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THE GRAY SUBSTANCE OF THE MEDULLA OBLONGATA AND TRAPEZIUM.

BY

JOHN DEAN, M.D.

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COMMISSION

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PREFACE.

THE principal object in view, in the following memoir, has been to give the entire topography of the medulla oblongata and trapezium, with illustrations from a series of photographs, the negatives of which have been prepared solely by myself, and have in no case received any retouching. Over two years of constant study have been devoted solely to this investigation, the results of which, both descriptive and histological, I have constantly endeavored to render as trustworthy as possible.

It was my original intention to comprise, in the same communication, the anatomy of the pons Varolii, including that part of the human pons corresponding to the trapezium. Such a plan, however, would have been attended with many difficulties, besides a great increase in the number of illustrations, and it has therefore seemed best to present the second part of this paper in a form which I am well aware is quite incomplete, with the hope of extending it at some future time.

A limited number of photographic prints from the original negatives have been prepared by myself for private distribution, and from these negatives other copies may be obtained, which will be supplied, as far as possible, either on direct application to the author or through the medium of the Smithsonian Institution.

For the labor and patience bestowed on the photo-lithographs by Mr. L. H. Bradford, and for the conscientious care and skill with which Mr. J. W. Watts has engraved my histological drawings, I owe and gladly render my most grateful thanks.

JOHN DEAN.
11 Louisburg Square, Boston.

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PART I.

THE FORM AND STRUCTURE

OF THE

GRAY SUBSTANCE OF THE MEDULLA OBLONGATA, HUMAN AND MAMMALIAN.

CHAPTER I.

MORPHOLOGICAL CHANGES IN THE MEDULLA OBLONGATA OF THE SHEEP.

(1.) THE first change in the form of the gray substance as it passes from the cord to the medulla oblongata, consists in a gradual pushing outwards and forwards of the *posterior* cornua, which are now traversed along the anterior edge of the *caput cornu*, especially at its junction with the *cervix*, by very numerous bundles of longitudinal fibres, forming a beautiful network along the lateral border of the gray substance. At the same time the *anterior* cornua have rapidly diminished in size, being encroached upon by similar longitudinal fasciculi, extending the above mentioned network into the antero-lateral and anterior columns. The network connected with the posterior cornua is traversed by the roots of the spinal accessory, whilst that of the anterior cornua is traversed by the upper cervical, and higher up by the hypoglossal roots. These changes are well shown in Plate I, Figs. 1, 2; Plate XIII, Figs. 1^a, 2^a, the network in the latter figure being further increased by numerous arciform fibres derived from the post-pyramidal and restiform nuclei.

Anteriorly (Plate I, Fig. 1; Plate XIII, Fig. 1^a, P') the fibres of the *pyramids* will still be noticed decussating to a considerable extent; but they have already begun to take a direction parallel with the median line. These latter fibres together with some bundles derived from the arciform plexus, partly running along the middle line, and partly decussating at this point, form the first indications of the raphè, which is shown completely formed in Figs. 2, 2^a, *R*.

The most important changes, however, occur in the posterior portion of the medulla. In Figs. 1, 1^a, it will be noticed that the posterior median fissure is still persistent, reaching quite to the posterior gray commissure, which latter is much thicker than in the spinal cord. On each side of the fissure, very minute tufts may be seen arising from the gray substance; these are the first indications of the network of fibres and cells, which higher up is so very conspicuous, nearly filling the posterior pyramids, and separated from the restiform bodies by a distinct sulcus (Figs. 1, 1^a, *p*). At the side of these little tufts a large and very distinct eminence will be noticed, occupying the remainder of the posterior portion of the cervix cornu, and projecting outwards into the restiform body, into which it sends numerous fibres and cells. These two new bodies, which appear to fulfil a very important part in the organization of the medulla, Clarke has already named the *post-pyramidal* and *restiform nuclei* or ganglia. "They exist in all the mammalia."[1]

The *caput* cornu, meanwhile (Figs. 1, 2, 1^a, 2^a, *b*), has been pushed forwards, and almost separated from the cervix by intervening network, until it nearly reaches the surface of the postero-lateral columns, forming the *tuberculo cinereo* or gray tubercle of Rolando (*b*). The cervix contains many scattered cells of various sizes, collected into several groups near the tufts which are the first indications of the post-pyramidal and restiform nuclei. The *caput* contains only very small cells, scattered about among the longitudinal bundles which traverse it. Numerous large cells are found among the fasciculi forming the fibrous network around the lateral and antero-lateral gray substance, especially in that portion reaching from the entrance of the spinal accessory along the lateral edge of the anterior cornu.

The *tractus intermedio-lateralis* is well marked here, but as we ascend, only a few large cells remain in the outer network, the majority being pushed inwards to form the nucleus of the spinal accessory; it is usually, however, quite possible to trace a continuous line of cells from the entrance of the spinal accessory nearly to the central canal.

The *anterior* cornua are much diminished in size, and contain but few large cells which are already partially collected in two small, round groups (Fig. 1^a, *H*), forming the first indication of the great hypoglossal nuclei.

In the lateral columns near the border of external arciform fibres, a group of large multipolar cells is found (Fig. 1^a, *B*) which become more and more prominent as we ascend, till the level of the vagus is reached, when it is broken up into smaller groups. From its situation in the antero-lateral columns I propose to call this group the *antero-lateral nucleus*. It is penetrated by the fibres of the arciform plexus, both external and internal, with which it is brought into very close connection.

(2.) A little higher up (Plates I, XIII, Figs. 2, 2^a) these changes in form are still more marked; the decussation of the pyramids has ended. The pyramidal columns which in the sheep are very small are now quite distinct; and numerous fibres run parallel to the axis of the medulla, forming with the arciform fibres which decussate with them the raphè (*R*). The principal morphological change is the appearance of the *olivary* bodies (*O*), which, though not particularly well marked in the sheep, are still quite too distinct to be overlooked, as has been done by some anatomists. They are composed of layers of small cells penetrated by the arciform fibres; but I shall reserve the discussion of their more intimate structure for a

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[1] Medulla Oblongata. Philos. Trans. 1858, 240.

subsequent chapter. The olivaries are connected with each other and with the raphè by the arciform fibres, and are also united to the hypoglossal nuclei by bundles of fibres, either directly or by the interposition of cell nuclei.

The *antero-lateral* nucleus (*B*) is now very prominent, from the number and size of its cells. These are mostly stellate, sending their processes in all directions, the group being traversed by the arciform fibres and by fibres derived from the central gray substance, as well as by longitudinal fibres. This group is also united to the caput, and in sections higher up to the remains of the cervix, by the cells formerly scattered throughout the antero-lateral columns, but which are afterwards collected into elongated groups (Fig. 3[a]). The *restiform* (*r*, *r*) and *post-pyramidal* (*p*, *p*) nuclei are now much increased in size, and are quite filled with cells of various dimensions and forms, the cells of both nuclei reaching out into and soon entirely filling the posterior and postero-lateral columns.

As we ascend, the nuclei of the hypoglossal and spinal accessory nerves rapidly increase in size and number of cells, the entire substance of the anterior or *hypoglossal* nucleus (*H*) being filled with large stellate cells, with the exception only of that portion which forms on each side the lateral boundary of the central canal. The posterior, *spinal accessory* or *vagus* nucleus (*S*), has also equally increased; its group of large, obovate cells is very conspicuous, the remainder of the nucleus being entirely filled with smaller, scattered cells. The *caput* is mostly filled with granules and smaller nuclei, with a few cells of medium size; numerous cells being scattered throughout the entire lateral and antero-lateral network.

(3.) Still higher up (Plate I, Fig. 3; Plate XIII, Fig. 3[a]) the *central canal* which has been hitherto somewhat elongated, of a narrow oval form, changes to a triangular shape with curved sides, the apex pointing forwards, and bridged behind by a thick band of commissural fibres connecting the posterior nuclei, now the nuclei of the vagus roots (Fig. 3[a], *V*). The principal changes to be noticed in this region are the rapid increase in the number of cells forming the *post-pyramidal* (*p*, *p*) and *restiform* (*r*, *r*) nuclei, which fill the entire posterior and postero-lateral columns, encroaching on the caput and thick band of external arciform fibres, with both of which they seem to be connected by numerous bundles of curving or wavy fibres (Fig. 3[a], *a*). A remarkable collection of longitudinal fasciculi is here plainly manifest, which, beginning a little lower down, comes now distinctly in sight just at the entrance of the vagus roots (*l*), separating them into anterior and posterior divisions. The cells of the *antero-lateral* nucleus, instead of being collected into compact groups as below, are somewhat scattered, forming various wavy groups which nearly fill the antero-lateral columns of the medulla (*B*).

(4.) As we continue to ascend (Plates I, XIII, Figs. 4, 4[a]) the commissural bridge between the two vagal nuclei is split open, forming the fourth ventricle, on each side of which are situated the nuclei of the hypoglossal and vagal nerves, the anterior portion of the vagus nucleus being especially conspicuous from its crowd of obovate cells.

The longitudinal fasciculi in connection with the vagus nucleus are very prominent, separating the roots into two divisions, the posterior bundles either entering a small nucleus behind the longitudinal fasciculi, or bending around them towards the anterior part of the nucleus. The *restiform* and *post-pyramidal* nuclei are filled with numerous cells, and the latter is closely connected with the vagus nucleus by means of a spur from each, the post-pyramidal body being as it were wedged or dove-tailed into the vagus nucleus. The cells of the *caput* gradually increase in size and number as we ascend, the caput itself being traversed by the vagus roots. The longitudinal fasciculi in connection with the vagus continually increase in size, and are reinforced by another system of bundles (m) which appear in that portion of the nucleus from which the auditory nucleus is subsequently developed. The lower part of the raphè constituting the olivary commissure contains many cells, rather larger than those of the olivary bodies, and scattered cells are found throughout the entire length of the raphè, as well as in all parts of the anterior and antero-lateral network. At about this height little nuclei are found connecting the raphè and hypoglossal nuclei with the olivary bodies and antero-lateral nuclei.

(5.) Still higher up (Plates I, XIII, 6, 6^a) the *hypoglossal* nucleus begins to diminish somewhat in size, its cells being smaller and much less numerous, though a considerable number of large cells are still to be seen as long as the nucleus continues distinct. The cells of the *vagus* nucleus are very numerous and the roots very distinct.

Posteriorly we begin to trace the formation of a new nucleus (A), in the hinder portion of the vagus, or rather between the vagal and post-pyramidal nuclei. This mass, which is pyramidal in shape, with its longest convex side fitted into the vagus nucleus, its concave side being turned towards, and receiving the post-pyramidal body, becomes the principal nucleus of the *auditory* nerve. The *vagus* nucleus is now much diminished in size, and is thrust forwards and wedged in between the newly formed auditory nucleus and that of the hypoglossal. The new mass contains cells of large size, especially at the apex, which projects into the restiform body and into the posterior border of the caput, with both of which it appears to be connected.

The *restiform* and *post-pyramidal* bodies in this region are thickly studded with large cells, and both the vagal and auditory nuclei are bordered by a network, formed by the passage of numerous longitudinal fasciculi, which continue to increase both in size and number as we ascend (Fig. 6^a, l, m).

The *caput cornu* through which the large roots of the vagus pass, is thickly studded with cells of medium size. The *antero-lateral* nucleus is still quite conspicuous, but the cells are separated into more distinct groups, intersected in every direction by the arciform and transverse fibres. Cells are also scattered in the network by which the entire edge of the caput is surrounded, embracing with their processes the large bundles of longitudinal fibres which traverse it. The olivary bodies have now obtained their maximum development, and soon begin to diminish in size with the diminution of the hypoglossal nucleus and roots (Figs. 6^a, 7^a, O). In the upper portions of the medulla the remains of the olivary lamina seem to be filled with larger cells, which have replaced the small regular cells of the lower portions. They still extend across the raphè through the commissure.

(6.) In the section just above the preceding (Plates I, XIII, Figs. 7, 7^a) the *hypoglossal* nucleus, though still large, contains but few cells, and these very much scattered; no distinct roots can be traced to the surface. The *vagus* nucleus still contains numerous cells, mostly crowded back from the apex. The nucleus has been pushed forwards so that its base no longer lies on the floor of the fourth ventricle, but is separated from it by a commissure of fibres and cells connecting the hypoglossal nucleus with that of the auditory.

The *auditory* nucleus (*A*) is now quite large, pyramidal in form, and has already absorbed the outer portion of the vagus nucleus as well as the post-pyramidal body. It is bordered along its outer edge by a network of fibres, inclosing large and numerous longitudinal fasciculi, forming a very conspicuous fringe, which still higher up is more distinctly separated from the inner portion, forming a very complete border, called by Clarke the "*outer nucleus.*" Both portions of the auditory nucleus contain numerous cells of medium size, obovate and stellate.

The *restiform* body is still crowded with cells, and at its outer edge gives off fringes of fibres reaching into the dark border of longitudinal fibres by which it is now bounded (*k*), the band of external arciform fibres (*a*) being pushed further forwards, and thinned off posteriorly more and more, to make way for the posterior and anterior divisions of the auditory roots, which presently make their appearance.

The *caput* is penetrated by the vagus roots and studded with small cells, particularly near the apex of the vagus nucleus. It is also connected with the restiform body, and with the point of the auditory nucleus, by a network of cells and fibres, and anteriorly with the remains of the antero-lateral nucleus.

The small cells of the olivary bodies have mostly disappeared, except in the immediate vicinity of the raphè. Some cells are still persistent in the locality of the antero-lateral nucleus, while further back and close to the caput a large group is seen, the commencement of a column which steadily increases as we ascend, its somewhat large cells being finally grouped together as the upper olivary bodies (Plates XIII, XIV, *O'*). In (Fig. 7[a]) these cells as well as the remains of the antero-lateral nucleus appear to be connected with the posterior portion of the hypoglossal nucleus by radiating fibres.

(7.) Still higher up the principal changes consist in the gradual pushing forwards of the vagus nucleus, which, as it is pushed towards the apex of the great triangular mass formed by the fusion of the vagal, hypoglossal, and auditory nuclei, becomes the nucleus of the glosso-pharyngeal. These changes have been well figured by Stilling (*Textur und Function der Medulla Oblongata.* Erlangen, 1843, Taf. vii, Figs. 1—6). The roots of the glosso-pharyngeal subdivide into many bundles in their course through the caput; some seem to pass into the auditory nucleus, some into their own proper nucleus, whilst some, especially in higher sections, reach forwards as far as the remains of the hypoglossal nucleus.

The *restiform* body is still further reduced in size by the dark border of longitudinal and oblique fibres by which it is surrounded, which has now attained very considerable breadth. The *olivary* bodies have entirely disappeared, with the exception of a few quite large cells which still linger about the raphè near the olivary commissure.

CHAPTER II.

MORPHOLOGICAL CHANGES IN THE MEDULLA OBLONGATA OF MAN.

(1.) In the region of the first cervical nerve the general form of the human medulla has been very well represented by Stilling[1] and by Clarke.[2] The general plan is similar to that observed in the sheep, with slight differences, chiefly due to the nearly circular form of the human medulla, as compared with the more elongated or elliptical form in most of the mammalia, producing a greater concentration of parts, especially in the lower regions, where the contrast is very decided. The *restiform* and *post-pyramidal* nuclei are developed earlier and are much larger in man and the carnivora than in the lower mammalia, and a few other differences occur higher up, which will be noticed presently.

(2.) Figs. 17, 17^a, Plates V, and XIV, show the general arrangement of parts in the vicinity of the decussation of the pyramids. By comparison with Plates I, and XIII, Figs. 1, 1^a, it will be seen that the principal differences consist in a more complete separation of the *cervix* (*d*) and *caput* (*b*), and in the much greater development of the *restiform* (*r*, *r*) and *post-pyramidal* (*p*, *p*) nuclei, which are already very prominent and contain very many cells. The *post-pyramidal* nuclei have expanded backwards into a fan-like network of cells and fibres, nearly filling the post-pyramidal bodies on each side of the posterior fissure. The cells of the *restiform* nucleus are scattered throughout the posterior portion of the cervix, but are mostly concentrated along its outer border, lateral as well as posterior; they are large and easily distinguishable, even with a low power. The cells of the *tractus intermedio-lateralis* (*t*) are still persistent along the outer border of the gray substance, between the anterior and posterior cornua, but are mostly pushed inwards towards the central canal, behind and on each side of which soon appears a large group of cells, constituting the nucleus of the spinal accessory. The *caput cornu* (*b*) contains a few scattered cells, as also does the network extending across to the anterior cornu, which latter contains very numerous large multipolar cells.

The large wings formed by the tractus intermedio-lateralis (*t*), are here plainly seen; they have been called by Reichert[3] the *lateral* cornua (seitliche Stränge oder Hörner). A little higher up, the anterior cornua are still further contracted, and the first indications are seen of the *olivary* columns and of the *antero-lateral* nuclei.

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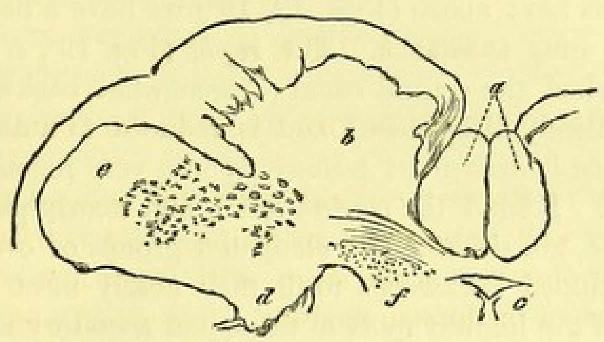
[1] Medulla Oblongata, pl. iv, fig. 1.

[2] Philos. Transactions, 1858, pl. xiv, fig. 23; pl. xv, fig. 19.

[3] Bau des Menschlichen Gehirns. II. Leipzig, 1861.

In the cat the form of the different parts is very nearly intermediate between the human medulla and that of the sheep. It is especially distinguished in this region by the very remarkable size of the *post-pyramidal* and *restiform* nuclei, which are developed to an enormous extent, filling the respective columns (Fig. 1).

Fig. 1.



Posterior cornu from the medulla of the cat, just above the decussation of the pyramids.—*a*, post-pyramidal nuclei; *b*, restiform nucleus; *c*, central canal; *d*, tractus intermedio-lateralis; *e*, caput cornu; *f*, nucleus of spinal accessory.

(3.) In the next section, Plates V, and XIV, Figs. 18, 18^a, the anterior cornua have almost entirely disappeared, and the group of cells constituting the nucleus of the hypoglossal (*H*) has become quite distinct. The nucleus of the spinal accessory (*S*) is plainly seen, as a long tract of cells reaching from the tractus intermedio-lateralis to a point just behind the central canal. The lateral cornu through which the roots of the spinal accessory run, is here quite prominent, and just beyond a line of cells can be traced connecting it with the *antero-lateral* nucleus. Reichert seems to consider the antero-lateral nucleus as simply a pushing outwards of the lateral cornu,[1] but I think this is not the case; it seems to be more probably a distinct group of cells, intimately connected with the development of the internal arciform fibres and appearing at the same time with these.

The commencement of the *olivary bodies* (*O*) is now seen as a somewhat elongated tract of cells along the margin of the pyramids, closely connected with the arciform fibres and with the antero-lateral nucleus. In the substance of the *anterior pyramids*, which are here very large, and from which the raphè is already partially formed, may be seen here and there little nuclei, connected with fibres both transverse and longitudinal (*Kleine Pyramiden-Kerne* of Stilling). (Fig. 18^a, i.)

The posterior portion of the medulla has undergone very considerable development; the *caput* (*b*) is filled with numerous scattered cells, and is connected with the external arciform fibres by little groups of cells, which its numerous radiating

[1] In his description of Fig. 7, op. cit., he makes the following statement: Die seitlichen Hörner haben ihre Verbindung untereinander und zum Theil auch mit der Centralpartie der grauen Kernsubstanz aufgegeben, sie erscheinen als einzelne unbestimmt begrenzte, in die Seitenstränge des Mantels eingelagerte Flecke die demnach als Durchschnitte von isolirt verlaufenden Strängen anzusehen sind. p. 100.

fibres enter. The *restiform* nucleus (*r*, *r*) is very conspicuous and is entirely filled with cells, some of which are quite large, and along its posterior border numerous tufts of fibres and cells are pushed out into the restiform body (*r*). The post-pyramidal nucleus has become a fan-like expansion of cells and radiating fibres, quite filling the post-pyramidal body (*p*). Both of these nuclei are traversed by the arciform fibres, many of which originate from their cells.

(4.) In the sections next above (Figs. 19, 19ᵃ) we have a decided change in the form of the central gray substance. The *raphè* (Fig. 19ᵃ, *R*) is now completely formed, and has pushed the central canal (*c*) somewhat backwards; the posterior fissure has almost entirely disappeared, and is reduced to a deep sulcus, while the central gray substance is drawn out posteriorly in a very remarkable manner, until it reaches the sulcus. Behind the central canal, and nearly parallel with the sides of the gray substance, are situated two elongated groups of oval and fusiform cells (*S*), which are continued backwards until they nearly meet at the middle line, forming the nuclei of the highest roots of the spinal accessory nerve. This nucleus is somewhat bifurcated by bundles of longitudinal fibres which pierce its apex (*l*), and in the anterior spur some remains of the tractus intermedio-lateralis are still persistent.

The cells of the *antero-lateral nucleus* (*B*) are very numerous, filling nearly the entire antero-lateral columns, and serving to connect the anterior and posterior portions of the medulla, by means of the arciform fibres which traverse this nucleus, and in many cases enter its cells, the processes from which pass in every direction transversely as well as longitudinally. This group is also closely related to the olivary bodies, which are now quite fully developed as a compact coil of small cells imbedded in a mass of fibres, situated on the lateral border of the pyramid outside the hypoglossal roots.

The situation of the olivary bodies (*O*) with respect to the hypoglossal roots, constitutes one of the most striking differences between the human medulla and that of most of the mammalia, and is produced by the great development of the pyramids, as well as of the olivaries themselves, in the human medulla, leaving insufficient room for the hypoglossal roots to pass on the outer side, as is easily done where the development of these bodies is comparatively so slight, as it is, even in animals possessing so distinct olivary convolutions as the carnivora.

On the inner side of the hypoglossal roots, we find in man a large and elongated group of cells (*s*) called by Stilling the *great pyramidal nucleus*, and considered by him, together with the small pyramidal nuclei, noticed above, as the chief source from which the fibres of the pyramidal column proceed. Although some of the transverse bundles by which the pyramids are everywhere pierced, undoubtedly arise from these cells, I entirely agree with Clarke[1] in considering this group (the great pyramidal nucleus) as a portion of the olivary column, the peculiar structure of which the cells assume more and more as we ascend, being often found in the upper part of the medulla (Fig. 23ᵃ), arranged in a little convolution, evidently of the same nature as the larger olivary lamina with which it is connected.

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[1] Philos. Trans. 1858, 244.

The *anterior* portion of the gray substance has become more compact, the little wings, noticed in the sections just below, at the entrance of the hypoglossal roots, have nearly disappeared, and the entire substance of the anterior cornua is filled with large multipolar cells, constituting the *nucleus* of the *hypoglossal*.

On comparing Figs. 19, 19ª, from the human medulla, with Figs. 2, 2ª, from about the same region in the sheep, the dissimilarity seems at first sight considerable. By a closer examination it will, however, be seen that the general plan is quite the same, and we may consider the form of the human medulla, as resulting from a greater concentration of parts around the central canal, together with the much greater development of some portions, especially the pyramidal and olivary columns. Here, as elsewhere, we see that if we should take the medulla of the sheep on each side the middle line, near the point where the restiform nuclei approach the posterior surface, and bring the two points towards each other, almost the same disposition of parts would be produced as is seen in the human medulla, making allowance only for the greater development of certain cell tracts in the latter case, as contrasted with the evident simplification of structural details in the sheep and other of the lower mammalia.

(5.) As we approach the opening of the central canal into the fourth ventricle, the development of the cell groups seen below continually advances, till we reach the level of the *calamus scriptorius* (Figs. 20, 20ª).

Just in front of the sulcus forming the apex of the fourth ventricle (Fig. 20ª, *w*), and on each side of the middle line, are seen the two tracts closely crowded with large multipolar cells, constituting the hypoglossal nuclei (*H*), from which the root-bundles of the hypoglossal (*XII*) may now be seen radiating to the surface of the medulla, between the pyramidal and olivary columns. The whole anterior and antero-lateral substance contains numerous scattered cells and small cell groups, entering everywhere into connection with the arciform fibres; the extremely complicated arrangement of the fibres constituting this plexus has already been very accurately described by Clarke (1858).

Little groups of cells are frequently found just at the entrance of the hypoglossal roots into their nuclei, as also scattered along the raphè, serving to unite the different sets of fibres, transverse, arciform, and longitudinal.

The *olivary* convolutions (*O*) have attained a very considerable development, and the *small pyramidal* nuclei (*i*) are likewise quite conspicuous. The *antero-lateral* nuclei (*B*) have reached their maximum development, being separated into smaller cell groups a little higher up. The *caput* (*b*) is large and distinct, and is closely united to the *restiform* nucleus; they are both crowded with cells, and are connected with the external band of arciform and oblique fibres (*a*) by quite numerous detached cell groups. At about this height the *post-pyramidal* and *antero-lateral* nuclei seem to have reached their greatest development; the commencement of the auditory ganglion, which is formed out of the substance of the first-named nucleus, is seen in sections lying just above, while the antero-lateral nucleus is continually encroached upon by the development of the olivary bodies.

(6.) In the next sections (Plates VI and XV, Figs. 21, 21ª) we have a still greater development of some parts, with a corresponding diminution in others.

The *hypoglossal* nuclei (H) are spread out into closely crowded clusters of large, multipolar cells. The *vagal* nuclei (V) are considerably developed, and filled with oblong, or obovate cells, the more posterior of which are now closely connected with those of the post-pyramidal nuclei. It is in this posterior cell group (g), developed, as Clarke has already pointed out,[1] from the substance of both nuclei, that the first appearance of the auditory ganglion can be traced. The *vagus* nucleus is here bifurcated, as that of the spinal accessory was to some extent, by large bundles of longitudinal fibres (l). The restiform nucleus (r, r) has expanded into a large mass of cells and fibres, nearly filling the entire restiform body and pushing the caput cornu still further forwards.

The *antero-lateral* nucleus (B) has diminished in size, a few cell groups alone remaining, crowded between the olivary body and the border of the caput; these groups are still closely connected with the arciform fibres and probably serve to co-ordinate distant parts of the medulla. A group formed at least partially from the antero-lateral nucleus, is seen (Figs. 20^a, 21^a, n) arranged in a long layer close to the border of the olivary lamina. This group, called by Stilling the *accessory olivary nucleus*, is evidently similar in structure to the olivary lamina, as has already been pointed out by Clarke. Its position and the number of its layers vary in different sections, as well as in different specimens, and there seems no reason for considering it as in any wise distinct from the olivary body.

At the junction of the restiform nucleus and caput, a network of cells and fibres is pushed out, extending to the border of the medulla (Fig. 20^a, x), where a large group of cells is seen closely connected with the band of external arciform fibres; several such groups are pushed out, either from the caput or restiform nucleus, and this tendency seems to increase as we ascend, till the whole restiform body is filled with a mass of more or less compact cell groups, reaching very nearly to the border of the medulla (Figs. 21^a, 22^a). The decussation along the raphè is very marked, and scattered cells are everywhere found mingled with its fibres. The arciform fibres interlace in a much more intricate manner than in the lower mammalia, and are connected with numerous cells and cell groups, which serve either as starting-points for new fibres or as co-ordinating centres.

(7.) In the sections just above (Figs. 22, 22^a) the principal changes are in the posterior portions of the medulla, the anterior and antero-lateral parts undergoing but little change. The *hypoglossal* nucleus is still very large and prominent, the nerve-roots (XI) winding in a serpentine course through a part of the olivary lamina, but never entering into communication with it. The great pyramidal nucleus of Stilling (s) is here very distinctly seen, as well as the little elongated lamina (n) situated just above the olivary body (accessory olivary nucleus of Stilling).

The *vagus* nucleus (V) has now reached its maximum development; it appears as a large elongated, pyriform mass, containing a group of densely crowded, obovate cells. From it the vagus roots (X) may now be seen proceeding in several very distinct bundles, traversing the caput cornu, which consists of a compact mass of cells connected together by wavy bands of fibres. The apex of the nucleus is quite

[1] Philos. Transactions, 1858, and Proceedings of the Royal Society, 1861.

deeply bifurcated by the longitudinal fasciculi spoken of above (*l*), and sends forward one of its spurs into the substance of the post-pyramidal body. Between the post-pyramidal nucleus and that of the vagus a new body has arisen, apparently developed out of the substance of both nuclei. This new body (Fig. 22, *A*), the formation of which has been described very accurately by Clarke,[1] becomes the principal nucleus of the auditory nerve, and is at first intimately connected both with the post-pyramidal and vagal nuclei. It presents the usual pyriform or triangular shape assumed by the other nuclei, and contains numerous scattered cells of varied form and dimensions. It seems to be inserted like a wedge between the vagus nucleus and that of the post-pyramidal body, the latter being partially blended with it and partly pushed aside, and is already pierced to some extent by little bundles of longitudinal fibres (*m*), appearing in the section as dark spots, which continually increase as we ascend, forming eventually a very remarkable marginal network, containing numerous cells, many of which are of large size, and embrace the longitudinal fasciculi in all directions with their processes.

(8.) These changes are still more evident higher up (Figs. 23, 23^a), and have been exceedingly well figured both by Stilling[2] and Clarke[3]. The *vagus* nucleus (*V*) is here rapidly thrust forward by the extension of the nucleus of the auditory, and soon becomes the nucleus of the glosso-pharyngeal, which is simply an upward extension of that of the vagus, between which and the glosso-pharyngeal it is impossible to fix any definite boundary.

The remains of the *hypoglossal* nucleus are quite conspicuous, and the place of the root is occupied by transverse, radiating fibres (*XII'*), running apparently into the hilus of the olivary body, but consisting mostly of obliquely ascending bundles of hypoglossal roots which are cut off by the plane of section.

The nucleus of the *auditory* (*A*) is now considerably extended, and sends out a spur or process into the post-pyramidal body, by means of which it is also brought into connection with the restiform nucleus, as well as with the caput. The bundles of longitudinal fibres (*m*) by which the auditory nucleus is bounded on its postero-lateral margin, rapidly increase in size and number, and in the sections just above (Figs. 24, 24^a), we find them arranged in a wide band or network along the outer edge of the auditory nucleus, of which they constitute the outer portion (*A'*), containing among the meshes of the network numerous very large multipolar cells.

(9.) The little nucleus of the *glosso-pharyngeal* is here seen (Fig. 24^a, *G*) thrust very far forward by the extension of the auditory nucleus, which quite overlies the remains of the vagus nucleus; it is entered by the glosso-pharyngeal roots (*IX*) in several distinct and wavy bundles.

In this part of the medulla (Figs. 24, 24^a) the entire outline is changed from the circular or somewhat crescentic form presented below, to one much more elongated along the posterior boundary; the restiform columns being drawn apart laterally from the middle line or raphè, so that the nuclei which in the lowest part of the

[1] Philos. Transactions, 1858, and Proceedings of the Royal Society, June, 1861.
[2] Medulla Oblongata. Atlas, pl. vii, figs. 1—6
[3] Philos. Trans. 1858, pl. xvi, figs. 31, 32; pl. xvii, fig. 36.

medulla were arranged with respect to the central canal much as in the spinal cord, are now spread out upon a very long base forming the extended floor of the fourth ventricle.

The upward extension of the hypoglossal nucleus still contains numerous small cells, from which is subsequently developed the *fasciculus teres*, forming the nucleus of the abducens and facial nerves. The *restiform* body no longer presents the same appearance as in lower sections, but consists interiorly of a large group of cells (*r*, *r*) the remains of the restiform nucleus, from which as a common centre, a mass of fibres radiate in an obliquely ascending course, becoming more and more horizontal as we approach the cerebellum, which the restiform body, as is well known, finally enters.

Winding around the outer border of the restiform body is seen the posterior division of the auditory nerve (*VIII'*), containing, as noticed by Stilling, numerous little cells (*z*) near its entrance into the medulla. The *caput* is still prominent and contains numerous cells, connected by a small group with the large nucleated mass from which the glosso-pharyngeal and auditory roots arise. The whole antero-lateral and anterior substance of the medulla in this region, contains numerous cell groups, some of considerable size, and small cell groups are very often found scattered among the decussating fibres of the raphè. The *olivary* columns have here reached their greatest development, and begin immediately to diminish in size, as is also the case with the anterior pyramidal columns, giving place to the extremely complicated plexus of fibres constituting the pons Varolii, many of which are intimately connected with and to some extent developed from the little cell groups so constantly found at different points in the substance of the pyramids (Fig. 24^a, *i*).

CHAPTER III.

THE HYPOGLOSSAL NUCLEUS AND ROOTS.

The Nucleus.—Stilling[1] was the first to point out the true origin of the hypoglossal roots, from the two groups of nerve cells which make their appearance just above the upper cervical nerves, in front of the central canal, extending laterally to a considerable distance on each side. These groups seem to be a continuation of the cell columns from which the anterior spinal roots arise, being situated within what is evidently the posterior portion of the anterior cornua, the anterior portion of which has already been broken up into an open network by the passage of numerous longitudinal fasciculi, to such an extent that the portion in the immediate vicinity of the central canal, together with a branching wing on each side the raphè, alone remains distinct.

