XXI. *Contributions to the Anatomy of the Central Nervous System in Vertebrate Animals.*

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[PLATES 59–63.]

Part I.—ICHTHYOPSIDA. Section I.—PISCES. Subsection I.—TELEOSTEI.

Appendix.

ON THE BRAIN OF THE MORMYRIDÆ.

MARCUSEN* has given a very good *résumé* of the zoological history of this family from the time of their first discovery by HASSELQUIST, a pupil of LINNEUS, up to the date of the publication of his paper by the St. Petersburg Academy, and as his treatise is easily accessible there is no occasion for my going into that part of the subject here. The external appearance of these Fishes gives no indication at all of anything extraordinary in the structure of the brain, and as the zoologist above referred to, did not pay much attention to anatomy, more than half a century elapsed before any steps were taken in that direction.

One of the species at least was very well known to the ancient Egyptians, to whom it was a sacred animal, and its portrait is even now quite easily distinguishable on some of the monuments.

A figure of one species is to be found in vol. 19, p. 250, of CUVIER and VALENCIENNES' 'Histoires Naturelles des Poissons;' RÜPPEL,† also, has given plates of three species. The position in nature of this family is defined in Dr. GÜNTHER's catalogue of fishes.

ERDL‡ was the first anatomical writer who mentioned any peculiarity about the

* Die Familie der Mormyren. Mém. de l'Acad. Impériale des Sciences de St. Pétersbourg, vii[e] serie, tome vii., 1864.

† Beschreibung u. Abbildungen mehrerer neuer Fische im Nil entdeckt, 1829 to 1835.

‡ Ueber d. Gehirn der Fischgattung Mormyrus. Gelehrte Anzeigen herausgegeben von Mitgliedern der K. Bayer. Akad. der Wiss., Bd. 23, 1846.

brain in these Fishes. He supposed that they had a Mammalian cerebrum; the pink colour and the minute striations of the surface, which superficially resemble convolutions, led him into this error.

Marcusen went more thoroughly into the subject; but even he, in his first* paper, was of the same opinion.

About this time Ecker† wrote a description of a brain of a very small species, probably a young *Mormyrus Cyprinoides;* the conclusion he came to was, that the highly-developed organ which is the subject of this paper, was the corpus quadrigeminum.

Eleven years after the first slight sketch referred to above, Marcusen ‡ took a view of the brain of this Fish more nearly approaching the truth, inasmuch as he supposed that the "Eigenthümliches Organ," as he termed it, was part of the cerebellum.

Oeffinger,§ whose paper, so far as I know, was the last that has been written on this subject, added nothing to the information possessed by his predecessors.

These Fishes are by no means easily procured by ordinary tourists on the Nile.

V. Miklucho-Maclay ‖ has placed it on record that he was unable to see one during his stay in Egypt. He appears to have been there twice, but his residence each time must have been short; else his great powers as a traveller would surely have come to his assistance in this, as in other matters.

I was more fortunate, and by enquiring of native fishermen, through the medium of my dragoman, succeeded in obtaining a sufficient supply of living specimens.

The two species which I obtained most abundantly were, *Hyperopisus dorsalis* (Günther), which was described by Marcusen under the name of *Phagrus dorsalis,* and *Mormyrus oxyrhynchus,* but this latter was much more rare than the former. Of a species of *Mormyrops* I obtained one or two specimens.

The mode of procedure which I adopted in the treatment of the brains of these Fishes was the following. All sensation, or at least all sensation of pain, having been eliminated by section of the spinal cord at, or nearly opposite the region of the pectoral fins, parts of the top or sides of the skull together with the facial bones and all superfluous tissue were removed, and the skull containing the brain was placed in Müller's fluid and spirits of wine in the proportion of one-third of the latter to two-thirds of the former. This solution was changed the next day, and again in three or four days, one more change was made at about the tenth day, and after being in this fluid for three weeks, the brain was removed into a 2 per cent. solution of potass-bichromate. The potass-bichromate was changed once a fortnight. It is not absolutely necessary to change the solution so often; the more frequently it is renewed,

* Gaz. Méd. de Paris. Sur quelques particularités des Mormyrus, 1853, p. 136. Also Bull. de la classe Phys. Math. de l'Acad. Imp. des Sciences de St. Pétersbourg, tom. xii., 1854.

