THE DEVELOPMENT OF THE ORGAN OF CORTI.[1]

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In a paper read before the Royal Society of London in 1876,[2] I traced out the development of this structure as far as I was then able. Having since that time been fortunate enough to succeed in filling up certain gaps in the process which has made the research more complete, I venture to think that the same might be worthy of publication.

The organ of Corti is developed from a certain number of the epithelial cells lining the rudimentary ductus cochleæ, and in this paper I propose tracing the various changes which these cells undergo as they become transformed into the organ.

The ductus cochleæ is the first portion of the cochlea to make its appearance; it starts as a bud and then as a prolongation from the vestibular labyrinth. This prolongation gradually elongates, and in so doing assumes a spiral form, so that quite at an early stage of development we find the cochlea represented by a spiral tube lined with epithelium, and surrounded by stellate embryonic tissue. The development proceeds from base to apex, both as regards the spiral tube itself and the organ of Corti contained in it; so that in the same cochlea we find the organ in several stages of development, the sections at the base showing more advanced changes than those at the apex. This tube is at first oval in section, but as development advances its shape becomes more and more triangular, as in the adult animal. The whole of the tube is at first lined by the same kind of epithelium, namely, a single layer of somewhat cuboid cells. Those lying on the floor of the ductus soon show signs of elongation, becoming more or less columnar. This change is more noticeable on the inner side (the side nearest the modiolus or axis of the spiral), and on the middle of the floor of the tube.

As this change is going on in the cells an alteration takes

[1] Read before the British Medical Association, August 1878.
[2] *Proceedings*, vol. xxiv

place in the floor itself by the sulcus of the lamina spiralis gradually making its appearance, the concavity of which is, for a considerable period of fœtal life, completely filled up by the columnar cells just mentioned; and these, besides being the tallest of all the cells, are now seen to have multiplied their nuclei three or four fold. These tall cells do not persist, but dwindle down before birth so as to become cuboid again, and merely line the sulcus of the adult animal. In the drawings taken from Kölliker in many of our text-books, the sulcus is represented as filled up with cells; this error is no doubt due to the examination of fœtal preparations only.

Just to the outer side of these taller cells may be seen five rather shorter ones: these are by far the most important cells, as they form the chief part of the organ of Corti; and therefore the changes in them must be described in detail.

I have called these the five *primary cells*, and for the sake of description have numbered them from within outwards, Nos. 1, 2, 3, 4, 5.

On referring to fig. No. 1, these five cells will be seen to have scarcely altered their columnar shape, with the exception of No. 1; this has already divided transversely into two, forming a larger upper cell and a smaller lower one. Nos. 3, 4, 5, have each a double nucleus, their original ones having divided so as to form a larger one above and a smaller one below. Cell No. 2 has still only one nucleus, which is nearer its lower end—this is the cell from which the rods are to be developed; while the other four go to form the four ciliated cells of Corti above and the cells of Deiters below. As the changes are more easily followed in these four cells (Nos. 1, 3, 4, 5), I propose dealing with them first. It is the contents of the cells which divides, the cell-wall taking no part in this division. The upper of these portions, both as regards the nucleus and its surrounding protoplasm, is larger than the lower, besides which, the outline is more marked; in fact it may be seen that while the upper cells (of Corti) soon receive a distinct cell-wall, the lower cells (of Deiters) never have a distinct outline at all. The next point to be observed is the appearance of a bud projecting from the summit of each cell of Corti: these buds after a time appear to split and thus form the four cilia, or, more correctly, the four bristles.

Most of the wall of the original cells disappears, but the outer side of the 3d, 4th, and 5th, and the inner side of the 1st, become developed into vertical fibres or bands. These will be again considered in describing the formation of the membrana reticularis.

We now come to the most interesting point—namely, the development of the rods of Corti.

On examining fig. No. 1, the 2d primary cell is seen to have altered very slightly: the nucleus is single, and has a tendency to sink to the lower end. On passing to fig. 2, this cell will be seen to have become distinctly triangular, a very peculiar shape for a columnar cell: the nucleus is quite low down, and has increased considerably in size.

Next we turn to fig. 3, and here we see a more decided change: this triangular cell has largely increased in size, especially in width at its base; the nucleus has divided into two, and between these two has appeared a vacuole or space, which is the rudimentary tunnel of the organ of Corti.