The form of the hypoglossal nucleus as it appears just above the decussation of the pyramids, is nearly pyramidal, with its apex directed forwards towards the roots, varying but slightly in those mammalia I have examined, from its shape in man, the only difference arising from the greater general concentration of structure in the human medulla. These slight differences will be readily seen by comparing Figs. 17, 18, 19, 20, 21, 22, Plates V and VI, from the human medulla, with the corresponding sections from the sheep, Plates I, II, Figs. 1, 2, 3, 4, 5, 6.

Higher up the nucleus increases somewhat in size, and is gradually pushed slightly backwards and outwards, changing its form somewhat, becoming almost square close to the *calamus scriptorius* (Plates I, II, Figs. 4, 5; Plate VI, Fig. 21), and having attained its greatest development, gradually diminishes in size, reassuming presently its former pyramidal shape, finally becoming covered over by the auditory ganglion. Fig. 7, Plate II, shows the last remains of the hypoglossal which in Fig. 8 is completely merged in the auditory nucleus.

The oval cell groups which occupy already a large portion of the nucleus on each side of the middle line, increase rapidly in size and number of cells as they ascend, until their point of greatest development is reached a little above the *calamus scriptorius.*

The cells are mostly quite large, stellate or oblong in shape, and multipolar, resembling in every respect those found in the anterior cornua of the spinal cord, for which they might easily be mistaken.[2]

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[1] Medulla Oblongata. Erlangen, 1843.

[2] The great similarity both in the form of the cells and the general relations which these bear to the roots may be seen by comparing one of the figures from my memoir on the spinal cord (Memoirs of the American Academy, 1861, fig. 4), with pl. x, fig. 37 of the present memoir, the principal difference being solely that the cells of the hypoglossal nucleus are much more closely crowded together

Intermingled with the large multipolar cells are others presenting every variety of form and size, obovate, stellate, and fusiform.

The larger cells measure on an average in their longest diameter, in the sheep $\frac{1}{555}$ to $\frac{1}{500}$ of an inch. In the cat $\frac{1}{1250}$ to $\frac{1}{555}$ of an inch. In the human medulla $\frac{1}{1000}$ to $\frac{1}{666}$ of an inch.

These cells are collected into groups more or less distinct according to the region in which they are observed, and are also connected by their processes in the same manner as I have shown to be the case in the anterior cornua of the spinal cord, though from the cells being so closely crowded together, the connections are very difficult to trace satisfactorily.

The cell processes are sent out in various directions, both longitudinal and transverse, their general course having been already described by Clarke.[1] Some of them go upwards to cells of the same nucleus, some run backwards and enter the neighboring spinal accessory, or vagal nuclei, or are continuous with the roots of these nerves; a third set decussate at the raphè, and are either continuous with its fibres, or cross over into the opposite nucleus, the two nuclei being thus brought into close connection; whilst a fourth set pass out into the network by which the nucleus is bounded anteriorly and antero-laterally, the network itself containing, as mentioned above, very numerous cells of different form and size. Many of the cell processes, especially those from the anterior part of the nucleus, are continuous with the hypoglossal roots.

The courses pursued by these cell processes will be seen at a glance to be strictly analogous with the general direction which the cell processes follow in the anterior cornua of the spinal cord.

The connection between the hypoglossal nuclei and olivary bodies, by direct fibres and by numerous little cell groups scattered along the raphè and hypoglossal roots, will be noticed in describing the olivary bodies and their accessory nuclei.

The Roots.—In man the hypoglossal roots enter between the olivary column and the anterior pyramid (Plate VII, Figs. 25, 26, 27), penetrating the olivary body in the upper part of the medulla in a serpentine course (Fig. 27), but never, so far as I have been able to ascertain, entering into any immediate connection either with the cells or fibres of the olivaries.

In most of the mammalia the plan is somewhat different, owing to the greatly diminished size of the pyramids and olivary bodies, the latter being situated behind the pyramids on each side of the raphè, allowing the hypoglossal roots to pass outside of them (Plates I, II, and XIII).

The hypoglossal roots in man, after curving around the border of the olivary bodies, or penetrating them in one or more bundles, pursue a direct course to the nucleus, the apex of which they enter; in the mammalia the course is the same, with the single exception that they pass along the outer edge of the olivaries, and only penetrate among the scattering cells near the extreme outer edge.

On reaching the nucleus the greater part of the fibres proceed directly inwards, as do those of the anterior spinal roots, becoming connected with the large groups

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[1] Philos. Trans. 1858

of multipolar cells noticed above. The further course of the roots will be best understood by reference to Plate XI, Fig. 40, representing a transverse section of the hypoglossal nucleus, on a level with the vagus nucleus and just above the *calamus scriptorius*. A portion of the fibres are connected with cells of the outer group (*b*), thus becoming united secondarily with the great bundles of fibres proceeding from the vagus, by which the hypoglossal nucleus is bordered anteriorly (*D*). By far the greater number, however, pass through these border fibres and cells, penetrating the nucleus, until they reach the groups lying in the central and posterior portion (*h*). A few fibres may be seen to leave the bundles, either just before or soon after they cross the border, and pass along with the latter towards the raphè, or else branch out into the anterior columns and join some of the numerous bundles passing towards the raphè, where they decussate with those coming from the opposite side (*c*). It is impossible to trace their further course. Numerous fibres, often forming considerable bundles, may be seen either just as they enter the nucleus, or not unfrequently in its central region, sometimes forming quite a sharp curve (*m*, *m*), and bending back towards deeper lying cells, or towards the nucleus of the vagus, which some fibres from the hypoglossal certainly enter, forming a counterpart to the relation established, as noticed by Clarke[1] and confirmed by my own observations, between some of the hypoglossal roots and those of the spinal accessory.

The decussation of the hypoglossal roots, first pointed out by Kölliker, has recently been denied by Schröder van der Kolk. Kölliker[2] states that there is a "total decussation of the roots of both sides, on the floor of the fourth ventricle, so that those from one nucleus pass over into that of the opposite side." Lenhossek[3] also makes a similar statement with regard to the inner nerve bundles. Clarke[4] states that fibres from the hypoglossal "bend inwards and decussate through the raphè with their opposite fellows."

On the other hand, Schröder van der Kolk,[5] after many investigations on different animals, as well as on the human medulla, was able "to completely satisfy himself that this nerve does not decussate, but is lost entirely in the hypoglossal nucleus, being connected with multipolar cells by numerous fibres." He states, however, that the two nuclei are brought into connection by means of commissural fibres crossing the raphè and derived from the cells on each side.

The question is by no means an easy one to decide; my first attempts at solving it led me to think that Schröder van der Kolk was right in his opinion, but in going over the whole ground again with very great care, and examining specimens from the medulla of man and various animals, prepared by different methods,[6] I could have no doubt that some of the hypoglossal roots certainly decussate directly at the raphè, standing about in equal proportion to the main bundles as do those of

[1] Philos. Transactions, 1858, 252, 253; pl. xvii, fig. 35.

[2] Mikroskopische Anatomie. II, 459.

[3] Neue Untersuchungen, 32.

[4] Philos. Transactions, 1858, 253.

[5] Medulla Spinalis and Oblongata, 1859, 97.

[6] Especially specimens hardened in chromic acid and made transparent by turpentine, this method seeming to me decidedly the best for tracing the *course of fibres*.

the anterior spinal roots which can be traced into the anterior commissure of the spinal cord.

Some of the fibres of the hypoglossal roots, especially those lying along the inner edge of the bundle nearest the raphè, turn off either just before or immediately after they enter the broad band of marginal fibres, and pursuing the same course, proceed towards the raphè, where they decussate with their fellows from the opposite side. Schröder van der Kolk is undoubtedly right in his assertion that the great loops of decussating fibres figured by Kölliker, and named by Lenhossek *ansa hypoglossi*, are formed not from the hypoglossal roots, but by the band of border fibres described above, which he has clearly shown to be derived from the vagus, and as he has also pointed out, this adds greatly to the difficulty of deciding the question. Most of the fibres forming the hypoglossal roots undoubtedly penetrate deeply into the nucleus, as maintained by Schröder van der Kolk, but a careful and repeated examination especially with high powers, has convinced me that some of them turn aside, and that a direct decussation exists of *a few* at least of the root bundles. In the cat, especially in the lower part of the hypoglossal nucleus, the course pursued by the roots is very distinct, and quite numerous bundles may be traced, accompanying the marginal fibres derived from the spinal accessory to the raphè; higher up the course is somewhat more obscure, as the band proceeding from the vagus is so much broader and more prominent than that from the accessory.

The roots of the hypoglossal are brought into intimate relation with those of the vagus, by means of a group of large multipolar cells, situated just within the marginal band of fibres proceeding from the vagus roots, by which the hypoglossal nucleus is inclosed (Plate X, Fig. 37, Plate XI, Fig. 40, *b*). Most of these cells are grouped together just behind the entrance of the hypoglossal roots, and thrust out some of their processes into the anterior columns, embracing the longitudinal columns, with some of the fibres of which they are perhaps continuous. They are connected by the remaining processes with the marginal fibres derived from the vagus (Plate X, Fig. 37, *B*), and with the hypoglossal roots (*A*), and also send fibres forward which decussate at the raphè. This group further serves to connect the marginal fibres with the deeper lying cell groups in the hypoglossal nucleus.

The hypoglossal and spinal accessory roots are also connected by a corresponding group, but the cells are comparatively few in number, which may probably be accounted for partly by the different respective situations of the nuclei; that of the spinal accessory lying so much more behind the hypoglossal, a more direct connection is doubtless established between them, as is the case between the anterior and posterior cornua of the spinal cord. I have however had no difficulty in making out the little group connecting the hypoglossal with the accessory in the human medulla, and in the cat it is very distinct, containing cells quite large and compactly arranged.

The lowest roots of the hypoglossal are so precisely similar in arrangement and connection to the anterior spinal roots, as to render it somewhat difficult to mark with precision the limit between the highest cervical nerves and the commencement of the hypoglossal.

CHAPTER IV.

THE PASSAGE INTO THE MEDULLA OF THE POSTERIOR VESICULAR COLUMNS AND TRACTUS INTERMEDIO-LATERALIS.

In order to arrive at a clear understanding of the nature of the tract from which the sensitive nerves of the medulla arise, it will be necessary to study carefully the passage into the medulla of the two remarkable columns of nerve cells found in the posterior cornua of the spinal cord, and described by Clarke under the name of *posterior vesicular columns* (*columnæ vesiculosæ posteriores*) and *tractus intermedio-lateralis*. The posterior or sensitive nerve roots of the cord were shown by Clarke[1] and myself to be very intimately connected with the posterior vesicular columns, either directly, or as I have shown to be the case in the lumbar region,[2] after passing through the *longitudinal columns of the cornua*. The tractus intermedio-lateralis which is developed in the dorsal and cervical regions of the cord, seems to be a means of uniting the anterior and posterior cell groups, and serves especially to connect them with the very interesting longitudinal fasciculi, by which the lateral portions of the gray substance are bordered near the junction of the anterior and posterior cornua.

In his last memoir on the spinal cord (1859), Clarke has traced at considerable length the changes which are observed in the *tractus intermedio-lateralis* and *posterior vesicular columns*. Of the latter he states, that in the mammalia, "in the upper part of the cervical region, near the origin of the third pair of nerves, a darker and more defined mass reappears at the base of the cervix cornu. It is composed of cells both large and small, and of bundles of the posterior roots which interlace amongst them. This mass is not distinctly circumscribed like that of the posterior vesicular column in the dorsal region, but is somewhat triangular, with one of its angles directed towards the point of the posterior cornu, another towards the transverse commissure, and the third obliquely forwards and outwards towards the antero-lateral column. It gradually diminishes upwards, and disappears near the first pair of nerves." (*Philos. Trans.*, 1859, 447.)

In the spinal cord of man, as we ascend through the cervical enlargement, "the dark oval masses decrease, and at length disappear; but the spaces which they occupied along the inner halves of the cornua are still interspersed with a multitude of cells, and traversed by the posterior roots. The cells, however, are very much

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[1] Philos. Transactions, 1859. [2] Memoirs of the American Academy, 1861.

smaller than in the dorsal region; the majority are scarcely larger than those in the middle of the gelatinous substance; but a few of superior size are unequally scattered amongst them. Above the cervical enlargement the dark masses present nearly the same appearance as in mammalia, but they are rather paler, and the cells they contain are of smaller size." (*L. c.*, 450.)

The existence of the *tractus intermedio-lateralis* was first pointed out by Clarke in 1851, and described by him subsequently with great accuracy and detail (1859). This tract, which is situated on the lateral border of the gray substance just at the junction of the anterior and posterior cornua, is said by Clarke to gradually disappear as it ascends through the cervical enlargement, a few scattered cells remaining, which resemble those of the tractus intermedio-lateralis.

"In the upper part of the cervical region, a similar but somewhat larger tract reappears in the same situation, and projects in the same way into the lateral column. It increases in ascending to the third pair of nerves. This tract is traversed by several roots of the *spinal accessory* nerve, in their course forwards to the *anterior* cornu, and contributes with the edge of the posterior cornu to form a beautiful network in the lateral column, through which the nerve enters. There is reason therefore to believe that this tract forms a part of the *tractus intermedio-lateralis*. In the sheep and ox, and probably in all mammalia, a *peculiar* group of cells, which is traversed by the roots of the spinal-accessory nerve, is found in the same situation; and this group in ascending the medulla oblongata, retires inwards to the space behind the canal, and there contributes to form the nucleus which gives origin to the highest roots of the nerve."[1]

The changes which the posterior vesicular columns and the tractus intermedio-lateralis undergo, are very well illustrated in the cat, the two groups being more plainly distinguishable, and their relations more distinctly marked than in any other animal I have examined. At a point near the 2d or 3d cervical nerve, a very distinct, dark, oval mass of cells is seen (Cervicalkern of Stilling),[2] situated rather further inward than the posterior vesicular column in the upper part of the cervical enlargement, but so closely resembling it in form and general relation to the surrounding fibres, that no doubt can exist of this group being an upward extension of the column. Along the posterior edge of the cervix will be noticed numerous scattered cells. The tractus intermedio-lateralis in this region is very distinct, and is continued outwards along the course of the spinal accessory, forming a projecting mass of gray substance, and is brought into close relation with the longitudinal fasciculi by which the cervix and caput are separated. In the wood-cut, Fig. 2, showing the posterior cornu a little higher up, the group representing the posterior vesicular column is larger, but rather less distinctly circumscribed (*a*); it is closely connected with the tractus intermedio-lateralis (*f*), the cells of which are very numerous, and are continued along the lateral edge of the cervix around the

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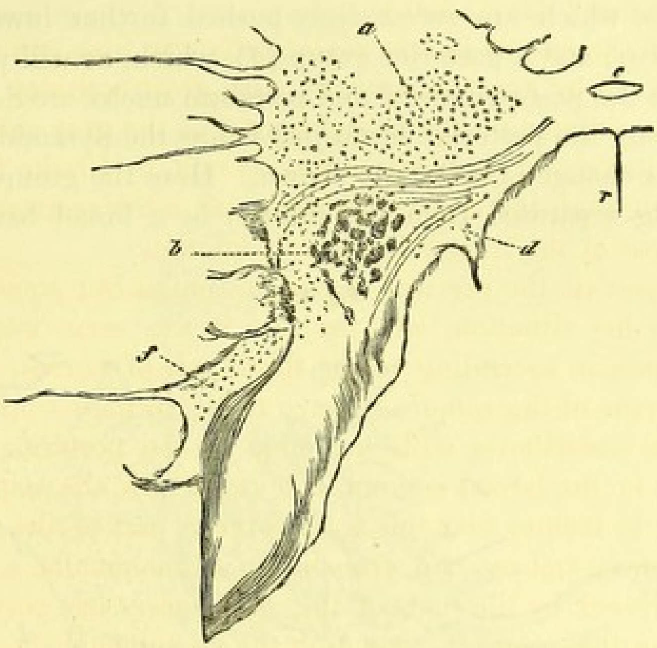
[1] Philos. Transactions, 1859, 451, also 458.

All these facts have been verified by my own observations, but as they were already so excellently stated by Clarke, I have preferred to give them in his words.

[2] Neue Untersuchungen. Description of pl. iv.

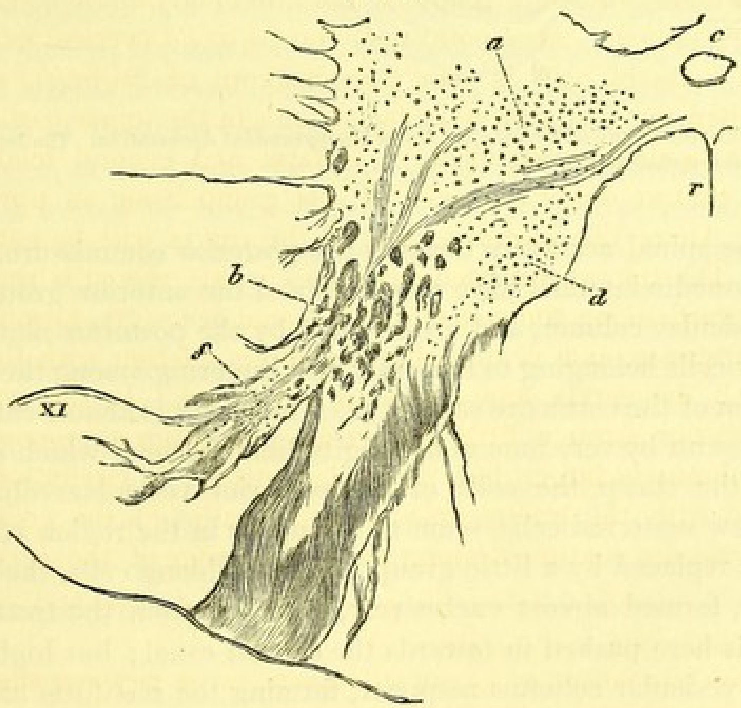
longitudinal bundles (*b*), which latter are now surrounded by a network of fibres formed from transverse fibres looping around the fasciculi, together with cell pro-

Fig. 2.



Posterior cornu from the spinal cord of the cat, near the second cervical nerve.—*a*, Cell group representing the anterior portion of the posterior vesicular column, and constituting the principal nucleus of the spinal accessory; *b*, longitudinal fasciculi; *c*, central canal; *d*, cell groups representing the posterior portion of the posterior vesicular column, from which the restiform nucleus is developed; *f*, tractus intermedio-lateralis; *r*, raphè.

Fig. 3.

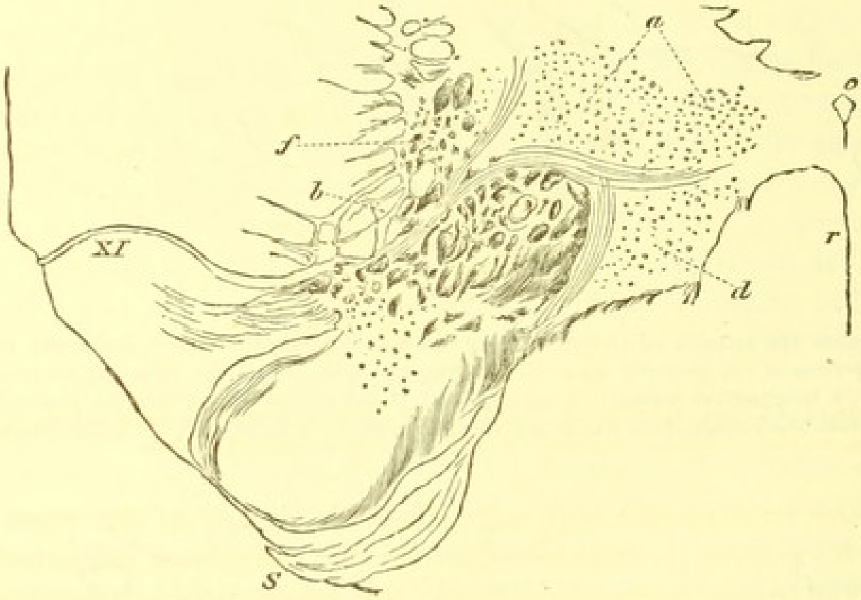


Posterior cornu from the spinal cord of the cat, a little higher than the preceding, the letters corresponding with fig. 2; *XI*, root of the spinal accessory.

cesses by which they are embraced. In Fig. 3, still higher, the group we have been considering appears to be divided; it is more completely within the limits of the cervix, and consists of two portions, the anterior (*a*), reached by the posterior roots of the spinal accessory (*XI*), constituting together with the cells of the tractus intermedio-lateralis, which are successively pushed further inwards, the posterior nucleus of this nerve; and a posterior group (*d*), which, as will presently be shown, is that from which the post-pyramidal and restiform nuclei are developed.

In Fig. 4, showing the posterior cornu just below the pyramidal decussation, the continuance of this change is strikingly shown. Here the groups are very distinct, the posterior being separated from the anterior by a broad band of fibres which

Fig. 4.

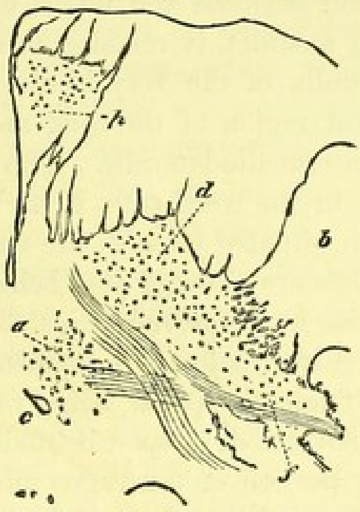


Posterior cornu from the spinal cord of the cat, just below the pyramidal decussation. The letters correspond with fig. 2; *S*, posterior spinal nerve root.

proceed from the spinal accessory towards the posterior commissure. The cells of the tractus intermedio-lateralis have mostly joined the anterior group formed from the posterior vesicular column, and are reached by the posterior roots of the spinal accessory; a few cells belonging to this tract still lingering among the network along the lateral portion of the cornu are seen at *f*. The cervix is almost entirely separated from the caput cornu by very numerous longitudinal fasciculi which pierce the gray substance. In the sheep, the cells of the posterior vesicular columns, with the exception of a few scattered cells, seem to disappear in the region of the first cervical nerve, being replaced by a little group of small, oblong cells, the nucleus of the spinal accessory, formed almost exclusively, however, from the tractus intermedio-lateralis, which is here pushed in towards the central canal; but higher up the cells of the posterior vesicular columns reappear, forming the restiform and post-pyramidal nuclei, and uniting with the above-mentioned group in forming the much larger nucleus of the upper roots of the spinal accessory, the nucleus of which continually increases in size as we ascend towards the vagus.[1]

In man I have usually been able to trace the continuity of these columns into the medulla. The cells of the posterior vesicular columns are often very much scattered, but rarely if ever disappear, and although the nucleus of the accessory, between the first cervical and lowest roots of the hypoglossal, is principally formed from the tractus intermedio-lateralis, it is constantly united to and reinforced by cells from the vesicular column. (Fig. 5.) In the upper part of the

Fig. 5.



Posterior cornu from the human medulla.—*a*, Nucleus of the spinal accessory; *b*, caput cornu; *c*, central canal *d*, restiform nucleus; *f*, tractus intermedio-lateralis; *p*, post-pyramidal nucleus.

spinal accessory nucleus and still more distinctly in that of the vagus, it will be noticed that the nucleus is composed of two distinct cell groups, one anterior, derived chiefly from the tractus intermedio-lateralis, this group apparently serving to receive the anterior roots of these nerves, and to unite them with the hypoglossal nucleus; the other posterior, derived from the posterior vesicular columns, receiving the posterior roots, and united by means of cells with the post-pyramidal and restiform nuclei, which are entirely derived, as we have seen, from the posterior vesicular columns. It will thus be seen that in the medulla, cell groups are formed, which if not direct continuations of the posterior vesicular columns and tractus intermedio-lateralis, are doubtless connected with them, and may certainly be considered as representing them, bearing the same relation to the posterior nerves of the medulla which these columns have been shown to sustain to the posterior spinal roots in the cord. These columns, moreover, though not always so compact and well defined as they are seen to be in the region of the accessory and vagus, may nevertheless be traced continuously throughout the medulla in close connection with the spinal accessory, vagus and glosso-pharyngeal nerves, as well as a part of the auditory and trifacial roots.

[1] In the sheep the nucleus of the spinal accessory seems to be formed more exclusively from the tractus intermedio-lateralis, than it is in the human medulla or in that of the cat.

A moment's reflection suffices to show that by this means a relation is at once established between the nerves of the posterior column of the medulla and the posterior spinal roots, and that the *plan* in both is precisely similar, although the arrangements of parts may at first sight seem to differ. The analogy between the upper roots of the spinal accessory, vagal and glosso-pharyngeal nerves and the posterior spinal roots seems to be perfect; they traverse the caput cornu, and are connected with cell groups which completely correspond with each other, if not in all respects identical, and this analogy is still further established by the relation they form with the motor roots, as we have already had occasion to notice.

Having noticed the relation between the nuclei of the posterior cornua of the spinal cord and those of the medulla, it remains to add a few words with regard to the passage into the medulla of the very interesting columns of longitudinal bundles, which in the cervical region of the cord are shown to be so intimately connected with the tractus intermedio-lateralis. The situation of these bundles in the spinal cord is well seen in the wood-cuts, Figs. 2, 3, 4. In Plate XIII, Fig. 1^a, *l*, the same column is seen, situated close to the entrance of the spinal accessory roots; higher up these bundles are situated just behind the entrance of the roots, and continually increase in size as we ascend (Figs. 3^a, 4^a, 19^a, 20^a, 21^a, 22^a), till the vagus nucleus has reached its greatest development, from which point upwards they gradually diminish and finally disappear, being replaced by a similar collection of longitudinal fasciculi, which are developed behind these in the substance of the post-pyramidal and posterior portion of the vagus nucleus, and stand in close connection with the outer portion of the nucleus of the auditory.

The longitudinal columns in connection with the vagus and spinal accessory nuclei have been noticed by Stilling, Schröder van der Kolk, and Clarke, and appear from their connection in the medulla with the centres, as well as with the anterior and posterior cornua in the spinal cord, to be intimately concerned in co-ordinating and bringing into harmony the different respiratory movements.

The connections of these fasciculi with different parts of the medulla are very striking; as I have shown in various places in the present memoir, they constantly penetrate the meshes of a network of cells and fibres, many of these cells being of very considerable size, embracing the bundles with their processes, and in many cases becoming continuous with them, while, on the other hand, some cell processes are sent transversely in all directions, many of them entering the nuclei (vagal and spinal accessory). It is chiefly in this way, I think, that connection is brought about between the roots and the longitudinal columns, for I have not been able to find any *direct* communication between them, notwithstanding the assertion of Schröder van der Kolk.[1] On the outer side of the longitudinal column in the direction of the caput, many cells are found, some of very large size, serving to connect the column with the caput, through the substance of which fibres descend from the trifacial. The opposite columns are brought into commissural connection by means of radiating fibres, some of which join the marginal bundles passing around

[1] Medulla Oblongata, 171.

the border of the hypoglossal nucleus and decussating at the raphè, while others pass backward along the floor of the fourth ventricle.

In the following paragraphs Clarke has pointed out very clearly some of the connections established between the tractus intermedio-lateralis and the respiratory tract above. "It has been seen that the cells of the *tractus intermedio-lateralis* are elongated with their processes in a longitudinal direction, and reached by both the *posterior* and *anterior* roots of the *spinal* nerves, and perhaps by the *spinal accessory;* that the latter nerve extends *forwards* to the cells of the *anterior cornua*, which also send some of their processes *longitudinally*, and are reached by the *posterior* roots. Moreover, I have in another memoir shown that, while *one* portion of the *upper* roots of the *spinal accessory* nerve and *one* portion of the *vagus roots* proceed *inwards to their respective nuclei behind the canal*, *other* portions *of both bend forwards to the vesicular network into which the anterior cornu has become resolved.* Again, I have shown, in the same memoir, that some of the roots of the *trifacial nerve descend longitudinally through the caput cornu*, between the transverse roots of the *vagus;* in which course they are probably brought into connection with the *respiratory centres*, and perhaps also, like the *vagus*, with the anterior gray substance of the medulla. These extensive and intimate connections seem to afford an explanation of the mechanism by which impressions made on the vagus and on the incident fibres of the trifacial and spinal nerves, may call into action the whole class of respiratory muscles; and if the tract which I have just described in the upper part of the cervical region be continuous, as it probably is, with the *tractus intermedio-lateralis*, which is reached by the dorsal nerves supplying the intercostal and other respiratory muscles of the trunk, the explanation in question will be still more complete."[1] If to these facts, all of which I have had abundant opportunity to confirm most thoroughly, we add the connections pointed out above of the *vagal* and *spinal accessory nuclei* with the *longitudinal columns*, which are undoubtedly continuous with the *longitudinal fasciculi* in the *spinal cord* separating the *cervix* and *caput cornu*, and standing in close connection with the cells of the *tractus intermedio-lateralis*, from the upward extension of which tract the *spinal accessory* and *vagal nuclei themselves* were shown to be partially formed, we have a series of very extensive and highly interesting connections brought about, the physiological importance of which is at once obvious, though it does not fall within the province of the present communication to do anything more than simply to call attention to them.

My own observations thoroughly confirm all the important facts pointed out by Clarke and Schröder van der Kolk, only differing from the latter in some of the minor details. The main point, however, I consider completely established, that the *respiratory centres* are brought into connection with *descending fibres from the trifacial*, *forming together a system of descending longitudinal fasciculi connected with columns of cells*, *continuous with those in the cervical and dorsal regions of the spinal cord*, and thus connected with both *anterior* and *posterior cornua*, serving to bring into action a series of movements, both direct and reflex, the importance of which can hardly be over-estimated.

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[1] Philos. Transactions, 1859, 451.

CHAPTER V.

THE VAGUS NUCLEUS AND ROOTS.

The Nucleus.—Stilling[1] was the first to point out the exact locality of this nucleus, and to give an accurate description of its form. The vagal nuclei are, as both Clarke and Stilling have shown, an upward extension of the vesicular columns from which the spinal accessory nerves arise, and in the lower portion of the medulla share so closely the characteristics of the latter, that it is quite impossible to determine any line of demarcation.

The roots of the vagus appear to be first given off, soon after the central canal opens into the fourth ventricle, and the two nuclei, which are at first joined by the transverse commissure forming the posterior boundary or roof of the central canal, are shortly after entirely separated, and lie on each side of the hypoglossal nuclei on the floor of the ventricle.

The form of the vagus nucleus is much the same as that of the hypoglossal, with the exception that it is bifurcated at the apex, forming two spurs or processes, between which run numerous thick and very conspicuous longitudinal fasciculi, which are the upward extension of those penetrating the spinal accessory nucleus. Most of the nerve roots appear to be given off from the inner process, a few only passing from the outer or posterior spur, which is brought into very close connection with the post-pyramidal and restiform nuclei, into which it is as it were wedged, forming in the upper part of the medulla a starting point for numerous arciform fibres (Plate XIII, Fig. 6″).

The changes in form which the vagal nuclei undergo as they ascend are but slight, and may be readily studied in Plate XV from the human medulla, and in Plate XIII from that of the sheep.

The changes in position of the nuclei have already been sufficiently dwelt upon in the chapters on the morphology of the medulla, the most important of these changes consisting in the gradual development of a new pyramidal mass formed partly out of the substance of the vagus, and partly from the post-pyramidal nucleus, by means of which the nucleus of the vagus is pushed more and more forwards, till it becomes blended with the mass now constituting the great pyramidal nucleus of the auditory, the base of which forms almost the entire floor of the fourth ventricle.

The cells of the vagus nucleus closely resemble those of the spinal accessory, being rather more oval or fusiform than those of the hypoglossal. They are exceed-

[1] Medulla Oblongata.

ingly numerous, especially in the anterior portion of the nucleus, where they are very closely crowded together. The larger cells are found chiefly in the anterior and antero-lateral portions, in the neighborhood of the hypoglossal nucleus and near the entrance of the vagus roots; those lying further inwards, more especially in the posterior and postero-lateral portions of the nucleus and in the neighborhood of the caput cornu and post-pyramidal nucleus are mostly quite small and are oblong or fusiform in shape.

The cells measure as follows, the measurements being made on their longest diameter and as near as possible to the point where the nucleus attains its greatest development. In the medulla of the sheep, the cells in the anterior part of the nucleus measure from $\frac{1}{666}$ to $\frac{1}{444}$ of an inch, and in the posterior portion $\frac{1}{2000}$ to $\frac{1}{1000}$ of an inch. In man $\frac{1}{1333}$ to $\frac{1}{666}$ of an inch, the smaller cells measuring not more than $\frac{1}{4000}$. In the cat, about $\frac{1}{1333}$ of an inch.

The group of cells represented in Plate X, Fig. 38, is from the anterior portion of the vagus nucleus; *V*, the bundle of vagus roots, many of which pass inwards to the cell group. Intermingled with the larger cells are very numerous smaller ones, and many of exceedingly small size with numberless single nuclei (not represented in the figure) are found scattered throughout the entire substance of the nucleus. It is quite impossible to determine the nature of these very small cells; they closely resemble those found in the posterior cornua of the spinal cord, and some of them are probably fragments of larger nerve cells, or cells which are still undeveloped, whilst many doubtless belong to the connective tissue.