† Anatomische Beschreibung des Gehirns vom Karpfenartigen Nilhecht. Leipzig, 1854.

‡ *Loc. cit.*

§ Neue Untersuchungen ü. d. Bau d. Gehirns vom Nilhecht. Arch. f. Anat., 1867.

‖ Beiträge z. vergleichenden Neurologie d. Wirbelthiere, p. 69, note.

the quicker the hardening process goes on. It appears that it is not desirable that the specimens should be kept in the same solution more than one month.

This method is a modification of that proposed by HAMILTON,* and is much more convenient than the process which I formerly used, which was to place the brain first in absolute alcohol and iodine and then in chromic acid.

The MÜLLER's fluid and spirits of wine has very great penetrating power, so that it is not necessary to remove the brain entirely from the skull, but two or three holes made in the latter are quite sufficient. So far both methods are equal; but the latter has a great advantage inasmuch as it does not cause any contraction in the nervous tissue; on the contrary, the brain swells and becomes enlarged so as partially to project through the holes in the skull. The hardening process takes a long time to be effected. The brain requires at least six months to become sufficiently firm to be submitted to the section knife; but it remains in that state for twelve months longer, more or less.

Here a curious thing is to be noticed, indicating, probably, different chemical composition in brains of various species; for instance, the brain of *Mormyrus* is still in a good condition for making thin sections after having remained eighteen months in the hardening fluid, while those of some other Teleostei, Gurnard or Ballan Wrasse, for instance, are too friable to make satisfactory sections after twelve months.

In consequence of this slow method of hardening the nervous tissue, the histological elements are not contracted or distorted, but show much better the form which they possessed during life; so that we see none of those angular nuclei or cells which MEYNERT† reports that he has seen in sections of the brain of Fishes.

Another advantage especially in travelling is, that there is no necessity, as there is with absolute alcohol and chromic acid, to make sections soon after they have been put into the hardening fluid on account of their becoming too friable; but they can be safely left until a convenient opportunity occurs of attending to them.

When the brains have become sufficiently hard, sections of any degree of fineness can be made in the microtome; and after having been stained with rosaniline or carmine, they can be cleared with oil of cloves and preserved in Canada balsam. RANVIER‡ and other writers on histology recommend that before the application of the oil of cloves, the sections should be immersed in alcohol; this is not at all necessary for the nervous system, since the oil of cloves renders the sections quite transparent even when they are taken direct from the watery fluid; the only precaution required being to absorb all superfluous moisture with blotting paper. This makes one operation less to perform, and it is obvious that when a hundred sections or more have to be placed in consecutive order, the fewer processes they have to go through the better.

* Journal of Anatomy and Physiology, vol. xii., 1878.

† STRICKER's Handbook, Sydenham Society, vol. ii.

‡ Traité Technique d'Histologie, p. 112. Paris, 1875–78.

In order to obtain an idea of the brain of a *Mormyrus*, we may take that organ of any ordinary Teleostean, and imagine a fungoid growth taking place from the region in front of the cerebellum; we may then imagine this growth to burst through the tecta lobi optici, forcing them asunder, repressing them to the basal part of the brain, and then to spread out in all directions, covering over and concealing every one of the remaining portions of the brain.

We have thus a stalk or peduncle on each side of the region referred to above, and expansions which take the form of wings growing in every direction—forward, upward, outward, and backward—until the obstacle of the walls of the skull is encountered, when, growth still continuing, foldings in various directions occur: thus the anteriorly directed wing turns backward on itself on reaching the front extremity of the cranium, the dorsal wing turns inward on attaining the roof of the skull, the outer wing turns upward under the same condition, while the posterior wing ends in a free edge directed backward. This is the state of affairs in the young animal, but as age creeps on the complication in the folding of these wings increases. Another lobe becomes developed between the outer and the ascending wings; this also projects forward between the anterior wings of each side; the posterior wing now becomes folded into a number of small transverse convolutions, and the dorsal wing develops an additional fold at its upper extremity.