But, besides these changes, the sides of cell have become developed into rudimentary rods; the shape of these can now be distinctly made out, although they are at present very clumsy in form and not very definite in outline. On tracing the development further, as seen in fig. 4, the rods may be seen to have become much more shapely, but even yet they have not attained their perfect adult form. Fig. 4 represents the state of the organ in the newly-born kitten, and as the age of the animal advances the rods become more and more delicate in form, the shafts become finer, and the extremities gradually assume their peculiar adult shape; this change is especially noticeable in the upper extremity of the inner rod, which is quite rounded off at birth, whereas in the adult rod it is square.

The next point to be considered is the formation of that peculiar network structure which covers the rods and cells, connecting and binding them together—the membrana reticularis. Unfortunately, the development of this part is not so easily traced as that of the rods and cells, but there is no doubt that it is formed from the united tops of the primary columnar cells; in other words, from that bright band which is seen forming the surface of every layer of columnar cells. The meshes of the network are probably produced by the absorption of the central portion of the cell tops and the thickening of the margins, in the same way as the sides of the primary cells are developed into the vertical bands or trabeculæ already alluded to; the phalanges, or long meshes, are probably formed by the fusion of two or more of the rounded meshes. The vertical bands are inseparably connected with the membrana reticularis, and, in my opinion, form part of that structure; they thus connect the membrana reticularis above with the membrana basilaris below; this lower extremity of the trabeculæ is enlarged into a sort of foot very like the lower end of the rods, and is easily detached from the membrana basilaris. The vertical bands I regard as analogous to the fibres of Müller in the retina, the former connecting the membrana reticularis with the membrana basilaris, and the latter, the inner limiting membrane with the outer.

Covering over the whole organ of Corti and the sulcus spiralis is the thick membrana tectoria: this has no definite structure, no nuclei, nor any appearance of cell formation, and is no doubt of a mucoid nature. Waldeyer considers it as a secretion from the original layer of epithelium, and I have confirmed that view by tracing it as a very thin layer lining the whole of the ductus cochleæ. It first appears as an even layer covering the cells on the floor of the rudimentary ductus cochleæ; this gradually increases in thickness, especially that portion which covers the organ of Corti itself, so that at birth, and in after life, this membrane, where it covers the organ, is very much thicker than elsewhere.

Besides the parts of the organ of Corti already referred to, there are the supporting cells of Hensen, the nuclear cells (forming the nuclear layer of Waldeyer), on the lower lip of the sulcus spiralis to the inner side of the rods, and the nerves to be considered. The supporting cells of Hensen, which form the outer boundary of the organ, and also some similar cells on the inner boundary, are merely slightly modified epithelial cells, and therefore their development requires no special consideration. The nuclear cells of the lower lip of the limbus are formed from certain of the nuclei of those very tall columnar cells with many nuclei, which in early fœtal life filled up the whole of the sulcus.

[*To face Plate IX.*]

EXPLANATION OF PLATE IX.

Fig. 1 × 300. Epithelium, primary cells, at a very early stage. (1) First or innermost cell; (2) second or rod-cell; (3, 4, and 5) outer cells.

Fig. 2 × 300. A later stage. (2) Triangular rod-cell; (1, 3, 4, and 5) dividing to form upper and lower cells.

Fig. 3 × 300. A further advanced stage. (2) Rod-cell showing rudimentary rods and the vacuole.

Fig. 4 × 300. At birth, taken from lower part of the spiral.
These four figures are from the kitten.

Fig. 5. Diagrammatic section of lamina spiralis membranacea,—

1. Lamina spiralis ossea; (*a*) nerve.
2. Membrana basilaris.
3. Ligamentum cochleæ; (*b*) stria vascularis.
4. Sulcus spiralis; (*c*) upper, (*d*) lower lip.
5. Membrana tectoria.
6. Hair cells; (*e*) inner, (*f*) outer.
7. Membrana reticularis.
8. Supporting cells.
9. Rods; (*g*) inner, (*h*) outer.
10. Spiral tunnel.

Fig. 1.

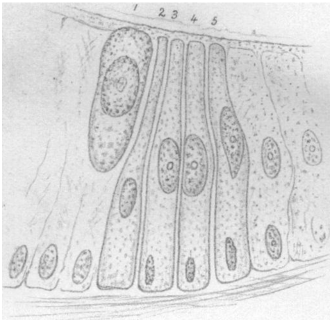


Fig. 2.

