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LECTURES

ON THE

PARTS CONCERNED IN THE

OPERATIONS ON THE GLOBE,

AND ON THE

STRUCTURE OF THE RETINA,

Delivered at the Royal London Ophthalmic Hospital, Moorfields, June 1847.

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LECTURE I.

General view of the eyeball—its size, shape, and tension—Structure of the SCLEROTICA—*Implantation of the recti—thickness at different parts. Of the* CORNEA—*shape—surfaces—thickness—Is it a lens? Of the lamellated tissue—Number of superposed lamellæ—Tubular interstices—Union with sclerotica. Anterior elastic lamina—how tied down—Conjunctival epithelium—Posterior elastic lamina—Marginal plexiform tissue—The triple distribution—Circular sinus—epithelium of the aqueous humor.*

GENTLEMEN, — The benevolent founders and supporters of this hospital have ever been desirous that it should not merely minister (as it does so largely) to the relief of the poor of the metropolis and surrounding counties, but that its ample resources should be employed as means of instructing the rising generation of medical men in the very important class of diseases which are daily treated within its walls. I need not inform you particularly of the share it has had in enlarging and diffusing the knowledge of ophthalmic diseases. It will be enough that I refer, as evidence on that point, to the names of Saunders, Farre, Travers, Lawrence, and Tyrrell,—the distinguished men who, for more or less of the first forty years of its existence, were the instruments of its usefulness, and the main source of that amount of celebrity which it has acquired. Of these we can still number but one amongst our present colleagues; and I cannot mention the name of Dr. Farre without a passing acknowledgment of what this institution owes to him, and of the honour I feel it to be associated with one so venerable and respected.

It is our wish, according to our ability, to continue to make the Ophthalmic Hospital subservient to the same ends as heretofore. The number of patients considerably exceeds that at any former period, being now upwards of 7000 annually, and these afford the means of studying on a great scale the several forms of disease which attack the complex and important organ of sight.

The lectures which we offer are not intended to supersede the necessity of your observing, each one for himself, with minute and accurate attention, the realities of disease and the effects of remedies, but rather, by opening the subject, and acquainting you with the general outlines, to remove the first difficulties from your path, and to stimulate your minds with a fore-taste of the pleasure which all will certainly experience who devote themselves to the earnest pursuit of knowledge in the field before us.

In the arrangements for the present season the task has devolved upon myself of giving you some account of certain structures of the eye-ball, which are of primary consequence to the practitioner, as being those involved in the operations he will be called on to perform, and also as being the seat of several of the more common, as well as severe, morbid actions which affect the organ. That you may form some estimate of the importance of that class especially which belongs to the *cornea*, I may mention a circumstance which I remarked with concern during a visit to that noble institution the School for the Indigent Blind, in St. George's Fields. It was this — that a very large number of all the cases of total and irremediable blindness which those walls receive are the result of inflammations of the front of the eye, its transparent inlet having been darkened or destroyed by the ravages of disease, which we are *quite sure* might, in a great majority of instances, have been controlled by skilful and timely treatment. These cases occur amongst the poor—a class to whom the eye is, if possible, even more valuable than to the rich, because without it they can hardly obtain their daily bread, or enjoy the common comforts of existence, —a class, too, among whom it is probable that most of you will be called on to minister during the early years of your professiona life. More than this, I think, need not be said to impress you with the importance of the subject which is about to engage our attention.

It would be easy to expatiate on the utility of an exact knowledge of the structure of the body to one who desires to study that body in its morbid states; but I am willing to hope that such an argument would be almost superfluous; and, at any rate, (that I may not detain you any longer on introductory topics) I shall content myself with observing, that, though a man of genius has now and then become a great physician, like Hippocrates or Sydenham, by an acute and persevering observation of disease, and of the effects of remedies, and without much acquaintance with anatomy yet that the common voice of mankind proclaims that he who best knows the *mechanism* of the body will, with a like study of the other departments of medicine, be the best able to comprehend the *actions* of the body, both in health and disease.

General view of the eyeball.—The eyeball, gentlemen, as you know, consists primarily and essentially of a *sheet of nervous matters visually endowed*,—that is, capable of being so affected by light, that, when duly connected with the sensorium, what we call *sight*, or *perception of light*, is the result. This sheet, which we term the *retina*, is brought towards the surface of the body to meet its appropriate stimulus, the commissure of nervous substance which connects it to the brain and to the opposite retina being called the *optic nerve*. In front of the retina are placed *transparent media*, which, as a whole, refract the light so as to bring it to a focus on the nervous layer, which is spread out in a concave form to receive the more perfect image. The retina is supported behind by a firm resisting tunic, the *sclerotica*, which is prolonged in front of the transparent media, as a transparent integumental membrane, the *cornea*. Between the retina and the sclerotica is a very vascular membrane, of a dark brown colour, the *choroid*, which is advanced behind the cornea under the form of a vertically-hung contractile curtain, the *iris*, in the centre of which is an aperture, the *pupil*, capable, by varying its size, of regulating the quantity of light admitted to the retina. To allow of the movements of the iris, the transparent medium across which it is extended, and which fills the concavity of the cornea, is a *fluid* one, the *aqueous humor*. Behind the aqueous humor and the iris is the *crystalline lens*, the most solid and highly refracting of the media, imbedded in the front of the third humor, the *vitreous*, which itself occupies nearly four-fifths of the globe, and fills and supports the hollow of the retina. To hold the crystalline in its place, the choroid is fixed to the outer case at the junction of the sclerotica and cornea, and sends inwards a circle of folds, the *ciliary processes*, which impress and fasten themselves to the vitreous humor all round the lens.

It is unnecessary that I should speak at present, even in general terms, of the mobility of the eye, of its outer protective appendages, or of the source of its supply of blood. The limits to which I am confined oblige me to proceed at once to those points in the anatomy of the globe which more immediately concern our present object. And, first, of *the size and shape of the eyeball*.

Shape.—The human eye, when carefully separated by dissection from the muscles implanted in it, and from the surrounding fat and areolar tissue, is seen to be about spherical in shape, with this exception—that the cornea which forms the front clear part, whereby the light has access to the interior, bulges somewhat beyond the rest, is more convex, and is the segment of a smaller sphere. The sphere of the sclerotica, however, is not absolutely geometrically true in all cases, or even generally. I have found it many times slightly spheroidal, with the longer axis sometimes transverse, sometimes longitudinal; and even other and more irregular departures from the exact spherical shape occur, the lateral regions occasionally presenting trivial swellings, chiefly between the muscles, and not affecting the integrity of the organ as an optical instrument. Behind, where the retina is spread out, the sclerotica is thickest and stiffest, most completely retaining its proper curvature even after it has been cut into small pieces; and it is interesting to observe how carefully the exactness of its curvature in the posterior region has been provided for in the construction of the eye generally in the animal series: in some instances by extraordinary thickness and density of the fibrous tissue; in others by the development of very thick or highly elastic cartilage, and even bone, in its stead.

Size.—The size of the adult human eye varies within certain limits, as might have been expected. Nevertheless, as it is a part which, by reason of its complex mechanism, and the peculiarity of some of the textures it comprises, attains its complete development, like the internal ear, before most other organs of the body have reached their adult condition, these limits are very confined, if we except instances amounting to disease. Of many measurements which I have made, the general result is that the diameter of the sclerotica is from seven-eighths of an inch to an inch.

The transparent cornea forms by its anterior surface a portion of a sphere, the diameter of which is from $\frac{19}{32}$ to $\frac{21}{32}$ of an inch (that is, of usually less than two-thirds of an inch), and it often happens that the surface of the globe recedes or is depressed very superficially near the line of junction of the sclerotica and cornea. The cornea forms from one-sixth to one-seventh of the horizontal circumference of the whole globe. In considering the size of the eye, I should guard you against judging of it in any degree by the size of the aperture of the eyelids; the latter, indeed, is that which most governs the *apparent* size of the ball, and is also of much importance to the practical surgeon, as enabling him more or less readily to manipulate in his operations on parts within the lids. Moreover, the cornea is often *apparently* smaller than it really is, in consequence of a degree of opacity creeping over its border in the declining stages of life.

Tension in health and disease.—The eyeball has naturally a certain tension, arising from the due repletion of the outer case with the tissues contained within. It gives a tight or resisting feel to the finger applied upon it, and the exact degree of this tension belonging to the healthy state it is essential for you to know, both that you may be aware of the resistance your instruments will encounter, and also that you may be able rightly to appreciate by the touch the departures from the healthy standard of tension which occur in the course of several diseases. When disorganizing processes have occurred in the interior, the eyeball frequently becomes soft, although, perhaps, the finger alone can inform you of this evidence of the impaired nutrition of the organ. On the other hand, in inflammations of an acute kind attacking the globe, an unnatural hardness is perceptible on pressure, usually accompanied by that dull sickening pain which attends distension of the fibrous tissues, and due in this case, I suppose, in a great measure, to the sclerotica and cornea. The unyielding nature of these coats occasions all internal distending forces—as vascular engorgements, fibrinous or purulent effusions, if their accession has been sudden and rapid,—to react in the way of counter-pressure on the parts within, impairing their functions in the first instance, and soon irrecoverably destroying them, if allowed to continue unchecked. We have analogous phenomena in the case of other organs enveloped, like the eye, in a tunic incapable of hasty dilatation.

To proceed now to a more particular account of the sclerotica and cornea. And first of the sclerotica.

Structure of the sclerotica.—The sclerotica consists of a very dense and intricate interlacement of white fibrous tissue. The surface is dead white, not glistening, like most other examples of the tissue, by reason of the working up of its fibres in an irregular way, into a web which exhibits little indication of their course. In tendons, in fasciæ, even in the dura mater, a silvery lustre results from the parallel course of contiguous fibres; and the small creases occurring on these confer a satiny surface, which is extremely characteristic and beautiful: but this is not the case with the sclerotica. Those parts of it which are seen, as the white of the eye, have no lustre of their own: the brilliant reflection of light is rather from the moist surface of the investing conjunctiva, set off, it is true, by the opaque dead white of this tunic behind. The fibres of the sclerotica, when unravelled from one another, and examined in minute portions under a high magnifying power, do not quite resemble those of tendon and fascia: they are more straight and stiff, less wavy, less connected: they also tear and break more easily, so that you cannot run them out into such long shreds as in the case of tendon or ligament. Nevertheless, they swell out and become semi-transparent with acetic acid or the caustic alkalies, just as ordinary white fibrous tissue. You can best see the characteristic differences I have now alluded to in the posterior part of the sclerotica of the ox or sheep. This much resembles the thick coat of the air-bladder of the sturgeon, which I had once an opportunity of examining in the fresh state, and it is possible that it might even be made to yield isinglass like that structure. There is also a good deal of yellow elastic tissue intermixed with the white in the sclerotica.

But although it cannot be said that the fibres of the sclerotica are arranged with regularity, yet they appear to have a more or less determinate direction from behind forwards in the hinder and middle portion; and we may also observe on the inner surface, after the choroid has been removed, an appearance of arching fibres, having their convexities turned forwards, ; and, moreover, the anterior part usually presents a different arrangement on its outer and inner surfaces, the fibres of the former being more circular, following somewhat the border of the cornea, especially over the insertion of the recti muscles; while those of the latter are more obviously directed forwards.

With reference to this subject, I may refer to the *mode of implantation of the tendons of the recti muscles into the sclerotica.* These, as is well known, become flattened and expanded somewhat before joining the sclerotica; and I believe it is a common opinion that they join side to side, and spread out as a kind of external investment to the front of the sclerotica, advancing up to the cornea, and constituting the white tunic which is visible between the lids. I do not find, however, that this description, as regards the human eye, agrees with nature. On the contrary, the tendons of the recti appear to be truly implanted into the sclerotica, penetrating its substance, so as to be buried from view, and leaving its exterior layers exposed under the conjunctiva. I have several times traced the continuation of these tendons for a considerable way forwards in the middle substance of the sclerotica, to a certain extent making a division of it into an inner and outer layer, and gradually becoming lost to the eye, as they break up into laminæ, and blend with the neighbouring structure very near the margin of the cornea.

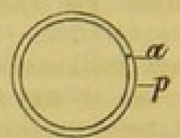
Thickness of the sclerotica at different parts.—It may not seem very important in a practical point of view to inquire into the relative thickness of the sclerotica at different parts of its extent. It is interesting, however, in a physiological sense, especially with reference to comparative anatomy, and is really not without its practical bearings, since we find the effects of certain morbid actions to be limited or otherwise modified in correspondence with it. The sclerotica is thickest behind, for the sustentation of the retina, and for the preservation of its due curvature at the most material spot. Around the foramen by which the optic nerve enters to the retina, and which is near the bottom of the eye, the sclerotica is about $\frac{1}{25}$ of an inch thick. Hence it becomes thinner forwards as far as to a quarter of an inch behind the cornea, where it is only about $\frac{1}{40}$ of an inch thick. From this line to the cornea it again increases in strength, and is from $\frac{1}{30}$ to $\frac{1}{35}$ of an inch thick, so as to be able to give greater support to some of the internal parts, which I shall have to speak of in a subsequent lecture. In the monkey I have found this front part the thickest of all.

The recti muscles being inserted as described, groove the sclerotic before entering it, and hence this membrane is rendered very thin immediately behind their insertion, hardly, in fact, being more than $\frac{1}{60}$ of an inch thick in those parts. These being, therefore, the weakest parts, are those which might be expected to yield earliest under any inward distending force; and accordingly I have observed that abscesses of the eyeball are prone to point in these situations. While upon the subject of the insertion of the recti muscles, it may be mentioned that, in cases where the contents of the globe are diminished in quantity, as a result of pre-existing inflammation of a destructive kind, and the eye consequently shrinks to a smaller size, the softness of the organ allows the recti muscles to impress it in the lines of their transit, and to bulge it in their intervals, thus pinching it, as it were, into a quadrangular shape. In such examples the thinner parts of the sclerotica under the tendons of the recti, being pressed upon by those tendons, and unsupported from within, are sunk in or flattened.

We will now turn our attention in a more particular manner to the transparent portion of the outer case, the *cornea*, a part of which it would be difficult to exaggerate the importance in reference to the operative surgery, or the pathology of the eyeball, and which can hardly fail to attract your interest in a high degree, however imperfect my description of it may prove.

I shall not stop to inquire what light comparative anatomy, or the early stages of its development, might throw on the true affinities and nature of this structure, but will merely observe that there is some reason to suppose that the cornea, considered from this point of view, comprises two orders of parts—one belonging to the nervous vesicle which forms the earliest indication of the appearance of the eye in the early embryo; the other, and the larger, pertaining to the outer integument. I prefer, on this occasion, remembering the object before us, to take the cornea as we find it in the adult human subject, and to describe it, layer by layer, as it actually exists in those in whom you will be called upon to study and relieve its morbid states.

Fig. 1.



Relative size of the two surfaces of the cornea in one instance: *a*, anterior surface; *p*, posterior surface.

The cornea is nearly circular in shape, though we often find it wider from side to side than from above downwards. Its anterior surface is generally less extensive than its posterior, sometimes considerably so. The edge, therefore, by which it is continuous with the sclerotica will be bevelled, so that the sclerotica will overlap a little. Sometimes, on looking at the surface of a vertical section of these parts at their junction, we see the cornea received as it were into a groove of the sclerotica, but even here the hinder surface of the cornea is almost invariably the more extensive; and I cannot say that I have ever seen an instance in which the bevelling was reversed, so that the cornea should overlap the sclerotica.

The two surfaces of the human cornea are, as far as I can judge, perfectly parallel to one another—that is, their corresponding points are equidistant, and the substance of the cornea is of the same thickness throughout. This has been doubted by some anatomists, who have described the central part as thicker than the margins, and have supposed that the cornea was a meniscus-convergent lens, capable of magnifying objects. But the mode employed to prove this, viz. that of first dipping the detached cornea into water to smooth its surfaces, and then, holding it over objects, finding it act as a slight magnifier, seems open to fallacy, since the only way in which it can be conveniently held is with the convex edge downwards, in which position, the water still adhering would fall to the central part, and make a lens of it. But I have failed to find the membrane magnify when secured against this source of error; and, moreover, an exact vertical section of a recent cornea exhibits an uniform thickness. When the part has been macerated it swells somewhat, and bulges less at the sides where it is tied to the sclerotica than in the rest of its extent. I need not observe that the cornea, though not itself a lens, yet acts as a powerful converger of the rays of light by virtue of the aqueous humour, which differs little from it in density, filling up its concavity in the natural state. That the cornea is not thicker in the middle is indicated by the phenomena of the disease called *conical cornea*, in which the weak or bulging part is always at or near the central region. In fishes the cornea is much thinner in the middle, to allow for the very projecting lens.

The absolute thickness of the cornea is greater than that of the anterior region of the sclerotica, being, according to the measurements I have made, from about $\frac{1}{22}$d to the $\frac{1}{32}$d of an inch. These measurements exhibit considerable variety, which it is important for the practical surgeon to be aware of.

The first portion of the cornea that comes under our review is the *cornea proper*, or the *lamellated tissue*. It is this which forms the greatest proportion of the thickness of the cornea, and gives it strength and toughness. It is bounded externally by a peculiar lamina, the *anterior elastic lamina*, on which rests the *anterior* or *conjunctival epithelium*, and it is bounded behind by another peculiar lamina, the *posterior elastic lamina*, behind which is the *epithelium of the aqueous humor*. It is the cornea proper alone which is strictly continuous with the sclerotica.

Of the cornea proper. — That the cornea proper is lamellated has long been known, and may be shown in a variety of ways. If a flap be shaped out on its surface by superficial incisions and then torn up, the surface of laceration will be nearly parallel to the outer surface, and in this way layer after layer may be removed, especially in the eyes of the larger domestic quadrupeds. The knife, too, especially if blunt, having once pierced this tissue, is found to pass most readily in a horizontal direction, at whatever depth. These are circumstances with which all should render themselves practically familiar who propose to make the living eye the subject of their operations. This physical construction of the lamellated cornea makes it desirable for the surgeon, when about to penetrate the cornea, to thrust the knife somewhat perpendicularly into it, since the arrangement of the tissue tends to carry the instrument in a horizontal course. The lamellated cornea is tough, unyielding, and almost perfectly transparent; and it is interesting to study the precise nature of its lamellæ, because there are facts which show that its transparency is very easily impaired by any derangement of their relative position, or by an increase of their natural tension. For example, if a thin vertical section of this part be made, and laid upon a slip of glass moistened with water, it remains transparent; but if you attempt to stretch it, in whatever direction, or to compress its parts into a smaller space, it instantly becomes milky and opaque. Again, if you squeeze a fresh and perfect eye between the finger and thumb, the cornea, it is well known, becomes immediately opaque in your hand, but quite recovers itself as you remit the pressure: and in all cases the degree of opacity is proportionate to the pressure you exert. This is a very remarkable experiment, and may serve to illustrate in some measure the opacity or haze of the cornea, which is apt to occur at an early stage of acute internal inflammation of the eyeball, attended with great engorgement of its vessels—a state also elucidated by what occurs in artificial injections of the eye, for when the vessels become gorged, and the globe tense and hard, the cornea invariably grows dim, and shuts off the iris from view.

Now, that the lamellæ of the lamellated cornea are not individually co-extensive with the cornea itself is easily proved by a vertical section, in which we see the lines bounding the lamellæ to be very limited and interrupted, not extending far along the cut surface; the same view proves the lamellæ to run into one another at very numerous points throughout the entire cornea, so that the interspaces are very limited in their superficial extent: though their number is correspondingly great. Moreover, in tearing up a flap in the way I have already alluded to, innumerable connexions between the lamellæ are seen to be torn through, and the surface exposed is not smooth, but covered with numberless minute lacerations of tissue. It would, therefore, be most correct to say that the strength of the tissue lies in a horizontal rather than in a vertical direction—that the horizontally-extended elements are thicker, and stronger, and less easily lacerable, than the more delicate, more fragile, vertically-placed elements which connect them with one another. Now if we endeavour to count the superposed lamellæ, it is evident that we can arrive at no very exact result, in consequence of their mutual connexions and overlappings: but nevertheless it will be found in general, that on the surface of a vertical section, somewhere about sixty intervene between any two corresponding points on the opposite surfaces of the tissue.

There is a fact of some interest to be learnt from such a section, if it be made extremely thin, and it is this:—that the connections between the horizontally-extended lamellæ of the cornea are themselves membranous or lamelliform, and not mere fibres; for on opening out the lamellæ, so as to enlarge their interspaces, very delicate membranes are seen passing from one to another, and it is but rarely that complete perforations exist, however thin the section have been made. In such specimens, viewed under a high power, we have a faintly fibrous texture apparent in even the *most delicate* of these films of membrane, the fibrous elements being held together in that form by an homogenous intervening substance.

The nature of the *interstices* of the corneal tissue does not appear to have been particularly inquired into. It has been generally considered that the interlamellar spaces are themselves flattened or lamelliform, and that they contain fluid in sufficient quantity to fall easily from one part to another ; and it has been imagined that inflammatory products, lymph or pus, might gravitate in such natural spaces to the most dependent part of the cornea. For the existence of fluid, stress has been justly laid on the fact, that if we lay bare the corneal tissue and make strong pressure on the globe, we shall observe first a dewy moisture, and then distinct drops of transparent fluid over the entire surface. But this shews the porosity of the entire cornea, rather than the existence of free fluid in its interspaces ; for in the perfectly fresh eye the dew does not form until the pressure has been kept up for some time, and under continued pressure the aqueous humour gradually passes out ; while if this humour have been previously evacuated by puncture and replaced by air, no dew forms upon the surface. Moreover, an incision into the lamellated cornea does not set free any visible fluid. It has been sometimes thought that pressure produces opacity of the cornea, by driving out fluid from its interstices, but the return of transparency is so simultaneous over the whole surface, when the pressure is remitted, as to forbid the supposition of any fluid having escaped and re-entered at the border, while the presence or absence of the aqueous humour does not affect the result at all : pressure produces opacity if the chambers are filled with air. Hence it may be concluded that the fluid existing in the corneal tissue is only sufficient to moisten its elements, not enough to lie free in its interstices : and further, that the elementary lamellæ are naturally in contact with one another, much in the same way that the filaments of the areolar tissue touch one another in other parts.

