at the angle of the chamber, sections of the eye show that the sclero-corneal tissue some distance inside of it was incised. Secondly, it shows that a wound in the sclero-corneal tissue at the periphery of the anterior chamber in a glaucomatous eye will, unless it has an epithelial lining, soon heal up, and not remain as a permanent fistula. In this eye the aqueous humour escaped beneath the conjunctiva at the time of the operation, but in the specimen the outer layers of the sclero-corneal tissue have already become united, with round-celled exudation between them.

Von Graefe pointed out that cystoid cicatrices are not met with in the cornea and we can easily understand how this is due to its not being covered by conjunctiva. A permanent gap established in it would lead to a leaking fistula. Cystoid cicatrices are rarely, if ever, met with anywhere but within a few millimetres of the sclero-corneal margin—i.e., they are rarely if ever met with anywhere except in the region in which prolapses of folds of iris are likely to occur. It is the loose and mobile character of the iris which allows of a piece of it so readily protruding into a wound. The more firmly fixed and stretched arrangement of the other portions of the uveal tract, the ciliary body and choroid, tends to prevent folds of them becoming entangled.

The pathological examination of eyes upon which operations have been performed has shown me that there are three conditions, presenting somewhat different clinical appearances, which result from entanglements of folds of iris in a scar. More than one of these conditions may be present in the course of the same cicatrix. First, there is the typical translucent cystoid cicatrix, the condition which is essential for its formation being the protrusion of a fold of iris through the whole thickness of the sclero-corneal tissue, so that there is nothing but conjunctiva external to its most prominent part. A tendency to increase of tension after healing of the wound favours its development, for when the tension is increased, the gap, which is a weak spot in the walls of the globe, more quickly stretches, the iris lining it consequently becoming more rapidly atrophied and permeable by the aqueous humour. (After a cystoid cicatrix is once established the tension is often found slightly minus, due to the ready escape of the aqueous humour through it into the sub-conjunctival tissue.) The smaller the fold of iris entangled, provided it is sufficient to line completely both edges of the sclero-corneal wound, the more readily will the cystoid condition develop, for then there is less iris tissue to become stretched out and atrophied. Thus the condition is often met with after iridectomy, when a portion of the root only of the iris is left to become entangled as a fold in the wound.

The second condition which results from the incarceration of a fold of iris is what would be termed clinically a bulging scar. In it the fold does not extend throughout the whole thickness of the sclero-corneal tissue, so that from before backwards there is conjunctiva, reunited anterior layers of sclero-corneal tissue, entangled iris, and then a gap in the posterior layers of the sclero-corneal tissue. Such a spot in the walls of the eyeball would also be a weak one and, as the result of increase of tension, or even sometimes as the result of normal tension, liable to give and bulge. But owing to the presence of the reunited anterior layers of sclero-corneal tissue it does not allow of the filtration of aqueous humour through it and has not the translucent appearance of a cystoid scar.

The third condition is what might be spoken of as a staphylomatous scar, though the name does not very definitely distinguish it from the previous condition. It is met with when the whole length of the iris from its ciliary to its pupillary margin has become prolapsed as a fold into a wound at the sclero-corneal margin, so that its entire thickness is kept from reuniting. Before the whole iris becomes sufficiently atrophied to be permeable by the aqueous humour it is capable of considerable distension. Hence in this condition a large, thin-walled, greyish prominence of considerable dimensions forms in the region of the scar. This is the form of cicatrix which frequently resulted from the operation of sclerotomy as performed by the late Mr. Bader, who after completing his incision encouraged the iris to prolapse.

Suppurative Panophthalmitis in Eyes with Cystoid Scars.

The chief danger in connexion with cystoid scars is, as was pointed out by von Graefe, the liability of such eyes to become the seat of a suppurative panophthalmitis months or years after the healing of the wound. Many cases of this sort have now been recorded. The following is a typical one in which I have had the opportunity of making a pathological examination of the eyeball.