The cell processes pass out in various directions, both transversely and longitudinally; many of them are directly continuous with the nerve roots, whilst others run in the direction of the neighboring hypoglossal nucleus, and are continuous either with processes from its cells, or with the nerve-roots themselves (*A*, *A*), thus forming connections analogous to those which I formerly demonstrated between the anterior and posterior cornua of the spinal cord.[1] A third set send their processes transversely into the antero-lateral columns, embracing the numerous longitudinal fasciculi which pass upwards in the bifurcation of the nucleus. Many cells serve also to connect the nucleus with the caput cornu, establishing thereby a possible relation between the vagus and the trifacial, the nucleus of which has been shown by Clarke to send descending fibres into the numerous longitudinal bundles by which the caput is pierced, a statement which I have been able thoroughly to verify. Other processes pass backwards, and serve to connect the roots as well as the anterior portions of the nucleus with the deeper lying parts, and also directly or through the intervention of cells, with the post-pyramidal and restiform nuclei.

As mentioned above, the vagus nucleus seems to consist of two more or less distinct portions (Plates XIII, XV). The anterior portion, divided from the posterior by the great bundles of longitudinal fibres (*l*), is for the most part occupied by a very large and closely crowded group of cells (*V*) with which many of the vagus roots are connected; the posterior part of the nucleus contains but very few cells, mostly of exceedingly small size, its substance being chiefly made up of fine fibres

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[1] Memoirs of the American Academy, 1861, 10.

crossing each other in every direction, intermingled with nuclei and granules, and forming an inextricable web closely resembling the structure of the *substantia gelatinosa* in the spinal cord.

The union of this portion of the nucleus with the post-pyramidal and restiform nuclei appears to be very intimate, numerous fine fibres passing between them. Along its apex fibres also pass forwards, some winding among the longitudinal bundles, others curving around and becoming arciform fibres, whilst quite a large tuft pass anteriorly into the caput cornu. Some fibres uniting with bundles which apparently turn off from the nerve-roots, loop around the longitudinal fasciculi in every direction, forming a network of fibres containing a few cells, and closely resembling the network formed around the numerous longitudinal bundles in the neighborhood of the tractus intermedio-lateralis as figured by Clarke in the cervical region of the spinal cord.[1] This network is continued anteriorly and antero-laterally out towards the caput, and backwards towards the restiform body.

From the postero-lateral or intermediate portion of the nucleus, we have the following classes of fibres produced. 1st. Bundles which proceed from the interior portion and pass directly outwards as radiating fibres, winding among the longitudinal bundles or turning off with the arciform fibres. 2d. Bundles which turn off at a more or less acute angle and pass forwards to join the bundles decussating at the raphè. 3d. Very numerous bundles serving to connect the nucleus with the *post-pyramidal* and *restiform nuclei*, and with the *caput cornu*. 4th. Fibres joining cells in the anterior portion of the nucleus.

Along the back of the nucleus constant indications are met with of single fibres and bundles cut across by the plane of section, many of which are evidently ascending bundles; some of them turning off from their longitudinal course and passing through the nucleus as transverse fibres, serve probably to connect various parts of the nucleus with the lower portions of the medulla.

The nucleus is bordered posteriorly by a thick band or commissure of fibres, which is especially distinct in the upper regions of the medulla; some of its fibres turn downwards and others upwards, but quite a regular band may be traced along the posterior border of the hypoglossal nucleus to the raphè, where it meets and decussates with a similar band coming from the nucleus of the opposite side, not only serving to connect the posterior portions of the vagal nuclei, but also co-ordinating to some extent the post-pyramidal and restiform nuclei.

The Roots.—Clarke has given a very accurate, though brief, description of the general course pursued by the vagus nerve.[2] As stated by him, the bundles pass through the caput cornu on their inward course, penetrating the longitudinal fasciculi derived from the root of the trifacial which are inclosed in its substance. I have not, however, been able to trace any *direct* communication between them, the roots of the vagus passing directly onwards, pursuing apparently an unbroken course. Stilling[3] states that the roots of the vagus pass both before and behind, as well as

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[1] Philos. Trans. 1859.

[2] Philos. Transactions, 1858, 253.

[3] Medulla Oblongata, 37.

through the *substantia gelatinosa*, and this is perhaps true in the lowest sections (Fig. 3^{a}), in which it is, however, probable that the roots passing in front of the caput cornu are the uppermost of the spinal accessory. In sections higher up, all the roots *penetrate* the caput, a circumstance which Stilling was the first to point out as proving the resemblance between the vagus and posterior spinal roots.

The roots of the vagus enter the anterior spur of the nucleus, just in front of the great bundles of longitudinal fasciculi, which separate it from the posterior process, their fibres being distributed much on the same plan as those of the accessory. Their course can be studied in Plates X, XI, Figs. 38 and 40. A portion of the fibres belonging to the great bundle of roots (*V*), enter deeply into the nucleus, becoming sooner or later united with cells which are very numerous and much crowded together (Plates XIII, XV, 3^{a}, 4^{a}, 6^{a}, 21^{a}, 22^{a}). Another portion of the roots, as will be seen in Fig. 40, turn backwards and pass out among the longitudinal bundles (*H*), or form loops around them, while some pass still further back into the posterior spur. Of the bundles which pass *forwards*, without entering the cells of their own nucleus, Clarke makes the following statement: "A separate bundle turns *inwards*, and after sending forwards in succession a number of single returning fibres, which wander through the network of the lateral column, proceeds through the side of the hypoglossal nucleus, where its fibres mingle with those of the hypoglossal nerve—I may almost affirm that some at least are continuous with the cells. Such is the course I have repeatedly observed in man; and in the sheep and ox I can show, without any difficulty, that while some of the fibres of the last mentioned *inner* bundle are apparently continuous with those of the hypoglossal nerve, others pass inwards to decussate at the raphè."[1]

On the other hand, Schröder van der Kolk[2] has endeavored to show that there is no *direct* decussation either of the sensitive or motor nerve roots of the medulla, but that the decussation of both is produced through the *intervention of cells*.

This statement is, I think, incorrect in regard to the spinal accessory and vagus roots, the course of which I have had repeated opportunity of studying in very many specimens, both from the human medulla and that of various mammals.

The course of the spinal accessory roots has been described and figured with very great accuracy by Clarke,[3] with whose observations my own have agreed very fully,[4] proving to my entire satisfaction, that while a part of the roots enter the nucleus and proceed directly towards the cells, quite a large bundle turns forwards, and passing in front of the hypoglossal nucleus, for the most part without entering cells, decussates at the raphè with a similar bundle from the opposite side.

The same is true of the vagus roots, but here the bundles turning forward to decussate are much larger and more conspicuous than is the case with those proceed-

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[1] Philos. Transactions, 1858, 253—4.

[2] Medulla Spinalis and Oblongata, 96, 185.

[3] Philos. Transactions, 1858, pl. xviii, fig. 35.

[4] A sketch drawn from one of my own specimens was so exact a reproduction of Clarke's figure in all important particulars as to render the publication of it, as well as of my own observations on the course of the spinal accessory roots, quite superfluous.

ing from the accessory. A glance at Figs. 38 or 40 will show large bundles of the vagus roots taking this course, and the same is also true in the human medulla, where this course is very evident, though perhaps not quite so distinctly made out as in the sheep.

These large bundles turning forwards from the vagus roots, appear to be composed of fibres which may be divided into three classes according to the course they pursue while passing towards the raphè. 1st. An uppermost layer (Plate XI, Fig. 40, *D*), which passing along the edge of the hypoglossal nucleus for a short distance and then turning outwards, pursue a wavy course among the longitudinal bundles of the antero-lateral and anterior columns; some of them may be traced to the raphè (*c*), while many of them are soon lost sight of. 2d. The next set pass along the hypoglossal nucleus, forming a complete marginal border; the fibres cross the hypoglossal roots with which they frequently interlace, and proceeding onwards still along the edge of the nucleus, are sometimes joined by a few fibres from the hypoglossal roots which they accompany to the raphè. (See page 16.) 3d. This set is composed of the deepest lying fibres; these pass through the hypoglossal nucleus at various depths, many as far back as the middle of the nucleus, and some even through its posterior portion. Some of the fibres composing the two last sets enter cells in the hypoglossal nucleus, and are thereby brought into indirect relation with the hypoglossal roots. (Fig. 38.)

The further course of the fibres after decussating is not easy to make out, and although I have carefully studied very many specimens in the endeavor to ascertain their destination, I can only briefly state that while many are immediately lost sight of in the anterior columns, some are seen passing along the raphè anteriorly for some distance, soon, however, curving outwards into the anterior portion of the medulla, probably becoming longitudinal fibres. A few seem to bend backwards, and pass along the raphè posteriorly, either entering the hypoglossal nucleus, or passing still further backwards towards the posterior commissure of the opposite side, along which they may sometimes be traced.

The posterior commissure, or marginal border of fibres forming the floor of the fourth ventricle, is chiefly derived from the posterior portion of the vagus nucleus, though occasionally reinforced by fibres from the nucleus of the hypoglossal. I have had repeated opportunity of verifying the truth of Clarke's statement quoted above (p. 27), in regard to the connection of cells in the hypoglossal nucleus with fibres derived from the vagus roots, as well in the human medulla as in various animals.

A very remarkable cell group located just at the point where the marginal bundles passing forwards from the vagus cross the hypoglossal roots, intended apparently to connect the two, in the same manner as the anterior and posterior spinal roots are united, has been described in the section on the hypoglossal roots. (p. 16.)

It is a question of great interest to ascertain, if possible, whether, as is the case with the spinal roots, any of the vagus fibres are *directly* continuous with those of the hypoglossal, but it is extremely difficult to decide this point with accuracy. I have repeatedly thought that I could make out a direct continuity between single fibres from the anterior bundles of the vagus and some of the hypoglossal roots, especially those which turn backwards. Clarke seems to have traced a similar continuity between some of the fibres of the hypoglossal and spinal accessory nerves, stating that some of the fibres of the latter nerve "may be traced even to the cells of the hypoglossal nucleus, where apparently they form loops of continuation with the fibres of the hypoglossal nerve."[1]

If such be the truth, we have in the medulla three classes of nerve fibres, analogous to those I pointed out formerly as existing in the spinal cord,[2] viz:—

(1) Vagus (spinal accessory) and hypoglossal roots which arise from or terminate in cells in their respective nuclei.

(2) Vagus (spinal accessory) and hypoglossal roots meeting in cells.

(3) Vagus (spinal accessory) and hypoglossal roots directly continuous.

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[1] Philos. Transactions, 1858, 252.

[2] Mem. American Academy, 1851, 349.

The three classes referred to are as follows: (1.) Anterior and posterior roots which arise from or terminate in anterior or posterior cells. (2.) Anterior and posterior roots which meet in cells near the central part of the gray substance. (3.) Anterior and posterior roots which are directly continuous.

CHAPTER VI.

THE GLOSSOPHARYNGEAL NUCLEUS AND ROOTS.

The form and development of the glossopharyngeal nucleus, and the general course of its nerve-roots in the human medulla, have been described by Stilling[1] with very considerable accuracy. More recently Clarke[2] has given a detailed description of the course of the fibres within the nucleus, to which but little remains to be added.

The course of the glossopharyngeal roots, and the distribution of their fibres within the nucleus resembles very strikingly the course and distribution of the vagus roots as described above, and the connection between these two nuclei is very close, the nucleus of the vagus passing gradually forwards as that of the auditory makes its appearance, until the three nuclei (hypoglossal, vagus and auditory) are fused as it were into one mass, the remains of the vagus nucleus now constituting one of the sources from which the glossopharyngeal roots are derived. The transition, however, between the vagal and glossopharyngeal roots or nuclei is so gradual, that it is quite impossible to point out any exact line of demarcation.

In the sheep the glossopharyngeal roots pass inwards in two or three bundles, which, after crossing the arciform plexus, often subdivide into as many as six or eight smaller ones, penetrating the caput cornu on their way to the nucleus. In the cat and in man the main bundles, usually not more than two or three in number, pass inwards without subdividing, till they reach the apex of the nucleus (Plate VI, Fig. 24) which a portion of them enter, other portions of the bundles diverging, and the fibres spreading out in various directions either forwards or backwards, passing, as Clarke has noticed, among the longitudinal fasciculi which adjoin the margin of the nucleus. Some of the fibres pass into the loose network formed from the remains of the posterior pyramid, others pass forwards towards the remains of the hypoglossal nucleus. Some of the fibres, as mentioned above, proceed directly inwards, joining the group of rather large cells which constitutes the remains of the vagus nucleus. The cells near the apex are mostly very small, but further inwards, near the back of the little nucleus, measure about $\frac{1}{1333}$ to $\frac{1}{800}$ of an inch in length; in the human medulla they are mostly obovate or fusiform, resembling the vagus cells, and are evidently connected with a portion of the glossopharyngeal roots.

As in the case of the vagus, a large anterior bundle is formed, which turns off at or near the apex of the nucleus, and as described by Clarke, "turns inwards round

[1] Medulla Oblongata. [2] Philos. Trans. 1858.

the summit of the antero-lateral column, and passing through the most anterior and largest cells, sends forward a series of returning loops, first through the antero-posterior bundles along the inner border of the *caput cornu posterioris*, and then in succession through the network of the lateral column as it makes its way towards the raphè; but in this course its fibres lie side by side with those which have been already described as proceeding from the antero-lateral column to decussate through the raphè with their opposite fellows, so that it becomes almost impossible to identify them and ascertain if they share in the decussation; that they do so, however, is rendered extremely probable by the fact that in birds *all* the fibres of the eighth pair of nerves, of which the highest correspond to the *glossopharyngeal*, may be distinctly seen to decussate through the raphè, after passing through and around their nuclei."[1]

In the cat the course of this anterior bundle is very distinctly seen, and I have several specimens showing the anterior division as it passes along the margin of the nucleus towards the raphè, where it decussates with a similar bundle from the other side. As the bundle turns forwards at the apex of the nucleus, it gives off a few fibres which enter among the cells, some of which they undoubtedly join, and in its course along the border of the nucleus, a few fibres are seen at intervals turning inwards towards the deeper lying cells, while on the outside of the bundle fibres constantly turn off, forming loops or joining the numerous radiating fibres which everywhere penetrate the anterior and antero-lateral columns; a part of these pass across the anterior columns to the raphè with some of the radiating fibres, but most of them are soon lost sight of, and probably pass upwards with the longitudinal fasciculi. A portion of the middle roots may be traced forwards, as stated by Clarke, to the group of large cells occupying the place of the *fasciculus teres* and representing the continuation of the hypoglossal nucleus; and fibres are also seen to turn off from the anterior bundle towards the same group.

In the cat the decussation at the raphè is very distinct, quite as much so as in the case of the vagus; but in the sheep and especially in man, I have had much difficulty in tracing the course of the anterior bundle, for the reasons which Clarke has given in the passage quoted above. In the cat, however, the entire course of the glossopharyngeal roots is very distinct and easily made out.

In Plate IX, Fig. 33, the upper roots of the glossopharyngeal may be seen passing through the caput cornu in the medulla of the cat. Plates II and XIV, Figs. 8, 8^a, from the sheep, and Plates VI and XV, Figs. 24, 24^a, from the human medulla, also illustrate the course and appearance of the glossopharyngeal roots.

Schröder van der Kolk has supposed that a connection exists between the trifacial and glossopharyngeal, from the fact that the latter passes through the caput, but as in the case of the vagus, I have found no evidence of any direct communication between the glossopharyngeal roots and the bundles which descend through the caput from the fifth nerve.

[1] Philos. Transactions, 1858, 255.

CHAPTER VII.

THE OLIVARY BODIES IN MAN.

THE resemblance between the convoluted folds of the *corpora olivaria* and the *corpus dentatum* of the cerebellum, could hardly fail to attract the attention of many anatomists. This resemblance, pointed out by Reil,[1] Prochaska,[2] and Gall,[3] the latter, however, seeming to have overlooked the convoluted structure, has been very plainly shown by Rolando,[4] who makes the following statement. "Il résulte de mes observations, qu'il n'existe presqu' aucune diversité, relativement à la structure, entre les éminences olivaires et les corps dentelés du cervelet. En effet, si on suit les coupes qu'ils offrent tant les uns que les autres, il est facile de se convaincre que la lame jaunâtre et dentelée est disposée autour du noyau, de manière qu'il en résulte une bourse aplatie, dont le col ouvert et un peu rétréci est tourné vers la ligne médiane et en arrière, s'il est question des eminences olivaires; tandis que si on parle des corps dentelés du cervelet, la dite lame jaunâtre est plus plissée, et forme une bourse plus longue et presque ronde, dont le col, plus ouvert et plus large, serait retourné en avant et vers le 4^e ventricule."

The resemblance pointed out above, and the probability that the same general plan exists in all cases where this peculiar convoluted structure is found, at once invest the study of the minute anatomy of the olivary bodies with very great interest, from the light thus likely to be thrown on the analogous structure of the hemispheres of the cerebrum and cerebellum.

The external and internal form and relations of the olivaries, as seen in transverse sections, have been well described by several observers, among whom Clarke[5] certainly deserves first mention, both for the extreme accuracy and detail of his descriptions. The subject is by no means an easy one, but after going over the whole ground very carefully, and studying very many different preparations, I find that my own observations are *entirely in accordance with his in every important particular.*

As pointed out by Clarke, the olivary column is developed amongst the network into which the anterior cornu is resolved. This is evident by reference to Plate XIV, Fig. 18^a, where the origin of the olivary bodies is seen just behind the pyramid, and close to the course of the hypoglossal roots, as an elongated, somewhat rounded collection of cells (*O*), scattered at first among the arciform fibres with

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[1] Archiv für die Physiologie, IX, 490. [2] De Structura Nervorum.

[3] Gall et Spurzheim, Système, 198.

[4] Recherches anatomiques. Magendie, Journal de Physiol. IV, 336.

[5] Philos. Transactions, 1858.

which they appear to be closely connected. In longitudinal sections, the lower portion of the olivary column presents a similar appearance, consisting of successive layers of scattered cells, separated from each other by thick bundles of transverse fibres, penetrating the column in every direction. Higher up, the cells are more and more compactly arranged, soon becoming collected into a convoluted lamina, the form of which has so often been drawn and described.

The principal changes in the general form of the olivary bodies are well shown in Plates VII and XV. In Plate VII, Fig. 25, a section is seen soon after the full development of the convolution is attained, at a point just above the opening of the fourth ventricle, some additional details being given in Plate XV, Fig. 20^a.[1] The olivary body, which in the preceding figure, 19^a, consisted of a closed convolution in the centre of a large fibrous mass, is now an open series of folds, with very numerous transverse fibres radiating towards the centre or hilus, across which the hypoglossal roots pass; the fibrous mass within and around the lamina still however predominating. In Fig. 26, Plate VII, the convolutions have become much deeper and closer, the course of the fibres proceeding from the interior is much more distinct, and many of them may now be seen passing directly forwards, towards the raphé, where they decussate with their fellows from the opposite side, forming a commissure between the two olivary bodies. In this course they are joined by numerous arciform fibres, which everywhere surround and penetrate the olivaries, forming an exceedingly complicated plexus radiating from the posterior portion of the medulla.

From this stage upwards, the principal changes consist in the rapid increase in number and size of the convolutions, which soon occupy nearly the entire mass of the olivary column (Plates VII and XV, Figs. 27, 28, 22^a, 23^a, 24^a). In the outline figures (Plate XV) I have merely attempted to *indicate* the relation of the arciform fibres to the lamina, these fibres forming so intricate a plexus as they pass through the convolutions of the lamina, either joining cells or passing onwards towards the decussation at the raphè, that anything more than the *merest indication* of their course would have required the use of many additional figures on a much larger scale than those given.

In the neighborhood of the olivary bodies will be noticed several smaller nuclei, occasionally assuming the convoluted form to some extent. These bodies, called by Stilling[2] the *accessory olivary nucleus* (Oliven-Nebenkern) and *larger pyramidal nucleus* (grosser Pyramiden-Kern), have been shown by Clarke[3] and Schröder van der Kolk[4] to be similar in structure to the olivaries, and are undoubtedly groups of similar cells, more or less removed from the main body, but identical in structure and relations. Moreover, as Schröder van der Kolk has pointed out, the so called

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[1] Figs. 20, 20^a and 25 are from the same section; Fig. 26 is from a section a *very little* higher than Figs. 21, 21^a; Fig. 27 is also from a section a little higher up than Figs. 22, 22^a, but they may be regarded as representing substantially the same level; Figs. 23, 23^a, and 28 are from the same section.

[2] Medulla Oblongata, 30, 31.

[3] Philos. Transactions, 1858, 243.

[4] Medulla Oblongata, 133.

pyramidal nucleus is not everywhere isolated, but, on the contrary, as will be seen from my own figures (Figs. 21^a, 22^a, 23^a, 24^a, *s*), is in some places closely connected with the lamina and in others separated from it, while in some cases it is divided into three or four little groups, some of which, though doubtless connected more or less with the pyramids, are still evidently offshoots from the olivary lamina. The accessory olivary body of Stilling seems to be a sort of intermediate group between the cells of the antero-lateral nucleus and the olivary lamina, and in sections from the upper part of the medulla (Figs, 23^a, 24^a) it is replaced by the cells of the former nucleus and by large multipolar cells lying in the same situation.

As we ascend towards the pons, the hilus of the olivary bodies becomes successively more and more contracted, the folds of the lamina increasing somewhat in depth, but diminishing rapidly in number, until, finally, the lamina is reduced to much the same state as at its outset, becoming a closed coil of cells and fibres, which soon entirely disappears, leaving only a few scattered cells to mark its situation in the antero-lateral network which is now much encroached upon by the rapidly increasing fibres of the pons Varolii.

The cells of the olivary lamina are quite small, measuring about $\frac{1}{1666}$ to $\frac{1}{1333}$ of an inch, agreeing very closely with Clarke's measurement ($\frac{1}{1300}$—$\frac{1}{1600}$); they are very numerous and are quite uniform in size. My measurements of the average thickness of the lamina vary much in different specimens, the smallest measurement being about $\frac{1}{200}$ of an inch, and the largest $\frac{1}{80}$ of an inch; in the same medulla I have however found but very little variation, either in longitudinal or transverse sections.

Each olivary body is joined to its opposite fellow by a transverse commissure of fibres decussating at the raphè, by means of which they are brought into very close connection, as has already been pointed out by several authors. These commissural fibres may be well seen in Figs. 25, 26, 27, and 28, and especially in Fig. 29, but I have nowhere found such a strongly marked band without any intermingling of longitudinal fibres, as is represented by Lenhossek,[1] and I cannot fail to agree with the criticism of Kölliker[2] on Lenhossek's description of the olivary commissure. The fibres which serve to connect the olivaries, are for the most part as stated by Kölliker, a direct continuation of the inner bundles of arciform fibres, which, as was shown above, penetrate the olivary lamina at varying angles, a portion entering cells, and the remainder forming a most intricate and complicated plexus with the fibres derived from the cells of the lamina. Both of these sets of fibres, viz., those entering cells and those passing among the cells, are, many of them at least, continued forwards towards the raphè, forming a very beautiful network around the numerous longitudinal bundles which pass upwards in the anterior part of the medulla on each side of the median line. Some of these fibres turn upwards, accompanying the longitudinal bundles, but very many of them may be seen to decussate at the raphè, forming a commissural connection between the opposite sides of the medulla. At the same time, however, it must be borne in mind, that while some of these decussating fibres do undoubtedly originate in the cells of the olivary lamina and

[1] Neue Untersuchungen. Wien, 1859, pl. ii, fig. 2. [2] Gewebelehre, 1862, 320.

form a true olivary commissure, they are constantly accompanied by the arciform fibres, which here, as elsewhere, decussate in so great number, connecting the various parts of the medulla with those of the opposite side.

Schröder van der Kolk[1] and Lenhossek[2] have described at considerable length a large and well marked bundle, called by the latter "*pedunculus olivæ*," serving to connect the olivary body with the hypoglossal nucleus, with the roots of which it is nearly parallel. "These fibres arise from the gray substance of the olivary body, and form a tolerably large bundle, which does not differ much in thickness from the roots of the hypoglossal, and which we can follow uninterruptedly into the nucleus of this nerve. The fasciculi in question appear not to perforate the olivary body, as they do not appear on the other side; but they arise, as can be easily shown, from the ganglionic cells of the olivary body itself. They pass through the hilus, and are collected in bundles, which run into the hypoglossal nucleus."[3] I have nowhere been able to find such bundles as are figured by Schröder van der Kolk (*op. cit.*, Fig. 14, Plate v), or by Lenhossek (*op. cit.*, Fig. I, Plate ii), with their fibres spreading out like a brush into the hilus, my own observations on this point being very closely in agreement with those of Kölliker.[4] As stated by him, the roots of the hypoglossal do not always run in front of the olivary bodies, but frequently penetrate the lamina at a greater or less depth, and often pursue a wavy or zigzag course before emerging (Figs. 26, 27, 21^a, 22^a). It of course often happens that such bundles are cut off, and may easily be mistaken for fibres originating in the hilus, and when we take into consideration the slightly ascending course of the hypoglossal roots, which may be easily demonstrated in longitudinal sections, the probability becomes very great that the bundles seen in the upper part of the medulla apparently terminating in the hilus (Figs. 22^a, 24^a) are mainly cut off bundles of hypoglossal roots which emerge lower down.[5]

The fibres from the hilus and from the cells of the lamina pass in every direction, both forwards towards the raphè, and transversely towards the posterior portion of the medulla, contributing to form the very beautiful and complicated network with which the entire anterior and antero-lateral portions of the medulla, between the nuclei on the floor of the fourth ventricle and the olivary bodies, is filled. The cells found in this network are mostly single, though sometimes collected into little groups which serve to unite the distant parts of the medulla, and seem especially intended to connect the olivary bodies with the hypoglossal nucleus, perhaps also with that of the spinal accessory, though I have never been able to trace any direct communication between this and the olivary column, notwithstanding the assertion of Schröder van der Kolk.

At points where the hypoglossal roots cross the olivary lamina, it becomes very difficult to decide whether or not any connection is brought about between the

[1] Medulla Oblongata, 164.
[2] Neue Untersuchungen, 34.
[3] Schröder v. d. Kolk, l. c. 134.
[4] Gewebelehre, 1862, 321.
[5] This opinion is further confirmed by the figures given by Stilling and Clarke, in which no such bundles as are represented by Lenhossek are to be found. (See Stilling, Medulla Oblongata, pls. v and vi, and Clarke, Philos. Trans. 1858, figs. 29, 30, 31, 32, and especially fig. 36.)

nerve-roots and the cells of the lamina; processes from the cells cross the root-bundles in every direction, and I have occasionally been able to trace fibres derived from these cells, running parallel to the roots and apparently accompanying them for some distance towards the nucleus, but I have never been able to satisfy myself that there is any direct connection between the hypoglossal roots themselves and the cells of the olivaries, not even where the roots pass directly through the lamina.

The fibres derived from the hilus, or even from the cells of the lamina, which I have been able to trace continuously for any considerable distance in a course parallel with the hypoglossal roots, are very few in number, not at all corresponding to the very large bundles represented by Lenhossek, which had they existed could hardly have escaped the observation of Stilling and Clarke. That the hypoglossal nuclei are, however, connected to some extent with the olivary bodies, by fibres and by the network of cells in the anterior part of the medulla, admits I think of no doubt, and will be still more evident when we examine presently the arrangement of these cell groups in the medulla of the sheep.

In longitudinal sections the olivary bodies present a very beautiful appearance, the convolutions being compact and numerous; this is especially evident in Fig. 30, Plate VIII, representing a longitudinal section through the olivary body, in a direction nearly parallel to the hilus. A series of such sections presents several striking points; in the outermost, the convoluted lamina has the appearance of a closed circle or ellipse, from which various other foldings radiate, filling up the whole interior, but as we approach the hilus, the lamina opens at the bottom (Fig. 30), into which some of the great bundles of longitudinal fibres turn, often quite abruptly, radiating in every direction towards the centre of the olivary body. At different heights small bundles of longitudinal fibres turn off from the main bundles, running some upwards and some downwards towards the convolutions, which they often cross, proceeding towards the interior, though not unfrequently joining cells of the lamina.

In sections cut at right angles to the raphè (Figs. 31, 32), the appearance is somewhat different. Near the surface of the olivary body (Fig. 31), the longitudinal columns are seen ascending on each side of the raphè in a perpendicular course, in the midst of which the olivary body seems to be thrust, as it were, the folds of the lamina branching off from a stem of transverse and oblique fibres, like the branches from a tree; nearer the centre of the olivary body (Fig. 32) the folds of the lamina are very distinctly seen, and as the plane of section has in this case gone somewhat obliquely across the thickest portion of the convolutions, the lamina appears nearly double the thickness of that in Fig. 30, though these two specimens were from the same medulla.

In longitudinal sections made in this direction, the internal arciform fibres pursuing a course at right angles to the raphè (Fig. 29) can often be traced for a considerable distance, and may plainly be seen curving upwards and downwards to become longitudinal fibres, just as the longitudinal fibres on the other hand turn off and radiate towards the interior of the lamina; in this way it is highly probable that a series of loops is formed, serving, as is so often the case in the spinal cord, to connect parts lying at different heights.

Various authors have attempted to trace the course of the fibres within the olivary bodies, and their relations to the cells of the lamina, but with little success, with the single exception of the very complete and accurate description given by Clarke.[1] The subject is an exceedingly difficult one, but after studying a large number of preparations, both colored and uncolored, in which the course of the fibres was as clear as possible, I am satisfied of the *entire accuracy* of Clarke's description in *all particulars*. The only point remaining was to ascertain whether the structure was the same in longitudinal as in transverse sections.

Fig. 39, Plate XI, represents one of the folds of the lamina as seen in a longitudinal section (Fig. 30), in which the arrangement of cells and fibres is strikingly the same as that represented by Clarke (*Philos. Trans.* 1858, Plate xv, Fig. 25) in connection with which it will be well to study it. From the longitudinal bundles which proceed upwards in the vicinity of the raphè (Fig. 30), forming the very beautiful network seen in transverse sections (Fig. 29), numerous bundles turn off at varying angles, especially in the lower part of the medulla, radiating towards the convolutions of the lamina. The course of one such bundle as it enters the fold is seen in Fig. 39, Plate XI. The main bundle (*A*) enters the convolution just as Clarke has described and figured the course of similar bundles in transverse sections. (1st.) The inner fibres constituting the axis of the bundle proceed directly inwards to the apex of the fold, where they spread out more or less towards the cells of the lamina, with the processes of which many of them are continuous, while others radiate and pass among the cells in the most varied directions. These fibres sometimes cross over the lamina and pursue an onward course towards more distant convolutions, or pass still further forwards to the anterior portion of the medulla, nearly parallel to the surface of which a folded portion of the lamina is disposed (Fig. 30). The fibres passing through the lamina pursue a transverse course for a very short distance, but soon turn upwards or downwards, joining the longitudinal marginal fibres which run along the anterior surface of the medulla, forming quite a thick band in connection with the arciform fibres with which they are interwoven.

(2d.) The external fibres of the bundles are very divergent, some of them terminate in cells lying near their course, but by far the greater number traverse the lamina either singly or in bundles; the latter are sometimes very conspicuous (*C*, *C*), partly crossing over and partly joining the next lying bundle, entering the neighboring lamina in a course opposite to the one we have been considering. Some of the cells belonging to the next fold of the lamina are represented at (*D*), the lamina folding around the bundle (*B*) at each extremity, just about where the letters (*B*, *B*) stand, so that the bundle (*B*, *B*) which constitutes the outer bundle to one fold of the lamina, becomes in its turn the inner bundle of the next two, such bundles as (*C*, *C*, *C*) uniting them, or, as is frequently the case, passing still further onwards to more distant folds of the lamina. These bundles follow so varied courses, and cross and interlace in so many directions, that any description, however careful, must of necessity be exceedingly indefinite.

It is evident that fibres from *all* the different nuclei of the medulla pass among

[1] Philos. Transactions, 1858, 244.

the cells of the olivary bodies, and in many cases are doubtless continuous with their processes, so that the probability deduced by Clarke, from the study of transverse sections, viz., that "the *olivary bodies* are co-ordinating centres for the different ganglia or nuclei of the *medulla oblongata*," derives additional strength from the study of the laminæ in the beautiful convolutions in which we find them arranged in their longitudinal course.

The olivary bodies are connected most intimately with the great system of *longitudinal fibres* running on each side of the raphè, by means of which parts lying *above* and *below* are brought into co-ordination. The *two sides of the medulla* are also united by the intimate relation existing between the olivary bodies and the arciform fibres, as well as by means of the olivary commissure; while posteriorly the olivaries receive radiating fibres from the *nuclei lying along the floor of the fourth ventricle*, to which they are still further united by means of the internal and external bundles of arciform fibres, which bend around them and also enter them, forming such an intricate plexus in the antero-lateral portions of the medulla (Plate XV). Their relations with the *antero-lateral nuclei* are very close and intimate, as also with the *caput cornu*, and in the anterior portion of the medulla, fibres are everywhere seen turning off, especially in longitudinal sections, towards the *outer layer of marginal fibres*.