Of the corneal tubes.—Being desirous some years ago to discover whether the interstices of the cornea-proper had any regular shape or arrangement, I made a small puncture near the border of the cornea of an ox, and, introducing the mouth of a mercurial injecting tube, was delighted to find the metal, under gentle pressure, running in a beautiful and curious manner, quite unlike anything that occurs in any other tissue, and from its constancy and peculiar figure evidently demonstrative of a natural structure. The mercury coursed rapidly along in perfectly parallel and very delicate lines for a short distance, then diverged at an angle into other similar tubes, which were found to cross the former either above or below. The tubular spaces thus injected appeared to be jointed or broken at varying intervals, and to present what in the nerve-tubes would be termed a varicose condition. The whole lamellated cornea was filled with such tubes, for at whatever depth or part the mercury was inserted the same results followed ; although from the unnatural distension occasioned by even a small extent of such injection, it was impossible in a single specimen to fill the interstices of every portion of it, and at different depths, at one and the same time. These definitely-marked passages in the corneal tissue it seemed not very easy to force or burst, but when the mercury was urged to that extent it separated the horizontal lamellæ for a greater or less space, and formed irregular flat patches, very similar in shape to those which are met with in the morbid state known as *onyx*, and which latter, I therefore conclude, is attended with a breaking down of the membranous connections between the horizontal lamellæ—connections which form the side walls of the corneal tubes now described.

FIG. 2.

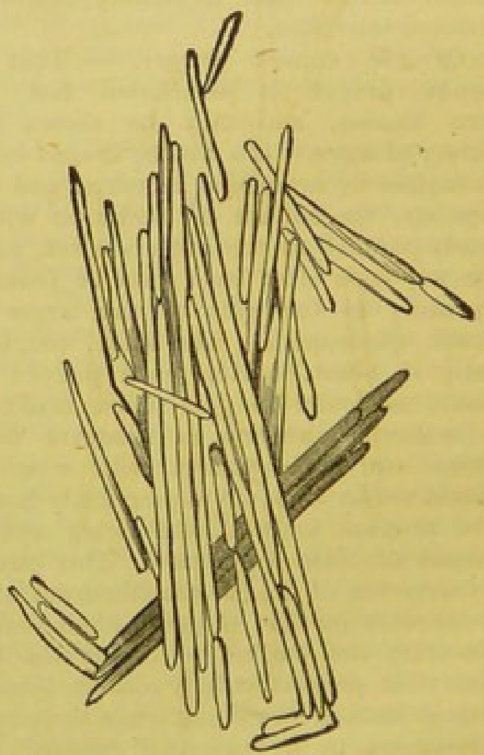


FIG. 2.—Tubes of the cornea of the ox, injected with mercury.

I found that I could inject the tubes with size and vermilion quite as definitely, though not so easily, or so as to form so beautiful an object, as with mercury ; but this fact was sufficient to prove that the peculiar varicosities of the tubes were not a false appearance due to the tendency which mercury has to collect itself into the globular form.

What I have now mentioned is what occurred with the cornea of a large quadruped. I found it far more difficult to make a similar injection of the human cornea, or of that of the cat or smaller animals, and it is not probable that interstices of equal size—perhaps hardly of the same shape and arrangement—exist in the latter specimens. From the greater thinness of the membrane, and the greater proximity of the entire tissue to the vascular arches from which its nutrient supply is drawn, it may be supposed that such a free and ample system of canals may be dispensed with. In the human cornea, however, (as in fig. 3) I have clearly seen a tubular arrangement of the interstices under favourable circumstances: although, in general, the tissue too readily gives way under the distending force which it is requisite to employ. The length of the canals between the constrictions does not exceed the 12th of an inch, and is for the most part much less, while their width is from 1-500th to 1-600th of an inch : this is in the human cornea.

Fig. 3.

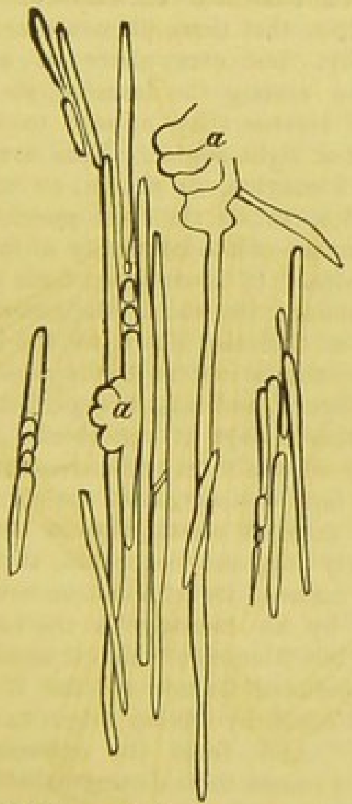


Fig. 3.—Tubes of the human cornea, injected with mercury. At *a a* extravasation has occurred.

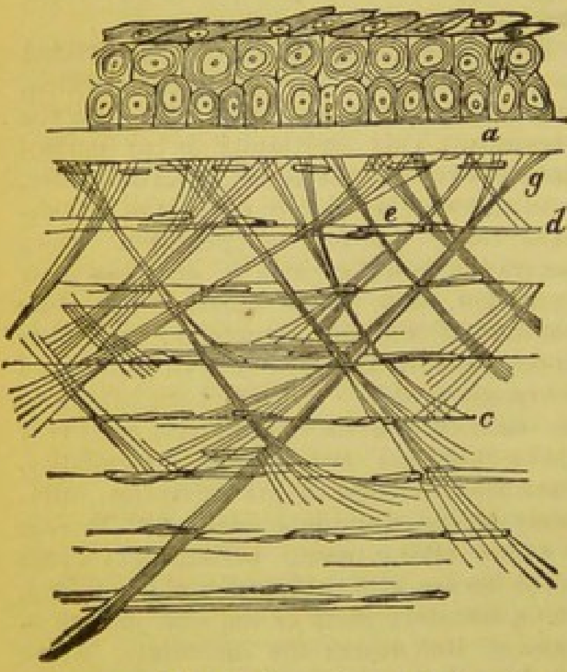
It might be conceived that these corneal tubes were a modified form of lymphatic vessels, as it is generally thought that a close lymphatic net-work may be injected in a somewhat similar fashion under the skin and in other parts. But I have not found the mercury escaping along the lymphatic trunks when pushed from the cornea towards the sclerotica. On the contrary, it requires hard pressure to make it escape from the cornea at all, and then it enters the anterior chamber of the eye, or the space between the sclerotica and choroid, or even subconjunctival blood-vessels. Hence it is probable that the corneal tubes do not communicate *directly* with any other set of vessels or natural channels.

With regard to the use of these corneal tubes, we shall probably not be far wrong in supposing that they serve to promote and facilitate the permeation of this thick non-vascular structure by those fluid portions of the blood which alone have access to it. Whether the special arrangement of the tubes which I have described is concerned in endowing the cornea with its necessary transparency, it does not seem possible to determine. It might be imagined to contribute to hold all the lamellæ in place, and to prevent derangement of their relative position. A brief account of these and other points which I shall notice is given in the third part of the Physiological Anatomy and Physiology of Man, just published by Dr. Todd and myself.

I have already stated that the lamellated tissue of the cornea is the only one which, properly speaking, is continuous with the sclerotica. This continuity is so perfect that the two textures cannot be torn asunder, or in any way be shewn capable of detachment along the line of junction. Even maceration is not capable of effecting their separation, and if we consider the close affinities of the two structures, and their mode of union, it will be easy to understand the reason of this. In fact, both belong to the class of fibrous tissues, and have very similar physical and chemical properties. The fibrous bundles of the sclerotica, intricately interlaced and intermixed with threads of yellow elastic tissue, become continuous at the border with the lamellæ of the cornea. The elementary parts of the one join on to those of the other; the interstices, which are irregular and open on all sides in the sclerotica, assume a regular arrangement, and become tubular in the cornea. On the surface of a very thin vertical section of the two structures, carried through their line of junction, the transition of one into the other can be very satisfactorily traced. By acetic acid the sclerotica swells and becomes transparent, and exhibits the yellow fibrous element of its structure, and also sparing nuclei, like those belonging to tendinous parts. By the same agent, the cornea first grows opaque as the arrangement of its parts is interfered with by the swelling of the tissue during the progress of the acid through it, but subsequently it all very nearly resumes its transparency, merely displaying here and there on the surface of its lamellæ the elongated nuclei which were previously indistinctly seen, and which correspond closely with those of the sclerotica and other fibrous tissues. The description of the lamellated cornea will be most conveniently concluded in connexion with that of the *anterior elastic lamina*, to which I shall, therefore, now direct your attention.

The *anterior elastic lamina* has not hitherto, as far as I know, been distinguished by anatomists, and yet it seems a structure of a very interesting kind, an acquaintance with which will perhaps enable us to discriminate some morbid phenomena from others with which they have been classed. It is a continuous sheet of homogeneous membrane, nearly similar in essential characters to the posterior elastic lamina of the cornea and the capsule of the lens, being perfectly transparent and glassy, without appearance of internal structure, and being very slightly or not at all influenced by acids or by boiling. Its thickness in

FIG. 4.



G. 4.—Vertical section of the human cornea near the surface. *a*, anterior elastic lamina ; *b*, conjunctival epithelium ; *c*, lamellated tissue ; *d*, intervals between the lamellæ, showing the position of the corneal tubes collapsed ; *e*, nucleus of the lamellated tissue ; *g*, fibrous cordage sent down from the anterior elastic lamina. Magnified 300 diameters.

the human eye is from about $\frac{1}{1200}$th to $\frac{1}{2000}$th of an inch, and it forms an unbroken covering to the whole laminated cornea, giving it that smooth glistening surface which is exposed by scraping off the conjunctival epithelium. This latter rests upon it as the epithelium does upon the basement membrane in other situations, and I may observe that it appears to me to be strictly a highly-developed form of the basement membrane of the mucous system, remarkably modified in this particular part to answer a special purpose. The manner in which the anterior elastic lamina is united to the lamellæ which it serves to cover is very interesting. It must be borne in mind that the anterior surface of the cornea is convex, and that the maintenance of its exact curvature is of primary importance to vision, as it is there that the first inflexion of the rays of light falling on the eye takes place: and further, that the conjunctival epithelium being a soft and fragile substance, must take the figure of the surface on which it rests : hence, probably, the arrangement I am about to mention. The anterior elastic lamina, a firm, resisting, uniform layer, placed in front of the more soft and porous lamellated tissue, is tied down to the anterior lamellæ, at innumerable points, by filaments of similar texture to itself, which it sends in among them. These, as they penetrate the lamellæ, divide and expand in such a manner as to take firm hold of them, and are thus gradually spent among the four or five lamellæ which lie nearest to the surface. It is singular, too, that these filaments are not sent vertically, but everywhere in a slanting direction among the lamellæ, so that in a vertical section they appear to cross one another at right angles. This arrangement might, I imagine, be shown, on mechanical principles, to be the best possible for the maintenance of the convexity of the front of the cornea. It is obvious, from the elaborate manner in which the anterior elastic lamina is thus tied down to the lamellated texture, that it can hardly be raised as a separate layer; and it is this, probably, which has hitherto kept it concealed. In fact, it scarcely admits of being demonstrated except on the face of a section of the cornea.

The anterior elastic lamina becomes exceedingly thin, and disappears, at the margin of the cornea, its attenuation being accompanied by an increase in the number and size of the filaments which it sends down to the lamellated tissue; so that it seems to expend itself by giving origin to these filaments. And from its extreme border, where it ceases to be distinguishable, a great abundance of them runs into the sclerotica, in that slanting direction which the elastic lamina would have itself taken if it had been prolonged in the same curve. These filaments mingle with the elements of the sclerotica, and are gradually lost among its middle fibres. The artificial mode in which the margin of the anterior elastic lamina is thus fixed, may be roughly likened to that of the awning of a tent : it is rendered much more obvious if a thin vertical section of the parts at the junction of the sclerotica and cornea be treated with acetic acid.

That this lamina, although apparently homogeneous, like a sheet of glass, is very permeable to fluids, as is the capsule of the lens, may be readily shewn by squeezing an eye after the conjunctival epithelium has been scraped off: the small drops which collect on the surface rest upon this lamina after having transuded through it.

The existence of this lamina will help, I think, to explain, what must have often puzzled surgeons, viz., the tenacity with which small particles of steel, or other sharp angular fragments, stick in the front of the cornea only just within the surface. These will often remain for many days, or even weeks, and prove the cause of much inflammation, and yet still be found difficult of extraction; which could hardly be the case if the lamellated tissue and the conjunctival epithelium were the only textures in which such particles could be imbedded.

The *conjunctival epithelium* of the cornea may be now conveniently adverted to: it is that delicate, soft, almost pulpy layer, which forms the anterior surface of the cornea, and is so easily raised by the knife or needle. It is a continuation of the epithelium of the conjunctiva covering the front of the sclerotica and lining the lids, and consequently of the cuticular investment of the body It is a familiar fact, that in animals which cast their entire skin periodically, this layer is detached with the rest of the epidermis.

In those animals which lose and renew the cuticle, by a constant process, unmarked by periods of intermission, the superficial particles are gradually shed after arriving at their mature state, while others are as gradually originated in the deepest region, on the tissue which serves as a basis of support, and near which lies the source of their nutriment. This is precisely what occurs on the outer surface of the cornea in the human eye. The epithelial particles are exceedingly transparent, but in position, form, and mode of growth and decay, they bear a close resemblance to the epidermis. In different animals the number of epithelial layers varies according to the size of the eye; in man, they constitute only a triple or quadruple series, altogether not exceeding the $\frac{1}{500}$ of an inch in thickness. The deepest, which rest on the anterior elastic lamina as on a basement membrane, are slightly elongated vertically, and stand endwise; the next are angular, or subglobular in shape, and the most superficial are flattened scales, more or less overlapping one another, and of a darker hue than the others when seen by transmitted light. The imbricated scales of the surface have their minute inequalities filled up in the natural state by the watery secretion of the lacrymal gland, so as to present a nearly smooth refracting surface to the impinging rays of light; and by the frequent movements of the eyelids, the particles which are decaying and losing their place are brushed away and escape by the nose. In a learned and interesting paper by Dr. Mackenzie,* you will find described a method of seeing in your own person the nature of the corneal surface. This epithelium is rapidly renewed, if scraped off.

We may now, gentlemen, turn our attention to the *posterior elastic lamina of the cornea*, a layer which has been long known as the membrane of Demours or of Decemet, or as the elastic lamina of the cornea, or as the corneal part of the membrane of the aqueous humour.

This layer is very easily detached by scraping from the hinder surface of the lamellated tissue of the cornea, for it adheres but slightly to this tissue, and sends no filaments among the lamellæ as the anterior elastic lamina does. It is a uniform, transparent, homogeneous layer, considerably thinner than the anterior elastic lamina, (being only from $\frac{1}{2000}$ to $\frac{1}{3000}$ inch thick) but like it not affected by maceration, by boiling, or by the action of acids. Though very hard, and capable of resisting much pressure, and giving a crisp sound when divided by the scissors, yet it is very brittle and easily torn, and its fragments then show a remarkable tendency to curl up on all sides into rolls, and always with the anterior or naturally convex and attached surface inwards in the roll, so that it would appear to be formed or laid down *in situ* in a shape precisely the reverse of that which its elasticity inclines it to assume.

When an ulcer has destroyed the lamellated tissue, it sometimes happens that, for a short time, the posterior elastic lamina is thrown forwards into the breach, by the pressure of the aqueous humour behind it, and forms there a small pellucid vesicle, which soon, however, gives way by rupture, allowing the humour to escape, and the iris to fall forwards against the opening. This morbid state illustrates very well the properties of the layer now under consideration.

With regard to the behaviour of this posterior elastic lamina at the margin of the cornea, much difference of opinion—I might say, much uncertainty—prevails: some holding that it is reflected in a modified form over the whole of the anterior and posterior chambers of the eye, others believing it to terminate with the cornea; but none, as far as I am aware, having given a full and accurate account of its actual condition, which is one of considerable impor-

* On the Vision of Objects of and in the Eye. Ed. Medical and Surgical Journal, No. 164.

tance to a correct knowledge of the physiology of the organ, and to the understanding of several of its diseases.

Marginal plexiform tissue of this lamina.—This layer, then, will be found to terminate at the border of the cornea in the form of plexiform fibres of the yellow elastic kind, or that variety which is allied to itself in essential characters. In this respect it resembles the *anterior* elastic lamina. The plexiform fibres spring only from its anterior surface, or that towards the lamellated cornea. They begin to appear a very short distance from its edge, and as they arise the lamina itself becomes thinner, and is at last altogether spent. They all pass irregularly outwards, occupying, of course, a position between the posterior elastic lamina and the lamellated cornea; and are finally reinforced by those fibres which come from the thin and extreme edge of the lamina. Immediately beyond this edge, therefore, at the rim of the anterior chamber, there is a layer of open flexiform fibres, passing outward, or from the axis of the eye, and being the continuation or representative of the posterior elastic lamina. The posterior of these fibres then curve backwards to the iris, and become inserted into its anterior surface at its greater circumerence in the form of small pillars; and near their insertion begin to resemble the white fibrous rather than the yellow fibrous tissue in chemical and other qualities. I have found these pillars of the iris much more evident in some animals than in others, but time will not allow me to enter on comparative details. They exist in all mammalia, and have their analogues in other classes. They are in contact with the aqueous humour, where they form the rim of the anterior chamber. A needle may be passed underneath them from the anterior chamber so as to suspend by them a considerable fragment of the eyeball. The great portion, however, of the fibrous continuation of the posterior elastic lamina goes not to the iris but to the ciliary circle,—a name by which anatomists refer to a flattish circle of gray semi-transparent tissue, which intervenes between the ciliary processes of the choroid and the sclerotica, immediately behind its junction with the cornea, about which extraordinary differences of opinion prevail, but which I shall hope to show you in a subsequent lecture is muscular. For convenience, therefore, I will now assume that it is such, and term it the ciliary muscle. This muscle arises, then, from the fibrous tissue coming from the posterior elastic lamina, — the fibrous tissue passing in a sheet backwards to the anterior region of the ciliary processes, and giving origin on its outer surface, or that turned from the anterior chamber, to the fibres of the ciliary muscle, which then clothe the outer surface of the choroid for about one-eighth or one-tenth of an inch, as far as the ora serrata.

There are still other fibres derived from the posterior elastic lamina—viz those placed most anteriorly, and which were the first to take origin from it. These, after a short course outwards, become separated from the sclerotica by a narrow space all round, known as the *sinus circularis iridis*, and which has been considered as a venous canal; afterwards they pass to be united firmly to the sclerotica beyond this sinus, and in so doing share principally in its formation. But there also exists here a series of *circular* fibres, those just described being more or less radiating; the circular lie outside the others, are opaque, white, and stiff, contributing to the formation of the circular sinus, and to that firm union, the *ciliary ligament*, which subsists between the ciliary processes and the anterior rim of the sclerotica: and which, as a whole, effectually serves to retain the aqueous humour from escaping into the space between the sclerotica and choroid.

I am aware of the difficulty I must experience in attempting to give you a clear description of this structure, before I have passed in review those others with which it is associated. What I have now said, however, must suffice for the present, and I shall return to it in connection with the iris and choroid and lens. A few words remain concerning the *posterior epithelium of the cornea*, or the *epithelium of the aqueous humour*.

This is so extremely delicate and so perishable a layer, that it has only of late years been recognised, and yet it is very easily prepared for examination. It is a single series of flat epithelial nucleated particles, placed side by side, and united by their margins. Even in large animals the epithelial cells are not in a double layer. It is co-extensive with the posterior elastic lamina, which it separates from the aqueous humour. It would appear, however, from what has just been said concerning the conversion of the posterior elastic lamina at its border into fibrous tissue which in part passes through the aqueous humour to the iris, that this epithelium must cease with the elastic lamina, since there is no longer any stratum on which it can rest. I have not been able to discover the smallest appearance of it upon the pillars of the iris, and I conceive, therefore, that it is limited to the cornea.

I have called this the epithelium of the aqueous humour, because it is the only true epithelium which can be found in contact with that fluid. I shall have to show in a future lecture that the front of the iris has no true epithelial investment, and that the front of the lens is also destitute of such a covering. It seems, therefore, incorrect to speak of the chambers of the eye as lined by a serous membrane, or of the aqueous humour as contained within a proper capsule; and I suppose that practitioners must abandon the *name*, at least, of that affection, which is now generally termed *aquo-capsulitis*, even if they continue to regard it as a distinct disease.

In my next lecture I shall proceed to notice some of the morbid states of the sclerotica and cornea; and shall endeavour to connect my remarks as far as I can with the anatomical, and, I fear, rather dry details, which I have had to dwell upon to-day.

Lecture II.

Blood-vessels and nerves of the sclerotica and cornea—character of the nutritive process in these structures.—Morbid states of the sclerotica and cornea.—Sloughing of both corneæ from defective nutrition.—Reparative process in the cornea—anatomy of a simple ulcer of the cornea—formation of vessels in the cornea—effect of general disease on the cornea.—Lymph or pus in the lamellated tissue.—Pustules.—Opacities of the cornea—development of papillæ on the cornea—anatomy of Staphyloma corneæ.

Gentlemen,—In my last lecture I reviewed the structure of the outer tunic of the eyeball, consisting of the sclerotica and cornea, and described the several layers of which the latter is composed. It remains for me, before proceeding to the more internal parts, to make some observations on the nature of the process of nutrition, as it obtains in these structures, and on the bearing of their anatomical construction on the nature and progress of some of their more important diseases.

