March 2, 1876.

Dr. J. DALTON HOOKER, C.B., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

In pursuance of the Statutes, the names of the Candidates for election into the Society were read as follows:—

William de Wiveleslie Abney, Capt. R.E.
Henry Edward Armstrong, Ph.D., Sec. C.S.
John Attfield, Ph.D., F.C.S.
Charles Barry.
Robert Bentley, F.L.S.
Charles Orde Browne, Capt. R.A.
George Buchanan, M.A., M.D.
George Chesney, Lieut.-Col. R.E.
William Chimmo, Capt. R.N.
Latimer Clark, C.E., F.R.A.S.
Rev. William B. Clarke, M.A., F.G.S.
Cuthbert Collingwood, M.A., M.B., F.L.S.
James Croll (Geol. Survey, Scotl.).
Richard Daintree, F.G.S.
Herbert Davies, M.D.
Edwin Dunkin, Sec. R.A.S.
John Eric Erichsen, F.R.C.S.
Sir Thomas Fairbairn, Bart.
Sir Joseph Fayrer, M.D., K.C.S.I.
Rev. Norman Macleod Ferrers, M.A.
David Ferrier, M.A., M.D.
Augustus H. Lane Fox, Colonel.
Francis Stephen Bennet François de Chaumont, M.D.
Thomas Richard Fraser, M.D.
Alfred Henry Garrod, B.A.
Charles Alexander Gordon, M.D., C.B.
George Griffith, M.A.
Thomas Hawksley, M.I.C.E.
Robert Baldwin Hayward, M.A.
John Hughlings Jackson, M.D.
John W. Judd, F.G.S.
William Carmichael M'Intosh, M.D., F.L.S.
Robert M'Lachlan, F.L.S.
Richard Henry Major, Sec. R.G.S.
John William Mallet, Ph.D.
Charles Meldrum, M.A.
Henry Nottidge Moseley, M.A.
Richard Norris, M.D.
William Overend Priestley, M.D.
Edward James Reed, C.B.
William Roberts, B.A., M.D.
William Rutherford, M.D.
Sir Sidney Smith Saunders, C.M.G.
Michael Scott, M.Inst.C.E.
Robert Swinhoe.
George James Symons, Sec. Met. Soc.
Thomas Edward Thorpe, Ph.D., F.C.S.
Edwin T. Truman, M.R.C.S.
Henry Willett, F.G.S.
Sir Matthew Digby Wyatt.

The following Papers were read:—

I. "The Organ of Corti in Mammals." By URBAN PRITCHARD, M.D., F.R.C.S., Lecturer on Physiology (Evening Classes), King's College, London, Surgeon to the Royal Ear Dispensary. Communicated by Prof. HUXLEY, Sec.R.S., LL.D., &c. Received January 18, 1876.

(Abstract.)

I have divided my subject into three parts, namely, I. The Structure, II. The Innervation, III. The Development of the Organ of Corti, concluding with a few remarks on its function, the mode of preparation employed, and the nature of the animals examined.

Part I.—THE STRUCTURE OF THE ORGAN OF CORTI.

This apparatus, the essential portion of the cochlea, is situated partly on the lower lip of the limbus, or terminal portion of the bony lamina spiralis, and partly on the membrana basilaris; on either side it is bounded by epithelial cells, being itself developed from epithelium, as will be shown hereafter.

It consists of the following parts:—

(1) The rods or fibres of Corti.
(2) The ciliated or hair-cells.
(3) Certain nuclear cells.
(4) The supporting cells.
(5) The membrana reticularis.
(6) The membrana tectoria.

(1) *The Rods of Corti* are arranged in two rows, an inner and an outer, with their upper extremities in close contact, but separated by a considerable interval below; so that the two rows, sloping towards each other, form the roof of a triangular tunnel.

The rods stand almost in the centre of the organ, the foot of the inner rod standing on the lower lip of the limbus, and that of the outer on the membrana basilaris. On either side of the rods are situated the various cells; above and closely adherent to them is the membrana reticularis, and above this again lies the thick membrana tectoria.

The form of the rods is similar to that of a long bone, consisting of a cylindrical shaft with two enlarged extremities. The lower of these is conical in both the outer and inner rods, but their upper extremities or heads differ considerably in form. The head of the inner rod is somewhat cuboid in form, compressed laterally; and at its upper part it is prolonged into a long slender process, which overlaps and covers the head of the outer rod, this process being a direct prolongation of the upper surface. The outer surface of this rod-head presents a concavity for articulation

with the outer rod; and below the concavity is a little tubercle, from which point the head tapers off to the shaft. The inner surface is continuous with the shaft below, and forms a distinct angle with the upper surface. The sides are marked by a raised curved ridge.