A man, aged 20 years, was admitted to the Moorfields Hospital in September, 1893. His left eye was said to have been first affected when he was two years old; he never remembered having seen much with it. He had had several operations performed, the first when he was three and a half years old. One of these had resulted in the formation of a small cystoid scar at the lower and inner part of the corneal margin. Three weeks previously to admission to the hospital, while boxing, he received a blow on the defective eye. The lids afterwards became discoloured and the eye inflamed and watery. On admission there was conjunctival and ciliary injection, haze of the cornea, an hypopyon, an opaque lens, and a coloboma of the iris down and in, in the direction of the cystoid scar. The tension was minus and the vision reduced to bare hand movement. The eye was excised and on examination, in the region of the cystoid scar, a well-marked gap in the sclero-corneal tissue was seen, lined by the root of the iris. The lens was *in situ.* There was extensive suppuration in the vitreous, most intense, and radiating from the lower and inner part of the ciliary body. Microscopically extensive round cell infiltration could be seen in the sub-epithelial tissue around the scar, and extending along the iris tissue incarcerated in it. There was also much round cell infiltration of the ciliary body and vitreous in its neighbourhood. In this case I think there can be no doubt that the infection of the eye passed through the cystoid cicatrix and was consequent upon the blow. This blow may have caused an abrasion of the epithelium over it or started an inflammation of the conjunctiva in the course of which the epithelium overlying it became softened; in either case, a route being formed for the passage of infective material into the sub-epithelial tissue of the conjunctiva it had evidently spread into the iris tissue adherent to that membrane and so through the gap in the sclero-corneal tissue to the ciliary body.

Wagenmann[25] has collected 13 cases from Leber's clinique in which suppurative hyalitis occurred at periods varying from a few months to some years after the healing of a wound and in which a cystoid cicatrix or entanglement of iris was present. He made a microscopical examination of 11 of the eyes and in all of them found micro-organisms. He considers that the history and anatomical appearances in these cases is in favour of a new infection of the cicatrix from without rather than that the micrococci entered the wound before it healed and had then for a long time remained inert, or that they had been brought to the cicatrix by the circulation and found there a congenial soil.

[25] Archiv für Ophthalmologie, 1889, Band xxxv., Abtheilung 4, S. 116.

Serous and Plastic Inflammation in Eyes with Cystoid Scars or Sub-conjunctival Entanglements of Iris.

It seems, then, that there is good evidence that the infection which gives rise to a suppurative inflammation may find its way into the interior of the eye along the track of a piece of sub-conjunctivally prolapsed iris some considerable time after a wound has healed. It would be very probable, therefore, that the infection which gives rise to less severe forms of inflammation, of a serous or plastic type, might gain access to the interior of the eye in a similar manner. The following is the brief epitome of a case, which I have elsewhere recorded in full, in which this is what seems to have occurred.

A lady had an iridectomy performed for chronic glaucoma; this was followed by relief of tension and the formation of a cystoid cicatrix. A year later when out driving she caught cold in the eye, after which iritis ensued with the formation of posterior synechia. The eye was excised for the relief of pain and microscopical examination showed the atrophied root of the iris and anterior part of the ciliary body lining the cystoid scar.

The next case which I wish to bring to your notice is that of a woman, aged 56 years, who was struck on her right eye by a fist and who attended as an out-patient three days later, when it was found that there had been a rupture of the sclerotic extending round and concentric with the upper half of the cornea, but without any lesion that could be detected of the conjunctiva. The iris was drawn up into the rupture so as to simulate a coloboma. 24 days later she again attended the hospital with circum-corneal injection in the left eye, iritis, and numerous posterior synechiæ. She stated that 18 days after the injury she first noticed a dimness of sight in that eye. The right eye, which was at that time also much inflamed, was then excised. The left eye, in spite of treatment, ultimately became quite blind. Microscopical examination of sections at the seat of the rupture in the right eye showed the epithelium of the conjunctiva forming an unbroken layer, and in the tissue immediately beneath it and superficial to the sclerotic much round-celled infiltration. The iris was folded in two in the middle and drawn into the fibrous tissue at the seat of the rupture. In this position it was much thickened with infiltration of small round cells, as also was the ciliary body and choroid in the interior of the eye.

