An atlas of the medulla and midbrain / Edited by H.McE.K.

Contributors

Sabin, Florence Rena, 1871-1953.
Knower, Henry McE.
University College, London. Library Services

Publication/Creation

Altimore, 1901.

Persistent URL

https://wellcomecollection.org/works/bs7a6she

Provider

University College London

Presented to the Library by
Dr. Gordon Holmes.

Sabin Florence R (1900) Bull. Johns Hopk
Hosp. Rep. IX: 925

2
Nat Hosp

A MODEL OF THE MEDULLA OBLONGATA, PONS AND MIDBRAIN OF A NEW-BORN BABE.

BY FLORENCE R. SABIN.

OUTLINE.

I. Introduction.

II. Description.

PART I.

The Long Tracts.

1. The Central Fibre Mass.
    - *A.* Distal subdivision of the central fibre mass.
    - *B.* Proximal subdivision of the central fibre mass.
        - (*a*) Ventral portion.
        - (*b*) Dorsal portion.
        - (*c*) Middle portion.
    - *C.* Relation of the central fibre mass to serial sections and to other structures in the model.
2. The Funiculi of the Spinal Cord.
    - *A.* Funiculi ventrolateralis.
        - (*a*) Pars ventralis.
        - (*b*) Pars dorsalis.
    - *B.* Funiculus dorsalis.
3. Corpus Restiforme.
4. Brachium Conjunctivum.

PART II.

The Cerebral Nerves and their Nuclei.

1. The Median Group.
    - (*a*) N. hypoglossus.
    - (*b*) N. abducens.
    - (*c*) N. trochlearis.
    - (*d*) N. oculomotorius.
2. The Lateral Group.
    - *A.* Motor nerves.
        - (*a*) N. accessorius.
        - (*b*) N. glossopharyngeus et N. vagus.
        - (*c*) N. facialis.
        - (*d*) N. trigeminus.
    - *B.* Sensory nerves.
        - (*a*) N. glossopharyngeus et N. vagus.
        - (*b*) N. trigeminus.
        - (*c*) N. vestibuli.
        - (*d*) N. cochleæ.

PART III.

The Nucleus Olivaris Inferior and the Accessory Olivary Nuclei.

PART IV.

THE MIDBRAIN.

1. Relation of its Structures to the Central Fibre Mass.
2. The Nucleus Ruber and its Capsule
3. The Fasciculus Retroflexus (Meynerti).
4. The Decussatio Tegmenti Dorsalis (Meynerti).
5. The Decussatio Tegmenti Ventralis of Forel.
6. Stratum Album Profundum.
7. Substantia Centralis Grisea.
8. Substantia Nigra.

PART V.

THE FORMATIO RETICULARIS ALBA AND GRISEA.

III.—CONCLUSION.

I. INTRODUCTION.

At the suggestion of Dr. Franklin P. Mall and Dr. Lewellys F. Barker, I have undertaken a study of the medulla, pons and midbrain of the new-born babe, by the wax-plate method of Born. This method has already been used by many observers in the fields of embryology and comparative anatomy, but, as far as I am aware, no one, except His, has employed it in the study of the central nervous system. The models of His represent the development of the external form of the neural tube and the positions of the cerebral nerves. In the present work, the representation of external form has been wholly secondary, the aim having been to show the form of the internal structures, namely, of the nuclei, the nerves and the central tracts. The great work of His must form the basis of any study dealing with the development of the nervous system, and the conclusions of this paper are, in the main, in accord with his views. The model constructed by Edinger, which has been of marked help to teachers and students of neurology, gives the general position of the different structures, but does not attempt to illustrate their form.[1]

Material.—This model has been made from a series of horizontal sections passing through the medulla, pons and midbrain of a new-born babe. A second set of sections cut transversely, and representing almost the same stage of medullation, has been used as a check upon each point of the model. The specimens were prepared by Dr. John Hewetson in the Anatomical Laboratory of the Uni-

---

[1] Edinger, L. Modell des oberen Rückenmarksteiles und der Oblongata. Anat. Anz., Jena, Bd. VIII, 1893, S. 172-175.

versity of Leipzig. The material was preserved in Müller's fluid and the sections stained by the Weigert-Pal method. The sections were cut at 70 μ. Each brain was made to give two separate series by mounting alternate sections; therefore, in building the model, each section represents two, or 140 μ, instead of 70. The material was embedded in celloidin. The sections were numbered serially and care was taken not to invert any of them. No record was made, however, of the right and left sides of the original medulla. For building the model, the horizontal series was preferable to the transverse; first, because the sections were larger and fewer (108 instead of 221); and secondly, because there was less danger of distortion, for a majority of the fibre-bundles of the model run longitudinally, and hence it often happens that the entire course of a bundle may be seen in one longitudinal section while the same bundle may extend through from 50 to 60 of the transverse series.

Method.—The method of Born for making wax models from serial sections is as follows: It is necessary (1) to have an accurate drawing of each section magnified to a certain degree, (2) to transfer the drawing to a wax plate (care being taken to magnify the thickness of the section in the same proportion as the length and breadth), (3) to cut each structure from the plates, (4) to pile each so as to show its own form and its relations to all other structures and (5) to fuse the pieces of each structure into a unit. The magnification decided upon, namely, 14.5, was merely one of convenience; in the first place it gave a wax plate of 2 mm. thickness, which was easy to work with, and, secondly, made a model of convenient size.

To make the drawings, it is the custom of the laboratory to use a Zeiss projection apparatus and electric lamp. The light passes through a condenser and lens and the image is received on a movable though firm screen. In adjusting the apparatus certain points are to be noted: (1) the screen and the slide upon which the section is mounted must be kept parallel to each other and perpendicular to the ray of light passing the centre of the section; (2) each section must be placed in the same relative position to the light and screen in order that none of the drawings be reversed; (3) it is necessary to focus for the centre of the section and to test the magnification each time the apparatus is used; (4) the micrometer slide used for this test must be placed with the ruled side next the cover-slip to bring the lines and section into focus at the same time; (5) the checking must be done on the paper which is to receive the drawings.

The drawings thus obtained are merely outlines. In making them two points are essential—accuracy and definiteness. This is easy to accomplish in the case of a bundle of black fibres placed against a light background, but many of the structures are by nature indefinite. For example, it will be seen in Fig. 6 that the nuclei of the vestibular nerve fade gradually into the gray masses about the central canal. To limit the error as much as possible the following precautions were taken: (1) each section was studied with a dissecting microscope and a Leitz Obj. 3. before making the drawings, (2) each line of the drawings was controlled with the microscope, and (3) all of the masses outlined were measured and compared with the corresponding structures in the transverse series.

After clear and definite outline drawings had been obtained, an elaborate color system was devised, so that each structure in the series could be indicated by its own shade. Such a system is essential in reconstructing so complex a structure. After all controls had been made the drawings were transferred to the wax plates.

The wax plates are made in the anatomical laboratory in a large pan 90 cm. wide by 120 cm. long. The mass employed consists of ordinary beeswax mixed with $\frac{1}{19}$ of its weight of resin. The melted wax is then poured through a strainer into a tarred receptacle on a balance, the weight of wax necessary for one plate of 2 mm. thickness being in turn poured into the large pan which is half full of hot water. The wax spreads evenly over the surface of the water, any bubbles being removed by means of a strong gas flame. When the wax has solidified enough to be firm, yet not brittle, the plate is removed from the pan and laid on a level surface so that the edges will not curl. Every fifth plate is made black by mixing soot with the melted wax. This is of much help, for it is then easy to determine quickly the number of any plate in the model.

The drawings were transferred to the wax plates by means of carbon tracing paper, and were colored with oil paints. Each section was then cut from its plate. The cutting is made easy by placing the slightly warmed wax plate on a sheet of glass and following the outlines of the section with a thin, narrow-bladed knife.

Each plate gives two parts, one corresponding to the section itself, and the other to the shell. These two parts, numbered to correspond, were placed in two separate piles. Since, unfortunately, no pictures of the original medulla from which the sections were cut were available, the parts corresponding to the sections were piled repeatedly until the external form of a babe's medulla was reproduced. The shells were then piled to correspond and a plaster cast of the cavity thus made gave the external form of the medulla to be modeled. On the plaster cast the markings corresponding to the edges of the individual wax plates were visible so that it was an efficient control for later work.

Inasmuch as the whole of the ventral portion of the sections was made up of non-medullated fibres, this portion of the cast was duplicated and used as a pedestal upon which to support the model. This pedestal is of interest, inasmuch as it contains the pyramidal tract except at the extreme spinal end of the model. The position of the pyramidal tract can be imagined in connection with Plate I; starting at the cerebral end of the model, the tract lies first ventro-lateral to the substantia nigra; it then plunges into the pars basilaris pontis, and enters the ventral border of the medulla where its decussation can be related by the distal border of the olive.

In building the model I made use of two main guides—(1) the external form and (2) the median longitudinal plane. By a study of the series it was found that, at a certain level, the medial lemniscus ran through the entire length of a section, and could be related, therefore, both to the external form and to the median plane. With this in view, the section No. 122, shown in Fig. 16, was chosen as a starting-point, and drawn upon the surface of a flat board. The median longitudinal axis of the section was drawn as a guide. From the wax plate corresponding to this section the medial lemniscus was cut and secured in position on the drawing on the board, thereby fixing its relations to the guiding lines, namely, the periphery and central axis. The medial lemniscus was then cut from each of the sections in series. To find the position of each successive piece of wax representing the medial lemniscus, it was necessary to determine the position of its plate. This was done by placing the plaster cast parallel with the section on the board and then examining the position of each plate on the cast with reference to the plate numbered 122. Measurements were made, especially from the ends of the sctions, and the median plane was kept true. By this comparison a wax plate could be held in proper position with reference to the board; it was then easy, on holding the plate a little higher, to sight through the space made by the removal of the bundle representing the medial lemniscus and adjust the piece of wax corresponding to it into place below. The position of each piece was checked also by measurements from various points on the sections. In this preliminary reconstruction, which may well be called the foundation of the model, the trapezoid body was included, inasmuch as it forms a cross-bar and, therefore, gave many points for control measurements.

Before fusing the pieces of this foundation, I used as a further check upon the piling the external form of the inferior olive, which is so complex that its parts must be piled accurately in order to fit at all. Moreover, since the olive makes a definite curve on the surface of the medulla oblongata, the shells left after cutting out the nucleus were piled with reference to this curve; the nucleus in turn was piled by measurements from the shells. The olive thus modeled was placed in position with reference to the medial lemniscus, and it was found that measurements taken from various points on the olive to the lemniscus agreed with the corresponding measurements on the sections. This confirmed the conviction that the latter had been piled correctly. A further check of the accuracy of the work was found by comparing the dorsal border of the lemniscus in the model with the same border, as seen in a sagittal section of the medulla oblongata. Having made sure of the accuracy of the piling of the foundation, its parts were fused by means of a hot iron, strengthened by buried wires and fastened securely to the pedestal.

With the help of this foundation, all the structures of the model were piled. Each bundle was taken up separately, its parts cut from the plates, piled and fused into a unit. At the end, the entire model was found to fit, which was a further test of the accuracy of the work.

The value of such a model lies in its illustration of spatial relations and the suggestions which these give with regard to the course of the development. It is necessary to point out certain limitations of the method. First, in making the model, fibres were grouped together according to their function. The bundles thus made have very different values, some consisting of many fibres closely packed, others of few and scattered fibres. This is well illustrated in the case of the root of the N. facialis, in which the pars prima makes a much larger bundle than the pars secunda, though it contains the same number of fibres. The size of the bundle, then, is no indication of the number of the fibres, and such details must be studied on the sections themselves. Secondly, in several instances, a bundle of fibres passes directly through another bundle or through a nucleus. In such cases some sacrifice had to be made, but the rule has been to give enough of each bundle to show its direction and extent.

The treatment of the formatio reticularis deserves special mention. As has been said, in order to model a bundle, it must be possible to give it a definite outline. Though this was impossible in the case of the formatio reticularis, in building the model it became clear that the area as a whole was fairly definitely bounded by other structures and could, therefore, be represented as a space. Moreover, though most of the fibres of the formatio reticularis alba are diffusely distributed, some of them make fairly definite bundles for a part of their course. The gray matter, or formatio reticularis grisea, likewise has a few groups of cells definite enough to be represented by their boundaries.

Though, as has been said, a complex color system was necessary in building the model, in presenting it as a finished structure the color system has been made simple. All the fibres are shown in white and black, the nuclei of the gray substance in colors. Of these but three have been used—red for the motor nuclei, blue for the sensory and yellow for all other nuclei. In describing the model, the words proximal and distal have been used, proximal meaning toward the cerebrum, and distal away from it.

No review of the literature has been given, inasmuch as the ground has been so ably covered by Dr. Lewellys F. Barker, in his recent book. In the study of the sections I have been guided constantly by the works of Forel, von Monakow, Flechsig, v. Koelliker, His, Ramón y Cajal, v. Bechterew and Held. References to articles will be given in foot-notes.

It may be well to state at the outset wherein this work pre-

---

[1] Barker, L. F. The Nervous System and its Constituent Neurones. D. Appleton and Co., 1899.

sents new features. It is believed that here, for the first time, the form relations of the fibre-bundles and gray masses of the pons and medulla oblongata are shown in three dimensions. Certain observers have given descriptions that permit most graphic mental pictures, but as far as I am aware no one has treated the subject as a whole from the point of view of form. In several instances weight has been added to previous discoveries by showing that they agree with the anatomical relations shown more clearly in the model than in sections. In the description of the model each point mentioned has been supported by both series of sections, and it may be well to state that no claim of originality is made in reference to determining the structures in the sections save in a few minor points which will receive especial mention.

II. DESCRIPTION OF THE MODEL.

The model as a whole will be most readily understood by a study of Plates I and II. Plate I is a view of the lateral surface in which the model is related to the spinal cord, the cerebellum and the third ventricle; Plate II is a view of the dorsal surface in which the fourth ventricle is the important guide. This model brings out the three dimensions—length, breadth and thickness of its component parts—hence, in a description, there will be a definite advantage in following the course of its construction, which was to make the central fibre mass the skeleton of the model and to relate all other structures to it. Since the region has been studied only by means of sections, the central fibre mass has been considered in its parts—the medial, lateral, superior, lemnisci, etc.—and not as a structural unit. The description will be divided into five parts: (1) the long fibre-tracts that relate the spinal cord with the higher centres; (2) the cerebral nerves and their nuclei; (3) the nucleus olivaris inferior; (4) the midbrain and (5) the formatio reticularis.

PART I.

THE LONG FIBRE TRACTS.

1.—The Central Fibre Mass.

The central fibre mass is shown best in Plate VI. For convenience it may be considered divided into two parts, a distal and a proximal, by a cross-bar of fibres, namely, the corpus trapezoideum. These two parts show a marked contrast both in form and in position.

The distal part consists of a thin sheet of fibres extending the whole length of the medulla, and reaching almost from the dorsal to the ventral surface (Plate V). It lies close to the middle line in a plane parallel to the raphe (Plate II). This "medulla sheet," as I have named it, shows almost no evidence of being composed of different groups of fibres.

The proximal part, on the other hand, is clearly divided into three systems, the fibres of which spread so as to occupy the entire region between the raphe and the lateral surface of the pars dorsalis pontis and tegmentum. Only the ventral portion shows in Plate VI (Lemniscus medialis), while the dorsal and medial parts are seen in Plates IV and VII (Fasciculus longitudinalis medialis and Formatio reticularis).

A.—THE DISTAL SUBDIVISION OF THE CENTRAL FIBRE MASS, OR "MEDULLA SHEET."

The "medulla sheet" is irregularly quadrilateral in shape. The dorsal, ventral and distal edges are free, while the proximal edge is an imaginary line corresponding to the position of the radix N. abducentis (Plate V). The ventral edge is parallel with the long axis of the medulla; the distal and dorsal edges make a curve which follows the central canal and the floor of the fourth ventricle. On the dorsal border is a secondary curve corresponding to the position of the nucleus N. hypoglossi.

At the distal ventral angle is a projection in the form of a trough which corresponds to the ventral funiculi of the spinal cord. The trough makes a slight angle with the distal edge of the medulla sheet. It is deep in the part directed toward the spinal cord, but as it approaches the medulla oblongata it grows more shallow until it finally opens out onto the flat surface of the sheet.

The medulla sheet is of nearly uniform thickness, except at the ventral edge where the fibres are more scattered. The lateral surface of the sheet is comparatively flat; in the ventral portion, however, the ends are curved, which will be understood by comparison with Sec. 146, Fig. 20 (S. i. l.). The section shows that the trough (F. l.) lies lateral from the main sheet owing to the position of the decussatio pyramidum, and that this accounts for the distal curve. The proximal curve is due to the fact that the fibres curve lateralward just as they enter the corpus trapezoideum.

Proximal to the opening of the trough, near the ventral edge of the medulla sheet is a deep depression; dorsal to it is a second smaller depression which lies near the middle of the distal border of the sheet. Both of these correspond to the position of portions of the nucleus olivaris accessorius medialis. The two spaces left in the sheet correspond to nuclei; the smaller one (.89x.41 mm.) represents the so-called accessory nucleus of Roller, while the larger (3.7 x 1.5 mm.) corresponds to the nucleus centralis inferior of the formatio reticularis grisea.

The mesial surface of the medulla sheet is level and shows well in Plate VI.

B.—PROXIMAL SUBDIVISION OF THE CENTRAL FIBRE MASS.

It has been said that the fibres of the proximal segment scatter and are divided into three groups; (1) a ventral, (2) a dorsal and (3) a middle portion. The ventral group, which includes all the fibres that run through the cross-bar, is in contrast with the "medulla sheet," for instead of being spread out in a vertical direction, the mass rotates so that the sheet comes to lie horizontally (Plate VI). The border of this sheet lies far out on the lateral surface of the pons. At the junction with the midbrain the mass again rotates so that it once more assumes almost a vertical (*i. e.*, dorso-ventral) direction (Plates I and IV).

The dorsal portion of the proximal segment continues upward in a line with the direction of the medulla sheet (Plates IV and V, Fasciculus longitudinalis medialis). In passing through the pons it is practically level, while just beyond it turns ventralward, taking part in the midbrain curve (Plate VII).

The middle portion can be related as follows: while the ventral fibres make a floor, as it were, at the junction of the pars dorsalis with the pars ventralis pontis, the dorsal fibres remain close to the median line, and into the area thus left between these two fibre masses the middle fibres spread out (Plates V, VI and VII, Formatio reticularis alba).

It is now necessary to describe the various portions of the proximal subdivision of the central fibre mass more in detail. It will be most convenient in this description to follow (*a*) the ventral portion, (*b*) the dorsal portion, and (*c*) the middle portion separately through the pons and midbrain.

(*a*) *The Ventral Portion of the Proximal Subdivision of the Central Fibre Mass* (*Lemniscus lateralis*, *Lemniscus medialis and Lemniscus superior*).—The ventral fibres of the proximal subdivision of the central fibre mass make (1) the horizontal pontal sheet and (2) the vertical midbrain sheet. In entering the pons the ventral fibres of the medulla sheet curve rapidly dorsalward, so that they all pass through the cross-bar (Plate V). As the mass of fibres leaves the cross-bar, it spreads out into " the horizontal pontal sheet " (Plates V and VI). The lateral portion of this horizontal sheet consists of a new mass of fibres which does not exist in the medulla sheet, but is added on in passing through the cross-bar. It forms a part of the pontal sheet for a short distance only, inasmuch as it inclines rapidly dorsalward in order to reach the nucleus colliculi inferioris in which a large part of it disappears (Plate I). The space shown in the model between the lemniscus lateralis and the pontal sheet is occupied at this stage of development by indifferent substance.

The pontal sheet is best seen from its dorsomesial aspect (Plate V). The mesial edge is clearly defined. The sheet is comparatively thick as it emerges from the trapezoid body, but it grows thinner as it approaches the midbrain. The dorsal surface is level within the pons but curves ventralward in approaching the midbrain, while the ventral surface shows an anteroposterior curve in crossing the pons (Plate I). The fibres of the medial third of the sheet, its thinnest portion, are cut off abruptly in the model as they are entering the midbrain in order to accommodate the radix N. oculomotorii. In reality they pass toward the nucleus ruber and appear to form a part of its capsule (Plate VI).

The lateral portion of the pontal sheet contains the bulk of its fibres. They make a definite bundle which runs through the midbrain sheet at approximately the same level as in the pontal sheet. This bundle shows a cut edge at the proximal end of the midbrain sheet to signify that it passes onward beyond the limits of the model (Plates I and IV). It is the lemniscus medialis on its way to the diencephalon.

Having thus outlined the pontal sheet by itself, its form will be best understood in connection with the midbrain sheet. From the lateral view it will be seen that as the pontal sheet approaches the midbrain, it spreads out into a fan which is placed obliquely in a dorsoventral plane (Plate IV). The gradual rotation by which the horizontal pontal sheet becomes this obliquely vertical midbrain sheet is best seen from the mesial view (Plate VI). The medial lemniscus runs in the centre of this fan and determines its shape. This can be seen in Sec. 122, Fig. 16, for the section passes through the central bundle and shows that in crossing the pons its fibres slant lateralward, while at the beginning of the midbrain they turn and run more nearly parallel to the central axis. Proximal to the slight angle thus formed, the lateral border of the bundle is curved, owing to the position of the substantia nigra.

From the lateral view it may be seen that the midbrain sheet, ventral to the medial lemniscus, is flat and lies more obliquely across the midbrain (Plate IV). It receives its fibres from the mesial part of the pontal sheet, and enters into the formation of the capsule of the nucleus ruber. One further point should be mentioned in connection with the view of the lateral surface of the model, namely, that just as the lemniscus medialis enters the midbrain, it gives off from its ventrolateral portion a small bundle which enters the substantia nigra (Plate IV, M. l. to Sn.).

Having outlined the central bundle of the midbrain sheet, *i. e.* the lemniscus medialis, and the fibres ventral to it, namely, the lateral capsule of the nucleus ruber, the dorsal segment of the sheet may next be considered. This is the so-called lemniscus superior, or *obere Schleife,* of the Germans (Plates I and IV). In contrast with the central bundle, this dorsal portion has a flat surface. It has been seen that the fibres ventral to the medial lemniscus were derived from the mesial portion of the pontal sheet; the dorsal fibres, on the other hand, are related to its lateral border (Plate IV).

The lemniscus superior lies near the lateral surface of the midbrain (Fig. 13). The lines in the model show that its fibres are inclined dorsalward. The shape of the bundle in the model is that of a triangle with its apex at the point where the lemniscus lateralis separates from the lemniscus medialis and its base in a dorsoventral line near the upper end of the model. The base is a curved line which indicates that, unlike the lemniscus medialis, the fibres of the superior lemniscus end within the limits of the model (Plate I). The ventral side of the triangle lies adjacent to the medial lemniscus; the dorsal side has in part a free border, but near the base of the triangle the lemniscus superior fuses with the lemniscus lateralis. At the point of fusion, the lemniscus lateralis is hollowed out so as to form a capsule for the nucleus colliculi inferioris (Plates VI and VII).

The description of the ventral portion of the central fibre mass is now complete. Its most important element is the medial lemniscus, which enters into the formation of three great sheets—a medial, vertical sheet in the medulla; a horizontal sheet in the pons; and a lateral obliquely vertical sheet in the midbrain.

The pontal sheet includes another group of fibres, the lemniscus lateralis, while the midbrain sheet contains the superior lemniscus and the lateral capsule of the nucleus ruber.

(*b*) *The Dorsal Portion of the Proximal Subdivision of the Central Fibre Mass* (*Fasciculus longitudinalis medialis*).—The next bundle under consideration is the fasciculus longitudinalis medialis, which forms the dorsal part of the proximal subdivision of the central fibre mass, that is, the continuation of the dorsal part of the medulla sheet (Plates IV and VII). As has been said, this portion follows the course of the central canal. It passes through the pons at the same level as in the medulla, and then turns ventralward to conform with the midbrain curve.

In the model of the medulla sheet, a space left for a nucleus of the formatio reticularis is the only indication that the sheet is made of different parts. (Plate VII, Nu. centralis inferior. This space is not labeled in the plate, but lies just ventral to the nucleus N. abducentis). The fibres dorsal to this space become a separate bundle in crossing the pons. This is clear in sections where the coarse black fibres of the fasciculus longitudinalis medialis contrast with the delicate fibres of the formatio reticularis just ventral

(Fig. 40). The fibres of the radix N. abducentis pass directly through the edge of this dorsal bundle, and just proximal to this nerve the bundle flattens out and becomes triangular in cross section. At the beginning of the midbrain the bundles of the two sides broaden, and, at the same time, form a trough (Plate III). The centre of this trough is deep and its floor is made, not of decussating fibres, but of longitudinal fibres running in the middle line (Fig. 18). The sides of the trough show shallow depressions, three on the right side and two on the left. They represent the position of the nuclei of the oculomotor and trochlear nerves (Plate VII). Beyond these depressions is a space left in the wall for the exit of the main mass of fibres of the root of the oculomotor nerve (Plate VII). This space is artificial, the wall being in reality almost continuous. Just proximal and lateral from this space is a long groove which opens out into the proximal capsule of the nucleus ruber. This part of the capsule is a sheet of fibres placed dorsoventrally across the midbrain. The groove contains the nucleus of Darkschewitsch and marks the junction of three different fibre masses, viz., (1) the fasciculus longitudinalis medialis, (2) the posterior commissure and (3)the capsule of the nucleus ruber. These relations will be more fully considered in connection with the description of the midbrain. To return to the fasciculus longitudinalis medialis, the sides of the trough formed by the bundles of the two sides come into relation, in the model, with a large hollow shell which occupies the centre of the dorsal part of the midbrain. This shell is the stratum album profundum.

The dorsal bundles of the two sides making up the fasciculi longitudinales mediales occupy the dorsal part of the medulla sheets, where they form two dense bands on either side of the raphe. In the pons each band becomes broader, and in the midbrain the bundles of the two sides unite to form a deep trough. As a whole, each bundle is characterized by two curves, one in the medulla, the other in the midbrain. It is related to four nuclei, namely, the nuclei of the N. hypoglossus, N. abducens, N. trochlearis and N. oculomotorius. At the distal extremity of the medulla oblongata it is connected with the ventrolateral funiculi of the spinal cord, while at the proximal limit of the model it is related, at least in position, to three structures—a nucleus, a decussating bundle and a nuclear capsule.

(*c*) *The Middle Portion of the Proximal Subdivision of the Central Fibre Mass* (*Formatio reticularis alba*).—By reviewing the shape of the two great fibre masses just described, the ventral, with its tendency to form sheets, and the dorsal compact bundle following the course of the central canal, a good idea of the area left between them can be obtained. Into this area, dorsal to the pontal sheet and medial to the midbrain sheet, the fibres of the middle portion of the proximal subdivision spread out (Plates V, VI and VII). The area left for a nucleus in the proximal border of the medulla sheet lies in the course of this fibre mass and appears both to receive and to give rise to its fibres (Plate VI). Just proximal to this nucleus, the fibres of the middle portion turn slightly lateralward and spread out into the pars dorsalis pontis and the tegmentum of the midbrain. The part of the midbrain they enter is bounded laterally by the lemniscus superior, medially by the stratum album profundum, and ventrally by the capsule of the red nucleus (Plate VII). In the model, this middle mass of fibres had to be sacrificed somewhat on account of the representation of the brachium conjunctivum. The mass will be considered later in connection with the formatio reticularis as a whole, and was introduced here on account of its relations to the central fibre mass.

The general form of the central fibre mass of the model, with its contrasting distal and proximal parts, has now been outlined. The part distal to the cross-bar is a thin median sheet which extends in a dorsoventral plane parallel with the raphe, and shows but little evidence at this stage of development of being made up of different parts; the part proximal to the cross-bar is clearly made up of three different fibre masses which spread out to cover a wide area and show varied connections with other structures.

C.—RELATION OF THE CENTRAL FIBRE MASS TO THE SERIAL SECTIONS AND TO OTHER STRUCTURES IN THE MODEL.

The components of the central fibre mass must now be related to known bundles as seen in sections at different levels. The position of the sections with reference to the model can be estimated by the lines on Fig. 52. These lines are labeled with the series and section number, I standing for the horizontal series, and II for the transverse.

In a series of sections extending from Figs. 28-36, the main characteristics of the medulla sheet are well illustrated, (1) its median position, (2) the gradual increase in its dorsoventral diameter due to the cervical curve, (3) the lack of differentiation of its fibres, except in the last section which shows the middle fibres disappearing in a nucleus.

The ventral portion of the sheet will be recognized in the sections of the new-born child as the stratum interolivare lemnisci. In a section of adult tissue so many more fibres are crowded into this portion that it forms a triangle in cross-section, with the base against the pyramid.

The fibres of the stratum interolivare lemnisci, or ventral part of the medulla sheet, have been traced in the model from this sheet (1) through the corpus trapezoideum, (2) through the pontal sheet and (3) through the central part of the midbrain sheet. Here the lemniscus medialis, now deflected far to the side, lies lateral to the nucleus ruber. The model takes the bundle only as far as the hypothalmic region (Plate I).

Thus far I have not discussed the origin of these fibres. There are three groups of fibres to be considered with reference to the stratum interolivare lemnisci. (1) In Plate IV will be seen a small bundle of fibres connected with the lateral funiculus of the cord. It passes toward the middle line and appears to end blindly against the root of the hypoglossal nerve. In reality, its fibres pass on between the root bundles of the nerve adjacent to the stratum interolivare lemnisci. From the Weigert specimens alone I cannot say that these fibres enter the stratum interolivare lemnisci, but the model shows the possibility of an uncrossed path from the lateral funiculus of the cord to the main sensory path toward the cortex (Fig. 19). (2) By far the thickest bundles of fibres entering the lemniscus in the medulla are the bundles of internal arcuate fibres from the nucleus funiculi gracilis and the nucleus funiculi cuneati. These arcuates form two principal groups, one of which lies just distal to the root of the N. hypoglossus, while the other lies opposite the proximal third of the nucleus funiculi cuneati (Plate V). In sections the two groups show in Figs. 28 and 31. These bundles can be described best in connection with the dorsal funiculi of the spinal cord. (3) As a further source of fibres for the lemniscus are the arcuates from the nuclei of termination of the cerebral sensory nerves. These arcuates are too diffuse and scattered to be modeled as bundles.

A series of transverse sections corresponding to the proximal portion of the central fibre mass illustrate the region well (Figs. 38 to 49). The first two sections pass through the trapezoid body; the second, taken where that body is widest, shows that all of the fibres of the lemniscus pass through it. The next five sections pass through the pontal sheet. Fig. 43 shows the separation of the lateral from the medial lemniscus. Plate I. The area between the two lemnisci is wider in proportion in the transverse series owing to the obliquity of the sections; moreover, it contains a few medullated fibres, whereas there are none in the same area in the longitudinal series.

The lemniscus superior is shown in Figs. 46 to 48. It will be considered later in connection with the midbrain. Fig. 47 passes through the midbrain sheet just distal to the red nucleus. The oblique position of the sheet is evident as well as its relation to the substantia nigra.

Fig. 48 shows the relation of the medial lemniscus to the red nucleus and its capsule.

The longitudinal series gives a far more comprehensive view of the medial lemniscus than the transverse (Figs. 12 to 23). As has been said, the section shown in Fig. 16 was used as a starting point in building the model, for it contained a bundle, the lemniscus medialis, which ran the entire length of the section. This bundle includes the stratum interolivare, the pontal sheet and the midbrain bundle. The shape and the curves of the tract are evident. The points of especial interest are (1) the radiation of the fibres in passing through the corpus trapezoideum, (2) the distribution of the fibres in the pontal sheet, the main mass lying in the lateral part, and (3) the midbrain curve in relation to the substantia nigra. The junction of the pons and midbrain is plain, and many scattered fibres can be seen entering the midbrain from the medial part of the sheet.

In considering the lemniscus medialis, it is necessary to relate it (1) to the lemniscus lateralis, (2) to the lemniscus superior and (3) to the capsule of the red nucleus. The beginning of the lateral lemniscus is seen in Fig. 16 but the main mass of it is seen at a level farther dorsal in Fig. 13. This section is taken just at the junction of the medial lemniscus with the lemniscus superior, while in Fig. 12, the medial lemniscus disappears and the superior lemniscus becomes visible by itself.

This description will perhaps suffice for the structures that lie dorsal to the level of the pontal sheet. Fig. 19 is farther ventral, and, owing to the arch formed by the pontal sheet (Plate IV), it shows the medulla sheet and midbrain sheets but not the pontal sheet.

In this section two points are well shown, (1) the radiation of the lemniscus fibres as they emerge from the trapezoid body, and (2) the curves which the lemniscus forms in the midbrain. It will be noted that by means of two curves the fibres of the lemniscus adjust themselves to the substantia nigra and the red nucleus. Passing still more ventralward the lateral capsule of the red nucleus becomes visible (Fig. 20). It consists at this stage of very few fibres. The rest of the sections show simply the stratum interolivare lemnisci.

The fasciculus longitudinalis medialis can be seen in the transverse sections from Figs. 28 to 51. In the model it will be remembered that the ventrolateral funiculi of the cord are represented as a trough in which the ventral horn-cells lie and that this trough opens out upon the surface of the medulla sheet (Plate VI). The walls of this trough are the ground bundles, the fasciculus ventralis et lateralis proprius. In the medulla oblongata the fibres curve dorsalward into the border of the medulla sheet. This is best made out in sagittal section. In Fig. 28 the trough is cut in cross-section and its fibres can be traced to a point just ventral to the central canal. A single section will suffice to show the relations of the fasciculus longitudinalis medialis in the pons. In the midbrain the trough described before in connection with this bundle is seen in Figs. 46 to 51. Its shape, its relations to the nucleus N. oculomotorii and the nucleus N. trochlearis, and especially the superior connections of its walls deserve notice. In the last section, Fig. 51, the relation to the nucleus of Darkschewitsch is evident. These connections will be considered in detail in the study of the midbrain.

The longitudinal series, as in the case of the lemniscus medialis, gives the best idea of the medial longitudinal bundle (Figs. 7 to 20). A view of the model from the lateral aspect shows that this bundle reaches its most dorsal point opposite the nucleus N. abducentis (Plate VI). The section in Fig. 7 passes through this point. Fig. 9 gives the best view of the bundle, both as to its shape and its relations. The two extremities of the bundle in this section represent the positions of the cervical and midbrain curves.

By tracing the series ventralward the following points can be studied: (1) the ventral course of the fibres at either end, (2) the widening of the bundle at the proximal end, (3) the formation of the midbrain trough, (4) the relation of the latter to the nuclei of the oculomotor and trochlear nerves, and (5) the relation to the nucleus of Darkschewitsch, the posterior commissure and the capsule of the red nucleus.

Since the medial longitudinal bundle is especially related to a group of cerebral nerves, it may be well to consider these relations in detail. In the model there are four depressions in the bundle, one in the medulla oblongata, one in the pons, and two in the midbrain. These four depressions correspond to the nuclei of (1) the N. hypoglossus, (2) the N. abducens, (3) the N. trochlearis and (4) the N. oculomotorius. The nucleus N. hypoglossi corresponds to the shallow depression just proximal to the distal dorsal angle of the medulla sheet (Plate VI and Fig. 31). The nucleus is a long one and lies in the gray matter ventral to the central canal.

The nucleus of the N. abducens lies in this same central gray matter close to the floor of the ventricle (Plate VI). It lies farther lateral than any other nucleus of this group, as though it had been pulled from the middle line by the knee of the root of the facial nerve (Plate II). The fibres of the root of the N. abducens pass through the edge of the medial longitudinal bundle. The relations of the nucleus N. abducentis are shown in Fig. 7. In the midbrain trough of the medial longitudinal bundle are embedded the nuclei of the oculomotor and trochlear nerves (Plate VII). Since the nucleus N. trochlearis is asymmetrical, there are two depressions in the fasciculus longitudinalis medialis on the right side and one on the left (Figs. 44 and 46, and Figs. 10 and 12). Proximal and ventral to the position of the nucleus N. trochlearis are the depressions for the nucleus N. oculomotorii (Fig. 47 and Fig. 13).

The main features of the medial longitudinal bundle have thus been illustrated in the model and proved in the sections. In brief, they are as follows: It is a long tract running through the entire area covered by the model.[1] As to position, it lies just ventral to the central canal save at its superior limit; as to form, its striking features are (1) the two curves, (2) the depressions for the nuclei, (3) the midbrain trough; as to origin, it is known to consist in large part of the continuation of the ventrolateral funiculi of the spinal cord. It receives, however, many fibres from adjacent gray masses on its course, and gives off fibres to these. It has undoubted relations at the superior limit with the nucleus of Darkschewitsch. Indeed, this nucleus has been called by at least one writer the nucleus fasciculi longitudinalis medialis. The question of higher connections will be discussed later. There are fibres in the fasciculus longitudinalis medialis running in both directions, as Golgi studies by various investigators have demonstrated.

The middle portion of the central fibre mass can be studied to better advantage in connection with the formatio reticularis as a whole. I shall refer, therefore, in this place merely to one section (Fig. 13), which will show the essential points, viz.: (1) that the fibres spread out into the pars dorsalis pontis and the tegmentum; and (2) that the fibres come into relation with several groups of cells.

It remains now to show how the central fibre mass, so fundamental in the construction of the model, is, in fact, a foundation for the entire structure. It is clear that in each of the three principal regions of the model, namely, the medulla oblongata, the pons and the midbrain, this central bundle, at least the main part of it, has a characteristic shape; in the medulla oblongata it is a median ventical sheet, in the pons, a horizontal sheet, in the midbrain,

---

[1] The description given differs from that found in many books where the term is applied only to the bundle in the pons and midbrain. The authors of these books usually refer then to the portion in the medulla oblongata as the "remains of the ventrolateral funiculi of the spinal cord" (*Vorderseitenstrangreste* of the Germans). It seems to me more satisfactory to include in the fasciculus longitudinalis medialis the fibres of the medulla sheet which are continuous with the bundle in the pons.

a lateral obliquely vertical sheet. If now the medulla is considered in the light of its development from the comparatively simple structure of the cord, it will be seen that, as the central canal moves dorsalward to make room for the intrinsic structures of the medulla, the ventral ground bundle, which underlies the canal, becomes enormously developed so as to form the medulla sheet. This medulla sheet, indeed, represents far more than the ventral funiculus, for it is made up of fibres from the lateral and dorsal funiculi as well. Indeed, at the beginning of the medulla oblongata, almost the entire dorsal funiculus passes by means of secondary neurones, arcuate fibres, either dorsally to the cerebellum or ventrally into the medulla sheet. This change is interesting in connection with the fact that the cerebellum develops from the dorsal wall of the neural tube at this position according to the work of His. About this vertical sheet can be grouped all the other structures of the medulla oblongata. Just ventral to it, lies the pyramidal tract; while the region lateral to it can be divided into two levels, a ventral and a dorsal. The ventral level is characterized by the nucleus olivaris inferior; the dorsal level corresponds to a formatio reticularis area which is bordered by the roots of the cerebral nerves and their nuclei.

In the pons, the central fibre mass makes a complete floor for the pars dorsalis pontis. The whole of the structure which characterizes the pons, namely, the pontal nuclei, lies ventral to the sheet; while on the other hand, all the structures, which more or less correspond to the upward continuation of the spinal cord, lie dorsal to it. This pars dorsalis pontis is composed chiefly of formatio reticularis. It receives (1) the middle portion of the proximal subdivision of the central fibre mass, and (2) a mass of fibres from the formatio reticularis of the medulla oblongata. The brachium conjunctivum, or superior cerebellar peduncle, passes through it.

The midbrain structures in turn can be grouped around the central fibre mass. The lateral course of the lemniscus medialis above the medulla is interesting in connection with the size and central position of the red nucleus. In the ventral region of the midbrain are the substantia nigra and nucleus ruber separated from one another by the lateral capsule of the red nucleus and the lemniscus medialis, while dorsal to the red nucleus is a formatio reticularis area. This area is bounded laterally by the lemniscus superior and medially by the fasciculus longitudinalis medialis and stratum album profundum (Plate VII).

The cerebral nerves can be grouped in part with relation to the foundation of the model. In Plate IV of the model, is shown the trough which contains the ventral column of gray substance of the spinal cord opening out onto to the medulla sheet. From this point can be traced two separate groups of nuclei pertaining to the cerebral nerves, a median, motor group, and a lateral, mixed group. The median, motor group includes the nucleus N. hypoglossi, nucleus N. abducentis, nucleus N. trochlearis and nucleus N. oculomotorii, which have already been related to the faciculus longitudinalis medialis. The lateral group, on the other hand, is not directly related to the central fibre mass, but rather lies within or bordering upon the area of the formatio reticularis. This lateral group can be subdivided into two parts, a ventral, motor group and a dorsal, sensory group. The ventral group includes the nucleus N. accessorii and the motor nuclei of the N. glossopharyngeus, N. vagus, N. facialis and N. trigeminus. They all lie within the formatio reticularis. The sensory group includes the nuclei of termination of the sensory portions of the N. glossopharyngeus, N. vagus, N. facialis and N. trigeminus together with all the nuclei of the cochlear and vestibular nerves. This group lies far dorsalward and its nuclei and nerve tracts border upon the formatio reticularis. In the positions of these groups as here outlined is a striking contrast. On the one hand, the motor groups are both placed in close relation to association fibres, the median group to a definite compact bundle (the fasciculus longitudinalis medialis), the lateral to diffuse association paths (formatio reticularis); the sensory group of nuclei, on the other hand, lies not actually in but rather bordering upon the formatio reticularis. This grouping of the cerebral nuclei which will be used in connection with the model has been noted in comparative anatomy as well as in connection with the human brain.

Beside these special form relations the model illustrates certain general relations. A view from the lateral surface (Plate I) shows that the ventral regions of the model are occupied largely by nuclear masses: the olive, the pontal nuclei, the substantia nigra and the red nucleus.

The absence of medullated fibres in this region is due to two facts, (1) that the pyramidal tracts and the brachium pontis which belong here become medullated at a later period, and (2) that, at the cervical curve in the medulla, most of the fibres of the spinal cord curve dorsalward, and thus leave the olivary region comparatively free. At this stage of development the ventral level of the medulla oblongata, pons and midbrain is a nuclear region. Dorsal to this level is the area corresponding more or less to the continuation of the spinal cord. In the views of the model, one is struck by the number of fibre bundles it contains, long and short parts, that is, tracts to the cerebrum and cerebellum as well as fibres to and from many way-stations. These fibres represent in part the funiculi of the cord. The region is not wanting in nuclei, for the dorsal and ventral columns of the cord are represented by the nuclei of the cerebral nerves; the ground bundles of the cord correspond to the extensive formatio reticularis alba and grisea, while the central gray matter of the cord becomes much enlarged to form the substantia grisea centralis of the medulla, pons and midbrain.

2.—The Funiculi of the Spinal Cord.

Having given a general sketch of the regions of the model and shown how its principal structures are related to the central fibre mass, each of the structures of the spinal cord may next be traced into the medulla oblongata. Starting with the central canal its entire course is not shown in any one plate, but it can be traced as follows:—In Plate IV the canal is shown within the cord. In entering the medulla oblongata it curves dorsalward along the border of the medulla sheet until it opens out into the fourth ventricle as seen in Plate II. The relation of the aquæductus cerebri to the third ventricle can be traced in Plate I.

A view of the lateral surface of the model gives the best idea of its relations to the spinal cord (Plate I). The ventral funiculus is not seen, but the lateral and dorsal funiculi are plain.