The head of the outer rod is more rounded, and fits into the concavity of the inner-rod head already mentioned. From its upper part also proceeds outwards a process which is more slender than that of the inner-rod head, and passes further outwards.

The length of these rods is graduated (as I pointed out in my former paper), and ranges from $\frac{1}{150}$ inch (or ·17 millim.) at the apex of the spiral to $\frac{1}{500}$ (or ·05 millim.) at its base, where the two rods are of equal length; but proceeding upwards the outer increase in length much more rapidly than the inner, so that at the apex the former are twice the length of the latter.

The number of the rods in each row is not the same, there being three of the inner for every two of the outer. According to a careful calculation of mine, there are about 5250 inner and 3500 outer rods in each human cochlea. In substance they resemble delicate hyaline cartilage, show a tendency to split into fibres, and contain no nuclei.

(2) *The Hair-cells* are very delicate, columnar in form, with large round nuclei and nucleoli; the rest of their contents is finely granular. Their summit is flat, and from it project a row of four bristles or cilia; the rows of bristles run in the direction of the spiral.

There are four rows of these hair-cells, one situated internal to the rods, and the other three to their outer side.

The lower ends of the outer hair-cells are evenly rounded off, and both in man and in the monkey this end is enlarged, giving the cell a flask-shape; the lower end of the inner hair-cells tapers off, and the whole cell is somewhat larger than the outer ones. The summits of all these cells are attached to the membrana reticularis, and their bristles project through the circular meshes of that membrane.

(3) *The Nuclear Cells*, which include those of Claudius, Deiters, and the granular layer of Waldeyer, besides some others scattered about.

These cells have very distinct nuclei with small nucleoli, and are surrounded by some protoplasm, but have no cell-wall; they are all connected with nerve-filaments.

These are found:—1st, on the lower lip of the sulcus internal to the rods, in a mass of three irregular layers (this group has been termed the granular layer by Waldeyer). 2ndly, below the level of the outer hair-cells, and corresponding to them, are found three or four rows of these nuclear cells, which usually go by the name of the cells of Deiters. 3rdly, there is one of these cells found in each lower angle of the triangular tunnel formed by the sloping rods. Lastly, there are one or two scattered about, which will be considered with the nerves.

(4) *The Supporting Cells of Hensen* form the outer boundary of the organ;

they consist of several oval or columnar cells, which gradually merge into the epithelial cells; they form, in fact, the link between the hair-cells and the epithelium.

One or two similar cells, but with ill-defined outlines, are found forming the inner boundary of the organ; these I would term the inner supporting cells.

(5) *The Membrana Reticularis* is one of the most peculiar structures in the cochlea, and has never been satisfactorily described. It consists of a fibrous network which covers the hair-cells and rods, and is firmly attached to them. On either side it grows finer and finer, until lost among the epithelial cells. The reticulate form of this membrane is only seen when viewed from above; to the inner side of the rods there is only one row of regular circular meshes, through which the bristles of the inner hair-cells project. Over the rods and their processes the membrane passes in the form of long meshes, and in the region of the outer hair-cells it presents a very peculiar aspect. Here there are two forms of meshes—the one elongated, called a phalanx, the other circular, called an annulus, so arranged that each phalanx is surrounded by four annuli. Through the annuli project the bristles of the outer hair-cells.

Connected with this reticulate membrane, and, in my opinion, belonging to it, are found three rows of fibrous cords, situated on the outer side of each row of outer hair-cells. These cords, or trabeculæ, pass downwards to the membrana basilaris, to which they are loosely attached by an enlarged extremity. The trabeculæ have been described by other authors as belonging to the hair-cells; and Waldeyer figures them, together with the hair-cells and cells of Deiters, as forming so many twin cells. My observations totally discountenance these views, as in the upper part of the cochlea these three structures are seen to be quite separate, and again in the human fœtus the two cells are very far apart.

(6) *The Membrana Tectoria* or *Membrane of Corti.*—Great misconception existed even down to the last few years as to the form and structure of this membrane. It was regarded as an elastic membrane of equal thickness stretched straight across from the upper lip of the sulcus internus to the corresponding projection of the ligamentum spirale; nor has it yet been properly described. I quite agree with later writers in regarding it as a mucous mass secreted from the epithelial cells, and therefore soft in the fresh state; but I further regard it as only a thickened portion of a layer which lines the whole ductus cochleæ, and which I have traced right round.