Both the sclerotica and the cornea are sparingly supplied with the materials of nutrition, as a glance at the arrangement of the blood-vessels will show. The sclerotica is pierced behind with numerous arteries derived from the ophthalmic, termed the *posterior ciliary*; but these go almost exclusively to the choroid, only giving a few minute twigs to the sclerotica as they pass. In front, too, the arteries which have supplied the muscles of the eyeball, send forwards small prolongations beyond the tendons, which are visible under the conjunctiva, and lose themselves in the sclerotica, about one-eighth of an inch from the margin of the cornea. These, however, traverse rather than supply the sclerotica, and anastomose with vessels of the ciliary muscle and iris. Hence, in the most successful injections, the sclerotica itself is with difficulty tinted by the artificial colour, and the microscopic inspection of parts so prepared, exhibits only a few slender capillaries coursing among the greatly preponderating mass of the white fibrous tissue. And if we pass from the sclerotica to the cornea, we shall find the most unequivocal proof that no blood-vessels at all encroach far beyond its border. The evidence which injections are capable of affording on this head is very decisive. We now know that the capillaries are, in almost every organ, definite and determinate tissues, having proper walls, which may be distinguished from the parts among which they lie; that they have a certain limit as regards minuteness, and that they form everywhere a closed system of tubes, porous, indeed, so as to be capable of transmitting fluid materials, both inwards and outwards, by a process of imbibition, but nevertheless having walls of unbroken membrane, without breach or orifice. Hence if an injected specimen exhibits a system of such canals, replete with artificial coloured contents—its ramifications regular, having margins formed by rounded, arched, entire capillaries—we may assert positively that the vascular net-work terminates naturally in those directions, and that the tissue beyond has been as impermeable to the red particles of the circulating blood as we find it to be to our prepared fluids. This is precisely what occurs in the case of the cornea. The vessels of the sclerotica, and of the conjunctiva covering the sclerotica, send numerous twigs towards the cornea; but all, on arriving within the corneal tissue, turn back, forming numerous arches, which run parallel to the margin of the cornea for some way, and then return from whence they came. Thus we have a striking difference between the sclerotica and cornea in addition to those before insisted on—that the one is permeated by blood-vessels, the other is entirely devoid of them.

I may say a few words here on the *nervous supply of the two structures*. No doubt the nerves of both are few; the sclerotica gives passage to the ciliary nerves, and although they have not been demonstrated, it is possible that it receives some filaments from them. In a state of health it seems to be very insensible, but when inflamed, like many other dull and almost insensible parts, it appears to be capable of becoming the seat of very acute pain. In the cornea, nerves derived from the ciliary are said to have been discovered by more than one anatomist of trust; I cannot say that I have myself seen them, although I cannot doubt their existence; for when we remember that nerves in their peripheral distribution may lose their tubular nature and their characteristic microscopic appearance thence derived, (and I have constantly found the ciliary nerves do this,) we may well be content to receive *pain* as sufficient evidence that a part is not destitute of nerves. That the cornea has a degree of sensibility capable under some forms of irritation of being exalted to a considerable height, is matter of common experience to every one.

From what has been said, it may be safely concluded that the sclerotica and cornea are slowly renewed in their elementary constitution by the process of nutrition. No doubt the presence in or near them of the materials of change is absolutely necessary for the continuance of their life; but what I would endeavour to impress upon your minds is this—that their structure is feebly supplied with blood, or the nutrient part of that fluid—that the process of nutrition in them is therefore slow, gradual, and easily impaired, either by impoverishment of the nutrient material or by any mechanical interference with its due and regular supply. These observations apply more to the cornea than to the sclerotica, because the latter has vessels, the former has none; the latter, therefore, is supplied interstitially, as it were, with the power of life, growth, and nutrition; the latter must derive through the medium of its circumferential parts whatever is requisite to sustain the integrity of its more central portion.

Morbid states of the sclerotica.—I shall have but few observations to make, gentlemen, on the morbid states of the sclerotica, in their special relation to its structure: wounds of this part readily heal by the adhesive process, the cicatrix being semitransparent as in tendon; and minute punctures are generally harmless, even when they penetrate not only this coat but the choroid. It is possible that the readiness with which lacerations and incisions of the sclerotica heal, is ascribable to the thinness of the tissue, and to the fact that it has on both its surfaces an abundant supply of blood in the contiguous textures. The experience which surgeons have acquired in their operations on cataractous eyes, affords ample proof of the slight tendency which simple wounds of the sclerotica have to take on an unhealthy action. The form of inflammation which the sclerotica usually undergoes is the rheumatic: into the nature and symptoms of this it would be out of place to enter, as we must limit ourselves at present to the anatomical conditions.

In inflammation of the sclerotica, when least complicated with conjunctival disease, its vessels are seen to be unnaturally filled with blood; its capillaries are distended, so as to become visible by imparting a tint to the fibrous tissue, and the minute arteries and veins enlarge and become tortuous. All these are distinguished by their purplish hue, compared with the more superficial vessels of the conjunctiva under inflammation.

In some delicate persons the sclerotica is so thin in its anterior part as to derive a bluish tint from the choroid underneath. This is no disease, but in cases of old-standing choroidal or other disease within the globe, which has operated so as to cause a slow and gradual distension of the outer coat, the pigment is in like manner disclosed under the bulging and attenuated sclerotica; and I have observed in some cases that under this internal stretching force the sclerotica is apt to yield in lines passing backwards from the cornea, so as to form slits or chinks more or less radiating, through which the choroid is more obviously seen. This depends on the disposition of the fibres of the sclerotica, which I alluded to in the last lecture, viz. their passing at the anterior region rather in a radiating direction from the cornea than in any other arrangement.

Morbid states of the cornea.—To the surgeon as to the anatomist, the cornea is a much more interesting and important texture than the sclerotica, and I therefore propose to be a little less brief in commenting on some of its principal morbid states, especially such as either illustrate, or are illustrated by its structure, as explained in the former lecture.

And first, gentlemen, in evidence of the comparative feebleness of the process of nutrition in this texture, I shall relate the following case which occurred at this hospital during the present spring.

Sloughing of both corneæ from defective nutrition.—On the 8th March, a mother, herself reduced in strength and looking ill, brought her infant, 13 months old, to the hospital, on account of its eyes. I found that both corneæ were in a state of slough, flaccid, of a pale yellow, like macerated leather; that this slough comprised the whole area, except a very narrow belt of about 1-20th inch nearest to the sclerotica, from which a few minute vessels were shooting towards the line of separation which was already beginning to be established between the dead and the living parts. The conjunctiva exhibited very little vascularity, and had evidently not been suffering from inflammation. The infant was pallid and puny, with a pinched and anxious countenance. I found that the mother had been suckling the child till seven weeks from the time I speak of, being herself ill and weak, and very insufficiently nourished;

that on going into the workhouse they had been parted, and that she first noticed the eyes to look "weak" three weeks since. The bowels have been constantly purged for eight days; and she has taken Rhubarb and Magnesia. The compound powder of chalk, with opium, was given every four hours, with Liq. Cinch. of Battley, and beef-tea, with small quantities of brandy, and Mr. Howard kindly undertook to visit her at her own home. On the 11th (three days afterwards), I found more evidence of vascularity at the margin of the corneæ, and over the white of the eye, but with hardly any secretion. The bowels had been less relaxed, but the stools still green and loose. She had taken some wine and bark, but would not touch the beef-tea. She was evidently weaker, and moaned constantly. In two days afterwards she died.

In this instance we find the cornea falling into a state of gangrene from defective nutrition; the impoverishment of the blood, manifested in various degrees in the other textures of the body, here leading to the complete destruction of a tissue which naturally has a very small supply of that necessary fluid, and which therefore is but too ready to yield its vitality when that supply is withheld. The case of this poor child finds a parallel in others which have been related, as occurring from actual starvation, or the privation of all sustenance, and perhaps still more aptly in those animals which Magendie confined to a diet of sugar and water, or other non-azotised food, and of which one of the more constant evidences of declining power was the sloughing of the corneæ, and the consequent destruction of the eyeballs. I may also mention the case of a woman who is now in attendance here, and who, on her first appearance some months ago, had a dull, hazy state of both corneæ; the surface having lost its brilliancy, and the whole texture being very uniformly obscured. The approach of this condition had been very gradual. It had been attended with no redness, nor was there, at that time, any excitement of the circulation in the neighbouring sclerotica or conjunctiva, or any development of new vessels in the cornea itself. She was pallid, but her muscular strength was not remarkably reduced, nor could I discover that she had been insufficiently fed in regard either to quantity or quality, or that she had any disease affecting a vital organ. Nevertheless, her pulse and countenance bespoke a system in which the powers of life, from some cause or other, were considerably depressed, and Mr. Dixon concurred with me in recommending a strictly tonic course of treatment, comprising steel and quinine, with such modifications in diet, place of abode, and mode of life, as her situation appeared to render desirable. Under this plan, which has been continued up to the present time, a steady improvement has taken place in the condition of the corneæ. The haze is clearing away in the most gradual manner, and without any unnatural vascularity of the part or neighbourhood, and her looks are much improved in every respect. I cannot help regarding this affection as simply the result of an impairment of the nutritive process in the whole body showing itself in a special manner in this texture of feeble power.

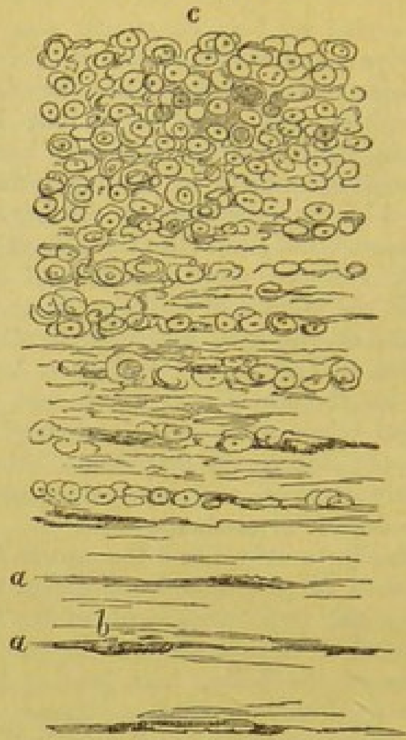
Reparative process in the cornea.—The cornea when healthy is readily repaired after injury; punctures and incisions being followed in general by speedy reunion of the divided parts, without suppuration or sloughing. The adhesive process is here presented to us in its simplest form, for it takes place in a structure which contains no blood-vessels, and therefore where none have been divided. But if we bear in mind that all tissues have a proper life of their own, of which their several properties and actions are the necessary manifestations, and that the blood-vessels are but ministerial to the proper life of the tissues they supply, by serving as the medium through which the materials essential to life are brought within their reach, and what is rejected by them is carried away, we shall readily understand how it is that a tissue which, like the cornea, orginally grew, and has its ordinary life sustained without the presence of interstitial vessels, may be also repaired and renewed without them within certain limits. For the reparative actions, in their natural form, are nothing more than those of growth and nutrition, modified by the new conditions occasioned by external accident, and tending constantly to a removal of those new conditions, and the restoration of the normal state.

If we puncture or incise the cornea the first effect is a change wrought in the natural actions of nutrition then existing in the wounded part,—a change which can only be described as a mechanical interruption to those actions, and which, from the resultant train of phenomena, has been often called a stimulus. This is speedily followed by the presence of an increased quantity of blood in the vessels that are nearest to the wounded part, viz. in those of the conjunctiva and those of the sclerotica, and thus the materials from which the breach is to be made good are brought in greater abundance to the part that requires them. We cannot doubt that as these vessels, comparatively so remote, are thus affected, so the part of the corneal tissue intervening between them, and the exact seat of injury, is pervaded by a corresponding change, of which the general expression is this,—that it is one of exalted nutritive vigour; the play of forces, and the interchange of material which mark the nutritive function, being more energetic and more rapid than before. And whatever phenomena of this kind occur in the intermediate tissue are concentrated in an especial manner about the wound itself. In a short time, even in the course of a few hours, as I have ascertained in the case of the lower animals, the vicinity of the injured part begins to contain in abundance those minute particles, nuclei, or cytoblasts, as they are called, which exist naturally, though sparingly, in the corneal lamellæ, and the relative quantity of which may be regarded in most tissues as an index of the intensity of the nutritive function. These particles, I say, hastily, indeed, and imperfectly formed, are speedily found choking the interstices of the tissues in the lips of the wound, and covering its surface, so as to occupy whatever space was left between its opposite sides, and bringing them into temporary union. From the presence of these embryo materials of new tissue, intermingled among the elements of the old, is derived that slight milky opacity which envelopes and marks the seat of wound, and which, if the injury be extensive, may engage a considerable extent of the cornea in the direction of the neighbouring blood-vessels. The subsequent changes I need not particularly dwell upon. The breach being filled, the new material is gradually transformed into products, resembling those tissues among which it has been poured; the blood-vessels, at the border of the cornea, resume their size, and at length, in the most favourable instances, all vestige of the wonderful process which has taken place vanishes away.

Such is the progress of the actions which usually ensue when the surgeon punctures the cornea with his needle for the purpose of operating on a cataract, and the same takes place, in general, where there is no destruction of substance, and where the wound is not too large, and its margins have been accurately adapted. But it will readily be conceived that, in cases of wounds with loss of substance, or attended with extensive division of parts, the demands on a tissue so feebly nourished must exceed its limited powers. The result will then oftentimes be the failure of the adhesive process, with the establishment of a temporary ulcer or open breach, or with an actual sloughing of the lips of the wound. The reparative actions then advance more slowly, and in a modified form, by a species of granulation very similar to that which obtains in corresponding states of the skin or mucous membrane.

Fig. 5.

Free surface.



Vertical section of a minute ulcer on the surface of the cornea of a cat, three days after the application of caustic potass. *a*, *a*, indicate the position of the corneal tubes in the sound tissue below the bed of the ulcer; *b*, nucleus of the lamellated tissue. The surface of the ulcer is seen formed by a crowd of vesicular nuclei, most of them with a nucleolus. These were in various stages, and mingled with firmly granular matter. Magn. 300 diameters.

I had an opportunity last year of examining a small ulcer which had been occasioned on the centre of the cornea of a cat, by the contact of a small piece of caustic potash, three days previously. The conjunctival epithelium and the anterior elastic lamina had been removed, and the superficial lamellæ of the cornea proper formed the bed of the ulcer. These were softened and semi-opaque, from the presence of great numbers of the nuclei already alluded to, in and around; and it was interesting to observe that their numbers were greatest on the surface of the ulcer and diminished in proportion to their distance from it. In the section of the ulcer, represented in fig. 5, the nuclei are seen occupying chiefly the position of the corneal tubes, especially in the deeper part. We have in this example, perhaps, the simplest condition of an ulcer that can occur in any texture, and it is therefore well deserving your attention.

Development of vessels in the cornea.—Few things are more interesting in the history of reparative processes in the cornea, than the fact which we observe every day, of its capacity of becoming furnished with blood-vessels derived from those of the conjunctiva and sclerotica. If any irritation is long kept up, or if an ulcer exists having to heal by a slow and gradual process, we find in the interval between it and the neighbouring vessels, a greyish, half-transparent tract, distinguishable from the healthy cornea; and in this there are soon developed a series of vessels which presently declare themselves as arteries, capillaries, and veins, carrying the blood in a circuit through and about the seat of reparative action. It is obvious that these are produced out of new matter, laid down before their actual formation in the line which they are to occupy. As a punctured wound is made good by the simple transformation of the new matter into the natural tissue, without the formation of new vessels, so, when time allows, and the extent of repair requires it, a portion of the new material is developed into vessels, which may serve the temporary purpose of expediting and fortifying the reparative actions, by bringing to them an immediate and interstitial supply of blood. Thus is the cornea made dull and useless for a time, by the introduction of a structure destructive of its transparency, in order that its integrity may be restored according to the natural laws of growth. When its restoration is somewhat advanced, and less blood is required, these new vessels dwindle; their coats, which are at best imperfectly organised, soon disappear, and the cornea becomes once more permeable to light. I have a specimen in which these adventitious vessels are displayed injected with artificial colour. They pass into the cornea from the conjunctiva, and from the whole thickness of the sclerotica, and occupy, in this particular instance, almost the whole thickness of the lamellated tissue.

The cornea may further become vascular without ulcer or wound, and as a result of continued inflammatory action, and this in two principal ways: either the new vessels may form a network on the front of the cornea, anastomosing on all sides with those of the conjunctiva, and only obscuring the lustre of its surface, or they may pass in very close and more parallel series from the sclerotica, so as to make the cornea uniformly of a dull red. The former state is the result of long-continued irritation of the conjunctival epithelium by granular lids or displaced lashes, and the vessels in all probability lie immediately beneath the anterior elastic lamina in the more superficial lamellæ of the cornea proper; but I have never had an opportunity of actually ascertaining this. They can hardly lie over it, and it is too thin to contain them in its substance. The latter condition results from chronic inflammation of the lamellated tissue, and is attended with an opaque deposition of new matter. The vessels run in among the lamellæ, and may occupy the entire thickness of the cornea proper, rendering it nearly impervious to light. In both the forms of morbid vascularity now mentioned, the vessels are to be regarded as originally a result of diseased action, not as themselves the disease. They are developed under the salutary or conservative law of the organism, to enable a part of feeble vitality to sustain a morbid action to which it has become subject, and under which its vitality would otherwise sink. It is true that their presence marks the existence of disease, and is to a certain degree an index of its extent, but we must be on our guard against imagining that it constitutes its essence. Unless these vessels had been developed, the diseased process would long ago have terminated by the total destruction of the tissue. If, in the case of the impoverished infant which I related just now, there had been sufficient vigour in the nutritive and organising process to fill the corneal tissue with offshoots from the surrounding vessels, the eyes might not have perished.

The cornea, and other parts of low vitality, or of such a texture as cannot speedily develope new vessels, often fall into gangrene under any sudden inflammation, because their vascular supply is either very limited, or cannot expand in correspondence with the demands of the morbid action. On the other hand, practical surgeons know that it is very difficult to induce destructive inflammation in erectile tumors, which are distinguished by the abundance of their vascular supply.

We may even go further, and maintain that these adventitious vessels are necessary to a cure, and to their own removal, which may seem a paradox, but is nevertheless a very sustainable proposition. For as the morbid products (including the vessels) laid down in the cornea, require for their existence a certain accession of new material, in the way of continuous nutrition, so they cannot be removed unless means are found for the absorption and removal of the old material of which they are composed, and these means are mainly the vascular channels. As long as the material capable of being removed remains, the vessels remain also, though gradually, atrophied, and ready to disappear; and sometimes when the morbid products have been so long laid down as to have become organised into permanent forms of morbid and opaque tissue, the vessels, in reduced number, are found to remain, as being necessary for the existence of that which cannot now be taken away by any interstitial process of absorption, and which must therefore be either nourished or die.

The unity which reigns throughout an organised body of so much complexity as our own, renders every part liable to be influenced by the state of the great organs subservient to nutrition; the digestive which provide, the respiratory which renovate, the circulating which distribute, and the excretory which purify, the blood. The nutrition of every organ or tissue is subject to derangement, when the blood from which it derives its materials of renewal is impoverished or altered in quality, or when that healthy balance of the circulation is lost, to which Dr. Farre called your attention a short time ago.

It is not to be thought, therefore, that the morbid phenomena of any of the textures of the eye, or of the body at large, can be rightly comprehended by one who never has regard to the condition of what is termed "the *general health*," and, least of all, those of a texture like the cornea, which, being itself bloodless, and deriving its supply of nutriment by a frail tenure from surrounding parts, must necessarily be obnoxious in a peculiar degree to certain of those disturbances which another more favoured part might have sufficient vigour of life to disregard or overcome. It would be very easyto enlarge on so fertile a theme; but I must dismiss it with this simple allusion, or itwould lead us too far from the proper subject of these lectures. It is perhaps of even greater importance still that these views should influence our minds in considering the propriety of an operation for cataract in any particular case, and especially of that of extraction, which involves an extensive division of the corneal tissue, and to the success of which, reparation of the wound, by the first intention, is absolutely essential.

Lymph or pus in the lamellated tissue.—As a result of inflammation of the lamellated tissue, lymph or pus may be formed in the interstices of the lamellæ, attended, in the first instance, with irregular haze, and then with mottled or patchy opacity, as it accumulates in greater abundance in certain situations. If the inflammation be of an acute kind, and the effusion rapid, so as to gorge and distend and press upon the lamellæ too much before their supply of blood can be suitably augmented by newly-organised vessels, and especially if the system be at the same time in an enfeebled state from defective nourishment, or the scrofulous diathesis, the lamellæ become irregularly separated from one another, their tissue is broken up and destroyed, and a slough results which is usually of a flattish form, often engaging a considerable area of the cornea, but not its entire thickness, *i. e.* following the direction of the lamellæ; or a simple abscess may form, which may discharge itself either backwards into the aqueous chambers, or on the external surface of the cornea. In either case it very commonly happens that the remaining part of the thickness of the cornea gives way, making a complete perforation, through which the aqueous humour escapes, and the iris prolapses. The injury done to the eye by such extensive disease is severe and permanent; a portion of the cornea has its place supplied by new matter, which becomes developed into an opaque tissue very different in constitution and elementary arrangement from that which has been removed, and the pupil is more or less distorted or dragged away from the axis of vision.

If, however, the inflammation of the lamellated tissue be less acute, and less disposed to run rapidly to destructive results, the lymph which is poured out collects in small portions among the lamellæ, giving an irregularly mottled aspect to the cornea, because some parts retain more of their transparency than the rest, though all are dim; and vessels are gradually formed in the corneal tissue, entering it at various depths from the neighbouring sclerotica. When this occurs, the sclerotica itself, for a short distance from the cornea, appears of a dull red, owing to the augmented quantity of blood passing through its vessels to supply this new demand. If the disposition to the formation of lymph in the corneal tissue continues, the enlargement of its vascular supply tends to accelerate the subsequent changes, the whole tissue gets interfused with opaque matter and additional vessels, and the original lamellated structure becomes thickened, softened, and obscured. After so delicate and important a part has been apparently spoiled by a serious disease, it is not a little interesting to notice how completely and how speedily, in many instances, its perfect transparency may be restored by timely and judicious treatment. For in such cases you will observe that the original tissue of the cornea is not in any measure destroyed, or its arrangement permanently altered, unless the duration of the morbid state have been considerable, and time have been thus afforded for the organization of permanent forms of unnatural tissue in its interstices. Moreover, when once the inflammatory action and the inclination to the formation of morbid products have been subdued, the blood-vessels which pervade the deteriorated structure begin to assist largely in its restoration, by expediting the absorption and removal of the newly-deposited lymph; and in proportion as this clearance is effected the vessels themselves diminish in size, and finally disappear. The speed and completeness with which the cornea resumes its previous state will depend much on the promptness with which the treatment is undertaken, and the energy of the nutritive function in the part and in the whole body. In scrofulous subjects, who are especially prone to this affection, it is notorious that there exists in the constitution a grave and deep-seated defect, which manifests itself chiefly in imperfect or perverted nutrition; and until this is in some degree corrected, this disease can hardly be checked, or its consequences got rid of.

