LECTURES ON THE HISTOLOGY OF THE EYE: (BEING THE ARRIS AND GALE ANATOMICAL LECTURES.)

Delivered at the Royal College of Surgeons of England, June 1869.

BY

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LECTURE III.

MR. PRESIDENT AND GENTLEMEN,—Last Thursday, the clock struck before I had finished the anatomy of the tunica uvea, and obliged me to leave the structure of the ciliary processes undescribed. I regret that I cannot now supply this omission; but the exigencies of my present task—which is to try to make clear what is known of the fine structure of the retina—leave me no choice but to apply myself at once to its accomplishment. The best plan, perhaps, having regard to the short time at my disposal, although in other respects not altogether a good one, will be for me to portray, in a diagrammatic manner, the general forms of the elementary tissues, with the order of their superposition in parallel layers, as seen in a vertical section; afterwards to trace the modifications which these tissues undergo; and lastly, if I have a few minutes left, I wish to devote these to a short account of some of the morbid alterations which reveal themselves by characters recognisable in the living eye with the ophthalmoscope.

In all vertebrates (except the lowest fishes, *e.g.*, myxine and lancelet) a section vertical to the surfaces of the retina shows the following superposed layers.

First, there is a layer of columnar bodies, the rods and cones abutting against the choroid—the bacillary layer, known also as Jacob's membrane. To this succeeds the layer of corpuscles called the outer granules. Next follows a fibrillated stratum—the inter-granule layer; then another layer of corpuscles, the inner granules; next to this the layer called by some the granular layer, by others the grey vesicular, or grey nervous layer; then a stratum of ganglion-cells; and, finally, a stratum of optic nerve-fibres, bounded internally by a thin membrane, the “membrana limitans interna retinae.”

In all these layers, nervous and connective tissues are intimately commingled; and it is just this interpenetration of the two tissues which constitutes our principal difficulty whenever we attempt to decide the nature of a particular retinal element.

Before proceeding to a detailed account of its tissues, a few words on the best methods of studying the retina may be useful to some present. First, it is absolutely essential that the eyes be perfectly fresh—the lapse of half an hour after the circulation has ceased, or even of a few minutes if the eye have been opened, makes differences in the appearance of the bacillary elements. Next, the outer surface of the fresh retina should be carefully scrutinised, in order to learn if both rods and cones are present. The latter will be known by their greater stoutness, and by their outer ends lying in a deeper level than those of the rods; while in birds, in some reptiles, and in the batrachians, they are immediately betrayed by their bright coloured beads.

But there are many things which cannot be made out in the fresh retina, or which can only be recognised by a practised observer already familiar with their characters when they have been artificially hardened and stained. The fresh retina is also too soft to allow us to cut vertical sections sufficiently thin without greatly disturbing the tissues. The most useful agents are chromic and osmic acids. Of the former acid, solutions of about a half per cent. are most useful; they have a pale straw tint; small eyes may be placed in them entire, but large ones should be cut in two before immersion. After remaining during three or four days in this solution, the retina will be hard enough to allow sections to be cut sufficiently thin for study with one-twenty-fifth-inch object-glass. The usefulness of chromic acid lies chiefly in its hardening the retina well, with little alteration in the shapes of most of its elementary tissues, and enabling us to cut our sections in any given direction we choose—for instance, through the fovea, or tangential to it. But it has the disadvantage of distorting the elements by distending them, when the solution is too weak, or by shrinking them when it is too concentrated. It also renders them granular and proportionately opaque. Sections so prepared may be still stained with carmine.