On the distal edge of the model (Plate I) is a shallow groove which divides the lateral funiculus into two parts. This groove corresponds to the line on Fig. 1. The ventral portion is the fasciculus ventrolateralis, which, as the model will show, is subdivided in the medulla oblongata into four definite bundles and certain scattered fibres. The dorsal part, or funiculus lateralis, is divided into two parts, (1) the fasciculus cerebellospinalis, or direct cerebellar tract, which occupies the lateral surface at the distal end of the model, and (2) a mass of fibres concealed from the surface which enters into the formation of the formatio reticularis area of the medulla oblongata. The fasciculus cerebellospinalis lies near the surface and joins with a bundle belonging to the system of the dorsal funiculi to make the corpus restiforme (Plate I).

The dorsal funiculi of the spinal cord are shown in the first five plates.

In entering the medulla oblongata the fasciculi gracilis and cuneatus slant dorsalward and spread out into a nuclear capsule (Plate I). This capsule is continuous with the corpus restiforme. The nuclei of the dorsal funiculi can be seen in Plates III and VI.

The dorsal horn is visible in the surface view in the model, for the fasciculus of Lissauer has been removed. At the beginning of the medulla oblongata, the dorsal horn, swollen into a large substantia gelatinosa, becomes continuous with the nucleus of the tractus spinalis nervi trigemini (Plates I and III). A full discussion of the gray matter of the cord in relation to the model is left for Part II.

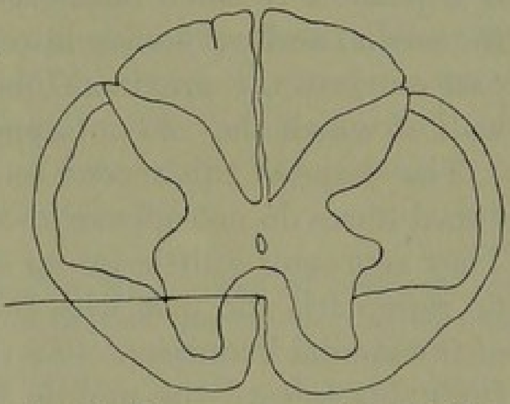


FIG. 1.—Transverse section of the Spinal Cord at the level of the distal end of the model.

A.—VENTROLATERAL FUNICULI.

(*a*) *Pars Ventralis of the Ventrolateral Funiculi.*—The separate funiculi of the spinal cord will now be considered in detail, beginning with the ventrolateral fasciculus. This fasciculus includes all of the white matter below the transverse line in Fig. 1, for the pyramidal tracts are not yet medullated. It will be clear that the ventrolateral fasciculus as seen in Fig. 1 is a cross-section of the trough at the distal end of the model (Plates IV and VI). As has been said the walls of the trough are divided in the medulla into four definite bundles, and certain scattered fibres.

The first group includes the most medial and ventral fibres (Plate VI). They have already been described as turning dorsalward along the border of the medulla sheet to make the fasciculus longitudinalis.

In the transverse sections they are visible in Figs. 27 and 28, both of which give a cross-section of the trough where it is opening out onto the medulla sheet. Fig. 20 shows these fibres in longitudinal sections. The trough is lettered F. l.

The second bundle leaves the lateral funiculus a little farther cerebralward (Plate IV, Fasciculus lateralis [2]). It passes obliquely toward the midline and is represented in the model as stopping abruptly against the root of the N. hypoglossus. In reality the fibres pass on between the root bundles of the nerve adjacent to the medial lemniscus (Fig. 19). In some of the sections it is possible to trace the fibres of this bundle through the parts of the medial accessory olive into the lemniscus medialis. Other fibres pass out into the proximal lobe of the nucleus olivaris inferior, the wall of which they do not appear to penetrate.

The shape of this second bundle in the model is peculiar, for the dorsal fibres do not appear to come from the lateral funiculus at all. They represent a little group of fibres which come from the formatio reticularis and pass with the bundle in question toward the area of the medial lemniscus. As the bundle is crossing from the lateral funiculus toward the middle line a small group of fibres becomes separated from the mesial surface of the main mass, passes parallel to it for a short distance and then joins with it again. It cannot be seen in the lateral views given in the plates but it shows in Figs. 19 and 28. It is not labeled in either section but is a small bundle of fibres within the trough. Its meaning I do not know. To return to the main bundle, the model shows the following points: (1) The bundle is connected with the lateral funiculus of the cord; (2) it does not decussate in the medulla oblongata; (3) it runs parallel to the medial lemniscus at the level of the inferior olive; (4) its fibres appear to join the lemniscus in part and in part to turn toward the olive, beyond which they cannot be traced in these preparations. If this bundle joins the lemniscus medialis in may represent a sensory path from the lateral funiculi which does not decussate in the medulla oblongata.

The two bundles just described receive the medial and ventral fibres, the fasciculus ventrolateralis (Fig. 1). The lateral fibres pass onward to a point opposite the distal end of the inferior olive, where the bundle divides into two parts (Plate IV). This statement is made without regard to the direction of the axones of the fibres. The larger and medial of these two bundles extends between the lateral funiculus of the cord and the lemniscus lateralis (Plate IV). It does not join the lemniscus, but rather passes beyond the point of meeting; its fibres, however, could not be traced farther in the longitudinal series. The lateral lemniscus leaves the trapezoid body just dorsal to the nucleus olivaris superior which lies embedded within the trapezoid body. The bundle connected with the cord touches the lemniscus lateralis just dorsal to the medial border of the superior olive. The two bundles make a slight angle in which lies the nucleus of the facial nerve. The bundle will be traced spinalward inasmuch as this is the direction taken by at least a portion of the axones of its constituent fibres. Starting from the point where it touches the lemniscus, it passes at once ventralward, lateralward and spinalward. The bundle spreads out in its course and sweeps around the surface of the inferior olive to join the lateral funiculus of the cord (Plate IV).

This bundle must be studied carefully in both series of sections. In the longitudinal series, a considerable portion of the bundle can be seen in one section (Fig. 13, Tr. fr. Nu. D.). Its approach to the fasciculus lateralis of the spinal cord can be seen in Fig. 16. I wish to emphasize two points shown in Fig. 13: (1) that though the bundle adjoins the lateral lemniscus, its fibres are cut at a different angle, that is, more obliquely (compare Plate IV), (2) that the bundle can be recognized from its relation to the nucleus of the facial nerve.

Turning to the transverse series the bundle is determined readily by this relation. In Fig. 38 the bundle corresponds with the tract described as passing from Deiters' nucleus to the spinal cord. It can be seen in Figs. 36 to 38, in which its fibres are passing dorsalward through the formatio reticularis. These sections include the area between the pars prima and pars secunda of the N. facialis (Plate IV); hence the bundle scatters in its dorsal course so that it is not strange to lose it in the longitudinal sections, in which its fibres must be cut across. Even in the transverse series I can not demonstrate the connection of the bundle with Deiters' nucleus.[1]

The last and smallest of the four bundles from the ventral part of the lateral funiculus maintains a lateral position throughout its course. It passes along the surface through the entire length of the medulla oblongata and joins the trapezoid body midway be-

---

[1] The position of the bundle corresponds with Ramón y Cajal's description. Ramón y Cajal, S. Beitrag zur Studium der Medulla oblongata, des Kleinhirns und des Ursprung der Gehirnnerven. Deutsche Uebersetz. von Bresler, Leipzig (1896), S. 71.

tween its dorsal and ventral aspects (Plate IV). In the trapezoid body it is wholly lost from view.

The bundle is horizontal, so its complete course can be seen in one section (Fig. 17). It can be followed as readily in the transverse series (Figs. 30 to 35) (F. l.). This bundle is labeled the fasciculus anterior by Edinger.[1]

It may correspond to v. Bechterew's[2] aberrant bundle. As regards Gowers' tract the section in Taf. IX of Hoche's article,[3] shows the fibres of Gowers' tract just ventral to the tractus spinalis N. trigemini. The section is taken opposite the middle of the inferior olive proximal to the passage of the fasciculus cerebellospinalis into the corpus restiforme. In the series I have studied, a corresponding section has this area as a non-medullated space, while ventral to it lies the bundle shown in the model. A second section in my series, taken to correspond with Fig. 7, Taf. IX of Hoche's paper, will show still more clearly the non-medullation of the fibres of Gowers' bundle as described by Hoche (Fig. 38). At this level Gowers' tract cuts across the pars secunda of the facial nerve, just as it plunges into the corpus trapezoideum and this area in my series is non-medullated. At the level of Fig. 38, the fourth bundle of the model is no longer visible.

These four bundles in the medulla oblongata contain all of the fibres of the fasciculus ventrolateralis, medullated at this stage, with the exception of certain fibres of the formatio reticularis. These come from the mesial part of the lateral wall of the trough (Plate VI). They spread out in the medulla oblongata and constitute the ventral bundle of the formatio reticularis.[4] This bundle is much smaller than the dorsal bundle of the formatio reticularis.

(*b*) *Pars Dorsalis of the Funiculus Lateralis.*—Turning now to the dorsal part of the lateral funiculus of the cord, the section in Fig. 1 shows that it contains two fibre masses; one lateral, the fasciculus cerebellospinalis, or direct cerebellar tract, and one more medial, a part of the fasciculus lateralis proprius (Flechsigi), or the so-called lateral ground bundle.

---

[1] Edinger, L., Vorlesungen über den Bau der nervösen Centralorgane, Leipzig (1893), S. 186.

[2] Barker, L. F., op. cit.

[3] Hoche, A., Ueber secundäre Degeneration, speciell des Gowers' . . . schen Bündels, nebst Bemerkungen über das Verhalten der Reflexe bei Compression des Rückenmarkes. Arch. f. Psychiat. u. Nervenkr., Berl., Bd. XXVIII (1896), S. 510-543.

[4] This is a part of the *vordere gemischte Seitenstrangzone* of Flechsig. Flechsig, P., Die Leitungsbahnen im Gehirn und Rückenmark, Leipzig, (1876), S. 305.

At the distal edge of the model the direct cerebellar tract forms a band or ribbon on the surface of the spinal cord (Plate I and Fig. 1.) In approaching the medulla oblongata the fibres converge to form a compact bundle (Fig. 28). In this bundle the fibres pass on to a point opposite the distal end of the inferior olivary nucleus where the entire bundle turns dorsalward at almost a right angle (Fig. 30). The lines in Plate I of the model showing this dorsal course are perhaps a little too abrupt. They should follow the course of the lines of the transverse sections shown on Fig. 52. The fibres extend dorsalward beyond the level of the tractus spinalis nervi trigemini; here they turn cerebralward again and join with the dorsal external arcuate fibres to enter the corpus restiforme. This arcuate bundle shows in the model as the direct continuation of the capsule of the nuclei of the dorsal funiculi (Plate I). The line in which the direct cerebellar tract meets this arcuate bundle forms an arch, beneath which the tractus spinalis nervi trigemini and its nucleus can be seen. The corpus restiforme passes cerebralward, and at the same time slightly lateralward, to a point opposite the level of the nucleus N. abducentis. Here it turns dorsalward to enter the cerebellum and hence is cut off in the model.

To return to the cross-section of the spinal cord shown in Fig. 1, all of the medullated fibres of the lateral funiculus have been traced save the ground bundle, for at this stage the lateral pyramidal tract is non-medullated. The model shows that the ground bundle of the lateral funiculus has only to turn slightly dorsalward, in agreement with the cervical curve in order to enter the formatio reticularis of the medulla oblongata. (See the cross-section of the cord in Plate IV). This formatio reticularis region extends throughout the length of the medulla. It lies dorsal to the nucleus olivaris inferior and lateral to the medulla sheet.

B.—FUNICULUS DORSALIS.

The dorsal funiculi of the spinal cord form a wedge-shaped mass as seen in cross-section (Fig. 1). Each funiculus runs to the beginning of the medulla oblongata without change of form save that the groove between the fasciculus gracilis and the fasciculus cuneatus deepens (Plates III and IV). At about the junction of the spinal cord and medulla oblongata, the fasciculus gracilis becomes hollowed out to make a capsule for its nucleus and a little farther cerebralward the fasciculus cuneatus shows the same change. This capsule can be best understood after the nucleus has been described.

The nucleus of the dorsal funiculus of the cord is seen best after removing the fibre capsule (Plates III and VI). It is an irregular mass of cells, which is divisible into three parts; moreover, this division, made from form alone is strengthened by the mode of distribution of the fibres. In general the distal portion of the nucleus has a long diameter in a dorsoventral plane (Plate V) at right angles with the long axis of the proximal portion (Plate III). The three divisions, as seen from a lateral view are (1) a distal, (2) a middle and (3) a proximal part. The middle portion does not extend to the mesial surface of the nuclear mass and so may well be called the lateral portion. (Nucleus funiculi cuneati lateralis, Plate III.)

The distal part or nucleus funiculi gracilis consists of a column of cells placed in a dorsoventral direction. Its distal margin is straight but the dorsal margin is curved and raised above the rest of the nuclear mass (Plate III). It is separated from the middle nucleus by a deep groove but its surface is smooth, thereby contrasting with the proximal portion. The rest of the mass has been called the nucleus funiculi cuneati, but Blumenau has shown that it consists of two distinct parts. The middle part, or nucleus of Blumenau is a mass of cells projecting from the lateral surface. (Plate III. Nucleus funiculi cuneati lateralis). It is separated from the distal nucleus by a deep groove but fades gradually into the proximal nucleus. Its distal border is about opposite the middle of the nucleus funiculi gracilis, while its proximal limit is opposite the lower part of the nucleus olivaris inferior, and the distal end of the radix descendens nervi vestibuli.

In the model, the nucleus cannot be traced as far cerebralward as Blumenau was able to trace it from histological details. Blumenau[1] places the proximal limit opposite the lowest plane of entrance of the fibres of the N. acusticus. The sections of both my series show small, scattered masses of cells in the corpus restiforme, and these can be traced even into the cerebellum itself. They are considered by Blumenau to be part of the nucleus which bears his name. As has been said, the nucleus of Blumenau does not reach the mesial surface of the nuclear mass. The thin mesial zone con-

---

[1] Blumenau, L., Ueber den äusseren Kern des Keilstranges im verlängerten Mark. Neurol. Centralbl., Leipz., Bd. X (1891), S. 229.

sists (1) of a small column of cells projecting parallel to the nucleus funiculi gracilis, and (2) a layer of cells associated with the proximal nucleus. This will be explained in connection with the course of the fibres from these cells.

The proximal portion of the mass is oblong in shape. It is characterized by the irregularity of its lateral surface which is broken by fibre bundles. One deep depression is to be seen near its ventral surface.

Further evidence of the division of this nucleus into three parts is seen in the course of the fibres from it. In Plate VI it will be noted that, while both the distal and proximal divisions give bundles of fibres that run toward the raphe no such bundle comes from the lateral nucleus. These two bundles of internal arcuate fibres, distal and proximal, are wholly distinct from one another in the longitudinal series. In the transverse series, on the other hand, it can be made out that the thin medial border of the middle zone makes a transition between the distal and proximal bundles.

The distal bundle leads to the decussatio lemniscorum. It is a small, compact bundle, which comes (1) from the distal third of the nuclear mass, the nucleus funiculi gracilis, and (2) from the distal part of the thin middle zone of the mass, the nucleus funiculi cuneati. The bundle leaves the proximal border of the nucleus funiculus gracilis and hence appears in transverse section to arise wholly from the nucleus funiculi cuneati (Fig. 28). It is found in the distal part of the medulla oblongata, distal to the olive and opposite the proximal end of the decussatio pyramidum.[1] The bundle passes along the border of the central gray matter, to a point ventral to the central canal, where it decussates in mass between the medulla sheets of the two sides and joins the stratum interolivare lemnisci (Plate VI).

The proximal bundle of internal arcuate fibres, on the other hand, is different both in position and in form. It is related to the proximal part of the nuclear mass and forms a broad band which appears as a direct continuation of the entire proximal third of the nucleus into a fibre bundle (Plates III and VI). This bundle sweeps across the medulla in a curve, dorsal to the olive, pierces the medulla sheet, turns ventralward to decussate in the raphe, and joins the stratum interolivare lemnisci of the opposite side. This

---

[1] Ramón y Cajal, op. cit., S. 52.

bundle contrasts with the distal arcuate bundle: (1) in position, for it lies opposite the middle of the nucleus olivaris inferior, while the latter is distal to it; (2) in course, for its fibres arise far lateralward and pass through the formatio reticularis instead of bordering upon the central canal; and (3) in the arrangement of its fibres into a broad band instead of a compact bundle (Figs. 28 and 31). According to v. Bechterew[1] the fibres from the fasciculi of Goll and Burdach can be distinguished from each other throughout the pons. The mesial border of the middle zone gives off a few fine arcuate fibres which make a transition between the distal and proximal bundles. At first they lie near the central gray matter after the type of the distal bundle, but they gradually pass farther to the side until the proximal bundle is reached.

The model shows that the lateral nucleus of Blumenau[2] is in the exact position to send its fibres lateralward to the cerebellum rather than medialward to the medial lemniscus on its way to the cerebrum. This will appear clear by comparing Plates I, II and III.

The capsule of the nuclei of the dorsal funiculi of the cord is continued directly into the corpus restiforme. This connection is made by means of dorsal external arcuate fibres. These arcuates come from two sources, (1) from the dorsal funiculi of the cord, (2) from the nucleus of Blumenau.[3]

The transverse series will be used first to illustrate the points of the model (Figs. 25 to 31). Fig. 25 shows that the nucleus funiculi gracilis is well developed at a level in which only the ventral part of the nucleus

---

[1] v. Bechterew, W., Ueber die Schleifenschicht auf Grund der Resultate von nach der entwickelungsgeschichtlichen Methode ausgeführten Untersuchungen. Arch. f. Anat. u. Phys., Anat. Abth., Leipz. (1895), S. 379-395.

[2] Blumenau, op. cit., S. 226.

[3] In regard to the literature on this subject, Edinger, Flechsig, Hoche and v. Monakow say that fibres of the dorsal funiculi pass directly to the corpus restiforme. Vejas on the ground of experimental degeneration says that the dorsal funiculi and the corpus restiforme are connected only by mediation of a nucleus.

(1). von Monakow, C., Arch. f. Psychiat. u. Nervenkr., Berl., Bd. XIV (1883).

(2). Edinger, L., Neurol. Centralbl., Leipz., Bd. III (1885), S. 73-76.

(3). Flechsig, P., Neurol. Centralbl., Leipz. (1885), No. 5.

(4). Vejas, P., Arch. f. Psychiat. u. Nervenkr., Berl., Bd. XVI (1885), S. 200-214.

(5). Barker, L. F., Op. cit., p. 560 and p. 575.

Flechsig calls these fibres, "Fibræ transversales." Die Leitungsbahnen im Gehirn und Rückenmark des Menschen, Leipzig, 1876.

funiculi cuneati is visible. Fig. 28 shows both the nuclei of the fasciculi of Goll and Burdach, together with the nuclear capsules and the distal bundle of internal arcuate fibres. The capsule of the nuclei of Burdach's fasciculus is dense, while that of the nucleus of Goll's fasciculus is delicate. The characteristics of the distal internal arcuate bundle are evident in Fig. 28. The proximal bundle on the other hand is shown in Fig. 31, while the transition between the two is represented by Fig. 29. Figs. 29 and 30 show the lateral nucleus of Blumenau. In the second section its close connection with the fibre capsule and the contrast of its cellular arrangement with that of the proximal nucleus is evident.

The relative positions of the three parts of the nuclear mass are more clearly made out in the longitudinal series (Figs. 5 to 17). The sections in Figs. 5 to 7 illustrate these relations. The nucleus funiculi gracilis and a small part of the nucleus funiculi cuneati form a common mass that gives rise to the distal internal arcuate bundle. The middle, lateral portion is the nucleus of Blumenau (N. f. c. (l) Fig. 5). At the level of Fig. 7 it is separated from the proximal third by a band of fibres entering the nucleus from the capsule. All three sections pass through the corpus restiforme. The fibre bundle opposite the nucleus of Blumenau is much broken, due to the entrance and exit of the fibres of the capsule.

In passing ventralward the internal arcuate fibres can be traced to their decussations. On Fig. 9 the proximal third of the nucleus seems to have been transformed into fibres. These fibres can be traced through Figs. 12, 13 and 15. The distal bundle which lies farther ventral is seen first on Fig. 15 and is traced to the decussatio lemniscorum in Figs. 17 and 19.

3.—Corpus Restiforme.

The description of the dorsal and lateral funiculi of the cord leads naturally to the corpus restiforme, or inferior cerebellar peduncle, inasmuch as, at this stage of medullation, it receives most of its fibres (1) from the direct cerebellar tract of the lateral funiculus, and (2) from the dorsal external arcuate fibres of the dorsal funiculus. The fibræ olivocerebellares are non-medullated. The view of the model from the lateral surface shows the relation of the corpus restiforme to the spinal cord, as well as its position with reference to the cerebellum and the other two cerebellar peduncles (Plate I). The superior cerebellar peduncle, or brachium conjunctivum, is shown clearly. The middle peduncle, or brachium pontis, on the contrary, is non-medullated and its location must be imagined from the positions of the pons.

The corpus restiforme, as seen from the side is a great sheet of fibres continuous with the capsule of the nuclei of the dorsal funiculus (Plate I). Reference has already been made to the direct cerebellar tract—how it forms a ribbon on the edge of the cord, how this band narrows on entering the medulla oblongata, passes cerebralward as a compact bundle, then turns dorsalward[1] to join the dorsal external arcuate fibres to form the corpus restiforme.

Plate I illustrates a point Flechsig has made, that the direct cerebellar tract in the spinal cord lies ventral to the dorsal horn, while the corpus restiforme in the medulla oblongata lies lateral to the tractus spinalis nervi trigemini, which represents the upward continuation of the dorsal horn.[2]

In passing cerebralward the corpus restiforme becomes narrower forming a compact bundle which passes between the nuclei of the cochlear nerve laterally, and the descending tracts of the vestibular and trigeminal nerves medially. Just proximal to the level of the nucleus nervi abducentis the bundle turns dorsalward to enter the cerebellum and hence is not shown in the model. In entering the cerebellum, the corpus restiforme spreads out markedly. It lies lateral to the brachium conjunctivum and passes dorsalward and cerebralward while the latter passes dorsalward and spinalward. The two bundles then form an angle in which lies the corpus dentatum.

The corpus restiforme at this stage of medullation contains three sets of fibres,[3] (1) the direct cerebellar tract, (2) the dorsal external arcuates, and (3) fibres connecting the vestibular nerve with the cerebellum. This third group will be described in connection with the nerve. In the sections used in making the model the lateral portion of the corpus restiforme, corresponding, according to Flechsig,[4] to the fibræ cerebelloolivares is a non-medullated area (Fig. 33).

The corpus restiforme was shown in longitudinal sections in connection with the nuclei of the dorsal funiculi of the cord (Figs. 6, 7 and 9). The first two sections show the relations of the dorsal external arcuate fibres while the third shows the direct cerebellar fibres in their

---

[1] In this dorsal course the fibres are called fibrae transversales externæ posteriores by v. Koelliker.

[2] Flechsig, P., Die Leitungsbahnen im Gehirn und Rückenmark, Leipzig, (1876), S. 325.

[3] v. Bechterew gives five sets of fibres in the corpus restiforme, the three mentioned above, (4) fibres from the nuclei laterales and (5) from the nucleus olivaris inferior. v. Bechterew, W., Arch. f. Anat. u. Phys., Anat. Abth., Leipz. (1886), S. 403-410.

[4] Flechsig, P., Die Leitungsbahnen im Gehirn und Rückenmark, Leipz. (1876), S. 329.

dorsal course. They can be seen also on the right side of Fig. 12, lateral to the tractus spinalis N. trigemini. The connection with the lateral funiculus is made at the level of Fig. 16, which is just ventral to the substantia gelatinosa (Rolandi).

In the transverse series the corpus restiforme can be traced from the spinal cord to the vermis of the cerebellum (Figs. 25 to 37). The sections in Figs. 25 to 28 show the direct cerebellar tract; while Fig. 28 shows the nucleus of Blumenau which gives origin to the dorsal external arcuates. The direct cerebellar fibres in their dorsal course are seen in Fig. 30, and beginning of the corpus restiforme is on Fig. 31. In Fig. 33 the corpus restiforme lies between the cochlear nuclei and the descending tracts of the trigeminal and vestibular nerves. The section in Fig. 35 is taken at the point where the inferior cerebellar peduncle turns to enter the cerebellum opposite the proximal end of the corpus dentatum; while Figs. 36 and 37 carry the corpus restiforme to the vermis.

4.—Brachium Conjunctivum.

The brachium conjunctivum, or superior cerebellar peduncle, is shown in four views (Plates I, II, III and VII). In order to illustrate the decussations, the peduncles of both sides have been modeled. The origin of the fibres cannot be seen, inasmuch as the corpus dentatum was removed with the cerebellum. However, the position of this nucleus and its relations to the superior and inferior peduncles can be determined by a study of Fig. 52 in connection with the transverse series. The level of section 146, Fig. 33, can be found on Fig. 52, and this section passes through the corpus dentatum and both peduncles. Section 182, Fig. 36 shows the peduncles but is at a level proximal to the nucleus. The corpus dentatum, then, lies in the angle between the corpus restiforme and the brachium conjunctivum. From this nucleus, the superior peduncle can be traced to its decussation in the pars dorsalis pontis. Proximal to the decussation, the peduncle on the left side has been sacrificed to other structures, while on the right, the peduncle alone has been modeled (Plate VII).

For a more detailed study of the brachium conjunctivum, the view from the dorsal surface gives the best starting-point (Plate II). On the right side of the figure the superior peduncle is dissected out; on the left it appears as a narrow band placed obliquely in the long axis of the pons (Fig. 6). The band is straight save at the distal end where it turns out slightly.

In the views of the lateral surface of the model (Plates I and III), the peduncle can be traced toward its decussation. The band on the dorsal surface was really the edge of a sheet which passes ventralward, inward and slightly cerebralward. This sheet is not of uniform thickness, for its proximal border grows thicker as it passes ventralward; moreover, its surface curves lateralward, thereby increasing the distance between the two peduncles.

Reference was made in connection with the dorsal view, to the flaring out of the distal end of the band. Plate I shows that this portion of the band meets the nucleus N. vestibuli superior, a connection which is clear in the sections (Fig. 7). On the other hand the proximal border of the lateral sheet is made of a small bundle of fibres distinguished from the main mass by their direction (Plates III and VII). Opposite this group of fibres is a small bundle which crosses from the lemniscus lateralis to the brachium conjunctivum (*a* on Plates II and VII).

The brachium conjunctivum of the model represents not one but at least three different fibre masses. (1) A distal bundle connected with the nuclei N. vestibuli superioris, (2) the main mass of fibres from the corpus dentatum which decussate at a ventral level, and (3) a small bundle which runs in the proximal border and decussates at a more dorsal level. This group of decussations makes a complicated structure in the model, difficult to describe.

It may simplify matters slightly to mention at the outset two morphological features. First, the main bulk of the decussation of the brachium conjunctivum lies far ventralward and cerebralward and thereby comes into relation with the nucleus ruber; secondly, that between the superior peduncles of the two sides in the pons is a wide area in which are situated masses of gray matter belonging to the formatio reticularis grisea. In Plate VII it will be seen that the decussating mass makes a hollow shell in the floor of the pars dorsalis pontis. This shell is open toward the dorsal aspect. Its sides are formed by the curved lateral sheets. The distal borders of these sheets project medialward as a sharp ledge and extend ventralward to a decussation that makes a distal wall for the shell (Plate VII). The sides of the sheet decussate both in the floor of the shell and in its proximal wall. The floor of the decussation is very thin, for the proximal wall receives the most of the fibres. As has been said, this wall seems to be made of two different masses of fibres (Fig. 44). A simple difference in direction of the fibres at the point of decussation might not be sufficient evidence to determine two masses, but in the transverse sections it is possible to distinguish the smaller dorsal mass, as it lies in the border of the sheet to a point where it is joined by a small bundle of fibres from the lateral lemniscus (a). The fibres of the dorsal bundle of the brachium conjunctivum are coarser than those from the lateral lemniscus.

It now remains to trace the superior peduncle to its destination. The proximal wall of the decussation almost touches the dorsal part of the nucleus ruber, and the fibres after crossing either pass directly into the nucleus or spread over its dorsal surface to help to make a capsule (Plate VII). Of the fibres which enter, some end in the nucleus, while a distinct bundle passes through. It will be noticed that on the right side of the model, the curve of the capsule represents the position of the nucleus. The nucleus itself was not modeled as it was desired to indicate better the disposition of the fibres within. This will be made clear in the description of the nucleus itself.

In Figs. 31 to 48 the brachium conjunctivum can be seen in its relations to the corpus dentatum. In Figs. 31, 33 and 34, and in Fig 36 the superior vestibular nucleus lies immediately adjacent to the distal part of the peduncle, that is, to that portion of it which represents the decussation between v. Bechterew's nuclei. In tracing the series farther cerebralward, the superior cerebellar peduncle is seen to pass ventralward, while the inferior peduncle passes dorsalward. The succeeding sections illustrate the points brought out in the model. The ventral course of the fibres, the curve, and the wide space between the lateral walls, are all clear. Fig. 42 shows the cross bundle extending between the lateral lemniscus and the brachium conjuctivum. The fibres of the commissure between Bechterew's nuclei cross in Fig. 43, while in Fig. 44 the decussating fibres in the floor of the shell are seen. Still farther forward (Fig. 46) the proximal wall is reached, and here the distinction in its dorsal and ventral parts is evident. The ventral part of the decussation can be traced through Fig. 47 and its relation to the nucleus ruber becomes evident in Fig. 48. The decussating fibres seen at this level just ventral to the nucleus N. oculomotorii belong to Meynert's decussation, while the most ventral fibres are those of Forel's decussation. The dorsal bundle of the brachium conjunctivum can be traced from Fig. 42 to its decussation on Fig. 46. In Fig. 42 it lies opposite the bundle crossing between the lemniscus lateralis and the brachium conjunctivum.

In the longitudinal series these relations are still more clear (Figs. 4 to 19). The brachium conjunctivum, in the wall of the velum is seen in Fig. 4. From here it can be traced ventralward to its decussation. In Fig. 6 is the cross bundle between the lemniscus and peduncle; in Fig. 7 the relation to the vestibular area is clear, while in Fig. 9 the two ends of the band are characteristic, the distal edge sharp and projecting, the proximal edge full and round.

The section in Fig. 13 shows the dorsal bundle of the brachium conjunctivum. This section illustrates the nuclear masses of the formatio reticularis between the walls of the peduncles. Section, Fig. 16, shows a wide decussation; it includes the distal wall, or Bechterew's decussation, together with the floor and proximal wall or the brachium conjunctivum proper. This section, together with Fig. 17, shows the relations of the peduncle to the red nucleus. One very definite group of fibres lies immediately adjacent to the lemniscus medialis in Forel's Feld BATh. Fig. 19 brings out the fact that the fibres that enter the medial part of the red nucleus end there, while the more lateral fibres pass through.[1]

With the brachium conjunctivum the description of the larger fibre masses of the model is complete. The central fibre mass, consisting of the medulla sheet and all of its continuations in the pons and midbrain, made the foundation for the model. By it the cord is connected with higher centres in the thalamus and the cortex. It includes also a specialized formatio reticularis bundle that connects a group of cerebral nerves, as well as a more general bundle that makes connections with the pons and midbrain at least. Each of the funiculi of the cord has been traced as far as its fibres are medullated and the relations of each to the central fibre mass have been demonstrated. The cerebellum has been related both to the cord and to higher centres by means of the corpus restiforme and the brachium conjunctivum. It remains now to trace the relation of the gray matter of the spinal cord to the nuclei of the cerebral nerves, to study the formatio reticularis and to consider the large ventral nuclei of the model.

---

[1] The model of the brachium conjuctivum illustrates well the work of v. Bechterew in dividing the brachium conjuctivum into sections. The decussation between the superior vestibular nuclei corresponds with his description; the dorsal bundle agrees with his dorsal bundle while the ventral part of the decussation in the model includes his second and third systems.

(1). v. Bechterew, W., Die Leitungsbahnen im Gehirn und Rückenmark. Leipz. (1894), S. 135.

(2). The lateral descending cerebellar bundle of Ramón y Cajal was not found in the sections. Ramón y Cajal. Op. cit., S. 20.

PART II.

THE CEREBRAL NERVES AND THEIR NUCLEI.

An indication has already been given of the grouping of the cerebral nerves, suggested by the model, namely, into a median and a lateral group. This grouping has been used before by several authors, notably by His, but it is rather more common to consider the nerves in three groups according to the region they occupy, namely, four in the medulla, four in the pons and two in the midbrain. Dr. L. F. Barker, in his recent book, has divided the nerves into a sensory and a motor group on the basis of the direction followed by the fibres. The division herein used, on the basis of the position of the nuclei, it seems to me has decided advantage, not only for the purpose of describing the model but in illustrating the relation of these nuclei to the gray matter of the cord.[1]

The two groups possess characters in marked contrast. Each contains four motor nuclei, while the lateral group has sensory nuclei as well. The median group consists of the nuclei of the N. hypoglossus, N. abducens, N. trochlearis and N. oculomotorius. The four motor nuclei of the lateral group are the nuclei of the N. accessorius, N. vagus, N. glossopharyngeus, N. facialis and N. trigeminus. Its sensory nuclei are nuclei of termination associated with the N. vestibuli, N. cochleæ and N. trigeminus. The nuclei of the median group all lie near the middle line just ventral to the central canal and closely related to the fasciculus longitudinalis medialis (Plate IV). The nuclei of the N. hypoglossus and N. abducens are very near the dorsal surface, while the nuclei of the N. trochlearis and N. oculomotorius are farther ventral inasmuch as they lie on the midbrain curve. The nerve-fibres from all the nuclei of the groups, except those of the root of the N. trochlearis, pass directly ventralward to the surface near the middle line. The root of the N. trochlearis, on the contrary, takes an anomalous course, since it passes dorsalward, decussates in the velum and has

---

[1] This division is in accord with the embryological work of His. Cf. His, W., Zur Geschichte des Gehirns sowie der centralen und peripherischen Nervenbahnen beim menschlichen Embryo. Abhandl. d. math.-phys. Cl. d. K. sächs. Gesellsch. d. Wissensch., Leipz., Bd. XIV (1887-88), S. 339-392.

its superficial origin on the dorsal surface of the isthmus of the rhombencephalon.

The motor nuclei of the lateral group lie in the formatio reticularis at a considerable distance from the middle line, and at a level ventral from the central canal. With the exception of the N. trigeminus the root-fibres from these nuclei do not take a direct course toward the surface of the central nervous system. The root-fibres of all four of the nerves have their superficial origin in the lateral sulcus. In the model the nucleus of the N. accessorius does not appear, for it could not be outlined with sufficient definiteness for reconstruction. This is an interesting form relation, for the nucleus of the N. accessorius lies just at the point where the ventral horn of the spinal cord divides into two parts to make the median and lateral motor groups of the region modeled. The nucleus of the N. accessorius then marks the transition from the indefinitely outlined nuclei of the cord to the definitely circumscribed nuclei of the cerebral motor-nerves.

The sensory nuclei of the entire region belong to the lateral group. The sensory nuclei are associated with the N. vagus, N. glossopharyngeus, N. vestibuli, N. cochleæ, N. intermedius and N. trigeminus, and the superficial entrance of their root-fibres is without exception on the lateral surface (Plates I and III). These nuclei tend to occupy a position farther dorsal than the motor nuclei of the lateral group, which is, as one might expect, inasmuch as these nuclei correspond more or less closely to the gray matter of the dorsal horn of the cord. In making this general statement, I do not intend to enter into the discussion in regard to the development of the optic and cochlear nuclei. These sensory nuclei cover a wide area, thus contrasting with the compact motor nuclei; in some cases they spread even to the mid-line.

1.—The Median Group.

(*a*) *N. Hypoglossus.*—The first nerve of the median motor group is the N. hypoglossus (Plate IV). In two instances, namely, in regard to the nucleus of the hypoglossus, and the nucleus ambiguus, the model represents the position but not the exact form. Inasmuch as the nucleus N. hypoglossi lies on the medulla curve, it will be seen that only a small portion of it would be cut in any one longitudinal section. Moreover, the nucleus lies in the central gray matter, and the scarcity of fibres tends toward the rapid washing out of the stain from the cells. However, the nucleus itself has a few fibres which have a characteristic arrangement. They are fine fibres that come up into the centre of the nucleus and spread out like a fountain.[1] In longitudinal section these fibres are cut across, and make a row of fine dots that represents the nucleus. The position of the nucleus was determined (1) by the presence of these fibres, (2) by well-known relations to neighboring structures, (3) by measurements from the transverse series and (4) by the position of the nuclear end of the root-bundle. Of the form of the nucleus, I shall make but general statements, namely, that it is long, that its dorsal border conforms with the cervical curve, and that its breadth, judging from the transverse series, is not wholly uniform.

The nucleus extends more than one-half the length of the medulla and corresponds in length, generally speaking, to the nucleus olivaris inferior. The distal end is slightly farther spinalward than the olive, being opposite the distal end of the median accessory olive. It lies lateral to the central canal before it opens out into the fourth ventricle. Farther toward the cerebrum, the nucleus is just beneath the floor of the fourth ventricle. Mention has been made of the slight curve in the fasciculus longitudinalis medialis which corresponds to this nucleus (Plate V). The accessory nucleus of Roller lies within the fasciculus longitudinalis medialis (Fig. 10) opposite the proximal end of the nucleus of the hypoglossal nerve.

The root-fibres of the nerve leave the nucleus from its ventral border (Plate IV). When modelled, the root bundle makes a sheet which passes ventralward and slightly lateralward to a superficial origin between the olive and the pyramidal tract. As seen from the side, this sheet has three borders—a distal, a proximal and a ventral. The distal border is shorter than the proximal, owing to its position on the cervical curve. It will be noticed that near the ventral surface of the medulla some of the root-fibres leave the surface of the sheet and turn lateralward. They enter the hilus of the nucleus olivaris inferior and there the bundle ends ab-

---

[1] They have been well pictured by Koch and termed Fibræ afferentes nu. XII. Cf. Edinger, L., Vorlesungen über den Bau der nervösen Centralorgane, Leipz. (1893), S. 180.

ruptly, for the sections were too decolorized to permit one to trace it to a superficial origin (Fig. 21).

The ventral border, namely, the line of the superficial origin of the fibres, has a slightly greater length than the nucleus. It lies in the groove between the pyramid and the olive. Its inferior limit is just distal to the olive, while its proximal end is at the junction of the medulla and pons. The surface of the sheet is smooth, except for the bundle of fibres that projects into the hilus of the olive. The direction of the fibres is worthy of attention. Starting from the ventral border of the nucleus the fibres pass ventralward and slightly lateralward to the level of the dorsal border of the olive. In passing the olive the fibres turn slightly more lateral, while farther ventral still the lateral curve is marked. The reason for these two curves will be evident. In the dorsal part only the medulla sheet intervenes between the middle line and the hypoglossal nerve. In the middle part, the medial accessory olive, as well as the medulla sheet, lies between the raphe and the nerve, while in the ventral region the pyramidal tract intervenes.

These points are shown in Fig. 31. The nerve can be traced through the following sections (Figs. 7-23): The first section shows a few cells of the nucleus, while Fig. 9 shows the fine fibres that aided in its determination. In all of the succeeding sections it will be noted that the root-fibres of the nerve pass out in small, definite bundles rather than as single fibres. By tracing the series the course of the fibres outlined above can be seen. In the dorsal part the fibres lie against the medulla sheet; in the middle part they lie between the medial accessory olive and in the inferior olivary nucleus, while in the extreme ventral portion the fibres are bent markedly from the middle line, owing to the volume of the pyramidal tract. The last two sections of the series give a good idea of the surface-origin.

(*b*) *N. Abducens.*—The N. abducens is the second nerve of the median group. Its nucleus makes a landmark in all of the views of the model, but shows best in Plates IV and V. In Plate IV it will be seen that a considerable distance (2.5 mm. in the medulla) intervenes between the nucleus N. hypoglossi and the nuclus N. abducentis.

The nucleus of the N. abducens lie in the distal part of the pons, just beneath the fourth ventricle and lateral to the fasciculus longitudinalis medialis. In this relation to the fasciculus longitudinalis medialis it differs from the other nuclei of the group, all of which lie dorsal to the tract and make a groove on its surface. The model will show that the fibres of the N. facialis in curving around the nucleus of the N. abducens appear to draw it from the middle line. The root-fibres leave the nucleus at its ventromedial portion, and pass ventralward and slightly spinalward to emerge between the pons and medulla near the median line.

The nucleus itself is nearly round, with a diameter of 1.7 mm. It projects above, that is to say, dorsal to the fasciculus longitudinalis medialis (Plate V). The relations of the root of the facial nerve to the nucleus of the N. abducens will be considered in detail in connection with the former nerve. The median boundary of the nucleus is made by the root-fibres of the facial nerve and by the fasciculus longitudinalis medialis (Figs. 6 and 7). The proximal boundary is made in part by the root of the facial nerve. The root-fibres of the N. abducens leave the medio-ventral part of the nucleus in small but dense bundles (Fig. 37). In passing to the superficial origin at the junction of the pons and medulla, these small bundles make a fairly compact bundle which passes ventralward and spinalward. In Plate V it will be seen, however, that the fibres describe a curve in their course, for in starting from the nucleus they pass first toward the cerebrum, as well as ventralward, before turning toward the cord. The bundle passes through the trapezoid body, and leaves the central nervous system just proximal to the groove between the medulla and pons.

The nucleus is prominent in both series: in the transverse series because it projects so far into the central gray matter; in the longitudinal series because it is so definitely outlined by the root of the facial nerve.

Fig. 36 and Fig. 37. In tracing the nerve in the transverse series, the curve, seen in Plate V, is slightly exaggerated by the obliquity of the sections (Fig. 53). Three sections will illustrate this point; Fig. 36, which shows simply the nucleus; Fig. 38, which shows the root-fibres just as they are leaving the nucleus and again at the superficial origin, and Fig. 39, which shows simply the middle of the curve with neither the nucleus nor the superficial origin.

The shape of the bundle in the dorsal portion is fairly rounded, as seen in Figs. 16 and 19, but farther ventral, near the superficial origin, the bundle becomes oval in shape, with the long axis perpendicular to the long axis of the pons. The fibres emerge from the lower part of the pons just proximal to the groove between the pons and medulla.

(c) *N. Trochlearis.*—In the case of the remaining two nerves of the group, the N. trochlearis and the N. oculomotorius, the nuclei of both sides have been modelled (Plates I, II and III). These nuclei lie in the trough of the fasciculus longitudinalis medialis on its midbrain curve. The walls of the trough, as has been seen, are hollowed out on either side of the deep central groove to receive them (Plate VII). The nucleus of the trochlear nerve lies farther distal and hence farther dorsal on the curve. It lies in the proximal part of the colliculus inferior (Plate II).

The nuclei of the two sides are not symmetrical, being single on the left side and double on the right. However, the volumes of the cell-masses of the two sides are about equal. In the case of the double nucleus, the proximal part is evidently the main nucleus, that is to say, it corresponds to the nucleus of the other side. The left or single nucleus is approximately cubical in shape, with a projection at the distal medial angle. It measures about 1 mm. in diameter. On the right side it is as if the small projecting portion had been pulled dorsalward until it just separated from the main mass.

This lack of symmetry of the nuclei of the two sides is brought out in the sections. The accessory part of the double nucleus, which lies farther dorsal and farther distal, shows on Fig. 10, while sections in Figs. 11 and 12 show the main nuclei of both sides. The transverse series does not show just the same irregularity, for in it the nuclei of both sides are double. Moreover the distal nucleus of either side lies at least 1 mm. from the proximal. The section in Fig. 44 shows this distal part, while Fig. 46 shows the main proximal part. In both sections the root-fibres of the nerve can be seen.