In this case infection evidently found its way into the sub-epithelial tissue of the conjunctiva and caused cell exudation there, though no apparent lesion of it was discovered. The iris lying in contact with the sub-conjunctival tissue next became affected, and along it through the line of the rupture in the sclerotic infection spread to other portions of the uveal tract in the interior of the globe, exciting in them a plastic inflammation. The plastic inflammation thus started, like plastic inflammation of the uveal tracts started by penetrating wounds of the eye, was capable of exciting inflammation of a similar character in its fellow eye—that is, sympathetic ophthalmitis. Other cases similar to this have been recorded; Schirmer collected several, in some of which the evidence as to absence of any lesion of the conjunctiva seemed undoubted.

How Sympathetic Ophthalmitis may arise Months or Years after the Receipt of an Injury.

The possibility of infection which gives rise to a serous or plastic inflammation finding its way into the interior of the eye from the sub-conjunctival tissue along the track of a piece of prolapsed iris offers, I think, a possible explanation of the way in which sympathetic ophthalmitis may be set up months or years after the receipt of a wound to the exciting eye. In such cases it is usual, previously to the onset of the sympathetic disease, for some fresh attack of inflammation or irritability to have been noted in the exciting eye. Indeed, a committee of the Ophthalmological Society of the United Kingdom after much collective investigation could only find nine undoubted cases of sympathetic ophthalmitis arising after a long interval in which such an attack was not noted in the exciting eye, though they describe those in which it was present as fairly numerous. The fresh attack of inflammation or irritability in these cases is probably the starting-pointing of fresh infection of the exciting eye from without. Any eye with a sub-conjunctival entanglement of the uveal tract is probably liable, as the result of some conjunctivitis in which infective material enters the sub-epithelial tissue, to become the starting-point of sympathetic disease, no matter how long a time may have elapsed from the receipt of the original injury.

How Sympathetic Ophthalmitis may arise after the Operation of Abscission.

Eyes which if left to themselves were not likely to have started sympathetic inflammation have sometimes had the operation of abscission performed on them, and then, after complete recovery from the operation, as the result of some fresh irritation, such as that caused by the wearing of an artificial eye, have become the exciting cause of an attack of sympathetic ophthalmitis. The way in which such a course of events may be brought about is, I think, suggested by the following case.

An eye was wounded by a nail and the same day the operation of abscission was performed. Two and a half years later the stump of the eye which was left, having become irritable and painful, was excised. Pathological examination of it showed that at the abscission operation the sclera had been divided close to the corneal margin; on one side nearly all of the ciliary muscle had been left, whilst on the opposite side it had in great part been removed. The retina was detached from the choroid but remained adherent at the optic disc; some remnants of degenerated vitreous were contained between its folds. The lens was absent. Microscopical examination of the cicatrix where the two edges of the sclerotic had been brought together showed a piece of the anterior portion of the ciliary body incarcerated in it. Beneath the epithelium in the sub conjunctival tissue overlying the cicatrix was some round cell infiltration; there was also much round cell infiltration of the entangled piece of the ciliary body lying in the cicatrix. The infiltration had not, however, extended to the uveal tract within the eyeball, though it probably would have done so if the eye had been left and not enucleated. This eye might then later have excited sympathetic inflammation in its fellow. I may here remark that an entangled piece of the uveal tract may easily escape detection by clinical examination. To be sure that no entanglement is present it is necessary to examine microscopically sections taken from different portions of the whole length of a cicatrix. The above case is one in point, clinically no entanglement was noted.

A Reason why Wounds of the Ciliary Region are Specially Prone to be Followed by Sympathetic Ophthalmitis.

The ciliary region is the part of the eye in which sub-conjunctival prolapses of the uveal tract are most likely to occur. Behind the ciliary region the choroidal tissue but rarely prolapses through an opening in the sclerotic; it tends to retract away from the sides of the wound when divided. In wounds of the cornea entanglements of the iris may occur, but then the iris is not left with a vascular membrane lying over it prone to inflammation like the conjunctiva. The possibility of sub-conjunctival entanglements of the iris or ciliary body forming the track along which inflammation likely to excite sympathetic disease may enter an eye, any time after the receipt of an injury, may be one reason why wounds of the ciliary region are specially liable to be followed by this complication.

Decrease in the Amount of Sympathetic Ophthalmitis.