Osmic acid is, in some respects, more useful than chromic. It was first brought into notice by Max Schultze of Bonn, whose labours have

thrown much light on retinal histology. Solutions of from a quarter to a half per cent. are best. It not only blackens the transparent nervous tissues, making them distinct, but it enables us, with a couple of fine needles, to split the retina in vertical planes, which afford us beautiful sections much thinner and clearer than any that the most practised hand can cut with the sharpest knife. Another advantage is, that it does not make the tissues so granular as chromic acid; but it has this drawback, that with it we cannot run the section in any direction we choose. It is of greater service in those vertebrates whose retinae are devoid of blood-vessels, because their presence seriously interferes with clean cleavage. The retina, stained and hardened by osmic acid, may be kept for use in distilled water without undergoing any further change during several weeks. It is best mounted in glycerine for microscopic examination.

To return from this digression to the description of the retinal layers; in the outermost or bacillary there are two sorts of elements, distinguished as *rods* and *cones*.

Every rod and every cone consists of two segments—an outer one, the bacillus or shaft; and an inner one, the appendage or body. The shafts of both rods and cones are highly refracting conspicuous microscopic objects; whilst the appendages are pale, have a low refractive index, and are less evident.

The inner and the outer segment are separated by a sharp, transverse line, where the slightest violence snaps them asunder.

The rod-shaft is a long, slender cylinder—in profile, a narrow rectangle. The ends are truncated; the outer rests on the choroidal epithelium, and the inner joins the appendage. In the perfectly fresh shaft I cannot discern any differentiation of parts, except an external outline indicative of a containing membrane, and a homogeneous contained substance; but very soon after death the shafts begin to alter. The fresh perceptible change is, I think, a very faint longitudinal striation, and this is followed by the appearance of cross lines, which divide the shaft into light and dark segments; at the same time the shafts swell and bend and lose their rectilinear figure. This segmentation, which must have been familiar to every one since Hannover first wrote on the retina, I have never seen in absolutely fresh shafts examined instantly after death; so that, in common with others, regarding it as a *post mortem* change, I did not attach much importance to it. Professor Schultze, however, has founded upon it the ingenious view that the shafts are built up of discs of alternately nervous and connective substances. The segmentation is often very distinctly perceptible in chromic and in osmic acid preparations.

The inner segment or rod-appendage has commonly the shape of a slender triangle or spindle; and one of the outer granules, as I shall shortly show, is always associated with its inner end. In its outer end, immediately inside the line which marks it off from the shaft, there may often be seen, particularly in the large rods of amphibia, a small hemispherical body of the same refractive index as the shaft to which it sometimes remains attached when the shaft and appendage separate. It was long ago described by the late H. Müller, whose loss every histologist deplores, and I figured it myself in a communication to the Royal Society in 1862. Schultze, who has lately called attention to it, suggests that it may act as a collecting lens.

The outer segment of the cones—the cone-shaft—is usually shorter than the rod-shaft, and it commonly tapers slightly outwards, the outward end being slightly narrower than the inner. The cone appendage is usually flask-shaped or bulbous; and, like the corresponding part of the rod, its inner end always has its associated “outer granule.” In the outer end of the appendage in birds, in some reptiles and in batrachians, lies the well known coloured bead which forms so exquisitely beautiful a microscopic object in the retina of these animals.

The interstices between the bacillary elements are occupied by a soft, homogeneous connective substance, which in all vertebrates below mammals contains a granular pigment. This extends inwards from the choroidal epithelium around and between the shafts as far as their line of union with the appendages. It completely insulates the shafts, and would have the effect of absorbing any pencil of light which, making a relatively small incident angle, might escape laterally outwards through the shaft-wall, and in this way the escaped pencil would be prevented from entering a neighbouring shaft.

In mammals, the greater slenderness of the shafts probably renders such a provision unnecessary, because the incident pencil, to enter the shaft, must nearly coincide with its axis; and, as regards the side of the shaft, the angle of incidence would be so large that the pencil would probably be totally reflected.

The inner ends of the rods and cones pass through apertures in the connective membrane, called the *membrana limitans externa retinae*, and are produced inwards amongst the outer granules as slender bands or fibres. The *membrana limitans externa* is the sharp hard line, always

perceptible in vertical sections between the bacillary and the outer granule layers.