The cornea evinces its near alliance with the integumental tissues, by its disposition to the formation of small pimples, or *phlyctenulæ*, on its anterior surface. These, too, are most common in young strumous subjects: they are generally situated at or near the margin, and appear on the conjunctiva at the same time. They are slow in their progress, and ere they have reached their full size are generally provided with a leash of conjunctival vessels, which give a characteristic appearance to the eye. They are formed on the *front* of the cornea, and, I should suppose, immediately under the anterior elastic lamina, and the vessels they acquire also, of course, lie under that lamina, and come from the sub-conjunctival tissue. These pimples may contain a minute quantity of lymph, which may become organised into a raised vascular tubercle, or they may advance into the pustular stage, and form ulcers by opening on the surface, with a destruction of the anterior elastic lamina and the conjunctival epithelium. An opacity remains after they are healed, which is usually proportionate to the previous depth of the ulcer; but it is gradually lessened with the growth of the little patient, and often altogether disappears. Occasionally such an ulcer will heal with a depressed but nearly transparent surface, leaving a mark only apparent to others in certain positions of the eye, when the light is reflected from the part; but for the same reason painfully obvious to the patient himself (if it happen to be situated near the pupil) by the distortion of objects which it occasions.

I shall now, gentlemen, say a few words concerning *opacities of the cornea*, such as are commonly left by a variety of causes in different portions of the corneal tissue, and shall endeavour to explain their nature and seat according to the particular tissue they affect.

We have already seen that the proper laminated tissue is capable of enlarging its vascular resources for its support under disease, and for the subsequent removal of diseased products, to such an extent that if it have itself escaped disorganization, it is able, under favourable circumstances, to completely resume its transparency. The nature of the nutritive process in the laminated tissue is such that this tissue recovers itself in a great measure, by timely treatment, from almost any amount of inflammation and consequent effusion which falls short of actual destruction of its elements. But when these elements are at all displaced or consumed under the morbid process, then permanent opacity is very likely, and indeed almost certain, to follow: for so artificial is the mechanical arangement of the elementary lamellæ, on which the transparency of the cornea depends, that when their substance is once removed its place cannot be supplied with a tissue of an equally elaborate organization. The new material, though its bulk and strength may be equivalent to those of the old, is fibrous instead of being lamellated, and opaque instead of being translucent. It contains a considerable quantity of yellow fibrous tissue, intimately mixed with the white, and both most irregularly interwoven and ill-developed—ready to become the nidus of small granules of earthy or fatty matter, such as readily settle in parts of deteriorated structure. From this condition recovery is not possible; the blemish has become indelible.

It is to be observed, however, that during the progress of the reparative process, there exists in the part and its immediate vicinity a quantity of fresh material of that kind which denotes an over-activity of the nutritive function, and which, not being wanted for conversion into permanent tissue, will in due course be absorbed. This augments the opacity while it lasts; and it is not till a certain time has been allowed for its removal, after the healing of the breach, that we can say how extensive or deep the permanent opacity may prove; we may generally venture to predict a gradual improvement during some time, in a recent opacity, particularly in young subjects.

What I have now said applies to the greater part of the more common opacities of the cornea: I may allude to one or two other forms which may prove interesting in regard to the question of their precise seat. There are some varieties which appear to be on or near the very surface of the cornea, and which it is probable may occupy the anterior elastic lamina. The very opaque chalky-looking films which often follow the application of quicklime or new mortar to the eye, seem to be of this kind, and so, also, do those which have been supposed by some to be stainings of the surface of the corneal tissue by a deposit from the lead lotion in common use. Occasionally we have a superficial excoriation of the cornea—one can hardly call it an ulcer—which the epithelium limits with abrupt edges, thus favouring the accumulation, on the depressed surface, of the frothy mucus or sud which the movements of the lid furnish. The opacity thus produced is often very opaque, and, unless you were aware of its cause, might seem more serious than it really is. A lens, or the point of a needle, will inform you of its real nature.

There is another form of opacity, which I believe to have its seat in the anterior elastic lamina, although it is vain to endeavour to prove it, except by a section of the parts. It has a silvery lustre, and a very fine texture of interweaving striæ, and it creeps very gradually from near the border, over the surface of the cornea, towards the centre. The epithelial surface retains its smoothness and lustre, and the opacity does not appear to have much depth. Other varieties of opacity, very chronic in their course, and evidently not inflammatory, are liable to form, as I believe, in the same tissue. They may be of a brown tint, with an indefinite margin, and may affect both corneæ at the same time. I am not aware that these are particularly described in books, nor whether they admit of removal, or even arrest. They are probably connected with an imperfect nutrition of the eyeball, and must be left to take their course.

There is a variety of opacity consisting of minute dots, sometimes so small as not to be distinguished separately without a lens; at others, as large as a small pin's head. These are evidently seated on the posterior part of the cornea, and may be referred to the posterior elastic lamina. They accompany an inflammatory affection in which the walls of the aqueous chambers seem to be chiefly involved, in which the iris is usually mottled and dull, the pupil inactive, and the sclerotica more or less injected. Such a dotted opacity was long since pointed out by Mr. Wardrop, and admits of removal, provided the proper treatment is commenced early enough. It probably consists of an ordinary inflammatory deposit of lymph.

There is still another kind of dotted opacity, occurring in the posterior elastic lamina, which I would distinguish from all those yet mentioned, and which is met with in eyes which have suffered a slow disorganizing process, through sympathy with the opposite organ previously lost by operation or accident. In this the dots are remarkably round and separate from one another, often brownish, and therefore overlooked, and scattered pretty uniformly over a portion or the whole of the cornea. Though these sometimes grow fainter under appropriate treatment, I have never seen them altogether removed.

Warty opacity of the cornea.—It will readily be conceived that opportunities but seldom offer of submitting specimens of the several forms of opacity to exact scrutiny by the microscope. On this account I shall make no apology for describing the appearances of an opaque spot which occurred on the front of the cornea of an ox, and which I examined in the fresh state. It was about an eighth of an inch across, slightly raised and densely opaque, and it seemed to have been the result of an ulcer, for the lamellated tissue was involved to a slight depth, and had been replaced by new tissue, as represented in Fig. 6. This new tissue was dense

Fig. 6.

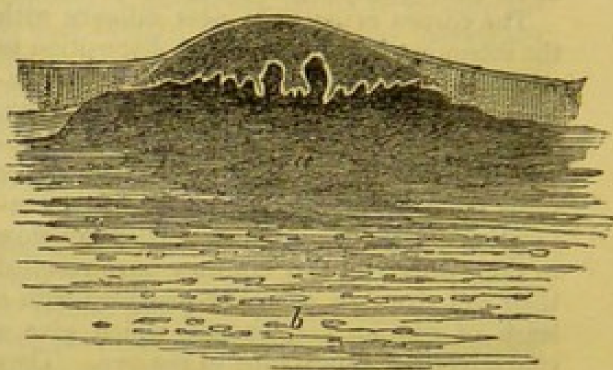


Fig. 6.—Vertical section of an opacity of the cornea of an ox. *a*, new tissue in place of destroyed lamellated tissue: papillæ are developed on it, surmounted by opaque and thick conjunctival epithelium, or, as it might be here called, epidermis. *b*, healthy lamellated tissue below the opaque spot. (Magnified slightly).

and fibrous, and hardly admitted the light to pass through it even when cut very thin. It contained a large admixture of irregular nuclei and elastic tissue passing in all directions. But what was most remarkable was, that this substitute for the proper corneal tissue was thrown up under the conjunctival epithelium in the form of numerous *papillæ*, arranged in much the same way as we find them in the more highly developed parts of the skin, though apparently without vessels, and of a texture too opaque to be precisely described. The *epithelium* over these papillæ was likewise opaque and diseased, being composed of a compact aggregation of nucleated particles, which contained numerous opaque granules, and failed to present that regular gradation from the spheroidal to the scaly figure, which is natural in this situation. The extreme surface only was scaly. I cannot help regarding this morbid condition as one of considerable interest, both as a proof of the affinities of the cornea to the integumental tissues, and as an example of the definite organization of the new materials into persistent forms, opaque and otherwise different from the original structure which they supplant, and incapable of remedy.

I shall conclude the present lecture with a short description of the structure which replaces the cornea when wholly or partially destroyed, so as to constitute the state known as *staphyloma*.

The whole thickness of the cornea, in a larger or smaller extent, having perished from any cause, the iris is exposed, and occupies the breach, becoming adherent to the border of the gap formed by the removal of the lost part. If the contents of the globe do not further escape, and the eyeball consequently collapse, time is afforded for reparative processes to take place, by which the opening is filled with new material by granulation. At first this new material is soft, vascular, and nearly on a level with the surrounding parts; and, if nature is allowed to proceed with her operations undisturbed, it gradually acquires firmness, toughness, and considerable density, so as to appear not unlike the original cornea, except that it is opaque. It becomes covered with an epithelium continuous with the conjunctival, just as an ulcer of the skin acquires an investment of cuticle as it heals. This process was first explained by Mr. Wharton Jones, in an able paper published in the MEDICAL GAZETTE, vol. xxi. p. 847. Now in some cases, from causes which it is unnecessary for me at present to specify, this cicatrix continues to retain the contents of the globe within their proper bounds, and the patient experiences little inconvenience beyond the loss of vision; but in other instances the new material begins after a time to evince its want of coherence and strength, by bulging slightly under the pressure occasioned by the accumulation of fluid behind it,—that is, of course, behind the iris, in the posterior chamber of the eye. Should the projection increase beyond a certain size, it assumes an unsightly appearance, interferes with the movements of the lids, so as at last even to prevent their closure, and, in a word, grows into such a source of annoyance and irritation, that it requires to be got rid of. This is usually done by the knife, and, the lens being allowed to escape, the eyeball permanently shrinks to a small size.

The whole substance of the cicatrix being shaved off from the front of the globe, affords us, now and then, the opportunity of examining its structure in the perfectly recent state, which we can seldom do with any other of the morbid tissues of which this organ is the seat. I had such an opportunity last summer, in the case of a little girl; and the following, in few words, is a description of the structure of the tough opaque membrane which occupied the place of the lost cornea. Its thickness was very unequal; its posterior surface, to which portions of the iris adhered, being irregularly pitted, or, as it were, worm-eaten; its anterior surface was formed by a thickish coating of epithelium, somewhat resembling cuticle, being composed of eight or ten layers of cells, the deep ones globular, the superficial ones scaly, and more like epidermic cells than those of the healthy cornea. There was no anterior elastic lamina, and no posterior elastic lamina. The entire remaining portion of the thickness of the staphyloma consisted of a dense and most irregular interweaving of white and yellow fibrous tissue, with imperfectly developed nuclei intermingled, and the meshes of the tissues large, unequal, and open on all sides.

FIG. 7.

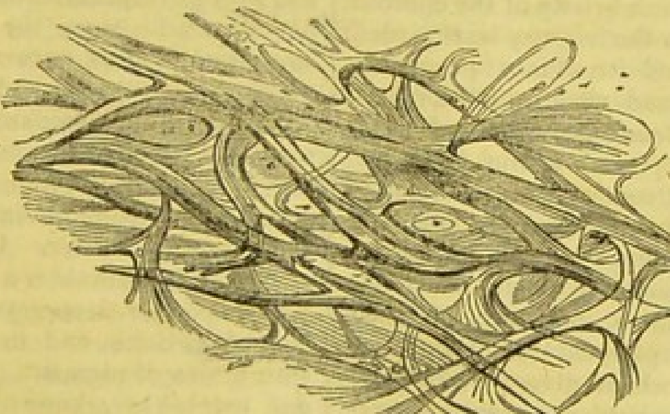


FIG. 7.—Section of staphyloma; treated with acetic acid: from a girl. (Slightly magnified.)

In this condition we have an eminent example of those results of the reparative action, after loss of substance of the cornea, which we have already had occasion to notice as the consequence of ulcers or small sloughs, the difference here being that the new material is derived in a great measure from the vascular iris, and not merely from the cornea itself. We see how far the reparative powers fall short of restoring the complex and elaborate structure of the cornea as it is originally laid down in the development of the body. The thickness of the new cuticle is attributable to the constant friction of the lids.

Lecture III.

Structure of the choroid coat—its inflammatory products poured out on its inner surface and why?—Choroidal epithelium.—Ciliary body and processes.—Course of the needle in the operations on the lens through the sclerotica. Internal structure of the ciliary processes—their influence on the nutrition of the vitreous and lens.—The Iris—description of the iris in an albino.—Contractile tissue.—Vessels and nerves.—Mobility of the iris. Ciliary muscle—ciliary nerves.—The vitreous humour.—Suspensory ligament of the lens—its attachment to the capsule of the lens, with a description of the latter.—Relation of the suspensory ligament to the hyaloid membrane.—Mode of formation of the canal of Petit.—Adjustment of the eye to distinct vision at different distances.

In the preceding lectures I have described to you the structure of the sclerotica and cornea, and have endeavoured to illustrate some of the processes that occur in them in the living subject, both during health and disease. At present I propose to proceed with the parts that lie within the outer case.

Of the internal structures, the most important for the surgical student to acquire an exact knowledge of are, undoubtedly, the iris and the lens, as these both lie full in view, and are often the seat of mechanical hindrances to sight, which it is in the power of the operator to remove.

To understand the position and arrangement of these two structures it will be necessary for me to speak briefly of the choroid membrane (of which the iris may be regarded as a production), and its ciliary processes, and of the aqueous and vitreous humors.

Of the choroid membrane.—The delicate choroid membrane, placed within the sclerotica, between that coat and the retina, has, of course, the same general shape and curvature that these have. It is essentially a vascular coat, and consists chiefly of blood-vessels, amongst which, however, in most cases an abundant pigment is interspersed in nucleated cells which diverge into very irregular, often branching, processes, variously inclined as regards the other tissues. A peculiar fibrous tissue is added, which holds all in place and confers some little toughness upon the membrane.

If we remove the sclerotica and cornea from a recent human eye under water, we find that the choroid is of a dark sepia colour, slightly adherent to the outer case, near where the optic nerve passes through them both to terminate in the retina, but in the rest of its extent hardly if at all united to that dense fibrous membrane; except, indeed, at the anterior margin, where the sclerotica joins the cornea, and where the adhesion of the choroid is of such a kind as to require a separate description afterwards.

The exposed surface of the choroid is slightly flocculent, and some of the pigment easily separates and diffuses itself in the water. The ciliary nerves, which have pierced the sclerotica a little in front of the optic nerve, are seen now taking a forward course (having become flattened), and dividing sparingly into branches till they enter the ciliary muscle, which presents itself as a broad semi-transparent greyish belt intervening between the sclerotica and choroid for about an eighth of an inch all round the cornea. When the choroid has been so fully injected through the ciliary arteries that the fluid has traversed the capillaries and also the veins, we see its outer surface to be composed of the arterial and venous branches, and its inner surface of the capillaries. The arteries, comparatively small, take a meandering course forwards between the veins, while the veins run in curves, *vasa vorticosa*, to four or five principal trunks, by which the blood leaves the organ. The capillaries form on the inner surface of the choroid a plane plexus with close meshes known as the *tunica Ruyschiana*. This network is closer, *i. e.* its meshes are smaller in the hinder part than in front, and the vessels finer. It is the most important part of the choroid, because the capillaries are a more important structure than either arteries or veins—more important, I mean, in regard to the function of the membrane, and also as respects its diseases. In no other part of the body are the arteries and veins so separated by a natural disposition from their own capillaries, and it is most interesting to notice in accordance with this circumstance, that when the choroid is inflamed so that inflammatory products result, they are poured out from its inner surface rather than from its outer. Covering the inner surface of the choroid is a layer of *epithelium*, with more or less regular hexagonal nucleated particles, and in most cases loaded with grains of pigment. This is the *choroidal epithelium*, known also as the *membrane of the black pigment*; so called by Mr. Wharton Jones, who first observed its hexagonal arrangement. The pigment, however, you will observe, is not limited to this epithelium, but exists also in the substance of the choroid, though there the cells which hold it are irregularly star-shaped and furnished with diverging processes. In perfect albinos the same epithelium contains no pigment; while in imperfect albinos, I have observed that it contains pigment, though no other tissue in the body does.

What has now been said is intended to apply to the choroid only as far forwards as a circular line about an eighth of an inch distant from the cornea. In front of this line the choroid is covered, and more or less concealed from view, by the ciliary muscle which lies on its outer surface; and if we divide the globe from side to side, so as to look at the inner surface of the choroid through the vitreous humour, we shall see the retina lining it as far forwards as this line, but there ceasing by a finely jagged border, *ora serrata*, in front of which the choroid is modified in appearance, assumes the name of *ciliary body*, and *appears* to come into immediate contact with the vitreous humour.

Tracing the choroid forwards, then, from the ora serrata, we find it leaving the sclerotica, being separated from it by the thin ciliary muscle, and inclining gradually inwards towards the axis of the eye, so as to encroach upon the vitreous more and more, as the ciliary muscle increases in thickness forwards.

If we examine the *inner surface* of this part of the choroid, or that towards the vitreous humour, it appears marked by striæ which are in reality very slight foldings, but are made more evident by variations in the depth of the pigment. The striæ pass from the ora serrata about 3-4ths of the way towards the lens. This is the *pars striata* of Zinn. Then commence the *ciliary processes* of the choroid, which run as far as the edge of the lens, and often a little beyond the edge, so as to overlap it, but not to touch it. These ciliary processes, the *pars plicata*, are true and very decided foldings of the choroid running in between corresponding folds of the vitreous humour, and thus taking firm hold of it. They are from 60 to 65 in number; but it is impossible to enumerate them with exactness, because there intervene smaller ones of various size, some of which may be either counted or not with the rest. Examining the ciliary processes individually, each commences gradually from the striæ already mentioned, and projects into the cleft between two corresponding folds of the vitreous, increasing in depth forwards, until close to the border of the lens as it lies imbedded in the front of the vitreous humour. Arrived here, each ciliary fold attains its greatest depth, and terminates abruptly by its extreme edge changing its direction and turning forwards and outwards from the lens towards the back of the iris, with which latter it becomes continuous and then suddenly ceases. In thus bending away from the lens, each ciliary process, of course, leaves the vitreous humour, and is no longer buried in its surface and united to it, but leaves a very narrow space around the lens in which the vitreous humour *appears* to contribute to bound the posterior chamber of the eye: the remainder of each ciliary process in passing to the back of the iris likewise helping to limit the same chamber near its rim. Thus you will observe, looking at the eye in the living subject, that a needle passed through the sclerotica towards the axis of the eye at any distance within an eighth of an inch of the cornea, would first pierce the ciliary muscle; then, if in the hinder part of this space, it would traverse the pars striata and enter the vitreous humour; if in the fore part, it would pass through or between the ciliary processes of the choroid, and according to the direction given to it might be made to enter the vitreous humour behind the lens, or the lens itself, or the posterior chamber of the eye; but that to enter the latter without wounding the lens would be almost impossible, so narrow is the space.

Internal structure of the ciliary processes.—The ciliary processes are covered with a modification of the choroidal epithelium, of a dark brown colour, which is deepest in the clefts between them, their tips being generally pale in the adult human eye, though not in animals generally. Under this is spread out a close network of vessels, continuous with those of the choroid behind, but more capacious, and therefore coarser in appearance in an injected specimen. Their meshes follow the line of the folds. These vessels must have a great influence on the nutrition of the vitreous body and of the lens itself, from their proximity to both, and from the multiplied surface of the vitreous which they are in relation to: of which I shall give you this proof derived from a morbid process—viz. that in a case of destructive inflammation of the eye attended with the formation of lymph in large quantity on the inner surface of the choroid generally, forcing the retina inwards upon the vitreous humour, this humour itself contained throughout a multitude of those particles which appear under inflammation, and which I alluded to in my last lecture; but while the superficial parts of the vitreous were every where more loaded than the central parts, in no portion was there so dense a deposit of this morbid material, the result of inflammatory action, as opposite the ciliary processes and around the lens. The morbid state of the choroid was uniform, but the vitreous was chiefly contaminated in those regions in which the natural process of nutrition is most actively conducted, in consequence of their contiguity to the supply of blood.

Such is the complexity of the parts which we are now endeavouring to understand the disposition of, that I am at some loss to determine which it will be best to place next in the order of description. Perhaps on the whole it will be most convenient for us now to turn our attention to the iris.

Of the Iris.—This, as you are aware, is a contractile curtain, suspended in the aqueous humour before the lens, with the pupillary aperture near the centre, (though rather to the inner side), to give passage to the light. It may be regarded from its position as a process of the choroid membrane, although its texture is in a great degree different therefrom : still it is continuous with that coat by its vessels and its surfaces, and it is besides convenient to the learner to consider it in this relation.

To understand the position of the iris, we will revert for a moment, if you please, to that most important region, that key to the anatomy of these parts, the line of junction of the sclerotica and cornea, on their inner surface. Here, you will remember, the posterior elastic lamina of the cornea terminates in a network of plexiform elastic fibres which run backwards so as to form a threefold connexion—some to the sclerotica, on the further side of the circular sinus; a large quantity to furnish the origin of the ciliary muscle; and, lastly, a smaller set, which, after bounding the aqueous humour at the rim of the anterior chamber, implant themselves into the anterior surface of the iris at its circumference. By these, then, the iris in part arises, or acquires an attachment to the outer case. These are what I have termed the *pillars of the iris;* they are much more developed in some animals than in man, but in the human eye they nevertheless are very distinct, and to be seen without difficulty. I have drawings on the table of their appearance in several of the lower animals. In the bird they are very largely developed, and come not merely from the posterior elastic lamina, which is not thick in that class, but also from the posterior lamellæ of the cornea proper. Behind the pillars the iris is fixed to some of the fibres from which the ciliary muscle arises, and which are there passing almost directly backwards towards the tips of the ciliary processes, which last abut in the posterior chamber against the iris, and become continuous with its posterior surface. The iris is, therefore, intimately connected at its origin with the ciliary muscle; a fact important to remember with reference to some of the functions of these parts.

