LECTURES ON THE HISTOLOGY OF THE EYE:

(BEING THE ARRIS AND GALE ANATOMICAL LECTURES.)

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BY

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LECTURE I.

MR. PRESIDENT AND GENTLEMEN,—In the course of lectures on the minute anatomy of the eye which I had the honour of delivering here, last summer, I described the histology of the cornea and vitreous humour, of the retina and tunica uvea. There remain for this course the parts concerned in the accommodation of the eye, and the conjunctiva, sclerotic, and optic nerve, an account of which will complete the normal anatomy of the eyeball. I propose to devote to-day to the apparatus of accommodation; Wednesday to the conjunctiva, sclerotic, and the optic nerve, including, if time permit, the histology of neuritis; and on Friday to give you some account of the anatomy of tumours and new growths originating on or inside the eyeball.

The Apparatus of Accommodation.—Let me, in the first place, endeavour to explain what the term *accommodation* technically means. That we cannot see perfectly distinctly at the same instant two objects placed at different distances before the eye, is a fact of the truth of which a moment's attention suffices to convince the most unobservant person. The fact is most easily realised when the objects are near; for when they lie at a great distance from the spectator the minor distinctness of one of them is less appreciable; but when they are relatively close to the spectator, it is impossible for him not to become aware of the phenomenon. Thus, when I look at the nearer of two trees placed several yards apart, nearly in the same line, in a distant field, the minor distinctness of the farther tree is so slight that I may fail to notice it; but when I look at a book through a veil, both being near me, and only a few inches apart, I find that when my eye is fixed on the print I see it quite distinctly, while I am scarcely conscious of the presence of the intervening veil; and, again, when I look intently at the veil, and perceive its texture distinctly, at that same moment the print becomes confused and unrecognisable. What is the explanation of this?

In order to see an object distinctly, an exact image of it must be formed on the bacillary layer of the spectator's retina. Every luminous point in the surface of the object turned towards the spectator must be represented by a corresponding image-point upon his retina. This is effected by the refractive power of the eye—that power which its transparent parts possess in common with inanimate transparent bodies, of changing the original direction of the luminous rays which enter it, and of giving these rays a new direction of a kind dependent on their relative densities and their curves.

Luminous pencils coming from remote objects consist of parallel rays; and, having regard to the small opening of the pupil, the pencils which enter the eye from an object twenty or more feet distant may be considered to be composed of parallel rays. Now, the refractive power of the eye is such that parallel rays entering it are collected in exact foci upon its retina without the exercise of any vital effort, the eye itself being quite passive. It would occur as well in a dead eye, so long as its media remained transparent, and while they retained their proper curves.

The luminous pencils which a near object sends to a spectator's eye consist of divergent rays, and the unaided refractive power of the eye which sufficed to unite the parallel rays from a distant object in the bacillary plane of the retina, is insufficient to collect divergent rays in exact foci in this plane. The foci of these rays lie behind the retina which the pencils strike as spots, the sections of cones, called circles of dispersion, and not as points. The result of this is a blurred confused image, and not a clear one, the production of which requires the rays to be brought to exact foci in the bacillary layer.

We are, however, conscious that we possess the power of seeing distinctly near objects as well as distant ones, which proves that the eye has the power to unite divergent as well as parallel rays in exact retinal foci; and this implies the possession of a power of altering its refractive state, so as to suit it to the distance of the object which we

desire to see distinctly, or, in other words, to adapt it to the degree of divergence of the luminous rays entering the eye from the object.

This adaptation of the refractive state of the eye is technically called its *accommodation*. It has been at different times attributed to a change of the figure of the eyeball, to an alteration of the curve of the cornea, and to a shifting of the position of the lens; but more delicate methods of observation than were formerly at the command of the physiologist have shewn all these views to be erroneous, and by the direct inspection of the human eye with instruments specially contrived for this investigation, it has been demonstrated that its accommodation for a nearer object is effected by increased convexity of the lens, and this chiefly of its anterior surface, the curve of its posterior surface being altered in a scarcely appreciable degree. With the increased convexity of the lens, its axis is proportionately lengthened, the pupillary region of the iris approaches the cornea, and the peripheral portion of the iris recedes from it.