The nuclei of the nerve are compact and definitely outlined; nevertheless small groups of cells may be traced all along the root-fibres on either side. When the root-fibres leave the lateral and dorsal border they first pass lateralward in scattered bundles and then turn dorsalward and slightly spinalward. In their dorsal course the fibres are collected into from two to four compact bundles. The fibres lie in the central gray matter just within the stratum profundum album. Plate II shows the decussation dorsal to the central canal. The superficial origin of the fibres is asymmetrical. On the side of the single nucleus the fibres have a larger and more ventral superficial origin than those of the other side.

The course of the fibres can be traced in the longitudinal series in the following sections: Figs. 12-10 show the nucleus and its relation to the fasciculus longitudinalis medialis. It will be noticed that the section in

Fig. 12 shows no root-fibres, since it passes through the ventral portion of the nucleus. The root-fibres can be followed through the rest of the series from Fig. 10 to Fig. 3. They are to be distinguished from the fibres of the fasciculus longitudinalis medialis by a difference in direction. The last section, Fig. 3, shows the decussation.

By looking at the nerve in the model from the side and from the dorsal aspect, the appearances in the transverse series can be readily predicted (Plates I and II). The most distal section would show the decussation, while each succeeding section would show two or three small bundles cut across or slightly obliquely, and occurring a little farther ventral in each section until the level of the nucleus is reached, and here the fibres would turn directly medialward. This course can be followed in the following series, Figs. 41 to 46.[1]

(*d*) *N. oculomotorius.*—The N. oculomotorius is the last of the median motor group to be considered. The position of its nucleus is best seen from the dorsal surface (Plate II), but the course of the root of the nerve and the relations must be followed in a view from the side (Plate III). The nucleus as seen in Plate II is a long mass of cells lying in the midbrain trough of the fasciculus longitudinalis medialis. The root-bundle passes directly ventralward near the middle line and emerges in the fossa interpedunculare. The position of the nucleus in the trough of the fasciculus longitudinalis medialis determines two facts: (1) that the nucleus as a whole lies farther ventral than the nucleus N. trochlearis; (2) that the nucleus itself is placed obliquely to a horizontal plane, so that the distal end is farther dorsal than the proximal.

The oculomotor nerve is the only nerve in the central nervous system of which the nuclei of the two sides lie near enough together to be modelled as one. The nucleus as a whole consists of two lateral parts which are fused together in the ventral portion so as to make a gutter 3.1 mm. long for the median nucleus. The entire nucleus is 5.3 mm. long.

---

[1] The root-fibres have been described as making a double bend, passing at first dorsalward, then spinalward, and again dorsalward at a right angle. Cf. von Kölliker, A., Handbuch der Gewebelehre, Bd. II, Leipz. (1896); also Van Gehuchten, A., Anatomie du système nerveux de l'homme, 2 ed., Louvain (1897); and Barker, L. F., The Nervous System and its Constituent Neurones, N. Y. (1899), p. 938, et seq. This course does not appear on the model, which shows a gradual dorsal curve from the very start. Such an angle was not suggested in either of my series but there is no doubt that it might be missed in building the model. The matter might be settled by referring to sagittal sections. On the other hand Forel (Arch. f. Psychiat., etc., Berl., Bd. VII. [1897], S. 439) describes the course as it is shown in the model.

The shape of the combined mass is that of a triangular prism with the apex pointing ventralward and the base dorsalward. The dorsal surface is a triangle with the apex cut off. The distal end is the base of the triangle and the walls slant medialward, so that the proximal edge is about one-half the length of the distal. These two walls make the chief nucleus—the *Hauptkern* of the Germans.

The distal fourth of the nucleus is bounded definitely by the fasciculus longitudinalis medialis. In the next fourth of the nucleus, however, the cells scatter out into the fasciculus longitudinalis medialis, and these cells have been sacrificed to the fibres in the model (Fig. 48). These cells make the lateral part of the main nucleus as described by v. Bechterew.[1]

The median nucleus is clearly shown in Plate II. The small rounded proximal nuclei of v. Bechterew are shown as the proximal end of the main nucleus, but the small paired accessory nuclei did not come out clearly in the longitudinal series, though they were seen in the transverse series.

The following series taken from the transverse sections will show more details of the nucleus than have been introduced into the model (Figs. 47 to 50):

In the first place there are variations in the shape of the lateral nuclei: for example, Figs. 47 and 48 show an interesting contrast. The former shows cells spreading out to the side, making the outlines of the nucleus rounded, while the latter shows straight clean-cut sides narrowing to a sharp apex. Secondly, the sections show contrasts in the arrangement of the fibres within the nuclei. For example, compare the first two sections with the last two. Thirdly, the sections show that the median nucleus is not uniform. (Compare Figs. 48 and 49.) The longitudinal series shows practically the same points (Figs. 12 to 19). The last section, however, gives a different view of the anterior fused mass. All these details need a higher magnification.

Turning now to the course of the root-fibres after leaving the nucleus, it will be found that the best view is given in Plate III. This view shows the brachium conjunctivum, the stratum profundum album of the superior colliculus and the posterior commissure. The shell of deep white layer is connected with the fasciculus longitudinalis medialis. Through a space left in this shell a portion of the nucleus of the oculomotor nerve can be

---

[1] v. Bechterew, W., Ueber die Kerne des Oculomotorius, Abducens u. Trochlearis. Arch. f. Anat. u. Phys., Anat. Abth., Leipz. (1897), S. 308.

seen, while just ventral to this space the nerve-fibres emerge. The root-bundle runs ventralward between the brachium conjunctivum and the red nucleus to the superficial origin in the fossa interpedunculare.

The bundle representing the fibres appears to be an irregular one, but that is merely because it is encroached upon by other structures. Were it not for these, the bundle would be nearly regular in outline. The root-bundle can be considered as divided into two parts: (1) the part extending from the nucleus of the nerve to the ventral surface of the red nucleus including about three-quarters of the length of the bundle, and (2) the portion ventral to the red nucleus. The reason for this division can be made plain. In passing from the nucleus the fibres spread out to the side and make a bundle which fits around the distal surface of the red nucleus (Fig. 48). This makes the greatest breadth of the bundle in a transverse diameter. On the other hand, the second portion covers the exit zone of the nerve-fibres where the entire bundle rotates so that its broad side faces the surface of the fossa interpedunculare (Fig. 51). This is to be seen from the mesial aspect, but the idea can be obtained from Plate III. It is important to note that this relation of the shape of the bundle does not involve any rotation of the fibres. The first portion of the bundle has two curves: (1) a curve in a dorsoventral diameter which is concave toward the spinal cord and enables the bundle to fit in between the decussation of the brachium conjunctivum and the nucleus ruber; (2) a curve in the transverse diameter with the convexity toward the cerebrum by which the bundle accommodates itself to the ventral surface of the nucleus ruber. It must be stated that some of the nerve-fibres pass directly through the nucleus ruber, so this curve is only an arbitrary one. Opposite the extreme ventral part of the nucleus ruber the bundle is separated by a considerable space from the nucleus inasmuch as the surface of the nucleus curves away from the plane of the nerve

Of the irregularities on the surface of the bundle only one is due to the nerve-fibres themselves, namely, the projection on the lateral border near the dorsal surface. This is due to the fact that just ventral to the lemniscus medialis the nerve-fibres spread out laterally. The other irregularities are due to spaces left for other structures: (1) a nucleus in the lateral capsule of the red nucleus,

(2) a little mass of cells I have referred to as nucleus columnaris, and (3) the fasciculus retroflexus (Meynerti) (Plates III and VI).

The shape of the bundle can best be seen in the longitudinal sections (Figs. 16 to 24).

In the transverse series the nerve-fibres show in the same sections as the nucleus. The obliquity of the section must be taken into account in comparing it with the model. The transverse sections show well how some of the fibres pass through the nucleus ruber and the substantia nigra (Figs. 47 to 50).

This completes the description of the median group of nerves, and the group characteristics will now be plain. First, all the nerves are purely motor. Second, all the nuclei lie near the midline ventral from the central canal. Third, all are embedded in the fasciculus longitudinalis medialis except the nucleus of the N. abducens, which lies farther lateral than the others, possibly due to the knee of the facial nerve. Fourth, the fibres of each nerve are collected into small definite bundles soon after leaving the nucleus. Fifth, three of the nerves pass directly ventralward, while the trochlear nerve passes dorsalward and decussates dorsal to the central canal.

The relation of this group of nuclei to the medial part of the ventral horn of the cord is clearly illustrated by the model, and motor cells can be traced in the sections from the ventral horn all along the border of the medulla sheet to the nucleus of the hypoglossal nerve (Plate V). On the other hand, no such scattered cells exist between the hypoglossal nucleus and the nucleus of the N. abducens, for it is characteristic of the cerebral nerves, in contrast with the spinal, that their nuclei form definite and isolated groups of cells rather than a part of a column of cells. This distinction is being broken down by the recent work of Kaiser, Sano, van Gehuchten and others on the groups of cells in the spinal cord.

2. The Lateral Group.

The nerves of the lateral group are the N. accessorius, N. vagus, N. glossopharyngeus, N. cochleæ, N. vestibuli, N. intermedius, N. facialis and N. trigeminus. Instead of considering them serially, I propose to divide their nuclei into motor and sensory groups. The motor group contains four nuclei, the nucleus N. accessorii, the nucleus ambiguus of the N. vagus and N. glossopharyngeus and the nucleus N. facialis and the nuclei N. trigemini, while the sensory group has many nuclei belonging to the N. vagus, N. glossopharyngeus, N. acusticus, N. intermedius and N. trigeminus. This grouping is of value in two ways: it brings out the contrast (1) between the motor nuclei of the median group and those of the lateral, and (2) between the motor and sensory nuclei of the lateral group. Both of these distinctions are, in reality, distinctions of development. In Plate IV is shown the lateral group of motor nuclei and the course of the root-fibres of the nerves. The lateral funiculus of the cord has been removed in part in order to show the floor of the trough in which lie the ventral horn-cells.

A.—MOTOR NERVES.

(*a*) *N. accessorius.*—The part of the model representing the spinal cord has been added on from another series (Plate IV). Into this portion no details have been introduced. Thus it happens that only the extreme proximal part of the spinal portion of N. accessorius is illustrated. With regard to the study of the "vagus portion" of the nerve, considerable difficulty has been met with and it does not appear in the model.

Spinal portion.—The nucleus of the spinal part of the N. accessorius has not been represented. At the beginning of the medulla oblongata the large motor cells of the ventral horn scatter out into the formatio reticularis, so that it is quite impossible to group them into a nucleus. As has been said, some of these motor cells can be traced all the way from the definite ventral horn to the nucleus of the hypoglossal nerve. On the other hand, the cells lying farther to the side give rise apparently to the root-fibres of the N. accessorius. In brief, here is the point at which the motor cells of the cord divide into the two groups, the median and the lateral groups of the medulla.

It will be seen in the model that at least some of the root-fibres of the N. accessorius, instead of passing directly from their cells of origin to the lateral groove, pass dorsalward and then turn ventralward and lateralward toward the superficial origin.[1] The fibres, in their dorsal course, I shall refer to as the pars prima, and, in the ventrolateral course, as the pars secunda. Inasmuch as the bundle in the model represents but a few fibres of the nerve, it can

---

[1] Edinger, L. Bau der nervösen Centralorgane, Leipz. (1893), S. 168.

be taken to represent the nerve as a whole only in a general way. The general direction of the loop of the fibres is of interest, namely, that the loop is placed obliquely with reference to the transverse plane and the pars prima lies slightly farther toward the cord than the pars secunda. From this it will be seen that the pars prima and pars secunda would not be cut in the same transverse section. This is true, however, only in part, for certain of the fibres do not pass so far dorsalward, and these fibres lie in approximately the same transverse plane throughout their course (Fig. 25). On the other hand, Fig. 26 shows the longer fibres of the N. accessorius and includes only the pars secunda. The presence of these longer and shorter fibres shown in a diagrammatic form, gives an interesting suggestion of an easy transition from the condition of the cord.

The two transverse sections given above represent the spinal portion of the nerve. The same portion is shown in the longitudinal series in Figs. 17 and 16. Fig. 17 shows a very definite pars secunda and a small pars prima, while the second section shows these two portions of the nerve nearer together, that is passing toward the loop.

The question of a "vagus portion" of the nerve has been a difficult one; first, on account of the indefiniteness of the nucleus ambiguus, and, secondly, on account of the difficulty of finding the fibres in longitudinal sections. A definite nucleus of the vagus part of the N. accessorius has not been made out in either series, but there are motor cells scattered throughout the formatio reticularis of the region between the N. accessorius and the nucleus ambiguus shown in Plate IV.

In tracing the transverse series from the distal end of the medulla, where the spinal part of the nerve is clearly made out (Figs. 25 and 26) to a region, which is clearly that of the vagus nerve, it is certain that there are fibres corresponding to the description of the N. accessorius (Figs. 28 and 29). In the sections of this region certain points are of interest. First, no section contains a definite pars prima, though certain sections, as Fig. 27, have small bundles of fibres within the central gray matter suggesting a pars prima; a few sections show fibres of the nerve making a loop as well as a pars secunda. From a complete series of the N. accessorius it would be easy to construct a diagram showing how the N. accessorius is a transition in form between the nerves of the spinal cord and the N. vagus.

In the longitudinal series the nerve-fibres of the vagus portion must be cut across or nearly so and thus are exceedingly difficult to trace.

Near the level of Fig. 14 a few delicate fibres are seen cutting across the lateral funiculus of the cord. They were not definite enough to introduce into the model.

(*b*) *N. glossopharyngeus and N. vagus.*—The motor fibres of the N. hypoglossus and N. vagus make the second member of the lateral motor group (Plate IV). The nucleus ambiguus could not be determined in the horizontal series, for the longitudinal fibres of the formatio reticularis wholly obscure the cells. An oblong block representing the position of the nucleus has been made from a comparison with the transverse series and introduced into the model. This block does not represent the shape of the nucleus. In determining the length of the block, only those sections have been included which show a definite group of cells related to the fibres of the N. glossopharyngeus and N. vagus (Fig. 33). In this way the proximal limit of the nucleus could be made out definitely, but the distal limit was indefinite. I did not include in the nucleus any of the scattered motor cells lying in the formatio reticularis between the levels of the distal end of the dorsal accessory olive and the lower end of the medulla, though these cells are commonly called a part of the nucleus ambiguus. The block in the model corresponds to the region of the root-fibres of the glossopharyngeal and vagus nerves. It lies in the formatio reticularis, dorsolateral to the dorsal accessory olive and lateral from the tract from Deiters' nucleus to the spinal cord (Fig. 33). It lies at the same horizontal level as the nucleus N. facialis (Plate IV).

The root-fibres, starting from the nucleus, pass medialward and dorsalward to the floor of the fourth ventricle. In this part of their course I have called the fibres a pars prima. At the floor of the ventricle the fibres turn sharply to pass ventralward and lateralward, thereby making a pars secunda. The fibres of the pars secunda take the same course as the entering sensory fibres passing to the ala cinerea (Plate III). In this plate it is well shown that the fibres of the two nerves pass through the tractus spinalis N. trigemini. The loop made by the root-fibres of the N. glossopharyngeus and N. vagus lies transversely, so that the nucleus, pars prima and pars secunda all show in one section. In longitudinal series the fibres are cut across, and the pars prima thus becomes too delicate to be made out, while the fibres of the pars secunda are plain (Fig. 12).

(*c*) *N. facialis.*—The N. facialis is the third nerve of the group (Plate IV). Its nucleus lies at the same horizontal level as the nucleus ambiguus. It is situated in the distal part of the pons just dorsal to the level of the corpus trapezoideum. Moreover, it lies in the slight angle which the tract from Deiters' nucleus to the spinal cord makes with the lemniscus lateralis. The nucleus is a compact, oval mass of cells with its long axis parallel to the long axis of the pons. Its length is about 2 mm.

The course of the fibres is well known. The pars prima leaves the dorsal surface of the nucleus in the form of a round bundle 1 mm. in diameter. In this bundle the fibres are distinct and somewhat scattered. It passes medialward and dorsalward to the distal surface of the nucleus N. abducentis. Here the bundle curves around the latter nucleus, making the knee, or genu internum (Plates II, III and IV). In the knee the fibres form a small compact bundle which runs directly cerebralward along the medial margin of the nucleus, then turns sharply lateralward along the proximal border. This second part of the knee slopes very slightly ventralward (Plate IV), and ends abruptly at the lateral margin of the nucleus, where the bundle turns ventralward. The pars secunda is a small dense bundle more than twice as long as the pars prima. It plunges into the corpus trapezoideum just lateral to the nucleus olivaris superior, and leaves, just ventral to the bundle which enters the trapezoid body from the ventral nucleus of the cochlear nerve. From here the bundle passes to its superficial origin at the distal end of the pons. In Plate IV it can be seen that the pars prima and knee pass forward, that is, toward the cerebrum, but the pars secunda passes so far toward the cord that the superficial origin is in the same transverse plane as the nucleus.

The course of the fibres can be best followed by noting the lines of the sections on the diagram in Fig. 52 and comparing them with Plate IV. For example, the section Fig. 36 passes through the nucleus and the pars prima, Fig. 37 includes the longitudinal part of the knee and part of the pars secunda, while Fig. 38 shows the transverse part of the knee and the pars secunda.

In tracing the nerve in the longitudinal series it will be best to start with a dorsal section and thus pass toward both the nucleus and the superficial origin (Figs. 6 to 19). Fig. 6 shows the longitudinal and Fig. 7 the transverse fibres of the knee. From this it can be seen that transverse fibres are farther ventral than the longitudinal. In Fig. 9 the fine fibres of the pars prima (N. VII (a.) are in contrast to the dense black bundle of the pars secunda. The crescent shape of the pars secunda is maintained almost the entire extent of the bundle. Fig. 12 shows the nucleus of the facial nerve with the pars secunda just lateral from it. The nucleus is seen similarly in the next section (Fig. 13), but here the pars secunda is found plunging into the corpus trapezoideum. Within the trapezoid body the fibres scatter but can be made out in almost every section (Fig. 16). In emerging from the trapezoid body, the bundle again becomes clear and distinct (Fig. 19).

(*d*) *N. trigeminus.*—The last motor nerve of the lateral group is the N. trigeminus. The entire nerve is shown in Plate III, and the motor part can be seen in Plate IV.

The nucleus motorius princeps N. trigemini, lies in the middle of the pons, just proximal to the transverse part of the knee of the facial nerve. It is at a level ventral to the nucleus of the N. abducens and dorsal to the nucleus of the N. facialis. The distal end lies opposite the proximal end of the nucleus olivaris superior. The nucleus is oblong in shape, and its long diameter (1.6 mm.) lies in a dorsoventral direction. From the distal dorsal angle a small spur projects. This part of the nucleus shows on Figs. 9 and 38.

In comparing the motor and sensory roots of the N. trigeminus, as seen on Plate I, the two bundles seem of equal size; nevertheless, the motor root has been called the portio minor and the sensory the portio major. The reason of this apparent discrepancy is plain in Fig. 16, which shows that the motor fibres, which are few and scattered, cover as great an area as the closely packed sensory fibres.

The fibres of the portio minor border the entire lateral surface of the nucleus (Plate IV). Against the nucleus of the fibre bundle is curved so that in longitudinal section it forms a crescent (Fig. 8), but ventral to the nucleus it becomes triangular in section and passes directly ventralward, parallel to the entering sensory bundle.

In longitudinal series the nucleus shows well on Figs. 8 and 9; the root-fibres can be traced through Fig. 21. The distinction between the motor and sensory roots shows especially clearly (Figs. 13 to 19). In the transverse sections the motor nucleus shows on Figs. 38 and 39. The fibres adjacent to the nucleus show in Fig. 39. Ventral to the nucleus they can not be definitely separated from the sensory root-fibres.

The question of the radix descendens N. trigemini is a difficult one. The bundle is easy to model throughout most of its course, but at a most important point, namely, the distal end, where it comes into relation with the main part of the nerve, it is difficult to trace. The radix descendens (mesencephalica) N. trigemini, starts at the distal border of the stratum album profundum (Plate IV). At first sight it looks as if the fibres of the deep white layer might be continuous with the nerve, but closer inspection shows that in reality the nerve bundle lies just medial to the deep white layer (Plate II). The descending root traverses the pons as a narrow bundle (.2 mm. in width) parallel to the raphe. The dorsoventral diameter of the bundle measures on the average 1.2 mm., and throughout this part of its course the bundle lies embedded in the locus cæruleus. The locus cæruleus is a long flat nucleus, triangular in shape. It extends about half the length of the pons.[1] Within the locus cæruleus the nerve fibres are scattered, but opposite the main motor nucleus of the nerve the bundle becomes small and compact and then plunges directly ventralward.[2]

These relations will be made clear in the longitudinal sections before passing on to the more difficult question of the distal end of the bundle. The longitudinal sections are very valuable for the study of this part of the nerve, for a single section shows the entire course of the fibres from the proximal end of the bundle to the point at which the bundle turns ventralward. Fig. 5 shows the break in the continuity of the stratum album profundum just opposite the nucleus colliculi inferioris. The nerve bundle in this section corresponds to the bundle in Plate II of the model. Fig. 6 shows the locus cæruleus (not labeled) and the fibres of the descending root within it.

At the level of Fig. 7 there are many fibres apparently connecting the gray matter of the pons and midbrain, and these fibres are hard to distinguish from those of the root of the N. trigeminus. After determining the proximal end of the nerve in the longitudinal series it is not difficult to fix the point on the transverse series by noting the shape of the stratum album profundum. This will be clear by tracing the series (Figs. 51 to 45). On the last section will be noted the distinct bend of the bundle toward the median line.

The distal end of the nerve is difficult to trace in sections. Starting with Fig. 5 the distal end of the nerve turns ventralward and is seen in Fig. 6 just lateral to the bundle marked β. In Fig. 7 the fibres are near little groups of cells. In Fig. 8 the relation to the motor root is evident. The black coarse fibres of the motor root make a contrast with the delicate fibres of the mesencephalic root just lateral. Below this level the fibres are difficult to trace, but, together with the little groups of cells, they are seen as far as the level of the section (Fig. 9) which passes through the sensory nucleus of the N. trigeminus (substantia gelatinosa Rolandi).

---

[1] The locus cæruleus of the model probably includes the cells related to radix descendens (m) N. trigemini.

[2] This agrees with the description of Ramón y Cajal. Op. cit., S. 14.

In the transverse series the fibres are cut longitudinally in their ventral course and so can be followed to much better advantage. In Fig. 39, it will be noted, that on the left side of the section the mesencephalic root runs directly past the motor nucleus, through the sensory nucleus to the root of the N. trigeminus. This section should be compared with a Golgi section of a fœtal mouse given by Ramón y Cajal[1] in which the descending root definitely enters the main motor nucleus. In Fig. 39 the bundle on the left side just as definitely passes by the motor nucleus, but on the right side it runs directly to the motor root where it lies adjacent to the motor nucleus, thus corresponding with Ramón y Cajal's picture. A section (Fig. 38) shows the mesencephalic root splitting up as it enters the sensory nucleus. Thus it is clear that neither the sections nor the model decide whether the mesencephalic root is related to the motor nucleus, to the sensory nucleus, or to the root-bundle.

In the view of the dorsal surface of the model (Plate II) can be seen a small bundle of decussating fibres which lies just proximal to the transverse part of the knee of the facial nerve (Plate II). The bundle has been cut off to show the motor nucleus of the N. trigeminus. In reality, it spreads over this motor nucleus (see Fig. 7, N. v. dec.). This decussation has been called a motor decussation. Ramón y Cajal[2] says, however, that in no case has he seen any evidence of a motor decussation of the trigeminal nerve. The model adds weight to the view that this decussation is sensory, for the bundle passes directly over the motor nucleus and ends dorsal to the proximal end of the sensory nucleus.

Having now described the separate nerves of the lateral motor group and their nuclei, it will be well to note the points which they have in common. In this consideration the radix descendens N. trigemini, will be left out, since I am unable to place it.

The group characteristics are as follows: (1) The four motor nuclei in the series all lie in the lateral region at a level distinctly ventral from the central canal. (2) They all lie in the formatio reticularis. (3) As regards the course of the fibres, it is easy to group the root bundles of the first three together, namely, those of the N. accessorius, N. glossopharyngeus et vagus and N. facialis, inasmuch as each root-bundle has a pars prima and a pars secunda. The first two form a sharp angle at the junction of these two parts, while the N. facialis, in curving around the nucleus N. abducentis,

---

[1] Ramón y Cajal. Op. cit., Fig. 4, S. 15.

[2] v. Ramón y. Cajal. Op. cit., S. 16.

has its angle developed into a "knee." The pars prima of all these nerves consists of fine scattered fibres, the pars secunda of dense compact bundles. Such an agreement, of course, cannot but suggest development under similar circumstances. The motor root of the N. trigeminus, however, forms no such loop. Its fibres pass directly ventralward from the main nucleus. In considering this point, it is to be noted that its nucleus lies farther dorsal than any of the other nuclei of the group, and that the horizontal plane occupied by the nuclei of the group is filled in this region, not by formatio reticularis fibres, but by the definite and compact bundles of the lateral and medial lemnisci. The motor part of the N. trigeminus then seems to lack a pars prima.

B.—SENSORY NERVES.

The model shows the nuclei of four sensory cerebral nerves: (1) the sensory part of the N. vagus and N. glossopharyngeus, (2) N. intermedius, (3) the N. vestibuli and (4) the N. cochleæ. The optic nerve, though it has an end station in the superior colliculus, will not be included in the group, for it is probably not comparable with the other cerebral nerves, but corresponds rather to a tract inside the central nervous system.[1] All of the nuclei of this group lie in the lateral region dorsal to the level of the lateral motor nuclei; this is in accord with their correspondence morphologically to the dorsal horn of the cord.

(*a*) *N. glossopharyngeus and N. vagus* (*sensory*).—In describing the sensory nerves, I shall start in each case with the fibres as they enter the neural tube. The entering fibres of the glossopharyngeus and vagus nerves can be divided readily into two distinct groups: first, scattered fibres passing directly to the ala cinerea, and, second, a compact bundle passing into the tractus solitarius. Almost immediately after entrance, the fibres of both sets plunge either through or over the tractus spinalis N. trigemini, and hence are shown in the plate that represents that nerve (Plate III). The ala cinerea and the tractus solitarius, however, are seen best from the dorsal surface (Plate II).

Fibres to the ala cinerea.—The entry zone of the root-bundles of the glossopharyngeal and vagus nerves corresponds to about the

---

[1] Barker, op. cit., pp. 541-543 and pp. 782-783.

proximal third of the medulla oblongata (Plate III). The fibres passing into the ala cinerea cover fully two-thirds of this area. Their entry zone begins just proximal to the nucleus funiculi cuneati, at about the point where the most proximal of the direct cerebellar fibres pass dorsalward to enter the corpus restiforme (Plate I). It extends to the place of entry of the compact bundle making the tractus solitarius. The fibres to the ala cinerea enter as small scattered bundles, not to be distinguished from the motor fibres passing out. Since these bundles are too small to be modelled accurately, they are represented diagrammatically in Plate III. The sensory fibres pass dorsalward and medialward through the fibre-bundle and nucleus of the tractus spinalis N. trigemini. Beyond this nerve they continue in a direct course to the floor of the fourth ventricle. Here the fibres end in the nucleus alæ cinereæ. In entering the nucleus, the fibre-bundle as a whole does not split into an ascending and descending bundle, as do the tregeminal and vestibular root-bundles.[1]

The nucleus alæ cinereæ, as seen in Plate II, is a long narrow nucleus placed obliquely across the floor of the fourth ventricle. It lies parallel to the tractus solitarius, and is, at the same time, both dorsal and medial to it. The extent of the nucleus is about 6.2 mm., and its proximal end is 2.9 mm. from the median line. The distal end is placed directly dorsal to the nucleus N. hypoglossi near the raphe. The nucleus is nearly uniform in width, averaging about 1 mm. The model shows an interesting relation between the nucleus and the root-bundle, namely, that the root-bundle runs simply to the proximal end of the nucleus, and does not cover even a half of its length. Moreover, the fibres from the entering bundle cannot be traced running to the distal end of the nucleus, as in the tractus solitarius. However, there are fibres running between the nucleus alæ cinereæ and the tractus solitarius throughout the region not covered by the root-bundle fibres to the nucleus alæ cinereæ [2] (Plate II).

The full extent of the nucleus alæ cinereæ can be seen in Figs. 5 and 6. The second section shows the nucleus more clearly, for the cells have

---

[1] Ramón y Cajal, op. cit., S. 44. Barker, op. cit., S. 479.

[2] According to Held certain of the root-fibres send one branch to the tractus solitarius and the other to the ala cinerea. Held, H., Die Endigungsweise der sensiblen Nerven im Gehirn., Arch. f. Anat. und. Physiol., Anat. Abth., Leipz. (1892), S. 33-39.

taken the stain deeply. It is not possible to outline the nucleus accurately with low powers, for there are almost no fibres within the nucleus. Both sections show the fibres crossing between the nucleus alæ cinereæ and the tractus solitarius. With a Leitz Obj. 3 these fibres are much more abundant than they appear in the low-power drawings. In transverse series the nucleus shows in Figs. 31 and 29. In the second section it is made out only with high powers.

Tractus solitarius.—The fibres that make up the tractus solitarius enter as a definite, compact bundle on the lateral surface of the proximal part of the medulla (Plate III). This bundle enters at a level proximal to the entry zone of the fibres which go to the nucleus alæ cinereæ. The bundle passes dorsalward along the lateral surface of the tractus spinalis N. trigemini, rather than plunging obliquely through it, as do the fibres to the nucleus alæ cinereæ (Plate III). Thus it happens that the fibres which go to the tractus solitarius do not pass through the substantia gelatinosa (Fig. 34). At the dorsal surface of the tractus spinalis N. trigemini, the bundle arches medialward and dorsalward, curving over the substantia gelatinosa Rolandi, and then passes spinalward between the nucleus alæ cinereæ and the nucleus funiculi cuneati (Plate II). The bundle in the model includes not only the fibres of the tract, but also the cells which surround it, namely, its nucleus. Cells can be traced all along the length of the tract, but in two regions the nucleus is especially well developed, namely, at the proximal and distal ends. The nucleus of the proximal end is a small mass of cells which lies medial to the root-bundle at the point, where it turns spinalward, just ventral to the level of the medial vestibular nucleus (Plate II). It is not shown in the plate, but it lies between the proximal ends of the tractus solitarius and the nucleus alæ cinereæ. This nucleus extends farther cerebralward than the root-bundle fibres, and in this connection it should be noted that the entire root-bundle turns spinalward. The nucleus is readily made out in longitudinal sections by the basket-work-like arrangement of its cells and fibres (Fig. 7, Nu. tr. Sol.). It has been suggested that this part of the nucleus is related to the fibres of the N. intermedius.

The nucleus of the distal end of the tractus solitarius, possibly the commissural nucleus of Ramón y Cajal[1] is seen in Plate II.

---

[1] Ramón y Cajal, op. cit., S. 46. Barker, L. F., op. cit., S. 486.

The fibres of the tractus solitarius lie parallel to the nucleus alæ cinereæ; but beyond the spinal end of the nucleus alæ cinereæ a bundle of the fibres from the tract turns ventralward and plunges into a small nucleus which lies close to the raphe just medial to Burdach's nucleus. The complete course of the tractus solitarius, measuring from the proximal edge of its root bundle to the distal end of this commissural nucleus is 9.1 mm.

The points illustrated by the model are readily confirmed in sections. The compact entry bundle, and the fibres running to the distal nucleus, or commissural nucleus of Ramón y Cajal, are shown in Fig. 9. The entry bundle is more definite on the left side of the section.

The series from Fig. 7 to Fig. 5 will show the relations of the tract itself; its position, its oblique course, its relation to the nucleus alæ cinereæ and to the nucleus funiculi cuneati. The sections in which the fibres are fewest, show best the cells that accompany them, as well as the fine fibres crossing to the nucleus alæ cinereæ. In Fig. 7 the nucleus of the proximal end is seen, but the nucleus of the distal end is farther ventral.

In transverse section, the distal nucleus is well shown in Fig. 28. The tract itself hardly needs illustration (Fig. 31). Fig. 34 shows how the definite compact bundle skirts along the border of the fibres of the tractus spinalis N. trigemini, and passes medialward to the proximal nucleus of the tract. This proximal nucleus is still to be seen in Fig. 35 (left side).

(*b*) *N. trigeminus.*—The motor part of the N. trigeminus has already been described, but it will be of value to refer to it again on account of its sensory part. Plate III is designed to show the entire nerve which, it will be noted, covers almost the extent of the model, namely, the entire medulla oblongata the pons, and at least half of the midbrain.

The sensory fibres of the N. trigeminus enter the lateral surface of the pons just distal to the motor bundle. The fibres form a compact bundle, which passes nearly directly dorsalward past the lemniscus lateralis into the region of the pars dorsalis pontis (Plates I and III). After passing dorsalward a distance of 6.2 mm. from the surface of the pons, the bundle bifurcates into a Y. Into the notch of this Y fits the upper end of the nucleus. The lateral and larger arm of the Y passes dorsalward a distance of 2.7 mm. and then turns at an angle of 90° toward the spinal cord, making the long tractus spinalis N. trigemini. The medial and smaller arm of the Y passes dorsalward just medial to the nucleus. It does not show in the plates, being hidden by the nucleus; but it grows thinner in its dorsal course as if many of its fibres were ending. The model suggests that the inner arm of the Y contains the ascending branches of the bifurcating root-fibres, and that they end in the proximal part of the nucleus which makes a wedge in the fork of the Y.

The tractus spinalis N. trigemini is unfortunately shown only from the lateral aspect in which it appears as a long band of fibres (Plate III, labeled Radix N. trigemini). It was not introduced into the view from the medial aspect (Plate VI), inasmuch as it would entirely hide the cochlear nuclei and their relation to the corpus trapezoideum. Its position can be imagined on the left side of Plate VI. It extends from the middle of the pons to the substantia gelatinosa Rolandi of the spinal cord, which is to be seen just lateral to the nucleus funiculi gracilis. It lies medial to the cochlear nuclei and radix N. facialis, pars secunda, and lateral to the nuclei of the dorsal funiculi.

The tractus spinalis N. trigemini is a long tract in the shape of a trough, the lateral wall of which is nearly complete, while the floor and medial wall are complete only in the proximal half. However, the division line between the fibre-bundles and nucleus is not a clear-cut one, for fine bundles of fibres pass spinalward between the cells, especially in the proximal part of the nucleus.

The lateral wall of the trough is derived from the expansion of the lateral limb of the Y (Plate III). As seen from the surface, it is a broad band which gradually narrows in passing toward the spinal cord to a point about 3 mm. from the distal end of the medulla oblongata, where it expands into a sort of cap which fits over the nucleus. This wall completely conceals the nucleus from a lateral view except at the two ends.[1] At the proximal end the large wedge of the nucleus, which fits into the fork of the Y, is only in part covered by fibres, and at the distal end the ventral part of the nucleus projects beneath the level of the tract. This distal end is concealed in Plate III by the lateral funiculus of the spinal cord (cf. Fig. 25). The lateral wall of the trough is cut by the root-fibres of the N. glossopharyngeus and N. vagus in the manner already described. In the proximal third of the tract the

---

[1] For a resumé of the different views which have been advanced concerning the distal end of the tractus spinalis N. trigemini, see Barker, L. F., op. cit., pp. 517-528.

lateral wall underlies the descending root of the vestibular nerve, and it was impossible to determine the absolute line of separation between the two. As seen from the medial aspect, the lateral wall curves into the ventral wall or floor so that the two make a crescent, in which the nucleus lies. From the medial surface of the lateral wall fibres enter the nucleus all along its course, but at the distal end one large bundle cuts across the dorsal part of the substantia gelatinosa (Plate III). In consequence of the ending of the fibres, the walls grow progressively thinner. In Plate III is to be seen the relation of this lateral wall of the tract to the spinal cord, namely, that the tractus spinalis N. trigemini passes directly into Lissauer's fasciculus. The ventral and medial walls of the trough are not shown in the plates. The ventral wall appears to be simply a curving of the lateral wall underneath the nucleus. It is clearly derived from the lateral arm of the Y and extends a little more than half the length of the tract. The medial wall appears shorter than the ventral. Its fibres are derived from the medial arm of the Y. It fades out at its distal end opposite the area of the motor root-fibres of the glossopharyngeus and vagus nerves (Plate III), and the internal arcuate bundle from the nucleus funiculi cuneati (Plate VI). These medial descending fibres of the N. trigeminus are most clearly shown in a section by Ramón y Cajal.

The sensory nucleus of the trigeminal nerve has already been referred to in describing the fibres (Plate III). The nucleus conforms in shape to the tract except at the two ends. The proximal end is a wedge which fits into the fork of the Y, while the distal end projects below the ventral border of the tract. The proximal end of the nucleus shows best in the small view accompanying Plate III. The fact that the entering sensory bundle bifurcates into a Y has already been mentioned and is indicated by the lines on the sensory root-bundle. The medial arm of the Y runs just behind the nucleus, as seen from the side, and is parallel to the motor root, the edge of which shows just dorsal to the sensory nucleus. The proximal end of the nucleus is a forked wedge that fits into this fork of the fibre bundle. Internal to this wedge of the nucleus and covering much of its mesial surface, are the ascending sensory fibres side by side with the motor root, while external to the nucleus,

---

[1] Ramón y Cajal, op. cit., S. 4. The fibres of this tract are shown in Bruce's Atlas, as the descending fibres of the vestibular nerve.

at least in its ventral part, are the descending sensory fibres. Inasmuch as the nucleus is forked, a little spur of cells must be imagined as projecting on the medial surface ofthe fibre-bundle to correspond with the ventral tip of the nucleus seen from the side.

The dorsoventral diameter of this wedge of the nucleus is 2.7 mm., fully twice the corresponding diameter of the central part of the nucleus. It consists of cells so closely packed that it is evident that here the nucleus is well developed. Reference has already been made to the fact that the ascending branches of bifurcation of the sensory nerve fibres appear to end in it.

The nucleus of two-thirds of the spinal tract corresponds so closely to the shape of the fibres as not to be seen from the surface view of the model. In the distal third, however, the nucleus again shows an enlargement. This makes the nucleus project ventralward beneath the fibres. In the model the direct cerebellar tract lies just lateral from this part of the nucleus and, therefore, hides it (Plate III). The point, however, is shown clearly in section (Fig. 25). The lateral view shows that the nucleus of the tractus spinalis N. trigemini is a direct continuation of the substantia gelatinosa of the spinal cord. The dorsal horn of the spinal cord will be seen to swell into a rounded mass in approaching the medulla oblongata (Plate VI), which is continuous with the nucleus of the spinal tract of the N. trigeminus (Plates I and III).

The proximal wedge, or main nucleus, is continuous with the substantia gelatinosa. The dorsal edge of the nucleus is somewhat irregular. In the proximal third it shows an indentation where the fibres of the lateral wall of the trigeminal trough almost meet the medial wall. At the junction of the upper and middle thirds, the edge slants ventralward as it passes toward the spinal cord. This dorsal edge gradually broadens out into a surface toward the spinal end; this surface is cut obliquely by a bundle of fibres from the lateral wall. Over the end of the nucleus the lateral wall rounds up and fits like a cap. The ventral edge of the nucleus has been described; it is smooth except for the projecting forked proximal end and the bulging, rounded distal end.

The course of the nerve is seen far better in longitudinal sections than in the transverse (Figs. 19 to 12). Starting with the root-bundle in Figs. 19 and 17, it will be noticed how easy it is to separate the sensory from the motor root. Fig. 14 shows the ventral tip of the main nucleus or wedge, where it projects even farther ventralward than the tract itself. The next section (Fig. 13) passes through the ventral wall of the tract and shows the main nucleus. Fig. 12 passes through the entire nerve and shows many of its relations. Beginning at the proximal end, the main nucleus is well developed and lies just lateral from the motor root and medial arm of the Y. The medial and lateral arms of the Y are both plainly shown. The lateral arm of the Y becomes the lateral wall of the tract. The medial wall shows best on the right side and it ends opposite the bundle of the fibræ arcuatæ internæ. The nucleus likewise is seen in its full extent; its cells can be traced all the way from the main nucleus to the large substantia gelatinosa of the spinal cord. Between the lateral and medial bundles it is narrow, but toward the lower end of the section, it gradually broadens out, until it projects markedly from the surface of the cord.

The nerve can be traced through a long series of transverse sections (Figs. 39 to 25). Fig. 39 makes an interesting study in connection with Plate III. It shows (1) the sensory root bundle at the point of bifurcation into a Y, (2) the forked sensory nucleus which fits into the Y, the medial tip of the fork being very clear, and (3) the motor nucleus with its root-bundle just external. In the next five sections can be seen the nucleus, the thick lateral and ventral walls, and the thin medial tract. In Fig. 31 only the lateral fibre wall remains, but the nucleus is growing larger. Fig. 29 shows the lateral wall becoming more massed against the dorsal part of the nucleus, while in the last section, the dorsal fibre cap is clear. In this section the nucleus is evidently the rounded substantia gelatinosa.

In describing the motor nucleus, I referred to a decussation lying in the floor of the fourth ventricle just proximal to the transverse part of the knee of the facial nerve. The model can not settle the question as to whether this decussation is motor or sensory, but it certainly leads weight to the idea that it is sensory, for the fibres pass beyond the motor nucleus.

(*c*) *N. vestibuli.*—Thus far, in considering the sensory nerves, it has been found, first, that their nuclei are related to the dorsal part of the medulla oblongata and pons, and, secondly, that the intracerebral parts of the nerves consist in the main of long descending tracts with cells immediately adjacent. One part of the acoustic nerve, namely, the vestibular, conforms in the main to this type, while the other part, the cochlear nerve, is wholly different. The cochlear and vestibular nerve-roots enter together at the lower end of the pons (Plate I). The vestibular bundle lies proximal to the cochlear and is easily distinguished from it. The two nerve-roots pass dorsalward together, showing a slight spiral curve around each other so that the cochlear root partially surrounds the vestibular (Plate I). The cochlear nerve soon breaks up into the nucleus N. cochleæ ventralis, which, together with the fibres passing from it, completely surrounds the vestibular root-bundle

(Plates I and VI). Dorsal to the level of the ventral cochlear nucleus, the vestibular root continues its course between the corpus restiforme and the tractus spinalis N. trigemini until it reaches a level dorsal to the latter; here the bundle breaks up into ascending and descending bundles which lie exactly parallel to the tractus spinalis N. trigemini (Plates I and III). The vestibular nerve does not cover as extensive an area in the model as does the N. trigeminus. In reality, the areas of these two nerves cannot be compared, however, until the full course of the vestibular fibres to the cerebellum is known.

The view of the dorsal surface of the model shows the general relation of the ascending and descending vestibular fibres (Plate II). The point at which the root divides into its two parts is in the same transverse plane as the distal surface of the nucleus N. abducentis. The descending fibres make a long, narrow tract which passes toward the cord parallel to the corpus restiforme. The dorso-ventral diameter of the tract is greater than the transverse (cf. Plates II and III). In Plate II can be seen that the descending tract is tilted so that the dorsal surface is nearer the median line than the ventral.

The ascending bundle is broader than the descending. It passes obliquely lateralward and cerebralward adjacent to the corpus restiforme (Plate II).