MARCUSEN* tried to found genera partly on the greater or less extent of these wings, but this arrangement, so far as it is based on the nervous system, will not hold good; because even in species with the most highly developed brain, the more simple arrangement prevails in young specimens.

Each wing is provided on the outer side with numerous excessively fine parallel ridges, whose structure will be described presently; these ridges follow every curve and inequality of the surface, so that their sections present various appearances.

The consequence of this arrangement is that those parts of the wings which are turned back or folded show only the layer of medullary fibres, and are therefore white, while the parts which are not reflected, such as the posterior wing and the upper part of the dorsal wing, show the minute ridges which give these portions a pinkish colour in the fresh state, and cause the minute striations which gave occasion to the comparison with the convolutions of the cerebrum of Mammalia; we shall see presently that they have nothing to do with these convolutions, but that in fact, they belong to quite another part of the brain.

I have not given figures of the external aspect of the brain of the *Mormyridæ*, because MARCUSEN's† illustrations are very good, although his drawings of the sections and of the microscopic anatomy leave much to be desired.

* *Loc. cit.*

† *Loc. cit.*

Microscopic Anatomy of the Brain.

Lobi Olfactorii.

With the exception of the wings and of the tuberculum impar, the other parts of the brain have very nearly the same structure as in the ordinary Teleostean Fishes.

The *Mormyridæ* belong to that division of the Teleostei in which the olfactory lobes are situated at the extremity of a long peduncle far in advance of the anterior end of the brain and very near to the olfactory organ.

They are fusiform in shape and are placed near the anterior extremity of the olfactory peduncle like a bead on a string, and the olfactory nerve pursues a short course before plunging into the sense organ.

The structure of the olfactory lobes resembles that of the corresponding lobe in *Mugil cephalus;* on the outside is seen a layer of the fibres which go to form the olfactory nerve. Many of these fibres are broad and bandlike, resembling the fibres of REMAK in the sympathetic nerves ; they surround the whole lobe with the exception of the broader end which is directed towards the brain and from which the peduncle emerges. Towards the inner side of this layer of fibres and mingled with them is a stratum of larger sized cells which occur sometimes in groups of eight or ten and occasionally singly. They resemble those figured in my paper on the brain of Teleostei.*

The central part of this lobe is occupied by numerous nerve cells of the smallest category, which some writers consider to be nuclei, but which, in Fishes at least, are certainly cells if MAX SCHULTZE's† definition of a cell is to be accepted. They are rounded or oval, sometimes fusiform or pear-shaped. The more circular ones measure from 0·004 millim. to 0·005 millim. in diameter; the fusiform ones with a process at each end measure about 0·005 millim. by 0·0067 millim. The rounded cells are occasionally seen to give off processes. These small nerve cells occupy a space the basis of which is a granular material in which numerous fibrillæ are seen to ramify. The fibres of the olfactory commissure, on their entrance into the lobe, go directly into this central part; each fibre appears to be composed of an axis cylinder with a very small medullary sheath; they are smaller in diameter than the fibres of the olfactory nerve.

The layers of the olfactory lobe are arranged here as in *M. cephalus.* The fibres of the olfactory nerve are outside and in front, the larger cells come next, and the smaller cells with the fibres of the olfactory peduncle occupy the centre and the posterior part, thus confirming the comparison of the structure of this lobe in the Mammalia with that of the corresponding lobe in Teleostei, which I made in the case of *M. cephalus.*‡

* Phil. Trans., 1878.

† Ü. Muskelkörper und das was man eine Zelle zu nennen habe. Archiv f. Anatomie, 1861.

‡ *Loc. cit.*, p. 750.

Cerebral Lobes.

These lobes resemble in structure the corresponding parts in *M. cephalus.* Each lobe is partially divided into two by a transverse horizontal depression, which separates a rounded dorsal knob from the ventral portion. The olfactory peduncle is attached to a minute oval eminence situated at the inferior edge of the anterior part of the ventral lobe. Externally there is a single layer of epithelial cells, each sending a long process into the substance of the lobe perpendicular to the surface; within this there is a layer of small cells, sharply defined at parts from the central portions of the lobe. These cells are packed close together with a comparatively small quantity of neuroglia between them; many of them measure from 0·006 millim. to 0·0083 millim. in diameter; others are more oval in shape; the majority show a nucleus and a nucleolus; in some places they are separated from the central portion by a layer of fine transversely directed fibrillæ. This layer is shown in my paper on the brain of Teleostei.*