There are not any grounds for supposing that this change of figure is wrought by any power inherent in the lens itself, which is plastic, but is not endowed with contractile irritability, and is not dominated by the will, being devoid of nerves.

The active factor of accommodation must, therefore, be external to the lens. Now, in close relation to the lens there are two muscular organs, the iris and the ciliary muscle. The existence of accommodation in persons from whom the iris is congenitally absent, and its persistence where the iris has been in part or entirely removed, demonstrate its independence in man of this diaphragm. There remains, therefore, only the ciliary muscle as the active agent of accommodation in the human eye. To the ciliary muscle and lens I would invite your attention to-day. I shall take the lens first.

Lens.—The lens of the human adult has a flattened bi-convex figure. The anterior surface is less convex than the posterior, the radius of curvature of the former being nearly twice as great as the radius of the latter surface. The infant's lens is more nearly spherical, which makes the distance between its summit and the cornea smaller than in the adult's eye. This circumstance is not without influence in the causation of the minute white speck on the front of the lens (the central subcapsular cataract) not infrequent in persons who have suffered from infantile purulent ophthalmia, even where this has not been complicated with perforation of the cornea. The compression of the cornea by the swollen eyelids and oedematous conjunctiva, and a slight amount of deep congestion pushing forward the lens, may bring the lens and cornea together, and thus disturb the nutrition of the growing lens at the point of contact, and induce a perverted growth and retrogressive changes in the lens-tissue.

In other mammalia and in the lower vertebrata the figure of the lens is less flattened than in adult man, resembling more nearly the shape of the human foetal lens.

The lens of vertebrate animals is formed almost entirely of a peculiar fibrous tissue with a very scanty formless interstitial substance. It is enclosed in a short capsule, the integrity of which is of the highest importance to its transparency. This capsule is a perfectly transparent, very elastic, yet brittle, membrane. It is little prone to degenerative metamorphoses, and never undergoes absorption. I have found it transparent and unchanged sixteen years after the extraction of the lens for cataract. Its chemical constitution and reactions resemble those of the other hyaloid membranes: it is unaffected by weak acids and alkalies, and it resists putrefaction. With high magnifying powers, no indications of structure are discernible in it, except faint marks of lamination in the stout capsules of the largest mammalia.

The front half of the capsule, or more exactly that part of it which lies in front of the attachment of the suspensory ligament, is thicker than the posterior half; at a rough estimate, its thickness may be taken to be three times as great.

This difference, and the unavoidable implication of the front half of the capsule in operations for the removal of cataract, have led to the adoption of the terms anterior and posterior capsule. As these terms are convenient, their use is not objectionable if it be borne in mind that they refer to two halves of one and the same sac, and not to two distinct sacs.

Besides being stouter, the front half of the capsule differs also from the posterior in being lined with an epithelium. This consists in the central region of a single layer of large, flat, polyhedral cells, each enclosing a circular nucleus. These nuclei are remarkably uniform in size and shape. At the edge of the lens the epithelial cells are much smaller, and so closely crowded that their nuclei are separated by very small interspaces. In mature lenses the marginal epithelium is composed of only a single layer of cells, but in young and growing lenses it is formed of several layers of cells with an imbricated arrangement, which constitute the matrix out of which the fibrous tissue of the lens is evolved.

The capsular epithelium plays an important rôle in the so-called capsular opacities accompanying various forms of cataract, congenital as well as acquired; for out of it are evolved, by what may be called a perverted development, nucleated fibrous webs, often of great toughness and density, underlying the inner surface of the capsule. It must not be forgotten that the capsule itself never becomes opaque; what are called opacities of the capsule being always deposits of opaque substances and adventitious growths upon its surfaces. These may exceptionally be overlaid by a transparent colloid substance, and then an opacity may seem to be seated in the capsule; but the colloid mass is not a part of the capsule, it is something superadded to it.