Whether or not it is true, as Todd and Bowman have surmised, "that the olivary bodies constitute the essential portion or *nucleus* of the medulla oblongata, that on which its power as an independent centre depends,"[1] it is evident that they are very largely concerned in the *co-ordination* of action, bringing into harmony the most distant parts of the medulla, and appearing to stand, in connection with the system of arciform fibres, much in the same relation to the nuclei of the *medulla oblongata*, as the cerebellum and fibres of the pons Varolii do to the nuclei of that part of the central nervous system to which they belong.

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[1] Physiological Anatomy, I, 267.

CHAPTER VIII.

THE OLIVARY BODIES OF MAMMALIA.

The structure of the olivary bodies in the mammalia has received but little attention hitherto, and their existence has been entirely denied by some authors. Schröder van der Kolk and Clarke have given the only accurate description of the structure and connections of these bodies, and the results of their observations are both interesting and important. As already pointed out by both these authors, the situation of the olivaries is different in most of the mammalia from their position in man, lying directly behind the anterior pyramids between the raphè and hypoglossal roots; the latter running along the outer edge of the olivary bodies, instead of passing on the inner side, as is the case in man. In the sheep, the structure of the olivary bodies is reduced to a very simple type (Plate XIII, Figs. 2^a, 3^a, 4^a, 6^a, 7^a, and the corresponding figures Plates I and II, also Fig. 5); in this latter figure the olivary is seen to consist of a folded lamina, the convolutions of which are very few in number when compared with those in the human medulla.

The laminæ are united by a transverse commissure across the raphè, similar to that described in man, and contain numerous, rather small, oblong or fusiform cells, measuring about $\frac{1}{1333}$ to $\frac{1}{1000}$ of an inch on their longest diameter. The lamina is everywhere penetrated by regular, wavy bundles of fibres, between which the cells are arranged in layers, some of the fibres being evidently continuous with their processes. Just behind the pyramids, on each side of the raphè, the fibres, which are mostly derived from the arciform plexus, are arranged in a very regular manner, often forming beautiful, wavy bands which sweep through the olivary bodies, and cross at the raphè. In Figs. 5, 6, 6^a is seen the greatest development of the olivaries which is attained in the sheep, and even here the convoluted appearance is very slight, consisting only of three or four foldings, which are very much larger in proportion to the whole size of the olivary body than in the human medulla; while lower down (Figs. 2^a, 3^a) no indication of folding is visible, the cells being arranged in layers between bundles of arciform fibres. The form of the olivary body in the sheep, and the course of the arciform fibres as they pass through it, has been very well drawn by Clarke (*Philos. Trans.* 1858, Plate xv, Fig. 26).

The simple plan of structure of the olivary body in the sheep is well seen in longitudinal sections, where it appears to be inserted or thrust like a wedge between the external and internal bundles of longitudinal fibres which diverge very sharply at the point where the olivary first makes its appearance, the external bundles running in front along the curved surface of the medulla, while the internal fibres pursue their vertical course behind the olivary body, turning off at various angles to penetrate the lamina, joining the cells here or passing among them to more distant parts. The olivary column is terminated above by a group of large, multipolar cells scattered in the network about the raphè, which have replaced the smaller olivary cells, and measure about $\frac{1}{800}$ to $\frac{1}{400}$ of an inch in diameter.

The connection between the olivary bodies and the nuclei of the hypoglossal is much more apparent in the sheep than in man. Little bundles of fibres are constantly seen running from the nucleus on each side the raphè and close to it towards the olivary body, and these bundles are commonly studded throughout their entire course with small scattered cells and little cell-groups. In some specimens the hypoglossal nucleus on each side of the raphè sends out a little pointed promontory of some length containing cells, and along the raphè cell-groups are formed on each side at regular intervals, exactly opposite each other, connecting the hypoglossal nuclei with the olivary bodies (Figs. 2^a, 6^a, 7^a), while branching off from the apex of the hypoglossal nucleus, similar little cell-groups are found, connecting it with the antero-lateral nucleus (Figs. 4^a, 19^a).

In the cat and the carnivora generally, the anterior pyramids are deeper, and approach more nearly to the human type, the olivary bodies are much more fully developed and present a more decidedly convoluted form, which is occasionally very marked; they are still, however, as in the sheep, situated just behind the pyramids, close to the middle line, the hypoglossal roots running on the outside. Their position may be seen in Plate IX, Fig. 33, though as this section is from the upper part of the medulla, they have already begun to diminish in size and in the number of convolutions. The cells of the lamina in the cat are quite small, measuring about $\frac{1}{2000}$ of an inch in diameter; they appear to follow more closely the direction and form of the convolutions than in the sheep, being arranged within the lamina much in the same way as in man, while in the sheep, as stated above, the cells follow more nearly the direction of the arciform fibres, the layer of cells often crossing the lamina at right angles with the direction of the folding.

Schröder van der Kolk[1] has stated, that in all animals the inferior olivary bodies are situated within the limits of the hypoglossal roots, but this does not appear to be strictly true, since in the sheep we find distinct traces of the convolution after the disappearance of the hypoglossal roots (Fig. 7^a), and in the cat, this is also distinctly seen to be the case (Fig. 33), evident remains of the olivary body, still showing the convoluted structure, being found on a level with the roots of the glossopharyngeal. The same is true in the human medulla, the convolutions are distinctly seen in Fig. 24^a, and can be traced for a considerable distance above, as may be seen by reference to Stilling's admirable plates (Pons Varolii, Plate i). I have not been able to trace any direct communication between the accessory or vagal nuclei and the olivary bodies, nor any direct connection with the hypoglossal roots, though the latter often pass directly through the outer portion of the olivaries.

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[1] Medulla Oblongata, 164. His deductions seem to have been principally founded on external measurements, which of course are liable to error.

CHAPTER IX.

THE ANTERO-LATERAL NUCLEUS.

THE only notice which I find of this important and interesting column is contained in a brief description given by Clarke, stating that in the mammalia, "on the outer side of each olivary body, and separated from it by a groove which lodges the hypoglossal nerve, is another vesicular column of nearly the same length, but broader externally. Above, it blends as a flattened band with the trapezium, close to the origin of the facial nerve, which arises from the side of the latter; and below, it is continuous with a distinct fasciculus of the lateral column. From its side and that of the olivary body, the broad band of arciform fibres crosses the medulla to reach the posterior columns; but within, it is traversed by a network or plexus, formed by the interlacement of these fibres with those remaining from the anterior cornu, and inclosing the longitudinal bundles of the lateral column. Amongst this network lie the cells, which are larger than those of the olivary body, and more irregular in shape. They are oval in different degrees, or pyriform, fusiform, crescentic, club-shaped, triangular, or variously stellate, and give off processes which nearly encircle the longitudinal bundles, and contribute to form the meshes. All these appearances may be very distinctly observed in the sheep, ox, or cat. In man a similar structure was found, but owing to the difference in the shape of the medulla, it lies behind, instead of at the side of the olivary bodies, and is not so prominent externally; the cells also are rather less than those of the mammalia."[1]

This column of large cells, which, from the variety of its connections, would seem to be of very considerable importance, I have called the *antero-lateral nucleus*. It is developed in the antero-lateral portion of the medulla, just above the decussation of the pyramids, among the great bundles of arciform fibres which are here so conspicuous. The cells vary, as stated by Clarke, both in form and size, but are mostly quite large, measuring, in the sheep, from $\frac{1}{800}$ to $\frac{1}{400}$ of an inch in the principal group; while behind, a smaller group of very large cells is often found, connecting the main nucleus with the caput cornu, some of the cells of which measure $\frac{1}{400}$ to $\frac{1}{266}$ of an inch in diameter. The cells composing the body of the nucleus are disposed in a compact group, through which the arciform fibres radiate in various wavy bundles, forming an intricate network around the longitudinal fasciculi, which are embraced in every direction by the cell-fibres. The large cells, mentioned above, sometimes appear as a distinct group, just on the anterior border

[1] Philos. Transactions, 1858, 246.

of the caput cornu, but are more commonly an offshoot from the main nucleus, with which they are evidently closely connected (Figs. 2^a, 3^a, 4^a, 6^a). In the cat the cells of the antero-lateral nucleus are very conspicuous and well defined, they are collected into a group in the same situation as in the sheep, but form a rather more open plexus or network with the arciform fibres, many of which are distinctly seen to be continuous with their processes. As cell-processes also pass in many different directions transversely as well as longitudinally, this group doubtless serves to connect the arciform fibres with the other parts of the medulla, constituting apparently an accessory nucleus to each olivary body.

Its connections with the caput cornu have already been pointed out; and connections are also established between this nucleus and that of the hypoglossal, and with the vagal and spinal accessory nuclei; with the two latter sometimes directly, and sometimes through the caput. The connections established between the antero-lateral nucleus and that of the hypoglossal are often very striking. They are especially evident in the sheep, in which I have often noticed the formation among the border fibres of the hypoglossal nucleus, of a little cell-group, sometimes thrust out along the course of the roots for a considerable distance, and joined by scattered cells to quite a large, elongated group of stellate and oval cells, which are evidently a prolongation obliquely inwards of the antero-lateral nucleus (Fig. 4^a). Along the raphè on each side, little cell-groups are found at varying distances, each of which is usually provided on the opposite side with its exact counterpart, and these little groups are apparently entered by numerous fibres from the arciform plexus, which have just passed through the nuclei mentioned above.

In the human medulla the antero-lateral nucleus is quite conspicuous (Figs. 18^a, 19^a, 20^a, 21^a, 22^a, 23^a); the cells are rather smaller than in the sheep, measuring about $\frac{1}{1000}$ to $\frac{1}{400}$ of an inch. The relations between the antero-lateral nucleus and the other portions of the medulla, are the same in man as those described above in the sheep, and its changes in form and situation have been sufficiently dwelt upon in Chap. II, on the morphology of the human medulla.

By comparing Figs. 6^a, 7^a with Fig. 8^a (all from the sheep) it will be seen that the groups of very large cells, which will be subsequently shown to be the origin of the upper olivary bodies, are evidently developed from the remains of the antero-lateral nuclei, so that it is extremely probable that the *antero-lateral nucleus* is, in the lower part of the medulla, *accessory to the olivary column*, and that it is continued upward into the *trapezium*, where it is developed into the *upper olivary body*, the structure and relations of which will be described subsequently.

PART II.

THE FORM AND STRUCTURE

OF THE

GRAY SUBSTANCE OF THE TRAPEZIUM, MAMMALIAN.

CHAPTER I.

MORPHOLOGICAL CHANGES IN THE TRAPEZIUM OF THE MAMMALIA.

(1.) The most striking feature in the upper part of the medulla oblongata, is the development of the *auditory* nucleus, which is conspicuously presented in two distinct masses, an *inner* or *anterior* portion formed from the remains of the underlying nuclei, together with the new pyramidal mass, which, as we have seen in the foregoing chapters, is formed partly from the vagal and partly from the post-pyramidal nucleus, and an *outer* or *posterior* portion, consisting of a remarkable network inclosing in its meshes numerous longitudinal bundles, formed from the outer part of the post-pyramidal and inner portion of the restiform nucleus. The outer network is closely connected with the entire mass of the restiform nucleus, by numerous bundles of transverse fibres radiating from the network and traversing the dark mass of longitudinal bundles constituting the restiform body, which now forms the outer border of the medulla; a part of these radiating fibres are connected with the posterior auditory root, while another portion join the arciform plexus.

The *glossopharyngeal* nucleus is still somewhat distinct, and is situated in a depression near the apex of the anterior portion of the auditory nucleus, where it is entered by numerous bundles of nerve-roots, traversing the caput cornu. In the cat the roots of the glossopharyngeal are very distinct (Plate IX, Fig. 33), passing into the small, transparent nucleus, which is crowded with quite large cells, especially numerous near the posterior part. A portion of the glossopharyngeal roots do not enter at the apex, but pass along the posterior margin of the nucleus, entering farther back, spreading out both anteriorly and posteriorly in the posterior part of the nucleus.

The inner portion of the *restiform* nucleus contains many large multipolar cells, and is closely connected with the network forming the outer portion of the auditory nucleus. Both portions of the *auditory* nucleus, as well as the *caput cornu*, contain many scattered cells, mostly small.[1]

Numerous bundles of fibres proceed from the anterior portion of the nucleus near the raphè, taking the same direction as those noticed in the lower part of the medulla, serving to connect the olivary bodies with the motor nuclei; these fibres are also connected with the few remaining cells which are the uppermost of the lower olivary column (Plate XIV, Fig. 8^a, *e*). The upper olivary bodies (O') are now quite distinct, consisting of large and numerous multipolar cells, the processes from which in connection with transverse and arciform fibres, form a rather open network, inclosing numerous longitudinal bundles in its meshes.

(2.) Higher up (Figs. 8, 8^a, and 33), the nucleus of the glossopharyngeal becomes distinctly fused with that of the auditory, the apex of the *anterior* auditory nucleus projecting into the caput. The *posterior* portion of the nucleus (Fig. 8^a, A') is very large and distinct, and has already absorbed nearly, if not quite, the whole of the restiform nucleus. It is connected with the longitudinal fibres of the restiform body (r) by numerous curved and radiating bundles (r'), and is entered at its apex by the *anterior* division of the *auditory root* (*VIII*), which is at first a small bundle, passing through and apparently connected to some extent with the arciform fibres. The *posterior auditory root* (*VIII'*) is very large and well defined, and is connected with the posterior portion of both divisions of the nucleus.

TRAPEZIUM

(3.) As we approach the trapezium the plexus of external arciform fibres which has gradually diminished in the sections below, till it appears as a very thin band at times hardly distinguishable beyond the extremity of the caput (Fig. 8^a), quite suddenly enlarges (Fig. 9^a), and is now seen as a very thick and constantly increasing marginal band of fibres, which, as Clarke has pointed out, "proceed out of the restiform bodies and auditory ganglia, and sweep round the extremity of the caput cornu to the back of the anterior pyramids, to decussate across the raphè. As they pass the ganglion, or auditory nerve, they receive fibres from it."[2] In Figs. 8^a, 9^a, the course and origin of these fibres may be plainly seen, as well as their connection with both auditory roots.

(4.) In Plate XIV, Fig. 9^a, from a section just above the commencement of the trapezium, the *posterior auditory root* (*VIII'*) has reached its greatest development, and sends out from its substance numerous radiating bundles into the restiform body. Some of these apparently pass out with or join the anterior root; the majority, however, cross the root and become external arciform fibres, the number of which constantly increases as we ascend towards the pons Varolii, forming a very thick and compact marginal band, completely bounding the antero-lateral and anterior

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[1] My observations on the formation and development of the auditory nucleus agree so entirely with the description given by Clarke (Proceedings of the Royal Society, 1861), as to appear almost like a direct quotation of the particulars he has there given.

[2] Proceedings of the Royal Society, June, 1861

portions of the medulla, and decussating behind the pyramids at the raphè, with fibres derived from the opposite side. The posterior root of the auditory often contains at its entrance into the medulla a few scattered cells, which are less conspicuous in the sheep than they are either in the cat or in man. They may generally, however, be plainly seen, and were described by Stilling, in man, as a little ganglion, similar to those found on the posterior spinal roots. In the cat, the posterior root of the auditory is very large and conspicuous (Plate IX, Fig. 34); its pyriform swelling is very evident, containing numerous cells and fibres, the latter winding among the small cells in a somewhat spiral or serpentine course, resulting apparently from the obliquely ascending course which the posterior auditory roots take as they wind around the restiform body.

As the posterior root proceeds in its course, winding in a broad band round the posterior border of the restiform body, the cells which are scattered among its inner fibres become more and more numerous; they are principally oval or fusiform in shape, elongated in the direction of the fibres. As the roots pass the *flocculus*, with which the medulla is here connected, the cells increase in number and size, and the broad band of nearly parallel fibres soon expands, entering the posterior portion of the auditory nucleus, through which many of its fibres penetrate to the anterior portion.

The *anterior root* (*VIII*) is also quite well developed, entering close to the posterior, which a part of its fibres accompany, the majority, however, immediately diverging and passing on the inner side of the restiform body, which is thus completely grasped, as it were, by the two roots. In Plate IX, Figs. 33, 34, the development of the *anterior auditory root* in the cat is well seen: the roots lie at first just behind those of the glossopharyngeal, from which it is often somewhat difficult to distinguish them. At the point where the anterior roots cross the external band of arciform fibres, a little ganglion or group of cells is developed, in close connection with the roots, the root-bundle often splitting, a part of the fibres going on each side and completely inclosing this little group.

The network constituting the *outer nucleus* of the *auditory* contains very large and numerous multipolar cells, sending their processes in all directions around and among the longitudinal and transverse fibres of which the network is composed. The cells fill the entire network, extending from the apex at the entrance of the anterior roots, back towards the cerebellum, as far as the entrance of the posterior root, and reaching forwards into the anterior portion of the nucleus, along the back of which a group is formed sending out numerous fibres into the cerebellum. Both nuclei of the auditory are joined to the caput by numerous radiating fibres, some of which penetrate the caput and pass outwards as internal arciform fibres.

The *fasciculus teres* (*T*) which becomes the nucleus of the sixth and facial nerves, is first seen as a somewhat dark mass on the floor of the fourth ventricle, in that part of the auditory nucleus which represents the upward extension of the hypoglossal; it contains numerous small cells, which increase in size and become more numerous higher up.

In that portion of the anterior columns of the medulla representing the upward continuation of the lower olivary bodies, numerous multipolar cells are found, many of which are of large size, and are connected by their processes with the arciform fibres decussating at the raphè. Scattered cells are also found at various points in the substance of the raphè.

(5.) In the sections just above (Figs. 10, 10^a), the cells representing the lower olivary column are reduced to a little group in the immediate neighborhood of the raphè. The *upper olivary* bodies in the sheep, are now seen as compact masses, resembling those found in the carnivora, though not quite so large proportionally or so distinctly convoluted. The cells have diminished in size, but the arrangement of fibres is much more distinct and orderly. In the cat, the large cells found in the lower part of the upper olivary column soon disappear, the open network being cut in upon more and more by the wavy bundles of the trapezium, and are replaced by smaller cells arranged in a distinctly convoluted lamina.

The *roots* of the *abducens* or sixth pair of nerves (Fig. 10^a, *VI*), are now quite easily distinguishable, running inwards in two or three tolerably thick bundles to the nucleus, which is more distinctly seen a little higher up, the course pursued by the roots of the abducens as well as by those of the facial being slightly ascending. The commencement of the nucleus may, however, be seen in Fig. 10^a, *T*, partly separated from the anterior portion of the auditory nucleus, in a position exactly corresponding to the upward extension of the hypoglossal nucleus. The roots of the sixth form a remarkable exception to the usual course of the nerve-roots, *bending backward* to enter their nucleus just before they reach the floor of the fourth ventricle, instead of running *towards the median line* as do the roots of all the other nerves.

The *facial* first makes its appearance as a somewhat wavy band of fibres, running directly inwards towards that portion of the auditory nucleus which is close to the caput, and then bending forwards towards the *fasciculus teres*, which constitutes the common nucleus of the sixth and seventh pairs. It rapidly increases in size till it is seen as a thick and broad band of fibres (Figs. 10, 10^a, 11, 12, 13 and 36), running inwards towards the nucleus, and crossed, as it passes along the anterior margin of the auditory nucleus, by very numerous wavy bundles of fibres passing out into the antero-lateral columns (Plates XIV and XVI, Figs. 10^a, 12^a, and 44). The entire space between the fibres of the sixth and seventh nerves is studded with little cells (Figs. 10^a, 12^a), which are also frequently found throughout the entire antero-lateral network, serving to unite all the various nuclei, by means of the arciform and transverse fibres with which their processes are connected. Not unfrequently little groups of cells are found at the foot of the facial (Fig. 10^a, *v*), and at various points among the external arciform fibres, the latter being the first appearance of the numerous cell-groups from which the fibres of the pons Varolii are subsequently developed.

The *auditory nucleus* contains many very large, multipolar cells, especially in the network and postero-lateral portion. In the cat (Plate IX, Fig. 35), the network of the outer nucleus is very much developed, the restiform body being often quite hidden beneath the fibres of the network, which is crowded with very large cells reaching forward into the substance of the anterior part of the nucleus, and backwards in a straight line into the substance of the cerebellum. Large bundles of fibres following the course of the posterior root may be traced from the *flocculus* towards the back of the nucleus, crossed by bundles coming down from the cerebellum towards the apex of the nucleus.

(6.) In Plate XVI, Fig. 12", the projection formed on the *posterior auditory root*, as it emerges from the medulla, is still conspicuous, but the fibres of the root have very much diminished in number. The ganglionic enlargement consists partly of numerous longitudinal or oblique fibres, intermixed with others running in a transverse direction; the latter, which are derived from the posterior parts of the medulla, cross the fibres of both divisions of the auditory root and pass onward as part of the external band of arciform fibres so conspicuous throughout the trapezium. As we ascend, the projection still continues to be conspicuous (Plate IV, Fig. 13), but the posterior root-bundles continually diminish in number and presently disappear. The prominence is filled with numberless very small cells, round and obovate, measuring about $\frac{1}{2000}$ to $\frac{1}{800}$ of an inch in diameter. In sections still higher up the cells diminish in size, the prominence appearing more and more like an extension of one of the cerebellar folds filled with small cells and granular nuclei.

In the cat the group of cells placed on the back of the auditory root forms a very conspicuous prominence, seen in Plate IX, Fig. 35, as a dark mass lying along the roots, and separated by a deep sulcus from the *flocculus*. The cells become more and more numerous as we ascend, and are often found intermingled with the roots themselves. After the level of the facial roots is attained (Fig. 36), the mass is brought into close contact with the folds of the flocculus, and the cells are seen to be evidently of a similar nature to those found in the convolutions of the cerebellum, only in a somewhat denser and larger mass. The structure of the *caput* in this region is somewhat peculiar. Instead of consisting of a loose fibrous mass containing scattered cells, as is the case in the lower regions of the medulla, it is here divided into several rounded masses, five or six in number, closely crowded with cells of moderate size, very much resembling the appearance of those masses in the lower part of the trapezium which were shown to be the commencement of the upper olivary bodies. The caput is very early brought into connection with the anterior part of the auditory nucleus by several rather thick bundles of fibres, and its whole substance appears to be closely connected with both portions of the auditory nucleus.

(7.) As we ascend, the *restiform columns* are continually encroached upon more and more by fibres radiating from both roots of the auditory, which penetrate and almost conceal them (Plate IV, Fig. 13). They are, at the same time, pushed backwards together with the auditory nucleus, by the formation and enlargement of the nucleus of the abducens and facial, and by the contraction of the lateral boundaries of the fourth ventricle, until, as Clarke[1] and Stilling[2] have both shown, they are ultimately thrown backwards into the cerebellum, together with the posterior portion of the auditory nucleus.

The *anterior root* of the *auditory* seems to consist, in the upper part of the trapezium, of two quite distinct divisions (Figs. 12, 12", 13); a compact bundle proceed-

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[1] Proceedings of the Royal Society, June, 1861.

[2] Pons Varolii.

ing inwards to the anterior portion of the nucleus, accompanied by numerous small bundles which enter the loose network constituting the outer portion of the nucleus, while another division diverges, and winding around the outer edge of the restiform body, enters the posterior portion of the nucleus in company with the posterior roots. The connection between the *auditory* nucleus and the *cerebellum* is now very conspicuous (Plate IV, Fig. 13, Plate XVI, Figs. 12^a and 44); numerous bundles which proceed from the cerebellum pass down through the nucleus and enter the medulla, radiating in all directions in the anterior and antero-lateral network, and a portion of these fibres are also continuous with cell-processes in the postero-lateral portion of the nucleus.

The connection between the *upper olivary* bodies and the *facial* nucleus is very evident in the upper part of the trapezium, and will be referred to subsequently. The groups of large cells near the facial, figured by Schröder van der Kolk (Medulla Oblongata, Fig. 20, *o*), and another group found near the outer edge of the caput, are evidently of the same nature as the upper olivary bodies.

(8.) In the upper part of the course of the facial, the nucleus has entirely disappeared (Plate IV, Figs. 14, 15, 16 and Plate XIV, Fig. 16^a), and the roots are seen in two or three very large bundles, whose entire course can be traced inwards to the longitudinal columns on each side of the middle line, called by Stilling the "*constant roots of the trifacial.*" These columns are inclosed by the root-bundle, a portion of the fibres of which seem to abruptly terminate here; the remainder can, however, be traced onward to the raphè where they are seen to decussate with their fellows from the opposite side. Throughout their entire course the facial roots are crossed at various points by fibres radiating from the auditory nucleus, many of which proceed from the cerebellum either directly or after passing through cells.

(9.) The longitudinal columns on each side the raphè near the floor of the ventricle (Fig. 12^a, *j*, Fig. 44), referred to above, have been described by Stilling as the "*constant roots of the trifacial,*" and by Schröder van der Kolk as "*roots of the auditory.*" I have not been able to discover any connection between these columns and the trifacial or auditory roots, and in the chapter on the facial nerve, I have endeavored to show, that a portion of the facial roots probably descend in these columns to the underlying nucleus. With the exception that they are intermingled with descending facial roots, these columns seem to be simply bundles belonging to the general system of the longitudinal postero-lateral columns, from which they are separated to some extent by the facial roots on their way to the raphè, but to a still greater extent, especially in front, by the curving fibres which sweep out from the auditory nucleus.

(10.) In sections from the upper part of the trapezium the chief changes noticeable consist in the gradual disappearance of the nerve-roots we have been considering, as well as of the upper olivary bodies (Plate XIV, Fig. 16^a). The external arciform fibres constituting the border of the trapezium have increased very much in number as we approach the pons Varolii. The upper olivary bodies (O') are very much reduced in size, appearing now as simple rounded masses, containing a few small cells, almost hidden by the wavy bundles of arciform fibres.

The roots of the facial (Fig. 16, 16^a, *VII*) are reduced to a few small bundles, which are collected together as they pass the anterior border of the remains of the auditory nucleus, forming quite a broad bundle which may be traced onward to the raphê where it decussates with its fellow from the opposite side. As we pass upward the roots constantly diminish in number, and are presently replaced by the small or motor root of the fifth nerve, the nucleus of which appears to be an upward extension of the motor column from which the facial, abducens and hypoglossal roots are derived

The *caput cornu* steadily increases in size and in the number of its cells, contributing with the remains of the auditory nucleus to form the principal nucleus from which the sensitive fibres of the fifth or trifacial nerve originate. The remains of the auditory nucleus have at this height passed backwards towards the cerebellum, together with the restiform columns (Fig. 16ª, *r*). The little group of cells lying close to the remains of the auditory root is still persistent, and is now seen to be in very close connection with the flocculus.

(11.) The changes which are observable still higher up, in the form and structure of the gray substance, are chiefly produced by the development of the pons Varolii and the formation of the nucleus of the trifacial, the *motor* roots of which are derived apparently from the upward extension of the *fasciculus teres*, and its *sensitive* roots from a large pyramidal nucleus, composed of the *caput cornu* together with the upward extension of the *auditory ganglion*.

CHAPTER II.

THE AUDITORY NUCLEUS AND ROOTS.

The Nucleus.—In the preceding chapters on the morphological changes in the medulla and trapezium, it has been shown that the auditory nucleus is developed, as Clarke had already demonstrated,[1] between the outer horn of the vagus nucleus and the post-pyramidal body, as a small triangular mass, apparently formed from the substance of the two neighboring nuclei, with both of which it is very closely connected. It sends out numerous fibres into the restiform body, which cross each other at various angles, interlacing among and around the numerous longitudinal fasciculi which pass upwards along the outer border of the nucleus, thus forming an open network which is very much developed in the upper parts of the medulla, where it is closely connected with the remains of the restiform nucleus, forming what Clarke has called the outer portion of the auditory nucleus.

The inner mass or principal nucleus of the auditory, enlarges till the nucleus of the vagus is pushed quite forwards, the outer portion or network at the same time increasing, till it occupies a very considerable portion of the restiform column. The next stage is that in which the auditory nucleus together with the glosso-pharyngeal and hypoglossal nuclei, seem to be fused into one mass (Plates II and XIV, Figs. 8, 8^a), the glossopharyngeal distinguishable mainly by its more transparent substance, appearing as a separate nucleus near the apex of the broad triangular mass. From that portion of the triangle which is the continuation of the nucleus of the hypoglossal, fibres run out in the direction formerly taken by the hypoglossal roots (Fig. 8^a), and form considerable bundles accompanied by cells sometimes scattered and sometimes collected into groups, often quite filling the antero-lateral portions of the medulla and apparently serving to connect the transverse and arciform fibres with the neighboring parts.

The large triangular nucleus is now filled with numerous cells, mostly of rather small size, but larger near the apex and in the network or outer portion of the nucleus. As we approach the trapezium, the outer network becomes more and more developed, extending far out into the restiform column and containing numerous very large cells (Figs. 9, 9^a). Anteriorly or towards the raphè, the remains of the hypoglossal nucleus become more and more separated from the mass by the gradual pushing backwards of the auditory nucleus, its situation being almost

[1] Philos. Trans. 1858. Proceedings of the Royal Society, 1861.

entirely covered by a remarkable fringe of fibres emanating from the anterior border of the auditory mass (Figs. 10", 11"), among which are finally developed the cells of the *fasciculus teres* or common nucleus of the facial and abducens nerves.

As the roots of the facial are more and more developed the whole auditory nucleus is thrust outwards and backwards, changing form slightly, and sending out a process or bundle of fibres into the caput cornu with which it becomes closely connected. This gradual pushing outwards and backwards of the auditory nucleus, together with the gradual lateral elongation of the whole medulla in this region, continues as the facial makes its appearance, and the connection with the caput becomes more and more intimate, until in the lower part of the pons Varolii the two form together the great nucleus from which the trifacial nerve arises.

As already pointed out by Clarke, the outer portion of the auditory nucleus together with the restiform body, is thrown backward into the cerebellum, numerous fibres from the main nucleus arching over the fourth ventricle, whilst others pass backward into the cerebellum.

The cells of the auditory nucleus present almost every variety in size and form, some of them being exceedingly small, while, as already noticed by Schröder van der Kolk, some are the largest anywhere found, even exceeding in size those of the anterior cornua of the spinal cord. In the lower part of the medulla the cells of the auditory nucleus are mostly small, oval or stellate, with every variety of intervening form, measuring $\frac{1}{2000}$ to $\frac{1}{800}$ of an inch in the sheep, and are interspersed with scattered nuclei and granules with which the entire mass seems filled, resembling those found in the posterior cornua of the spinal cord. Higher up, the anterior part of the nucleus, especially that which represents the continuation of the hypoglossal column, contains the same small cells and nuclei, but posteriorly, near the entrance of the posterior division of the auditory nerve, the cells are at first small, and oval, fusiform or crescentic in shape; a little further inwards they are quite large, some of them being very much elongated, oval, fusiform or semilunar in shape, measuring in the sheep $\frac{1}{800}$ to $\frac{1}{250}$ of an inch in length. In the cat they are smaller, measuring $\frac{1}{800}$ to $\frac{1}{572}$ of an inch. The lateral and postero-lateral border of the main nucleus, together with its contiguous network, contains very many large multipolar and stellate cells, sending out their processes in every direction, especially among the longitudinal bundles which penetrate the network and are inclosed in meshes of fibres formed chiefly from the interlacing processes of these large cells. Some of the cell-processes pass inwards towards the deeper lying portions of the nucleus or towards the cerebellum, while others pass outwards among the longitudinal fasciculi towards the restiform body, where they often form a very complicated system of radiating fibres, connected with the root-bundles and with the longitudinal fibres of the restiform column. Some also pass longitudinally upwards or downwards, and serve to connect different planes of the medulla and trapezium. The cells situated in the outer network of the auditory nucleus are the largest I have anywhere found, measuring in the sheep from $\frac{1}{400}$ to $\frac{1}{220}$ of an inch in diameter, in the cat from $\frac{1}{572}$ to $\frac{1}{266}$ of an inch. In the cat they are especially numerous, quite filling the posterior and postero-lateral parts of the main nucleus as well as the outer net-work.[1]

At the apex, close to the entrance of the anterior division of the root, a group of cells is found, which are stellate or pyriform in shape and are quite large; they are connected partly with the anterior division of the root, and partly with numerous bundles of radiating fibres which pass from the vicinity of the apex into the caput cornu. All along the anterior border of the nucleus a beautiful fringe of very numerous wavy fibres is seen, passing out into the anterior and antero-lateral columns, derived apparently in part from the deeper lying regions of the nucleus, as well as from the cells along the antero-lateral border.

Stilling[2] has described a small nucleus in connection with the posterior root of the auditory, which he seems to consider analogous to the spinal ganglia attached to the posterior roots. It is situated at first on the outer side of the great bundle of fibres constituting the posterior root of the auditory (Plate XIV, Fig. 9^a, *z*), and consists of very small cells, which are continued upwards in nearly the same locality until the auditory nerve finally disappears (Figs. 10^a, 12^a, 16^a).

In Fig. 10^a this group is seen situated among the arciform fibres, just behind the auditory root; in Plate XVI, Fig. 12^a, it occupies a similar position in the projecting mass, which represents the upward extension of the posterior root, though now mainly consisting of the broad band of arciform fibres constituting the boundary of the trapezium or commencement of the pons Varolii. This little group can often be traced backwards towards the group situated in the posterior part of the auditory nucleus, seen (Fig. 12^a) to be in evident connection with the flocculus, and I have consequently been inclined to consider the little nucleus in question, rather as a rudimentary fold of the cerebellum, which it strongly resembles, than as a specific ganglion on the posterior auditory root; this resemblance is especially striking in the cat, a continuation of the flocculus being apparently folded down along the auditory root (Plate IX, Figs. 35, 36).