That the rods and cones are the percipient elements in the retina is now universally received, so that it needs hardly be mentioned; but it may be well to adduce the chief considerations on which this presumption rests. First, they alone of all the retinal tissues are so arranged as to be capable of receiving separate and distinct stimuli from small incident pencils of light. Next, their absence entails absence of perception. Mariotte's experiment proves this as regards the optic nerve disc, and the increase of the size of the blind-spot in myopia from posterior staphyloma, proportionately to the extent of the white atrophic crescent—a fact which is easily roughly verified—is another proof of the same thing; because here, together with the disappearance of the chorioidal epithelium and chorio-capillaris, I have had opportunities of proving microscopically the absence of the cones and rods.

When we endeavour to press our inquiries further, and try to ascertain what may be the respective functions of the outer and the inner segment of the rods and cones, and in what respect the functions of the rods and cones differ, we meet with difficulties which have yet to be overcome.

As regards the first part of this inquiry, the high refractive index of the shafts, and their insulation by a coat of pigment in many animals, points to a physical optical rôle; while the association of a nucleus (an outer granule) with the appendage, suggests a more vital dynamical share. If this be so, then the junction between the shaft and appendage marks the line where, so to say, the physical vibrations of light are converted into nerve-force.

Towards the solution of the second point of the inquiry, Schultz contributes the important fact that nocturnal mammals, as the mouse, bat, hedgehog, have no cones; and that in owls they want the bright orange and ruby beads of diurnal birds; and from this he conjectures that the cones may be concerned in perception of colour.

The *outer granules*, to which I must now pass on, are not minute, angular, solid particles, as their name implies, but cells or nuclei of very appreciable dimensions. Their numbers are directly proportionate to those of the rods and cones; and it is very probable—I may say certain—that each outer granule is associated with a rod or cone, and this in one of two ways. When the rod or cone-appendage is large enough to hold it, the outer granule lies inside the appendage in the plane of the *membrana limitans interna*, or at its inner surface; but, when the appendage is too slender to contain the granule, it is joined to the granule by a communicating fibre, the length of which is determined by the distance between the inner end of the appendage and the granule. In either case, the appendage is prolonged inwards in the form of a band or fibre beyond the “outer granule” towards the next stratum. This fibre I call the primitive bacillary fibre, or the primitive rod or cone-fibre, when I wish to distinguish it more particularly.

The *intergranule layer*, which, as its name conveys, lies between the outer and the inner granules, is a fibrous stratum. Some of its component fibres are nervous, passing between the outer and inner granules, and others are connective tissue. Of the latter set of fibres, those which traverse the layer vertically belong to the system of connective radial fibres, known by the name of their discoverer, H. Müller. The others, which extend parallel to the direction of the layer, constitute its proper substratum; and amongst these lie imbedded small nuclei, and in some of the lower animals, *e.g.*, chelonians and fishes, large branched corpuscles of very considerable dimensions.

The *inner granules*, like the outer ones, are also cells or nuclei. According to their sizes, which vary much, they fall into two sets—smaller granules, everywhere numerous; and larger ones, most abundant near the inner surface of the layer, which I cannot distinguish from ganglion-cells. On the one side, the inner granules receive the fibres sent inwards towards them through the intergranular layer from the outer granules; and, on the other side, they send fibres inwards into the granular layer towards the ganglion cells.

The *granular layer*, as Schultz correctly pointed out, is resolved, by a sufficiently high magnifying power, into a very finely fibrillated spongy web, which manifestly hangs together with, and is in great part a derivative of, the connective radial fibres entering it. The only nervous elements occurring in it are the internuncial fibres which traverse it, and the outermost ganglion-cells bedded in its inner surface. The term granular, which simply expresses its appearance under a low power, is therefore preferable to that of grey vesicular or grey serous layer, which gives a wrong idea of its essential composition.