I am aware that some good observers deny this origin of these intra-capsular fibrous webs, which are not optically distinguishable from a connective substance. They ask how can a connective substance be the derivative of an epithelium; and they maintain that in all these cases the capsule has not been entire, but it has had some rent through which these fibrous webs have intruded themselves from without. I cannot yield to this opinion, because I have found such webs on the inner surface of capsules which I could not doubt were entire, and where their intrusion was impossible, and because I have, as I believe, been able to trace the evolution of the fibrous tissue from the epithelial cells through intermediate phases. A normal lens-fibre, which all allow to be the final phase of a capsular epithelial cell, differs hardly less from its initial phase than do some of the elements of these fibro-nucleated webs.

The posterior half of the capsule has no epithelial lining; but its inner surface frequently exhibits polyhedral marks, which have been mistaken for an epithelium. They really express the hexahedral oblique cross sections of the swollen posterior ends of the lens-fibres.

The tissue composing the lens itself consists in greatest part of long, flat ribbon-like fibres. These have two wide surfaces and four narrow ones meeting in two thin bevelled edges, which give to their cross sections a hexahedral figure. The fibres are really long tubes filled with the protein substance to which chemists have given the name of globulin. When the fibres are broken across, it transudes in the form of globules from their ends. It often accumulates in large masses between the layers of fibre in lenses, which have been hardened with chromic acid.

A nucleus is present in the superficial fibres near the edge of the lens, but the deeper fibres are more sparingly nucleated. The fibres cohere very closely by their flat surfaces, and still more intimately by their bevelled edges. These latter, in some vertebrata, are serrated, which renders their union still more secure. This serration is very coarse in fish and in some chelonians, much finer in snakes, so fine in frogs that the edges appear only as if slightly frayed, and absent from the human lens-fibre.

The other constituent of the lens is the interstitial tissue—a formless substance present in a very minute quantity in the axis of the lens and in those extensions of it called the central or axial planes. In young persons, the refractive index of this substance agrees with that of the fibrous tissue; hence their lenses are free from the internal reflections which the lenses of elderly persons exhibit, and which give these an opalescence which an incautious observer may readily mistake for a cataractous opacity.

The axis in the simplest form of lens, as that of some fish and of amphibia, is a streak or line of this interstitial substance traversing the centre of the lens. The lens-fibres are grouped around it in the manner of the meridian lines upon a globe, the inner fibres progressively shortening towards the centre of the lens. In other fish and in the porpoise, and the rabbit amongst mammals, the axial streak is flattened. It extends in two opposite directions and forms a central plane, the ends of which make a linear stigma on the front and back of the lens. The directions of these stigmata do not coincide; they intersect at a right angle, as they would if the plane of which they are the ends had been twisted through 90 deg. in passing through the lens. From the two edges of this, which may be distinguished as the primary plane, others—secondary planes—run out in a complicated manner towards the circumference of the lens. The primary central planes in most mammalia diverge at equal distances of 120 deg. from the axis, and their ends form, on the back and on the front of the lens, a trifid stigma. The rays of one stigma intersect the angles included between those of the other stigma as they would do if the tripartite axis had been twisted through 60 deg.

In these lenses, the arrangement of the fibres with respect to the central planes is much more complicated than in the simple amphibian lens. All its details are probably not yet known to us; but, so far as they have been ascertained, it appears that the fibres pass between the front and back of the lens, winding round its equatorial edge in such a manner that a fibre, starting from the interval between two of the front planes, falls behind on the edge of a posterior plane; while a

fibre, starting from the edge of one of the front planes, would fall behind in the angle made by two of the posterior planes. The intervening fibres between these extremes take intermediate positions on the planes.