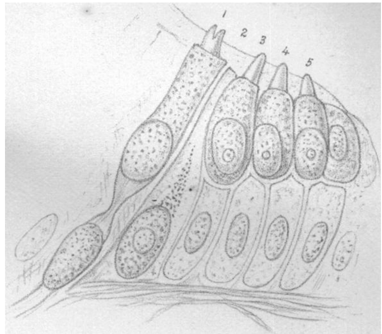


Fig. 3.

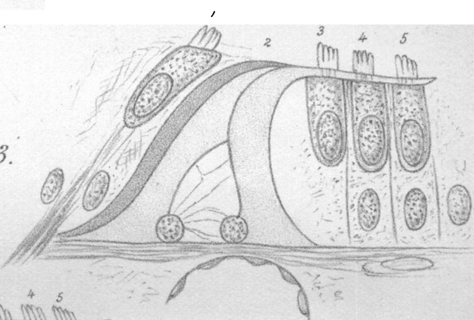


Fig. 4.

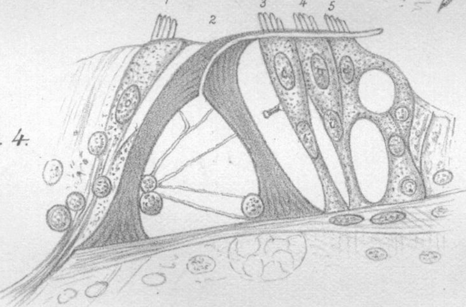
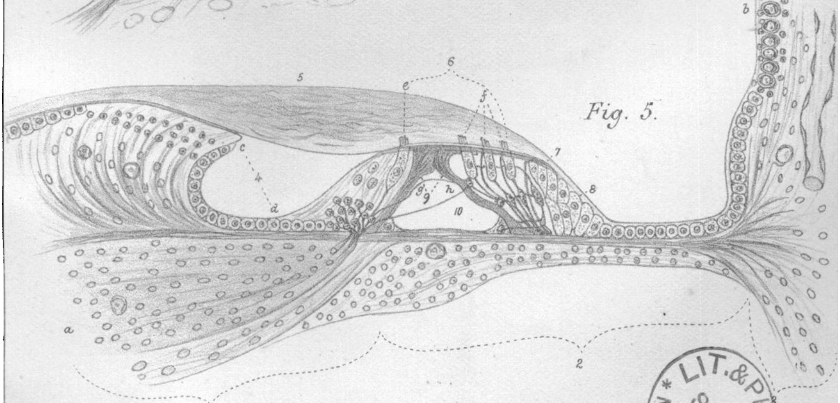


Fig. 5.



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Tracing the development of the nerves is of course a very difficult matter, and at present quite beyond my powers of observation. All that can be definitely stated is that some of the filaments make their appearance very early; thus one of those which cross the tunnel of the organ may often be distinguished before the vacuole in the rod-cell has made its appearance.

To briefly summarise the whole process, it may be stated that the rods, membrana reticularis, and vertical trabeculæ are developed from the walls of the original epithelial cells, whereas the ciliated and other cells are formed from their contents; and lastly, the membrana tectoria is a secretion from the same original epithelium.

In conclusion, I may remark that the foregoing observations have been made entirely from the study of my own preparations, and that I have not had the advantage of examining the specimens of my fellow-workers in Germany. Therefore, I am unable to explain the discrepancies in our conflicting interpretations of this delicate structure, but I feel confident that my explanation of the development of the rods is in the main correct. I have entirely failed to endorse Waldeyer's[1] statement that each rod is developed from a double or twin cell. Altogether my observations lead me to confirm those of Dr Arthur Böttcher,[2] rather than those of Gottstein[3] and Waldeyer.

Explanation of Plate IX.

Fig. 1, × 300 dia.—Epithelium, primary cells, at a very early stage. (1) First or innermost cell; (2) second or rod-cell; (3, 4, and 5) outer cells.

Fig. 2, × 300 dia.—A later stage. (2) Triangular rod-cell; (1, 3, 4, and 5) dividing to form upper and lower cells.

Fig. 3, × 300 dia.—A further advanced stage. (2) Rod-cell showing rudimentary rods and the vacuole.

Fig. 4, × 300 dia.—At birth, taken from lower part of the spiral. These four figures are taken from the kitten.

[1] Stricker's *Histology*, vol. iii.

[2] *Centralblatt für die medicinischen Wissenschaften*, 1870.

[3] *Nova Acta, Leopold. Acad.* 1870.