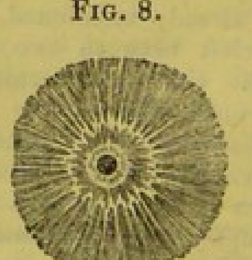
The iris has two *surfaces,* which are nearly parallel; the anterior is that which we see so elegantly bright through the cornea; the posterior, commonly known as the *uvea,* is always dark brown, with pigment disposed in cells which form a layer easily detached, and of the nature of an epithelium, traceable into that covering the ciliary processes of the choroid. This epithelium I have seen raised in blisters by the imbibition of water after death. The posterior surface of the iris usually presents small folds converging towards the pupil, especially when that aperture is contracted. It forms the anterior wall of the posterior chamber of the eye.

On the anterior surface of the iris are to be seen many varieties of colour and even of texture, with some of which every one is familiar; but it is not till the attention has been minutely drawn for some time to the appearances of this part that the extent of these varieties will be suspected. Much depends on the pigment, which is not only in some individuals disposed in considerable quantity on the front surface of the iris, but in all cases (excepting albinos, where no organ possesses it), is intermixed more or less with the elementary tissue of the iris, not only so as to modify the aspect of its surface, but even making it very difficult to trace the exact nature of the proper contractile material which we are quite sure exists in the membrane. And it is for this reason that albino specimens are the best adapted for examination of the iris.

Looking, then, at the eye of an albino, we observe on the front of the iris, when the pupil is contracted so as to bring the texture most completely into view, a number of elevated lines or fibres converging towards the pupil, and becoming more prominent as they approach it. As these lines are irregular in size and length, and run somewhat into one another, it is impossible to count them accurately, but they are about 40 in number. Arrived at about 1-10th of an inch from the margin of the pupil, they terminate in an irregular series of knotty prominences of similar texture, which are also joined to one another, so as to form a kind of zigzag, irregular ring, beyond which the iris is usually thinner, and marked with very fine converging and anastomosing lines which run on to the extreme edge of the pupil. In some examples, and it was so in that from which the diagram before you was taken (fig. 8), there is at the very verge of

FIG. 8.

Inner side.



Front view of the iris of an albino, with the pupil contracted in a strong sun-light. The appearances illustrate the verbal description given in the text. Slightly magnified.

the pupil an appearance of a set of circular fibres, delicate and narrow, but sufficiently distinct, while in the majority of those specimens which I have examined, even under high powers of the microscope, I have been unable to discover, and feel sure that there do not exist, any such circular constrictor fibres of the pupil. The fibres, however, in all cases, as they run to the edge of the pupil, join one another in a plexiform manner, and I am disposed to believe that this lateral junction of fibre with fibre may in effect answer the same purpose—viz. that of diminishing the central aperture of the iris—as a belt of circular fibres would do.

Fibres of the iris.—The fibres which make up the proper substance of the iris are of a peculiar kind, very nearly allied to the ordinary unstriped muscle, but not by any means identical with it. They are pale, soft, easily torn and separated from one another, and are intermixed with very numerous nuclei or cyto-blasts, either circular or elongated according to the direction of the fibres, and, indeed, very probably changing their shape in correspondence with the contracted or relaxed condition of the fibres themselves, as I have observed those to do which exist on and within the striped kind of elementary muscular fibre. In the iris we find abundance of fibres of a peculiar kind, extremely slender, looking under high powers like very fine hairs, and apparently not branching. Among these are numerous circular nuclei, and I do not know whether they are to be regarded as contractile or not.

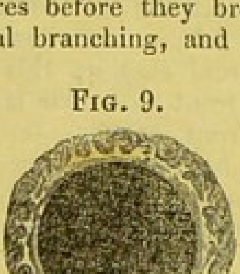
The fibres which we see on the front of the iris, with the ring of knotty elevations in which they join each other near the margin of the pupil, all consist of fibres loaded with nuclei, and must be regarded as of a contractile nature, although they are not in all respects the same as fibres which we know to be muscular in other parts. We have, however, the certainty that there is a structure in the iris which enables it to change its form. That this is not of an erectile nature I shall be able to show you, and we have no other resource, therefore, than to consider the fibres contrac ile of which we find it to consist. When we further discover that the corresponding fibres in birds and reptiles are of the striped variety of muscle, we need not hesitate to admit the muscularity of the unstriped fibres of the mammalian iris; for we have the same general grounds for doing so as for admitting the muscularity of unstriped muscle in other parts, and the latter confirmatory argument in addition.

Vessels of the iris.—The iris is vascular—about as vascular as unstriped muscle in other parts, and the vessels very similar in size and arrangement to those found elsewhere in like structures. They are slender, distributed among and along with the fibres, so that in a dry injected specimen you might infer the direction of the fibres from that of the vessels. Having already described the general course of the fibres, I need not detain you with that of the blood-vessels, but shall only remark that they are derived chiefly from the two long ciliary arteries, which, piercing the sclerotica behind, advance over the choroid, one on each side, in the horizontal plane of the eye, over the ciliary muscle as far as the border of the iris, near which they bifurcate, so as to encircle that part with a vascular ring, from which both it and the ciliary muscle are mainly supplied.

At a small distance from the margin of the pupil, on the anterior surface, a delicate circle of anastomosing vessels marks the line from which the membrana pupillaris passed in fœtal life, and from which it was supplied with blood. Small brown shreds of this membrane sometimes remain through life, hanging free in the aqueous humour. At the pupillary edge of the iris a minute circlet is formed by the junction of vessels of almost capillary size.

Nerves of the iris.—The iris is likewise supplied with nerves, which are abundant compared with its bulk. They are branches of the ciliary nerves, which, passing through the ciliary muscle, are prolonged into the iris. Arrived here, it is not easy to trace their further distribution on account of the pigment scattered amongst the several tissues, and also because they appear to lose that constituent which gives them their most recognizable character, viz. their double dark contour. The latter circumstance is, I think, more common in several tissues (and among them is the unstriped muscle) than anatomists have generally held; still, as the nerve-fibres do not lose their dark border all at once, they may be traced for some distance, especially in albino animals: and I have frequently found them inclining across the muscular fibres before they break up into their terminal branching, and become lost to view.

FIG. 9.



Front view of the same iris as that represented in the last figure; but here with the pupil dilated to the utmost by atropine.
Magnified as before.

Mobility of the iris.—The great extent to which the iris is capable of moving, so as to vary the size of its pupillary orifice, is very remarkable, and is well illustrated by fig. 8 compared with fig. 9. Both these represent the same iris of a male albino, with the pupil at first much contracted under a strong sunlight, and then fully dilated by the application of a solution of atropine to the front of the eye. I have already described the appearance of the iris in the former of the two states. The distance from the greater circumference to the margin of the pupil is about one-fourth of an inch: in the latter state, it is hardly one-twelfth of an inch; while the converging striæ, and circle of knotty elevations near the pupil, are thrown into a wavy slack condition, in which they can be but imperfectly traced. At the same time, the tissue immediately bounding the pupil is so extremely attenuated by the stretching it has undergone as to be hardly any longer visible. The pupil itself is capable of varying from one-twentieth to one-third of an inch in diameter.

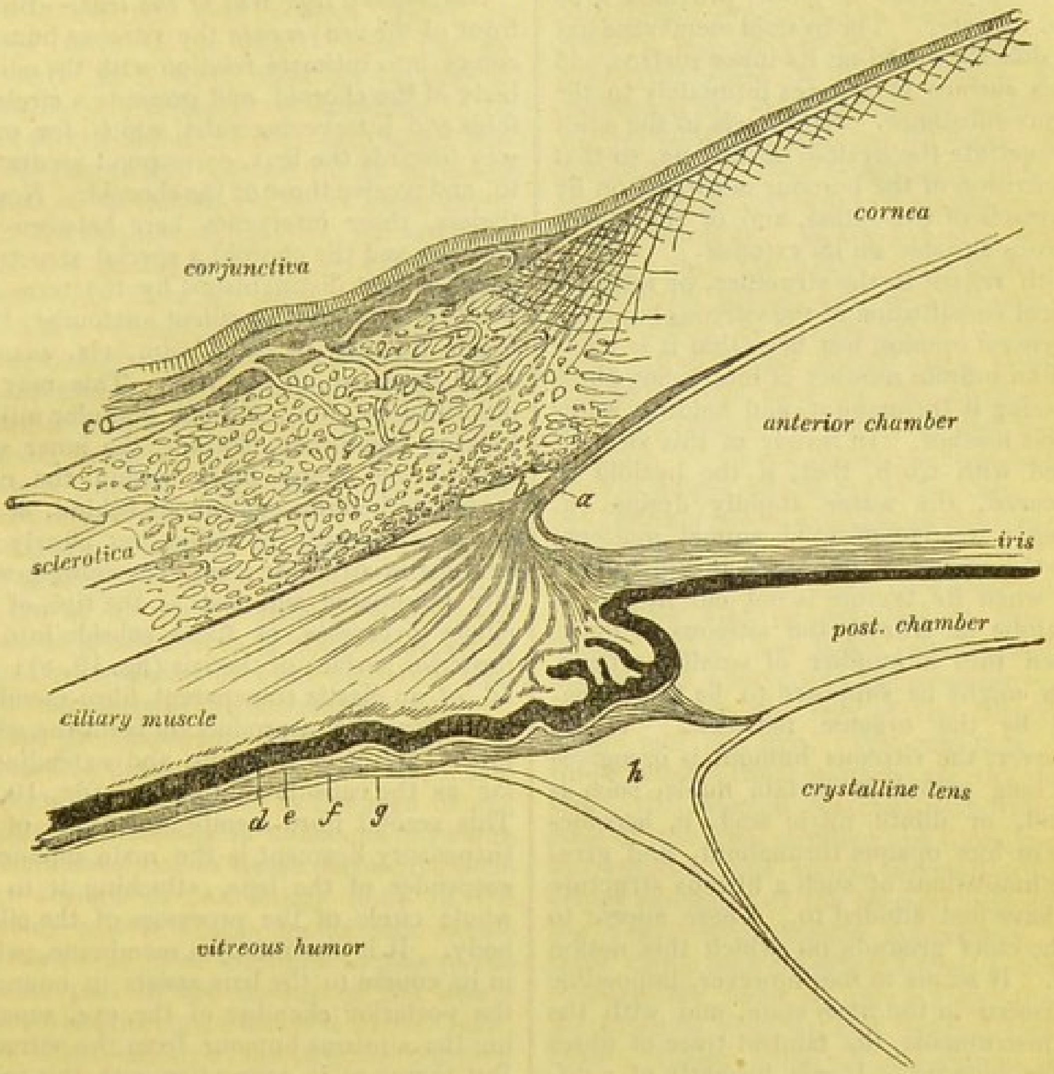
Of the ciliary muscle.—I now come to consider the structure and arrangement of the *ciliary muscle*,—a part not known under that name, but usually called the *ciliary circle*, on account of the general doubts entertained of its real nature. Some anatomists, especially the acute and ingenious Porterfield, deemed it to be muscular, although in his day minute anatomy was so little advanced that no sufficiently conclusive arguments could be advanced in support of either that or any other view. Others have regarded it as a nervous ganglion, or plexus, on account of the large supply of ciliary nerves which it receives; while the greater number, especially, I think, during the present century, have been content to look upon it as a cellular or peculiar tissue, establishing a connexion between the choroid iris and sclerotica. It forms a greyish semi-transparent band, about one-eighth of an inch broad, on the outer surface of the choroid, between the choroid and sclerotica; for I do not admit, with some anatomists, that the choroid encloses this structure by splitting in front into two laminæ. It is thickest in front, at its anterior edge, and becomes gradually thinner backwards, terminating about on a line with the *ora serrata* before mentioned, and corresponding, therefore, on its inner surface to that striated and plicated part of the choroid in front of the retina, where the choroid takes hold of the vitreous body. The outer surface of the muscle, when exposed by the removal of the outer case, looks soft, and almost gelatinous, and it is not easy to distinguish in it any thing like fibrous texture. This is partly because it is really less firm than many other muscular parts, and its fibres less separated into bundles; but partly also because its fibres are arranged rather in layers, of which the outer and larger, which goes from the origin of the muscle to its posterior edge, covers and conceals all the rest. But if a piece be a little raised by the knife, and then torn up by the forceps, the texture is found to give way in lines diverging from the border of the cornea more readily than in any other direction; and further, if a successful vertical section of it be made in a backward direction from the cornea, it will be seen to present more or less evidently the superposed layers as they are represented in the diagram. (See next page.)

Moreover, if we examine with a high microscopic power the texture of this part, we discover a fibrous arrangement in the same direction, which would be more obvious if the fibres were more separate from one another than they really are. The fibres are then seen to be loaded with roundish or oval nuclei, often precisely similar to those of the best marked examples of the unstriped muscle. Lastly, the vessels of the ciliary muscle resemble those of unstriped muscle in abundance and arrangement, and indicate in the most decided manner the backward direction of the fibres, from their origin at the junction of the cornea and sclerotica towards the anterior region of the choroid. The vessels are derived chiefly from the same source as those supplying the iris.

The ciliary nerves.—The ciliary nerves, 16 or 20 in number, divide as they advance between the sclerotica and choroid, and enter the ciliary muscle at its posterior border. In its substance they further branch, and in a great measure terminate, running more or less evidently across the direction of the fibres, and losing their tubular character as they blend with the elements of the tissue. Nothing can be more beautiful than the appearance of these nerves in the bird's eye; for example, in one of the common domestic species. Here the structure we are describing is indisputably muscular, as long since pointed out by Sir Philip Crampton, though at that period (more than thirty years ago) the proof derived from the anatomy of the elementary fibre was wanting. Like that of the iris in the same class, it is of the striped kind. The nerves are very large in the bird's eye, and very white; and, advancing to the muscle from behind, chiefly on one side, they change their direction to one transverse to the fibres of the muscle, and are distributed among these, after forming an anastomosis with other twigs going to the circular striped fibres of the iris.

It is interesting to notice in the human eye, and in that of other animals, an uniform correspondence between the size of the ciliary nerves on the one hand, and that of the ciliary muscle on the other, though no doubt the amount of contractile material in the iris likewise shares in governing the size of these nerves. All such considerations as I have now enumerated concur in indicating the *muscularity* of the structure, thence called the ciliary *muscle.*

Fig. 10.



General section, illustrating the arrangement of the parts treated of in the present lecture. *a*, Fibrous plexiform tissue derived from the posterior elastic lamina of the cornea, passing to the iris, ciliary muscle, and sclerotica; *b*, circular sinus; *c*, conjunctival vessels, running up to the margin of the cornea, and entering the anterior portion of the sclerotica: these become enlarged in inflammation of the cornea. *d*, Choroidal epithelium on the ciliary body; *e* and *f*, the two elements of the suspensory ligament of the lens; *g*, hyaloid membrane; *f* and *g* may be traced towards the lens, forming the anterior and posterior walls of (*h*) the canal of Petit. The capsule of the lens is seen becoming thinner behind the attachment of the suspensory ligament.

With regard to the use of the ciliary muscle this is not the time to descant: but it appears to be so placed as to be likely to advance the lens by drawing the ciliary processes towards the line of junction of the sclerotica and cornea, and also perhaps at the same time by exercising compression on the sides of the vitreous body. Such a movement of the lens would tend to adjust the optical mechanism of the eye to vision of near objects.

Of the vitreous body.—We may now, gentlemen, briefly turn to the *vitreous body or humour*,—a part of considerable importance to the surgeon, in consequence of its relation to the lens. We have already seen that it occupies four-fifths of the entire globe, filling the concavity of the retina, and that the lens is encased, as it were, in its front part. We shall find, however, that this humour, delicate and almost diffluent as it is, is not the only, or even the principal agent, that holds the dense and comparatively solid lens in place, but that an additional structure, the *suspensory ligament of the lens*, is in reality the chief suspender of that organ, while the vitreous humour itself affords it little more than a bed or support for it to rest upon.

The vitreous humour is perfectly transparent, and of the consistence of thin jelly; indeed, some portions of it appear to be hardly more coherent than white of egg. It is enveloped in a very delicate, transparent, homogeneous membrane, *the hyaloid membrane*, which enables it to retain its figure after removal from the globe, provided it be placed in water. The hyaloid membrane has a few delicate nuclei on its inner surface, and by this surface it adheres intimately to the vitreous substance. No vessels in the adult eye penetrate the hyaloid membrane, so that the nutrition of the humour is carried on by the vessels of the retina, and of the ciliary processes situated on its exterior.

With regard to the structure, or intimate physical constitution of the vitreous humour, the general opinion has been that it is made up of an infinite number of interlacing fibres traversing it throughout, and holding water in their meshes. In favour of this view, it is said with truth, that, if the hyaloid be punctured, the water rapidly drains off, leaving a vestige of solid animal matters; while the escape of its water is much more slow when its texture is not cut into. If the globe be frozen, the vitreous is found divided into a number of small portions, which might be supposed to be thus separated by the organic network. When, moreover, the vitreous humour is immersed for a long period in certain fluids, such as alcohol, or dilute nitric acid, it becomes more or less opaque throughout, and gives some indications of such a fibrous structure as I have just alluded to. These appear to be the chief grounds on which this notion rests. It seems to me, however, impossible to discern in the fresh state, and with the best instruments, the faintest trace of fibres in this humour. I was formerly of a different opinion, but believe I was deceived by the fibrous aspect of the suspensory ligament of the lens, which is in close contact with the front of the vitreous humour. In the examination of parts so delicate and transparent, the greatest care is requisite to avoid error. The texture of the specimens rendered opaque is not fibrous, but homogeneous, and finely granular.

The fluid collected from the vitreous humour by suspending it over a glass differs but little from water: it contains a little albumen, and some salts.

The vitreous body is in contact with the retina as far forwards as the retina extends, viz. up to the *ora serrata*, and presents a smooth surface, having but a slight connection with the retina, by means of a layer of very transparent cells. Near the bottom of the eye, however, at that part of the vitreous which corresponds to the entrance of the optic nerve, a more intimate union subsists between the hyaloid and the outer case, by an inflection of it inwards upon a structure which advances into the vitreous towards the lens, and which, in the earlier periods of development, appears to have been a process of the retina, together with the vessels, now altogether atrophied, which supplied the lens with blood.

Suspensory ligament of the lens.—But in front of the *ora serrata* the vitreous humour comes into intimate relation with the ciliary body of the choroid, and presents a circle of folds and intervening sulci, which, for some way towards the lens, correspond accurately to, and receive those of the choroid. Nevertheless, there intervenes here between the vitreous and the choroid a special structure, which is best distinguished by the term applied to it by that excellent anatomist, Professor Retzius, of Stockholm, viz. *suspensory ligament of the lens.* This may be described as, first, a tough granular milky-looking membrane, clothing the inner surface of the ciliary body, within the choroidal epithelium, continuous behind, at the *ora serrata*, with the retina, but clearly not nervous in structure; and, becoming gradually attenuated and lost at the tips of the ciliary processes, as these subside into the posterior surface of the iris (fig. 10, *e*): and 2d, of an elastic transparent fibro-membranous structure, a production from the whole inner surface of the first, and extending as far as the capsule of the lens (fig. 10, *f*). This second fibro-membranous part of the suspensory ligament is the main support or suspender of the lens, attaching it to the whole circle of the processes of the ciliary body. It is essentially a membrane, which in its course to the lens assists in bounding the posterior chamber of the eye, separating the aqueous humour from the vitreous. But there are in connection with this membrane a large number of flat, stiff, elastic fibres, which bend irregularly, like straws, and which are implanted separately into the capsule of the lens. These fibres are tough and strong, if such terms may be applied to parts of such delicacy; but I use them in a comparative sense.

Mode of attachment of the suspensory ligament to the capsule of the lens.—To enable you to understand how the suspensory ligament takes hold of the lens, it will be advisable to advert to the anatomy of its capsule. You are doubtless aware that the lens is a solid body of very complicated structure, enclosed in an entire and everywhere closed capsule. This capsule is the same in chemical and physical characters with the posterior elastic lamina of the cornea, with which you are already acquainted. The fibro-membranous element of the suspensory ligament is also very similar indeed in chemical characters, and I cannot help regarding it as having the same relation to the capsule of the lens as the fibrous cordage has to the posterior elastic lamina. They are intimately united, or, if you please, one is in both cases derived from, or a process of, the other. The capsule of the lens is much thicker in front than it is behind: and I shall now mention a circumstance that I believe has not been noticed before, but which bears on the view I have just expressed. It is this: that the capsule diminishes very suddenly in thickness at the line of attachment of the suspensory ligament, just as if a portion of its substance passed off in that shape, or, in other words, as if the suspensory ligament, on becoming fixed into the anterior portion of the capsule a little way from the rim, added its own substance to that of the capsule, so as to strengthen all that lay in front of the line of its attachment. It appears that the greatest strength is needed in the front part of the capsule, as there its surface is free, and the aqueous humour can scarcely afford it so good a support as the vitreous. If we trace the capsule of the lens backwards, we find it still getting gradually thinner till beyond the rim of the hinder surface, where it becomes so attenuated as in many cases not to exceed one-quarter, or even one-sixth part of the thickness of the anterior portion.

Thus the suspensory ligament of the lens commences behind at the ora serrata, where it seems to be continued at the edge of the retina; it increases in substance forwards by fibro-membranous tissue derived from the inner surface of the ciliary body of the choroid, and it finally leaves the ciliary processes near their summits to pass to the anterior part of the capsule of the lens a little within the rim, where it is fixed. Now, what is its relation to the vitreous body, or rather to the hyaloid membrane which bounds that body?

Relation of the suspensory ligament of the lens to the hyaloid membrane.—The relation appears to be this—and I state it with diffidence, because the parts we are now upon are extremely difficult of investigation, and have been the source of much difference of opinion among anatomists of the greatest acumen and industry. The account of what I am now going to speak of, as well as of the structures which I have already treated, is based upon what I have myself been able to see; and where I have succeeded in obtaining a clear view of the parts, I naturally am more disposed to rely on the conclusions I have myself formed than on those of others. I think, then, that the suspensory ligament of the lens is adherent to the hyaloid only opposite to the hinder part of the ciliary body, and that near the lens it leaves the hyaloid in order to pass to its attachment in front of the lens. The hyaloid, on the suspensory ligament leaving it, passes towards the posterior surface of the lens, and comes into contact with its capsule a little way beyond the rim, so that the rim itself, with a narrow belt of the anterior and of the posterior surface is *free*, and a cavity is left all round the lens, bounded in front by the suspensory ligament, and behind by the hyaloid membrane. This cavity is the *canal of Petit* (fig. 10, *h*), long since discovered by the illustrious French anatomist, but about the formation of which various views continue to be held. In the description of parts so delicate it is perhaps hardly to be expected that discrepancies should not exist. In some specimens I have thought that the hyaloid grew thicker as it formed the hinder wall of this canal, and subsequently, as it approached the lens, became thinner, and finally even altogether vanished from view as the observer approached the central region of the back of the lens. I do not myself believe that the hyaloid passes behind the entire lens. The substance of the vitreous seems there to touch the capsule.