The tripartite division of the axis, persistent in many mammals, is present also in the human foetal lens, which—as has been already mentioned—is nearly spherical. As the lens enlarges, the three primary planes detach secondary and tertiary ones; the multiplication continues during the whole period of growth, until in the human adult the minor planes form an excessively complex frame. With this excessive complexity of the planes, the fibres maintain a general direction between the front and the back of the lens; and since the surfaces of the fibres cohere more strongly than their edges, most lenses, when artificially hardened, can be split by a coarse dissection into concentric laminæ.

In youth, the lens is soft; but with advancing years it acquires greater consistence, becoming in aged persons really hard. It is to this change, in consequence of which the lens becomes less plastic as we advance in life, that presbyopia is mainly due.

In birds and in lizards, the nucleus only is concentrically laminated; and the outer fibres pass vertically and obliquely between the capsule and nucleus.

Connections and Relations of the Lens.—The back of the lens lies in a hollow in the front of the vitreous humour, bounded by an extension of the hyaloid capsule of this humour, which is so distinct from the posterior lens-capsule, that I should hardly have mentioned their separateness had this not been recently denied. It bends inwards near the edge of the lens, and forms the posterior wall of the space known as Petit's canal. The lens may be removed in its entire capsule without destroying the integrity of this partition between the vitreous humour and the lens-bed. But its chief support is the suspensory ligament which slings the lens to the ciliary processes. This arises from the whole inner surface of the ciliary body in front of the ora retinæ, from columnar epithelial-like bodies resting in the pigmented epithelium; and it is attached in a plaited manner to the capsule at the edge of the lens, advancing slightly upon the front, and to a less extent on the back of the lens. It is made of fibres, which chemically resemble yellow elastic tissue. They are remarkable for their hard and sharp outlines and their clear fracture. They break up near the lens into brushes of very fine fibrillæ, the interspaces between which are occupied with delicate membraniform expansions. Kölliker regards the elongated bodies from which these fibres arise as special modifications of the connective tissue radial fibres of the retina which are continued in front of the ora, the nervous retinal elements ceasing at this boundary line. The place of the attachment of the suspensory ligament to the lens varies within rather large limits in different animals: in birds and reptiles, it is nearer the front of the lens than in man.

Let us now now turn to the

Muscular Apparatus of Accommodation.—In the human eye, the ciliary muscle is the active factor of accommodation. When the cornea and sclerotic are removed, a greyish ring is seen behind the iris on the outer surface of the ciliary body. It was considered ligamentous, until Professors Brücke and Bowman nearly simultaneously discovered its muscularity.

In mammalia, the muscular tissue is unstriated. The deepest bundles of muscular fibre—those which are in close relation to the outer surfaces of the ciliary processes—are very obliquely directed; collectively, they form a ring resembling a sphincter, yet not completely separable from the other muscular bundles. Attention was first drawn to these circular fibres by the late H. Müller, who conceived that, acting through the intervening ciliary processes, they might compress the edge of the lens.

The outermost bundles of muscular fibre run in meridional lines. They stream backwards from the cornea and lose themselves on the outer surface of the ciliary body and choroid. These fibres are connected in front with the middle of the three divisions of the posterior elastic lamina of the cornea. (The inner division of this lamina spans the margin of the anterior chamber and forms the pillar of the iris, and the outer division passes backwards and outwards to the sclerotic behind the space known as the circulus venosus, or Schlemm's canal.)

The shortening of these meridional bundles of muscular fibre will tend to approximate their corneal and choroidal attachments; and if we regard the corneal one as the more fixed point—a view which best harmonises with the anatomical facts—the contraction of these bundles tends to draw the choroid forwards and tighten it upon its contents. According to this view, the ciliary muscle (as regards its radial bundles) is a tensor of the choroid, as Brücke named it.