In order to understand the ascending bundle in the model, it is necessary to make certain explanations: (1) its relation to the cut made in removing the cerebellum and (2) its relation to the superior vestibular nucleus. In regard to the cerebellum, its relation to the model is best seen in Plate I, where the cut surfaces of two of the cerebellar peduncles, namely, the corpus restiforme and brachium conjunctivum are plain. In Plate II the cut surface extends across (1) the edge of the corpus restiforme, (2) the surface of the ascending vestibular bundle, (3) the edge of the adjacent superior vestibular nucleus, and (4) the edge of the brachium conjunctivum. Thus it is seen that in cutting off the cerebellum a portion of the ascending vestibular bundle has been removed. The relation of the ascending fibre-bundle of the model to the nucleus N. vestibuli superior will be plain in Fig. 5. On the right side of the section the area proximal to the line labeled Nu. N. vest. l. is the nucleus N. vestibuli superior. Its lateral portion contains the ascending fibres and has been modeled as the ascending bundle; its medial half consists almost entirely of cells and has been modeled as the superior vestibular nucleus. The bundle of the ascending vestibular fibres is a complex one; it contains at least three sets of fibres and many cells of the nucleus N. vestibuli superior. These fibre-bundles are (1) a lateral set, which lie adjacent to the corpus restiforme (Plate II), and run toward the nucleus N. vestibuli lateralis (Plate III), (2) short scattered fibres that enter the nucleus N. vestibuli superior, (3) scattered fibres that enter the cerebellum from the cut surface shown in Plate II. They constitute a medial bundle. These two bundles will be made plain later.

Plate II gives the best idea of the form and relations of the nuclei of the vestibular nerve. In general, the vestibular nuclei might be divided into two parts. First, a great mass of cells lying for the most part medial to the vestibular tract, including its ascending and its descending roots. It includes the medial and superior vestibular nuclei. Secondly, two small masses of cells situated opposite the root-bundle, one lateral and the other medial to the tract and main nucleus. These are the parts of the nucleus N. vestibuli lateralis (cf. Plate III). The vestibular nuclei are difficult to outline from the central gray matter both on the medial and the lateral borders.

Taking first the main mass of cells, its outlines are irregular, but they can be related to surrounding structures (Plate II). The nucleus is divided by an hour-glass-like constriction into two unequal parts. This constriction is opposite the root-bundle and its meaning is evident if one notes that into the angle thus formed the lateral recess of the fourth ventricle dips down. This is to be seen by comparing the two sides of Plate II. The nucleus N. abducentis lies opposite this angle of the vestibular nuclei. The part of this nuclear mass lying proximal to the constriction corresponds to the ascending fibres and has been called the nucleus N. vestibuli superior, while the distal and larger portion corresponds to the descending root and has been called the nucleus nervi vestibuli medialis.

Nucleus N. vestibuli medialis.—The nucleus N. vestibuli medialis lies in the floor of the fourth ventricle (Plate II) between the nuclei of the N. hypoglossus and N. abducens. It is 6.8 mm.

long. In the proximal part it consists of a mass of cells reaching nearly to the median line. Toward the distal end the nucleus narrows rapidly as it runs along the border of the radix descendens N. vestibuli. The curve made by this rapid narrowing is occupied by the nucleus of the tractus solitarius and the ala cinerea. The dorsal surface of the nucleus is practically level in the lateral part, but the medial part slopes like a terrace toward the middle line.

By this curve of the surface the nucleus conforms in shape to that of the floor of the fourth ventricle. In the depth of the proximal part of the nucleus the cells are closely crowded. This area was referred to as nucleus Y in a previous paper, but the fact that it is an integral part of the nucleus N. vestibuli medialis is clearly shown in the model. In among the fibres of the descending vestibular tract can be traced cells which are not shown in the model. These cells have been called the nucleus nervi vestibuli spinalis (radix descendens).

Nucleus N. vestibuli superior.—As has been said, a portion of the nucleus N. vestibuli superior has been removed in cutting off the cerebellum, but nevertheless the main features can be made out. The relation of the superior nucleus to the ascending root-bundle has already been pointed out. The superior nucleus and fibre-bundle together extend well into the region of the motor nucleus of the N. trigeminus. The medial border of the nucleus makes an angle with the medial nucleus and extends forward parallel to the raphe. The lateral border is the line of the cut by which the cerebellum was removed.

Nucleus N. vestibuli lateralis.—Thus far the vestibular nuclei, both superior and medial, have conformed to the type of sensory nuclei already described; that is to say, they are masses of cells scattered along, ascending and descending fibre-tracts. On the other hand, the two small masses previously mentioned as occurring opposite the root-bundle, are quite different in character. Turning to the lateral view (Plate III) there is a small nucleus, trapezoid in shape, lying embedded in the root-bundle just dorsal to the point at which it divides into ascending and descending branches. On the other hand, from the dorsal view (Plate II), two small nuclei can be seen: (1) the mass just mentioned, lying lateral to the vestibular tract and (2) a mass in the angle between the superior and medial vestibular nuclei. These two masses lie opposite one another at the same dorsoventral level. They are in reality parts of a single nucleus, the nucleus N. vestibuli lateralis, for the motor cells of which they are made are scattered among the fibres that separate the two parts in the model.

The longitudinal sections give the best idea of the vestibular nuclei and roots. The main points, except the entering root-bundle can be seen in two sections (Figs. 5 and 6). The ascending and descending tracts can be distinguished, for the division line is marked, first, by the nucleus N. vestibuli lateralis; and second, by the distal border of the nucleus N. abducentis (see Fig. 5). An interesting point in connection with the shape of the descending tract is shown, namely, that its proximal third curves lateralward and thereby gives room for the widest portion of the medial nucleus. The root-bundle can be traced through Figs. 6 to 17. On Fig. 13 it is enclosed by the nucleus N. cochleæ dorsalis.

In regard to the nuclei, Figs. 4, 5 and 6 show that there is a continuity between the cells of the medial and superior nuclei as well as all the cells scattered between the ascending and descending root-fibres. The lateral portion of the nucleus N. vestibuli lateralis is plain in Figs. 5 and 6. The medial part is only made out with higher powers. In transverse section the radix descendens N. vestibuli can be traced through Figs. 31 to 36. The last section shows the entering root-bundle. All of these sections show the cells between the fibres and the medial nucleus. The medial nucleus is well developed from Figs. 33 to 36. Fig. 36 shows the root-bundle, the nucleus N. vestibuli lateralis, and the distal part of the nucleus N. vestibuli superior. This nucleus can be traced in Figs. 37 and 38.

Thus far, in describing sensory nuclei, no tracts of the second order from these nuclei, nor any special tracts, save the nerve-roots, have been described. This is because such tracts have not been definite enough to introduce into the model. In connection with the vestibular nuclei, however, several such tracts are to be described. (1) Internal arcuate fibres from the medial nucleus, (2) a commissure between Bechterew's nuclei, (3) a tract from Deiters' nucleus to the spinal cord, and (4) two sets of fibres relating to the vestibular area with the cerebellum.

(1) Thus far only two sets of arcuate fibres have been mentioned, namely, the bundles from the nucleus funiculi gracilis and nucleus funiculi cuneati. A glance at the longitudinal section (Fig. 9) will show that the entire region proximal to the nucleus funiculi cuneati is very rich in fine arcuates. These are to be related to the sensory cerebral nuclei. Fig. 33 shows such fibres from the trigeminal and vestibular nuclei. In the longitudinal series it can be seen that a great bed of arcuate fibres underlies the medial

vestibular nucleus, as can be made out by tracing the nucleus through the sections in Figs. 5, 6 and 7. These fibres were not modelled, since they cannot be separated into a definite group.

(2) In describing the superior cerebellar peduncle, reference was made to the fact that the distal decussation was really related to the superior vestibular, or Bechterew's nuclei (Plates I and VII). This bundle underlies the proximal end of Becterew's nucleus. The decussating fibres are readily distinguished from the brachium conjunctivum in the model, first, by the fact that they turn lateralward toward the superior vestibular nucleus, and, second, by the fact that they form a ridge on the medial surface of the brachium conjunctivum, which can be traced to the decussation.

The entrance of this bundle into Bechterew's nucleus is best seen in Figs. 6 and 7. Fig. 6 is slightly torn. This decussation has been traced in connection with the brachium conjunctivum through Figs. 7 to 16 and Figs. 43 to 37.

(3) The bundle from Deiters' nucleus to the spinal cord has already been described and notice taken of the fact that it is not possible in these sections to trace this bundle all the way from the nucleus.

(4) In a previous paper[1] mention was made of two bundles of fibres connecting the vestibular nuclei with the cerebellum, one lying in the medial border of the inferior peduncle or corpus restiforme, the other passing through the superior peduncle or brachium conjunctivum. Fig. 6 (F. v. c. [o.]) shows the lateral bundle with its coarse black fibres cut obliquely. The bundle appears to run toward Deiters' nucleus. The medial bundle passing through the brachium conjunctivum cannot be distinguished in the longitudinal series from the fibres ending in the superior vestibular nucleus. In the transverse series it can be traced in Figs. 34 and 35. The contrast between these two bundles is brought out by following their direction. The lateral bundle follows the course of the corpus restiforme, and is seen entering the cerebellum on section No. 182, Fig. 36 (cf. with the oblique lines on Fig. 52). The mesial bundle is last seen in the roof of the cerebellum on section No. 146, Fig. 33. It passes spinalward, while the other bundle

---

[1] On the Anatomical Relations of the Nuclei of Reception of the Cochlear and Vestibular Nerves. Johns Hopkins Hosp. Bull., Balt., vol. viii, (1897), pp. 253-259.

passes cerebralward. It is important to relate these two bundles as nearly as possible to the vestibular cerebellar bundles as described by Ramón y Cajal.[1]

(*c*) *N. Cochleæ.*—The nerve enters the pons just distal to the N. vestibuli (Plate I). The bundle passes dorsalward a distance of 1.6 mm. growing gradually wider until it spreads out into a nucleus. This nucleus is rectangular in shape, placed vertically against the corpus restiforme. From the surface it appears to be one continuous nucleus, but it has received two names, nucleus N. cochleæ ventralis and the nucleus N. cochleæ dorsalis. There is a reason for this division, however. even from form alone, for the ventral portion of the nucleus is thick and projects beneath, that is, ventral to the corpus restiforme, while the dorsal part, on the other hand, is a thin layer lying against the surface of the corpus restiforme (Plate I). The division is also justified on histological grounds. I wish to lay especial emphasis on the relative position of these two nuclei on account of an error in a previous paper. The previous flat reconstruction was made from cross sections taken slightly obliquely which threw the dorsal nucleus farther spinalward than is shown in the model. In point of fact, the dorsal nucleus lies dorsal to the ventral. The relative thickness of the two nuclei is best seen in the view from a dorsal aspect, which is given to show the relations to the corpus trapezoideum (Plate VI).

From what has already been said, it is evident that the cochlear nerve has no long descending tract similar to the other sensory cerebral nerves. The central paths leading from the nuclei of termination of the cochlear nerve pass cerebralward.

In Plate VI the fibres from the ventral nucleus can be traced. Two bundles leave the nucleus and pass medialward, forward and ventralward. They enclose the vestibular root, then fuse and pass medialward to become part of the trapezoid body (Plate III). The

---

[1] Ramón y Cajal speaks of the vestibular cerebellar bundle as lying in the border of the corpus restiforme and corresponding to the fibres described by Forel, Sala and v. Koelliker, namely, the lateral vestibular fibres of v. Koelliker. He says that the bundle has end stations in Deiters' nucleus, Bechterew's nucleus, Ramón y Cajal's cerebello-acustic nucleus and the nucleus of the roof. It is the medial bundle of my series that runs to the nucleus of the roof (Fig. 35) but this bundle passes through the brachium conjunctivum, not the corpus restiforme.

trapezoid body has already been mentioned in connection with its relation to the medial lemniscus. It is a bar of fibres stretching across the floor of the pars dorsalis pontis. The bar is thickest in its dorsoventral diameter (2.7 mm. approximately). On either side, 2.7 mm. from the raphe the nucleus olivaris superior lies embedded in the trapezoid body. Between the two nuclei of either side the bar is straight; but lateral to the superior olive the bar curves dorsalward and spinalward owing to the position of the nucleus nervi cochleæ ventralis.

The superior olive is a mass of cells ovoid in shape. It does not show the scroll shape of the corresponding nucleus of the cat. The other nuclei relating to the trapezoid body could not be outlined with sufficient definiteness to be introduced into the model.

The further course of the auditory path beyond the trapezoid body is shown in the views from the side (Plates I, IV and V). These views show well the relation of the lateral lemniscus to the corpus trapezoideum. The lateral lemniscus starts as a large bundle of fibres directly dorsal to the superior olive, passes dorsalward through the pons and into the midbrain. It forms a narrow band which lies at first adjacent to the medial lemniscus, but soon becomes separated from the superior lemniscus by a narrow area.

Though called lateral lemniscus, it does not lie as far lateralward as the medial lemniscus in this region. In the bundle of the model is a long groove which runs the full length of the bundle and opens into the space occupied by the superior olive. This groove contains the nucleus of the lateral lemniscus. The nucleus is, in reality, surrounded by fibres, but the lateral fibre-wall has been removed to show the area occupied by the cells.[1] At the beginning of the midbrain, the band of the lateral lemniscus fuses with the superior lemniscus and becomes molded into the capsule of the nucleus colliculi inferioris. The shape of this capsule is best seen in Plates VI and VII, which show that the fibres make a lateral, distal and dorsal wall for the nucleus. This capsule is not clearly defined in sections as is the capsule of the nucleus funiculi cuneati. However, in the lateral border of the nucleus the fibres are more

---

[1] That the nucleus is directly connected with the nucleus olivaris superior is quite in accord with the views of Roller and Held. Ramón y Cajal on the other hand does not agree, inasmuch as the character of the cells and the course of the fibres differ. Ramón y Cajal, op. cit., S. 100.

densely crowded than elsewhere. Only the distal wall of the capsule is thick, for it receives the main bulk of the lateral lemniscus fibres (Plate VI). The nucleus colliculi inferioris itself is oval in shape, with the long diameter in the dorsoventral direction. It fits accurately into the capsule made by the fibres.

There are four small bundles of fibres to be considered in relation
to the lateral lemniscus: (1) a bundle which projects from the 1
proximal edge of the capsule and appears to pass toward the region
of the medial geniculate body (Plate II), (2) a small bundle which
runs between the lemniscus lateralis and the brachium conjunc- 2
tivum (Plates II, VI and VII). It is placed just distal to the capsule of the nucleus colliculi inferioris. (3) Many scattered fibres
appear to leave the medial surface of the capsule to enter the 3
superior colliculus. (4) In Plate II there are two small bundles that decussate dorsal to the central canal and connect the nuclei of the inferior colliculi of the two sides.

Nucleus N. cochleæ dorsalis.—Turning now to the dorsal cochlear nucleus (Plate I), the model does not trace the fibres from it as completely as those from the ventral nucleus. In Plate II there is a small bundle of fibres—the striæ acusticæ—running from the dorsal edge of the nucleus obliquely forward and medialward across the descending vestibular tract.[1] It becomes lost in the medial vestibular nucleus, inasmuch as its fibres probably plunge ventralward to join the corpus trapezoideum, and in so doing pass through a complex formatio reticularis region.

As has been said, the model covers a considerable portion of the cochlear path—the dorsal and ventral nuclei, the fibres of the trapezoid body, the superior olive, the lateral lemniscus, the nucleus of the inferior colliculus and the arm of the medial geniculate body.

The form relations seen in the model are readily verified in the sections (Figs. 20 to 4). In the longitudinal series, the entering root-bundle of the nerve is seen on Fig. 20. The same section shows a few fibres of the extreme ventral portion of the trapezoid body. In passing dorsalward, the region of the trapezoid body is reached before the ventral cochlear nucleus. In Fig. 16 the trapezoid body is well seen; its relations to the superior olive and the straightness of its fibres between the two olivary nuclei are evident. On the right side of the section can be

---

[1] According to Held the striæ acusticæ are only sparingly medullated in the cat at birth. v. Held, H., Die centralen Bahnen des N. acusticus bei der Katze. Arch. f. Anat. u. Phys., Anat. Abth., Leipz. (1891), S. 274.

seen the fibres passing from the ventral cochlear nucleus to the trapezoid body. Fig. 14 shows the nucleus N. cochleæ ventralis, as well as the origin of the lateral lemniscus. In passing still farther dorsalward two structures can be traced: (1) the lateral lemniscus passing into the nucleus inferioris colliculi, and (2) the dorsal cochlear nuclei and its striæ acusticæ. In Fig. 12 the nucleus of the lateral lemniscus is well marked, and on the right side, the beginning of the dorsal cochlear nucleus. The longitudinal sections bring out the contrast between the dorsal and ventral cochlear nuclei well. Compare Figs. 14 and 9. In Figs. 7 to 5 the relations of the lateral lemniscus to the nucleus inferioris colliculi are well brought out as well as the bundle passing to the medial geniculate body. In the last two sections, the bundle passing between the lateral lemniscus and the superior peduncle is clearly shown. Still farther dorsalward, the nucleus colliculi inferioris becomes more and more developed and the fibres of the striæ acusticæ are seen (Fig. 4).

In the transverse series the nucleus N. cochleæ dorsalis is seen in Fig. 33, the nucleus N. cochleæ ventralis, in Fig. 35. Fig. 36 shows the beginning of the corpus trapezoideum, which is seen best on Fig. 39. From the superior olive the lateral lemniscus can be traced in its course to the midbrain through Figs. 40, 41 and 42. Fig. 43 shows well the relative positions of the lateral lemniscus and the superior lemniscus. The gap between them, it will be noticed, is filled by very fine fibres, apparently belonging to the lemniscus lateralis. The lemniscus lateralis lies slightly farther medialward than does the lemniscus superior.[1]

PART III.

NUCLEUS OLIVARIS INFERIOR.

Position.—The surface form of the olive, as seen on the uncut medulla, is familiar. The nucleus itself extends from the proximal limit of the decussatio pyramidum to the distal limit of the pons. It lies in the ventral portion of the medulla oblongata, lateral to the stratum interolivare lemnisci, from which it is separated by the root-fibres of the N. hypoglossus and the median accessory olive. Dorsal to the olive lies the large area of formatio reticularis in the medulla oblongata, but the lateral and ventral aspects of the olive are superficial. Opposite the distal half of the lateral surface is a considerable mass of medullated fibres belonging to the lateral funiculus of the spinal cord, but only one small bundle of these fibres extends opposite the proximal half of the olive (Plate III).

The dimensions of the olive are as follows: The dorsoventral

---

[1] The preceding description corresponds, in the main points, with the work of Held. It does not, of course, illustrate the details of the direction and course of the fibres. Cf. Held, Arch. f. Anat. u. Phys., Anat. Abth., Leipz. (1893).

diameter 4.48 mm., the transverse 6.5 mm., and the anteroposterior 7.5 mm.

The gray matter of the olive forms a hollow shell with a wrinkled wall. In the model it is made nearly solid inasmuch as, with the magnification used, its walls made strips of wax too thin to handle. It presents for examination six surfaces—dorsolateral, lateral, ventral, proximal distal and medial—the last surface including the hilus. The dorsolateral surface, as its name indicates, slopes toward the lateral surface and passes over into it by a gradual curve. On the other hand, the ventral surface is practically level, but likewise rounds onto the lateral surface. This corresponds to the familiar form of the olive in cross-section (Fig. 35).

In Plate VIII, Fig. 1, is shown a lateral view, including the dorsolateral surface. The general outline of this view is of interest. The dorsal border is practically level. Starting from the distal end of the nucleus, the outline passes ventralward and forward by a gradual curve which reaches its most ventral point at the proximal end of the ventral surface. This will be recognized as the curve of the olive seen on the uncut medulla. The proximal border is slightly curved and represents the edge that faces the pons.

The surface of the olive is marked by deep sulci and more shallow grooves, so that the whole suggests the surface of a brain. From the view of the lateral surface it will be noted that all of these grooves run in an approximately dorsoventral direction.

The dorsal or dorsolateral surface shows three sulci. They are approximately parallel and divide the dorsal part of the olive into four lobes. These sulci are distinguishable from the other grooves on this surface in being deeper, for they reach down to the opening of the hilus as can be seen in Fig. 19. The sulci do not pass over onto the curve of the lateral surface, which is marked by comparatively shallow grooves that more or less alternate with the deep sulci of the dorsolateral surface. From this fact it follows that the lobes are well marked only in the dorsal portion. It is evident that transverse sections of the olive would be all comparatively similar over the lateral curve, but would differ on the dorsolateral surface, according as the section passed through a sulcus or a lobe. This will be clear by comparing Figs. 31 and 32.

Of the four lobes, the first or proximal is the largest (Plate VIII, Fig. 1, L. p.). It is subdivided in the dorsal portion by two or three fairly deep grooves. The first sulcus runs a little obliquely, the dorsal end being further spinalward than the ventral. The first lobe has three surfaces (1) a dorsolateral, (2) a proximal and (3) a mesial. In other words, the first lobe curves around the proximal end of the nucleus to the mesial surface, so as to enclose a portion of the hilus. This explains why a cross-section of the proximal lobe shows the gray matter as a complete ring (Fig. 36). The first lobe is made up of three convolutions, or gyri, two of which are seen from the lateral view and the other from the mesial.

The second and third lobes consist each of a single convolution, or gyrus. They present but one surface, directed dorsolaterally. At the dorsal border they are comparatively narrow, but broaden out in joining the lateral surface.

The fourth lobe forms the distal end of the olive and is the smallest of all, consisting, like the second and third, of a single convolution or gyrus. It does not curve around the hilus as does the first lobe (Fig. 20). Nevertheless, the lobe is placed obliquely, so that a cross-section of the extreme distal part is a small closed ring, the same as the cross-section of the proximal lobe.

The surface of the lobes and the sides of the sulci are marked by small grooves which run in a dorsoventral direction. Indeed, in the depth of the sulci are small folds in the nuclear wall. These can be seen in longitudinal section (Fig. 19).

The lateral surface forms the curve of the shell. Its dorsal margin (Plate VIII, Fig. 1) is an indistinct line where it curves onto the dorsolateral surface. Its ventral border makes the curve of the surface form. This curve or ventral border is so placed that the distal part of the lateral surface is narrow, that is, the part opposite the fourth lobe. The greatest breadth of the lateral surface is at the proximal end. The entire surface is covered by shallow grooves, of which the deepest alternates with the first and second sulci. It is worthy of note that all of the grooves of this surface run in a dorsolateral direction, as do those of the dorsolateral surface.

The ventral surface is smaller than the dorsal (Plate VIII, Fig. 2). It is for the most part horizontal, but at the spinal end it passes by a gradual curve onto the distal surface (Fig. 33). In its surface markings it contrasts with the dorsolateral and lateral surfaces, for instead of taking a dorsoventral direction, its grooves all radiate out from a point in the ventral border of the hilus (Plate VIII, Fig. 2). This point is opposite the word mesial in the figure. Thus it happens that while the distal groove runs transversely, as do those of the dorsolateral surface, the proximal groove runs longitudinally parallel to the raphe and at right angles to the grooves of the dorsolateral surface.

The grooves of the ventral surface are not marked by secondary furrows, as are the sulci of the dorsolateral surface. As has been said, these grooves appear to radiate from a point about the middle of the ventral border of the hilus. The first or most medial of these grooves (s. p.) runs directly parallel to the long axis of the olive, that is, in an anteroposterior direction. It is a deep groove and extends far dorsalward on the median surface, separating off a small gyrus from the main lobe. This is seen only on a view of the mesial surface which, unfortunately, is not given. The second (S. s.) passes obliquely toward the cerebrum and becomes continuous with one of the grooves of the lateral surface. The third (S. t.) lies still more obliquely and does not leave the ventral surface. The distal part of the ventral surface is somewhat damaged, inasmuch as the sections were here a little too much decolorized in preparation, but enough can be made out to say that the grooves run transversely and are the continuation of the grooves of the lateral surface.

The medial surface is not given in the plates. It shows the hilus. From this aspect it can be seen that the ventral part of the olive makes a floor for the hilus and the dorsal part, a roof (Fig. 33). The proximal end of the hilus is closed in by the first lobe (Fig. 20). Opposite each lobe of the surface is a deep groove in the cavity to which the hilus leads, and the sides of these main grooves are marked again by grooves which correspond each to one convolution of the external surface. In brief, the essential points of the form of the olive are (1) its general shape as a hollow shell, (2) its hilus, (3) its transverse grooves on the dorsolateral surface, and (4) its radiating grooves on the ventral surface.

The olives of both sides were modelled in the effort to see if the fissures above described offered a basis of symmetry. The symmetry proved to be sufficiently apparent to lead one to an emphasis of the differences. The three deep fissures of the external surface, as well as the three radiating grooves of the ventral aspect, corresponded in the two lines. The differences consisted in the relative size of two of the lobes. The first lobe of the right olive was larger than the corresponding lobe of the other side, while the fourth lobe of the right side was proportionately smaller. The term proportionately is accurate, inasmuch as the two olives are of the same length and the second and third lobes correspond in size on the two sides. The symmetry of the two olives is shown in Fig. 19. At this level the fourth lobe of the right side is but a single fold in the nuclear wall.

It is now necessary to relate the appearance of the sections to the form of the olive in the model. A typical cross-section, so to speak, shows the thin folded wall and the open hilus (Fig. 33). Attention has already been called to the fact that the form of the wall varies according as a section passes through a sulcus or a lobe (Figs. 32 and 33). It will be noticed that, inasmuch as the sulci run slightly obliquely, no one section passes through the entire length of one sulcus. The sulci can be used in determining the symmetry of an olive cut in cross-section. In tracing the olive of the cross series of the same stage, it is found that the first lobe of one side is larger and the fourth smaller than the corresponding lobes of the other side, the same peculiarity that has been noted in the model. I have, however, no method of determining right and left side of either series as compared with a real medulla.

Sections in a longitudinal direction differ widely from those of the transverse series; they illustrate the symmetry of the olive, that is they show the relation of the lobes and sulci and the varying depth of the sulci and grooves far better than the transverse series (Figs. 16 to 23). The first section shows the dorsal border of the olive. In the next three sections the symmetry can be traced, and note made of the relative size of the first and fourth lobes. The relation of the wall of these two lobes to cross-sections is evident, that is, the obliquity of the fourth lobe and the curve of the wall of the first account for the closed circles at either end in the transverse series. The last three sections pass through the ventral wall and the direction of the sulci is the point of special interest.

In the various longitudinal sections it will be noted that there are groups of cells either as rings or as irregular figures, that are wholly separate from the main wall; some of these lie within and some without the hilus (Fig. 19). These can be understood by reference to the transverse series. If, for example, in Fig. 33, a transverse line is drawn across the dorsal wall of the olive, it will cut off rings of cells, and these rings will be of two types: (1) a ring from a fold that projects on the lateral surface, and (2) a ring from a fold that projects into the hilus. The rings of the first type lie without the hilus and have their outer margin corresponding to the surface of the olive; the rings of the second type lie within the hilus and have their inner margin corresponding to the surface of the olive. This is a practical point in modeling the olive.

Nucleus olivaris accessorius medialis.—The medial accessory olive is an irregular nucleus, much broken by bands of fibres running through it. It lies opposite the main olive, between the interolivary layer of the lemniscus and the root-bundle of the N. hypoglossus (Plate IV). Its inferior limit extends farther spinalward than the nucleus olivaris inferior, but its proximal does not reach as far cerebralward. From the view of the lateral surface (Fig. 2), it consists of three columns of cells running in a dorsoventral direction. Each of the columns has small separate masses of cells opposite its dorsal border. The first or distal column is by far the largest. Its ventral portion is thick and a prominent process from the distal ventral angle curves around the distal border of the N. hypoglossus and the main olive (Plate VI). It makes an indentation in the ventral part of the medulla sheet (Plate V). At the proximal ventral angle the first column connects with the second. The dorsal border of the first column shows a spur of cells from the distal half, while corresponding to the proximal half is a small separate group of cells. The spur corresponds to the second indentation on the medulla sheet (Plate V). The second column is thin and flat; opposite its dorsal border are two small masses of cells. The third column is about one-third as broad as the others; it makes a narrow column of cells, opposite the dorsal end of which is still another small nucleus.

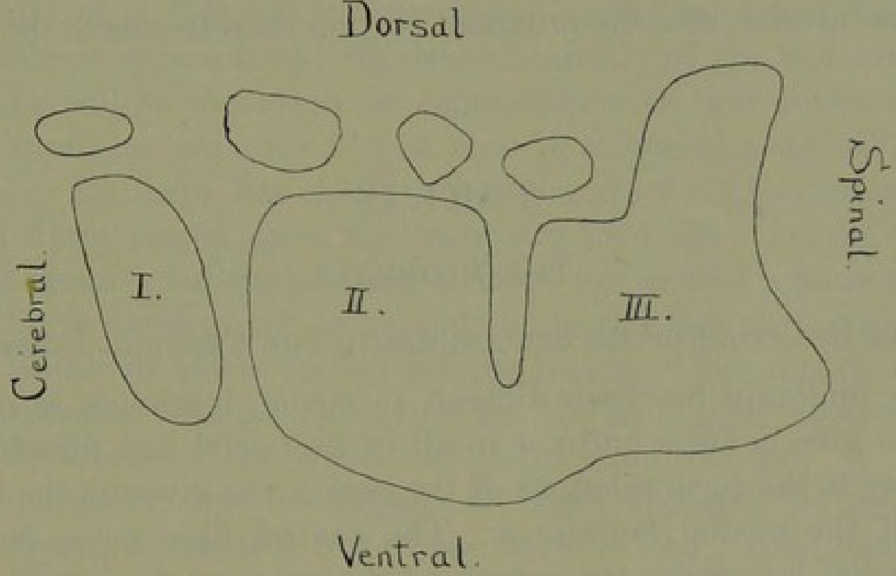


FIG. 2.—Diagram of Nucleus olivaris accessorius medialis.

In longitudinal sections these relations are clear. Fig. 20 passes through the three columns near the ventral border. The first, which is clearly the largest, appears curving around the inferior border of the main olive. The root-fibres of the N. hypoglossus cut through it. The second and third columns need only be mentioned. Passing dorsalward, we have the three columns, making groups of cells between the fibres of the N. hypoglossus and the stratum interolivare lemnisci (Fig. 19). Fig. 17 shows the scattered groups of cells of the medial-accessory olive. Cross-sections, in Fig. 29, is seen the ventral part of the first column. This is, however, much better developed in Figs. 30 and 31. In Fig. 32 the second column is present, while in Figs. 33 and 35 the third column is seen.

The nucleus olivaris accessorius dorsalis is not shown in the model, but Fig. 15 shows its shape. It varies in shape on the two sides. The distal portion lies dorsal to the third lobe of the nucleus olivaris inferior, and the proximal portion corresponds to the second lobe.

PART IV.

THE MIDBRAIN.

1. The Relation of its Structures to the Central Fibre Mass.

The midbrain has been difficult to model, inasmuch as it is not easy to give definite outlines to all of its nuclei and fibre-bundles. The key to the form relations of the region was given in the description of the medial lemniscus. The central fibre mass, including the medial lemniscus, the superior lemniscus and the lateral part of the capsule of the red nucleus, is placed obliquely in the midbrain and divides it into two areas. The medial area contains the red nucleus, a formatio reticularis area, the nuclei of the oculomotor and trochlear nerves and the fasciculus longitudinalis medialis (Plates II, VI, VII), while the lateral area contains the substantia nigra, and, later in course of development, the pyramidal tract (Plate I). In the view from the lateral surface given in Plate I, the midbrain sheet is shown, with the substantia nigra in place. In Plate IV the substantia nigra has been removed and the complete fibre sheet is thus revealed. In a third view (Plate III) the fibre-sheet itself has been removed and the whole midbrain medial to it is visible. In the ventral portion is seen the nucleus ruber and its capsule; dorsal to it is the space for the formatio reticularis, while toward the median line can be seen the fasciculus longitudinalis medialis, the stratum profundum album of the superior colliculus, together with the nucleus and root-fibres of the oculomotor nerve. These three views give a general idea of the whole area. The form relations of the region are (1) the great size of its nuclei, namely, the nucleus ruber and the substantia nigra and (2) the deflection of the medial lemniscus, apparently due to the development of the nucleus ruber. In describing the midbrain, then, the relations of the fibre-sheet will first be considered, secondly, the structures that lie medial to it, and finally, those that lie lateral to it.

The fibre-sheet as a whole has been described in connection with the medial lemniscus, and reference will be made here only to those parts of it that belong essentially to the midbrain, namely, the lemniscus superior and the lateral capsule of the red nucleus. The latter will be considered in connection with that nucleus.

The lemniscus superior is best seen in a lateral view (Plates I and IV). Its shape has already been described; it is a triangular sheet of fibres placed upon the lemniscus medialis. In the model the only means of distinguishing it from the medial lemniscus lies (1) in the thinness of the sheet and (2) in the fact that, while the medial lemniscus passes on beyond the region of the model, and is therefore shown with a square cut edge, the lemniscus superior ends within the limits of the model and has a rounded edge.

The lemniscus superior appears to begin opposite the proximal part of the pons, where a few of the fibres of the medial lemniscus seem to radiate from the main bundle, making a fairly thick sheet at the start, which, however, grows thinner as it becomes wider. A further point of interest is that the dorsal border of the superior lemniscus comes to lie adjacent to the capsule of the nucleus colliculi inferioris.

The transverse series shows many interesting points in regard to the lemniscus superior. In Fig. 40 there is no distinction to be made between the medial and the lateral lemnisci; but by passing farther cerebralward to Fig. 42, it becomes evident that the two separate; between them is an area of fine fibres, those of the lemniscus superior. In Fig.43 the fibres of the lemniscus superior are passing farther dorsalward. This shows clearly on the model. The lemniscus superior lies even farther lateral than the lemniscus lateralis itself. The next section (Fig. 44) shows interesting relations. The nucleus colliculi inferioris has almost disappeared. The lemniscus medialis is gradually curving into its characteristic midbrain position and the superior lemniscus is making its way to the region just lateral from the capsule of the nucleus of the inferior colliculus. Figs. 46, 47 and 48 take the superior lemniscus well into the region of the superior colliculus, and here the fibres are few, fine, and cut in cross-section. The transverse series is not complete enough to show the proximal limit of the lemniscus superior. In the longitudinal series, on the other hand, the lemniscus superior is apparently complete and the sections show that it does not pass beyond the midbrain (Fig. 12). Three sections will show the relative widths of the lemniscus medialis and the lemniscus superior: (1) Fig. 16, which shows the lemniscus medialis. (2) Fig. 13, a transition, and (3) Fig. 12, which shows the lemniscus superior. In this last section, as well as in Fig. 9, the superior lemniscus borders the large area of gray matter in the superior colliculus and, indeed, appears to have some relation with its cells. Indeed, there is a closely packed group of cells, almost a definite nucleus, opposite the end of the tract.[1] In passing still further dorsalward it becomes impossible to distinguish the superior lemniscus from the capsule of the nucleus colliculi inferioris (Fig. 7); but in the next section (Fig. 6) is seen the area of the nuclear capsule without question.

The model bears out closely the description of the relations of the lemniscus superior given by Forel.[2] If any of its fibres pass on, it must be those in the ventral part, where the bundle lies adjacent to the lemniscus medialis. On the other hand, the view of Flechsig, that the superior lemniscus ends in the superior colliculus, is well sustained.

The end of the tract, as seen in the model, is about opposite the point at which the fasciculus retroflexus of Meynert plunges into the nucleus ruber.

2. The Nucleus Ruber and its Capsule.

The nucleus ruber has a capsule of cells and fibres on its dorsal, lateral and superior surfaces. The spinal surface of the nucleus, on the other hand, is related (1) to the fibres of the N. oculomotorius, (2) to the brachium conjunctivum, (3) possibly to some fibres of the lemniscus medialis. The ventral surface at this stage

---

[1] This is in accord with v. Monakow, C., Experimentelle und pathologisch-anatomische Untersuchungen ueber die Haubenregion, den Sehhuegel und die Regio subthalmica, nebst Beiträgen zur Kenntniss früh erworbener Gross- und Kleinhirn defecte. Arch. f. Psychiat., Berl., Bd. 27 (1895), S. 1-128. On S. 452 in the same volume, he refers to what I have termed the proximal limit of the lemniscus superior, as the place where the superior lemniscus and the chief part of the lemniscus fuse.

[2] Forel, A., Untersuchungen über die Haubenregion und ihre oberen Verknüpfungen im Gehirne des Menschen und einiger Säugethiere mit Beiträgen zu den Methoden der Gehirnuntersuchung. Arch. f. Psychiat., Berl., Bd. VII (1877), S. 393-495.

lies in a mass of cells which underlies both the nucleus ruber and the substantia nigra (Plates III, IV and VII). This mass I have called the lectus or bed of the two nuclei.

The red nucleus will be described first, inasmuch as it makes so prominent a feature of the midbrain. It is seen from the side in Plate III, and from a mesial aspect, in Plate VI. In the latter view a portion of the superior capsule of the red nucleus has been removed, as can be seen by comparing with Plates IV and VII. The connection of the brachium conjunctivum with the red nucleus is seen in part on Plate III, but far better in Plate VII, where other structures have been sacrificed to show this relation on the right side of the view. The position of the nucleus ruber in this view is judged by the shape of its capsule.

The nucleus is roughly oval but not regular in shape. It is placed in the ventral portion of the midbrain, surrounded on its dorsal, lateral and superior surfaces by a capsule of cells and fibres. The lemniscus medialis, in passing toward the thalamus, lies adjacent to the dorsolateral angle of the capsule, where the two fibre masses are practically indistinguishable. Just distal to the red nucleus, or at least to its dorsal portion, is situated the decussation of the brachium conjunctivum. In order to study the relations of the brachium conjunctivum to the red nucleus, it will be necessary to recall the various decussations of the tegmentum. In the description of the brachium conjunctivum, note was made of three decussations: (1) a commissure between Bechterew's nuclei, (2) the dorsal bundle of the brachium conjunctivum and (3) the ventral or main part of the brachium conjunctivum.

In regard to the relations of the brachium conjunctivum to the nucleus ruber, the model makes three points clear: first, that some of the fibres of the brachium conjunctivum pass into the dorsal capsule of the nucleus; second, that some of the fibres pass through the nucleus, and third, that others end in the nucleus. The fibres entering the dorsal capsule are distinctly visible on the left side of Plate VII, where they appear to spread out over the nucleus. The relation is evident in section (Fig. 16) which is taken just dorsal to the level of the nucleus ruber. The fibres that pass through the nucleus appear as a bundle cut in cross-section at the lateral, proximal angle of the dorsal capsule (Plate II, left side). In regard to this bundle, a comparison of the two sides of the model will show three points: (1) that the bundle passes obliquely through the dorsal portion of the nucleus and leaves its dorsolateral portion; (2) that it enters Forel's[1] *Feld* BATh, which is the lateral region of the capsule; (3) that it comes to lie immediately adjacent to the lemniscus medialis. The fibres that end in the red nucleus enter the dorsomedian portion and the space has been left vacant in Plate VII to show their position. A single section will make these relations plain (Fig. 19). In passing ventralward through the nucleus, the fibres become much fewer and more scattered (Figs. 20 to 23). In fact, there are no medullated fibres in the ventral portion.

The capsule of the nucleus ruber is peculiar in being a complex of cells as well as fibres. The dorsal capsule is almost wholly made up of fibres; in the proximal capsule, however, cells predominate, while the ventral capsule at this stage of development is made up of cells with no medullated fibres.

The spinal surface of the nucleus is related to three groups of fibres: first, to the brachium conjunctivum; second, to the fibres of the N. oculomotorius, and third, to a few fibres that enter the midbrain from the lemniscus medialis (Plate III).

The medial wall of the capsule is incomplete and consists of a few fine fibres adjacent to the dorsal capsule. Besides these, the fasciculus retroflexus of Meynert bounds a part of this surface (Plate VII). The dorsal capsule consists mainly, as has been said, of fibres from the brachium conjunctivum (Plates III and VII). It covers the dorsal surface of the nucleus, and its lateral border lies adjacent to the medial lemniscus. Dorsal to this capsule is the formatio reticularis region of the midbrain, and medial to it is the fasciculus longitudinalis medialis. According to Forel,[2] the capsule receives fibres from each of these structures.

The dorsal capsule passes immediately into the superior capsule. Plate VII shows well the superior capsule with its relations to the fasciculus longitudinalis medialis, the fasciculus retroflexus Meynerti and the lemniscus medialis.

The area adjacent to the lemniscus medialis, including a portion

---

[1] Forel says that BATh consists mainly of an upward continuation of the brachium conjunctivum. Forel, op. cit., S. 426.

[2] Forel, op. cit., S. 424.

of the dorsal and superior walls of the capsule, corresponds to Forel's[1] *Feld* BATh.

The proximal capsule of the model will serve to illustrate in part Forel's description of the area between the nucleus ruber and the thalamus, though the model includes but the lower border of the region. The dorsal part of the proximal capsule is rich in fibres, which it receives from the dorsal capsule. The middle part consists of mixed fibres and cells, while the ventral part has more cells than fibres; indeed, toward the lateral border there is a fairly definite nucleus.[2]

In the centre of the dorsal edge of the proximal capsule the fasciculus retroflexus of Meynert plunges through the capsule and into the nucleus ruber (Plates III and VII). The capsule is thickest at its lateral border. The relation of the fasciculus longitudinalis medialis to the capsule is an interesting one. In Plate VII will be seen the trough of the fasciculus longitudinalis medialis and the groove for the nucleus of Darkschewitsch. This groove opens out onto the surface of the superior capsule. While the main bulk of the fibres of the fasciculus longitudinalis medialis do not pass beyond the nucleus, yet a small bundle of fine fibres passes onward into the medial border of the superior capsule and is gradually lost among its cells and fibres. This relation has been demonstrated already by Forel.[3]

Reference has already been made to the lateral capsule as a part of the midbrain sheet. The lemniscus medialis itself forms a part of the lateral wall of the nucleus. The part of the capsule adjacent to the lemniscus medialis is by far its densest portion and its fibres enter Forel's[4] *Feld* BATh, and Flechsig's *Haubenstrahlung*. The fibres of the ventral part are few and scattered.

The origin of the fibres of the lateral capsule deserves consideration. (1) The lemniscus medialis, as has been said, forms a part of the capsule; (2) fibres of the medial and ventral portion of the pontal sheet enter the midbrain and spread out over the lateral sur-

---

[1] Forel describes the area BATh as being dorsolateral to the nucleus ruber. Op. cit., S. 415.

[2] This agrees exactly with Forel, who has divided the area into three zones: a dorsal or Forel's *Feld* H, a middle or the zona incerta, and a ventral, or Luy's body. Forel, op. cit., S. 415.

[3] Forel, op. cit., S. 420.

[4] Forel, op. cit., S. 425; v. Monakow, op. cit., S. 28.

face of the nucleus. In the sections it is hard to separate these fibres from those of the brachium conjunctivum (Fig. 20). (3) Fibres of the brachium conjunctivum appear in some sections to enter the lateral capsule. (4) In Plate IV of the model can be seen a small nucleus lying in the lateral capsule and in the corresponding sections, certain fibres appear to be definitely related to this nucleus (Fig. 21). According to Forel, the capsule receives fibres from the nucleus ruber.

The description of the lateral capsule as given in Forel's article appears to me to apply more to its dorsal portion.

The longitudinal series is better than the transverse for obtaining a clear idea of the relations described above. Starting from the dorsal aspect, in Fig. 13, is seen the area of the formatio reticularis which lies dorsal to the nucleus ruber; from this, one passes into the area of the definite dorsal capsule in Fig. 16. The relation of the fasciculus longitudinalis medialis to the nucleus of Darkschewitsch and the superior capsule of the nucleus ruber may be followed at the same time as far as Fig. 21. In Fig. 19 are seen, (1) the lemniscus medialis as a part of the lateral capsule; (2) the brachium conjunctivum just distal to the nucleus; (3) the relations of the N. oculomotorius; (4) *Feld* BATh of Forel; and (5) the fibres of the fasciculus longitudinalis medialis passing into the nucleus of Darkschewitsch (Nu. f. l. m.). In this section it will be noted that there are a few fibres making a medial capsule.