Of the *canal of Petit* now mentioned, a good view may be obtained in the fresh eye of one of the larger quadrupeds, by making an aperture in the suspensory ligament, between the tips of the ciliary processes and the lens. We can then easily throw into the canal mercury, air, or coloured size; the injected material runs round the edge of the lens, swelling out those parts of the anterior wall which dovetail with the ciliary processes of the choroid, and assuming a somewhat beaded appearance. The same thing may be effected from behind by running the point of the syringe through the vitreous humour and hyaloid into the canal. Either mode of preparation shows that while the anterior wall of the canal is attached to the capsule of the lens, not at its border, but a little way on its anterior surface, so the posterior wall, which separates it from the proper vitreous humour, goes to be fixed all round a little way on the posterior surface, so that the exact rim of the lens projects into the canal; forms, in fact, its inner wall, and is free, as I before stated. I say free, and it is so in the main, but I have several times seen isolated elastic fibres of the suspensory ligament passing from the ciliary processes to the very margin of the lens, and there implanted. The width of the canal of Petit is about 1-10th, or 1-12th of an inch.

I find that I shall not be able to give a full description of the crystalline lens in the remaining part of the time allotted to the present lecture, and I shall therefore defer that subject, and now merely detain you for a few moments with some remarks on one part of the mechanism which the eye appears to contain for its adjustment to distinct vision at different distances.

You are aware that when we look at a distant object, the intervening ones at a less distance appear indistinct, but that when by a voluntary effort we render near objects distinct, distant ones become confused. If we use both eyes, the distant or near object which is indistinct, is at the same time double, but, with one eye, it is merely confused. In the former case the convergence of the optic axes can only be towards one of the objects at once, and the image of the other consequently falls on non-corresponding parts of the two retina, and is seen double. But in the latter case it is clear that the confusion arises simply from the rays from one of the objects not coming to an exact focus in the retina, while those from the other object meet exactly there, and form a distinct image, to which the attention is at the same time directed. This results from optical laws; and hence the necessity of a power in the eye to adjust its dioptric apparatus, so that objects at various distances may be brought successively into distinct view.

To enter upon a discussion of the several modes in which it has been supposed that this adjustment is or might be effected, would be now impossible. It has been thought that the antero-posterior axis of the eye is capable of elongation,—that the cornea, or lens, may become more convex, or that the lens may be advanced towards the cornea by a kind of erection of the iris or ciliary processes during near vision. It is manifest that numerous purely optical considerations must occur in the examination of such a question, but on the present occasion I am concerned rather with such arguments as the anatomical construction of the eye may contribute towards the solution of the difficulty; and I may be allowed to insist on the extreme and primary importance of such arguments in all similar questions, provided they are grounded on a correct appreciation of the facts.

We have, then, it appears, within the globe of the eye, a structure which is in all probability muscular, and which is undeniably so in certain animals. It has the arrangement of a muscle, very much the structure of a muscle, and is largely supplied with nerves, which are in great part derived from a motor source—the third pair. This muscle arises, or has its most fixed attachment, at the junction of the sclerotica and cornea, as much in front of the lens as is possible consistently with the preservation of the transparency of the cornea. That it may act more freely, a canal, the *circular sinus*, is interposed between its origin and the portion of the sclerotica which it lies against. Beyond this point it is hardly at all attached to the sclerotica, over which its fibres may be supposed to move in contraction, but it covers, and is inserted into, the anterior one-eighth of an inch of the choroid membrane, which is in this part tougher and firmer than elsewhere, and united in a very special manner to the lens by the ciliary processes, through the medium of a firm, tough membrane, and of a strong elastic fibrous membrane proceeding from it to the margin of the lens. And yet not quite to the margin,—for an elegant arrangement exists,—the canal of Petit,—by which traction is made, not on the vitreous around the lens, nor on the edge of the lens itself, so much as on its anterior surface. I confess it seems to me very difficult to doubt that this complicated system of parts is intended to advance the lens towards the cornea, so as to bring forwards, up to the retina, the focus of a near object, which would otherwise fall behind the nervous sheet. It is possible, also, I think, from the peculiar direction taken by the ciliary muscle, that it may compress the front of the vitreous, and thus help to throw forwards the lens.

Lecture IV.

Of the Crystalline Lens.—*Position, shape, size—Anterior chamber small in infancy—Occasional consequence of this. Capsule of the Lens—Experiment illustrating its endosmodic power and its elasticity — Thickness not uniform — Proneness to opacity during life—Characters of the opacity. Body of the Lens—Its fibres and laminæ—Nucleus—Central planes—their use—their complexity in the human lens—Mode of union of the fibres—Use of the toothed margins — Intracapsular cells — The "liquor Morgagni" a result of disease or post-mortem change—The "capsule of the aqueous humour" does not exist—Remarks on some appearances of cataractous lenses.*

Gentlemen,—We proceed to-day with the consideration of the structure of the crystalline lens and its capsule—a subject not more interesting to the anatomist than to the ophthalmic surgeon, on account of the large share of his attention which that important and common disease, the cataract, must always engross.

The crystalline lens, you will remember, is placed at the front of the vitreous body behind the iris, and is held in place there chiefly by a special fibro-membranous suspensory apparatus passing between its capsule and the ciliary processes, but partly by its adhesion to that portion of the vitreous body which is hollowed out to receive it.

Size and shape.—The lens is an almost perfectly transparent structure, about one-third of an inch wide, and one-sixth of an inch thick, more convex behind than in front. It has been doubted whether the curves of the lens are spherical or spheroidal —a question of much interest with reference to the corrections of an optical nature of which the eye is the seat, but not strictly bearing on the object before us in these lectures. The most accurate admeasurements, however, of the mammalian lens, which are those of Chossat, make it probable that the figure of the human lens is like that generated by an ellipse revolving round its lesser axis, the curvature being greater for the lateral than for the central parts.

The lens in early life is soft and nearly spherical, and grows larger and flatter with age, as well as harder, and somewhat amber-coloured. These circumstances should be remembered with reference to the diseases of the part at the several periods of life. The globular shape of the infant's lens renders the aqueous chamber small, and the iris almost in contact with the cornea; but in the adult the iris is usually not at all thrown forwards by the prominent centre of the lens. Nevertheless, in persons of full or declining age, who are the common subjects of hard cataract, the surgeon is accustomed to meet with very varying dimensions of the anterior chamber. This, however, depends rather on variation in the size of the lens than in its shape, and sometimes a prominent iris betokens an enlarged vitreous body, or chronic engorgement of the ciliary body of the choroid. In consequence of the prominence of the lens in infancy, it sometimes acquires a minute opacity in the very centre or most prominent point of its anterior surface, from coming in contact with the cornea, where this membrane is inflamed in cases of purulent ophthalmia. There is often a corresponding speck on the posterior surface of the cornea, precisely opposite.

Of the capsule of the lens.—The lens is enclosed in a capsule of perfectly transparent, homogeneous, and very elastic membrane—a part that should engage the special study of every one who proposes to operate on the eye. It is an entire unbroken layer, separating the lens from all that surrounds it, but very permeable by fluids, and, therefore, the medium through which the nutrition of the lens is carried on. Its elasticity, which is one of its most remarkable properties, is evinced by a curious experiment which presented itself to me accidentally when I was occupied in a series of researches into the anatomy of these parts. When removed from the eye, and placed in water, the lens imbibes fluid through its capsule, which thereby becomes distended and separated from the contained lens, being raised in the form of a vesicle. If it be taken from the water, and punctured with a needle, the fluid is ejected with violence by the resilience of the distended capsule, which instantly resumes its former bulk, and grasps the lens closely. The capsule is also very brittle, is easily torn in any direction when once a breach is made in it, and yet very tough, so as to offer considerable resistance to a blunt instrument which may be thrust against it. We see these points exemplified in the operations for cataract and artificial pupil. In the former, when the sharp-pointed needle touches the capsule (provided the membrane be sound), it enters and tears it with the utmost facility; while in the latter, the blunt hook often used to engage and draw aside the pupillary margin of the iris seldom does any injury to the capsule, though it must almost always touch it, and that sometimes somewhat rudely, in spite of the operator's caution. When ruptured, the capsule rolls up at the edges, whatever the direction of the laceration, and it is curious that the outer or convex surface always lies innermost in the roll, so that, like the posterior elastic lamina of the cornea, which it nearly resembles in other respects, it appears to be developed or laid down in a curve contrary to that which its elasticity inclines it to assume. It is a hard and dense structure, and determines the exact outline of the lens.

Thickness of the capsule not uniform.—The thickness of the capsule of the lens is different in different parts; particularly it is thicker in front than behind. This I alluded to in the last lecture, in speaking of the suspensory ligament or zonule; but I shall here repeat it, because of its importance. The anterior part of the capsule in the greater portion of its extent, in all its central region, and as far outwards as to within one-sixteenth of an inch of its margin, where the suspensory ligament is attached, is four or five times thicker than the posterior part. The diminution in thickness commences rather suddenly at the attachment of the zonule, and continues gradually as you proceed over the border to the posterior surface, where the minimum thickness is soon attained. This I have ascertained by careful examination. I need hardly point out to you how a knowledge of this fact may help us to understand some of the morbid processes met with in this part, and, by indicating with precision the direction in which lies the chief strength of the support of the lens in its position, may aid the surgeon, and give him confidence in certain of his nice and delicate manipulations.

The capsule retains its transparency after death, but is prone to lose it during life.—The capsule of the lens retains its transparency under the action of acids, of alcohol, and of boiling water, and will resist the putrefactive process for a great length of time: at least, I have frequently found it remain transparent after the lens itself had been completely destroyed by putrefaction, and the centre of the lens is itself very slow to putrefy. But, however difficult it may be to render it opaque after removal, it is rather prone to become so in the living body. An injury, such as laceration or puncture, is there almost sure to be followed sooner or later by a loss of its transparency, and we often see it of a decided dead white. The same also occurs in many cases where the opacity is primarily in the lens itself. After the operation for cataract by the needle, this opaque capsule is a not infrequent source of annoyance to the surgeon, obstructing the access of light to the retina, and demanding removal.

This proneness of the capsule to become opaque only while it continues a part of the living body, seems to shew that, hard and structureless as it appears, it is yet the seat of unceasing nutritional change—that its substance is in continual flux; for we can only regard the opacity as a result of depraved nutrition, the new material being laid down in an abnormal form. In some rare examples, one of which presented itself here during the present summer, minute vessels are developed upon the capsule, probably in lymph previously deposited there as a consequence of inflammation. They are continuous with those of the ciliary processes or adherent iris. It is interesting to observe that the opacity is usually denser when it takes place in the anterior part of the capsule than when in the posterior, because of the greater thickness of the former portion. But, besides this, the anterior seems more prone to become opaque than the posterior. When opacity occurs, the capsule usually loses its brittleness, and becomes tough. The opacity assumes an irregular figure, in flakes or patches, if the body of the lens remains, and may thus be distinguished from a similar change in the lenticular substance; but the opacity is more uniform if the capsule has been rent and the body of the lens absorbed. The opaque parts may even become so completely altered from their original texture as to be the seat of earthy deposits; but this is rare.

Of the structure of the body of the lens.—If we now turn our attention to the lens itself, that solid transparent mass thus enclosed and protected, we find it to be soft and pulpy in the outer portions, more firm, dense, and glutinous towards the centre, which is distinguished as the nucleus. Not that there is any special plane of division between the nucleus of the lens and its exterior or superficial portions: the change to more and more density is very gradual. No language derived from other objects can adequately describe the precise texture of the lens, as appreciated by the finger, simply because it is not a homogeneous texture, but one highly complicated and peculiar, which it will require some attention to understand.

Fibres of the lens.—The lens is composed of flattish riband-like albuminous fibres, having an average thickness of $\frac{1}{5000}$ of an inch, united side by side, so as to form plates, which are placed one within the other, somewhat like the leaves of an onion. The fibres all pass from the front to the back, so that each has two extremities, an anterior and posterior; and a middle part, which is directed towards the side or rim of the lens. In the lens of simplest construction—the spherical or spheroidal lens of many fishes, reptiles, and birds—the ends of the fibres all meet in the antero-posterior axis; and the surface of such a lens, viewed either before or behind, has the appearance of a globe marked by the lines of longitude passing from pole to pole. The same appearance, too, is seen after removing any number of the layers of fibres down to the centre. The individual fibres are of course narrower at the extremities and broader in the middle; and they would come to quite a point in the axis were it not that their lateral union becomes so intimate as they approach it, that the eye can no longer distinguish them individually, nor the skill of the anatomist isolate them. Moreover, it would appear that those coming from opposite sides do not form a firm junction across the axis, but rather that the axis is occupied by a substance of less density than the fibres themselves; so that, under ordinary circumstances, the lens may be made to break up, and its opposite sides to fall asunder along that line. In the lenses I am now referring to it is not uncommon to find a cup-shaped depression—a kind of crater at each pole; but I have never seen this so large as in the prolate-spheroidal lens of the cuttle-fish.

Nucleus of the lens.—It is further to be observed that the individual fibres become narrower and denser, as well as more intimately held together, as they approach the centre of the lens; and it is obvious that they must also become shorter and shorter. The degree in which their density augments, varies, however, very widely: in the bird, for instance, it is far less than in the fish; so that the lens of the former is soft and pulpy, even to the centre, while the nucleus of the latter is often of almost stony hardness.

What I have now said as to the shape and texture of the lenticular fibres applies in general to the eyes of most animals. These fibres are always narrowest at their ends, shorter and denser towards the centre of the lens. The mode, however, in which their extremities are arranged at the poles, exhibits many very curious modifications, as to the use and meaning of which we are still very much in the dark, but which, in the meantime, will repay a few moments' attention as instances of elaborate mechanism, in which may be concealed some clue both to the nature of the nutritive changes in the organ, and possibly to the better comprehension of some of its morbid states, and the means for their relief. The effect, also, of these modifications of structure on the transmitted light should not be lost sight of in considering their design.

Central planes.—The first departure from the simple arrangement already mentioned—in which all the fibres diverge from, and terminate in, the antero-posterior axis of the lens—is met with in some fishes and some mammalia, of which the porpoise is one. Looking at the front of the lens we see a straight line passing through the pole, and reaching about one quarter or one-third of the way towards the margin or equator on each side. From this line the fibres diverge in an uniform manner, and passing over the edge, may be traced converging on the opposite surface to a line of similar length passing through the pole, but at right angles to the first,—so that if the one is vertical the other is horizontal. This being so, a moment's consideration will enable you to understand that none of the fibres reach half round the lens—that, for instance, one which starts from the anterior pole (or the centre of the anterior line) cannot reach the posterior pole, but terminates at the extremity of the posterior line; while one which starts from the end of the anterior line is necessarily brought to the posterior pole; and the intermediate ones in a similar manner, according to their position. Now, if we remove the more superficial strata of fibres, we still find the deeper-seated fibres diverging from similar lines, and discover, in fact, that the lines seen on the surfaces are but the edges of planes which penetrate even to the central region of the lens,—these planes being productions or expansions of that axis in which, in the spherical variety of lens, all the fibres meet.

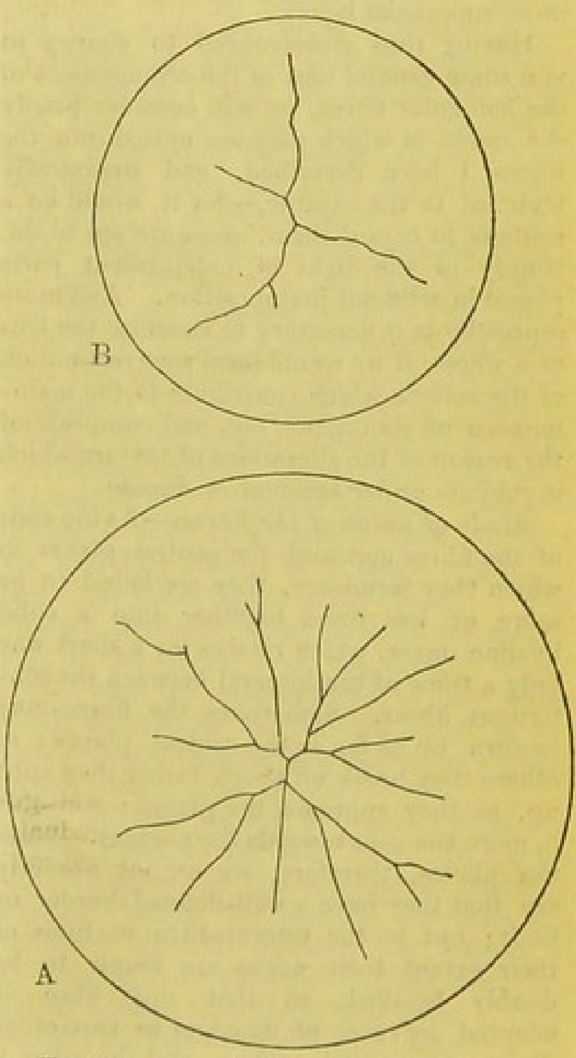
Object of the central planes.—These planes are widest where they appear on the surface of the lens, and are gradually narrower inwards; and those of opposite sides meet, although at right angles, somewhere in the antero-posterior axis, at a point the position of which (or in other words, the respective depth attained by the planes,) is determined by the various curvatures of the opposite surfaces of the lens. But as every fibre has in each plane a point answering to one of its extremities, it follows that the area of the two planes must in all probability be equal, and therefore that where one passes from the pole more deeply into the lens, the other must extend more widely towards the margin.

It certainly appears to me that the expansion of the axis into the planes now described, and the concomitant complexity of the arrangement of the fibrous constituents of the lens, are designed to furnish the mechanical means of producing a different curvature on opposite surfaces.

If we pass to the examination of other bases, further modifications of the axial planes, and consequently of the arrangement of the fibres, are met with. For example, in some of the cetacea I have found the planes to bifurcate irregularly, and to a variable extent, towards the margin of the lens—a disposition not, I believe, before observed; but the most elegant arrangement is certainly that of the mammalia in general, in which three equidistant planes diverge from the axis,—those of the front and back holding intermediate positions, precisely as in the more simple case already described.

Their complexity in the adult human lens.—But of all the specimens that have come under my own observation, those of the adult human lens have presented the greatest multiplication or subdivision of these planes; for while our own lens adheres to the ordinary mammalian type in possessing a triple divergence from the pole, each of the three planes is almost immediately branched, if I may use the term, and this not once only, but twice or more,—so that instead of three segments we have as many as twelve or sixteen, the numbers being irregular no less than the course, direction, and extent of each.—Fig. 11.

Fig. 11.



A. Division of central planes as seen on posterior surface of an adult human lens.
B. Same from the fœtus of nine months.

Fig. 11, copied with accuracy from an adult human lens, will convey a better idea of the arrangement of these planes than mere words can express; and if you will endeavour to picture the opposite surface as if seen through this one, and intersected with a somewhat similar radiation of planes, placed intermediately to these and receiving the opposite ends of the fibres, you will understand the extraordinary intricacy of the construction of this organ in our own eye.

Their simplicity in the human fœtus.—I may mention in this place an interesting fact which I noticed in comparing the fibres of the fœtal and adult lens in the human subject. It is this—that as development proceeds, and the lens becomes wider and flatter, the central planes extend themselves further and further from the axis, and at the same time branch again and again, so as to multiply the segments, into which they divide the lens.—See fig. 11.

From this it may be inferred that the multiplication of the mesial planes outwards is a process necessary to the expansion and flattening of the organ, and takes place by the deposition of new fibres on the surface of the old; and also, that even in the adult lens the planes remain simply tripartite in the nucleus, being only multiplied in the more superficial layers.

Having thus endeavoured to convey to you some general idea of the arrangement of the lenticular fibres, we will consider briefly the mode in which they are united into the forms I have described, and organically attached to the capsule,—for it would be a mistake to regard them, as we are apt to do, simply in the light of independent parts placed in artificial juxtaposition. And more especially is it necessary to consider the lens as a whole, if we would form a correct notion of the actions which contribute to the maintenance of its organic life, and comprehend the reason of the alterations of texture which it exhibits under accident or disease.

Mode of union of the fibres.—As the ends of the fibres approach the central planes in which they terminate, they are found to be more or less fused together into a solid hyaline mass, which retains for a short way only a trace of the interval between the contiguous fibres. Sometimes the fibres may be torn up as far as the central planes; at others they break off short, rather than split up, as they approach the planes: and this is more the case towards the nucleus. Near the planes, therefore, we cannot properly say that they have a well-defined border or limit; but in the intermediate portions of their extent their edges are found to be doubly bevilled, so that one fibre is adapted by each of its edges to two other fibres—one a little above, and the other a little below it; and if we consider these bevillings as separate sides, each fibre would be six-sided. But we further remark that the bevilled margins are more or less jagged, and that the projections and sinuosities of the opposed fibres mutually interlock. Thus each fibre is intimately united by its toothed edges to four others, and by its smooth flattened surfaces it touches two others—one over and the other under it. The lateral union of the fibres being the more intimate, determines the division of the lens into layers enclosed one within another, rather than into segments. But if we obtain a fortunate view of the fibres in situ and in section, it is easy to perceive that the lateral junctions of the fibres of successive layers lie in regular order one below another; and that if the splitting of the lens could be made to follow these joinings, we should reduce the organ to a number of segments, the thickness of which would correspond with the width of one fibre.

The indented margins of the fibres are much more obvious, and are no doubt really much more developed, in some classes of animals than in others. It was in the eye of the cod that Sir David Brewster first detected them, and they are nowhere more evident. The teeth have a certain average size; but, like those of the cranial sutures, they are irregular in shape, and have been manifestly formed by the shooting together of contiguous parts during growth. In the lens of the bird, and in that of mammalia and man, they are even less regular in size, and far less defined; and it is often difficult to see more than a soft woolly margin. The toothed borders are usually most apparent when the albuminous basis of the fibres has been hardened by heat, or a chemical reagent.