Let us next see what light these anatomical data throw on the process of accommodation. You will recollect, that in accommodation for a nearer object, the lens as a whole does not shift its place; but its anterior surface becomes notably more convex, and the convexity of

its posterior surface is very slightly increased. With this alteration of its figure, the axis is lengthened and the transverse diameter shortened. The pupillary region of the iris approaches the cornea, and the circumference of the iris retreats from it. The lens with its capsule is elastic, but without contractile irritability; its rôle is passive. When the suspensory ligament is tight, it must exert traction on both surfaces of the lens (chiefly on the front, by reason of the greater stoutness of the fibres and of their attachment to the lens advancing rather further from the edge of the lens), tending to compress the lens in the direction of its axis and to flatten it—the shape of the lens in looking at a distant object, which is a passive act, not requiring accommodation.

When the radial or longitudinal bundles of the ciliary muscle contract, and the distance between their extreme points of attachment is lessened, the previously tense suspensory ligament is relaxed; and the lens, no longer compressed by it, becomes more convex by virtue of its own elasticity. If at the same time the circular bundles of the muscle were to shorten, this would tend to contract the circle of the ciliary processes, by which the suspensory ligament would be still more slackened. I doubt, however, whether they can act as a compressor of the edge of the lens.

The ciliary muscle derives its nerves from the lenticular ganglion. They pierce the sclerotic not far from the optic nerve; and, gaining the inner surface of this coat, they run forwards between it and the choroid till they reach the ciliary muscle, on the outer surface of which they break up and recombine in the well-known beautiful plexus, a large portion of which is, however, destined for the innervation of the iris. From this coarse plexus, bundles of nerve-fibres dip into the muscle, in which they form a finer net, from which single fibres of extreme tenuity are traceable for long distances amongst the muscular bundles; but I have not yet discovered the actual nature of their ultimate connection with the muscular fibre. In my last course of lectures, I adverted to the occurrence of ganglion-cells in this plexus. They first became known to me by the beautiful preparations of Schweigger, and are not the coarser gangliform swellings recognisable under slight enlargement described by Dr. R. Lee, jun. The arteries of the ciliary muscle are drawn from the *circulus arteriosus major* iridis, which distributes many recurrent twigs to it. These are not infrequently offsets of the arterioles which this arterial circle sends to the ciliary processes. The venous blood escapes in two directions—posteriorly, through veinlets which join those of the ciliary processes and lead to the *venæ vorticosæ*; and in front, through veinlets which empty their contents into the *circulus venosus* in Schlemm's canal.

ON THE TREATMENT OF ACUTE AND CHRONIC BRIGHT'S DISEASE.*

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GENTLEMEN,—On the invitation of your President (Dr. Andrew Clark), I have undertaken to read a short paper "On the Principles which should regulate the Treatment of Acute and Chronic Bright's Disease." What is Bright's disease? I adopt the definition given in the *Nomenclature of Disease* published by the Royal College of Physicians: "Bright's disease is a generic term, including several forms of acute and chronic disease of the kidney, usually associated with albumen in the urine, and frequently with dropsy, and with various secondary diseases resulting from deterioration of the blood." The term Bright's disease is nearly, but not quite, synonymous with renal albuminuria.

The causes of renal albuminuria arrange themselves in two main divisions.

1. A mechanical impediment to the escape of the venous blood from the kidney, as from disease of the heart or lungs; the pressure of dropsical fluid in the abdomen; sometimes probably the pressure of the gravid uterus.

2. An abnormal condition of blood is by far the most frequent cause of albuminuria. Thus albuminuria occurs not infrequently as a result of scarlatina, diphtheria, erysipelas, typhus and enteric fever, pyæmia, cholera, measles, purpura, gout, etc. The albuminuria which sometimes occurs during the early stage of pregnancy is probably a consequence of blood-changes associated with that condition; while that which occasionally follows parturition is, in all likelihood, a result of absorption of septic materials from the uterus.

Thus albuminuria may result from a primary mechanical hindrance to the movement of blood, or from a primary change in the quality of the blood. On the present occasion I shall exclude from consideration that class of cases in which albuminuria is a result of a mechanical impediment to the circulation and consequent passive congestion of the kidney. My remarks will have reference only to the more numerous second class of cases—cases of albuminuria the result of abnormal states of blood. I shall endeavour to make my remarks as practical as possible, with only so much of reference to pathological theory as may serve to guide or to explain practice.