Ignorant as we still are as to the nature of the infective agent which causes sympathetic ophthalmitis and as to the course which it takes in travelling from one eye to the other, it is satisfactory to be able to show that at the Royal London Ophthalmic Hospital, Moorfields, of late years there has been a gradual decrease in the number of cases of this disease admitted for treatment. Thus, in the 15 years during which I have been connected with that institution (from 1884 to 1898) I find, dividing them into three quinquennial periods, that from 1884 to 1888 there were 97 cases of sympathetic ophthalmitis admitted, out of a total of 10,676 in-patients, or 0·9 per cent.; from 1889 to 1893 there were 62 cases of sympathetic ophthalmitis admitted out of a total of 10,095 in-patients, or 0·61 per cent.; and from 1894 to 1898 there were 47 cases of sympathetic ophthalmitis admitted, out of a total of 10,366 in-patients, or 0·43 per cent. This decrease in the amount of sympathetic ophthalmitis may in part be due to more thorough aseptic and antiseptic precautions. I think, however, that it is also in part attributable to the greater care which surgeons have instinctively come to take in avoiding entanglements of the iris in their operations, and in clearing accidentally inflicted wounds as much as possible of any incarcerated portions of the uveal tract.

Dangers resulting from the Prolapse of Tags of Vitreous Humour.

I have now to bring before you a specimen which exhibits another, probably not infrequent, way in which infective inflammation may gain entrance to a wounded eye, but in which the necessary conditions will not exist for any great length of time after the infliction of a wound.

A woman, aged 61 years, who had suffered from glaucoma in her left eye for four years, which had rendered it quite blind, with the hope of relieving pain had a puncture of the sclerotic performed with a Graefe's knife about the equator of the globe to the inner side of the superior rectus muscle. Ten days later the eye, being still very painful and the tension much raised, was excised. Pathological examination showed thickening and abnormal adhesion of tissue to the sclerotic between the superior and internal rectus muscles and just behind the line of their insertion. Yellow streaks were seen in the vitreous radiating from this position, where it was abnormally adherent to the retina. Microscopically, in the region of the incision a gap was seen in all three tunics of the globe passing through the anterior part of the choroid, the edges of which had become somewhat retracted, and through the retina just behind the ora serrata. Lying in the gap and protruding a little way on the external surface of the globe was a portion of the vitreous humour much infiltrated with small round cells and continuous with the rest of the vitreous in the eye, which in the neighbourhood of the wound and radiating from it was similarly infiltrated, as also were the divided edges of the retina and choroid.

There can, I think, be no doubt that in this case the prolapse of tag of the vitreous humour formed a channel along which inflammatory infection was able to travel into the interior of the eyeball. The possibility of infection gaining entrance from the conjunctival sac in this manner through a scleral puncture intentionally made can generally be guarded against by first displacing the conjunctiva in the position at which the operation is to be performed, so that when it is completed the openings in the conjunctiva and the sclera do not correspond. It shows also the importance of drawing together the edges of a scleral wound accidentally inflicted with superficial sutures.

Another surgical operation in which prolapses of tags of vitreous humour are sometimes met with is that of needling a membrane after extraction of cataract. Pieces of vitreous humour which follow the needle on its withdrawal may for days afterwards be seen as filamentous processes on the surface of the cornea. I have several times seen eyes in which such a complication has occurred become the seat of troublesome inflammation. I may add that since adopting the method of introducing the needle through the sclero-corneal margin instead of through the cornea for the discission of a membrane I have not had any prolapses of this nature.

Microscopical Appearances of Different Forms of Membranes left after Extraction of Cataracts.

The various conditions seen microscopically in membranes left after the extraction of cataracts are of considerable practical as well as pathological interest. The hyaline lens capsule left after removal of a cataract usually appears thicker than it does in the normal condition. This thickening is not due to any addition to its substance, for it is observed in eyes in which too short a time has elapsed since the removal of the lens to allow of any new growth. It is, I think, accounted for by the elastic character of the membrane, which is on the stretch and elongated when it surrounds the lens, but after its removal becomes shortened and thickened. Though there is a certain amount of shortening, it is not usually sufficient to allow of the anterior part of the capsule lying smoothly in contact with the posterior part over any large area. The anterior part is generally thrown into several folds. These folds by themselves must tend to break up rays of light and to cause some defect in vision; they are, however, nearly always associated with one of the other conditions to be mentioned directly. The microscopical examination of opaque membranes after the extraction of cataracts shows that they may be classified under the following headings: (1) retained lens substance; (2) new growth of capsule cells; and (3) adventitious fibrous tissue.