Foville,[3] as is well known, has described a connection between the auditory nerve and the flocculus, and at the same time to such an extent with the cerebellum that he has called the auditory a cerebellar nerve (nerf cérébelleux). The connections between the posterior portion of the auditory nucleus and the cerebellum are very striking and complicated, and merit more attention than I have been able to bestow upon them. In order to fully understand the meaning of the different bundles of fibres which everywhere stream out from the back of the auditory nucleus, it would be necessary to carefully trace them into the cerebellum, and to understand very fully their destination within this organ; this of course does not come within the limits of the present paper, but I shall briefly notice a few points which are most easily made out.

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[1] In the medulla of the cat I have been able to count over 60 large cells in a field measuring about $\frac{1}{30}$ of an inch in diameter, and as this was done with a $\frac{4}{10}$ objective without changing the focal adjustment, only those on the same plane were counted.

[2] Bau des Hirnknotens. Jena, 1846, 28.

[3] Traité complet de l' Anatomie et Physiologie du Système Nerveux Cérébro-Spinal, Paris, 1844, 503.

The connection of the auditory nucleus with the flocculus is very evident, as has already been noticed by Schröder van der Kolk, who attributes to it the "particularly large size of the flocculus in the Rodentia, which are possessed of acute hearing."[1] In the cat the flocculus is also very large, corresponding with the great development of the auditory root (Fig. 35, Plate IX), the latter sometimes, especially near its entrance, being quite bent out of its course and pushed in towards the facial by the size of the flocculus (Fig. 36). The connections between it and the auditory are very strikingly evident; just along the posterior portion of the network constituting the outer nucleus of the auditory, a row of large multipolar cells is found, intermingled with which are many of an oval, fusiform or semilunar shape, following each other quite closely and regularly, from which a very beautiful fringe of fibres proceeds, turning over and forming a very regular and conspicuous band which may be traced into the flocculus, where its fibres join the bundles radiating into the convolutions of the cerebellum.

In the sheep (Fig. 12ᵃ, Plate XVI) this connection is easily made out, though not quite so conspicuous as in the cat, where the size and regularity of the cells, together with the formation of thick bands of fibres which are very easily traced, leave no doubt of the fact.

In the upper portions of the medulla, the connection of the whole posterior part of the auditory nucleus with the cerebellum becomes more and more manifest. As we ascend, the outer portion of the nucleus together with the restiform body is gradually thrown backwards into the cerebellum, very numerous fibres from the inner portion of the nucleus arching over the fourth ventricle and meeting those from the opposite side, so that the *valve of Vieussens* together with the *lingula* is inclosed as it were, or overarched by these fibrous expansions, which, as Clarke has shown,[2] pass over the *superior peduncle* to the *inferior vermiform process*.

The fibres from the central and outer portion of the nucleus spread out in every direction into the substance of the cerebellum, especially towards the *corpus dentatum*, and finally (Plate XIV, Fig. 16ᵛ) the nucleus, together with the restiform body, is thrown far back into the substance of the cerebellum. The further destination of these fibres, which, whether derived from the auditory nucleus or the cerebellum, certainly serve to connect the two, and to bring them into very close relation, deserves careful study, but could hardly be entered upon without at the same time studying the anatomy of the entire cerebellum, in order to determine whether the connection is with the larger lobes, or only with those more nearly contiguous. The connection of the large cells near the apex and in the outer network, with the auditory roots, is very easy to demonstrate, as well as their connection with fibres emanating from the restiform body and cerebellum. In Plate XII, Fig. 41, we have a group of large multipolar cells from near the entrance of the auditory roots into the apex of the nucleus, from the medulla of the cat, drawn with all possible accuracy by means of the Camera Lucida. Bundles of entering fibres from the auditory root are seen (*A*, *A*, *A*) running inwards towards the cells, which, as will be seen, take every variety of form and send their processes in many different

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[1] Medulla Oblongata, 115.

[2] Proceedings of the Royal Society, 1861.

directions; some join the numerous bundles (*C*) which either pass into or originate from the cerebellum, or pass into the restiform body; while others join the bundles (*B*) which pass out into the antero-lateral portion of the medulla, forming with other transverse fibres a very beautiful network around the longitudinal bundles.

Fig. 43, Plate XII, represents a group of the very large cells found in the posterior portion of the auditory nucleus of the sheep, showing their connection with the numerous and distinct bundles of fibres which radiate from this part of the nucleus towards the cerebellum.

The Roots.—The auditory nerve, as is well known, consists of two portions, anterior and posterior, which, as Stilling has shown,[1] take a slightly ascending course as traced from without inwards, this course being more oblique in man than in most of the mammalia, the great thickness of the pons pressing the roots downwards, while in some of the lower mammalia in which the pons is very thin, the roots of the auditory nerve may be traced in a direct course to their nucleus.

Clarke has given in a few words an accurate description of the course pursued by the *posterior* division of the auditory root; as stated by him, this portion of the nerve takes its origin from both parts of the nucleus, "and winds outward as a broad convex band over the restiform body. In this course it contains, at first, a few small cells, elongated in the direction of its fibres; but as it proceeds, the cells gradually become larger and more numerous, until at the anterior border of the restiform body it enlarges into a pyriform ganglion, which is crowded with nerve-cells, similar in appearance to those of the inner nucleus. The nerve is also reinforced by fibres radiating from the centre of the restiform body as it winds round the latter."[2]

In Plate XIV, Fig. 8^a, we have the first appearance of the *posterior* auditory root, as a thickened band of fibres proceeding from the group of rather small, oval and fusiform cells in the posterior portion of the nucleus. In Fig. 9^a the fibres are seen arising from a similar group; some of the cells are of considerable size and are arranged mostly with their longer axes turned in the direction of the entering fibres; these cells are also connected with a little group near the flocculus, with which a few of the fibres of the posterior root seem to be connected. As the roots proceed onward through this cell group, it increases in size, and finally spreads out, as noticed by Clarke, into a pyriform mass containing numerous cells (*z*), among which some of the fibres interlace before passing outwards. The fibres from the restiform column, though mostly pursuing a longitudinal course, will not unfrequently be seen turning off at an angle more or less acute to reinforce the posterior root as it winds round it (Figs. 8, 9, 10). In the cat the posterior root is especially large and conspicuous (Plate IX, Figs. 34, 35), the pyriform enlargement being very evident; the fibres which constitute it appear to take a somewhat wavy course, many of them are obliquely ascending or descending fibres, interlacing among the cells at a great variety of angles resulting from the somewhat obliquely curved course taken by the root while winding round the restiform body.

The fibres of the *posterior* root are constantly reinforced by little cell-groups, until they arrive within the nucleus; some of them pass towards the large multi-

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[1] Pons Varolii, 39. [2] Proceedings of the Royal Society, June 20, 1861.

polar cells of the outer network, through which a few small bundles may be traced for a considerable distance, running around the inner border of the restiform body, and sometimes apparently joining the anterior division of the auditory nerve. By far the greater number, however, pass along the floor of the fourth ventricle, occasionally turning off to join the oval cells near which they pass, until the anterior border of the nucleus is nearly reached, in the neighborhood of the *fasciculus teres* (Plate XVI, Fig. 44). Here they turn off in every direction, joining numerous bundles derived from the cerebellum, as well as those derived from the anterior division of the root, with which they pass across the root of the facial or interlace with its fibres, forming the very beautiful fringe so often spoken of and which may be seen very distinctly in Plate XVI, Figs. 44 and 12^a. These fibres pass into the antero-lateral network between the facial roots and the raphè, some of them probably entering the numerous small cells found in this locality; others may be traced across the abducens roots, interlacing with some of their fibres and then passing onward towards the raphè, where some of these bundles are plainly seen to decussate with those derived from the opposite side.

With regard to the *anterior* division of the root, Clarke states that it "consists of two portions: the principal portion penetrates the medulla beneath the restiform body, and running along the outer side of the caput cornu, enters both parts of the auditory nucleus; the other portion runs backward along the upper border of the restiform body, which it accompanies over the superior peduncle to the inferior vermiform process of the cerebellum."[1] To this account, with which my own observations entirely agree, I shall add a few details. The *anterior* division of the auditory penetrates the arciform plexus in a broad, compact mass of fibres, which soon spread out somewhat, being separated by intervening longitudinal fibres into numerous smaller bundles. A portion of these turn off shortly after passing through the arciform plexus, and joining the posterior division of the root wind round the outside of the restiform body, in which course they are constantly joined and reinforced by other fibres, often very numerous, derived from the restiform body itself (Figs. 9^a, 10^a, 12^a); sometimes these fibres instead of turning off and winding round the outer border of the restiform body, pass directly through its substance (Fig. 10^a). Their ultimate destination cannot be distinguished from that of the fibres belonging to the posterior division of the root which they accompany. These fibres not unfrequently penetrate the restiform body to so great an extent that the latter nearly disappears, seeming almost hidden beneath the network of transverse fibres (Plates III and IV, Figs. 1, 2, 13, and Plate IX, Figs. 35, 36).

The principal portion of the *anterior* division of the root is subdivided into a considerable number of smaller bundles, which pass behind the caput cornu separating it from the restiform body, and enter both portions of the nucleus, just at the apex, where the anterior portion of the nucleus is prolonged laterally to join as it were, the outer network. Through the apex the fibres pass onward, spreading out into an almost inextricable network, crossing at different angles the fibres derived from the restiform body and from the cerebellum.

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[1] Proceedings of the Royal Society, June 20, 1861.

Some of the fibres from the *anterior* division of the auditory enter the cells lying in the immediate vicinity of the apex, the processes from these cells serving to connect the roots with the caput cornu, which is also brought into very intimate relation with this portion of the nucleus by means of wavy bundles of fibres, some of which are apparently continuous with the roots (Plate XVI, Fig. 44). Schröder van der Kolk, who considers the caput cornu as the trunk of the great trifacial nerve, thinks that a connection is established between this nerve and the auditory by means of these fibres radiating from the nucleus of the latter, but this conclusion is I think incorrect. The caput cornu, as has been shown by Clarke, and fully confirmed by my own observations, contains in its substance numerous longitudinal bundles which are descending roots from the trifacial, but is certainly mainly composed of quite distinct cell groups constantly increasing in number as we ascend. I have not been able to trace a direct communication between any of these longitudinal bundles and the fibres radiating from the auditory nucleus, and the latter more probably enter the cells of the caput, which are especially numerous near the upper part of the auditory tract. The nuclei of *all the nerves of the posterior column*, spinal accessory, vagus, glossopharyngeal and auditory appear to be connected with the *caput cornu*, which finally becomes itself a part of the nucleus of the trifacial, and may possibly serve to a certain extent throughout the medulla, to co-ordinate and bring into harmony all these different nerves. Another set of fibres from the anterior division of the auditory enter more deeply into the nucleus, and bend forwards into the antero-lateral network, either with or without passing through cells. Many of these fibres join the numerous bundles coming down from the cerebellum, and pursue the same course, radiating into the antero-lateral network; they cross the facial roots, and occasionally join their course for a short distance, but I have been able to satisfy myself that no *direct connection* is established.

Schröder van der Kolk states that many slender fibres pass from the nucleus of the auditory towards the facial nucleus, "so that no doubt can exist of a connection between these nuclei."[1] Though I have carefully examined many specimens in which the course of the fibres could be studied with great certainty, and have often been able to trace fibres from the auditory nucleus across or even into the substance of the facial nucleus, I have never been able to trace them with certainty into the cells of the latter, and although a connection to *some extent* is quite probable, I have been unable to see any sufficient grounds for so elaborate a theory of the reflex action of the auditory on the facial as is attempted to be established by Schröder van der Kolk (*l. c.*). Many of the fibres from the anterior border of the auditory nucleus may be traced across or behind the *fasciculus teres* to the raphè, where they are either seen crossing directly to the other side, or sometimes passing along the raphè for a short distance before crossing. Some of these fibres are undoubtedly either direct continuations of the anterior and posterior divisions of the root, or fibres derived from the cells entered by these, while others seem to be bundles coming directly from the cerebellum. At any rate by means of these bundles which are very numerous, and in many preparations very easily traced, the

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[1] Medulla Oblongata, 116, 117.

nuclei of the opposite side are brought into very close and intimate connection with each other, as well as with the various bundles traversing the antero-lateral network in the neighborhood of the raphè.

A large portion of the fibres belonging to the anterior division of the root bend backwards, towards the network constituting the outer part of the nucleus; these fibres interlace in every variety of direction among the longitudinal bundles, and very many of them are seen to enter the large multipolar cells; others either directly or after passing through cells, penetrate the deeper lying portions of the nucleus, from whence they turn off in the direction of the *superior peduncle* over which some of them pass towards the cerebellum. The more *anterior* or inner set pass towards the *inferior vermiform process*, the *middle* set inwards in the direction of the *corpus dentatum*, the *outer* or posterior set towards the *flocculus*.

The mass of the nucleus is, however, so large, and the course of the fibres so extremely intricate, and so complicated by the numberless bundles derived from and proceeding to different and often distant parts of the cerebellum, that the determination of the connections of the auditory nucleus and the destinations of its root-bundles becomes one of the most difficult problems in the Histology of the nervous system. The necessary study would, however, probably be well repaid, by the light thus thrown on the nature of the cerebellum, an organ evidently entering into very intimate relations with the great nuclei of the trapezium and pons Varolii.

CHAPTER III.

THE FACIAL NUCLEUS AND ROOTS.

THE course pursued by the facial nerve is so exceedingly distinct in most of the mammalia, that we are surprised to meet with difficulty in tracing the roots to their ultimate destination. Schröder van der Kolk has indeed stated that among all the nerves of the medulla, there is not one, the origin of which is so difficult to define with certainty as the facial.[1] As is the case with the auditory, the facial in man, especially in its outer part, is pressed slightly downwards by the great thickness of the pons Varolii, but in those mammalia in which the pons is but slightly developed, the facial pursues an almost directly transverse course, so that the fibres can often be followed inwards as far as the floor of the ventricle.

The facial enters the medulla on the inner side of the caput cornu, and runs in a curving course directly inwards and forwards to the fasciculus teres, which is, as shown above, an upward continuation of the column of large, multipolar cells with which the roots of the hypoglossal were connected lower down. As pointed out by Stilling,[2] the roots of the facial generally form a single bundle, though we sometimes find them separated into two or three fasciculi (Figs. 13, 14, Plate IV), forming thereby a remarkable exception to most other nerves.

Stilling has also noticed a remarkable difference between the upper and lower portions of the facial roots. The lower portion terminate in the nucleus, while the upper roots, without entering the nucleus, pass to the raphè where they decussate with their fellows from the opposite side. In this course they inclose a bundle of fibres which Stilling has considered to be roots of the trifacial, but I cannot discover that the column has any connection with this nerve. In the upper portion of the facial he found no remains of the nucleus, and came to the conclusion that a part of the fibres from this portion of the root turn downwards entering the underlying nucleus, while another portion pass downwards through the raphè to the columns of the spinal cord.[3] This difference between the upper and lower portions of the facial course is very conspicuous in the sheep and cat, as well as in man, the nucleus disappearing almost entirely in the upper portion, and we can at the same time trace the fibres from the facial, passing directly to the raphè. As long as the nucleus is persistent many of the fibres of the facial terminate abruptly, just outside the nucleus, that is, they are cut off, as seen in Plate XVI, Fig. 44, the inward course of the fibres from this point being slightly ascending.

Sometimes a portion of these fibres escape being cut off by the plane of section

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[1] Medulla Oblongata, 109. [2] Pons Varolii, 39. [3] *l. c.* 38.

and may be traced inwards, winding among the cells of the nucleus, and apparently becoming continuous with some of the cell-processes. This is especially the case in the human medulla, where a very considerable portion of the fibres may be traced, winding among the cells, and either joining them, or passing onward to the raphè. In the sheep this is rarely to be seen, the fibres of the facial seeming to take a sudden bend just at this point, so that they are cut off quite abruptly by the plane of section. A little higher up (Plate XVI, Fig. 44), the fibres of the facial in the sheep, are seen to pass behind the nucleus, crossing over the roots of the sixth nerve, some of them passing in front of the column of longitudinal fibres (called by Stilling the *constant root of the trifacial*); others passing behind this column to the raphè, where they decussate with those derived from the opposite side; a few may be traced into the nucleus. Still higher up, the whole bundle may be traced inwards to this longitudinal column, where the central portion of the root abruptly terminates, the outer fibres turning off behind and in front of the longitudinal column, which is thus completely encircled by the roots which afterwards pass onwards to the raphè. Those fibres, however, which reach the raphè, seem to be few in number as compared with those which terminate abruptly in the vicinity of the longitudinal column, and even in the upper portions of the facial course (Fig. 16^a), where the whole bundle seems at first sight traceable to the raphè, the number of bundles actually decussating or passing into the raphè, seems so small when compared with the great thickness of the root, that I am inclined to think that many of the fibres do actually turn downwards, passing down in the longitudinal columns on each side of the raphè to the underlying nucleus, justifying in this respect the conclusion of Stilling. I have been confirmed in this supposition, by frequently observing in the columns which Stilling has called the *constant roots of the trifacial* and Schröder van der Kolk *roots of the auditory*, great numbers of fibres obliquely cut across, which are especially noticeable in connection with the abrupt termination of the facial roots just at this point, and I am inclined to consider these columns as, at least, partial channels by means of which the upper portion of the facial roots are conveyed downwards, either to the underlying nucleus or to decussate below in the raphè.

The greater part of the facial roots undoubtedly decussate at the raphè directly, but I was unable to trace their farther course. It is not improbable, however, that they may enter the nucleus of the other side, the cells of which are very numerous on the side nearest the raphè, and send out many fibres in that direction. Schröder van der Kolk is undoubtedly right in the statement, "that no other nerve of the medulla oblongata has such an intimate connection with that of the other side, whether directly or through the intervention of ganglionic cells, as the facial."[1]

The cells of the fasciculus teres are very numerous in the sheep, filling a large space between the roots of the facial and abducens. They are mostly oblong or obovate in form, measuring about $\frac{1}{500}$ to $\frac{1}{400}$ of an inch in their longest diameter, and send out their processes in various directions, mostly, however, either laterally in the direction of the roots, or anteriorly towards the raphè, as well as longitudi

[1] Medulla Oblongata, 111.

nally. Very numerous bundles proceed from the inner edge of the nucleus, crossing the roots of the abducens, and decussating at the raphè with similar bundles from the opposite side, serving to bring the two opposite nuclei into very close connection. The cells of the anterior portion of the nucleus are more nearly stellate in form, and send out their processes either in the direction of the facial roots, or towards the raphè, or as is very often the case into the antero-lateral network, where they are brought into connection with the upper olivary bodies by little scattered cell-groups and fibres, just as the hypoglossal nuclei were joined to the lower olivaries (Fig. 10^a). In the cat the cells are fewer in number, and more scattered through the antero-lateral network, but are often large, measuring sometimes as much as $\frac{1}{500}$ of an inch in diameter. The connection between the upper olivary bodies and the nucleus of the facial, will be described in a subsequent chapter (Chap. V).

CHAPTER IV.

THE ABDUCENS NUCLEUS AND ROOTS.

THE course and origin of the roots of the sixth pair of nerves have been described by Stilling[1] and Schröder van der Kolk,[2] but their accounts differ very considerably. The general course of these nerve-roots before they reach the nucleus of the facial has been given with sufficient detail in a previous chapter, where it was also shown that they form a remarkable exception in their inward course, to all the other nerve-roots, bending *outward* as they approach the floor of the fourth ventricle, while all the other nerves of the medulla bend *inwards* or towards the raphè, where their fibres decussate to a greater or less extent with those coming from the opposite side. As a natural consequence resulting from their peculiar course, the fibres constituting the abducentes roots do not decussate, at least directly, and if the opposite nuclei are brought into connection it must be either through the intervention of fibres derived from cells, or by means of ascending or descending fibres connecting the nucleus with distant parts, for I have not been able to trace *any* fibres turning inwards towards the raphè.

According to Stilling the roots of the sixth nerve end in the same nucleus to which we have traced the roots of the facial, making this large group of cells a common nucleus for the two motor nerves of the trapezium. Schröder van der Kolk, on the other hand, does not admit that the abducens takes its origin from the same nucleus as the facial, and remarks that it would be very singular if two nerves so distinct in their action should arise from a common nucleus. This observation would seem to have but little weight, since we constantly find in the medulla, nerves very distinct in their action arising from the same column, the nucleus of the one changing so imperceptibly into the nucleus of the other, that it is entirely impossible to state with any approach to accuracy when or how the change takes place. Schröder van der Kolk states that the roots of the sixth penetrate those of the facial, after passing through the nucleus, and terminate on the floor of the fourth ventricle. Their further course he seems to have been unable to trace, but surmises that they may probably turn upwards, entering into close connection with the nucleus of the oculomotor nerve which is situated above.

According to my own observations, the roots of the sixth pair of nerves pass directly inward, in two or three somewhat curving bundles, which pursue a slightly ascending course until they nearly reach the floor of the fourth ventricle (Plates III and IV, Figs. 11 and 15, Plate XVI, Figs. 12^a and 44). As they pass along the

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[1] Pons Varolii, 36 and 153. [2] Medulla Oblongata, 120 et seq.

inner or anterior edge of the nucleus, a few fibres are seen turning off to enter the large multipolar cells found here. This I have frequently observed in the sheep, especially in preparations hardened by means of chromic acid, in which the course of the fibres can be traced with great certainty. The majority of the fibres, however, pass onward and presently cross the roots of the facial, their further course often becoming much obscured by these roots, as well as by the very numerous bundles passing down from the cerebellum through the back of the auditory nucleus and now radiating into the anterior network (Plate XVI, Fig. 44). I have, however, several specimens from the medulla of the sheep, in which the entire course of the root-bundle can be traced. It appears to be as follows: the bundle, after passing along the anterior border of the nucleus, and sending a few fibres into its cells, as stated above, bends around the nucleus, many of its fibres entering the large, stellate and oval cells situated along the posterior margin. Some fibres penetrate more deeply into the posterior part of the nucleus and enter cells. I have also thought that I could trace a few fibres as far back as the groups of large oval cells lying along the back of the auditory nucleus, and which are entered by the roots of the posterior division of the auditory as well as by fibres from the cerebellum. Some of the fibres from the sixth nerve certainly pass along the floor of the fourth ventricle for a considerable distance, but I was entirely unable to determine their ultimate destination, as they are constantly united to the bundles derived principally from the cerebellum, from which it is impossible to distinguish them.

It would seem on theoretical grounds quite possible that there may exist, as stated by Schröder van der Kolk, some connection between the nuclei of the abducens and oculo-motor nerves, and that some of the fibres from the abducens, which are lost sight of as they pass along the floor of the ventricle, may become ascending fibres passing upward to the nucleus of the oculo-motor. The attempt to determine this would, however, have carried me beyond the limits assigned to the present communication, and as I have been desirous to avoid anything approaching to theoretical consideration I shall leave this point for future investigation.

The cells in the posterior part of the nucleus, which are entered by the abducens, are similar in appearance and size to those described in connection with the facial. They are stellate, oval or fusiform in shape, and measure in the sheep, from $\frac{1}{800}$ to $\frac{1}{400}$ of an inch in diameter.

CHAPTER V.

THE UPPER OLIVARY BODIES.

THE nuclei within the mammalian trapezium, situated anteriorly on each side of the raphè, resembling in form and structure the olivary bodies of the medulla, were first pointed out by Clarke,[1] and subsequently described quite fully by Schröder van der Kolk.[2] They make their appearance in the upper part of the medulla, at a point near where the lower olivaries first diminish in size, in the situation formerly occupied by the cells of the antero-lateral nucleus. The cells of this group have, however, diminished very much in number prior to the appearance of the upper olivary bodies (Plate XIII, Figs. 6^a, 7^a), and in the cat they sometimes almost entirely disappear. By comparing Plate XIII, Figs. 6^a, 7^a with Plate XIV, Fig. 8^a, it will be seen that the upper olivary group is developed in a position exactly corresponding to that of the antero-lateral nucleus below, of which it may therefore be considered an upward extension, serving in the lower part of the medulla, as it were, as an accessory nucleus to the *lower olivary column*, and closely connected at the same time with the *caput cornu*, as well as with the *nuclei* of the posterior columns (*glossopharyngeal*, *vagal* and *spinal accessory*).

In the first stage of its development as an independent nucleus (Plate XIV, Fig. 8^a), the upper olivary body appears as a group of large, stellate, multipolar cells, measuring in the sheep from $\frac{1}{800}$ to $\frac{1}{400}$ of an inch in diameter, in the cat from $\frac{1}{1333}$ to $\frac{1}{800}$ of an inch. These cells are very numerous, especially in the cat, and are quite uniform in size when measured on the same plane; in the lower part of the nucleus they are quite large, but rapidly diminish in size as we approach the trapezium. At first they are arranged in a loose network, formed by the interlacement of their processes around the numerous longitudinal bundles of the anterior network. The cell-processes appear to run in every direction, being continuous before and behind with the transverse fibres radiating from the central gray substance, and laterally with the arciform fibres, in addition to which other processes are sent out above and below to join the longitudinal bundles. The meshes formed in this way are exceedingly numerous and intricate, and the development of anything like the regular convolution of a true olivary body is very gradual. The mass is still connected by little cell-groups with the caput cornu, as was the case with the antero-lateral nucleus, and is also joined more or less to the central and anterior portion of the great auditory nucleus, especially to that portion from

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[1] Proceedings of the Royal Society, 1857.

[2] Medulla Oblongata, 162 et seq.

which the *fasciculus teres* is subsequently developed, by numerous bundles of fibres, along which cells of medium size are frequently scattered.

Higher up (Plate XIV, Fig. 9^a), the outer border of arciform fibres has increased in breadth and in the number of bundles, and reaches backwards to the upper olivary bodies which are penetrated by the internal arciform fibres in a wavy course, the cells being quite regularly disposed among the fibres constituting the plexus, and thus becoming gradually arranged into a somewhat convoluted form.

From this region upwards the principal changes consist in the development of a still more convoluted arrangement of the cells and fibres, the cells being finally separated into two or three distinct masses, forming a lamina, which, in the sheep, is folded in a manner much more nearly resembling the convoluted lamina of the human olivaries, than the structure of the lower olivary bodies in the medulla of the same animal. In the cat, as noticed above, the structure of the lower olivary bodies approaches the human type more than in the sheep, and we find a coincident development of the upper olivaries, the structure of which is quite complicated (Plate XII, Fig. 42).

Schröder van der Kolk has already pointed out the striking differences which exist between the different classes of mammals in the development of the upper olivaries. He found the greatest development in the Carnivora, less in the Rodentia, and still less in the Herbivora; these bodies being so slightly developed in the ass as to be easily overlooked. These observations are quite in accordance with my own; the upper olivary body in the sheep consists of two or three distinct spherical bodies rather than a connected and convoluted lamina: on the other hand, in the rabbit the convoluted lamina is very distinct, and often quite uninterrupted, and in the cat the convolutions are very decided (Plate XII, Fig. 42, Plate IX, Fig. 36).

In the sheep the upper olivary body consists of a mass of small cells which rarely exceed $\frac{1}{1333}$ of an inch in diameter, varying in form from oblong or oval, to stellate; they are multipolar, their processes being everywhere continuous with the numerous bundles which either penetrate or radiate from the interior of the mass. The olivary body is completely surrounded by fibre-bundles chiefly radiating or turning off from the arciform plexus, many of the fibres of which penetrate the mass, forming a somewhat similar system of fibres alternating with layers of cells, to that noticed in the lower olivary bodies of the sheep. Sometimes a central bundle may be noticed in the interior of the mass, from which fibres radiate in all directions, but the type of structure is usually exceedingly simple.

As the great bundles of external arciform fibres forming the *trapezium* sweep down from the restiform body and posterior portion of the medulla, after crossing the roots of the facial, they pursue a wavy course (Fig. 10^a), in which they are joined by numberless deeper lying bundles. The more external of these sweep around the olivary body, many separate bundles turning off and curving quite around the mass, either penetrating its interior or completely surrounding it, till the upper side is reached, where the bundle frequently turns still more and enters the central portion of the mass, radiating in the same manner as the bundles which enter the convolutions in the lamina of the human olivaries.

In the rabbit the upper olivary body is represented by a very complete convolution, presenting three or four turns, entered and penetrated by the arciform fibres both external and internal as well as by numerous transverse and radiating fibres. In the mouse the upper olivaries consist of a wavy mass of quite large and numerous cells.

The structure of the upper olivary body is especially distinct in the cat, and I have, therefore, given an accurate representation of the entire mass, the outline being drawn by a power of about 20 diameters, to which some details were added as seen by higher powers (Plate XII, Fig. 42).

In this figure it will be noticed that the lamina is convoluted, and arranged much on the same general plan as in the lower olivary bodies of the same animal or of man. The bundles which surround the entire mass and radiate among the foldings of the lamina, are principally derived from the external and internal fibres of the arciform plexus. These bundles surround the outside of the olivary body pursuing a beautiful wavy course, and turn off at varying angles to enter different portions of the lamina, the cells of which are everywhere brought into connection with the fibres. As these bundles approach the inner or posterior side of the mass, they are joined by other bundles derived from the radiating fibres proceeding from the posterior gray substance, some of which seem to connect the olivaries with the *fasciculus teres* or nucleus of the facial and abducens. These bundles sometimes form quite large stems (Plate XII, Fig. 42, *D*), and are well seen in Plate IX, Fig. 36, where the general situation and relations of the olivary body to the surrounding parts is also well shown. The course of the fibres within the folds of the lamina bears much resemblance to that in the lower olivaries in man; in the cat it may be briefly described as follows:—

1st. The entire mass is surrounded by a broad marginal band (Plate XII, Fig. 42, *B*, *B*), principally derived from the arciform plexus (*A*, *A*), from which, however, single fibres and sometimes considerable bundles constantly pass off, penetrating the lamina, and either entering cells, or passing onward to join deeper lying bundles with some of the fibres of which they appear to be continuous, or else entering still more distant folds of the lamina (some of these fibres are seen at *C*, *C*). In its course around the margin of the olivary body the band is frequently joined, especially on the upper side, by fibres derived from the posterior gray substance.

2d. Traced from within outwards their course is as follows: (1). The fibres from the centre of one of the bundles (*D*) penetrating the lamina, proceed forwards, either joining cells or passing directly across the lamina, often curving around and joining the marginal band or crossing its fibres nearly at right angles, soon becoming lost among the fibres of the arciform plexus. (2). Those fibres forming the external portion of the bundle (*D*), penetrate the lamina and diverge more and more, radiating in all directions among the cells, some of which they enter, the remaining fibres passing outward into more distant folds of the lamina, or into the parts surrounding the olivary body, usually joining ultimately the bundles of the arciform plexus. From the anterior part of the olivary body numerous fibres radiate transversely into the trapezium, crossing its wavy bundles at right angles, and often forming quite a thick stem, which may be traced like the nerve roots to the outer limits of the medulla (Plate XVI, Fig. 12^a, *y*).

Schröder van der Kolk[1] has deduced from the connections between the upper olivary body and the nucleus from which the facial arises, the theory that the upper olivary body is a sort of accessory nucleus to the facial, establishing the same relation between them which he supposes to be established between the hypoglossal and the lower olivary body. A connection between these nuclei undoubtedly exists to some extent in those mammalia which I have examined, but the chief and by far the most important connection of the olivaries, both upper and lower, is with the arciform fibres, and I am therefore inclined to think that the upper olivary bodies, like the lower, are co-ordinating centres for the different nuclei lying in the same region with them, with all of which they are brought into more or less intimate relation by means of the plexus of arciform as well as transverse fibres with which they are connected. Within the human pons Varolii a collection of cells is found near the facial, undoubtedly representing the upper olivary body of the mammalia, but in man, the office of co-ordination would seem to be chiefly fulfilled by the numerous scattered cell-groups, which are so frequently found in the meshes of the intricate plexus of fibres constituting the pons Varolii.

Several other cell groups are found, both on the outer and inner side of the upper olivary bodies, and very many cells are found scattered throughout the whole anterior and antero-lateral network. Among these groups, the largest and most constant are, one on the inner side of the olivary body in the vicinity of the roots of the sixth nerve, consisting of stellate, multipolar cells of moderate size, and another on the outer side of the olivary body, near the entrance of the facial roots (Figs. 10^a, 12^a, *v*), consisting of quite large multipolar cells, and sometimes, as noticed by Schröder van der Kolk, forming two distinct groups, the cells of which become more and more numerous, and at the same time are pushed inwards as we reach the upper part of the course of the facial, continuing to increase both in size and number as we approach the fifth nerve, to the motor root of which, I suspect, this group is related as well as to the facial.

METHODS OF PREPARATION.