Their origin is hard to trace. In passing farther ventralward (Fig. 20), there is a great thinning out of the capsular fibres. In the first place, the lateral wall has become reduced to a few scattered fibres. By following carefully between the last two sections, it seems clear that some of the fibres of the lateral wall come from the pontal sheet and the brachium conjunctivum. At the level of Fig. 21, however, its fibres appear to be directly related to a small mass of cells lying distal to the nucleus ruber and surrounded by the fibres of the root of the N. oculomotorius (Nu. x. of l. c. of Nu. r., Plate III). Forel's *Feld* H shows clearly in Fig. 21. The fasciculus retroflexus on the medial border will be described later. In passing through Figs. 22 and 23, it is evident that the fibres around the nucleus are becoming fewer, while the cells become more and more numerous, especially in the proximal and adjacent lateral capsules. In Fig. 24 are the cell masses that underlie both the nucleus ruber and the substantia nigra.

3. Fasciculus Retroflexus of Meynert.

The fasciculus retroflexus of Meynert is easy to follow in sections. Its position and relation to the nucleus ruber are clear in the illustrations (Plates III, VI and VII). Its nucleus of origin is outside of the limits of the model. The bundle enters on the proximal aspect of the model as a band 1 mm. wide, and passes obliquely medialward and ventralward, and plunges through the nucleus ruber and its capsule. It both enters and leaves the medial surface of the nucleus entering near the proximal border just dorsal to the middle of the nucleus and leaving near the distal border at about the middle of the dorsoventral diameter. On emerging from the nucleus the bundle immediately spreads out into a sheet more than twice as broad as the entering bundle (Plate VI). The fibres end in the borders of the fossa interpedunculare just distal to the nucleus ruber. Between the fibres are to be seen a few scattered cells, the remains of the ganglion interpedunculare. The root-fibres of the N. oculomotorius pass through the area of the bundle as it emerges from the nucleus ruber.

In longitudinal sections the bundle is easily traced. In Fig. 16 are seen a few fibres just entering the edge of the section. It will be noted that only the peripheral fibres of the bundle are medullated. Figs. 19 and 20 carry the bundle to the edge of the nucleus ruber, while Figs. 21 and 22 take it through the nucleus. The last trace of the bundle is seen in Fig. 23, and here the cells of the ganglion are especially clear. The transverse series does not go entirely through the nucleus ruber, so the entrance of the bundle can not be seen; however, Fig. 50 shows its fibres near the region of the ganglion interpedunculare.

4. Decussatio Tegmenti Dorsalis Meynerti.

The decussatio tegmenti dorsalis Meynerti shows in Plate VII. It lies proximal to the ventral part of the brachium conjunctivum. The course of the fibres to the decussation is indicated in Plate III. If the bundle in Plate III be imagined as continued to the level of the radix descendens (m.) N. trigemini, the tract can be well traced. The fibres are difficult to follow in the longitudinal series in this part of their course, but easy to trace in transverse sections. The bundle then starts just lateral to the radix descendens (m.) N. trigemini,[1] and curves across the midbrain between the brachium

---

[1] Meynert believed that the bundle has a definite relation to this nerve. Cf. Forel, op cit., S. 442.

conjunctivum and the stratum album profundum. The decussation is just ventral to the fasciculus longitudinalis medialis. In Plate VII it can be made out that the decussation curves so that the fibres on leaving it turn toward the spinal cord. In the longitudinal sections these fibres can be seen to pass through the brachium conjunctivum and to enter the longitudinal bundles of the formatio reticularis alba of the pars dorsalis pontis. These fibres have not been differentiated in the model from the other longitudinal bundles of the middle region of the tegmentum.[1]

In tracing the fibres of this bundle in the longitudinal series, it will be easiest to begin with the decussation (Fig. 19). By passing dorsalward, one can trace at the same time the fibres coming to the decussation from the level of the radix descendens (m.) N. trigemini, and the fibres leaving the decussation to form a longitudinal path in the pons. In Figs. 16 and 18 are seen the fibres turning toward the pons. The bundles passing to the decussation do not come out in these drawings, since the fibres are delicate and are mixed with the bundles of the root of the N. oculomotorius. In Fig. 13 (D. t.), however, these fine fibres are plain.

In the transverse series the decussation is seen just ventral to the nucleus of the N. oculomotorius (Fig. 48), while the fibres passing to it are plain on Fig. 47. In this section the fibres show a broad curve and there is a space between them and the stratum profundum album.

5. Decussatio Tegmenti Ventralis of Forel.

The decussatio tegmenti ventralis of Forel is represented at this stage by a few delicate fibres ventral to the decussatio tegmenti dorsalis Meynerti. They show in Plate VII and in Fig. 48 and in Fig. 20 (D. t.).

6. Stratum Album Profundum.

The stratum album profundum of the superior colliculus is conspicuous in the model of the midbrain (Plates II, III, IV and VII). The deep white fibre layer is, in reality, a composite of

---

[1] The fibres from Meynert's decussation have been called the descending bundle of the tegmentum, and are pictured by Ramón y Cajal. Ramón y Cajal, op. cit., S. 114.

fibre systems, but its shape as a whole will be considered first. It is a hollow shell that outlines the central gray matter of the midbrain (Plate II). Through the centre of the cavity of the shell passes the central canal describing the midbrain curve; the sides of the shell rest upon the fasciculus longitudinalis medialis as a base (Plate III). As seen in Plate II the shell is open on its distal and dorsal aspects, while at the proximal end it is completed across the midline by an arch. The arch is placed vertically (Plate VII). The side view is of value in studying its relations (Plate III). This view shows the curve of the fasciculus longitudinalis medialis through which passes the radix N. oculomotorii. Dorsal to the fasciculus longitudinalis medialis stretches the lateral wall of the deep white shell. In this wall is an oval space, the distal end of which is just dorsal to the opening for the root of the oculomotor nerve. The wall is divided into two parts by a curved ridge that runs in a dorsoventral direction. This ridge lies at the junction of the middle and proximal thirds of the wall and extends dorsalward from the proximal end of the space just mentioned. Distal to the ridge is a depression, which is due simply to the prominence of the ridge. This ridge appears to mark a difference in structure between the two parts, for distal to it the wall consists of a thin flat sheet in which the fibres run longitudinally, while proximal to it is the arch of the shell in which the fibres curve across the midline. This arch, in contrast to the thin sheet below the ridge, is thick and densely packed, at least in its ventral portion. The details of the direction of the fibres are to be considered later. The distal margin of the flat sheet is marked on the external surface by a dorsoventral groove, below which pass the fibres of the radix descendens (m.) N. trigemini. This root of the trigeminal nerve passes spinalward in about the same plane as that occupied by the deep white sheet.

The internal wall of the shell is practically the converse of the external (Plate II), for opposite the external ridge is a concavity, while just distal to it is an internal ridge. Passing spinalward from this internal ridge is the flat sheet, which runs down to a second ridge on the internal surface. This ridge lies in the lower part of the midbrain and practically limits the deep white layer. Distal to it runs the radix descendens N. trigemini. The exact point at which the deep white ends and the root of the N. trigeminus begins has never been determined, but the model at least suggests that this ridge is the junction of two different fibre systems. The arch or commissure is to be seen in Figs. 2 and 7. In the latter the inner wall of the base of the arch comes into sight. Just at the junction of the pillars of the commissure with the fasciculus longitudinalis medialis and the proximal capsule of the nucleus ruber is the groove for the nucleus of Darkschewitsch. This groove has already been noted as opening out upon the superior capsule. The relative thickness of parts of the arch varies markedly. The ventral part contains most of the fibres. Dorsal to it is an area which shows no medullated fibres at all. The sections in this area, however, are decolorized more than the rest of the series. Just dorsal to this space is a narrow band of a few, fine, decussating fibres.

These form relations, namely, the external and internal ridges and the lower limiting ridge, together with the arch over the canal, will make clear the direction of the fibres, as seen in sections. For example, between the proximal, internal ridge and the lower limiting ridge, the fibres run in a longitudinal direction and form a definitely circumscribed, though narrow bundle (Figs. 5 and 6). At the limiting groove these fibres appear to break, and distal to the groove is situated the radix descendens (m) N. trigemini. This can be traced in Fig. 5 directly to the level of the main root of the N. trigeminus, a point which is seen clearly in the model (Plate IV). In section (Fig. 6) the descending root of the nerve is more broken, inasmuch as this is the level of its nucleus, of origin, which is situated in the locus cæruleus.

To return to the midbrain shell, the same two sections (Figs. 5 and 6) will show that the external ridge is made up of fibres running in a wholly different direction. Indeed, they slant into the deep white from the formatio reticularis, so that while the internal border of the deep white is definite, the external border is extremely indefinite. These fibres from (or to) the formatio reticularis slant into the ridge and decussate in the commissure.

Passing ventralward we come to a level in which no decussating fibres can be seen, but the external ridge continues to have the same structure (Fig. 9). The next few sections, however, enter into the area of the decussation and the pillars of the arch (Figs. 11, 12 and 13). The section in Fig. 16 passes through the nucleus of Darkschewitsch at the base of the pillars of the arch. In the transverse series the stratum album profundum can be traced through Figs. 43 to 51. Certain points are brought out more clearly here than in the longitudinal series: (1) the fibres that slant into the ridge (Figs. 47 and 48), (2) the posterior commissure and its relation to the nucleus of Darkschewitsch (Figs. 50 and 51) (Nu. c. p.).

In regard to the course of these fibres the model confirms the findings of Held rather than those of Ramón y Cajal, the former stating that the fibres slant into the posterior commissure from the superior colliculus. These fibres decussate in the arch and pass down in the pillars to the nucleus of Darkschewitsch.

The fibre relations of the deep white layer have now been completed, except the fact that the space left in the lateral wall really contains fibres (Plate III). A single section will show, however, why this space was left in the model (Fig. 12). The contrast between this section and Fig. 6 is marked, for instead of having the narrow band between the medial ridge and the N. trigeminus, as in Fig. 6, the corresponding area in Fig. 12 is evidently a place where fibres of the formatio reticularis alba end (or begin) in the central gray matter of the midbrain. This stratum profundum album forms the boundary of the central gray matter, and the area just described shows that at least some of its fibres are connected with the cells within. The contents of the midbrain shell are: (1) the nuclei of the oculomotor and trochlear nerves and the roots of these nerves, (2) the central gray matter, and (3) the central canal.

7. Substantia Centralis Grisea.

The shape of the central gray matter, substantia centralis grisea, is worthy of mention. Its outline is given in the model only in the region of the midbrain, where the stratum album profundum forms a definite border for it. In the medulla oblongata, however, it can be readily constructed from the shape of the floor of the fourth ventricle. Certain structures in the central gray matter have already been considered, namely, the various nuclei of the cerebral nerves. These can be divided into two groups, first, the median motor groups of nuclei, that is, of the Nn. hypoglossi, abducentes, trochleares et oculomotorii, which lie embedded in the fasciculus longitudinalis medialis on the border of the central gray matter; second, certain of the sensory nuclei, namely, the superior and medial, vestibular nuclei, the nucleus tractus solitarii and the nucleus alæ cinereæ.

Beside these nuclei connected with the cerebral nerves, there is a definite and clearly defined nucleus in the pons region. It corresponds to the descriptions of the substantia ferruginea and lies opposite the decussation of the brachium conjunctivum (Plate II). In both series, and in the model as well, this nucleus

Yes

Hinterer oder Westfla

Forel. Archiv f. Psychiat. Bd. 7

is situated in the central gray matter, exactly dorsal to the fasciculus longitudinalis medialis, whereas, in Forel's picture, it is placed slightly dorsolateral (Figs. 7 and 41).

The central gray matter of the midbrain is better developed than that elsewhere. Its shape is outlined by the stratum album profundum and the fasciculus longitudinalis medialis; it contains the nuclei of the oculomotor and trochlear nerves, as well as the nucleus of Darkschewitsch. It has been mentioned that certain of the fibres of the formatio reticularis appear to be connected with it.

To complete the description of the area of the midbrain medial to the midbrain fibre-sheet, there is left the large area which lies between the stratum album profundum and the lemniscus superior and dorsal to the nucleus ruber (Plate VII). This area contains, first, the nucleus colliculi inferioris, which has already been described, and second, the formatio reticularis of the inferior and superior colliculi. The formatio reticularis of the entire model, however, is to be considered together. So I will pass on to the structures lateral from the midbrain sheet.

These structures consist of the substantia nigra (together with a small nucleus possibly derived from it) and the pyramidal tract. This tract being non-medullated, leaves simply the nuclei to be considered.

8. Substantia Nigra.

The substantia nigra lies in the ventral part of the midbrain (Plate I). It is larger than the nucleus ruber. It is oblong in shape and is placed against the lateral surface of the lemniscus medialis and lateral capsule of the nucleus ruber. It lies at an angle to the long axis of the model, so that its proximal edge is farther from the midline than the distal. Just lateral to it is the area in which the pyramidal tract develops at a later stage, and though the model does not show the tract, it can readily be imagined plunging into the pons in this region.

The shape of the nucleus is fairly regular. The ventral border —a straight line in the model—rests upon the cellular area which the substantia nigra and the nucleus ruber have in common. The nucleus ruber can be easily outlined from this cell-mass by its color, but it is practically impossible to make a definite ventral limit in these sections for the substantia nigra. The dorsal border of the substantia nigra is curved, and, at the distal dorsal angle, the nucleus is notched to receive a bundle of fibres from the lemniscus medialis (Plate I). This bundle is shown in Plate IV.

The substantia nigra is familiar in the sections; it is to be seen in all the cross-sections of the midbrain and in all the longitudinal sections of the ventral part of the same. Its relations to the lemniscus medialis and the nucleus ruber are brought out well in both series (Figs. 19 to 24). The first two sections of the series show the bundle of fibres of the lemniscus medialis, that enters the substantia nigra. The last section shows the cell-area common to the two large nuclei of the midbrain. (Lectus substantia nigræ et nuclei rubri.) The absence of fibres except the small bundle from the lemniscus medialis is to be noted in the sections. The transverse series (Fig. 49) may be taken as a type of the nucleus. The angle, at which this section is cut, readily explains itself on the model. A cross-section taken at the extreme spinal end of the nucleus shows the bundle entering from the lemniscus medialis (Fig. 46). The connection appears to be much more intimate from this aspect than the longitudinal series showed.

PART V.

FORMATIO RETICULARIS ALBA ET GRISEA.

Though the formatio reticularis is represented in the model for the most part merely by a space, nevertheless certain of its relations can be made quite clear. In considering the three regions of the model, each is characterized, first, by a special form of the sensory or central fibre-mass, and second, by nuclei limited to the region. For example, the medulla oblongata has the vertical medial sheet and the olive; the pons has the horizontal sheet and the pontal nuclei, while the midbrain has the oblique-lateral sheet and the nucleus ruber and substantia nigra, which have, as has been said, a common bed (or lectus) of cells.

The position of the formatio reticularis has a definite relation to these main structures. It lies dorsal to the large nucleus of the region in every case. In the medulla oblongata it lies dorsal to the inferior olive and lateral to the vertical sheet; in the pons, it lies dorsal both to the pontal nuclei and to the pontal sheet, that is, the sheet forms a boundary between the pontal nuclei and the formatio reticularis. In the midbrain, the formatio reticularis lies dorsal to the nucleus ruber and the substantia nigra, but here the fibre-sheet is reversed in position as compared with the medulla oblongata, for it lies lateral rather than medial.

The reticular area of the medulla oblongata is best seen from the side (Plate IV); the pontal and midbrain reticular areas from the dorsal aspect in Plate VI, and the midbrain area in Plate VII.

The intrinsic structures of the formatio reticularis are its long and short fibre-tracts and its cells, both the diffuse areas and the more or less definite nuclei.

The longitudinal section in Fig. 9 gives a comprehensive view of the entire formatio reticularis. It is bounded medially by the fasciculus longitudinalis medialis and the stratum profundum album; laterally by the nucleus funiculi gracilis and the nucleus funiculi cuneati, the corpus restiforme, the sensory cerebral nuclei and the lemniscus lateralis. In this section several points are to be noted: (1) the large number of longitudinal fibres, some of which seem to run the entire length of the formatio reticularis; (2) the comparatively even distribution of these fibres; (3) the large number of cells, and (4) the absence at this level of special groups or nuclei, for the whole area seems to be one continuous nucleus. This section may be taken as a type of the dorsal area of the formatio reticularis.

This level of the formatio reticularis is in contrast to a level farther ventral (Fig. 13). Here we have the longitudinal fibres and the cells again; but the fibres run in fairly definite bundles and the cells form fairly definite nuclei. The first level was undifferentiated and showed fibres extending through the whole length of the medulla oblongata, pons and midbrain, while this level is distinctly differentiated and shows shorter tracts breaking up into nuclei. For example, distal to the radix N. abducentis is the middle part of the medulla sheet, namely, its formatio reticularis bundle; and proximal to the root of the N. abducens the fibre-bundle turns lateralward and splits into two parts, a medial and a lateral.

These two longitudinal fibre-bundles can be traced from the region just proximal to the N. abducens through the pons and into the midbrain; the fibres pass directly through the brachium conjunctivum. The more centrally placed of these longitudinal fibres run to the border of the central gray masses and there end abruptly, while the more lateral fibres end indefinitely in a great cell area in the midbrain, namely, the nucleus lateralis superior of Flechsig. The fibres from the decussatio tegmenti dorsalis of Meynert turn spinalward and pass through the formatio reticularis of the pons. They cannot be separated as a distinct bundle.

The formatio reticularis area of the entire section is one large nucleus; nevertheless five fairly distinct groups of cells can be differentiated within it. The first of these is the nucleus centralis inferior, which lies in the medulla sheet distal to the radix N. abducentis (Plate V, Fig. 35). The second, the nucleus reticularis tegmenti, lies between the formatio reticularis fibres just proximal to the N. abducens (Plate VII, Fig. 40). The third, the nucleus centralis superior medialis, lies between the two medial fibre-bundles in the proximal part of the pons (Plate VII, Fig. 42). In Plate VII the curve of the formatio reticularis bundle corresponds to this nucleus. The fourth nucleus is the nucleus centralis superior lateralis, which lies at the same level as the third but farther lateral. It occupies the hollow of the brachium conjunctivum (Plate VII, Fig. 42). The fifth is the nucleus lateralis superior, or formatio reticularis grisea of the midbrain (Plate VII).

As has been said, beside these fibre-bundles and nuclei, the section in Fig. 13 shows a diffuse formatio reticularis area extending throughout the section and lying lateral from the tracts just considered. This lateral area is in contrast to the lateral area of the more dorsal level. The longitudinal fibres are almost entirely wanting, their place being taken by transverse fibres or internal arcuates. These fibres are so delicate that they show better in transverse section (cf. Fig. 30). Beside the definite arcuate bunbles from the dorsal funiculi of the cord and the decussating fibres of the brachium conjunctivum, the entire area from the proximal limit of the fasciculus cuneatus to the level of the motor root of the N. trigeminus shows numbers of delicate arcuate fibres cut in cross-section. This area corresponds in extent to that of the tractus spinalis N. trigemini, and doubtless many of these fibres come from its nucleus.

It will make the sections of the formatio reticularis more interesting to compare them with two sections, one taken dorsal to the formatio reticularis and the other ventral. In the first place Fig. 6 lies dorsal to the formatio reticularis. This might be called the level of the dorsal cerebral nuclei or the level of the central gray matter and its differentiated nuclei. The longitudinal fibres of the formatio reticularis have disappeared, and the following nuclei of the cerebral nerves are visible, the N. glossopharyngeus, N. vagus, N. acusticus, N. facialis and N. trigeminus. Moreover, the central area of the section is a mass of cells around the central canal. The ventral level, on the other hand, as seen in Fig. 20, is the level of the main regional nuclei, the olive, the pontal nuclei, the substantia nigra and nucleus ruber. At this level there are no nuclei of cerebral nerves nor fibres of the formatio reticularis. It is, in fact, a non-medullated area in which the motor fibres, that are soon to characterize this level, can just be seen, as lines of brown stain on the sections.

In the reticular area of the medulla are two longitudinal tracts, first, the descending bundle from Deiters' nucleus to the spinal cord (Plate IV), and second, the tract described as extending from Burdach's nucleus up to the region of the nucleus ambiguus (Plate VI).

It will be noted in both of the sections (Figs. 9 and 13) that the formatio reticularis region does not reach either the proximal or the distal limit of the section; that is to say, the formatio reticularis of the model region is not connected with the cord, nor yet with the hypothalamic region at so dorsal a level. This is due to the cervical and the midbrain curves. The model shows this point well. A cross-section of the spinal cord, showing its reticular area is to be seen in Plate IV. The fibres of this area must curve over the dorsal surface of the olive to enter the formatio reticularis area of the medulla oblongata. On the other hand, the proximal connection shows best in Plate VII, where the transition is made just over the dorsal capsule of the nucleus ruber. It is not necessary to say that it is impossible to limit exactly the dorsal capsule from the formatio reticularis; indeed, Forel says that the formatio reticularis enters into the formation of the capsule of the nucleus ruber. Fig. 16 shows these relations clearly, for at either end of the section is to be seen an area of formatio reticularis.

Beside the large diffuse cell-masses of the formatio reticularis and the more definite cell-groups connected with the longitudinal tracts, there are scattered in the formatio reticularis certain definite little masses of cells. They are situated on either side of the brachium conjunctivum sheet in its ventral course from the cerebellum to the decussation (Plates II and III).

CONCLUSION.

General Summary.

With this consideration of the formatio reticularis, the description of the model practically ends. It will be possible, I think, to reduce the model to simple terms, even though it may seem to be complex. As viewed from the side, the model consists, in general, of two levels—a ventral and a dorsal. The ventral level is characterized, first, by a remarkable absence of medullated fibres at this stage of development, and second, by the presence of large definite nuclei. These nuclei characterize the regions they occupy; the olive of the medulla, the pontal nuclei of the pons, the nucleus ruber and substantia nigra in the midbrain. This is the level and these the structures by which the medulla oblongata, pons and midbrain differ from the cord. The absence of medullated fibres speaks for the later development of these structures. This level is eventually occupied by the brachium pontis and the pyramidal tract, the fibres of which have long been laid down at this period.[1]

The pyramidal tract, which develops in this level, lies wholly on the surface of this region, save where it plunges through the pontal nuclei. It lies far from the dorsal area, which represents the more developed part of the model and has no form relation to it save that the decussation makes a slight impression on the trough for the ventral horn; that is to say, the pyramidal tract has no influence in moulding the shape of other structures; it rather adjusts itself to structures already formed. In this it is in contrast to the sensory tract, which is so closely related in form to adjacent structures. This illustrates well the point which His has made, that the difference in time development determines the relative positions of structure.[2]

---

[1] Flechsig. Die Leitungsbahnen im Gehirn und Rückenmark des Menschen. Leipzig. 1876, S. 192.

[2] Die Neuroblasten und deren Entstehung im embryonalen Mark, Abhandl. d. math.-phys. Cl. d. k. sächs. Gesellsch. d. Wissensch., Bd. XV, Leipzig, 1889, S. 292.

The dorsal half of the model, on the other hand, corresponds rather to the spinal cord. The easy transition of the cord into the dorsal part of the model is clear in the view of the lateral surface of the model. This level, with all its complexity, is in reality simple. It consists (1) of long tracts on the way to the cortex, (2) of long tracts to the cerebellum, namely, the brachium conjunctivum and corpus restiforme; (3) of the cerebral nuclei, their root-bundles and paths; (4) the association areas or formatio reticularis alba and grisea.

The central fibre mass is a structural unit in the form of three sheets, the medulla, pontal and midbrain, which contain the medial and lateral lemniscus, or the main sensory path toward the cortex. It contains also certain short tracts, the fasciculus longitudinalis medialis, the lemniscus superior and unnamed formatio reticularis fibres. Of the tracts to the cerebellum, the corpus restiforme lies on the lateral surface of the medulla oblongata, while the brachium conjunctivum, being related to the nucleus ruber, lies within the pons and midbrain.

The cerebral nerves are divided into two groups, a medial and a lateral. The motor nuclei are definite, compact masses, with the exception of the nucleus N. accessorii, which represents the transition from the type of the nuclei to the spinal cord. The motor nuclei correspond to the ventral horn-cells. They are related to formatio reticularis areas; the median group to the fasciculus longitudinalis medialis, the lateral to the formatio reticularis alba. The root-fibres of the lateral group, with one exception, take an indirect course to the surface, showing that they have developed in an area of complex growth. The sensory nuclei all belong to the lateral group. They correspond, in the main, to the dorsal horn of the spinal cord, and thus occupy a dorsal level. They are diffuse and cover a wide area. All but two of them, namely, the nuclei of the N. trigeminus and N. cochleæ, lie in the substantia centralis grisea. With the exception of the nuclei N. cochleæ, they border the formatio reticularis. In general, they are characterized by long descending tracts accompanied by nuclei. The nerves of the special senses do not conform wholly to the general type, for the N. vestibuli is peculiar in its relations to the cerebellum, and the N. cochleæ in its well-developed and complex central path.

The formatio reticularis consists of mixed cells and fibres. The dorsal level represents the longer association paths of the model, and its cells are diffuse. In the ventral level the fibres are grouped into shorter paths and then the cells form nuclei in connection with these short bundles.

The model brings out the fact that the region is divided into four levels, as has been shown by His from a study of earlier embryos. I wish to emphasize the large number of nerves represented by nuclei in the first layer, or the substantia centralis grisea. They are (1) all of the spinal nerves through the nuclei of the dorsal funiculi (2) the nuclei of the four motor nerves of the median group, and (3) all of the sensory cerebral nuclei of the model except the nucleus of the N. trigeminus and the N. cochleæ. The second layer, that of the formatio reticularis, includes the remaining four motor nuclei of the cerebral nerves. That this position is not primary for these nuclei, but is rather the result of development, is suggested by courses of their fibres. The third layer includes the olive, pontal nuclei, substantia nigra and red nucleus, the fourth the pyramidal tract.

The question of the origin of these four layers is one of great interest. According to His, the motor nuclei, both of the median and lateral groups, come from the ground plate, while the sensory nuclei come from the medial part of the wing plates.[1] The third layer offers an attractive field for study.

Three of its nuclei, namely, the olive, the pontal nuclei and the red nucleus, are connected with the cerebellum. In the spinal cord the cells related to the cerebellum are in the nucleus dorsalis Clarkii which lies between the dorsal and ventral horns. The origin of the olive, according to His, is from the cells of the *Rautenlippe*, which forms the lateral part of the wing plate adjacent to the cells which form the sensory nuclei. This serves to open up the question of the origin and relations of this ventral nuclear layer. Have these nuclei a common origin, and what is the relation of the substantia nigra to the other three?

A part of this question is being studied in this laboratory. Problems along this line have been opened up by the work of His, and I can but believe that the application of the wax-plate method

---

[1] His, W., Die Entwickelung des menschlichen Rautenhirns. Abhandl. d. math.-phys. Cl. d. k. sächs. Gesell. d. Wissensch., Leipz., 1891, S. 1-74.

to the study of the development of the central nervous system has a promising future. With a series of models, the course of development may become a matter of sight and not of theory. Moreover, all those individual differences which may be misleading in any one model can be easily eliminated when each model is but one of a series.

In conclusion, I wish to thank Dr. John Hewetson for the material which has made this model possible. Both series were unbroken and so admirably prepared that any omissions in the model are due, not to the material, but to the nature of the structures in question. I am greatly indebted to Mr. Max Broedel for the beautiful illustrations of the model. They are so accurate and so clear as to be equal in value to the model itself. Dr. Franklin P. Mall has controlled the construction of the model and Dr. Lewellys F. Barker the study of it. I acknowledge with thanks their unfailing help and interest.

Description of Figures.

Figs. 3-24. Series of horizontal sections passing through the medulla, pons and midbrain of a new-born babe. The series is traced from the dorsal to the ventral surface. The following sections, Figs. 6, 7, 9, 12, 13, 16 and 19 are after Barker, L. F.: The Nervous System and its Constituent Neurones. D. Appleton & Co., 1899. (Preparations by Dr. John Hewetson.)

Figs. 25-51. Series of transverse sections passing through the medulla pons and midbrain of a new-born babe. The series is traced from the spinal cord toward the cerebrum. The following sections, Figs. 25, 28, 31, 33, 35, 36, 39, 41, 42, 46 and 49 are after Barker, L. F.: Op. cit. (Preparations by Dr. John Hewetson.)

Indexed Legend for Figures 3-51.

α, Fibres running from region of lemniscus lateralis toward the dorsal border of brachium conjunctivum.
A. c. (or Aq. c., or Aq. cer.), Aquæductus cerebri.
β, Decussating portion of root of N. trigeminus.
B. c. (or Br. conj., or Brach. conj.), Brachium conjunctivum.
B. c. (d.), Brachium conjunctivum (dorsal bundle).
C. a., Columna anterior (Columna ventralis).
C. c., Canalis centralis.
C. i. (or Coll. inf.), Colliculus inferior.
C. p., Commissura posterior cerebri.
C. r. (or Corp. rest.), Corpus restiforme.
C. s. (or Coll. s., or Coll. sup.), Colliculus superior.
C. t., Corpus trapezoideum.

D. b. c. (or Dec. B. c., or Dec. Br. Conj.), Decussatio brachii conjunctivi.

D. betw. nu. c. i., Decussation between nuclei colliculi inferioris.

D. c. n. r., Capsula dorsalis of the nucleus ruber.

Dec. Bect., Commissure between Bechterew's nuclei.

Dec. l., Decussatio lemniscorum.

D. p., Decussatio pyramidum.

D. rel. to N. V. (Same as β.), Decussation related to N. trigeminus.

D. t. v. F., Decussatio tegmenti ventralis, of Forel.

D. t. Vide F. to d. M.

D. t. d. M., Decussatio tegmenti dorsalis Meynerti.

F. a. i., Fibræ arcuatæ internæ.

F. a. i. (d) (or F. a. i. (Dec. l.)), Fibræ arcuatæ internæ (distal bundle) or Decussatio lemniscorum.

F. a. i. (p.) (or F. a. i. (cun.)), Fibræ arcuatæ internæ (proximal bundle).

F. a. i. (vest), Fibræ arcuatæ internæ, pertaining to central vestibular paths.

F. a. e., Fibræ arcuatæ externæ.

F. betw. B. c. & h. l. Vide α.

F. B. c. d. Vide B. c. (d.).

F. c. (or F. cu., or Fa. cun.), Fasciculus cuneatus.

F. c. s. (or F. clo.), Fasciculus cerebellospinalis.

F. c. to Fr., Fibres from fasciculus cuneatus to formatio reticularis.

F. fr. d. M., Fibres from Decussatio tegmenti dorsalis Meynerti.

F. fr. f. l. (l), Fibres from fasciculus lateralis (lateral group).

F. fr. f. l. (m.), Fibres from fasciculus lateralis (medial group).

F. fr. l. m. to s. n., Fibres from lemniscus medialis to substantia nigra.

F. g. (or Fa. gr.), Fasciculus gracilis.

F. i., Fossa interpedunculare.

Fib. arc. int. Vide F. a. i. (p).

F. l., Fasciculus lateralis.

F. l. m. (or Fasc. l. med.), Fasciculus longitudinalis medialis.

F. l. p., Fasciculus lateralis proprius.

F. l. p. (d), (or F. l. p. (4)), Bundle continuous with fasciculus lateralis of the cord.

F. p. (or F. Py.), Fasciculi longitudinales pyramidales. (In Fig. 36 F. p. is Fibræ pontis.)

F. r. a., Formatio reticularis alba.

F. r. M. (or Fasc. retrof.), Fasciculus retroflexus Meynerti.

F. sc. dl., Fasciculus cerebellospinalis dorsolateralis.

F. to d. M. (or F. to d. t. d.), Fibres to decussatio tegmenti dorsalis Meynerti.

F. v. c. (i.), Fibres connecting vestibular area with cerebellum (inner or medial group).

F. v. c. (o.), Fibres relating the vestibular area with the cerebellum (outer or lateral bundle).

F. v. l., Fasciculus ventrolateralis.

F. v. p., Fasciculus ventralis proprius.

L. c. nu. r., Capsula lateralis nuclei rubri.

L. l. (or Lemn. lat.), Lemniscus lateralis.

L. m., Lemniscus medialis.

L. nu. r., Lectus nuclei rubri.
L. s., Lemniscus superior.
Med. obl., Medulla oblongata.
Mesenc., Mesencephalon.
Mot. V. Vide N. V. (m.).
N. c. Vide N. VIII (Coch.).
N. l. l., Nucleus lemnisci lateralis.
N. III, Radix N. oculomotorii.
N. IV (or N. troch.), Radix N. trochlearis.
N. V, Radix N. trigemini.
N, V (dec.). Vide β.
N. V (m.), or N. Mot. V, Radix N. trigemini (motor).
N. V (s.) (or N. Sen. V.), Radix N. trigemini (sensory).
N. VI, Radix N. abducentis.
N. VII, Radix N. facialis.
N. VII p. p. (or VII (a.)), Radix N. facialis, pars prima.
N. VII, p. s. (or N. VII (c.)), Radix N. facialis, pars secunda.
N. VII g. (i.) (or N. VII (b.)), Radix N. facialis genu internum.
N. VIII (coch.) (or N. c.), Radix N. cochleæ.
N. VIII (vest.) (or N. vest.), Radix N. vestibuli.
N. IX & X, Radices N. glossopharyngei et vagi.
N. XI, Radix N. accessorii.
N. XI, p. p., Radix N. accessorii, pars prima.
N. XI, p. s., Radix N. accessorii, pars secunda.
N. XII, Radix N. hypoglossi.
Nu. a., Nucleus arcuatus.
Nu. a. c., Nucleus alæ cinereæ.
Nu. c., Nucleus columnaris.
Nu. c. i., Nucleus colliculi inferioris, Figs. 43 and 44. In Fig. 13, Nu. c. i. = Nucleus centralis inferior.
Nu. com., Nucleus commissuralis.
Nu. c. p., Nucleus comissuræ posterior, or nucleus fasciculi longitudinalis medialis.
Nu. c. s. (l.), Nucleus centralis superior, pars lateralis.
Nu. c. s. (m.), Nucleus centralis superior, pars medialis.
Nu. d., Nucleus dentatus.
Nu. f. c. (or Nu. f. cu., or Nuc. f. cun.), Nucleus funiculi cuneati.
Nu. f. c. (l.), Nucleus funiculi cuneati lateralis (Blumenau).
Nu. f. g. (or Nucl. f. gr.), Nucleus funiculi gracilis.
Nu. F. l. m., Nucleus fasciculi longitudinalis medialis or nucleus commissuræ posterioris (*oberer Oculomotoriuskern* of Darkschewitsch).
Nu. g., Nucleus globosus.
Nu. l. s., Nucleus lateralis superior of Flechsig.
Nu. N. c. d. (or Nu. N. cochl. cl.), Nucleus N. cochleæ dorsalis.
Nu. N. c. v., Nucleus N. cochleæ ventralis.
Nu. N. v. l. (or Nu. N. vest. l.), Nucleus N. vestibuli lateralis.
Nu. N. v. m. (or Nu. N. vest. m.), Nucleus N. vestibuli medialis (Schwalbe).
Nu. N. v. s. (or Nu. N. vest. s.), Nucleus N. vestibuli superior (von Bechterew).
Nu. N. III, Nucleus N. oculomotorii.

Nu. N. III, l., (or Nu. N. III (a.)), Nucleus N. oculomotorii, pars lateralis.

Nu. N. III, m. (or Nu. N. III (b.)), Nucleus oculomotorii (medial nucleus).

Nu. N. IV, Nucleus N. trochlearis.

Nu. N. V, Nucleus N. trigemini.

Nu. m. m. N. V, Nuclei motorii minores N. trigemini.

Nu. m. p. N. V, Nucleus motorius princeps N. trigemini.

Nu. N. VI (or Nucl. N. abd.), Nucleus N. abducentis.

Nu. N. VII, Nucleus N. facialis.

Nu. N. XII (or Nucl. N. hyp.), Nucleus N. hypoglossi.

Nu. N. XII, a. R., Nucleus of Roller.

Nu. o. a. d., Nucleus olivaris accessorius dorsalis.

Nu. of r., Nucleus of the roof.

Nu. o. a. m., Nucleus olivaris accessorius medialis.

Nu. o. i., Nucleus olivaris inferior.

Nu. o. s., Nucleus olivaris superior.

Nu. o. s. 2, Nucleus olivaris superior, at its junction with the nucleus lemnisci lateralis.

Nu. r., Nucleus ruber.

Nu. r. t., Nucleus reticularis tegmenti.

Nu. t. s. (or Nu. tr. sol.), Nucleus tractus solitarii.

Nu. x. of l. c. of nu. r., Nucleus capsulæ lateralis nuclei rubri.

Nu. y., Anterolateral extremity of nucleus of N. vest. medialis.

P. f., Pedunculus flocculi.

Py., Pyramis.

R. d. N. V, Radix descendens (mesencephalica) N. trigemini.

R. d. N. vest. (or Rad. desc. N. vest.), Radix descendens N. vestibuli.

R. l., Recessus lateralis ventriculi quarti.

S. 1., Transverse series.

S. 2., Horizontal series.

S. a., Striæ acusticæ.

S. a. p. (or St. a. p., or Str. alb. p., or St. alb. p.), Stratum album profundum.

Sen. V, Vide N. V. (s.).

S. f., Substantia ferruginea.

S. g. (or Sub. gel., or Sub. gel. Rolandi), Substantia gelatinosa Rolandi.

S. i. l (or St. i. l.), Stratum interolivare lemnisci. (In Fig. 20 extend the line through the olive.)

S. n., Substantia nigra.

St. g. c. (or St. gr. c.), Stratum griseum centrale.

T. fr. D. to c. (or Tr. fr. nu. D.), Tract from Deiter's nucleus to the funiculus lateralis.

T. s. (or Tr. s., or Tr. sol.), Tractus solitarius.

T. s. N. V (or T. s. n. t., or Tr. s. n. t., or Tr. s. N. V), Tractus spinalis N. trigemini.

V. q., Ventriculus quartus.

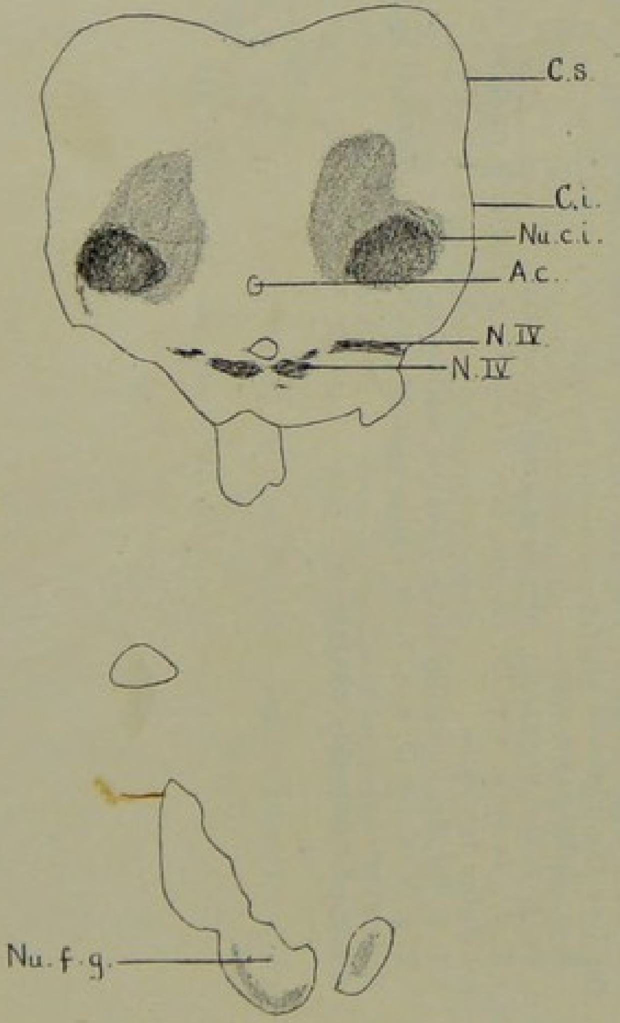


Fig. 3, Series I, Section 38.

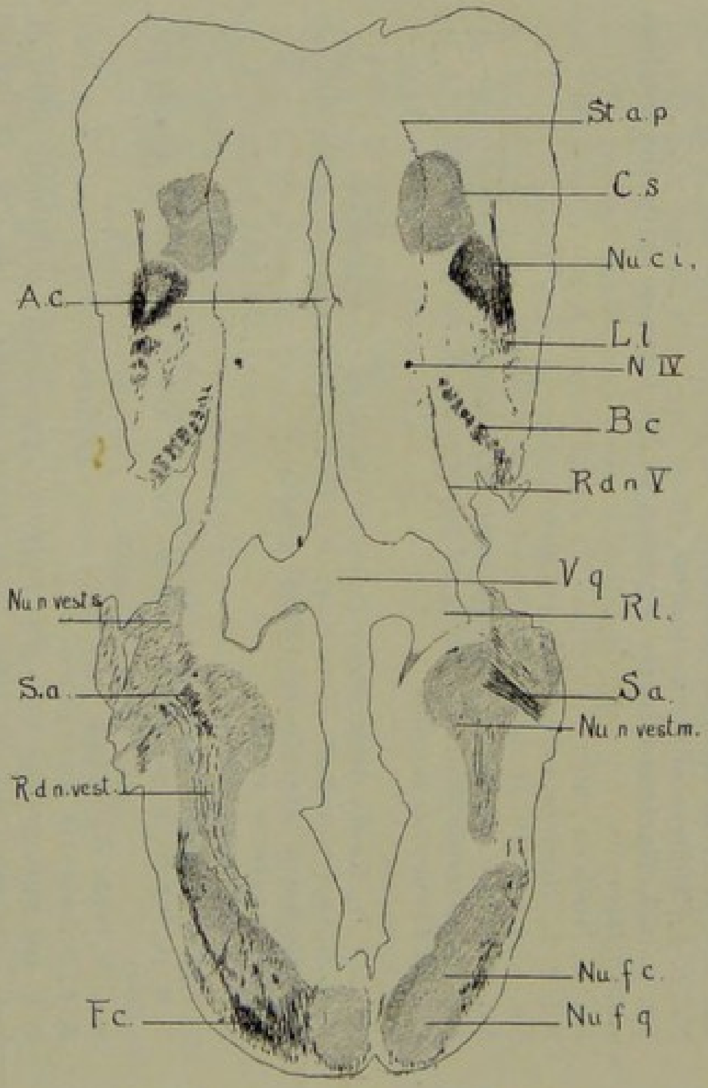


Fig. 4, Series I, Section No. 56.