1. After the extraction of a cataract any lens substance which is left is at first exposed through the opening made in the capsule to the action of the aqueous humour, but later the opening becomes sealed up by the proliferation of the capsule cells at its margins; any lens substance thus locked up, which if not originally opaque will have become so, is shut off from the dissolving fluid. A lens, unless extracted in its capsule, is hardly ever removed so completely that some of its peripheral portions are not left which become closed up in this way It is, of course, only when portions of lens substance are retained in the pupillary area that they give rise to any disturbance of vision, and opacity due to it is seen directly after extraction or within a few days of the

operation. Lens substance retained in this way for several years will sometimes have calcareous matter deposited in it.

2. The epithelial cells lining the capsule in the region of the nucleated zone, when left after the extraction of a cataract, tend to proliferate, shift round, and then become separated from the capsule, as they do when the lens is intact. They do not, however, as they afterwards enlarge, become flattened out into lens fibres, but form large vesicular cells, sometimes oval, sometimes circular, in shape, this alteration being due to the lessened amount of pressure to which they are exposed. The cells lining the more central portions of the capsule sometimes, also, multiply and develop into the same swollen, bladder-like cells, the capsule then being raised into prominences over little groups of them. A more frequent result, however, of the proliferation of the cells lining the more central portions of the anterior capsule is the lengthening of them out into spindle shapes and into delicate fibres, which form a dense laminated tissue. It is with this sort of tissue that the opening left in the capsule after the removal of a cataract becomes sealed up, and with this sort of tissue the spaces left by the rucking of the anterior capsule most frequently become filled. This tissue exactly resembles that which is met with in anterior polar opacities, which is produced in a similar way, and like it varies in its density according to the time which has elapsed since its formation Occasionally when it has been in existence for a long time hyaline bands are met with between the laminæ. It is the formation of this sort of tissue which gives rise to the opacity causing deterioration of vision coming on some time after the extraction of a cataract, and the longer it has existed the more fibrous, dense, and tough does it tend to become; consequently the more difficult to cut or tear with a needle.

3. Adventitious fibrous tissue may form as the result of cell exudation in iritis on the front of the anterior capsule after, extraction or behind the posterior capsule about the hyaloid of the vitreous as the result of cyclitis. Sometimes a blood clot on the anterior capsule will form a sort of matrix in which fibrous tissue will develop.

In severe cases of iridocyclitis the anterior and posterior capsule may become embedded in fibrous tissue, forming a dense partition between the aqueous and vitreous chambers. It is the contraction of adventitious fibrous tissue on the surface of the anterior capsule, united to the extraction scar, that gives rise to an updrawn pupil after the removal of a cataract. I have examined microscopically an eye in which at the operation for the extraction of a cataract an opening in the lens capsule was made by grasping and tearing a piece of it away with forceps and which eleven years later was excised on account of detachment of the retina, which was thought possibly might be due to a new growth. The sections showed that about two-thirds of what may be spoken of as the anterior capsule with its lining epithelium had been removed opposite the pupillary area the posterior capsule without any lining cells alone being left. It is obvious that if a portion of the anterior capsule is removed in this way any cortical lens substance which is left cannot in the region from which the piece has been torn become re-enclosed away from the action of the dissolving aqueous humour; so that any opacity occurring after the removal of a cataract due to opaque cortical substance in which capsulotomy was thus performed would only be of temporary duration. Further, no opacity could form in the region from which the piece had been removed due to the proliferation of the cells lining the anterior capsule. Occasionally in cataractous lenses cells are met with lining the posterior capsule where normally they are absent. If these were present they would be left both when the capsule is opened with forceps and with the cystotome. Whether if left freely exposed to the aqueous humour they would be capable of proliferating and causing some opacity I am unable to say, but seeing that lens fibres, which normally develop from them, are dissolved by the aqueous humour I think it is improbable. The removal of a piece of the anterior capsule opposite the pupillary area with forceps would seem, therefore, to be a procedure likely to obviate two of the causes known to give rise to secondary opacities.

PRINTED AT THE LANCET OFFICE, 423, STRAND, W.C.