Among all the different and numerous methods of preparing specimens of the medulla for microscopic examination, I have found none at all comparable to the methods given by Clarke (*Philos. Trans.* 1859), and I have therefore availed myself exclusively of these, with some slight modifications. Specimens colored by a solution of carmine in glycerine[2] have often been used for special purposes; but for the general study of the *course and destination of fibres*, I have found specimens hardened in chromic acid and made transparent by Clarke's method, particularly well suited. These specimens have usually been immersed for a few weeks in a solution of chromic acid, of about the strength given by Clarke (1859), and subsequently put

[1] Medulla Oblongata, 165. [2] Mem. of the American Academy, 1861.

into alcohol, by which means the specimens are hardened, without becoming so brittle as is often the case if they are kept for a long time in a solution of chromic acid or of bichromate of potash. I have also continued the use of copal-varnish in the place of Canada balsam as recommended in a former paper (*Spinal Cord*, 1861), as it still seems to me on many accounts more advantageous than the balsam.

The preparation of specimens for photographic use required some modification of the methods employed, since here the object in view was to obtain as much contrast of structure as possible, rather than that extreme transparency required for the use of higher powers. The sections, for this purpose, were immersed for a short time in very strong alcohol, and after careful washing placed in chloroform, where they shortly become semi-transparent; they are then placed on a slide on which a couple of drops of copal-varnish have been put, so that the section lies on the surface of the varnish: as the chloroform evaporates the varnish takes its place, and the section is kept soft for about twenty-four hours by adding at intervals either varnish or chloroform, or both, according to the degree of transparency required; a little practice only being necessary to attain any desired result. The varnish is then slightly softened by warming the slide over a lamp and the preparation covered with a thin glass as usual.

The methods employed in photographing the specimens were simple, and will readily be understood by those versed in the details of ordinary photographic manipulation. My apparatus consisted of a brass adapter, the tube of which fitted closely into the body of the microscope (Smith and Beck's first class), so that after removing the eye-piece and draw-tube I was enabled to attach the microscope very firmly to a common photographic camera. After a variety of experiments with different sources of illumination, I found the direct sunlight the only one on which I could rely with any degree of certainty, and although it will often appear that much time is lost in waiting for an entirely unclouded day, still, so far as my own work was concerned, I found that I lost much more time in endeavoring to work in uncertain weather. The common plane mirror may be used for reflecting the sunlight, or what is still better, the right angle prism which accompanies Smith and Beck's microscope. The objective with which the accompanying photographs were taken was a three inch, and I was able to enlarge the field of illumination to a considerable extent, by introducing directly behind the stage, as suggested by my friend Prof. Rood, a double convex lens, the focal distance of which measured a little less than the distance between the object and the back diaphragm of the objective; the exact focal length of the lens is, however, practically of little importance, and by diaphragming the lens to some extent, the central spot of light, should one appear, may be removed without sensibly diminishing the field. Whatever the power used may be, whether high or low, too much care cannot possibly be expended on careful and perfect illumination, not only in obtaining the greatest *amount* possible, but also in so modifying it according to the character of the object as to obtain the greatest degree of contrast between different parts, and this not only visually but also actinically, which of course is only to be determined by careful and repeated experiment.

The Wet Process was the one used for the majority of the photographs, the Dry

Process presenting difficulties which render it in some respects less suitable. In using as low an objective as a three inch, the first difficulty encountered is in adapting the collodion to a light which is so extremely brilliant as the direct sunlight reflected in the manner described above, it may therefore be well to give the formula used. In so brilliant a light not only is an ordinary collodion altogether too rapid, it being almost impossible to cover the lens quickly enough, but the resulting negative is excessively thin, and destitute of that intensity which is requisite in order to give a clear and brilliant print.

The pyroxyline used was chiefly the French (Poulenc-Wittman), and the plain collodion prepared as follows:—

Alcohol (.805)	10 ounces.
Ether (.725)	10 "
Pyroxyline	300 grains.

The iodizing solutions were prepared as follows, the formulæ being taken from Hardwich (*Manual of Photographic Chemistry*, 1861).

No. 1. (*Potassium Iodizer.*)

Iodide of Potassium	135 grains.
Alcohol (.816)	10 ounces.

No. 2. (*Bromo-Iodizer.*)

Bromide of Ammonium	40 grains.
Iodide of Ammonium	90 "
Iodide of Cadmium	90 "
Alcohol (.816)	10 ounces.

Two separate portions of the plain collodion were iodized with No. 1 and No. 2 respectively, in the proportion of two parts of iodizer for six parts of plain collodion, and the iodized collodion mixed after a few days, in the proportion of $\frac{1}{3}$ or $\frac{1}{4}$ of No. 2 with No. 1. The resulting collodion gave the best results after keeping from two to six months; it had then acquired a decidedly red color, and gave a thin, very even film, giving pictures remarkably free from imperfections of any sort, and though exceedingly insensitive for common purposes, requiring in the brilliant light of the microscope an exposure of only 8 or 10 seconds, which is much more easy to manage than any shorter time. The film was sensitized in the ordinary Nitrate Bath, *prepared with distilled water*, the strength being about 40–45 grains. For developing the picture, I have preferred the use of pyrogallic acid to the ordinary developer prepared with sulphate of iron, as I have found it much more controllable than the latter, and giving with more certainty the requisite degree of intensity. I have prepared it as follows:—

Pyrogallic Acid	$1\frac{1}{2}$ grain.
Acetic Acid, No. 8	30 minims.
Distilled Water	1 ounce.

The picture required no re-development, and I invariably made it a rule to throw away any picture which after the first development appeared deficient in intensity, as any attempt to re-develop injured very much the finer details of the picture. The fixing solution consisted of the usual saturated solution of hyposulphite of soda.

Major Russell's *tannin* process, is in many respects very well adapted for the purposes of microscopic photography; by modifying the collodion and developer we may obtain almost any desired result, and I sometimes employed it, though not so much as I undoubtedly should, had I known earlier how to control the strong tendency to solarization and thinness, of negatives obtained by the tannin process by means of direct sunlight reflected through a low objective. This control is best attained by using a large proportion of bromide in the collodion, in order to diminish the excessive intensity and hardness of the tannin negative, and a very large proportion of citric acid in the developer.

The formula for collodion which seemed to me to give the best results with the dry process was as follows:—

Bromide of Cadmium	40 grains.
Iodide of Ammonium	22 "
Collodion	8 ounces.

The plates were prepared as usual, and immersed in a solution of tannin (15–20 grains to the ounce).

The developer is made from the two following solutions:—

No. 1.—	Pyrogallic Acid	72 grains.
	Alcohol	1 ounce.
No. 2.—	Nitrate of Silver	20 grains.
	Citric Acid	120–180 "
	Water	1 ounce.

Fifty minims of No. 1 are diluted with two ounces of water, and a few drops of No. 2 added to the quantity necessary to develop a plate. The resulting pictures are very full of detail, and the great convenience of the dry process will not fail to be a very strong recommendation to the microscopist, who may by this means have a stock of sensitive plates on hand ready for use at any moment. Figs. 30, 31, and 32 were taken by the dry process, and are certainly not surpassed in detail and delicacy by any of the others.

EXPLANATION OF THE PLATES.

Plates I–IX are sections from the medulla, magnified about 7 diameters, as seen with a three inch objective.

PLATE I.

Fig. 1. Section of the medulla of the sheep, just above the spinal cord, showing the partial decussation of the pyramids from which the raphè is already formed, and the first appearance of the hypoglossal roots.

Fig. 2. Transverse section from the same, a little higher up, showing the formation of the olivary bodies, the hypoglossal roots, the restiform and post-pyramidal nuclei.

Fig. 3. Transverse section from the same medulla, showing the enlargement of the central canal, and the complete formation of the hypoglossal and vagal nuclei.

Fig. 4. Transverse section from the same, still higher, showing the opening of the central canal into the fourth ventricle which is now completely formed, and on each side of which are seen the vagal and hypoglossal nuclei.

PLATE II.

Fig. 5. Transverse section from the medulla of the sheep, showing the central portion on each side of the raphè. In front are seen the narrow pyramids and behind the olivary bodies; posteriorly on the floor of the ventricle lie the hypoglossal and vagal nuclei. The course of the hypoglossal roots is very plainly seen.

Fig. 6. Transverse section at about the same height, showing the same nuclei with their roots, and the commencement of the auditory nucleus.

Fig. 7. Transverse section, a little higher up; the hypoglossal roots are now no longer visible; the vagus nucleus has reached its maximum development and is already pushed forward by the formation of the auditory nucleus which has attained considerable size. The vagus roots are very distinctly seen, forming several quite large bundles which traverse the caput cornu.

Fig. 8. Section from the same medulla, still higher, showing the development and formation of the anterior and posterior portions of the auditory nucleus, with the posterior auditory roots.

PLATE III.

Fig. 9. Section from the medulla of the sheep, showing the auditory nucleus and roots together with their connections with lobes of the cerebellum.

Fig. 10. Transverse section from the same medulla, showing the further development of the auditory nucleus and anterior root of the auditory, together with the facial nucleus and root. The fibres from the anterior auditory root which penetrate the restiform body, joining the posterior root of the auditory, are especially well shown in this figure.

Fig. 11. Section from the same medulla, a little higher up, showing the antero-lateral portions. On each side of the raphè are seen the roots of the sixth or abducens, and a little further outwards is seen the facial root passing inwards towards its nucleus. Between the two roots is seen one of the upper olivary bodies.

Fig. 12. Section showing the postero-lateral portion of the same specimen of which the antero-lateral portion is given in Fig. 11. In the upper right hand corner is seen a portion of the flocculus. The formation and development of both roots of the auditory, as well as of the fibres radiating through the restiform body and serving to connect them, are well shown in this figure. The very numerous bundles passing from the posterior portion of the auditory nucleus back into the cerebellum are very conspicuous in the upper part of the figure.

PLATE IV.

Fig. 13. Transverse section from the sheep, showing the postero-lateral portion of the medulla. The restiform body is now pushed backwards towards the cerebellum, and the posterior auditory root is seen to be intimately connected with the flocculus. The connection between both portions of the auditory nucleus and the cerebellum is very conspicuous. In the lower part of the figure part of the facial course is seen, the root being now very large and distinct.

Fig. 14. Antero-lateral portion of the same specimen as the preceding figure, showing the course of the facial roots towards their decussation at the raphè as well as the development of the upper olivary bodies.

Fig. 15. Section from the same medulla, a little lower down than the preceding, showing the central portions on each side the raphè. The form of the fourth ventricle at this height is well seen, with the projecting lingula or *linguetta laminosa* derived from the cerebellum. The course and destination of the nerves of the sixth pair are well seen, and anteriorly the broad band of wavy fibres constituting the trapezium.

Fig. 16. Transverse section from the medulla of the sheep, still higher up, showing the gradual disappearance of the facial roots, just before the root of the fifth is developed. The broad band of fibres constituting the pons Varolii is seen in front.

PLATE V.

Fig. 17. Section of the human medulla just at the decussation of the pyramids.

Fig. 18. Transverse section from the same, a little higher up, showing the formation of the raphè and the hypoglossal and spinal accessory nuclei.

Fig. 19. Section from the same medulla, still higher, in which the nuclei are very conspicuous, the central gray mass being elongated posteriorly in a very remarkable manner. The restiform and post-pyramidal nuclei are very conspicuous, and anteriorly the olivary bodies have made their appearance.

Fig. 20. Transverse section from the same medulla, still higher up, showing the formation of the fourth ventricle, and the complete development of the hypoglossal and vagal nuclei.

PLATE VI.

Fig. 21. Transverse section from the human medulla, showing the further development of the nuclei and olivary bodies.

Fig. 22. Transverse section from the same medulla, showing the complete opening of the fourth ventricle, along the floor of which lie the hypoglossal, vagal and auditory nuclei, the latter just making its appearance on the outer side of the vagus nucleus.

Fig. 23. Section from the same, still higher up, showing the blending into a single mass of the nuclei seen in Fig. 22, the vagus nucleus being pushed outwards towards the apex of the mass.

FIG. 24. Section from the same medulla, still higher up, showing the formation of the auditory and glossopharyngeal nuclei.

PLATE VII.

FIGS. 25, 26, 27 and 28 are from the human medulla, and show the gradual development of the olivary bodies as seen in transverse sections and their relations to the hypoglossal roots. Fig. 25 is from the same section as Fig. 20: Fig. 26 is from a section a little higher up than Fig. 21: Fig. 27 is also from a section a little higher than Fig. 22: Fig. 28 is from the same section as Fig. 23.

PLATE VIII.

FIG. 29. Transverse section from the human medulla, showing the central part with the raphè and the olivary commissure, from the upper part of the medulla.

FIG. 30. Longitudinal section through the human olivary body, showing the convolutions of the lamina or *corpus dentatum*. The section is made obliquely inwards in a direction nearly parallel to the hilus, through the most dense portions of the lamina.

FIG. 31. Longitudinal section through the human olivary body, the section being made at right angles to the raphè, showing the outermost portions of the lamina. *a*, *a*, the raphè.

FIG. 32. Longitudinal section through the olivary body in the same direction as the preceding, but further inwards, showing the convolutions of the gray lamina cut through in a somewhat oblique direction. *a*, *a*, the raphè.

PLATE IX.

FIG. 33. Transverse section of the medulla of the cat, showing the auditory and glossopharyngeal nuclei.

FIG. 34. Section from the same medulla, a little higher up, showing the very large, posterior auditory root and the nucleus.

FIG. 35. Section from the same medulla, still higher up, showing both divisions of the auditory root, as well as the connection between the nucleus and the cerebellum, with the formation of the upper olivary bodies.

FIG. 36. Section from the same medulla on a level with the facial roots, showing the roots of the sixth pair, the facial and auditory nerves together with their nuclei. Anteriorly the upper olivary bodies are seen, and the broad wavy bundles constituting the trapezium.

PLATE X.

FIG. 37. Group of cells from the anterior portion of the hypoglossal nucleus of the sheep, magnified 120 diameters, from a transverse section. *A*, *A*, *A*, bundles connected with the hypoglossal roots: *B*, *B*, *B*, bundles derived from the vagus roots, passing along the outer margin of the nucleus on their way to the raphè: *D*, fibres derived from the hypoglossal roots, passing into the deeper portion of the nucleus and curving backwards towards the vagus nucleus.

FIG. 38. Group of cells from the vagus nucleus, from a transverse section of the medulla of the sheep, magnified 120 diameters. *V*, bundle of fibres constituting the vagus roots, some of which are seen to turn inwards towards the cells and deeper lying parts of the nucleus, while others sweep around the margin of the hypoglossal nucleus in the direction *A*, *A*.

PLATE XI.

FIG. 39. One of the convolutions of the lamina of the human olivary body, from a longitudinal section, magnified 120 diameters, showing the cells of the lamina and their relations to the fibres. *A*, fibre-bundle penetrating the convolution, sending out its fibres among the cells: *B*, *B*, bundle surrounding the fold of the lamina: *C*, *C*, bundles passing from the central bundle *A* through the lamina towards distant convolutions: *D*, a few scattered cells of the neighboring convolutions.

FIG. 40. Transverse section through the hypoglossal and vagal nuclei, from the sheep, magnified 20 diameters, some details being subsequently added with higher powers. *A*, *A*, *A*, the hypoglossal roots: *R*, the raphè: *X*, the apex of the fourth ventricle: *V*, the vagus roots: *D*, bundles derived from the vagus, sweeping round the margin of the hypoglossal nucleus on their way to the raphè, where many of them decussate with those from the opposite side: *H*, longitudinal fasciculi: *b*, group of cells situated in the anterior portion of the hypoglossal nucleus, in close connection with the hypoglossal roots and with the marginal fibres derived from the vagus. This group is represented in Fig. 37. *c*, marginal fibres derived from the vagus, passing to some extent into the antero-lateral columns: *m*, *m*, fibres derived from the hypoglossal roots curving backwards towards the posterior part of the nucleus: *e*, posterior commissure, on the edge of which is seen the epithelial layer: *h*, posterior cells of the hypoglossal nucleus: *v*, cells of the vagus nucleus.

PLATE XII.

FIG. 41. Group of cells from the auditory nucleus of the cat, magnified 120 diameters; from a transverse section near the entrance of the auditory root. *A*, *A*, *A*, fibres derived from the auditory root, some of which may be traced towards cells: *B*, curved fibres and bundles, some of which are derived from the root, radiating into the antero-lateral network: *C*, fibres coming down from the cerebellum.

FIG. 42. Upper olivary body of the cat, from a transverse section, magnified about 20 diameters. *F*, part of the facial root: *A*, *A*, bundles from the external arciform plexus: *C*, fibres from the arciform plexus penetrating the fold of the olivary lamina: *B*, bundles surrounding the folds of the lamina and also penetrating them: *D*, fibres derived both from the transverse and internal arciform fibres, forming as it were a stem to the olivary body, radiating subsequently within the lamina, with the cells of which these fibres are intimately connected.

FIG. 43. Group of cells from the postero-lateral portion of the auditory nucleus of the sheep, magnified 120 diameters. The bundles represented in this figure are mostly derived from the cerebellum, with which this part of the nucleus is intimately connected.

PLATES XIII, XIV, XV, and Fig. 12[a], Plate XVI, are outlines representing the situations of the principal cell nuclei, and a few other details of the photographs given in the preceding plates of which they bear corresponding numbers. The lettering is the same in all the figures.

a—border of external arciform fibres.

b—caput cornu posterioris.

c—central canal.

d—cervix cornu.

e—little cell group thrust out from the hypoglossal nucleus.

f—cells in the anterior spur of the vagus nucleus.

g—cells in the posterior spur of the vagus nucleus.

h—anterior cornu.

i—small pyramidal nuclei.

j—longitudinal columns (Stilling's constant root of the fifth).

k—border of longitudinal fibres, just above which the posterior division of the auditory root appears.

l—longitudinal fasciculi passing through the vagal and accessory nuclei.

m—posterior longitudinal fasciculi.

n—accessory olivary nucleus (Stilling).

p—post-pyramidal body.

r—restiform body.

p, *p*—post-pyramidal nucleus.

r, r—restiform nucleus.

s—great pyramidal nucleus (Stilling).

t—tractus intermedio-lateralis.

v—cell-group at foot of facial root.

w—fourth ventricle.

x—cell group pushed out from the restiform nucleus.

y—lower stem of olivary body.

z—cell group at foot of the posterior auditory root.

r'—fibres radiating through the restiform nucleus.

A—inner portion of the auditory nucleus.

A'—outer " " " " "

VIII—anterior auditory root.

VIII'—posterior " "

B—antero-lateral nucleus.

O—lower olivary bodies.

O'—upper olivary bodies.

H—hypoglossal nucleus.

XII—hypoglossal roots. *XII'*—roots cut off by plane of section.

S—spinal accessory nucleus. *XI*—spinal accessory roots.

V—vagus nucleus. *X*—vagus roots.

G—glossopharyngeal nucleus. *IX*—glossopharyngeal roots.

T—fasciculus teres, nucleus of sixth and seventh pairs of nerves.

VII—facial roots. *VI*—abducens roots.

R—raphè. *P*—anterior pyramids.

P'—fibres decussating to form the raphè.

D—flocculus. *K*—lingula or linguetta laminosa.

F—fibres of the pons Varolii.

PLATE XVI.

FIG. 44. Transverse section from the medulla of the sheep, from a preparation hardened by chromic acid, magnified about 11 diameters, some details being added by the use of higher powers, showing the course of the fibres constituting the roots of the facial, abducentes and auditory nerves within their respective nuclei. The location of the different cells has been omitted to avoid confusion, this being sufficiently shown in the smaller outlines, especially Fig. 12ª from about the same height. *VI*, roots of the abducens nerve: *VII*, facial roots: *VIII*, anterior division of the auditory roots: *VIII'*, posterior division of the same roots: *a*, external arciform fibres: *b*, caput cornu: *D*, a fold of the flocculus: *B*, bundles derived partly from the flocculus and partly from the posterior division of the auditory root, on their way around the restiform body towards the nucleus: *r*, restiform body: *A*, bundles derived from the cerebellum passing down into the nucleus: *t*, fasciculus teres or nucleus of the abducens and facial: *R*, raphè.

FIG. 45. Epithelial cells from the fourth ventricle of the sheep, from the same preparation. *a*, rounded cells, from the side walls of the ventricle. *b*, cells near the calamus scriptorius, just behind the raphè. *c*, cells at the apex of the ventricle, exactly behind the raphè, magnified 450 diameters.

FIG. 12ª. Outline of Figs. 11, 12, Plate III. *W*, *W*, fibres radiating towards the cerebellum, some of which overarch the fourth ventricle, while others pass back towards the corpus dentatum and outwards towards the flocculus: *M*, fibres connecting the back of the auditory nucleus with the flocculus. The remaining lettering of this figure is the same as that used for Plates XIII, XIV, XV.

Each division of the scales annexed to the preceding figures represents the $\frac{1}{100}$ or $\frac{1}{1000}$ of an inch.

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FEBRUARY, 1864.

Fig. 5

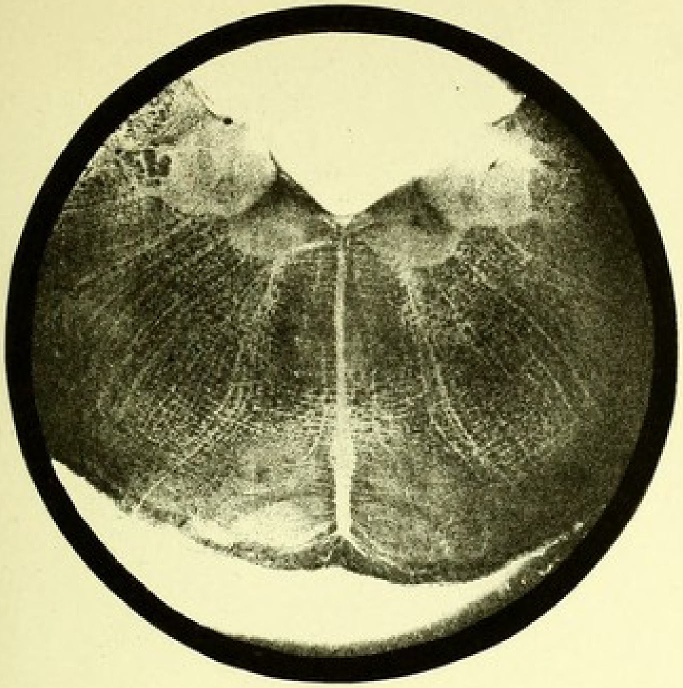


Fig. 6

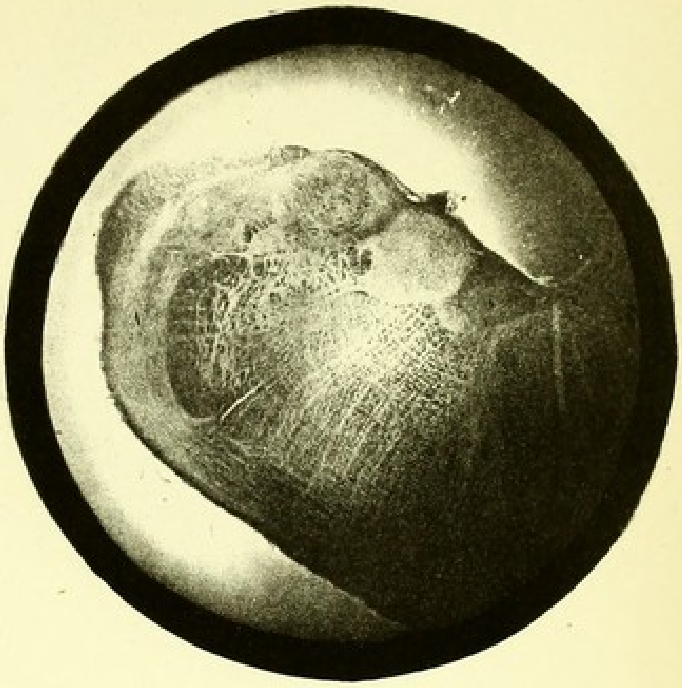


Fig. 7.

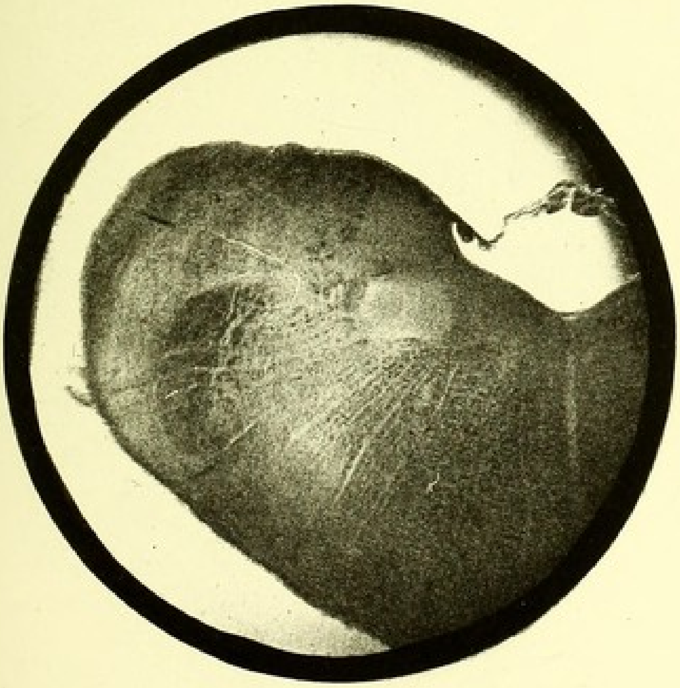
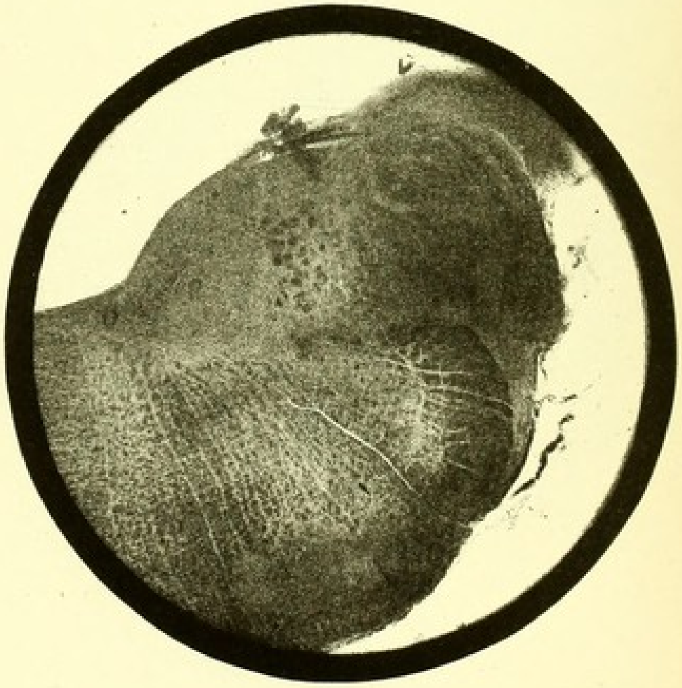


Fig. 8.



Photographed by J. Dean

Photo Lith by I. H. Bradford.

Fig. 9

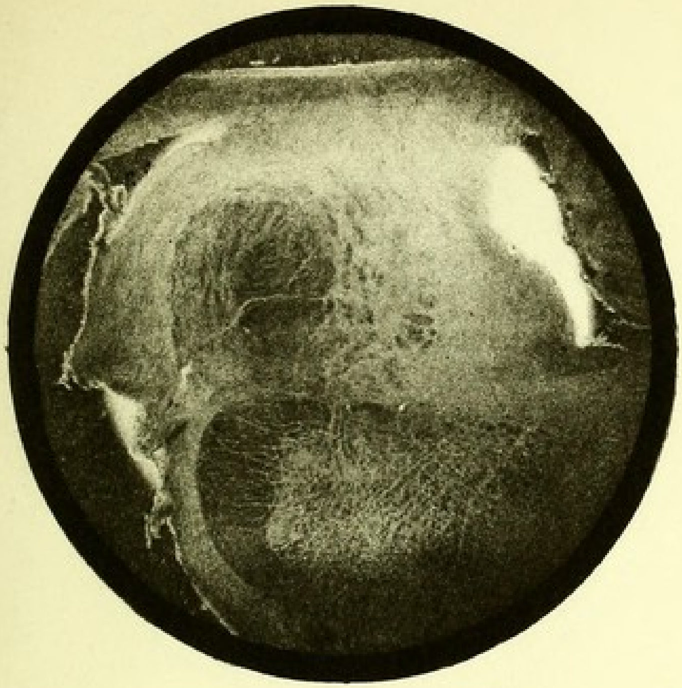


Fig. 10

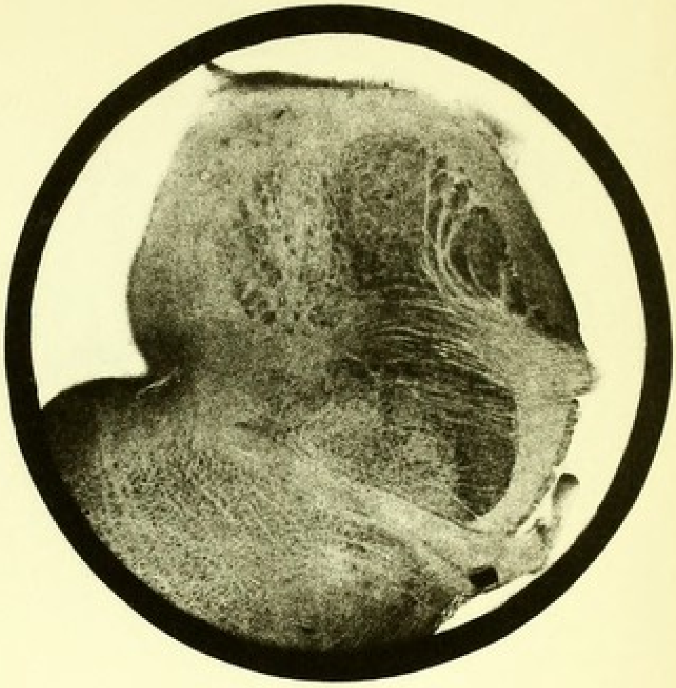


Fig. 11

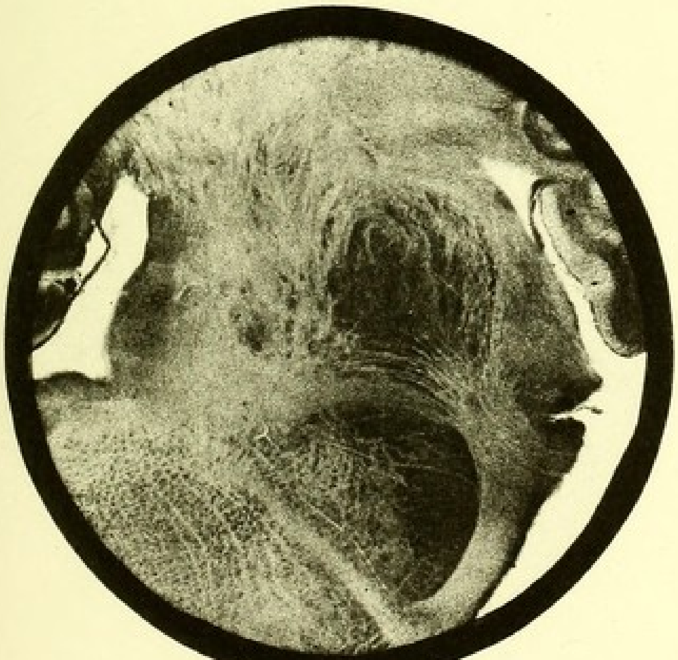
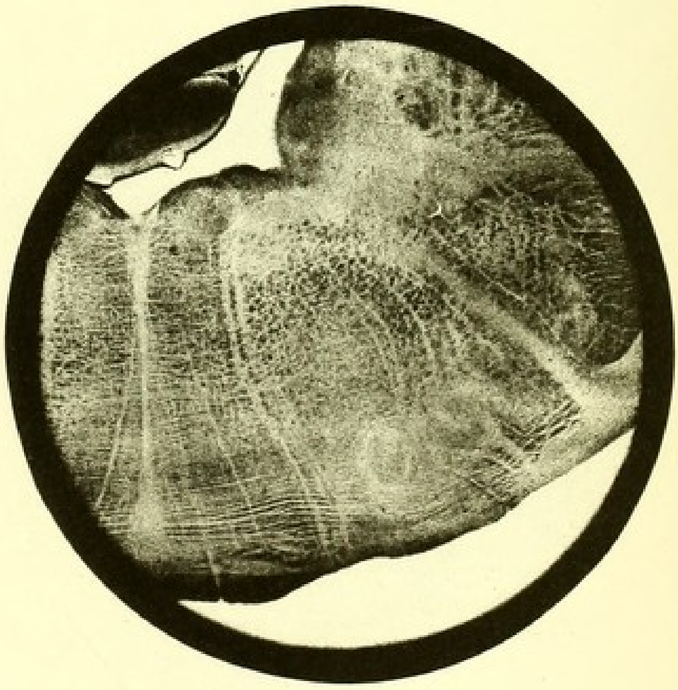


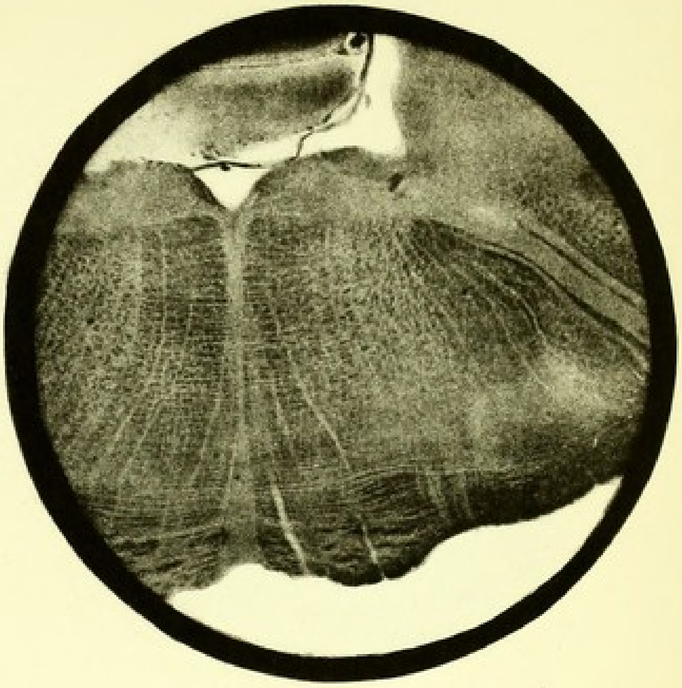
Fig. 12



Photographed by J. Dean. Photo-Lith. by I. H. Bradford.