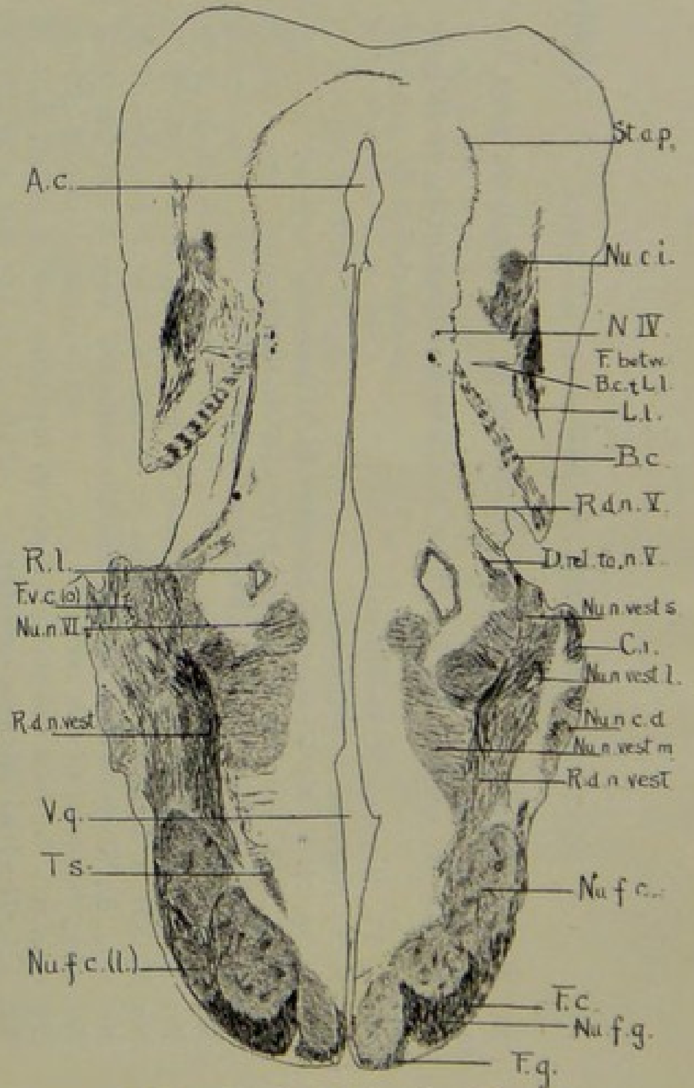


Fig. 5, Series I, Section No. 62.

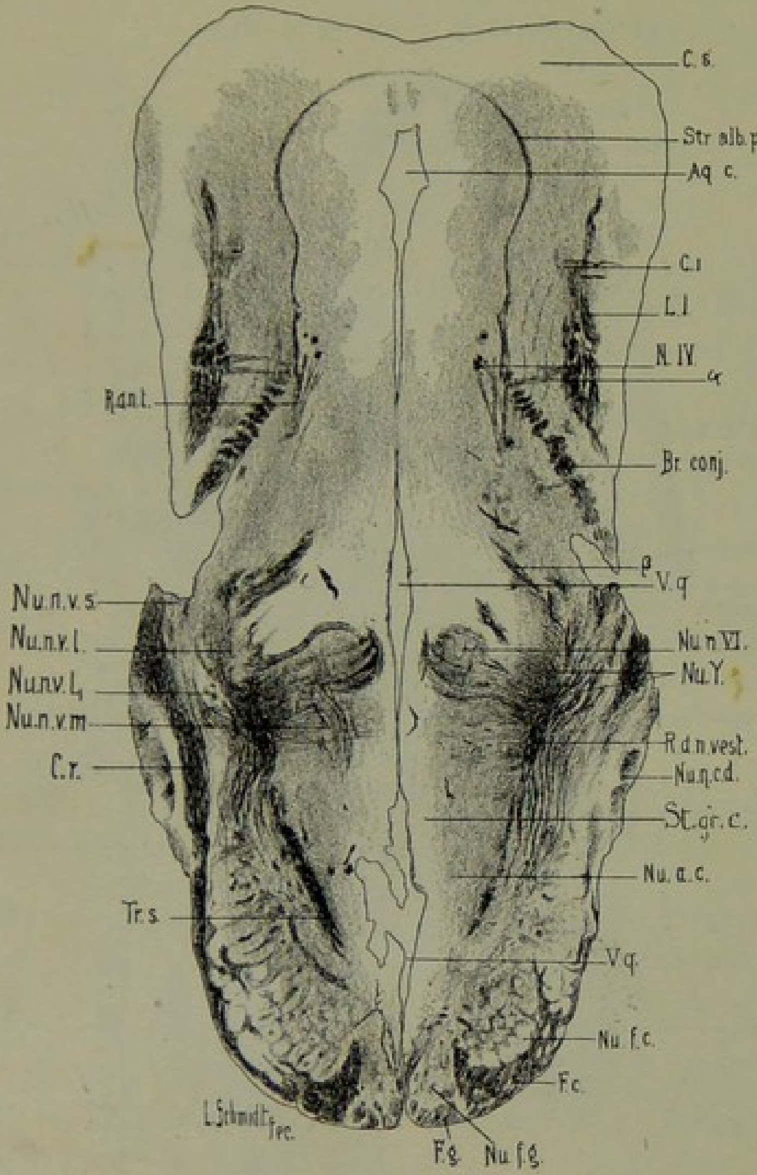


Fig. 6, Series I, Section No. 66.

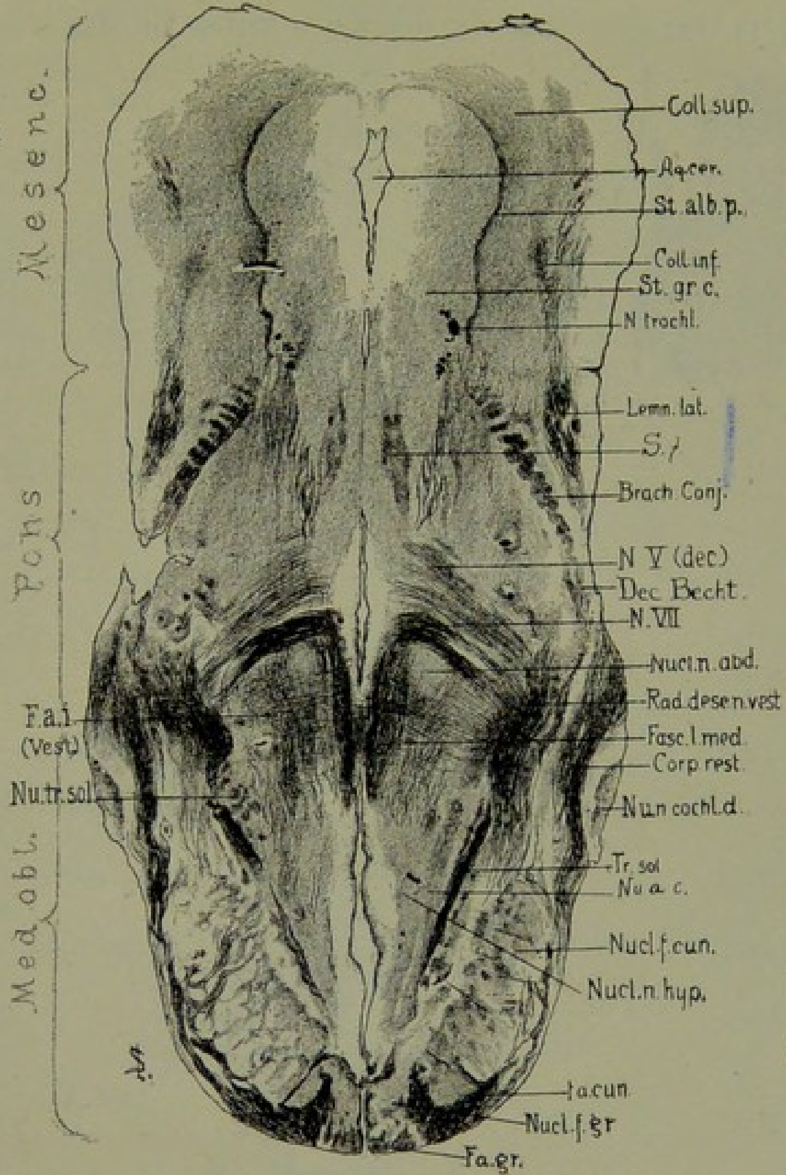


Fig. 7, Series I, Section No. 72.

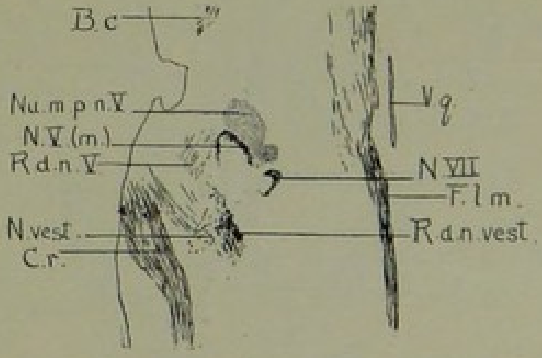


Fig. 8, Series I, Section No. 74.

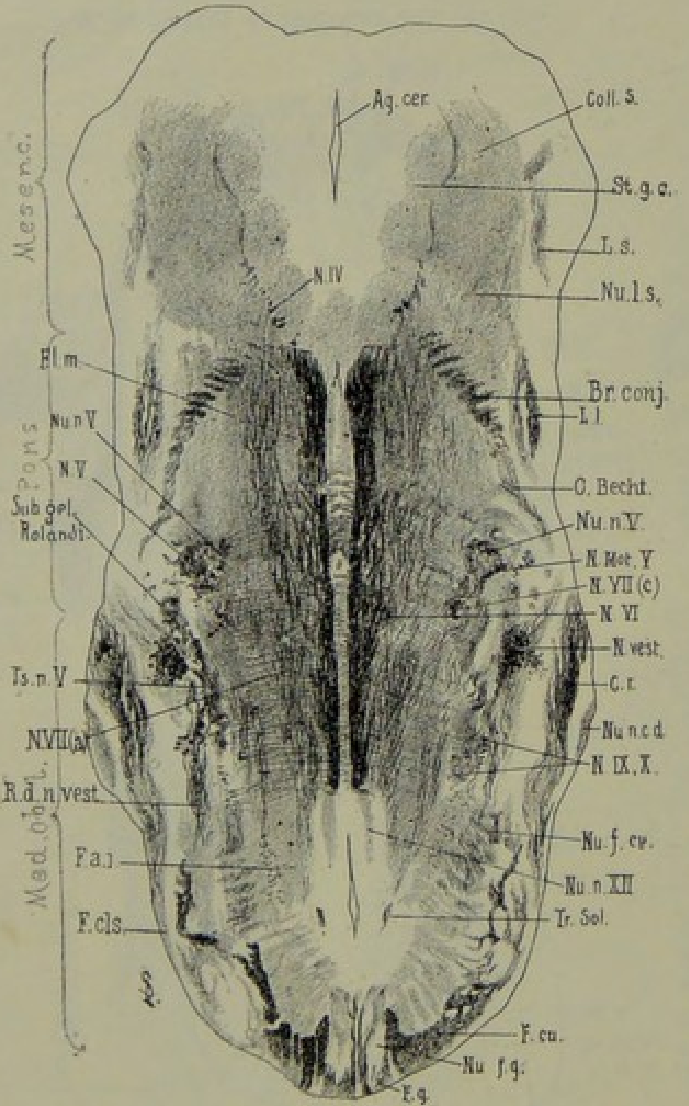


Fig. 9, Series I, Section No. 80.

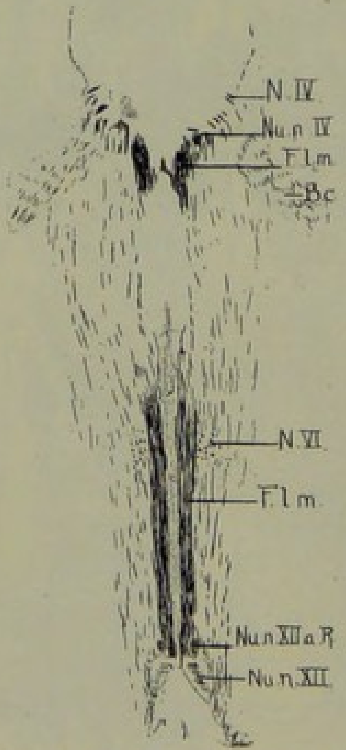


Fig. 10, Series I, Section No. 86.

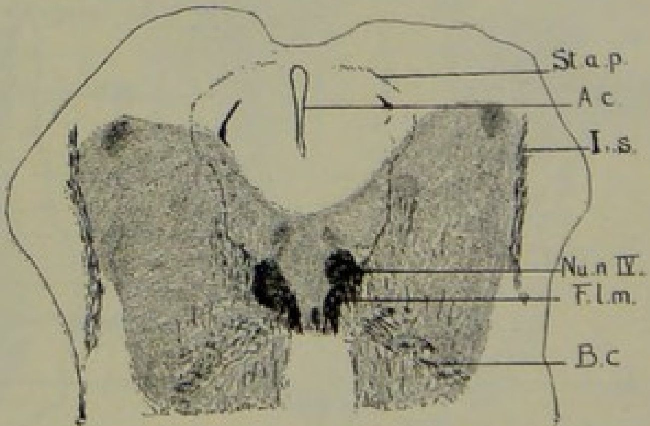


Fig. 11, Series I, Section No. 94.

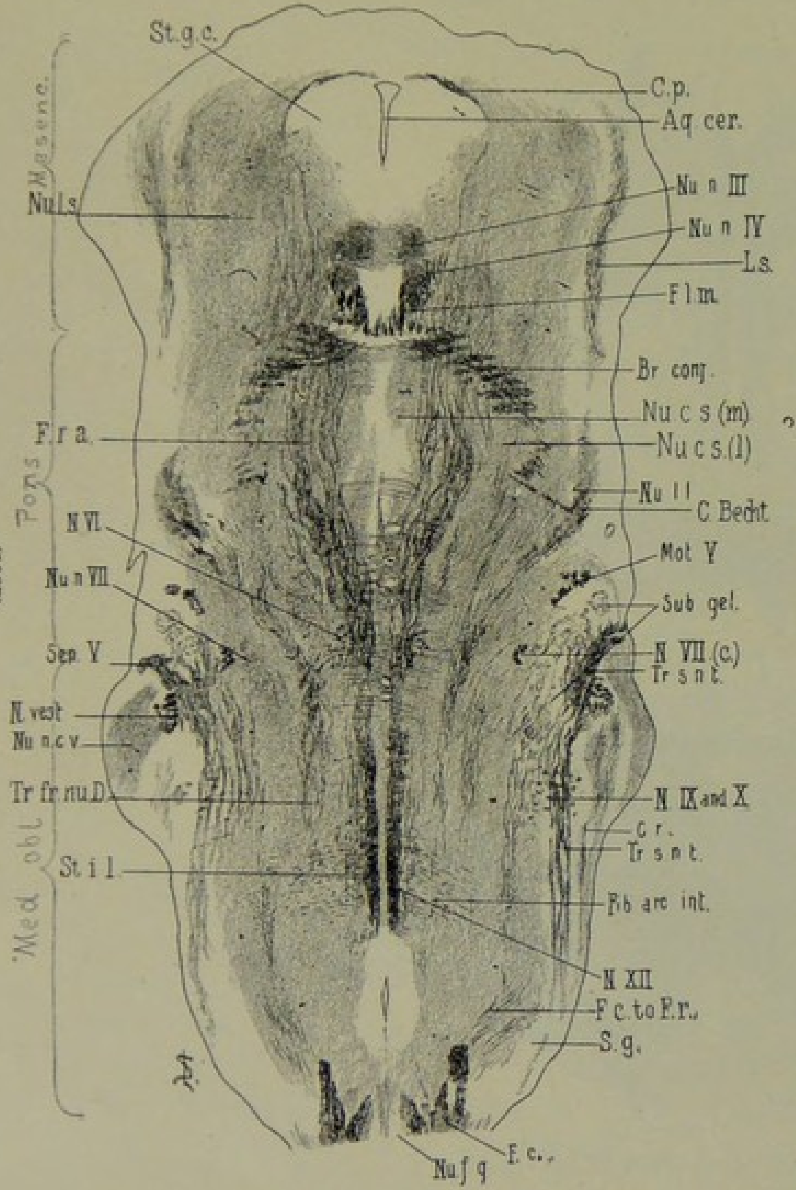


Fig. 12, Series I, Section No. 100.

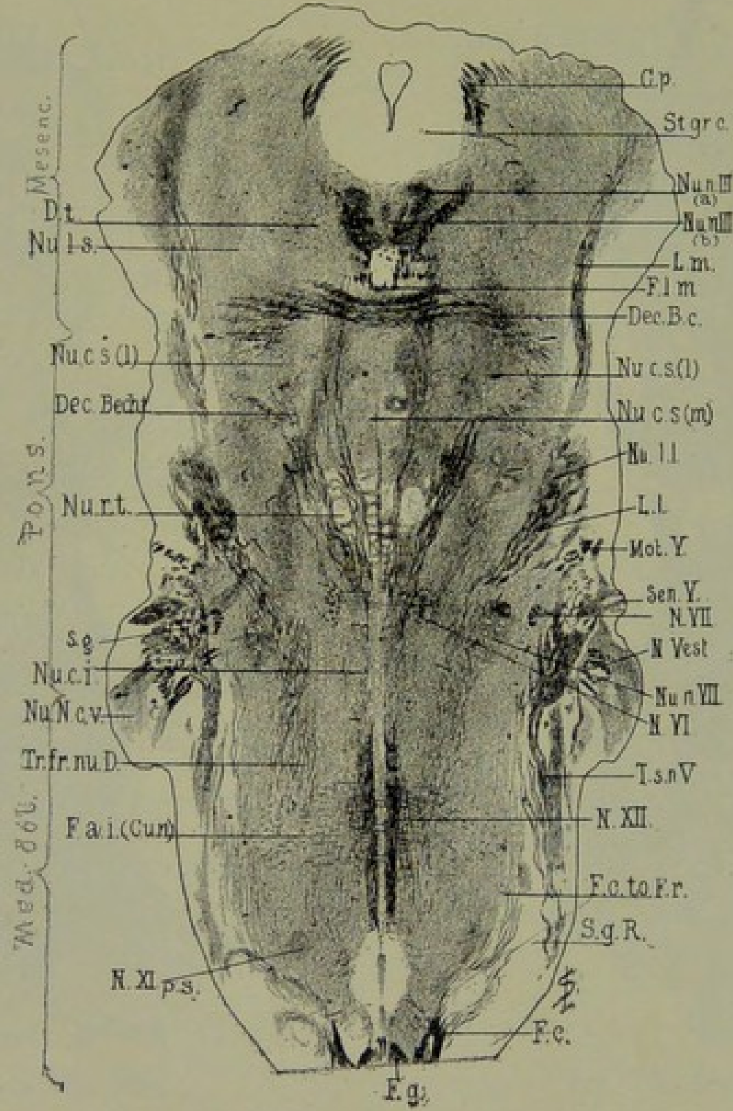


Fig. 13, Series I, Section No. 108.

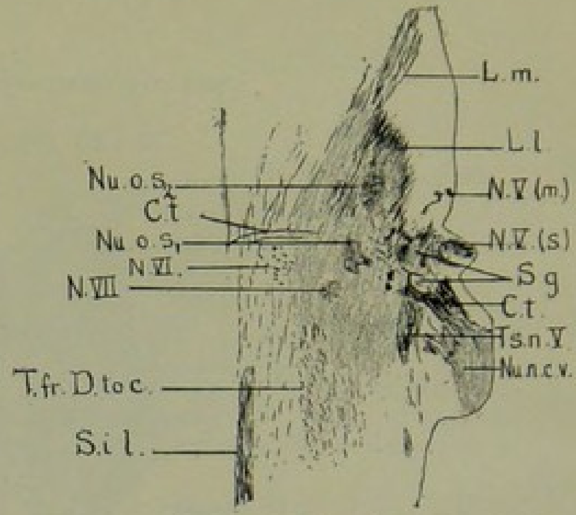


Fig. 14, Series I, Section No. 114.

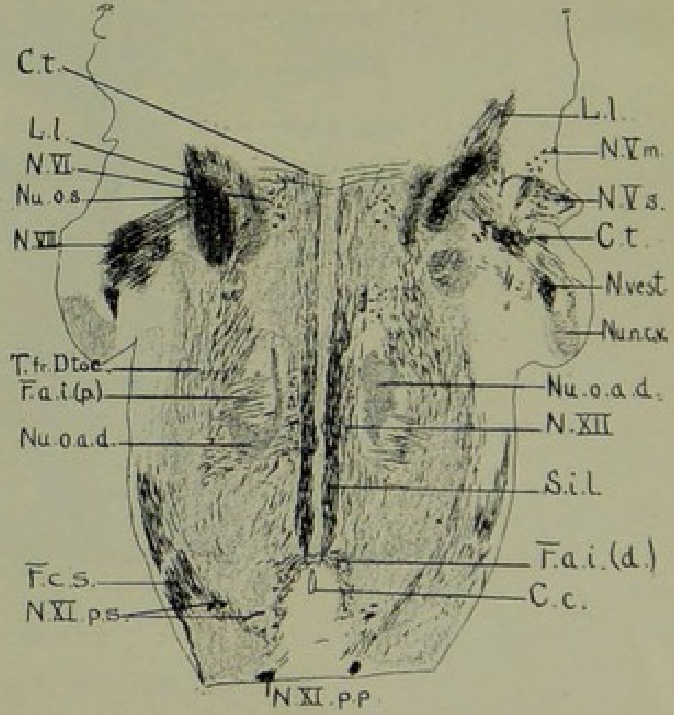


Fig. 15, Series I, Section No. 116.

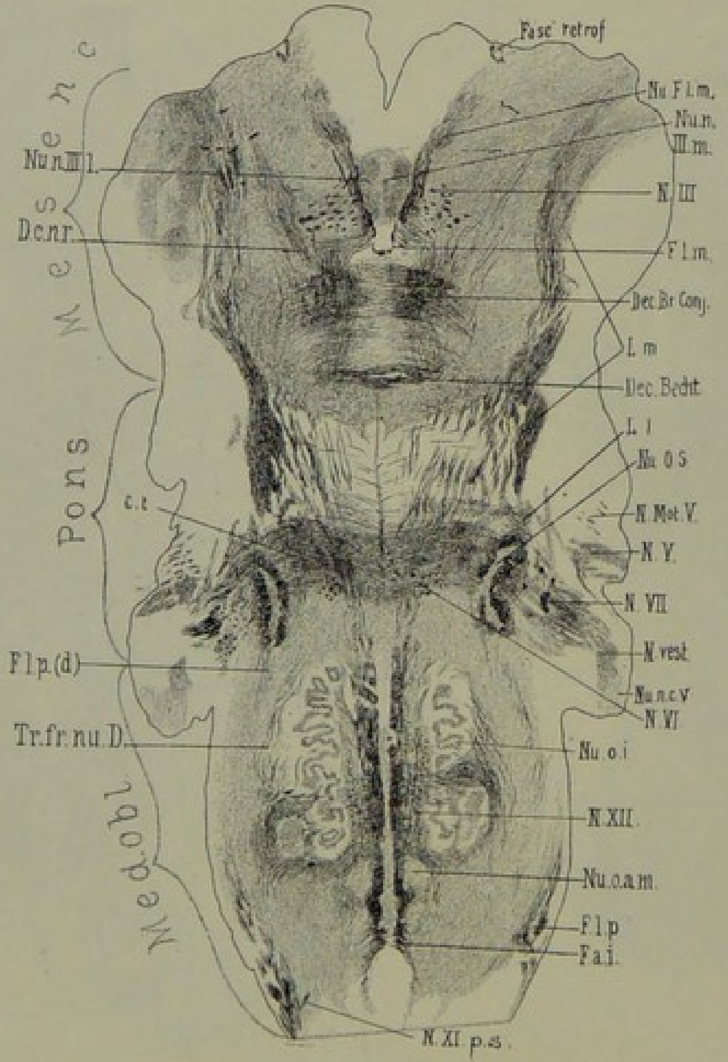


Fig. 16, Series I, Section No. 122.

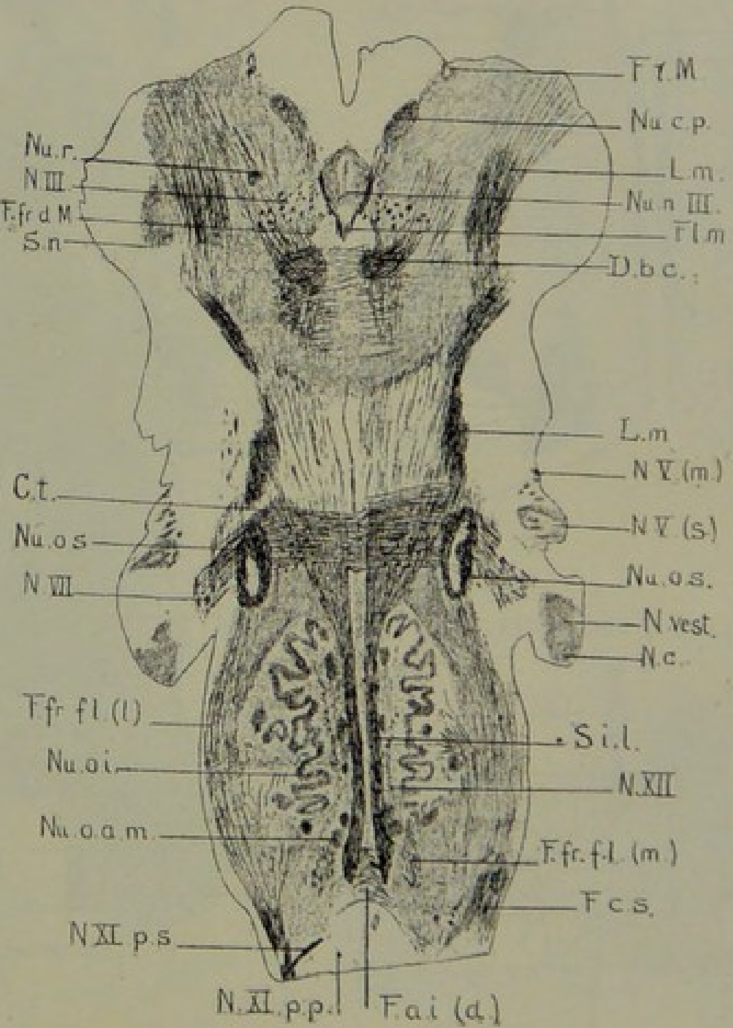


Fig. 17, Series I, Section No. 126.

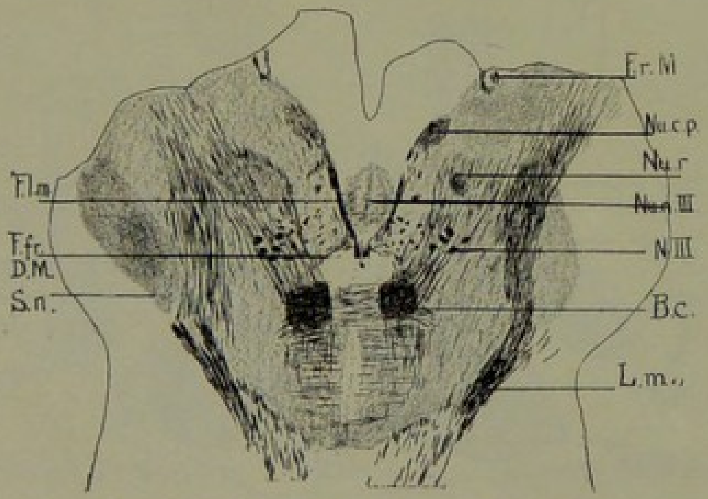


Fig. 18, Series I, Section No. 128.

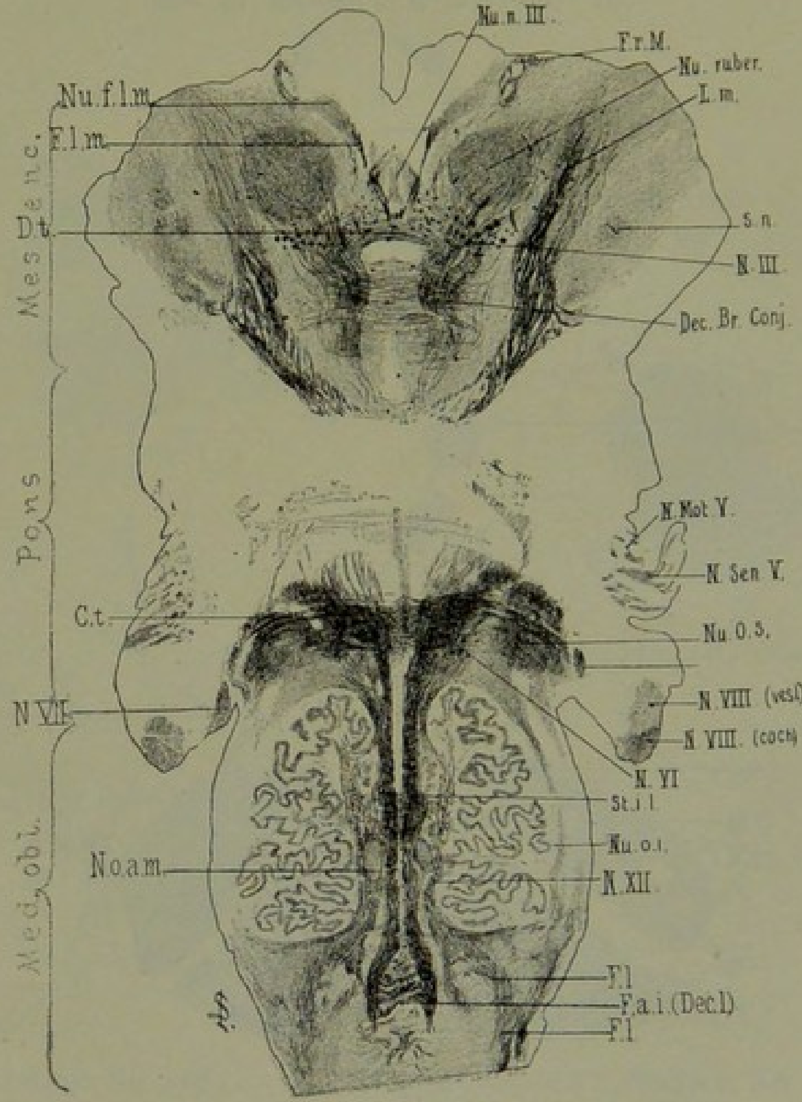


Fig. 19, Series I, Section No. 136.

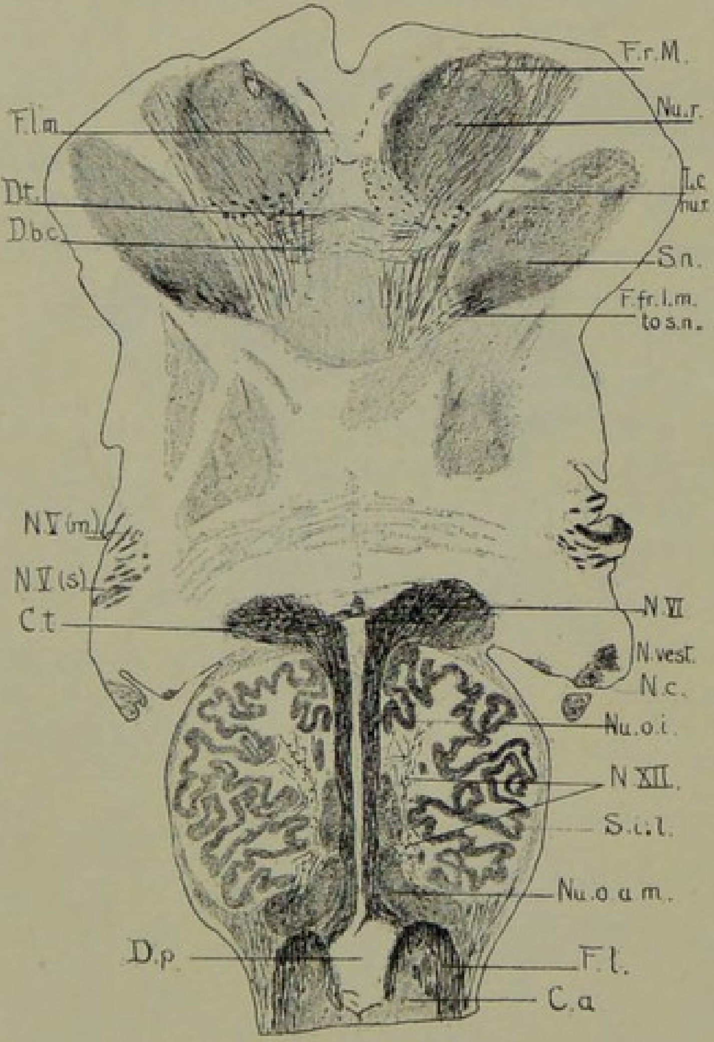


Fig. 20, Series I, Section No. 146.

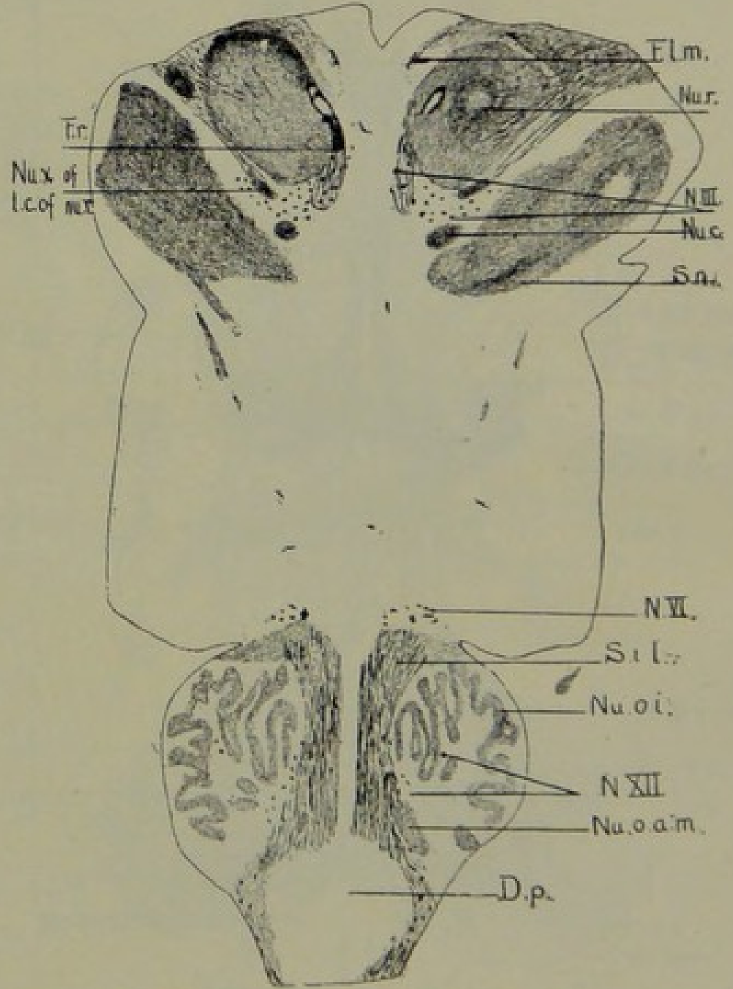


Fig. 21, Series I, Section No. 162.

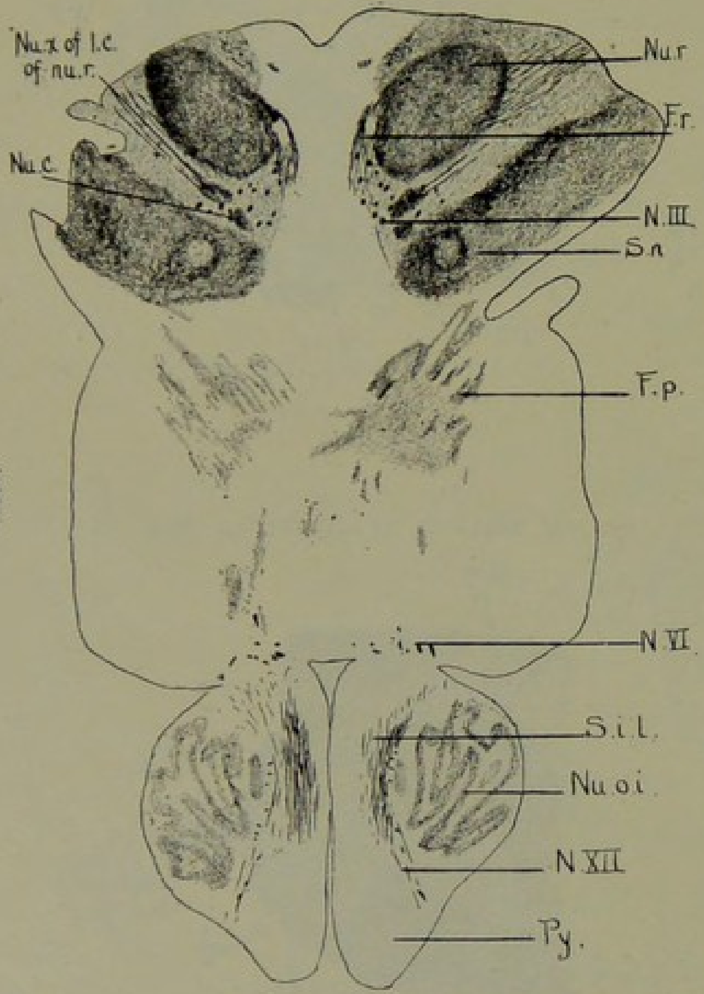


Fig. 22, Series I, Section No. 22.

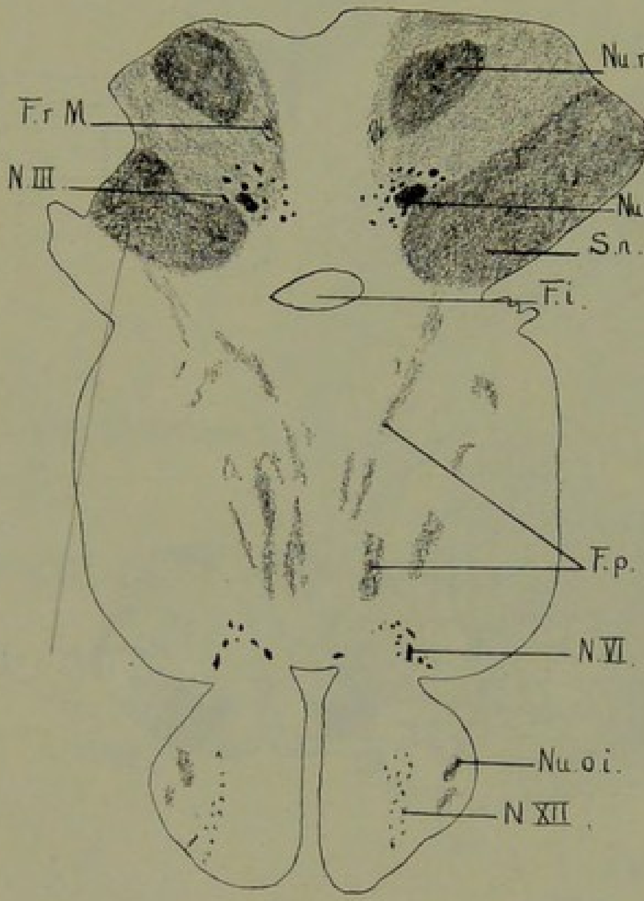


Fig. 23, Series I, Section No. 180.

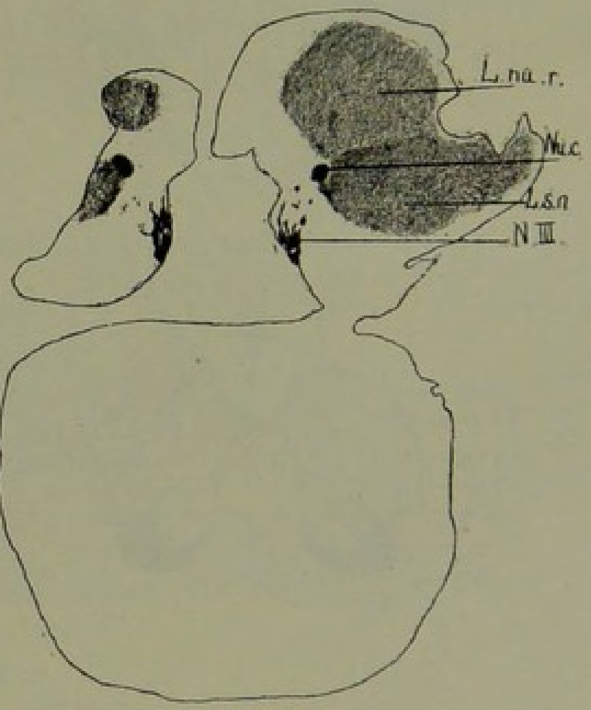


Fig. 24, Series I, Section No. 202.

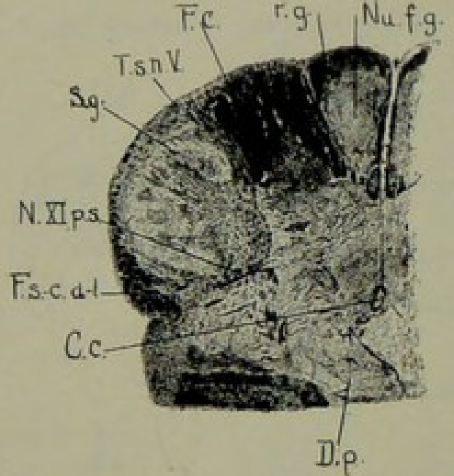


Fig. 25, Series II, Section No. 20.

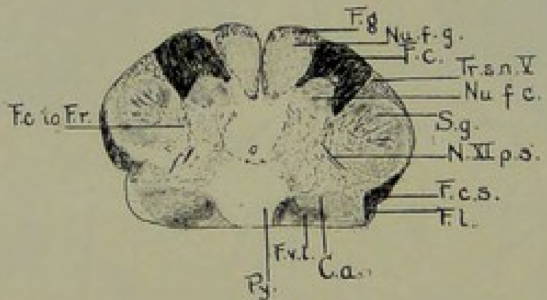


Fig. 26, Series II, Section No. 28.

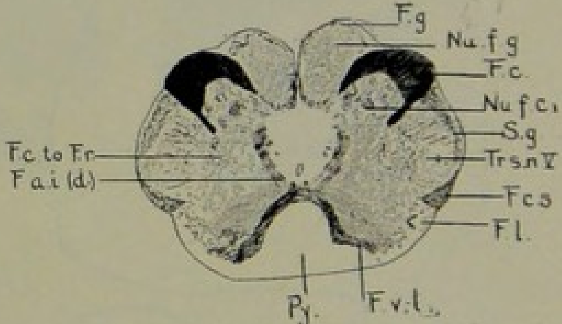


Fig. 27, Series II, Section No. 42.

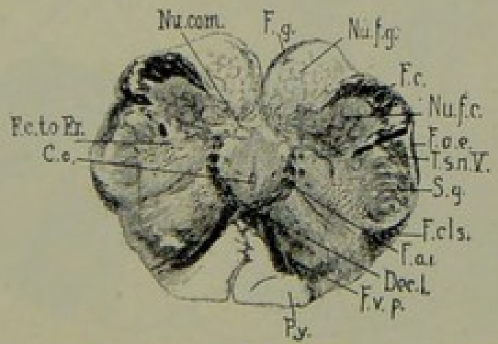


Fig. 28, Series II, Section No. 28.

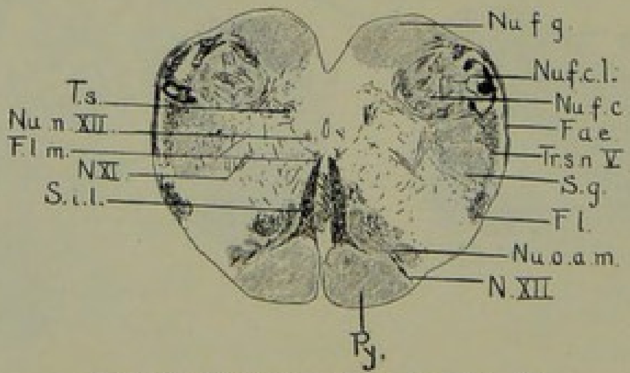


Fig. 29, Series II, Section No. 70.