The extreme frequency of renal disease is a physiological result of the kidney forming one of the main channels by which effete and noxious materials are cast out of the circulation. During the process of excretion, the kidney-tissues—primarily the gland-cells, secondarily the blood-vessels—undergo structural change. A leading principle of treatment is to lessen as much as possible the excretory work of the kidney, more especially in cases of acute Bright's disease. The main points are—rest in bed in a room of moderate uniform temperature; a carefully regulated and a somewhat scanty diet; the adoption of means to promote a free action of the skin and bowels.

In all cases of acute Bright's disease, rest in bed is an essential part of the treatment. In a large proportion of cases, this with a scanty diet will suffice for the cure. The diet may consist of milk alone if it suits the patient's stomach, or milk with an egg or two in the course of the day, or with the addition of beef-tea or other animal broth. Under this regimen the urine soon becomes copious, while the albumen diminishes and gradually disappears.

The copious flow of urine which usually occurs during convalescence from acute Bright's disease is thus explained. During the acute and congestive stage of the renal disease, the constituents of the urine—both solids and liquids—have accumulated in the blood, and have thence been effused into the areolar tissue and into the serous cavities. Now, urea is a most powerful diuretic. When injected into the veins of a dog, it quickly excites a copious flow of urine; and no sooner is the inflammatory congestion of the kidney removed, and thus the freedom of the renal circulation restored, than the urea retained in the blood begins to exert its natural diuretic action upon the kidney. The copious flow of urine thus induced speedily removes the accumulated urinary solids and water from the blood, the areolar tissue, and the serous cavities, into which they had been effused, and thus the dropsy is cured.

This abundant flow of urine occurs without aid from diuretics or drugs of any kind. I have seen it occur while a bread-pill or coloured water was given as a placebo. Stimulating diuretics, such as squills, or cantharides, or turpentine, would be injurious, by increasing congestion of the kidney. The best diuretics in such cases are those means which tend to lessen renal congestion—dry cupping or hot fomentations over the loins, hot air or water baths, purgatives, and a scanty diet, with a free use of diluent drinks—one of the best and pleasantest drinks being the "imperial drink", made with cream-of-tartar and lemon.

When the renal congestion is extreme, as shown by the scanty secretion of highly albuminous urine, local bleeding by leeches or cupping on the loins is often extremely useful. If by the abstraction of a few ounces of blood from the loins we relieve the renal congestion, we shall check the rapid destruction of blood-constituents which results from uræmia; moderate local bleeding, therefore, tends to economise blood, and to prevent its waste.

It has been asserted that cupping or leeching the loins can help an inflamed kidney no more "than if the blood had been taken from the arm or from the nape of the neck". But this, surely, is a mistake. The lumbar arteries, which supply the integuments of the loins, arise from the abdominal aorta, close by the origin of the renal arteries; and when leeches or cupping-glasses draw blood through the skin of the back, it is certain that the diminished pressure within the lumbar arteries will divert a certain quantity of blood from the neighbouring renal arteries. The same principle explains the good effects of leeching in cases of pericarditis. The internal mammary artery sends deep branches to the pericardium, and superficial branches to the intercostal spaces and the skin. By the application of leeches over the heart, we abstract blood from the integumentary branches of the internal mammary artery, and thus divert a portion of blood from the deeper pericardial branches. The blood will as surely take the course indicated by diminished pressure within the vessels as the water in a pump will, up to a certain height, follow the rising piston. It may be thought that the quantity of blood thus diverted is very small: so, in the case of venesection being practised in the arm or neck, how scanty is the stream of blood which escapes from the opening in the vein compared with the torrents of blood rushing through the *venæ cavæ* into the right side of the heart; and yet in a case of obstructed circulation through the heart or lungs, how promptly and decidedly does this small diverted current

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