Use of the toothed margins of the fibres.—What, now, is the use of the serrations of the fibres of the lens, and why do they exist only at the sides? In the fish, which has the fibres very flat, and consequently with thin edges, and a small surface for lateral contact, the teeth are large, stiff, and well defined; whereas in the higher animals, where the fibres are thicker, and their bevilled edges present a broader surface of union with those on either hand, the teeth are softer and less developed: and in all cases the broad surfaces of the fibres are not toothed at all. We may therefore regard the serrations simply as an artificial mode of increasing the points of union between the fibres, according as their shape renders necessary. If the fibres had been six-sided, and the sides equal, we may suppose, either that there would have been no teeth at all, or, if any, that they would have been developed to an equal extent on all the sides. Thus far, perhaps, it is legitimate to speculate on the final cause of this remarkable and elegant structure.

Intra-capsular cells of the lens.—Immediately within the capsule, separating it from the superficial fibres, is a layer of cells, extremely thin and transparent, of unequal size, and nucleated. These cells form an organic union between the body of the lens and its capsule, and it is through them that the nutrition of the fibrous part is conducted. It is by the multiplication and successive transformation of these cells into fibres that the body of the lens increases in size; and when its growth is complete, a single layer of them remains. The superficial fibres, even of the adult, often retain some of the nuclei, in an extremely transparent form, at irregular distances in their substance.

The liquor Morgagni a result of disease or post-mortem change.—When, after death, the lens is placed in water, or allowed to lie in contact with the aqueous humour, the water passes through the capsule, and distends and bursts these cells, collecting between the lens and the capsule, and raising the capsule as I mentioned at an earlier period of the lecture; but no fluid exists during life between the capsule and fibres of the lens, except what belongs to the texture of the cells. There is, then, no such fluid as the *liquor Morgagni* in the healthy lens. When this fluid exists in the cataractous lens, between the body and the capsule, or when it is found there after death, it is to be regarded as a morbid or false condition, indicative of the destruction of the layer of cells which has been just described.

The "capsule of the aqueous humour" does not exist.—Some authors speak of another layer of cells on that portion of the outer surface of the capsule which contributes to form the posterior chamber of the aqueous humour behind the iris, and they consider it to resemble, and to be a continuation of, the epithelium lining the back of the cornea, and which I have termed the epithelium of the aqueous humour. Such a layer has been imagined necessary for the completion of that serous sac which has been very generally supposed to enclose the aqueous humour, and which has passed under the name of the *aqueous capsule, or capsule of the aqueous humour.* Now, with regard to its existence on the front of the lens, I can only say that I have sought for it with great care, but in vain; and I therefore do not believe that it exists. Taking the perfectly fresh eye of a large animal, I have removed the cornea by a circular cut with scissors, without allowing the cornea to touch or rub against the lens. I have then, with equal caution, cut away the iris, so as fully to expose the front of the lens; I have then most carefully made a circular incision in the front of the capsule, near its rim, and have placed the portion so detached on glass, flat or variously folded, and always without being able to distinguish any trace of such cells. Now, with far less nicety, it is most easy to see the posterior epithelium of the cornea, and the intra-capsular cells of the lens; and the evidence, therefore, seems to me sufficient for disbelieving in the existence of the layer now spoken of: particularly as I am not aware that any author who has described it has stated that he has actually seen it.

I shall now say a few words on some varieties of cataract, the appearances of which (capable of being discriminated during life) derive illustration from what I have now explained of the structure and arrangement of the lenticular fibres.

Remarks on some appearances of cataractous lenses.—The congenital opacity of the lens, so frequent in children, affects the entire substance. We may sometimes observe upon its front surface the simple trilinear division into segments which, in the human subject, is peculiar to early life.

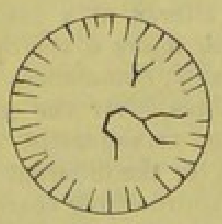
In the commencing cataract of middle or declining age, we not uncommonly find the posterior surface of the lens first affected, so that we look through the transparent lens upon an obviously concave opacity. This opacity sometimes, and indeed generally, encroaches from the margin in distinct streaks of irregular thickness, length, number, and distance apart; and we usually find that, when the pupil is widely dilated by belladonna, some at least of these streaks are traceable round the margin for some way over the anterior surface. So long as small portions of the hinder surface of the lens remain clear, the body and front being also clear, it is surprising how much visual power may remain. At a subsequent period, the centre of the lens begins to be cloudy, and then the progress towards blindness is more rapid. Now I can entertain no doubt that the streaks in these cases are sets or bundles of the superficial layer of lenticular fibres, reduced to a state of opacity by some nutritional change. There seems to be a disposition in the fibres of the lens to become opaque in their entire length when once they are morbidly altered at a single point, and hence the linear figure of the opacity. The opacity, probably, commences in the middle part of the fibres, near the margin of the lens; and the arrangement of the fibres would account for the different length of the streaks, some approaching nearer than others to the central point on the surface.

In another variety of opacity in adults, loosely allied to the last, there are streaks visible, either on the anterior or posterior surface, before the nucleus manifests any tendency towards dulness, but instead of converging from the border of the lens, they rather diverge from the central point. These streaks are also irregular in number and direction; and it has never occurred to me to distinguish in them any exact representation of the edges of the mesial planes as they are seen on the surface of the prepared lens: never, certainly, any trilinear figure. But a glance at the representation above given of the complex arrangement of the mesial planes in the adult human lens, will suffice to explain why they are rarely seen in such opacities. In the natural lens they are in reality too near together, and too irregular, to be detected without a glass. The triple divergence from the axis can, even then, only be recognised for a short distance, beyond which the planes seem to diverge and branch without any attempt at geometrical precision. We cannot, therefore, wonder that an opacity, spreading from the centre of the surface of the lens, and which consists of broad, ill-shapen streaks, should fail to disclose the delicate and complex radiation of the mesial planes: although it seems highly probable that its seat is, primarily and essentially, rather in the edges of both planes, than in the fibres themselves.*

In the lenticular cataract of adults, the glistening, silky, fibrillation of the lens may be often seen; but you will fail, even in the best-marked of these cases, to discover, with the naked eye, any thing like regularity in the mode in which the fibres pass off from the central region. Before becoming acquainted with the complex arrangement of the planes in the human lens, I could not satisfy myself why the triple line of the mammalian lens should be unseen; but the actual complexity is a sufficient reason. It explains, too, the appearances of many cases of opacity of the body of the lens, where the fibrous texture is in general obvious enough, but where, towards the centre, an amorphous, indefinable, obscurity exists.

* Since this lecture was delivered, I have seen two cases (one under the care of Mr. Dixon) in which the opacity radiated from the centre in clearly-defined branching lines, corresponding exactly in character with the branchings of the central planes. The opacity was confined to the

FIG. 12.



Cataractous lens, in which the opacity follows some of the divisions of the central planes of the lens, and some of the fibres at the circumference. The pupils dilated by atropine.

surface of the lens, and did not dip in the direction of the planes; neither did it occupy all the divisions of the central planes. It was accompanied, in both cases, with other streaks of opacity at the border of the lens, evidently in some of the fibres.

LECTURE IV.—*Concluded.*

Of the aqueous chambers—cyst of the iris—aqueous fluid—its source—removal of blood effused, if coagulated or not—if chambers are occupied by serum. Of the retina—vascular and non-vascular coats. Common elements. 1. *Gray fibres and their evolution from the optic nerve.* 2. *Gray vesicular matter.* 3. *Caudate nucleated vesicles.* 4. *Agglomerated granules, divided into granular and nummular layers, with intervening pale stratum. Peculiar elements.* 5. *Rods.* 6. *Bulbs, in man and animals—of the yellow spot—modification of the layers of the yellow spot—colour where situated.*

HAVING concluded what I had to say on the structure and arrangement of all the parts which bound and form the aqueous chambers of the eye, we may proceed to consider very briefly the shape and contents of these chambers themselves.

Of the aqueous chambers.—The chambers are that cavity in the eye occupied by the aqueous humour, and lying between the cornea in front and the lens with a portion of its suspensory ligament behind, and they are divided from each other by the iris, but communicate through the pupil. The cornea bulging forwards away from the iris, and the lens bulging forwards towards it, or even up to it, cause respectively the large and small size of the anterior and posterior chambers; but, besides this, the circumference of the anterior chamber is much wider than that of the posterior, by reason of the much nearer approach of the ciliary processes than of the pillars of the iris, towards the axis of the humours.

To speak more particularly of the limits of the two chambers, the *anterior* is bounded in front by the posterior epithelium of the cornea coating the posterior elastic lamina of that structure. At the border it is limited by the passage of a part of this lamina to the front of the iris, the epithelium being very imperfectly, or not at all, continued over that part. Behind, it has the anterior surface of the iris, which I believe is not invested with any definite epithelial structure distinguishable from its own peculiar fibrous and nucleated tissue, but is, as it were, bare and exposed to the contact of the aqueous fluid,—so that in cases where we are able to perceive the delicate fibrous cordage of the iris, as if elegantly dissected in the natural and living eye, this cordage is not seen through a film of epithelium; and, in those instances, especially of the darkly-tinted eye, where the interior arrangement of the iridial fibres is unseen, it is simply concealed from view by the quantity of pigmentary particles accumulated both in its interior and on its surface, not more on the latter than in the former, and not on the latter in the nature of an epithelial lamina.

In the fœtal eye, previous to the seventh month, and imperfectly at a later period, the membrana *pupillaris* passes across the pupil, and closes the anterior chamber, then very small. It passes from a circle on the front of the iris, a short way from the true pupil, where the knotted appearance of the fibres is so often visible in the adult eye, and where it sometimes leaves faint traces of its existence throughout life, in the form of minute threads or spurs standing off from the original line of attachment into the aqueous humour.

The *posterior* chamber is bounded in front by the surface of the iris, on which is a layer of epithelium, loaded with dark-brown pigment, and easily separable from the proper tissue of the iris. If we place a fresh human eye in water after having divided it through the middle, it is not uncommon to find this layer of pigmented epithelium rise in the form of a small blister from the surface of the iris, in consequence of the imbibition of the water in which it is placed; and sometimes after death the same thing occurs, from the imbibition of the aqueous humour itself, just as the aqueous humour is generally absorbed into the capsule of the lens, and distends it under the like circumstances.

Cyst of the iris.—I may here mention a very remarkable and interesting, but rare disease of the iris, which appears to me to consist in the morbid formation of transparent fluid between the iris and this posterior layer of epithelium (the *uvea*, as I omitted to say, it is called). This disease is not accompanied by any other, is of slow progress, and appears first as a bulge of a portion of the iris towards the cornea. I imagine that the first formation of the fluid is attended with a swelling of the uvea backwards towards the suspensory ligament and lens; but, as the contact of these resisting parts must very speedily arrest any further advance in that direction, the accumulating fluid next begins to push forward the proper tissue of the iris, which separates it from the anterior chamber. Here it meets with less resistance. The highly extensile fibres of the iris slowly yield, until in the course of months they bulge to a large extent before the fluid, and come into contact with the cornea, and that sometimes so widely as to throw the pupil towards the opposite side, and even to put it out of sight, by becoming rolled in front of it. A case of the disease is given by Dr. Mackenzie (Case 263, Practical Treatise on Diseases of the Eye). If the cyst be punctured in front, the transparent contents are ejaculated with force by the undiminished contractility of the distended iris, and in the course of a few minutes there remains no trace of the pre-existing disease, the iris having in all respects resumed its natural aspect. The cavity, however, is apt to refill more than once. In Dr. Mackenzie's case, it was punctured a second and third time, at intervals of six or eight weeks, and afterwards never returned, vision being perfectly restored. It is evident in this disease, that the muscular tissue of the iris is expanded over the fluid, and, therefore, the characters of the disease give no support to the opinion that the iris is invested in front with a serous membrane (aqueous capsule). If the wall of the vesicle were simply a serous membrane, it would not so immediately contract on being punctured; and besides, during the process of contraction the membrane can be seen gradually assuming the well-known fibrous aspect of the iris. It is also evident that the uvea (which is always dark) is not protruded with the muscular tissue, but separated and thrown posteriorly; for, if it were in front of the fluid of the vesicle, its pigment would be obvious enough in the attenuated tissue, whereas it is not visible there.

But, to return from this digression: the uvea thus bounding the posterior chamber in front, does not line the iris or the posterior chamber after the manner of a serous membrane, reflected from one part of the chamber wall to another, but appears to be a continuation of the epithelium of the choroid, as it may be traced to the iris from the ciliary processes. In the adult it has not usually so regular a form as where it lines the choroid, but in the fœtus it consists of spindle-shaped cells, with central transparent nuclei, and with dark pigment filling up all their other part.

Between the tips of the ciliary processes and the lens, the suspensory ligament of the lens, forming the anterior wall of the canal of Petit, bounds the posterior chamber, and then the front of the capsule of the lens. Neither of these structures is covered by any epithelium, both being in immediate contact with the aqueous fluid.

Aqueous humour: its source.—The aqueous humour itself is little more than water, less than one-fiftieth of its weight being solid matters (chiefly chloride of sodium). Thus, it is very different from the serum of blood, and may be strictly regarded as a secretion, depending for its integrity on a healthy state of the parts which furnish it. What these parts are, it is difficult to define with accuracy, although doubtless they are a portion of the walls of the chambers in which the fluid lies. It seems to me to be certain that portions of both anterior and posterior chamber secrete this fluid, not merely because it is found in both before the removal of the membrana pupillaris, but also from the fact, which we see in practice, that after the complete closure of the pupil by adhesive deposit, both anterior and posterior chamber may retain their aqueous fluid. When the pupillary margin has become adherent to the lens, we very frequently find the contents of the anterior chamber recovering their natural condition. But it may not be so generally known, that in some cases of slow enlargement of the globe, and distension of the anterior portion of the sclerotica, consequent on perforating ulcer of the cornea, and obliteration of the anterior chamber by adhesion of the iris to the corneal cicatrix, the aqueous humours secreted into the posterior chamber in too great abundance, but in a natural state as regards its quality, is the occasion of the enlargement. It appears probable from their structure, that the posterior surface of the cornea, and both surfaces of the iris, with the tips of the ciliary processes, are all concerned in the formation of the aqueous humour, and that the suspensory ligament of the lens, and the anterior capsule, do not share in this function.

Blood effused into the chambers.—It is a wonderful thing to see blood which has been poured into the aqueous chambers by some accidental blow upon the eye, disappear in the course of a few days by solution in the aqueous fluid and absorption. If the organ escapes active or disorganizing inflammation, a week or ten days are often sufficient for the removal of blood which has nearly filled the chambers: but something even then will depend on circumstances. If the blood has coagulated into a firm clot, its absorption is retarded. I had recently a case in which a young man had an injury to the eye late in the evening, but soon after went to bed and slept soundly. When I saw him next morning, I observed that he had been sleeping on his right side, for the blood had formed a clot, occupying about the right two-thirds of the chamber, and bounded by a very sharp but somewhat concave or cupped edge, placed vertically. It was remarkable that the iris (at least the uncovered portion of it) remained freely moveable. When the pupil was contracted by a strong light, he was blind with this eye, but the eclipse of the pupil became only partial when he turned with his back to the window, so as to dilate it in concert with the opposite one, and he could then see. This clot was absorbed in about a fortnight. On the other hand, when the blood is diffused through the aqueous humour, by frequent change of posture, during the period when it might coagulate, it does not form a solid clot, and is more speedily absorbed, sometimes, if in small quantity, in three days.

I imagine that the blood in such cases mixes with, and its red particles swell, and give up their colouring matter to, the aqueous humour as they would to water, and that this is the occasion of their very rapid disappearance; for a most remarkable difference is noticeable between the result in these instances, as compared with those in which blood escapes into the chambers, when they are already occupied by yellow serum, the consequence of pre-existing disease. For here the blood may remain for many months almost entirely unchanged, either in colour or quantity, just as it might do in a bottle of serum, excluded from the action of the air. The serum does not dissolve the red particles nor the coagulated fibrin, how then could we expect these to be absorbed? Nevertheless, a very slow change does go on; some slight differences are constantly taking place between the variable serum of the blood and that occupying the chamber, owing to which a very gradual interchange is wrought between them, and the clot becomes paler. I have watched a small clot during six months, under these circumstances, ere it lost its shape or characteristic hue. Time does not allow me to allude to the changes in the aqueous chambers occasioned by inflammation, many of which are of the most interesting character, and most instructive to the student of pathology.

I propose now to pass from the review of those parts of the eye which lie within the range of the operations usually performed on the globe, and to devote the rest of this lecture to a brief sketch of the structure of the retina, for I should be unwilling to conclude the present short course without some account, however imperfect, of that portion of the eye, which, in a physiological sense, is the most essential of all, and which will be found to be as wonderful and elaborate in structure as it is important in function.

Of the retina.—The retina is that peripheral nervous sheet on which the images of external objects are received. It is continuous with the optic nerve, and is expanded within the globe between the choroid and vitreous humour, as far forwards as the *ora serrata*, the situation of which has been already pointed out. Its surfaces may be styled choroidal or outer, and hyaloid or inner. It has the pinkish gray colour of the surface of the cerebral convolutions,—is very soft and easily torn,—and is arranged in certain layers, the inner of which contain the bloodvessels that impart the pink tint to the whole, while the outer are non-vascular. All the superposed layers of the retina are thicker at the bottom of the eye, around the entrance of the optic nerve, than in front near the ora serrata, and the entire nervous sheet becomes gradually thinner forwards, until it ends abruptly at the line indicated, being there continuous with that granular tissue which lines the ciliary processes of the choroid, and gives origin to the fibrous part of the suspensory ligament of the lens.

Constituents of the retina.—Now, the retina contains in itself all the structural elements which are to be found in other parts of the system, *except nerve-tubules*, which are not present in the human retina, nor in the retina of the higher animals, but only in the optic nerve; and it moreover contains, besides these, other structural elements not elsewhere met with, but peculiar to this part, and which we are therefore led to suspect may be in some way or other subservient to the proper action of the retina as a recipient of the vibratory impressions of light.

The *elements common to the retina with other portions of the nervous system* are placed internally, or towards the hyaloid surface. These are:—1. *Gray fibres*, radiating on all sides from the entrance of the optic nerve, towards the anterior border of the retina, and being a continuation of the nerve-tubules of the optic nerve. They are gradually less abundant forwards, terminating in succession among the next mentioned elements. 2. *Gray nervous matter, similar to the cineritious part of the cerebral convolutions* (being an amorphous finely granular matrix, containing nucleated nerve-vesicles). 3. *Caudate nucleated globules*, analogous to those found in the ganglia, spinal cord, and certain parts of the brain. 4. *Agglomerated granules*, usually highly refractive, with very little intervening material, and allied to the nuclei of cells, such as are met with in some portions of the encephalon. Capillary bloodvessels are distributed among all but the last of these.

The *elements peculiar to the retina* are situated externally, and together form the coat commonly known as Jacob's membrane. They are of two kinds—5. *Columnar particles, or rods*, arranged vertically in a single series; and 6. *Bulbous particles*, interspersed at regular intervals among the former. Both of these are found among the lower animals in many most remarkable modifications, some few of which I shall presently mention, on account of their singularity, and to shew that they probably play an important part in the physiology of vision, though into the nature of their function we have as yet no particular insight. These elements, like the agglomerated granules, have no bloodvessels proper to them.

Of the gray fibres of the retina.—We may now pass these several elements more distinctly in review, and first, of the gray fibres. If we make a section of the coats of the eyeball through the part at which the optic nerve traverses them to join the retina, we see that this nerve becomes reduced in bulk as it is passing through the sclerotica, so that a transverse section of it, where it approaches the sclerotica, has nearly double the area of its intra-sclerotic termination, and the sclerotic canal is a truncated cone. We also observe that whereas the nerve behind, and for a little way within, the sclerotic canal, is opaque white, the tubules having their proper investment of white substance, it becomes gray and semi-transparent ere it touches the retina, and the retina itself has never any white glistening aspect such as the nerves have. In different animals, indeed, even among the mammalia, you will find great variety as to the precise point at which the nerve loses its whiteness, this point being sometimes only at the very junction of the nerve with the nervous expansion within; and in certain cases (of which the rabbit is the best example) the nerve advances a certain way within the choroid, and spreads out on the surface of the retina before it loses its whiteness, so that the retina in these animals appears to present a white area of an oval shape, and an eighth of an inch long, at the sclerotic aperture, and in some animals yet lower in the scale, nerve-tubes, with a very delicate layer of white substance, can be traced even further, and more uniformly distributed over the retina. But still it remains true, as I believe, for all, and certainly for man, that nerve-tubules, such as form the optic nerve, do not exist as a part of the retina, and where they enter within the sclerotica they are to be regarded as still the optic nerve in its course to the retina.

Now, what is the nature of the change in the constituents of the optic nerve by which they lose their whiteness as they penetrate the sclerotica? They certainly do not terminate in the sclerotic canal; they cease to be characterized by their dark outline, and by their tendency to fall into the varicose or beaded state, but remain fibrous: in a word, they lose their white substance, but retain their axis or central fibre, and these fibrous parts coming together, advance and form the gray fibres of the retina. I have made many very thin sections through the nerve and retina in connection; and you will find, if you do the same, that these fibres, on entering the globe and encountering the hyaloid, pour themselves as it were on all sides in bundles over the hyaloid surface of the retina, and become coated at once, on their opposite or choroidal surface, with the elementary structures which I have enumerated as forming the other strata of the retina.

FIG. 13.

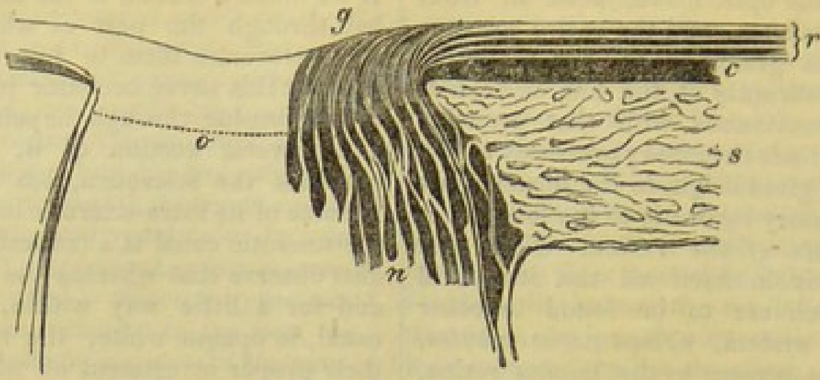


FIG. 13.—Section of the coats of the human eye at the entrance of the optic nerve, to shew the mode of origin of the layers of the retina. *s*, Sclerotica; *c*, choroid; *n*, plexiform bundles of optic nerve; *o*, line at which these lose their white substance; *g*, grey fibres advancing to the retina, and becoming clothed on their choroidal surface with other layers, constituting *r*, the retina.