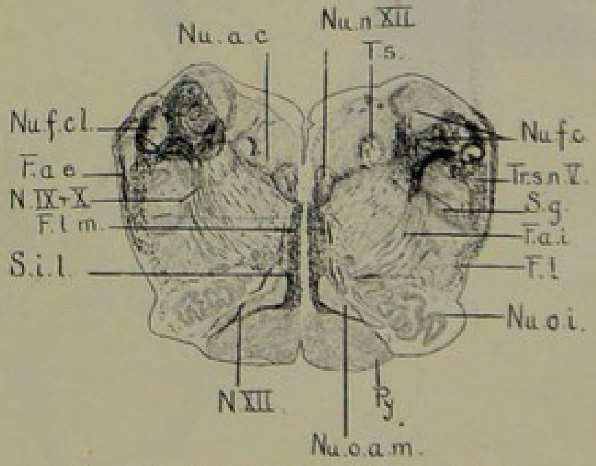


Fig. 30, Series II, Section No. 84.

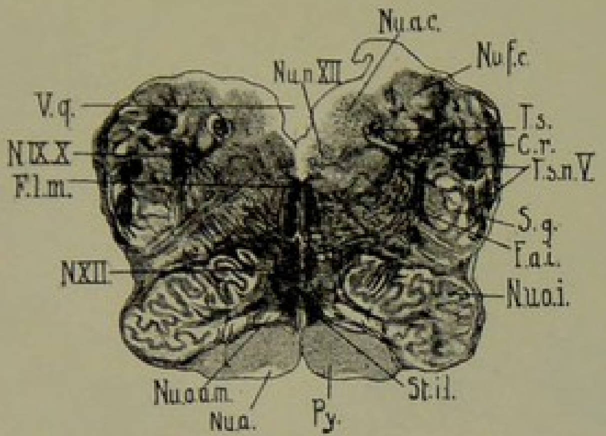


Fig. 31, Series II, Section No. 94.

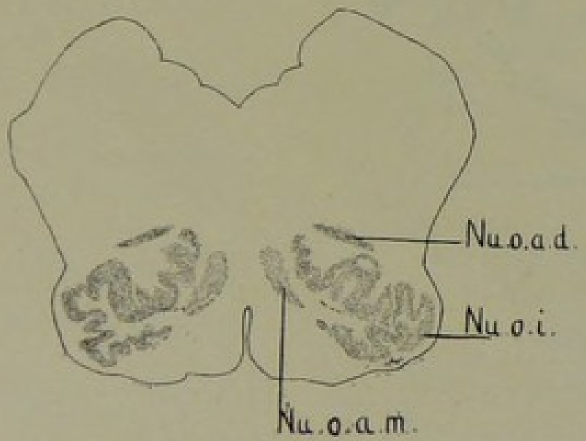


Fig. 32, Series II, Section No. 118.

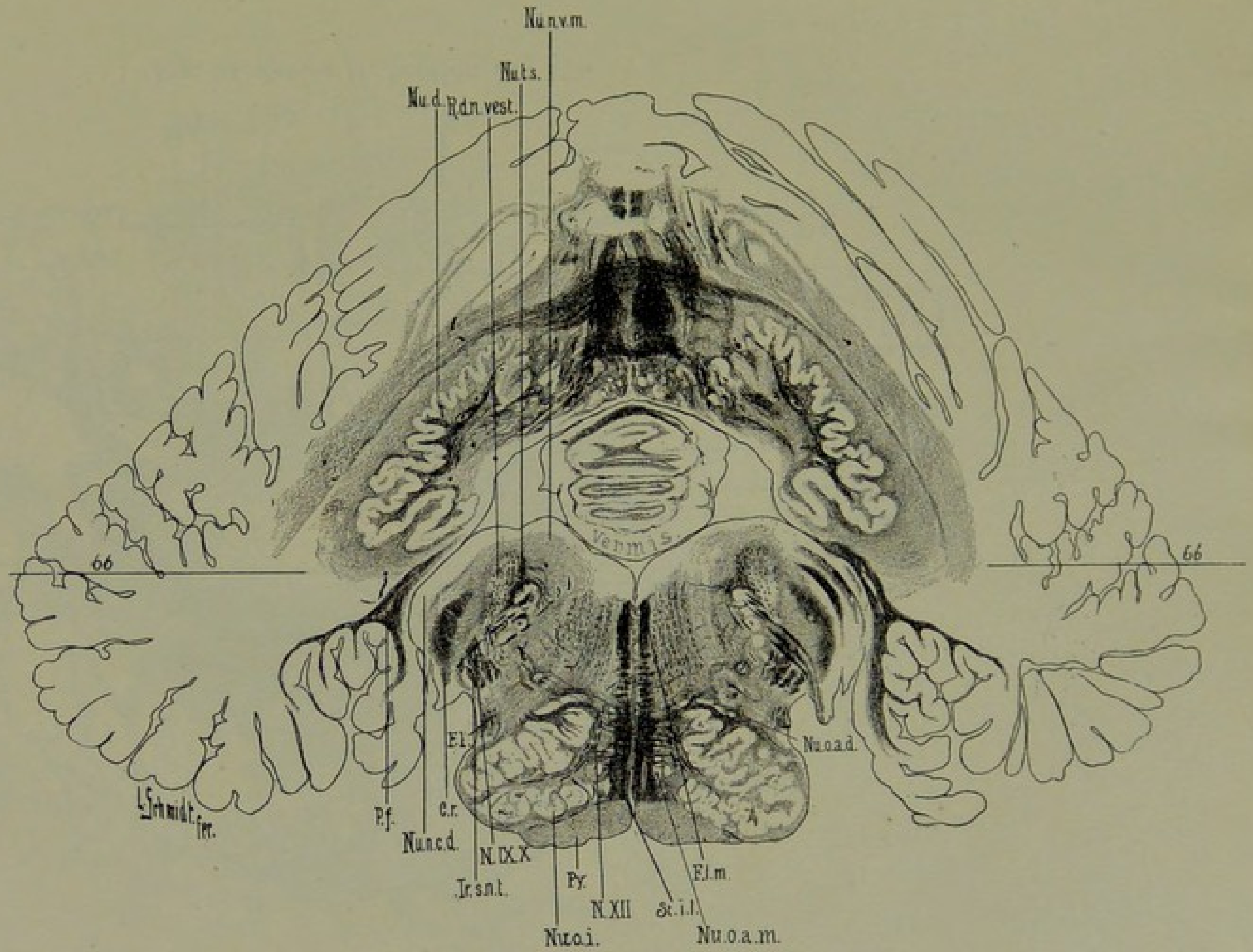


Fig. 33, Series II, Section No. 146.

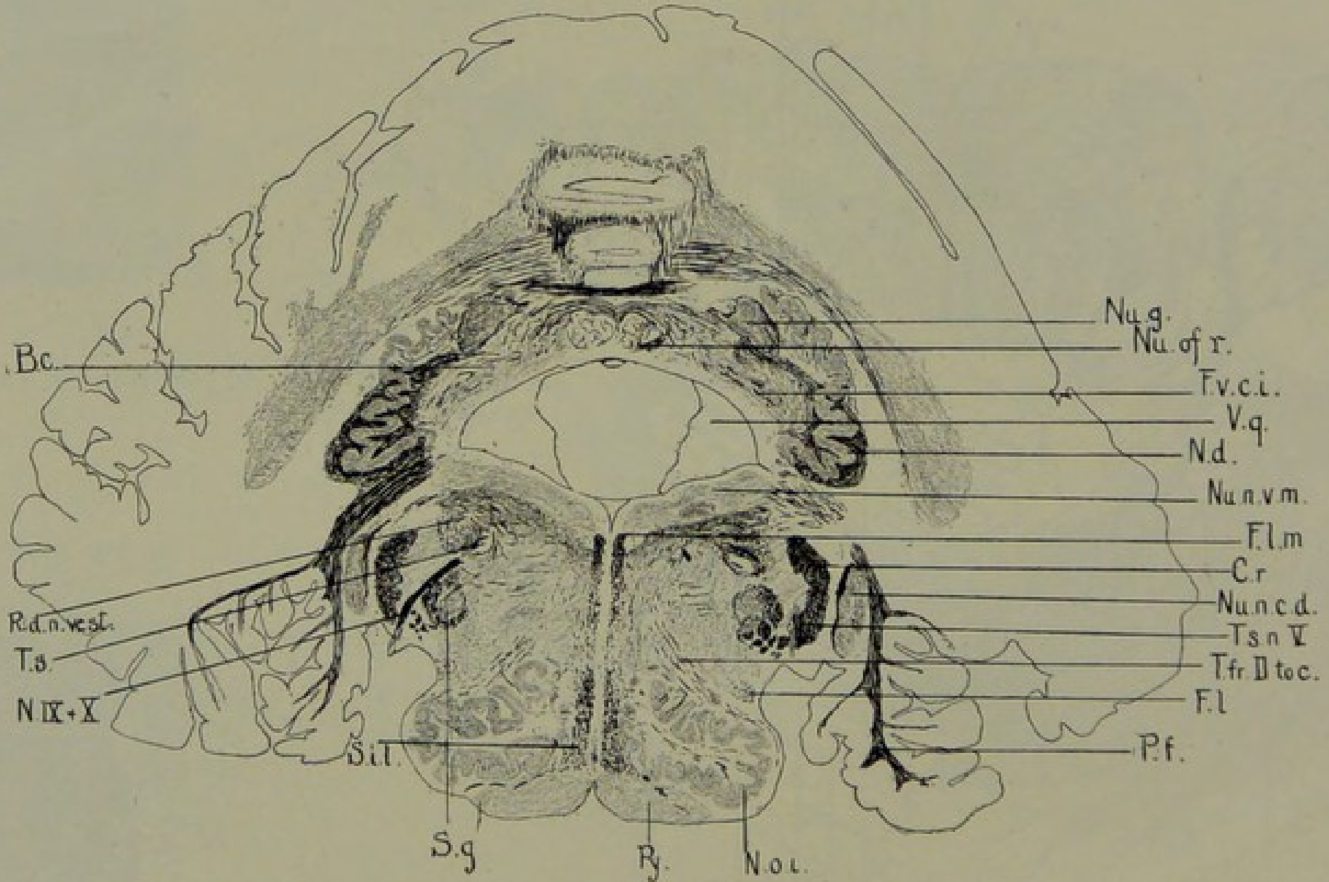


Fig. 34, Series II, Section No. 158.

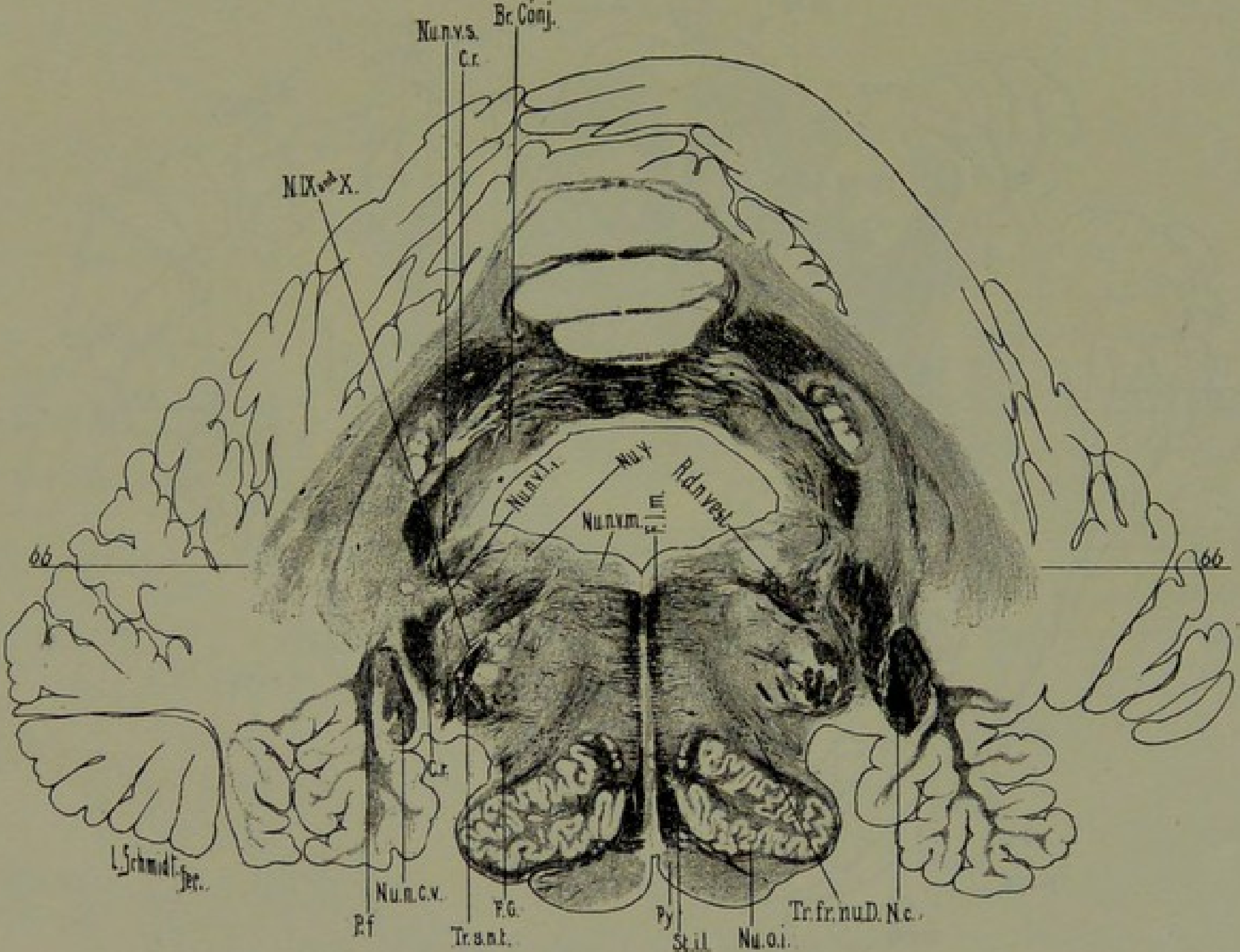


Fig. 35, Series II, Section No. 170.

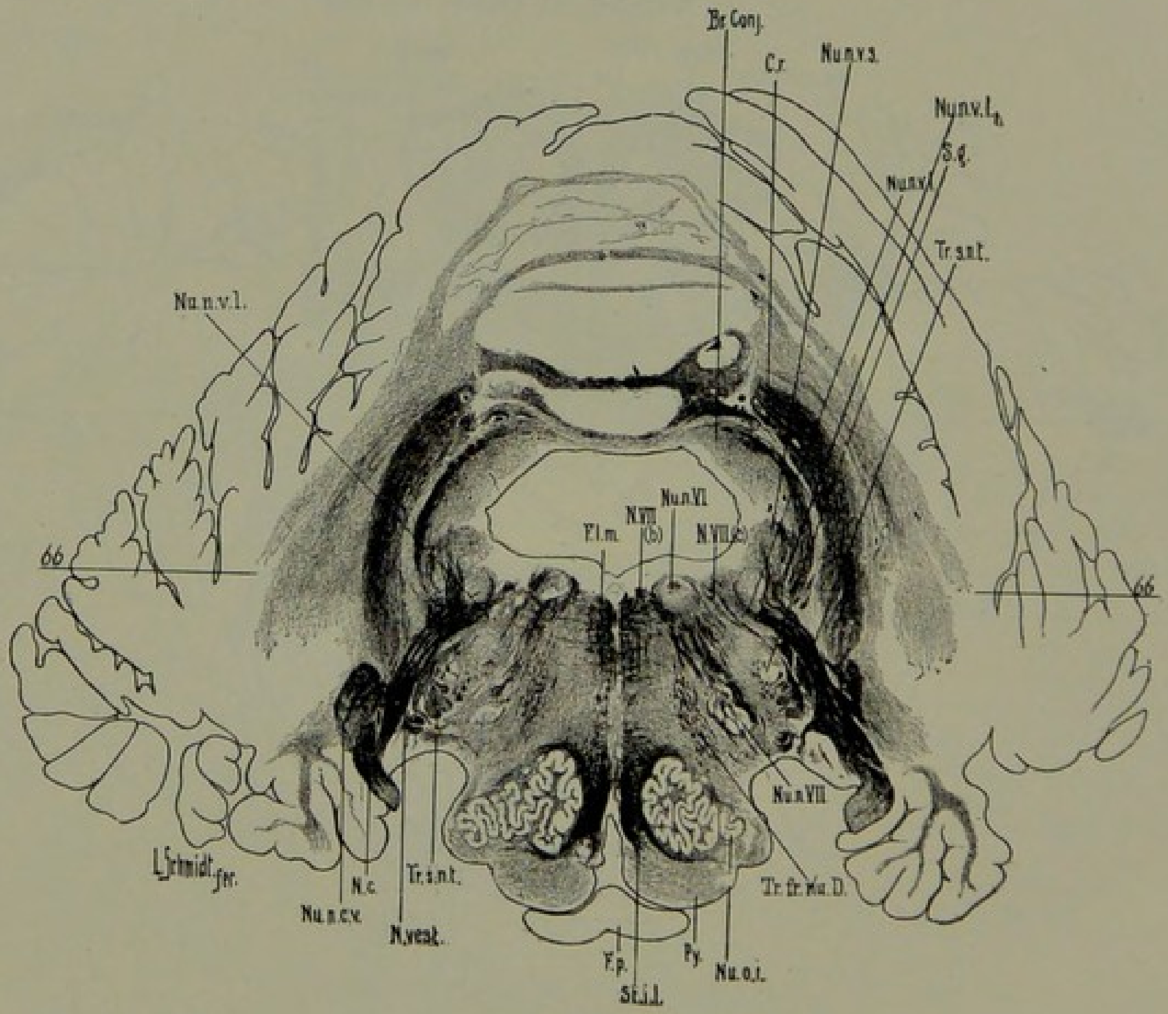


Fig. 36, Series II, Section No. 182.

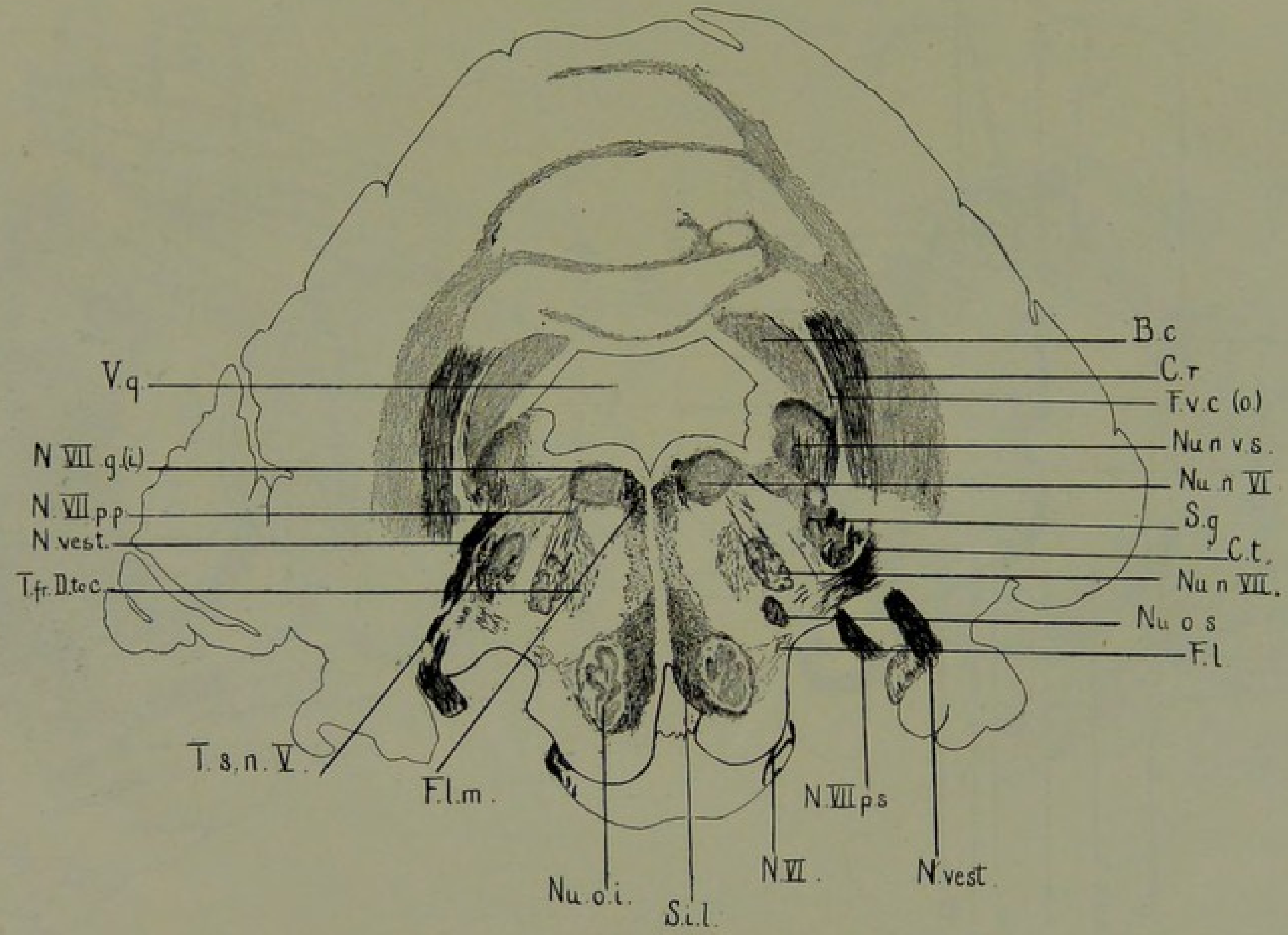


Fig. 37, Series II, Section No. 190.

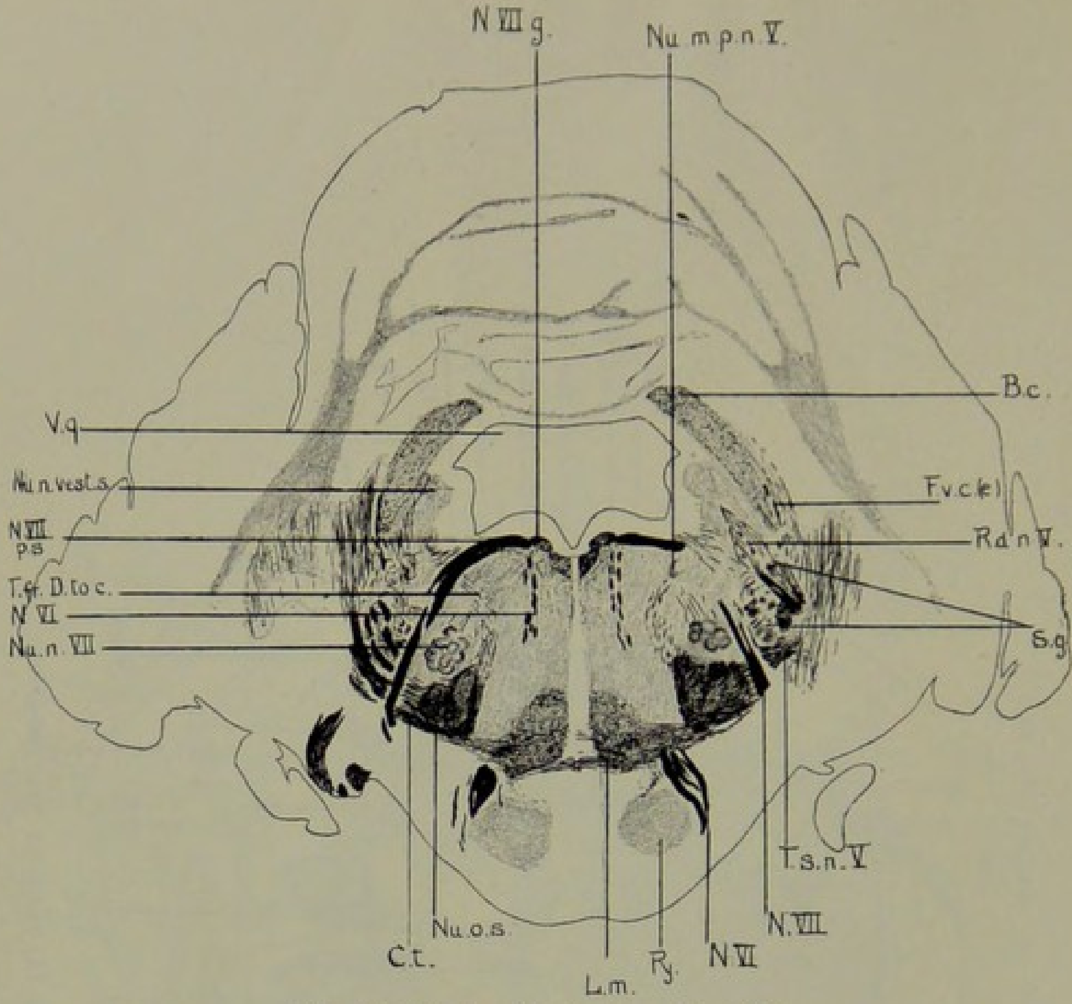


Fig. 38, Series II, Section No. 200.

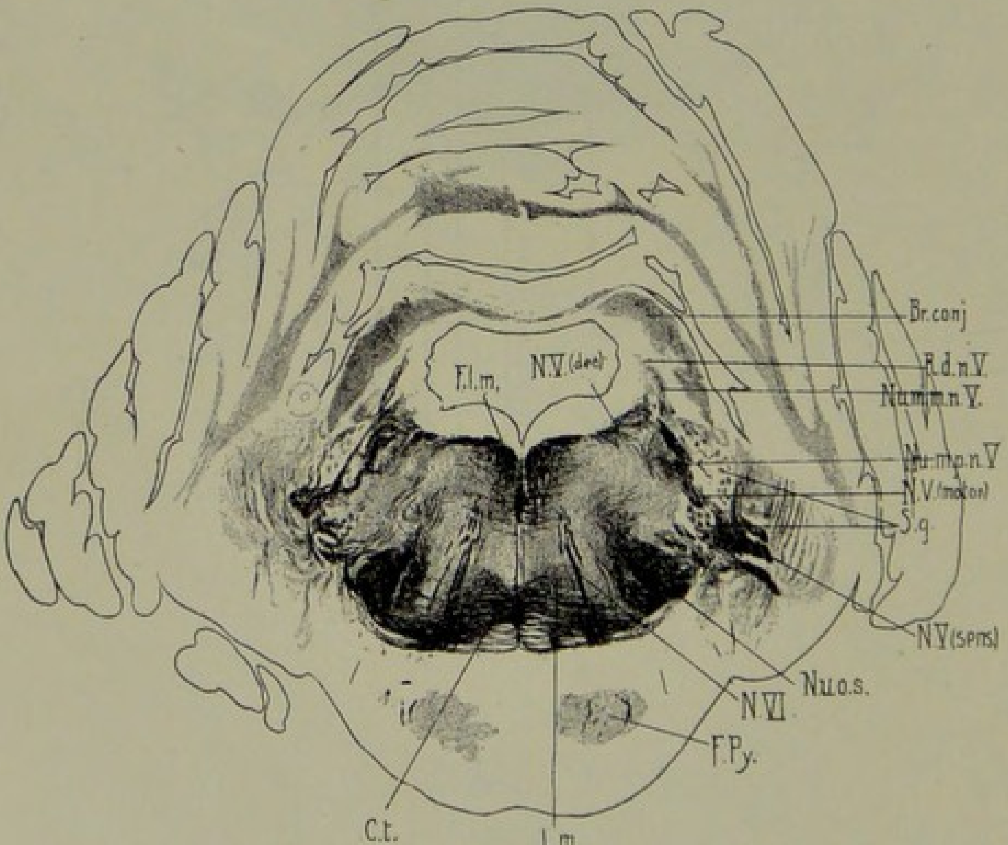


Fig. 39, Series II, Section No. 212.

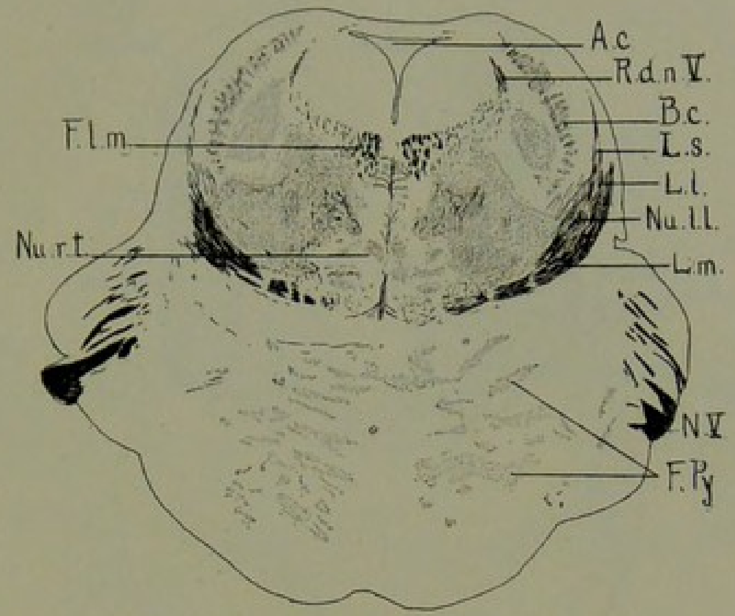


Fig. 40, Series II, Section No. 254.

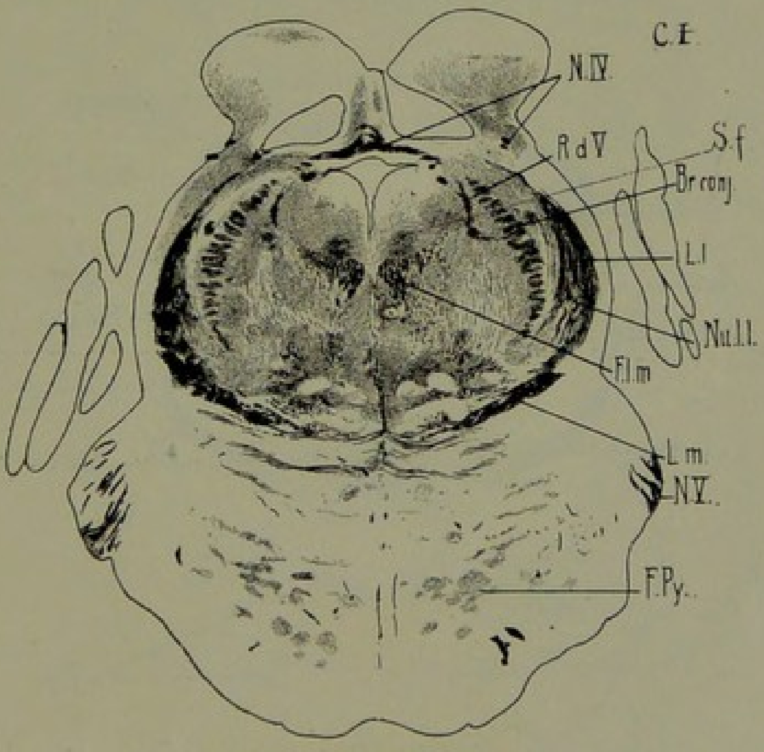


Fig. 41, Series II, Section No. 268.

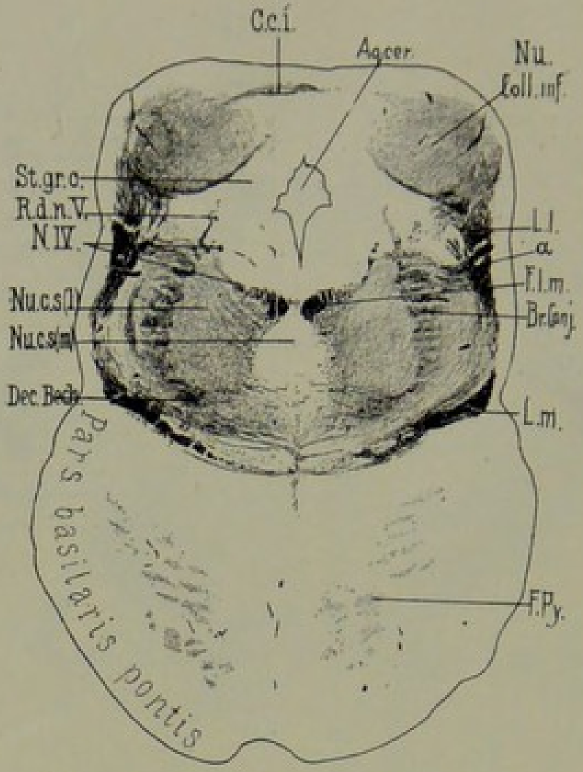


Fig. 42, Series II, Section No. 290.

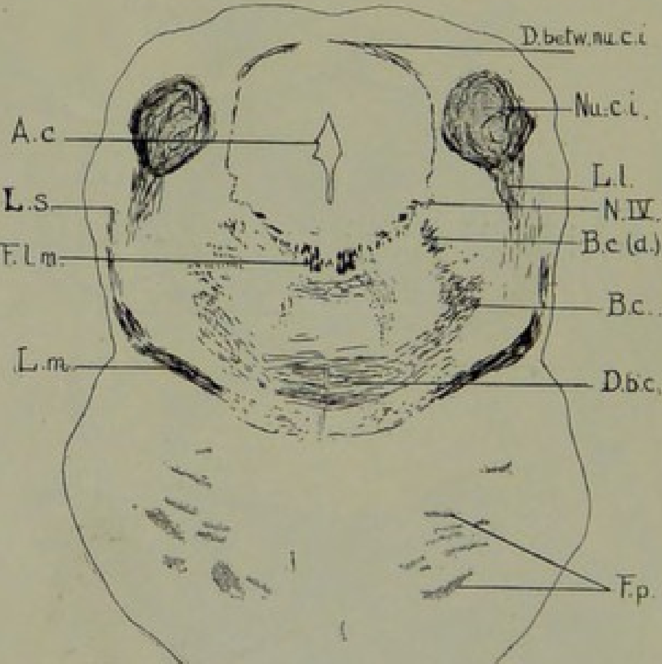


Fig. 43, Series II, Section No. 304.

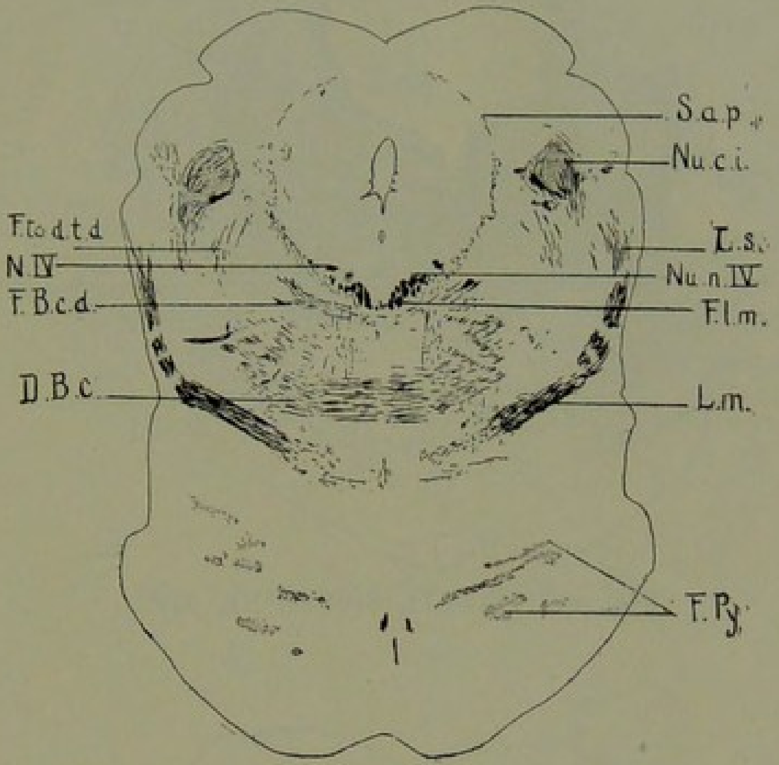


Fig. 44, Series II, Section No. 316.

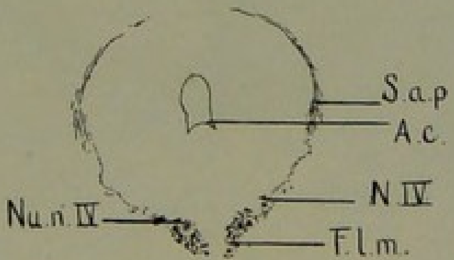


Fig. 45, Series II, Section No. 330.

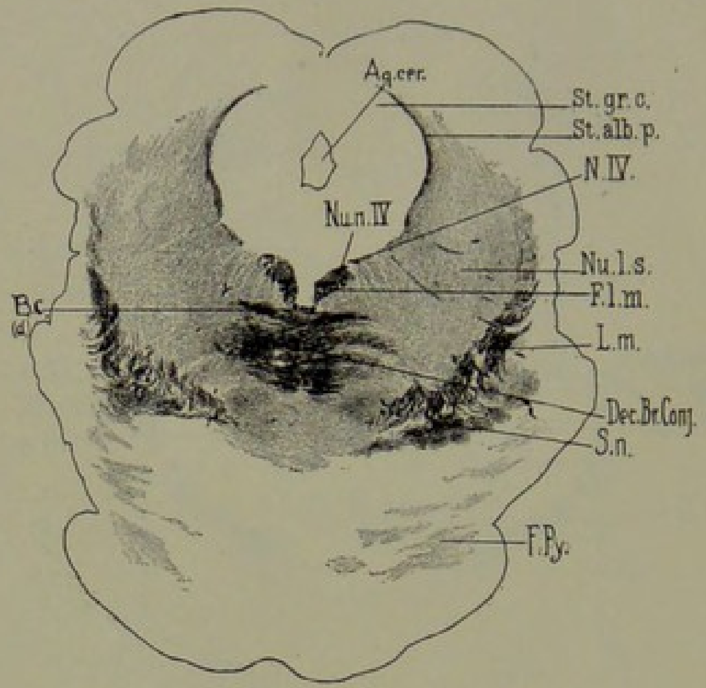


Fig. 46, Series II, Section No. 338.

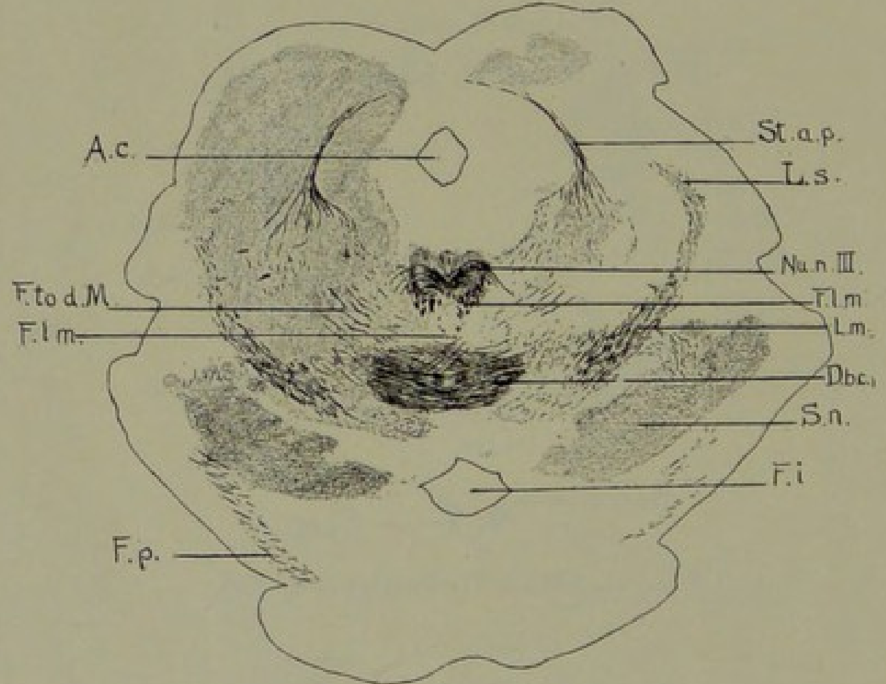


Fig. 47, Series II, Section No. 354.

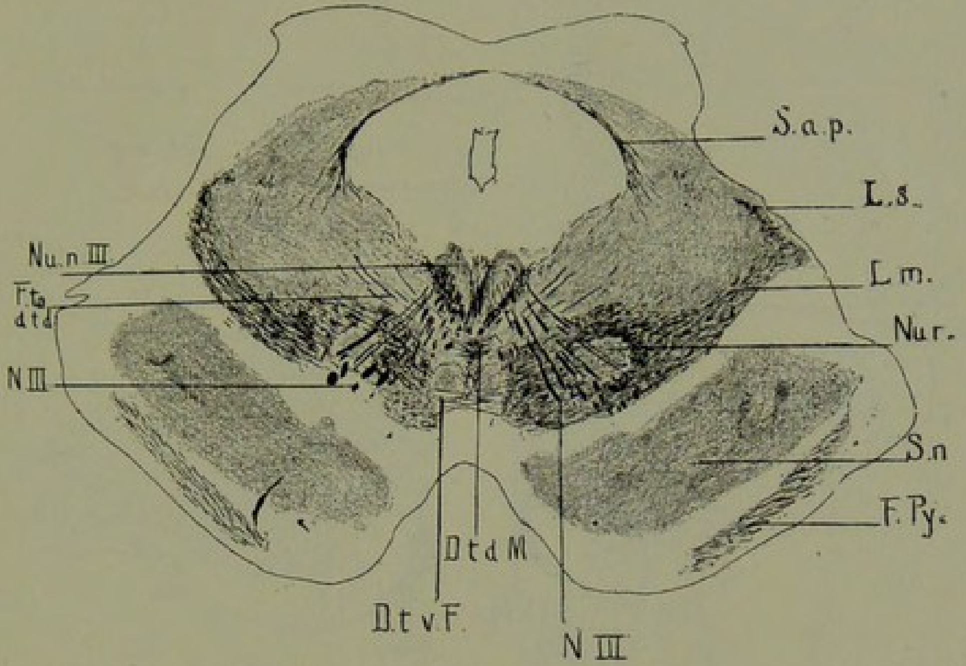


Fig. 48, Series II, Section No. 372.

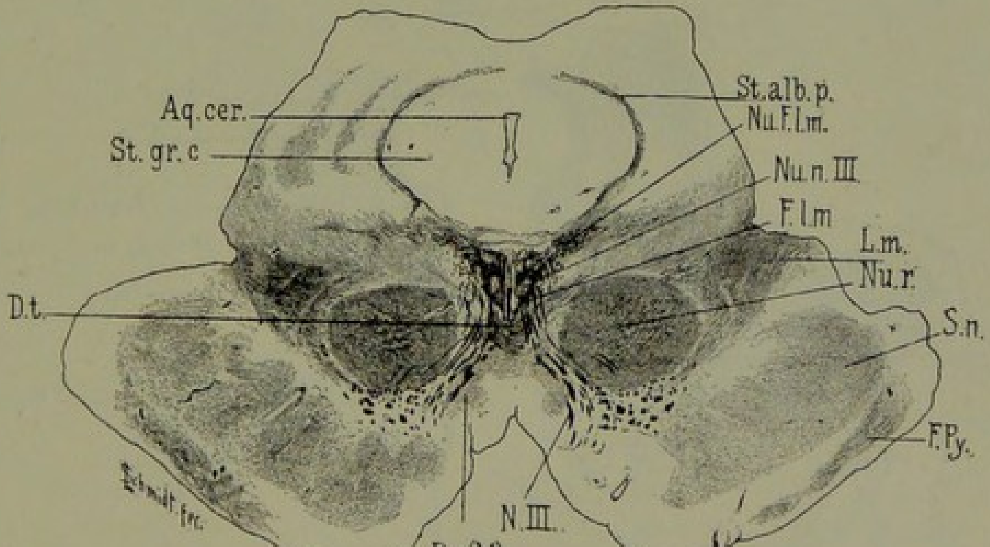


Fig. 49, Series II, Section No. 384.