The thickened portion forming the membrana tectoria commences at the attachment of the membrane of Reissner to the limbus, and passes over the teeth of the limbus as a layer of equal thickness; then passing outwards rapidly increases in thickness as it covers the organ, and gradually tapers off to the thin general layer, which, as already stated, lines the rest of the ductus cochleæ.

The bristles of the hair-cells penetrate into this membrane, which itself is analogous to the otolith mass of the vestibule.

The organ of Corti is not found at the two extremities of the lamina spiralis.

The whole organ increases regularly in breadth from base to apex of the spiral, measuring in the cat $\frac{1}{240}$ inch near the base, and $\frac{1}{120}$ inch near the apex.

The height, taken at the rod-heads, varies very little; but in the region of the outer hair-cells it again regularly increases from base to apex.

The component parts are further separated from each other on proceeding up the spiral. The rods, as already stated, increase in length, the heads widen, and the processes elongate. The hair-cells increase in height and breadth, and, lastly, the cilia or bristles themselves regularly elongate from base to apex of the cochlea.

In man and monkeys (but, curiously enough, in no other animals) a further change takes place; the number of the outer hair-cells increases from three to four, and at the apex to five rows.

These observations of mine are original, except as regards the increase in the organ as a whole.

Part II.—The Innervation of the Organ of Corti.

The cochlear nerve in the substance of the modiolus, in passing upwards, gives off branches at right angles, which traverse a spiral ganglionic mass, the ganglion spirale, and then enter the lamina spiralis. This ganglion is situated in the lamina at the base, and gradually becoming more central in position, is found entirely in the modiolus at the apex; its cells are bipolar fusiform, averaging $\frac{1}{1000}$ of an inch in man and most mammals, but are much larger in the porpoise, averaging $\frac{1}{600}$ inch. The nerve-fibres run in bundles, which form a plexus, to the end of the lower lip of the limbus, where they perforate its upper surface, and, losing their dark borders, reach the organ of Corti. The filaments are now divided into two groups—an inner, passing to the parts internal to the rods, and an outer, passing to the opposite side of those bodies. The inner principally enter and appear to terminate in the adjacent mass of nuclear cells (the granular layer of Waldeyer); one large filament, passing through one of the nuclear cells, goes to the inner hair-cell and enters its lower extremity. The outer group may be divided into three sets, which all pass between the rods and traverse the triangular tunnel. The upper filament passes along the roof of the tunnel, and on reaching the other side of the outer rod traverses a nuclear cell, and then passes on to the first of the outer hair-cells. The middle filament traverses the centre of the tunnel and enters the same nuclear cell, besides sending a branch downwards to another of the nuclear cells. The third or lower filament runs along the floor of the tunnel, being connected with the two nuclear cells in the lower angles of

it; on the outer side of the rods this filament enters the nuclear cell, which has received the descending branch from the middle filament; and this cell, again, is connected with the first cell of Deiters by another filament. Filaments in the form of festoons connect the hair-cells with each other, and analogous nervous connexions are found between the cells of Deiters. Besides these I have found numerous detached filaments, so arranged as to give the appearance of a plexus throughout the outer part of the organ.

This arrangement of the outer group of nerve-filaments has not been demonstrated before; up to the present time it is only the middle filament that has been described.

Part III.—The Development of the Organ of Corti.

The organ of Corti is developed from certain of the epithelial cells lining the ductus cochleæ, which at first consist of a single layer of cuboid cells; later on, those cells which line the floor and sides of the canal elongate into the columnar form, while those lining the inner part of the floor become longer still, and their nuclei multiply two, three, and fourfold. On the outer side of these are five cells, from which the chief part of the organ is developed; these I term the five primary cells.

The limbus is next developed and the sulcus formed, the latter being completely filled up by the tall columnar cells with proliferated nuclei; these, however, dwindle down again as age advances.

The contents of the first or innermost of the five primary cells are divided into two transversely, the upper division forming the inner hair-cell, the lower a nuclear cell. The same change takes place in the third, fourth, and fifth primary cells, their upper division forming the outer hair-cells, and the lower the cells of Deiters. The rods are developed from the second primary cell, which does not divide transversely, but widens at its base so as to form a triangular cell, the inner and outer sides of which thicken and form the rudimentary inner and outer rods. As this widening increases, the protoplasm disappears from the centre, forming the triangular tunnel, and the nucleus divides into two, one for each of the lower angles of the tunnel. The rods enlarge at their upper and lower extremities, but do not attain their perfect form until after birth; at this period the angle of the inner-rod head has not been developed, besides which the shafts are much thicker and more clumsy in form than in adult life.

The membrana reticularis is developed from the free border of the five primary cells and a few of the other adjacent tall ones, but the exact manner in which the reticulation is formed has not been made out.