Fig 13.

Fig 14.



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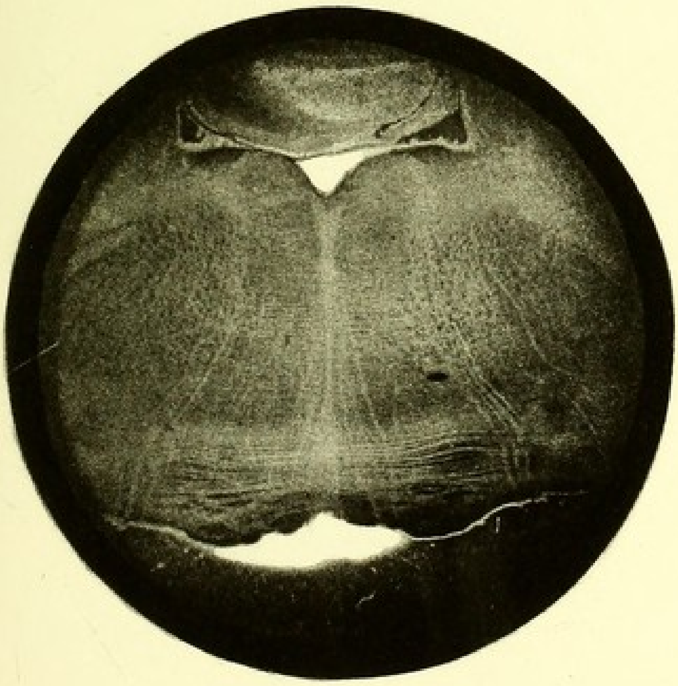
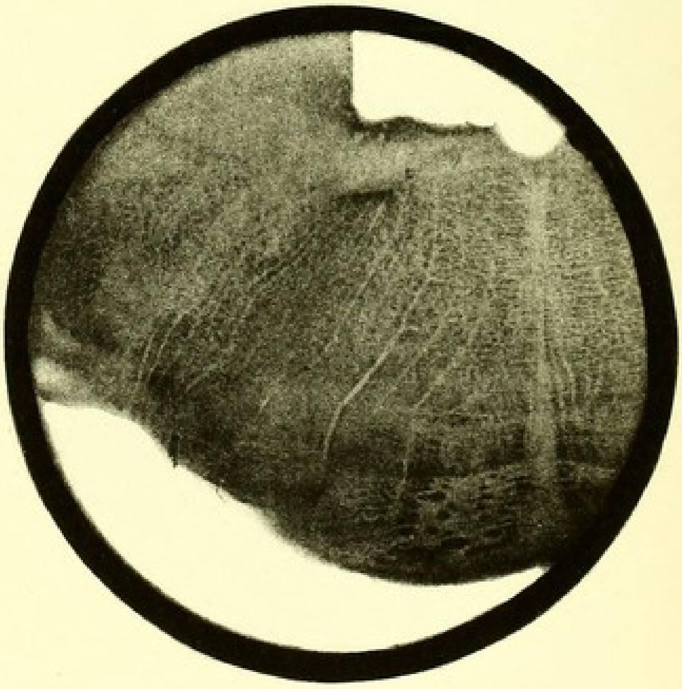


Fig. 16.



Photographed by J. Dean

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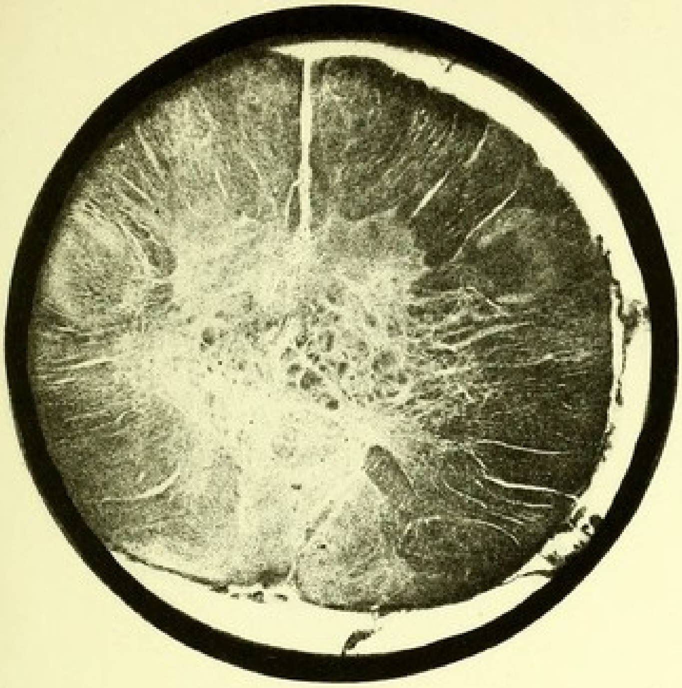
Fig. 17



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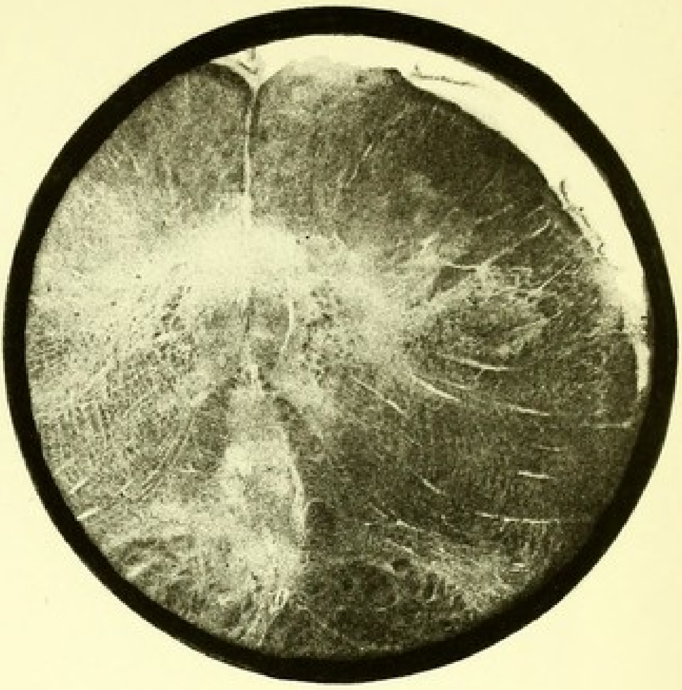

Fig. 19.

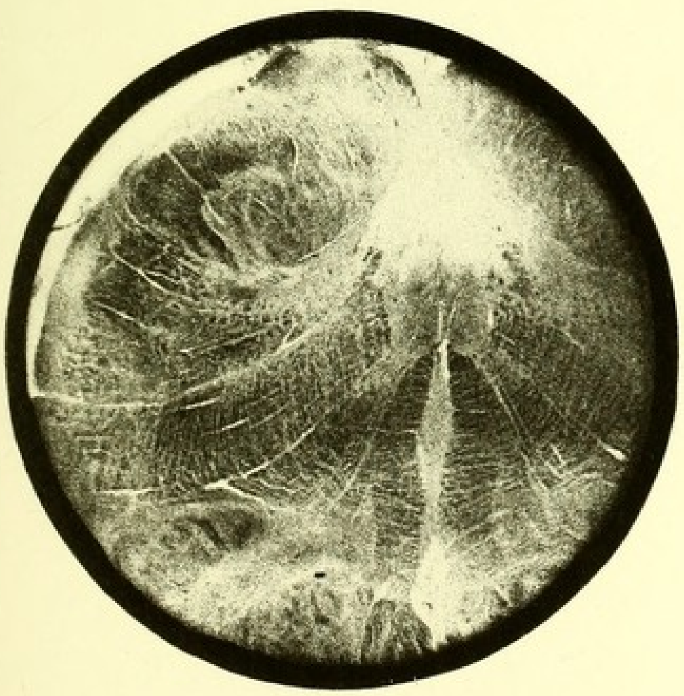

Fig. 20.

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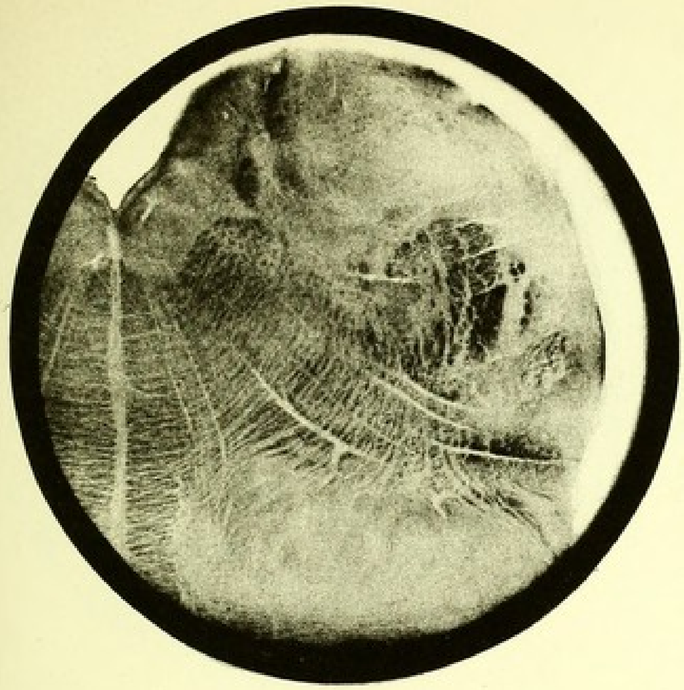
Fig. 21.



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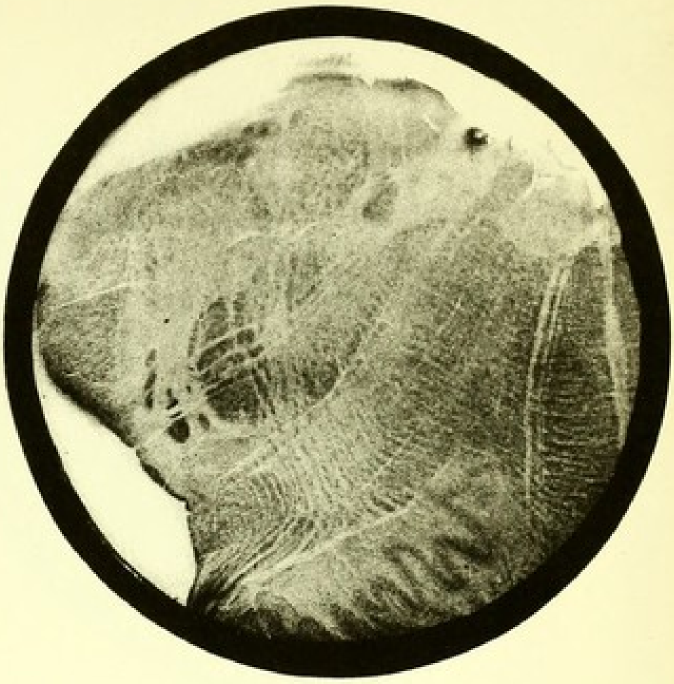

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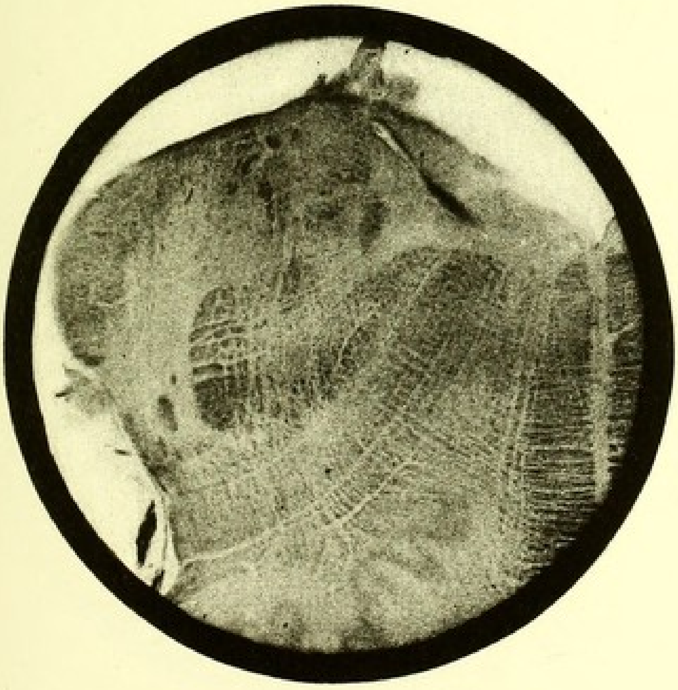

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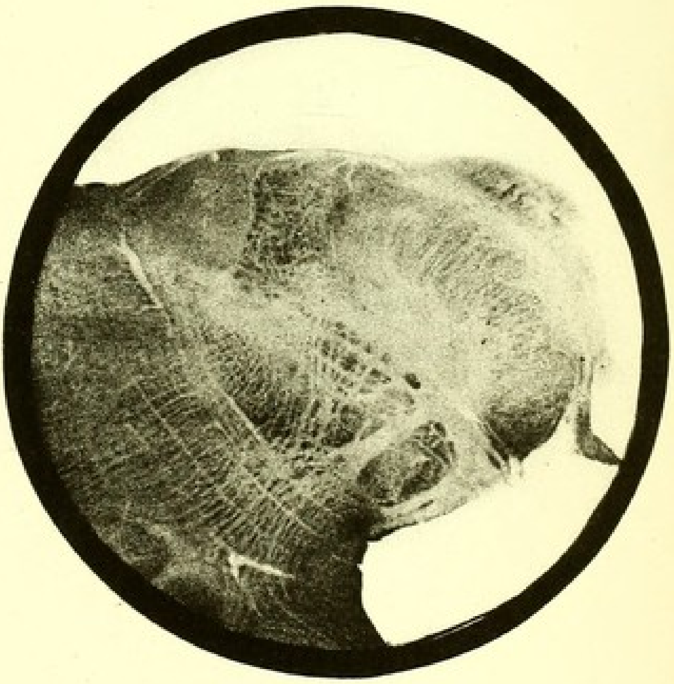

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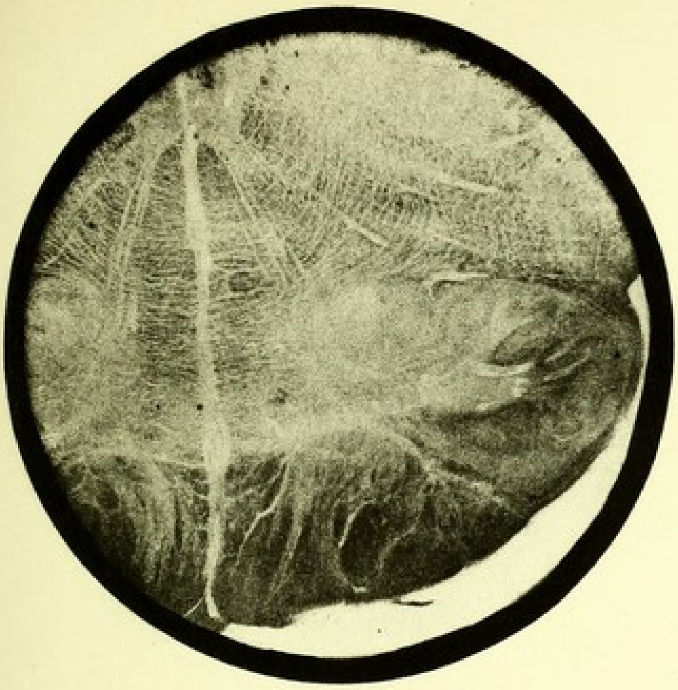
Fig. 25.



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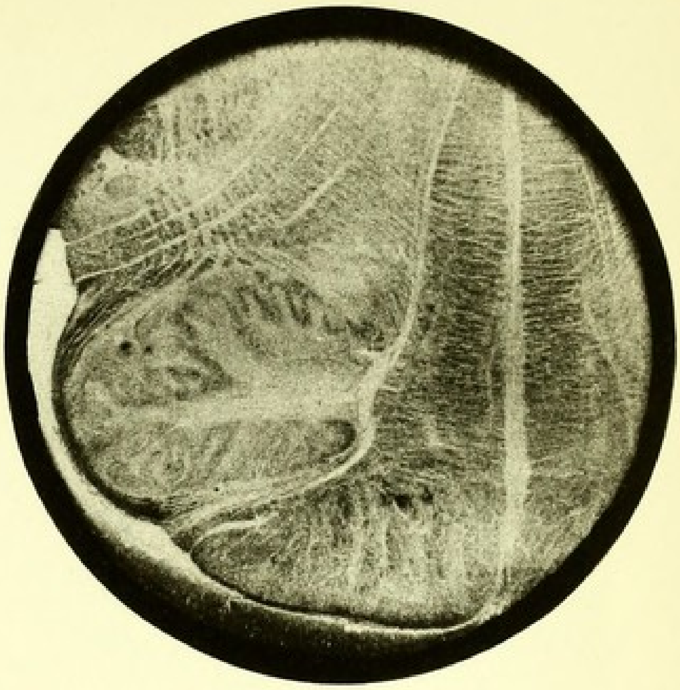
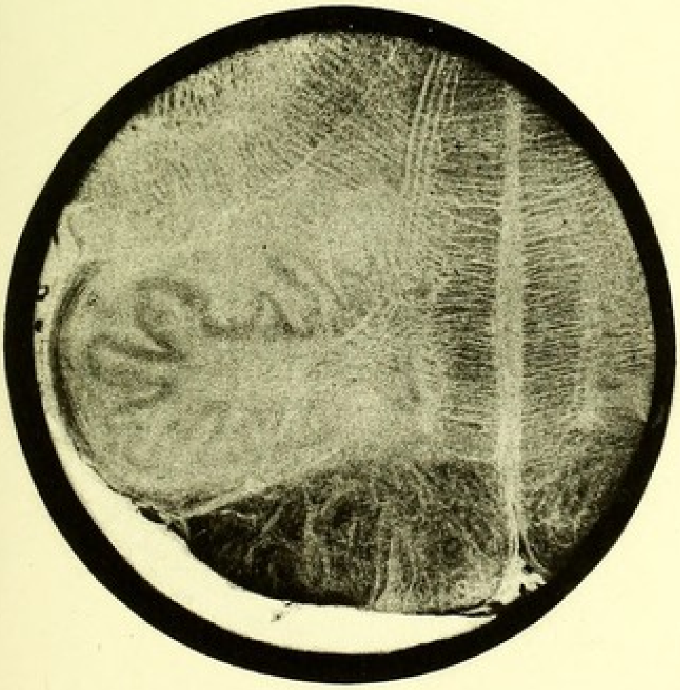


Fig. 27



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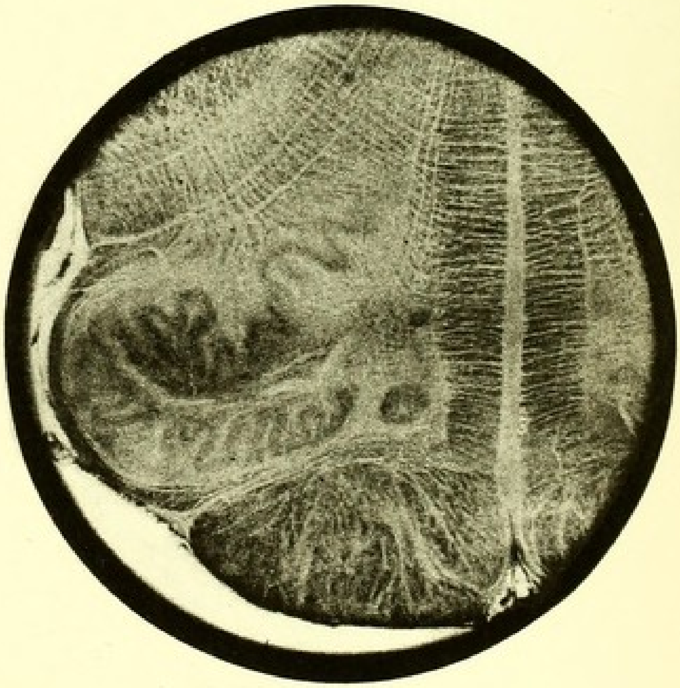
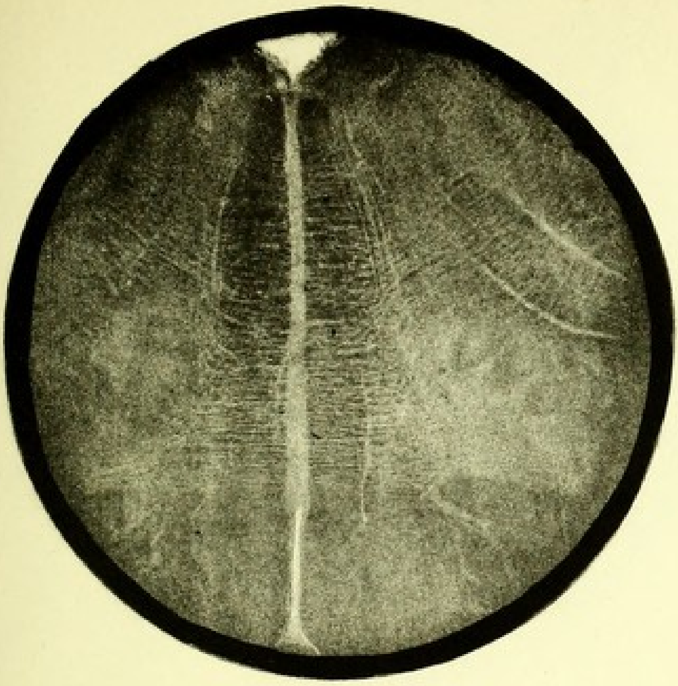


Photographed by J. Dean.

Photo-Lith by L.H. Bradford.

Fig 29



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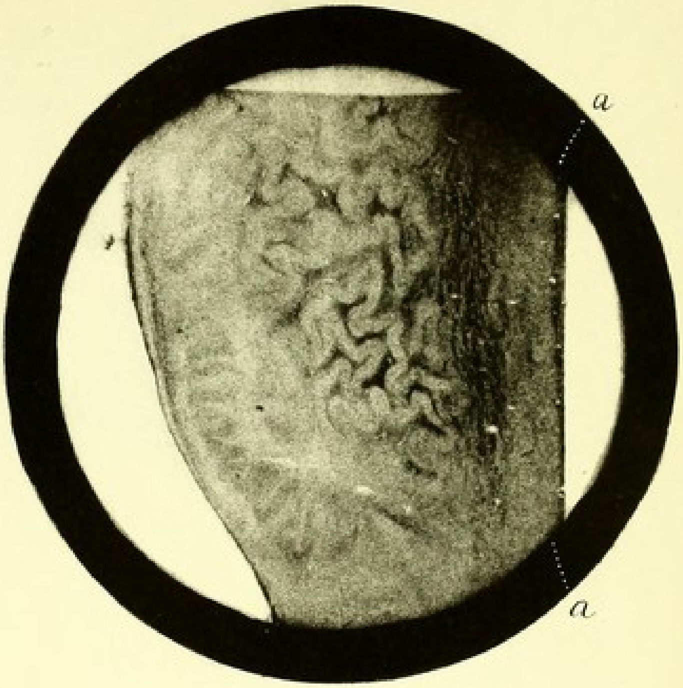

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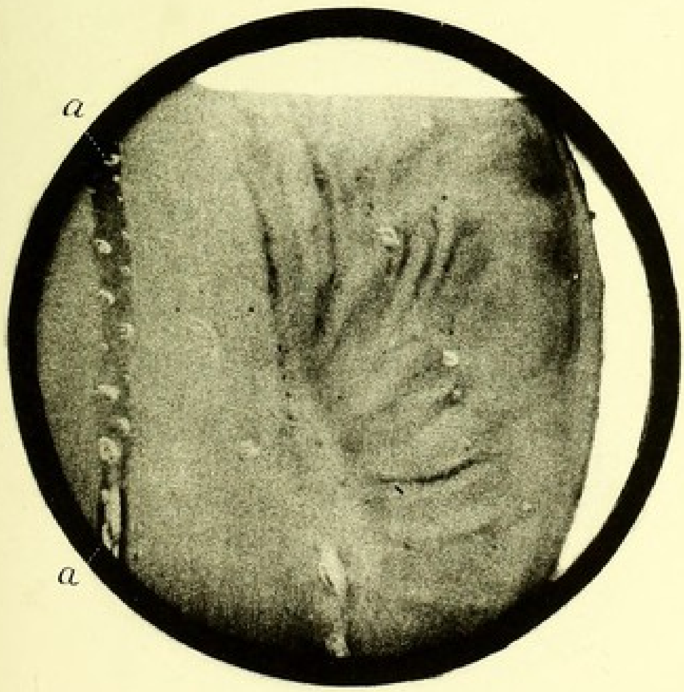

Fig 32

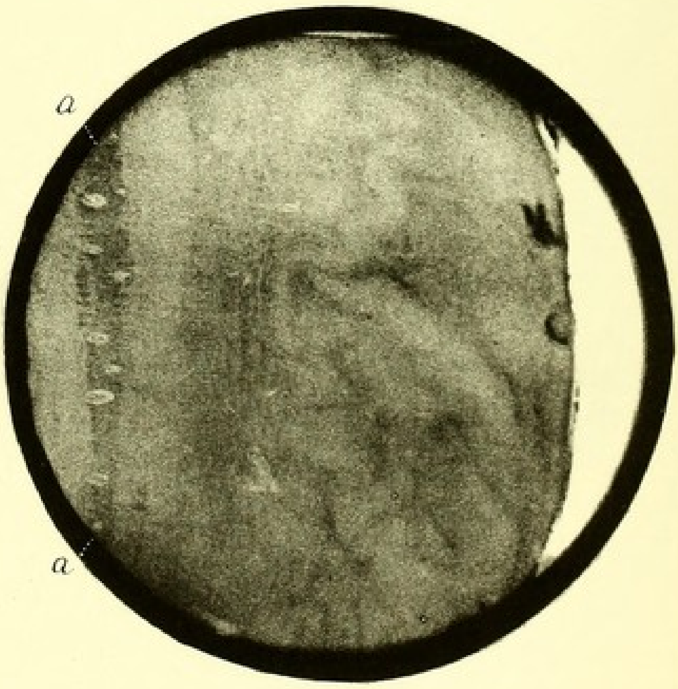

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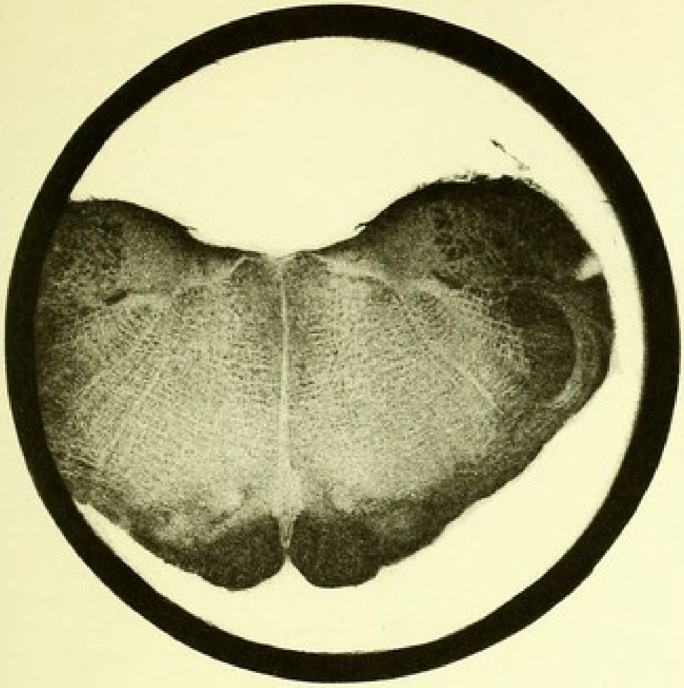
Fig. 33.



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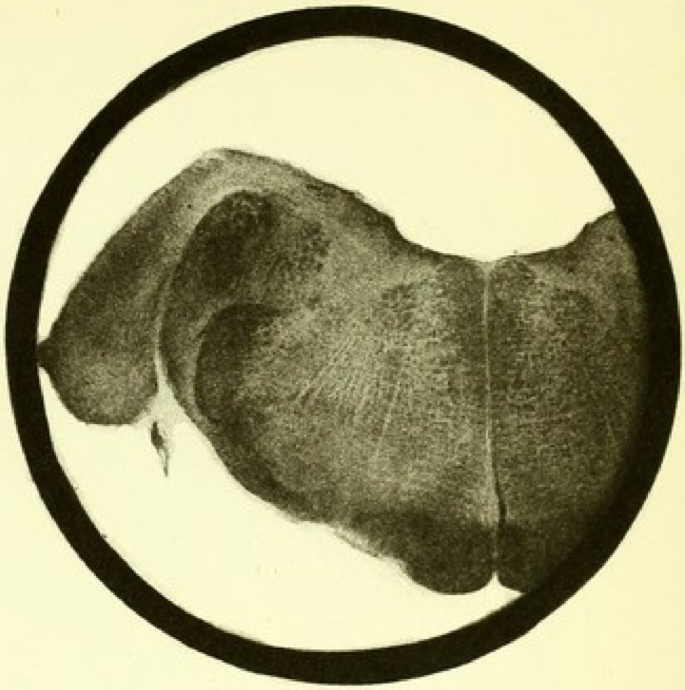

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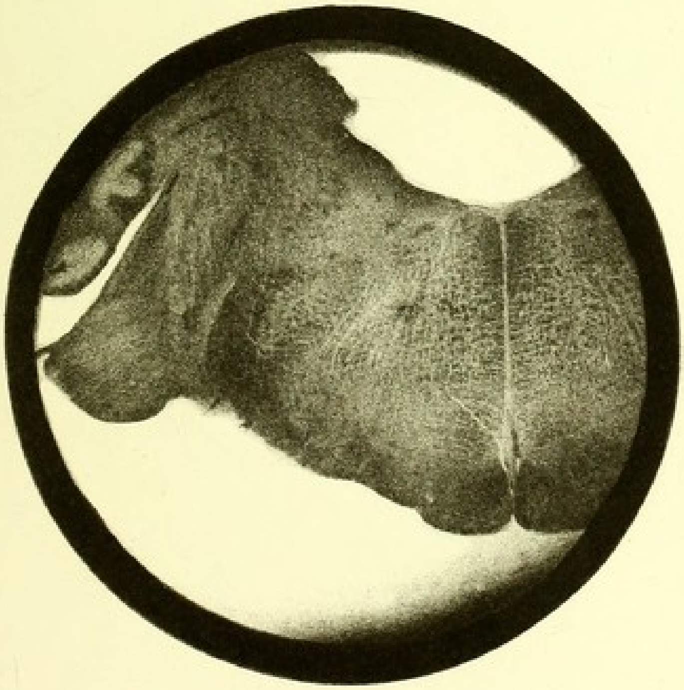

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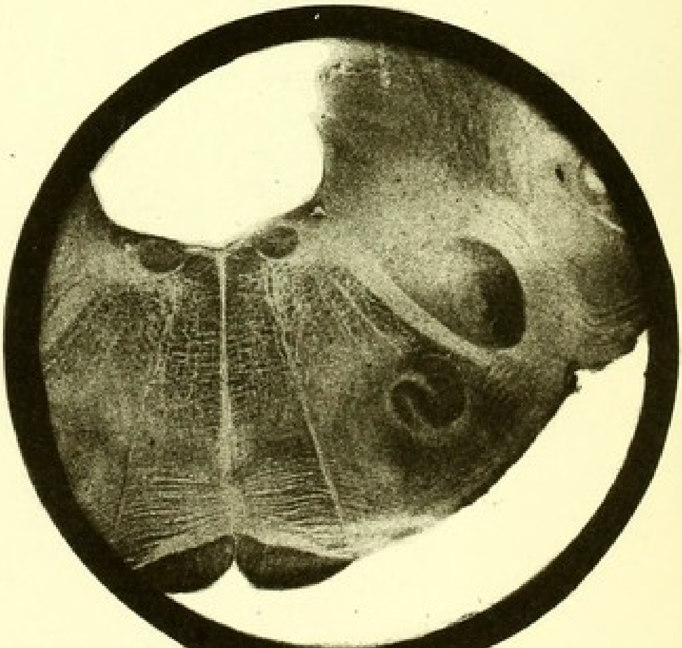

Photographed by J. Dean.