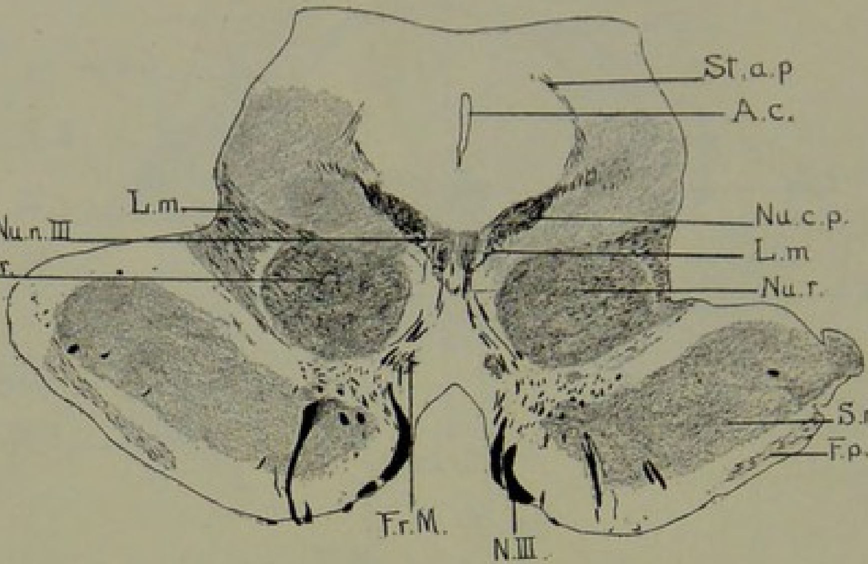


Fig. 50, Series II, Section No. 396.

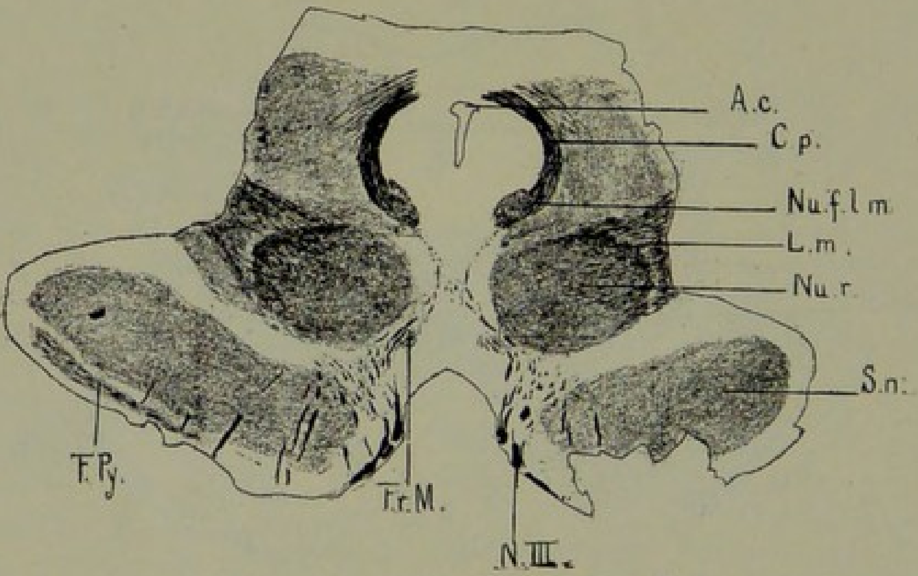


Fig. 51, Series II, Section No. 51.

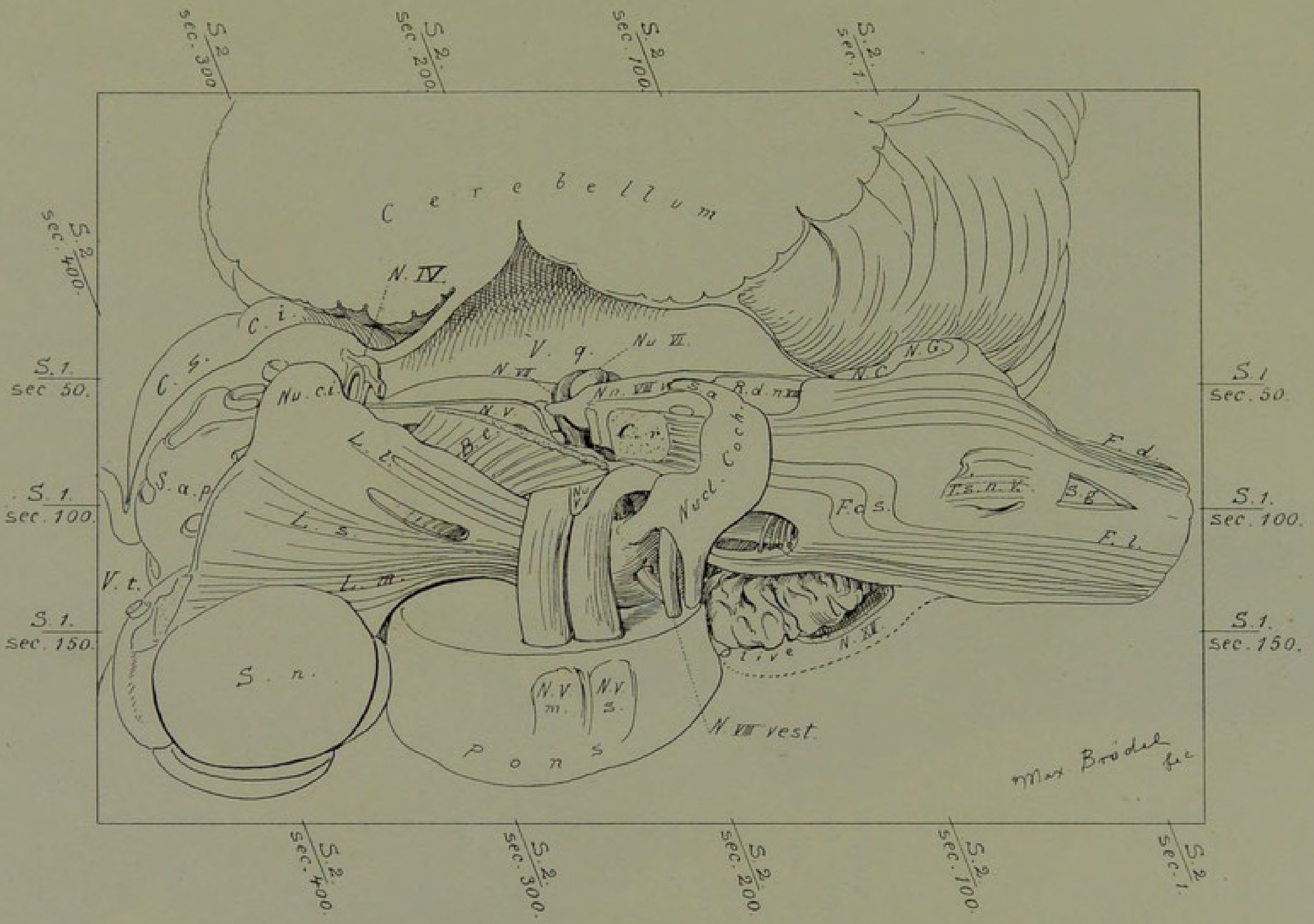


Fig. 52. Diagram from Plate I, to show the levels of the sections of the two series.

DESCRIPTION OF THE PLATES.

PLATE I.

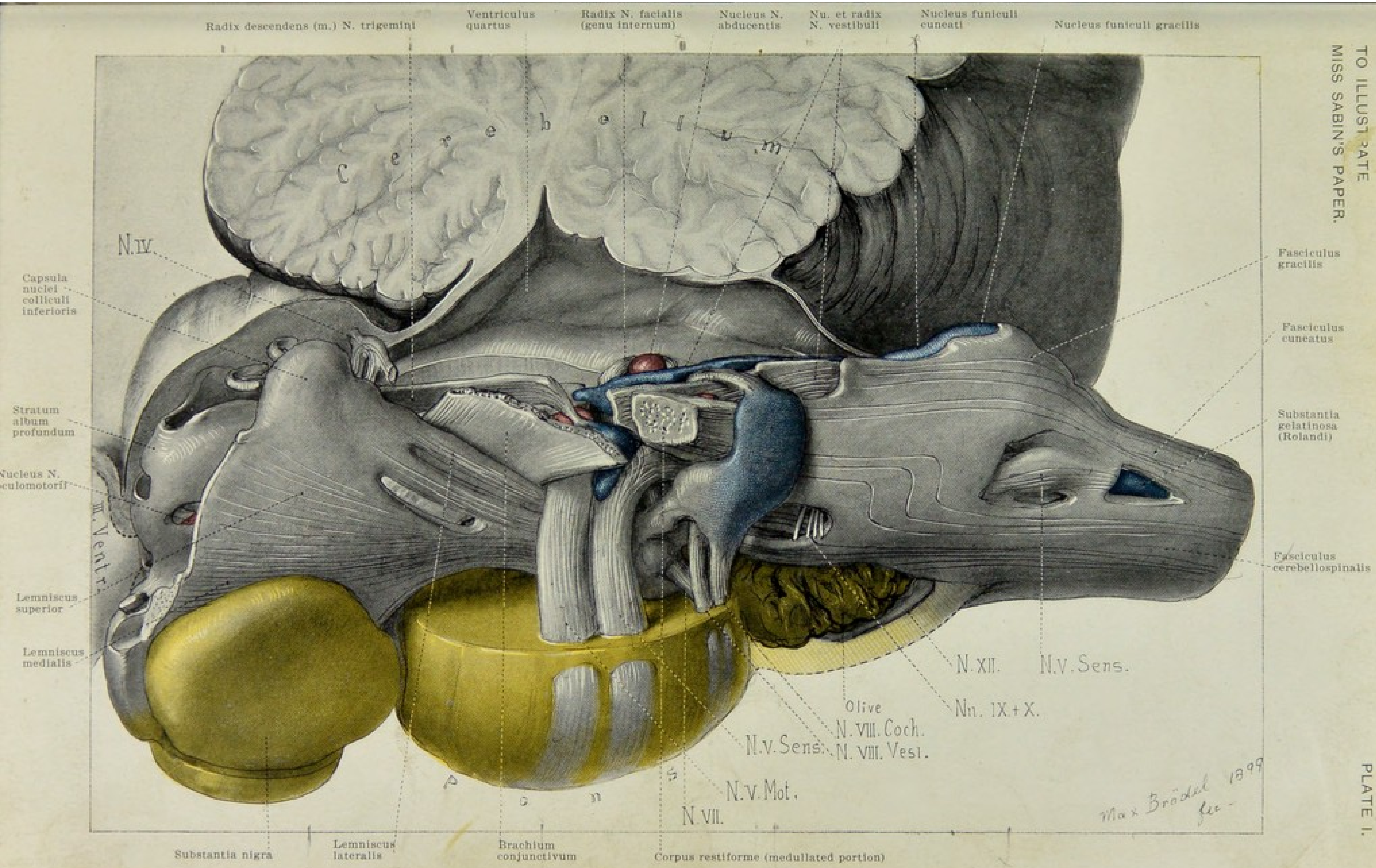
View of the model from the lateral surface. This view is designed to relate the model to the cord, the cerebellum and the cerebrum. The cut edge of the cord shows on the extreme right. The following points will make the position of the model clear: the dorsal and lateral funiculi and the dorsal horn of the spinal cord, the cerebellum, the fourth ventricle, the inferior and superior colliculi and the third ventricle.

The color system is as follows: all fibres are in white and black, all nuclei in colors. Red represents the nuclei of the motor cerebral nerves, blue the nuclei of the sensory cerebral nerves and yellow all other nuclei.

Nu et Radix N. vestibuli: The nucleus is distinguishable from the root by its color. The ascending and descending parts of the root are to be determined by their relation to the entering root-bundle of the nerve. The part of the vestibular nucleus distal to the nucleus N. abducentis is the nucleus N. vestibuli medialis; the part proximal, is the nucleus N. vestibuli superior. The nucleus N. vestibuli lateralis (Deiters') pars lateralis) lies in the vestibular tract just dorsal to the corpus restiforme.

TO ILLUSTRATE
MISS SABIN'S PAPER.

PLATE I.



TO ILLUSTRATE MISS SABIN'S PAPER.

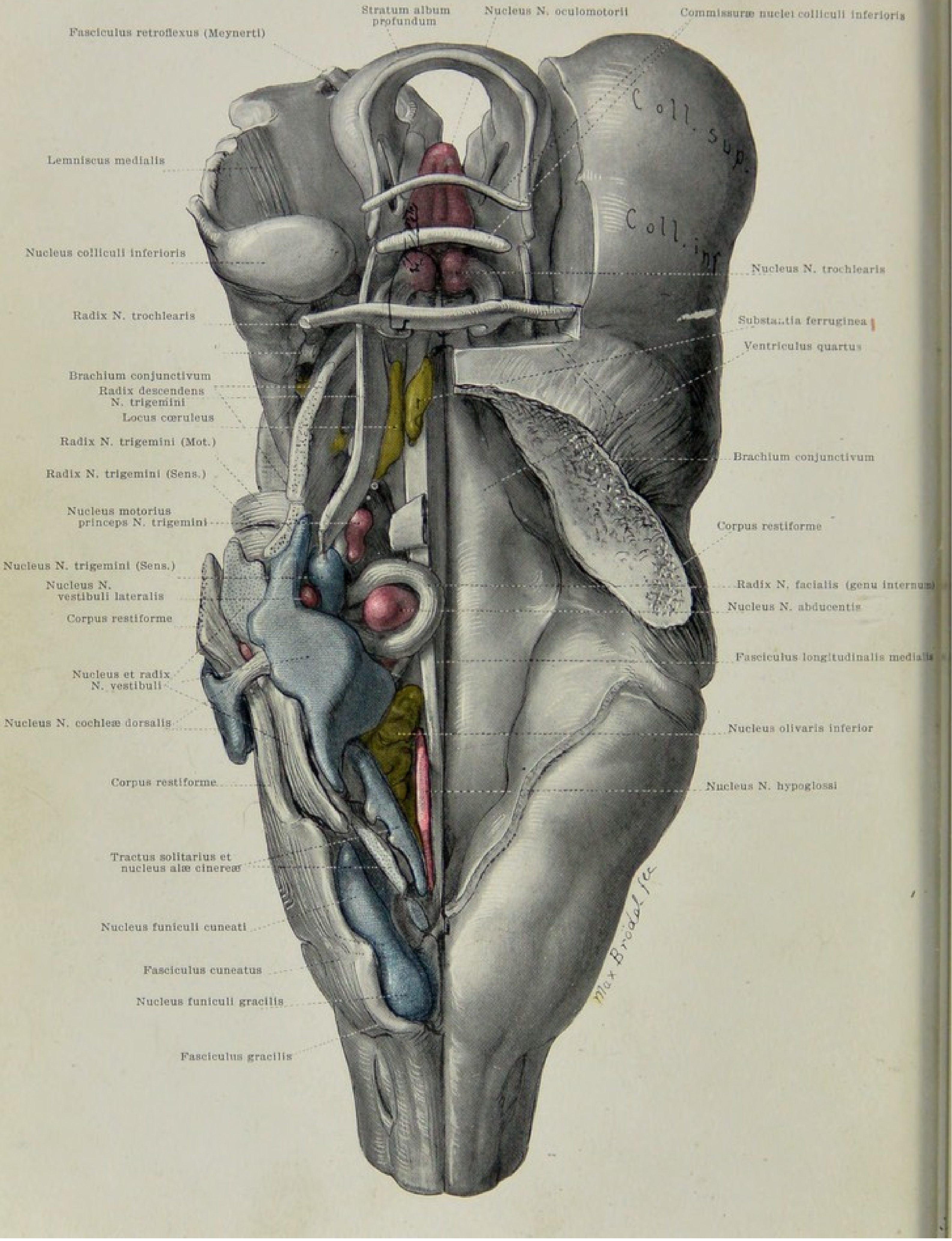


PLATE II.

View of the model from the dorsal surface. The right side of the view shows the surface form, the left the structures of the model. The position of these structures can be related to the dorsal funiculi of the spinal cord, the fourth ventricle, and the inferior and superior colliculi.

Nu et Radix N. vestibuli: To be distinguished by the colors. The ascending root is marked by the most proximal of the three lines on the figure; the descending by the most distal line, while the nucleus N. vestibuli medialis is indicated by the middle of the three lines. The nucleus N. vestibuli superior, is continuous with the medial nucleus and lies opposite the ascending root. The nucleus N. vestibuli lateralis consists of two parts, one between the corpus restiforme and the ascending root, the other in the notch between the medial and superior nuclei.

Nucleus N. cochleæ dorsalis: The more proximal of the two lines points to the striæ acusticæ.

Tractus solitarius et Nu. alæ cineræ: The former is in black and white, the latter in blue.

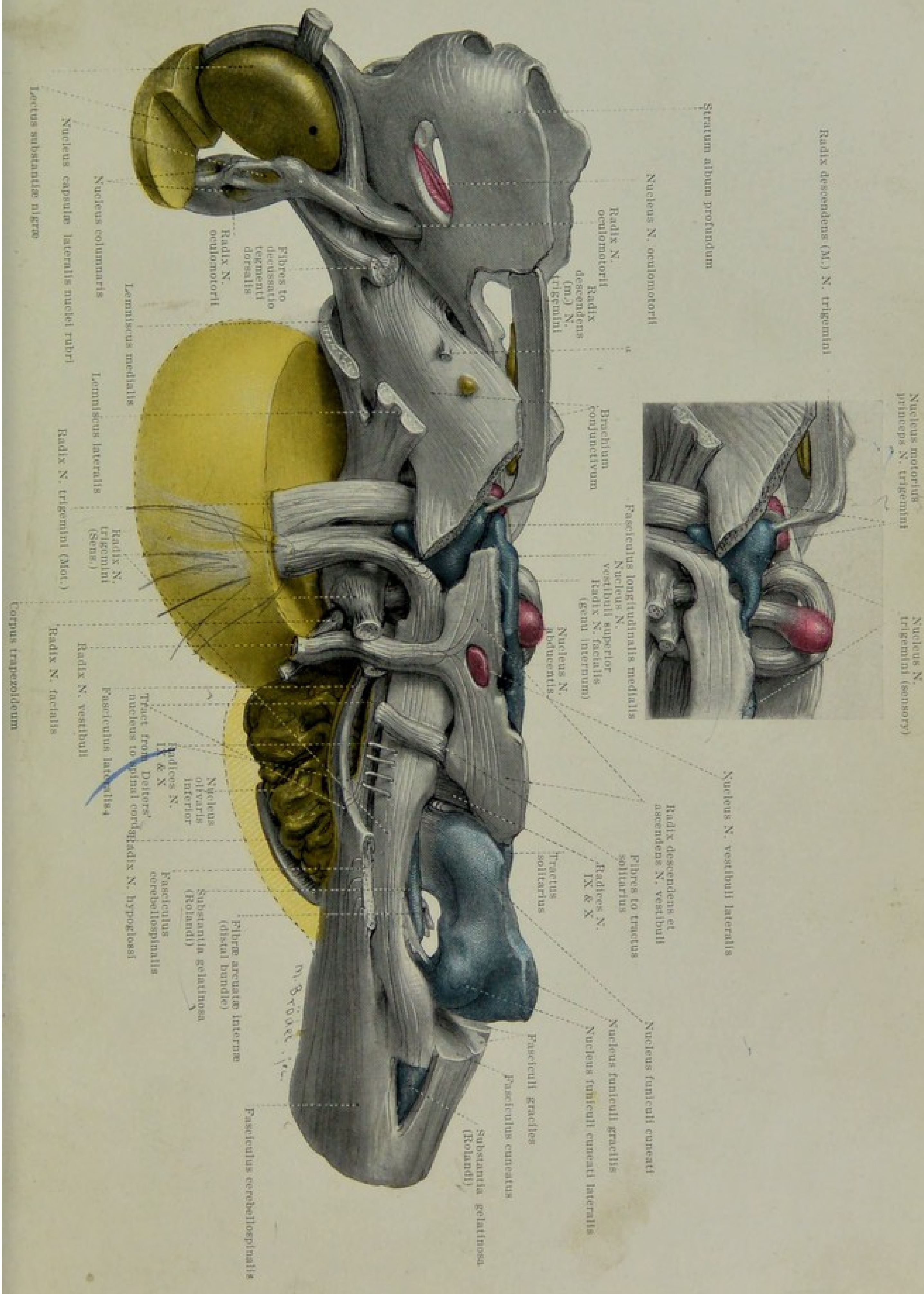
PLATE III.

View of the model from the lateral aspect. After removing from Plate I, the following structures: the corpus restiforme, the substantia nigra and the medial, lateral and superior lemnisci. The view is designed to show (1) the sensory nerves and their nuclei, and (2) the midbrain. The nuclei of the dorsal funiculi represent a way-station for the sensory fibres from the spinal cord; the sensory cerebral nerves are represented by the nuclei nervi glossopharyngei, vagi, vestibuli et trigemini. These include all of the sensory nerves of the region of the model except the N. cochleæ, which was removed with the corpus restiforme.

Radix N. trigemini (Sens.): The proximal line runs to the root bundle, the distal to the tractus spinalis N. trigemini.

Tract from Deiters' nucleus to F. i. (3), *and Fasciculus lateralis* (4): The numbers are explained in the text.

TO ILLUSTRATE MISS SABIN'S PAPER. PLATE III.



TO ILLUSTRATE MISS SABIN'S PAPER.

PLATE IV.

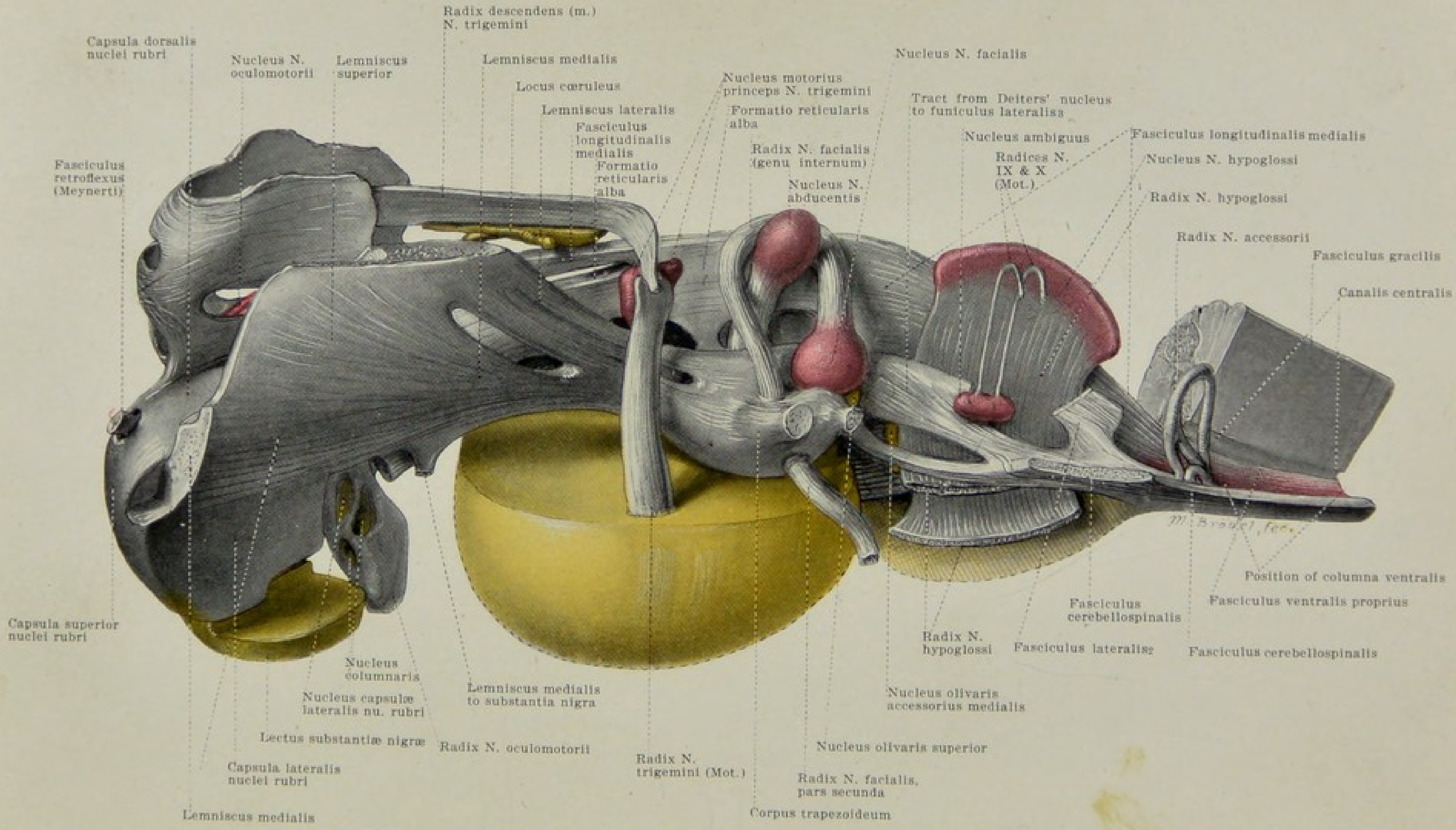


PLATE IV.

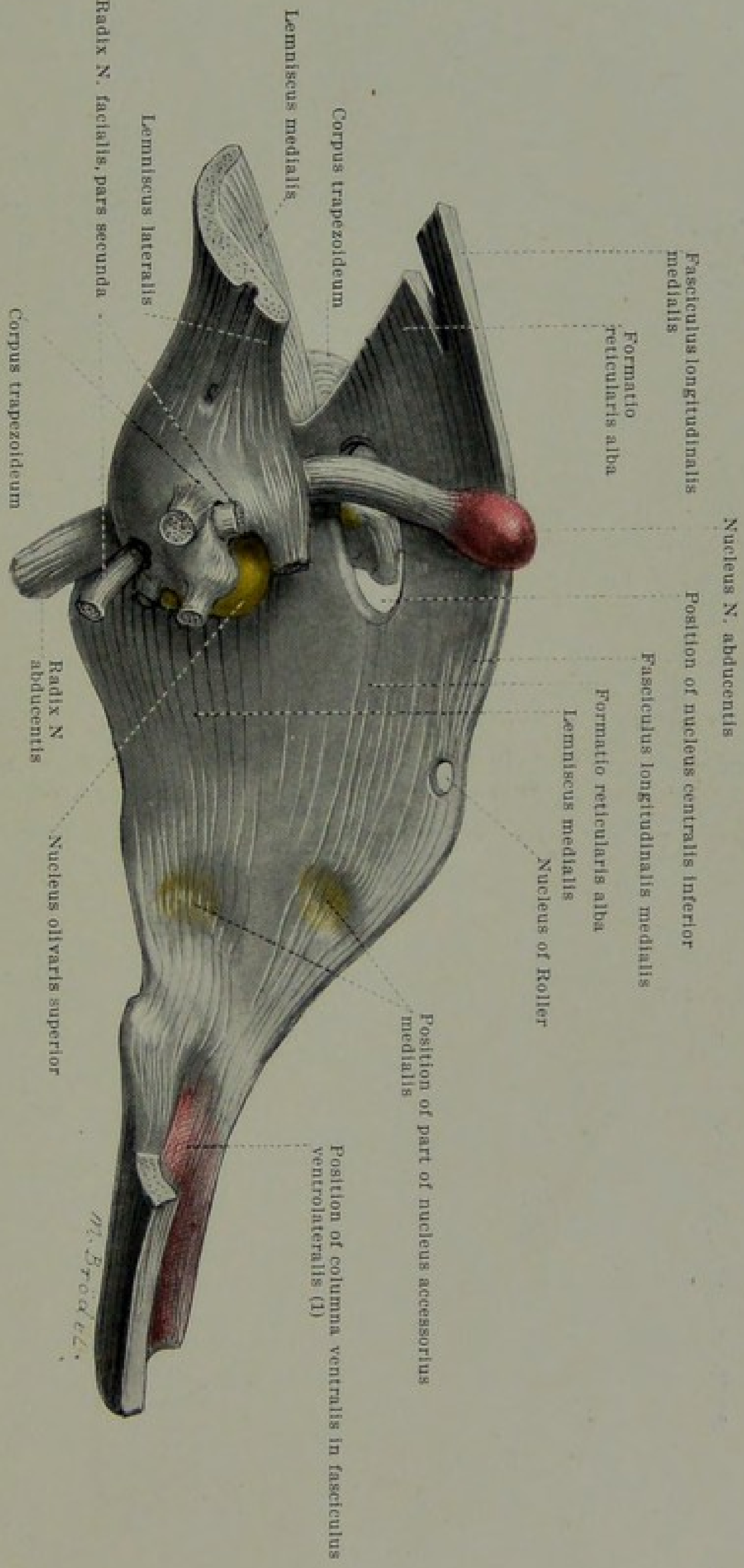
View of the model from the lateral aspect. The sensory nerves of Plate III have been removed and all of the motor cerebral nerves except the N. trochlearis are now shown.

Fasciculus lateralis (2), *and Fasciculus lateralis* (3)*:* The numbers are explained in the text.

PLATE V.

View of the lateral surface of the medulla sheet. The view can be related to Plates I, III and IV, by the position of the nucleus N. abducentis.

Fasciculus ventrolateralis (1): The number is explained in the text.


Radix N. facialis, pars secunda
Lemniscus medialis
Lemniscus lateralis
Corpus trapezoideum
Corpus trapezoideum
Radix N. abducentis
Nucleus olivaris superior
M. Brödel del.
Fasciculus longitudinalis medialis
Formatio reticularis alba
Nucleus N. abducentis
Position of nucleus centralis inferior
Fasciculus longitudinalis medialis
Formatio reticularis alba
Lemniscus medialis
Nucleus of Roller
Position of part of nucleus accessorius medialis
Position of columna ventralis in fasciculus ventrolateralis (1)

TO ILLUSTRATE MISS SABIN'S PAPER. PLATE VI.

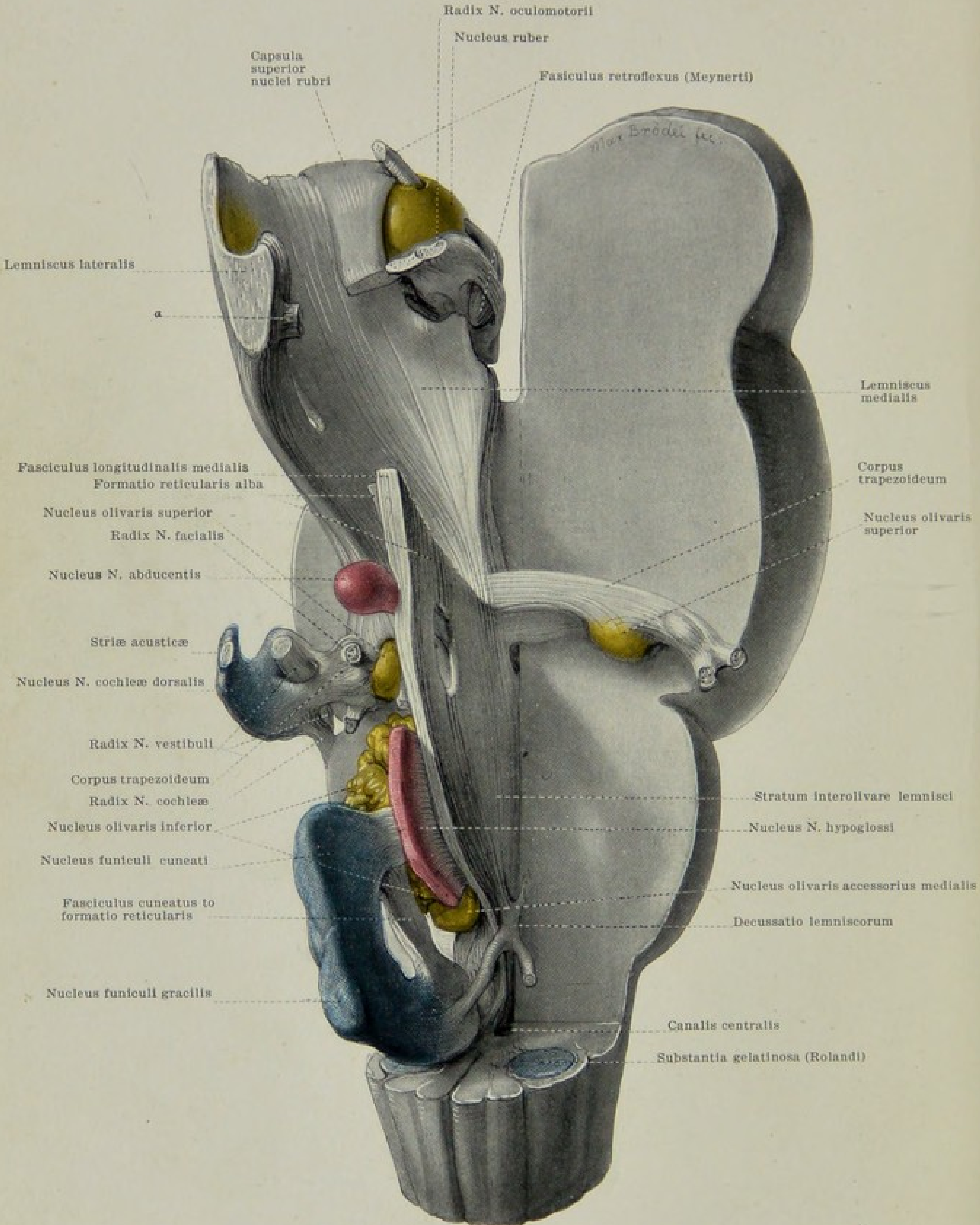


PLATE VI.

View of the model from a dorsomedian aspect. This view is designed to show the central fibre mass, that is, the medulla, pontal and mid-brain sheets, together with the corpus trapezoideun.

a. Fibres running from Lemniscus lateralis to the brachium conjunctivum.

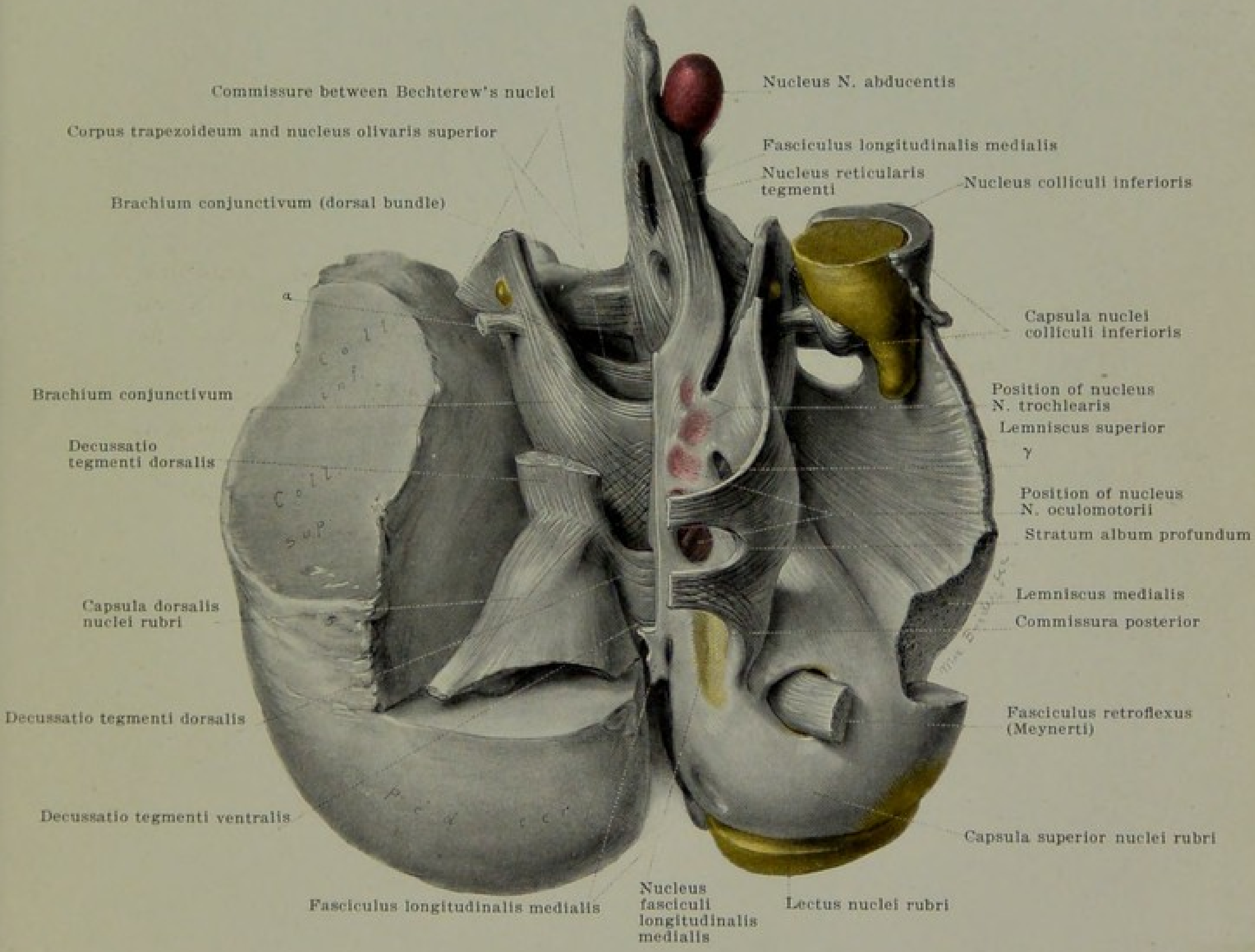
PLATE VII.

View of the mid-brain from the superior or cerebral aspect. This view can be understood by comparing it with Plates I, III and IV, which show the stratum profundum album, the lemniscus superior and the capsula nuclei rubri from the lateral aspect.

γ is a space in the model, in the stratum profundum album where fibres of the formatio reticularis alba are related to the substantia centralis grisea.

Fasciculus ventrolateralis (1): The number is explained in the text.

TO ILLUSTRATE MISS SABIN'S PAPER. PLATE VII.



TO ILLUSTRATE MISS SABIN'S PAPER. PLATE VIII.

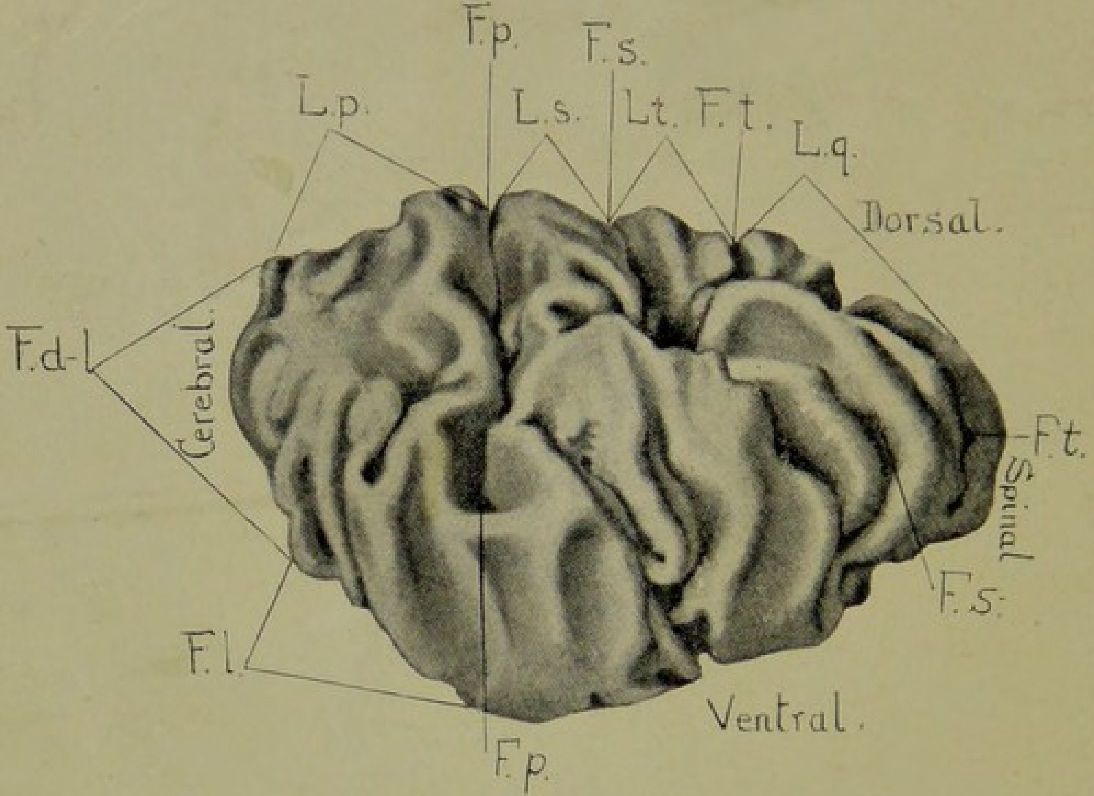


FIG. 1.

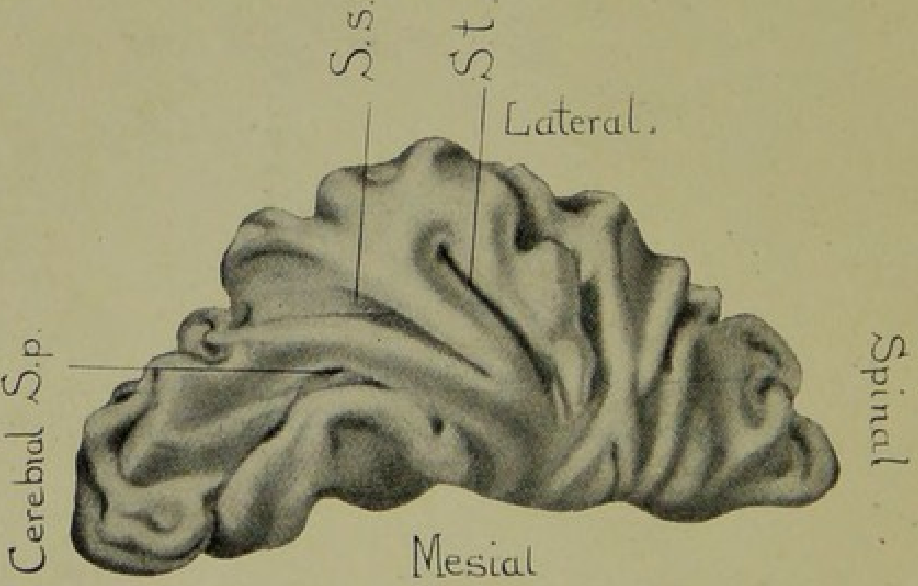


FIG. 2.

PLATE VIII.

Fig. 1. View of the dorsolateral and lateral surfaces of the nucleus olivaris inferior.

F. dl. Facies dorsolateralis.
F. l. Facies lateralis.
F. p. Fissura prima.
F. s Fissura secunda.
F. t. Fissura tertia.
F. q. Fissura quarta.
L. p. Lobus primus.
L. s. Lobus secundus.
L. t. Lobus tertius.
L. q. Lobus quartus.

Fig. 2. View of the ventral surface of the nucleus olivaris superior.

S. p. Sulcus primus.
S. s. Sulcus secundus.
S. t. Sulcus tertius.