FRITSCH† is of opinion that these cells belong to the connective tissue elements, and compares them to the layer of granular neuroglia which bounds the grey matter of the cerebrum externally in Mammalia; but to me they seem to present the characteristics of nerve cells, although this is a point which is often difficult to determine; in *M. cephalus* they certainly do not join the processes from the epithelial cells, which they ought to do if they were connective tissue elements. If they are nerve cells the layer of neuroglia referred to by FRITSCH is not present in the brain of Teleostei, although a corresponding one is found in the brain of the Elasmobranchii.

The central portion of these lobes (*br.br.*) is occupied principally by neuroglia of a granular appearance in which are dispersed at intervals cells of a larger size than those of the outer layer. They measure generally about 0·016 millim. by 0·012 millim., with a nucleus 0·008 millim. by 0·006 millim.; they mostly have a smooth outline with about three processes. A few were occasionally met with which possessed an irregular outline with five or six processes. Round each cell there was ordinarily to be seen a clear space; concerning the nature of this space anatomists are by no means clear; BOLL‡ considers that it is an artificial production; OBERSTEINER§ mentioned several reasons in favour of the view that it is natural; HENLE|| and FOREL¶ are entirely of this opinion; for myself I am undecided at present. In the *Mormyridæ* these spaces certainly do not present so natural an appearance as they had in *M. cephalus.* Perhaps sections of frozen brain tissue might decide the point, though this is by no means

* *Loc. cit.*, Plate 63, fig. 17.

† Untersuchungen ü. den feineren Bau des Fischgehirns. Page 48.

‡ Die Histiologie u. Histiogenese d. Nervösen central organe. Archiv f. Psychiatrie, Bd. iv.

§ Beit. z. Kentniss vom feineren Bau der Kleinhirn. Sitzb. d. Math-Nat. Classe d. k. Akad. der Wissenschaft, Wien. Bd. lx.

|| Nervenlehre.

¶ Untersuch. ü. d. Hauberegion, &c. Archiv. f. Psychiatrie, Bd. vii., 1877, p. 449.

certain, for even if they are natural and not artificial they might so collapse in the soft fresh state as to become obliterated.

The Hypoaria.

These bodies are not so well developed in the *Mormyridæ* as in *M. cephalus*—they scarcely project at all below the ventral surface of the brain, and do not form separate lobes ; the ventricle is also very small ; the trigonum fissum, however, is rather prominent, and forms a separate tubercle on the inferior surface. The hypophysis or pituitary body is attached to the apex of the trigonum, and the infundibulum passes through it. With regard to the minute structure of these parts it resembles that of the corresponding lobes in the *M. cephalus* in respect to the arrangement of the cells, which are dispersed separately throughout the neuroglia ; but many of the cells themselves differ in shape in being multipolar and in having as many as six processes, while some are pear-shaped. They usually measure about 0·0093 millim. by 0·007 millim. The nearly obliterated ventricle and the infundibulum are surrounded by a layer of small cells as in other Teleostei. These bodies may be considered to be in a rudimentary condition, and this is shown also by the absence of the nucleus rotundus and the transverse commissure connected with it.

Tecta Lobi Optici.

The position of these bodies in the *Mormyridæ* has become quite reversed. Instead of arching over the tori semicirculares on the dorsal side of the brain as in the ordinary Teleostei, they become relegated to the inferior surface and occupy a position below and to the outside of those bodies ; the roof in fact has been transferred to the foundation.

The tecta appear to have attained this position in consequence of the enormous development of the wings alluded to in the first part of this paper.