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Fig 37

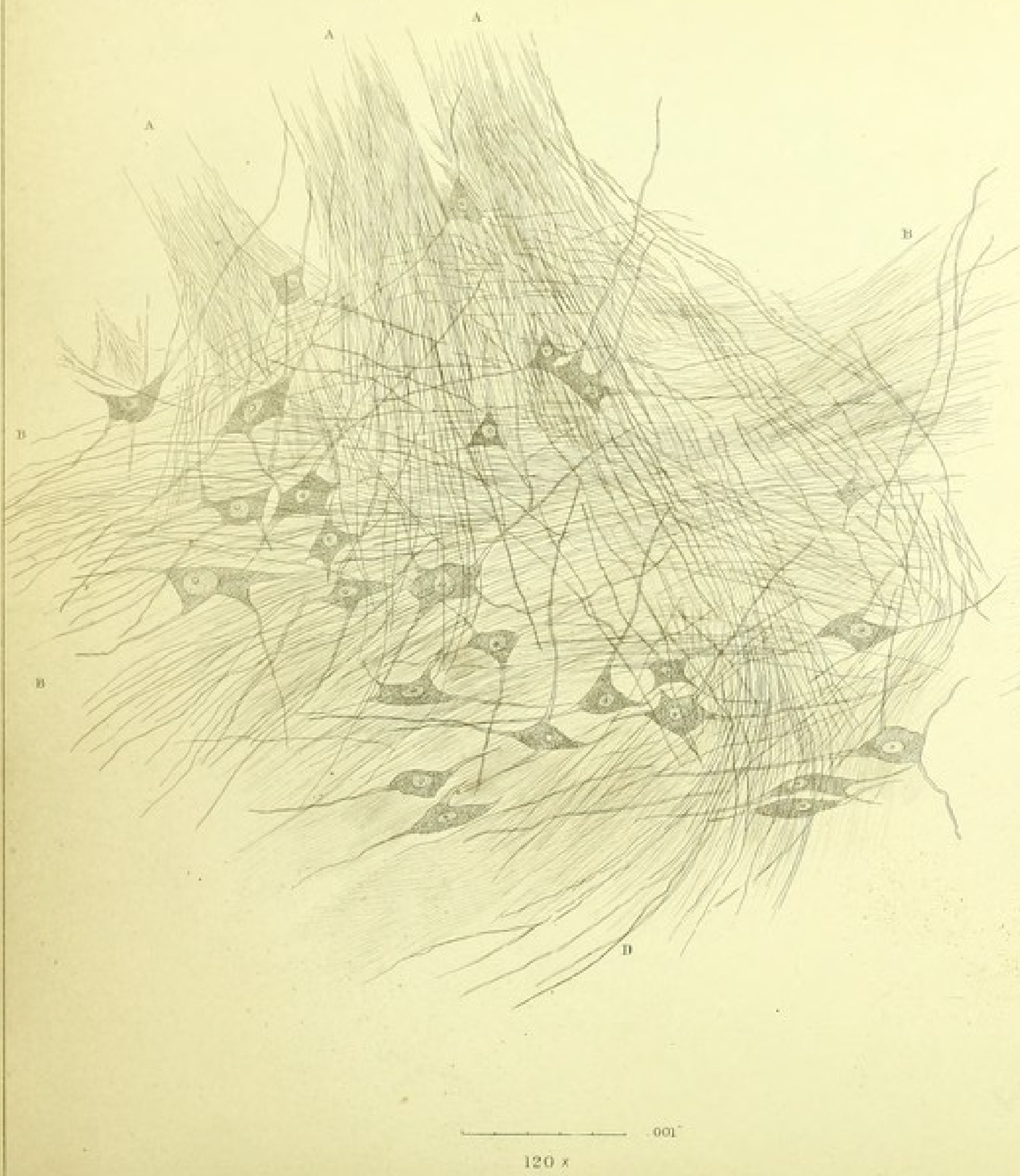


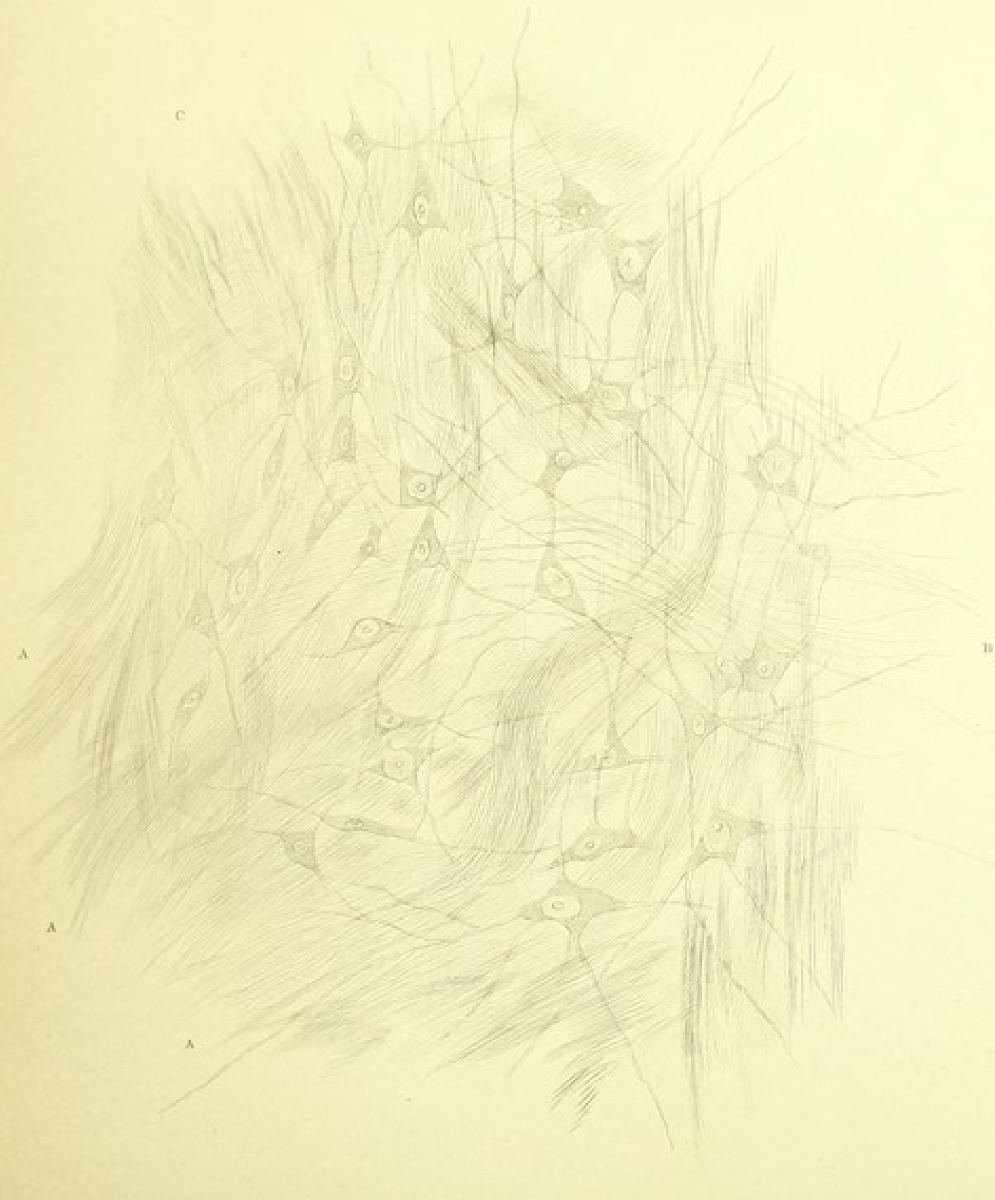
Fig 38

Fig 39.

Fig. 40.

Plate XII.

Fig. 41.



120 ×

Fig. 43. 120 ×.

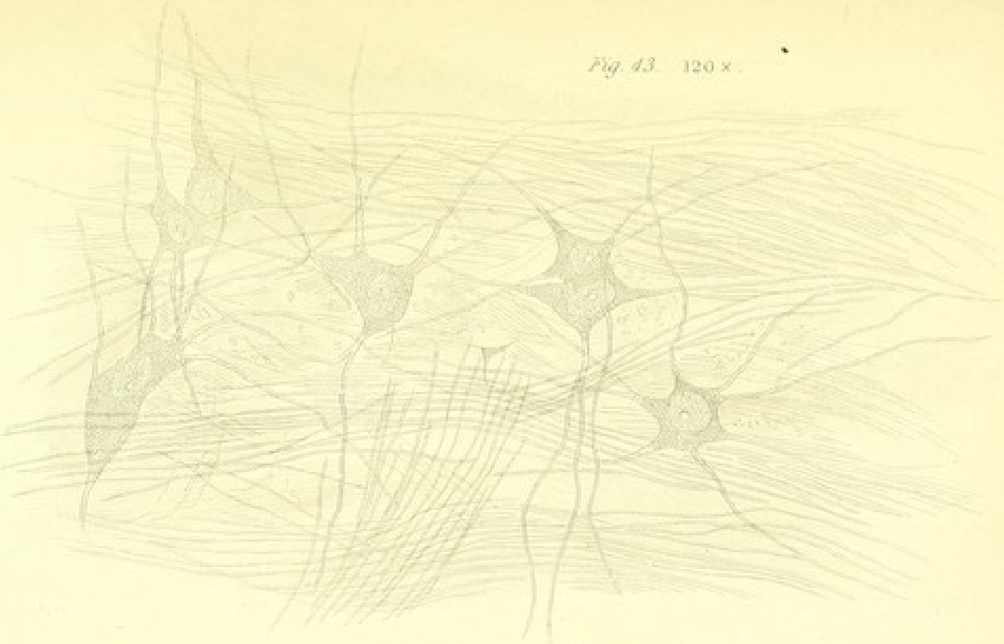


Fig. 42.

20 ×

Fig. 1a

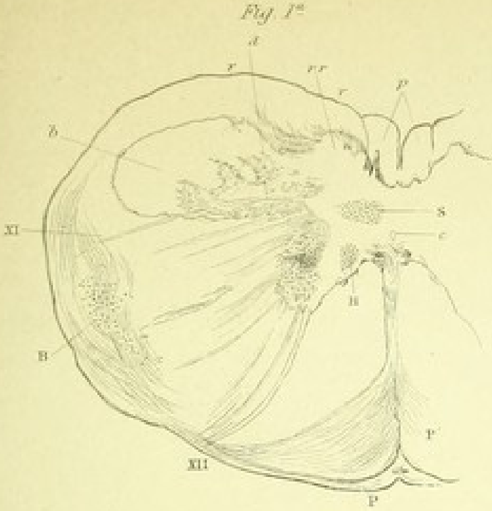


Fig. 4a

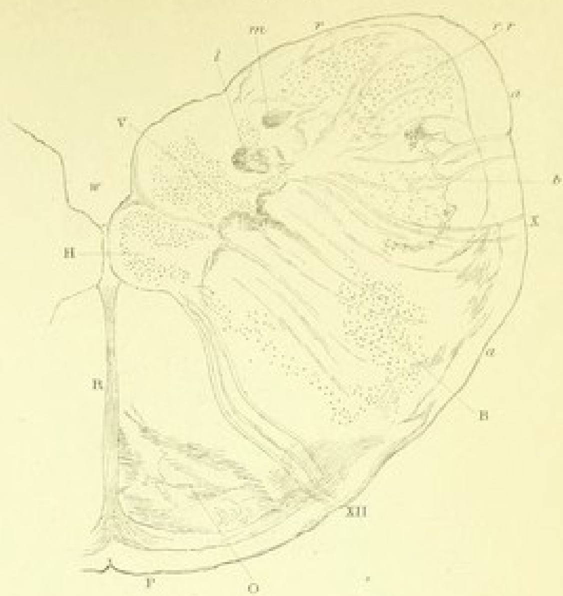


Fig. 2a

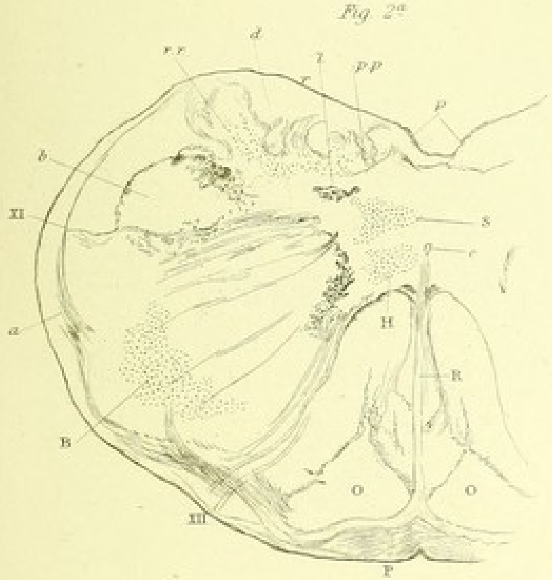


Fig. 6a

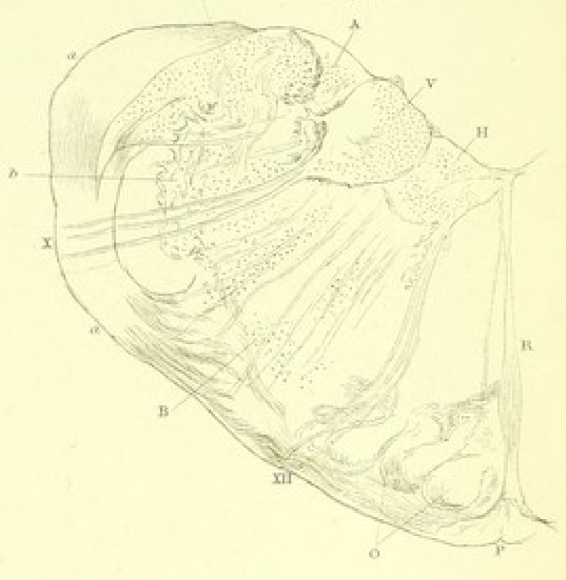


Fig. 3a

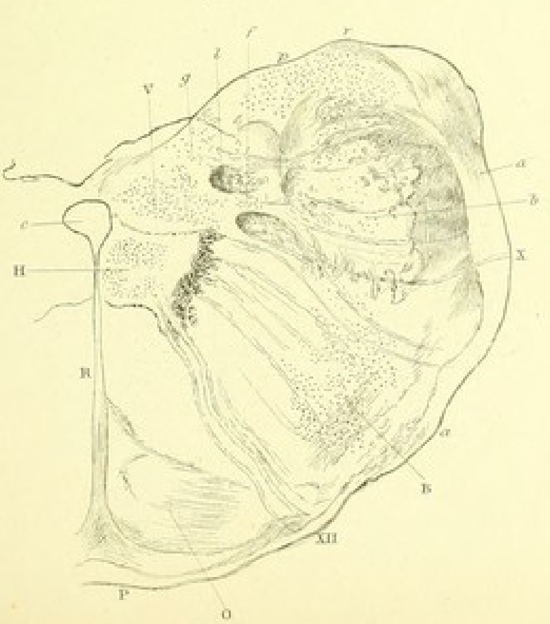


Fig. 7a

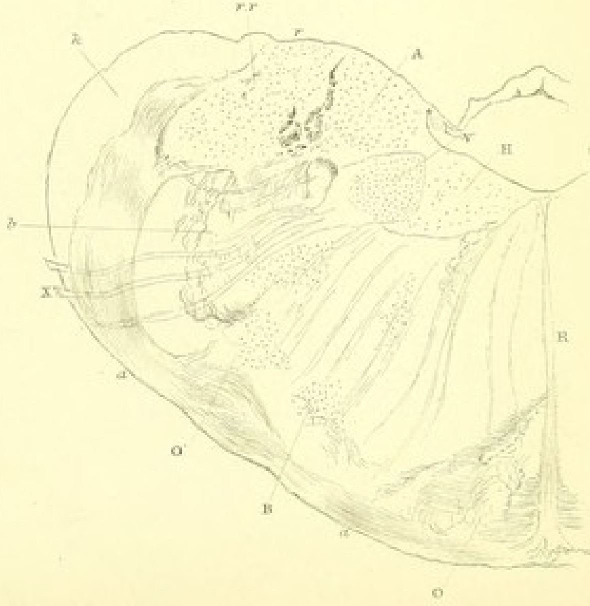


Fig. 8a

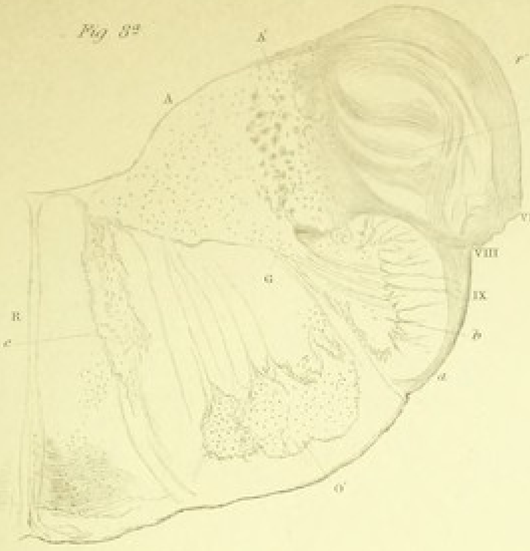


Fig. 9a

Fig. 10a

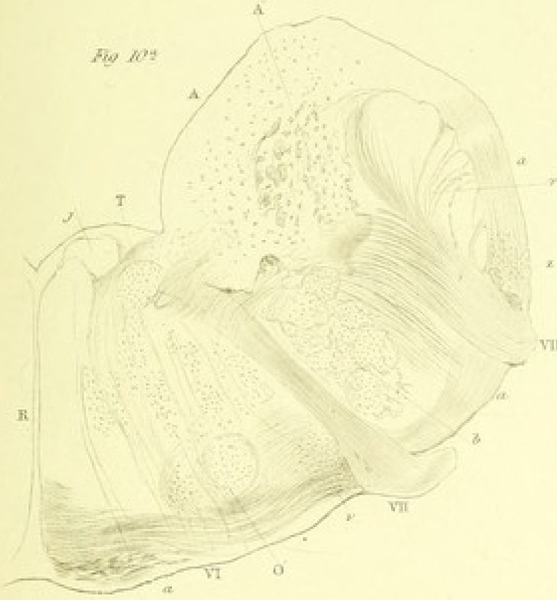


Fig. 16a

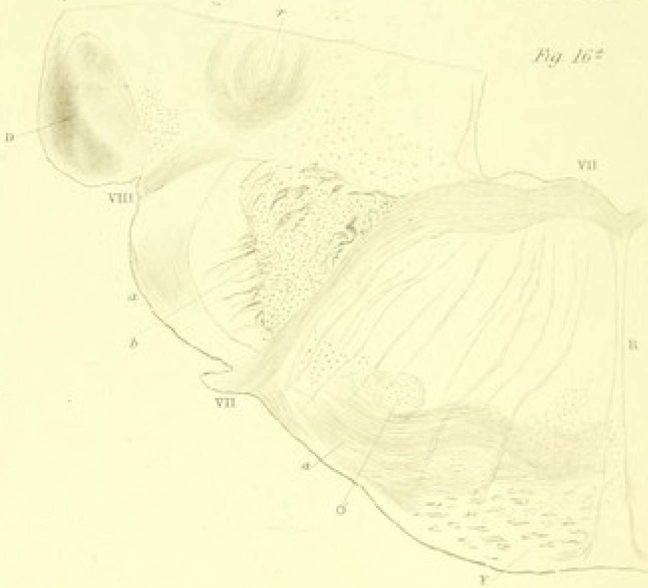


Fig. 17a

Fig. 18a

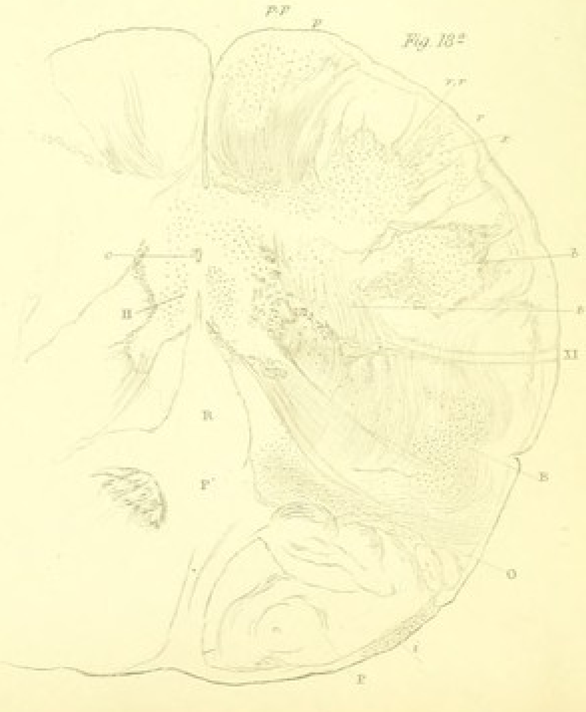


Fig. 19a

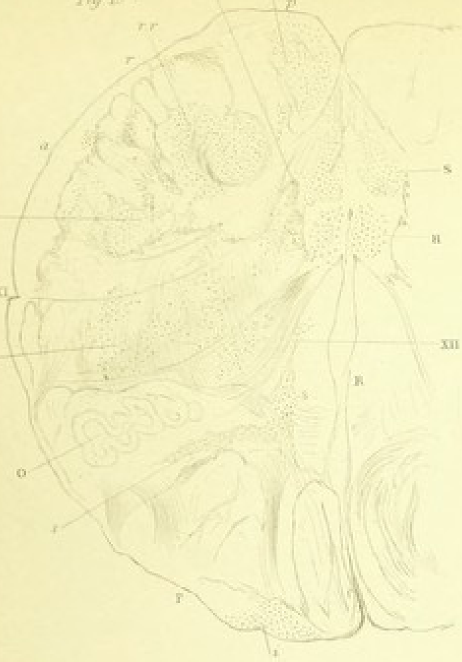


Fig. 20a

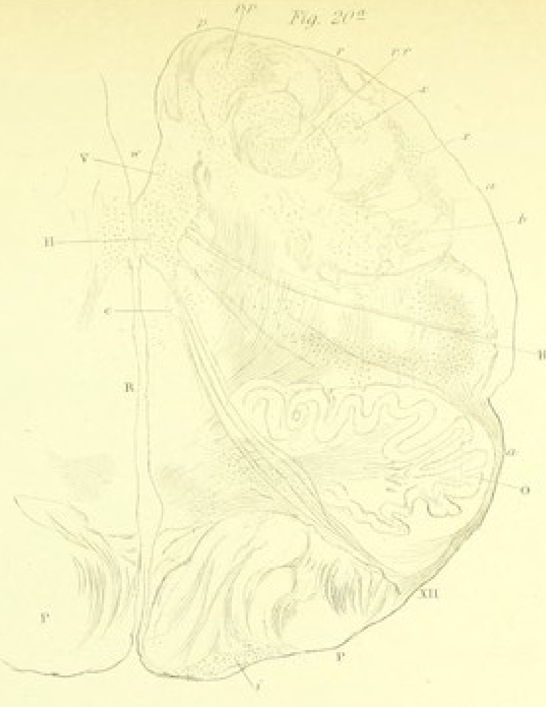


Fig. 21a

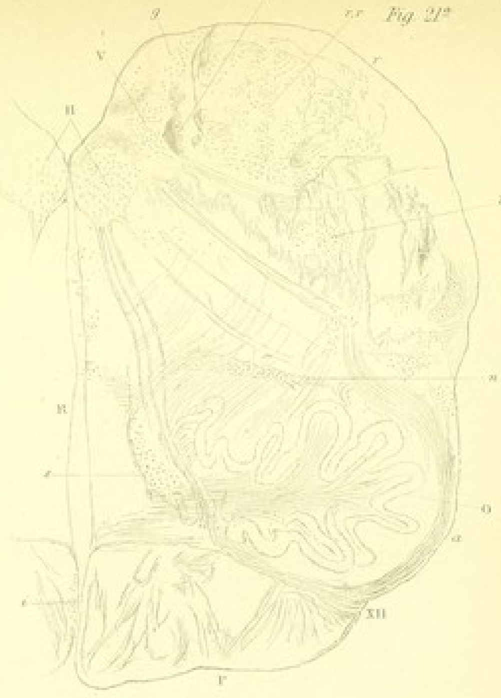


Fig. 22a

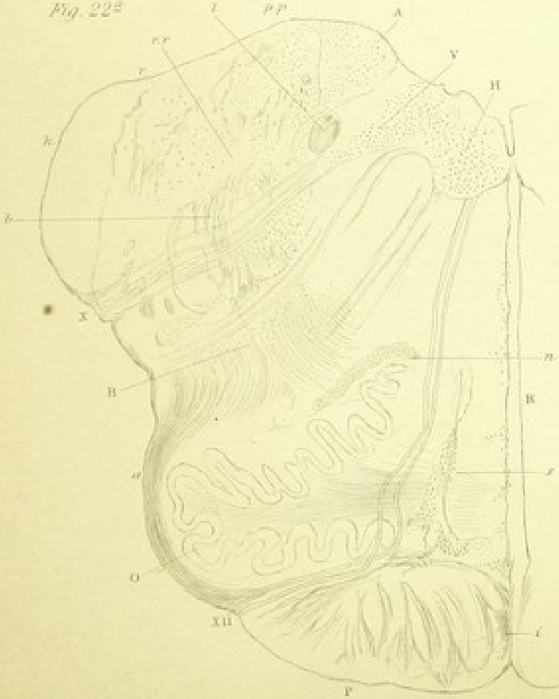


Fig. 23a

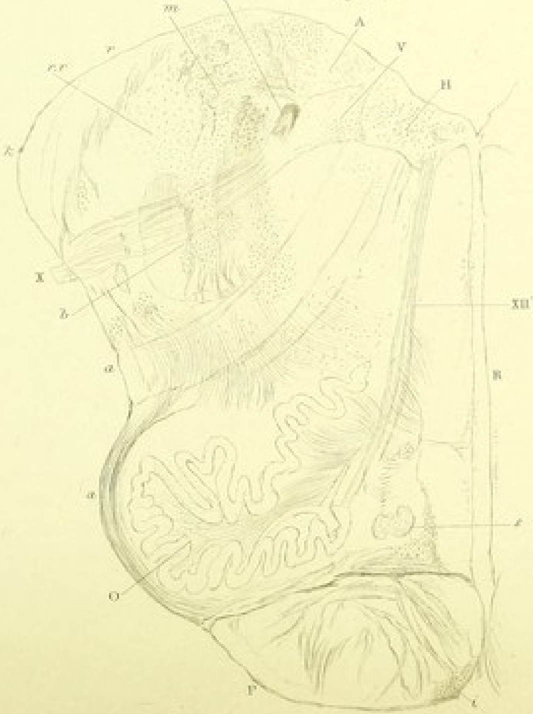
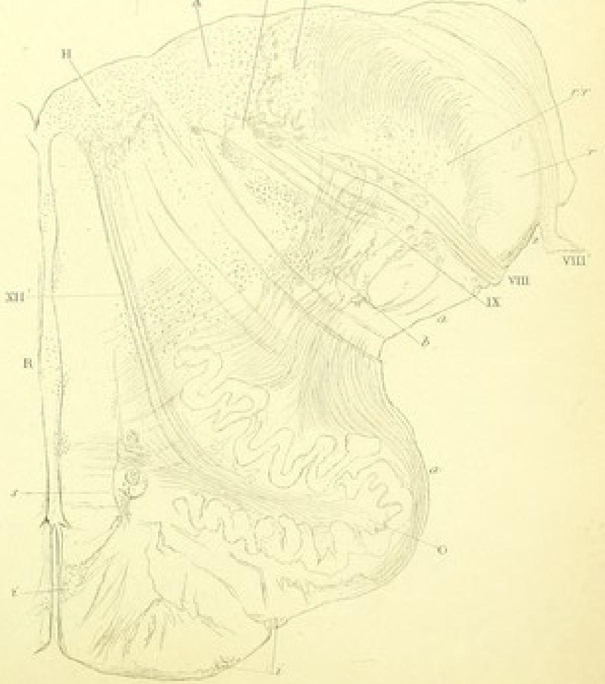


Fig. 24a



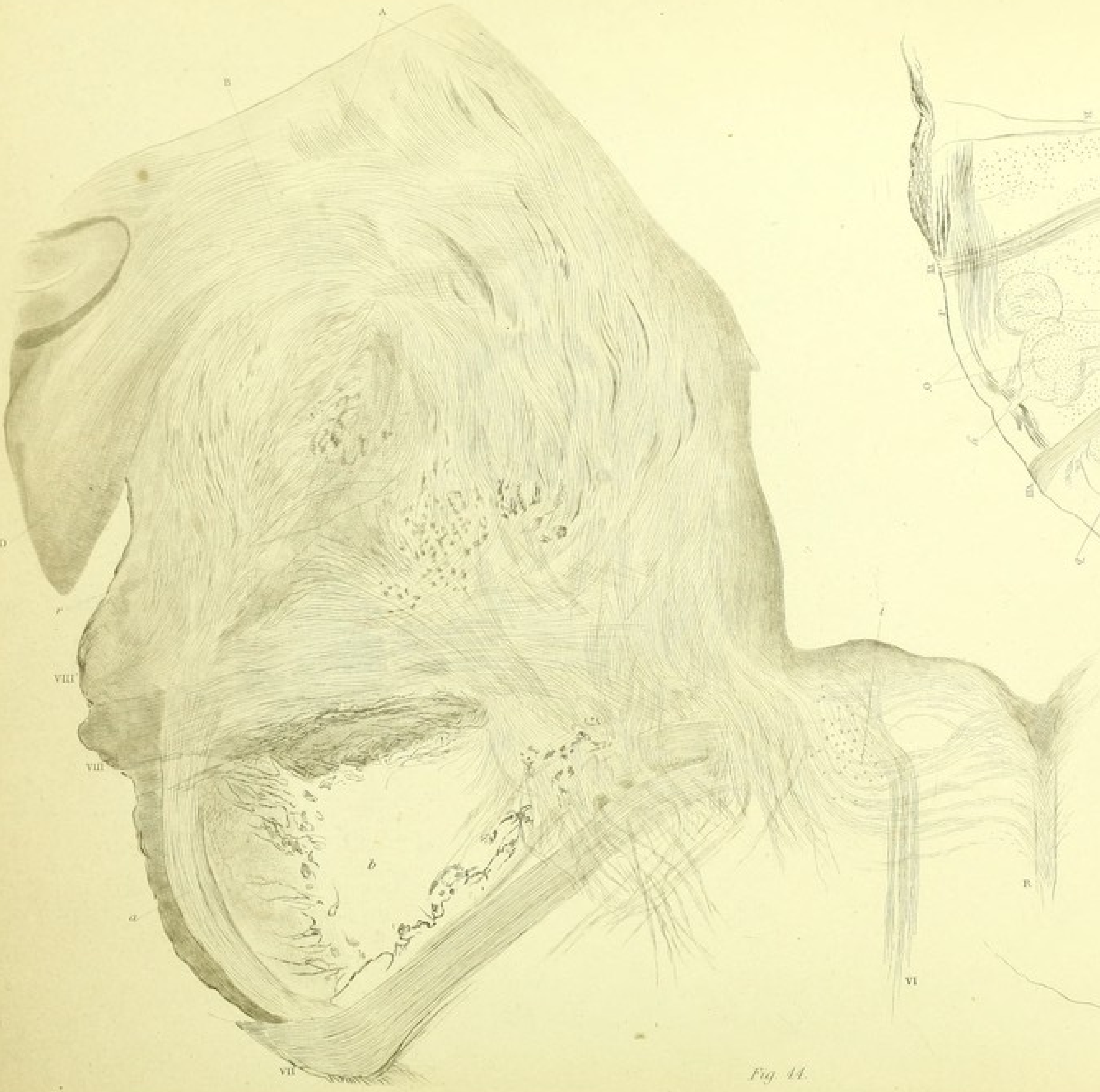


Fig. 14.

Fig. 12a

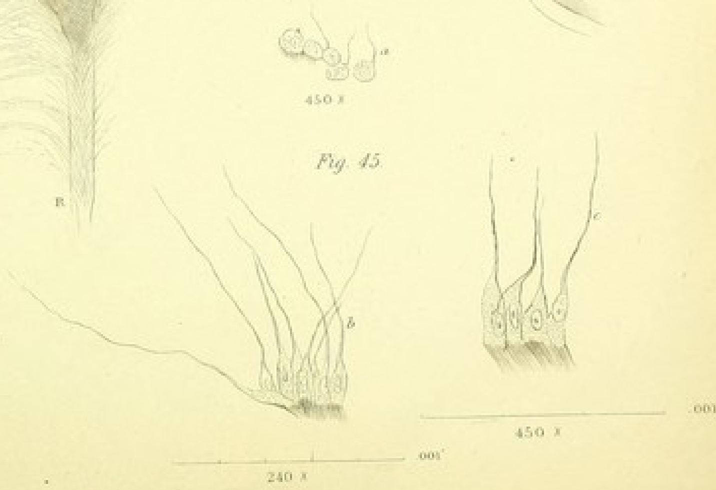


Fig. 45.