The cells of the ganglionic layer possess a very distinct roundish nucleus, imbedded in a pale and very soft protoplasm, about which there is not generally any distinct cell-wall perceptible. Often the nucleus only is visible, the protoplasm having been damaged in preparing the sections for the microscope. I believe that all the cells are branched.

The outer branches, which are the more numerous, run outwards into the granular layer to join those coming inwards from the inner granules, while their inner branches join the bundles of optic nerve-fibres.

These last radiate in a plexiform manner from the optic nerve entrance. Where there is a fovea centralis, as in men, apes, some birds, and reptiles, the nerve-bundles are so distributed that those only destined for the fovea and its surrounding maculae pass directly to it; while those bundles going to more distant parts beyond the fovea arch around it. With some exceptions, the nerve-fibres are devoid of the medulla, or white substance, of Schwann. In our own eyes, this ceases at the lamina cribrosa; and only pale fibres, equivalent to axis-cylinders, with perhaps an investment of the sheathing membrane, are produced into the retina.

The connective tissue-frame, which supports and holds together the nervous elements, consists of three segments. First, there are the two membranes;—the outer limiting membrane, which I have already described; and the *membrana limitans interna*, which some identify with the hyaloid capsule of the vitreous humour, but which I regard as a distinct membrane. This distinctness cannot be always demonstrated at pleasure; but I believe it to be a fact, because I have found the two membranes separated by inflammatory effusions, and because in the eyes of a Burchell's zebra, for which I was indebted to the liberality of the Zoological Society, I found a beautiful pavement epithelium on the outer surface of the capsula hyaloidea. The second member of the connective substances is a system of short pillar-like fibres, which arise by expanded wing-like roots from the outer surface of the *limitans interna*, and traverse vertically all the layers in a direction radial from the centre of the eye-ball. These are the fibres which, when originally discovered by H. Müller, were believed by him to link the percipient elements on the outer side of the retina—the rods and cones—with the conducting optic nerve-fibres at the inner surface of the retina, an error which he himself was one of the first to correct. These radial fibres (Müller's fibres) form a frame, which mechanically binds together the several layers in their order. Lastly, the retina contains a large amount of interstitial connective tissue, which is accumulated in larger quantity between the inner and outer granules, and between the inner granules and ganglionic layer, but which also pervades, in smaller quantity, all the nervous layers except the bacillary. Spinning an excessively fine web around the cells and fibres, it maintains them all in position, and it supports the blood-vessels when these are present. To sum up, the connective tissue occurs in three forms—membranous, as the *membrana limitans externa* and *interna*; fibrous, as Müller's radial fibres; and as an excessively finely fibrillated interstitial web.

[To be concluded.]

ON SLEEPLESSNESS IN INFANTS.

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It often happens that infants, apparently in good health, are seized with wakefulness at night. The child will not sleep; he is uneasy, restless, peevish, breaks out into violent fits of crying, and is with difficulty pacified, even when hushed in his mother's arms. For this condition, numerous specifics have been recommended, ranging from “soothing syrups” to bromide of potassium. In almost all cases, however, careful inquiry will discover some special cause to which this nocturnal restlessness of the infant may be referred, the removal of which is followed by the disappearance of the troublesome symptom under consideration.

All acute diseases in the child are accompanied by more or less restlessness at night, and fever; but in these cases, unusual irritability of the infant during the day, and other symptoms pointing unmistakably to some derangement of health, will have been observed. It is when the child is, to all appearance, in good health, or when, at any rate, no symptoms of functional derangement have been noticed during the day, that sleeplessness at night becomes a condition often as puzzling to the medical practitioner, as it is distressing to those in immediate attendance upon the infant.

If the infant be very young, *hunger* is commonly the cause to which his restlessness is attributed by the mother; for the tendency of mothers is to refer all crying in their infants to that one cause. Occasionally they may be right. Infants nourished solely by the breast, and deriving their entire support from a scanty supply of watery milk, are almost constantly hungry. The amount of fluid they swallow is scarcely sufficient to satisfy their appetite even for the time; and, being