The trabeculæ are, like the rods, developed from the side of primary cells; and although only three (on the outer side of the rods) persist in adult life, yet at birth numerous fine trabeculæ are found to the inner side of the rods.

I regard the membrana tectoria as a secretion from part of the general epithelial layer; it first appears as a thick but even layer, and as age ad-

vances that portion which covers the organ increases considerably in thickness.

From the foregoing observations it will be seen that the rods, membrana reticularis, and trabeculæ are developed from the walls of the original epithelial cells, whereas the hair- and various other cells are formed from their contents; and, lastly, that the membrana tectoria is a secretion from the same original epithelium.

The Function of the Organ of Corti.

It is generally assumed that this part of the labyrinth is concerned in appreciating the pitch and quality of sounds; and there are two prevalent theories to account for the manner in which this is accomplished. The first, Helmholtz's, assumes that each of the rods of Corti, which are not of uniform dimensions but graduated in length, as I clearly demonstrated in 1871, vibrates in unison with a certain note, when produced in the outer wall, and in vibrating affects certain nerve-filaments, which carry off the impression to the brain.

The second theory regards these rods as mere supports, and assumes the hair-cells to be the only essential structures.

The only objection of importance to Helmholtz's theory is the fact that there are no rods in the cochlea of birds.

As regards the second theory it is very incomplete, as it does not by itself explain the appreciation of the variations in pitch and quality. To make up for this deficiency, however, some further mechanical theories have been suggested.

Hensen was of opinion that the membrana basilaris, whose breadth is also graduated, acts as the mechanical appreciator, whereas Hasse believed that office to be performed by the membrana tectoria. Both of these ideas are not only very unsatisfactory but obviously fallacious, when the position and structure of these membranes are considered.

For my own part I prefer adhering to Helmholtz's view, with the modification that the rods are concerned only indirectly, and that their vibrations affect the hair-cells connected with them, so as to cause an impression to be transmitted through the nerve-filament to the brain. I consider it highly probable that the graduation in the length of the bristles alone may account for the appreciation of the variations to a considerable extent; but I cannot believe for one instant that the rods and rest of the organ are so beautifully graduated for no special purpose.

The membrana tectoria is undoubtedly analogous to the otolith mass of the vestibule; and I agree with Waldeyer in regarding it as a damper to the vibrations.

The method of preparation usually employed was as follows:—

The cochleæ were always quite fresh.

They were hardened in a $\frac{1}{3}$-per-cent. solution of chromic acid in ordinary methylated spirit; ten days required.

Decalcified in 1-per-cent. solution of nitric acid in water.

Transferred directly to gum-water, soaked a few hours, and then placed in a paper bag surrounded by spirit.

Imbedded in Stirling's machine and cut.

Gum gradually dissolved away in proof spirit.

Mounted, stained or otherwise, in glycerine or Canada balsam.

I have examined the cochleæ of the following mammals:—man, monkey, sheep, dog, cat, rat, guineapig, rabbit, porpoise, kangaroo. With the exception of the peculiarities in man and monkeys referred to, I have found a striking similarity in the organ of Corti of all these animals.

Unfortunately all my efforts to procure the cochlea of a monotreme have as yet proved unsuccessful, a circumstance much to be regretted, as I fully anticipate that it presents some appearances which link the very dissimilar cochleæ of mammals and birds.

II. "Preliminary Note on the Compound Nature of the Line-Spectra of Elementary Bodies." By J. N. Lockyer, F.R.S. Received January 20, 1876.

In a former communication to the Royal Society (Proc. vol. xxii. p. 380, 1874) I referred briefly to the possibility that the well-known line-spectra of the elementary bodies might not result from the vibration of similar molecules; and I was led to make the remark in consequence of the differences in the spectra of certain elements as observed in the spectrum of the sun and in those obtained with the ordinary instrumental appliances.

I have now clear evidence that the molecular grouping of calcium which, with a small induction-coil and small jar, gives a spectrum with its chief line in the blue, is nearly broken up in the sun, and quite broken up in the discharge from a large coil and jar, into another or others with lines in the violet.

I say "another" or "others," because I have not yet been able to determine whether the last-named lines proceed from the same or different molecules; and it is possible we may have to wait for photographs of the spectrum of the brighter stars before this point can be determined.

This result enables us to fix with very considerable accuracy the electric dissociating conditions which are equivalent to that degree of dissociation at present at work in the sun.

I beg permission to append the following Letter from Prof. Stokes and my reply:—

March 3, 1876.

My dear Lockyer,—You might perhaps like that I should put on paper the substance of the remarks I made last night as to the evidence of the dissociation of calcium.