It follows, of course, that in the space occupied by the evolution of these grey fibres from the optic nerve, *i. e.* for the area of the inner orifice of the optic foramen or sclerotic canal, these strata of the retina do not exist—that *the retina*, in fact, does not exist; therefore it is no wonder that this spot should be blind—insusceptible of stimulation by light. The blindness of the spot (proved by a well-known experiment), in connection with the anatomical fact which I now point out, shows how essential to the visual power of the retina are its non-fibrous parts, so that we might almost say that the visual impression is received by the non-fibrous parts, and merely propagated by the fibrous: that the true retina is not an expansion of the optic nerve, but a nervous organ of independent structure, brought into co-operation with the brain through the nerve. But to proceed with the anatomy of the grey fibrous stratum.

In some animals (I allude particularly to some fishes) their radiation over the whole retina may be very easily made evident to any one by a slight maceration, for the retina shaken in water becomes divested of all but these fibres, and they seem to form a brush directly continuous with the nerve.

But in the higher animals it is usually more difficult to demonstrate such a disposition; both because this layer is much less readily detached from the rest, and because its fibres are disposed in bundles which, after anastomosing together for some way, become blended with each other into a uniform lamina, and are lost among the grey nervous matter (2). In the fresh human retina they may be seen by looking directly on the inner surface, near the optic nerve, with a power of 50 diam.

FIG. 14.

FIG. 14.—Anastomosing grey fibres of human retina, seen on their hyaloid surface, near the optic nerve: magnified.

The bundles there are large, but of different sizes, and anastomose so as to form very elongated meshes, in which large nucleated vesicles soon begin to appear. The bundles of the plexus are not cylindrical, but much compressed on their contiguous sides, so that, on a vertical section, they appear oval; otherwise this plexiform arrangement is a mere continuation of that of the bundles of tubules in the optic nerve, now forming a sheet instead of a cylindrical cord.

Of the central artery and vein.—While speaking of the manner of evolution of the optic nerve at its coalition with the retina, it may be mentioned that the blood-vessels of the retina enter and leave it along the centre of the optic nerve, by two fibrous canals there provided, among the fibrous meshes in which the plexiform nerve bundles lie. Arrived within the sclerotica, they subdivide and ramify upon the retina, the large branches which they form being, for a short way, interposed between the hyaloid and the grey fibres, but very speedily sinking in among these, and breaking up, by successive divisions, into the capillaries which supply and occupy the substance of those layers to which I have already described them to belong.

2. *Of the grey vesicular matter of the retina.*—This lies contiguous to the hyaloid surface, in close relation with the last mentioned layer. It is the most vascular coat of the retina, and, in fact, receives the greater portion of the blood brought by the retinal artery. The capillaries form a very beautiful plexus, with meshes about as close as those of the grey matter of the cerebral convolutions, though arranged nearly on one plane. The walls of the capillaries are a simple membrane, with nuclei at intervals. It is easy, at a suitable period after death, to wash out the nervous matter from their intervals, and to obtain a separate view of the whole vascular system of the retina; and in a perfectly recent specimen, also, the capillaries can be discerned among the matter of the layer now under consideration, often with the red corpuscles still within them. The finely granular matter of this layer is readily seen with a sufficient magnifying power, and also the nuclei which it contains; but it is not so easy to discern the delicate nucleated vesicle, which it so abundantly contains; for, like those of the grey matter of the cerebral convolutions, they are very rapidly destroyed or altered by pressure or water. On some occasions they can be most distinctly seen, especially in one part to which I shall have to refer presently: and it is almost always possible enough to discover their clear globular vesicular nuclei, in a detached state, floating about the fragment examined.

3. *Of the caudate nucleated vesicles.*—It is most interestfng to meet with these very singular forms of nervous tissue in the retina, though we at present know little of their use. We have, now, ample proof of their being centres from which, in many parts at least, nerve-tubules pass, the slender processes of the vesicles becoming continuous with the axes of the tubules, and requiring, at a certain distance from their origin, a coating of white substance.

I am not aware that any one else has yet discovered this kind of vesicle in the retina. In man, and the higher animals, it is by no means easily distinguished, for the examples of it are small, and hard to detach from the substance of the last layer, with which they are in connection, and so similar in texture to that substance as not to be visible in it without separation. Nor have they here any pigment, as in so many other parts of the nervous system. That they do exist, however, is certain; for, on different occasions, I have seen many unequivocal examples of them, and especially in two or three specimens of diseased retina, in which the texture was somewhat broken down by a morbid process. Among the mammalia I have seen them in the human subject and in the horse: but I have never witnessed so satisfactory a demonstration of them *in situ* as in the retina of the turtle, where they lie at or near the hyaloid surface, dispersed at pretty equal distances, and with long and branching arms, which spread abroad, indifferently, in all directions, so widely as to approach each other near enough to anastomose together, though I have never seen them actually coalesce.

In making a vertical section of the retina in the higher animals, we very generally find an ill-defined, dark, but broken line, running parallel with the surface, in the substance of the vascular portion; and it has often occurred to me that this may be an indication of the position of a layer of these caudate vesicles intervening between the fibrous and the gray vesicular matter (1 and 2), but this explanation of the appearance requires confirmation.

It would not be difficult to hazard conjectures as to the connections of these caudate vesicles with the fibrous elements, and as to some special purpose they may serve in the economy of the retina; such, for example, as that of bringing into functional relation the several parts which their caudæ may connect, &c., but such conjectures can at present lead to nothing. When we come to know the general history of the caudate corpuscles in the several organs, and in the animal scale, we shall probably obtain some clearer insight into the meaning of their existence in the retina.

4. *Of the agglomerated granules.*—Lying externally to those already described, the agglomerated granules form a very considerable proportion of the entire thickness of the retina, viz. about one-fourth or one-third. They lie in *two layers* (*n* and *g*), between which intervenes a thin layer, *p*, of which I am able to give you no definite account, except that it is more transparent, exhibits no globules, nor any distinct texture, though sometimes looking finely fibrous, and that it apparently contains no blood-vessels. The inner of the two layers (*n*) is always much thinner than the outer, and often consists of but two or three series of granules, which are also different in figure from the others, being flattened, with their surfaces more or less corresponding to those of the retina, and often looking much like pieces of money seen edgeways. From this fanciful resemblance, and for distinction sake, I have sometimes termed this the *nummular layer*. The outer layer (*g*), or *granular layer*, is much thicker: its constituent granules are globular, closely packed, with little sign of any surrounding cells, though a matrix, or inter-granular substance, can be seen on a broken edge.

The granules cohere intimately, and when placed in water generally refract the light in a decided manner, quite different from that of the other elements of the retina. They have no blood-vessels.

FIG. 15.

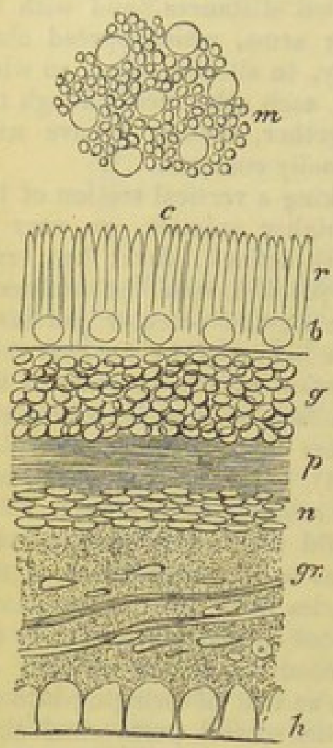


FIG. 15.—Vertical section of human retina (previously dried when quite fresh) half an inch from the *ora serrata*. *r*, Rods detached at the line *c* from the choroidal epithelium; *b*, bulbs; *g*, outer layer of granules; *p*, intermediate more transparent layer, obscurely fibrous; *n*, inner layer of flattened granules (nummular); *gr*, grey nervous layer, fibrous and vesicular, and containing capillary vessel; *h*, hyaloid; *m*, deep or inner surface of Jacob's membrane, shewing rods and bulbs. The appearances in this specimen were beautifully distinct, as represented. (320 diam.)

Of the peculiar elements of the retina.—These constitute that extremely delicate film on the exterior of the retina, first distinguished by Dr. Jacob, and since commonly called by his name. This film is in contact with the choroidal epithelium, and has a very slight organic connection with it, which I shall presently explain. Sometimes this epithelium is partially drawn off the choroid with the retina in consequence of this adhesion; at other times, Jacob's membrane separates with the choroid. It can easily be washed away from the rest of the retina, its adhesion to the layer of agglomerated granules being but slight. Jacob's membrane was at one time generally regarded as a serous membrane, though not by its discoverer himself. By some it has been supposed to belong rather to the choroidal epithelium than to the retina; while Hannover styles it *the retina properly so called.*

Much disagreement exists with reference to the precise structure of this singular part, which is attributable in some measure to the great proneness its elements have to change after death, either with or without contact with water or various fluids. On this account, it should be examined as fresh as possible, and with every precaution. The changes it undergoes are, however, very well worth studying in themselves, since they exhibit the peculiar properties of its elements, as tests do those of a chemical compound, and these properties may, I think, elucidate some morbid actions now most obscure. The elements may be distinguished as *rods* and *bulbs.*

Of the rods.—These are placed perpendicularly between the granular layer and the choroidal epithelium, are in close contact with each other, except where the bulbs intervene, and their length determines the thickness of the layer. They are transparent and solid, and either cylinders or six-sided prisms: at the inner end they are attached to the granular layer, and when detached from it terminate by a square extremity; at the opposite end, they run off into a slight cone or pyramidal process, which is received into a corresponding recess in the contiguous particle of the choroidal epithelium, each particle of this pigmentary epithelium thus imbedding the pointed extremities of many of the rods. The shaft of the rod is very apt, a short time after death, to become separated by a sharp transverse line, from the pointed process or leg. and the leg will then gather itself into a ball and disintegrate, while the shaft will bend into a hook at the outer end, or roll into a globule, or split up into transverse plates, or be reduced to a shapeless granular mass. These changes are assisted by immersion in water.

These points in the anatomy of the rods could, with difficulty, have been made out in the human retina, without the indications of structure provided in the corresponding parts of the lower vertebrata, where they are developed to a much greater size. Hannover has given a very admirable description of them in the vertebrate class, in all the great divisions of which they are constantly present; being very large in some fishes, especially the pike, and in batrachian reptiles.

From a careful examination of a perfectly-recent human eye, I ascertained that the rods were longest, and consequently Jacob's membrane thickest, at the hinder part of the globe, and that anteriorly, close to the ora serrata, they gradually shortened by more than a half, still retaining their general characteristics.

Of the bulbs.—These, in the human retina, are very much less numerous than the rods, among which they are scattered at even distances. On looking at the outer surface of Jacob's membrane with a sufficient power, (fig. 15, *m*,) we see an infinite number of minute globules (the ends of the rods), and among these, but at a deeper level, *i. e.* not coming quite up to the outer surface, solitary larger transparent rounded objects, which are the bulbs. When fortunate enough to obtain a view of the whole layer in section, cut or torn across, we see the bulbs sessile upon the layer of agglomerated granules, and distributed, at their proper intervals, among the rods, where these rest upon the granules. They appear to be globular or egg-shaped, and sometimes to have a small blunt spur upon them, turned towards the choroid. When looking down upon the choroidal surface of the retina, the bulbs, when best seen, have a small clear circle within their proper outline, and this seems referable to this projecting part.

Some light is thrown upon the nature of these bulbs by what seems to be a very large development of them in fishes, and here they present themselves in a very remarkable form, and with no less remarkable properties, as Hannover has well pourtrayed.* They are divisible into a body and legs, of about equal length; the body directed inwards—the legs outwards; the body implanted vertically among the rods—the legs tapering in the opposite direction, and imbedded among the pyramidal processes of the rods, and, in a similar manner, within sheaths furnished by the fibrous prolongations of the particles of the choroidal epithelium. The body is thicker than the legs, and has an oval or a circular section. It is also partially subdivided into two lobes: it has a distinct membranous covering, enclosing a colourless, transparent, highly refracting material, which soon changes after death. The legs are also double, one descending from each lobe and tapering to a point; and where they join the body is a transverse line of division, at which they readily break off. When placed in water, the body swells and shortens, assuming the form of a somewhat flattened balloon, which retains the bilobate form, and sometimes looks not unlike a coffee berry. The investing membrane readily gives way; the clear contents become coarsely granular, and may break up into irregular masses, or disintegrate. By the same medium there is occasioned first a transparent line of division between the body and legs, and the legs curl up at the end, or split into many transverse pieces, having a high refracting power.

Hannover supposes that these bodies (which he terms *cones jumeaux*) do not exist in reptiles (except chelonian). I have, however, met with objects which appear very similar to the bulbs of the human retina in the frog. Examining it quite fresh, under albumen, we find the appearances represented in Fig. 16. The bulbs seem nearly as numerous as the rods, among which they lie: they rest upon their proper base, are globular, with a projecting process, ascending towards the choroidal epithelium, and, near the root of this process or leg, contain a minute colourless oil-globule.

Fig. 16.

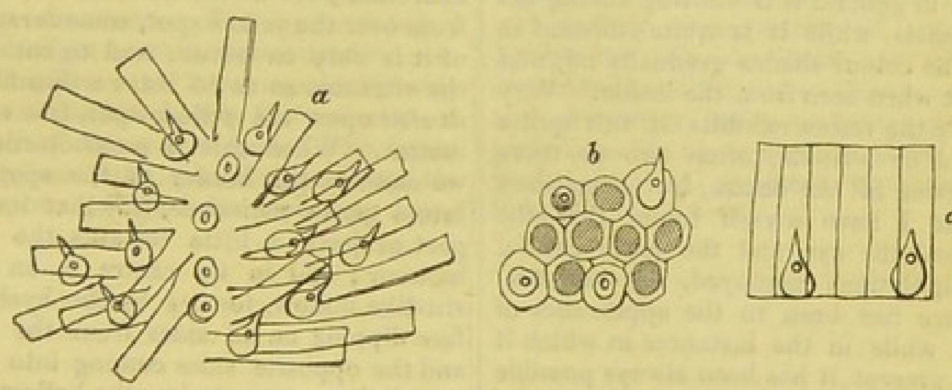


Fig. 16.—*a*, Bulbs and rods of Jacob's membrane in the frog, looking on the outer surface, the choroidal epithelium being removed. The rods are thrown down in various directions, so as to expose the bulbs among them at their base. The bulbs have a spur and pellucid globules. *b*, A similar view, but where the rods are upright, and not displaced; their base, with the bulbs, being brought into focus. The outer ends of the rods are out of focus, and appear dark shades in the centres. *c*, Same in vertical section.

This leads me to a very interesting point in the structure of both rods and bulbs in many animals, viz. the occurrence, in their outer or choroidal ends, of globules resembling oil, either colourless or possessing most brilliant tints of yellow or crimson. In the chelonian reptiles, and in birds, these are the most beautiful. I shall shew you

* Recherches microscopiques sur le système nerveux, 1844, pl. iv.

after lecture, the outer aspect of a portion of the retina of the tortoise, in which you will perceive a most elegant array of pale, of yellow, and crimson globules, scattered with regularity over the surface, the first being the smallest, and the last the largest, but all enclosed within the substance of the particles now described. It is not satisfactorily made out what is the precise relation of these globules to the rods and bulbs respectively, partly because the distinction between these elements in these animals is not fully determined; but Hannover considers the crimson globules to belong to the bulbs or *cones*, and all to be properly not globular, but of the nature of sheaths to the particles where inserted into the choroidal epithelium.

In birds we have even a more beautiful pattern of colours. In the sturgeon, among fishes, I have found the globules large, but colourless. In mammalia they are either very small, or wanting.

Of the yellow spot of the retina, or spot of Soemmerring.—If we cut across a fresh human eye, so as to look at the hyaloid surface of the retina, or if we carefully remove the sclerotic and choroid coats, so as to expose to view its choroidal aspect, we are struck with the rich yellow colour of one small spot about one-twelfth of an inch in diameter, situated at the very bottom of the eye, in the exact axis of the humours, *i. e.* at about one-tenth of an inch from the optic nerve. It exists in some monkeys, and, according to Dr. Knox, in certain reptiles, but in general it is wanting among the lower animals, while it is quite constant in man. The colour shades gradually off, and is deepest when seen from the inside. Very commonly the retina exhibits at this spot a small fold or wrinkle, often two or three folds meeting in the centre, but sometimes none; and I have myself found that the more recent the eye, and the more careful the manipulations employed, the less tendency there has been to the appearance of the fold; while in the instances in which it has been present, it has been always possible to obliterate it by delicate traction in the requisite direction. I am therefore disposed to regard this fold as a false appearance. All who are accustomed to dissect this organ are aware with how much facility any part of the retina is thrown into folds by slight violence done to the vitreous humour in exposing the inside of the eye, owing principally to the extremely feeble union existing between the retina and the choroidal epithelium. We have already seen, too, how readily the elements of Jacob's membrane absorb water. Now it appears to me that the texture of the retina at the yellow spot allows of a freer post-mortem transmission of the water of the vitreous humour through to Jacob's membrane than at other parts; and, consequently, that this part of the retina is earlier loosened from the choroid, and rendered liable to be thrown into accidental folds, than the rest; and in this way I account for the plicæ at the yellow spot, which some anatomists have regarded as a natural condition.

On removing the sclerotica and choroid with care from the back of an eye, so as to expose the outside of the retina, the yellow spot seems more transparent than the rest of the nervous sheet; no fold appears, but in its centre a minute dot, which seems like a circular hole, through which we can look into the vitreous humour. I have on some occasions seen this hole so distinctly, and with so definite a margin, that it seems impossible to deny its reality; but whether it occupies the whole thickness of the retina, being a deficiency in all the layers, I am unable positively to say. I have in one instance deemed it wanting in Jacob's membrane, which wore the appearance of passing uninterruptedly over it; but the difficulty of bringing the part under examination by sufficiently high powers, without mutilation or disturbance, and without swelling of the parts from imbibition, is such, that I would not speak too confidently on this point. The adhesion of the hyaloid to the retina is more intimate than that of the choroid to the same part; and, therefore, it is even more difficult to examine the hyaloid surface of the yellow spot with high magnifying powers, without disturbance of it, than the choroidal; for if the vitreous be detached from over the yellow spot, some derangement of it is sure to occur: and to cut through the vitreous, so as to leave a thin film of it *in situ* upon the yellow spot, is a very nice matter. When this is satisfactorily done, we observe the border of the spot to rise into a gentle eminence, so that its middle part projects a little towards the vitreous humour; and in its centre is an oval or slit-like hollow, formed by the hyaloid surface dipping on all sides from the hyaloid, and the opposite sides coming into contact, the vitreous not entering the hollow. Thus the surface of the retina at the yellow spot appears to present a slanting surface to the rays of light.

Modification of the retinal layers at the yellow spot.—The texture of the several layers at the yellow spot is much modified. In particular, the grey fibres do not pass over it in a direct course from the optic nerve to the side of the retina beyond the spot, but take a circuitous course, so as to avoid the spot, and only that small number approach the spot which properly belong to it, and terminate in it. In this respect it differs from the rest of the deeper portion of the retina, and must be regarded as more perfectly organized. In the same way, as is well known, this portion of the retina, though so near the main vessels, is not encumbered by any of the large branches, but the branches which supply the spot and the regions beyond it arch above and below it at such a distance as not to interfere with its perfection, and the spot itself has only capillaries which communicate with the arterial and venous twigs on all sides. This arrangement of the blood-vessels occurs also in animals which have no yellow spot.

The plexiform fasciculi of grey fibres approaching the spot have nucleated vesicles of large size interposed in the meshes; and as the fibres gradually lose themselves from view, these vesicles increase in number so as at length to occupy the whole surface. It is possible to see the fibres reduced to smaller and smaller bundles, and become overlaid by the vesicles; but I have never been able to distinguish any special relation subsisting between the fibres and the vesicular elements. The nucleated vesicles of which I now speak are not exactly like those met with in the retina generally; and whether they are a modification of those of the layer (2) or of the caudate vesicles, I cannot say; for at the yellow spot the inner layers are less distinguishable from one another than elsewhere: on a vertical section, they are more confused, and present, in common, a rather obscure, dark, yellow aspect. I incline to believe, however, that the vesicular nervous matter (2) is here in a high state of development, the vesicles being very numerous, and of more stable constitution than elsewhere. The layer, which I suggested might be that of the caudate corpuscles, appears to become considerably thicker, and to blend with the vesicular on the surface of the yellow spot. The layers of the agglomerated granules pass into the yellow spot, the granular layer, *g*, being thinner, the nummular, *n*, thicker than elsewhere. The two elements of Jacob's membrane are found over the yellow spot as on the surrounding parts of the retina; the rods are of the same length, but thicker, and the bulb-like bodies are nearer together.

The colour of the spot does not appear to be confined to any single texture, but appears to bathe all the textures, except those of Jacob's membrane, in a common cloud of rich yellow, deepening towards the centre. The colour is here and there in minute grains of deeper hue; but in general it does not seem to lie in proper pigment cells, but to stain fibres, vesicles, and granules alike. The colour soon disappears after death, or in water; in the dried retina it is permanently retained.

Such, gentlemen, is a brief account of the retina as I have found it in numerous examinations in man and animals during the last four or five years. If you take the trouble to compare it with the accounts which have been published, you will find it to correspond in most points with the most recent descriptions furnished by Hannover, Pacini, and others, but to differ from all in a few particulars. It has not been my object to discuss disputed points, but to combine in one view what seemed most consistent with the truth of nature. I would venture earnestly to advise those of you who have the opportunity, to examine this elaborate structure for yourselves, as it contains within a small compass a most admirable and orderly arrangement of parts, some having the common characters of nervous elements, but others of so singular an aspect and properties, as to present questions of great interest, upon which a more extended study may be expected to throw much light.

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