Accompanying this change of position there is a considerable degradation of structure. The seven layers which are distinguishable in *M. cephalus* are here reduced to two or at the most three ; the ependyma has disappeared ; there are only slight indications of radial striation. The outer layer in some places is separable into two subordinate divisions. The *Mormyridæ* are not good subjects for deciding any histological points in the structure of these lobes which as I have before remarked are decidedly undeveloped ; I was therefore not surprised to find that I am unable either to confirm or refute the statements of BELLONCI* as to the presence of a minute network of fibrillæ in the external layer of the tecta lobi optici, and I have not yet had

* Ricerche intorno all' intima tessitura del cervello dei Teleostei. Reale Accademia dei Lincei, Anno cclxxvi., 1878 and 1879. Also by the same author, Ü. den Ursprung des Nervus Opticus. Zeitschr. f. wiss. Zoologie, Bd. xxxv., 1880.

an opportunity of testing the method which he followed in obtaining his results, a description of which he was kind enough to send me. These results are, however, very interesting, showing as they do the mode of origin of the optic nerve primarily from a net-work of the finest possible fibrillæ, a statement which, however probable, had not before been demonstrated.

The two outer layers occupy only a small part of the tectum, the remainder extending to the inner surface corresponds to the second, third, fourth, fifth, and sixth layers in *M. cephalus;* it consists principally of neuroglia in which radial striation is indistinctly visible. The fusiform cells which ordinarily form a conspicuous feature in this lobe are few and far between; but they certainly are present and occur close to the outer edge of this inner layer. They are placed more obliquely than in *M. cephalus,* and as in that species, their outwardly directed process, which is probably the protoplasmic process, goes into the external layer. FRITSCH,* in his large work on the structure of the brain in Fishes, denies the existence of these cells, and supposes that STIEDA mistook a crossing of two capillaries for them; this seems to show that the former writer did not make his sections sufficiently thin; if they are properly made, so that only one layer of cells occupies their thickness, such a mistake would be impossible.

The cells which correspond to the sixth layer do not form here a distinctly continuous layer, but occur in scattered groups along the inner surface of the tectum; they are slightly larger than the cells in *M. cephalus;* they measure about 0·005 millim. by 0·004 millim. The interrupted layer thus formed is interspersed with longitudinally-directed fibres, which correspond to the fifth layer of the tecta in Teleostei; these fibres are medullated, each of them appearing to be a single fibrilla clothed with a very narrow medullary sheath. The reason why longitudinally directed fibres in one species correspond to transversely directed fibres in another depends on the position of the tori longitudinales, which in *Mormyrus* are widely separated from each other by the development of the wings of the valvula cerebelli. The tori longitudinales are only in contact in front, and posteriorly they are placed along the outer edge of the tecta and end in a free point. The consequence of this arrangement is that the commissure of these lobes only exists at the anterior end, and the fibres destined to form it must therefore necessarily run longitudinally. The structure of the tori longitudinales in *Mormyrus* resembles that of the corresponding parts in *M. cephalus* so far as they are made up of the smallest-sized cells; but the arrangement of these cells is different; they do not occur in rows between bundles of radiating fibrillæ, but quite irregularly, in a net-work of the smallest-sized fibres; they vary very much in form; some are rounded, some pear-shaped, some oval, and others irregular in outline; they give off numerous processes.

I termed these bodies "fornix" in my paper on the brain of Teleostei, following

* *Loc. cit.*, p. 51.

GOTTSCHE,* who gave them that appellation without any reference to the part of the same name in the Mammalian brain; but it seems that the other term, tori longitudinales, is more appropriate; the former term seems to indicate a theory; but FRITSCH, although he uses the latter name, really considers that the bodies in question homologise with the fornix of the human subject; this I hope to prove in the end is not the case, and thus the term fornix is a misnomer, as having been applied to a different structure. These objections do not apply to the name tori longitudinales, which involves no sort of consideration as to theory, but simply states a fact of form.

Tori Semicirculares.

The tecta lobi optici having changed their position, and having been relegated to the inferior surface of the brain, while the tori semicirculares have retained theirs without displacement, the relative position of these two parts comes to be that of the egg to the egg-cup, or, as ECKER puts it, that of an oyster to its shell. The torus semicircularis forms a tuberosity of rounded form, bounded below and on the outside by the tectum. It may be divided into two parts, easily distinguishable from each other, the upper part consisting principally of nerve cells and fibrillæ dispersed in a granular neuroglia. The lower part on which it rests contains more nerve fibres, which belong to the system of the commissura ansulata.

The upper part differs in structure from the corresponding part in *M. cephalus* and *Labrax lupus* in the same diffused way as the tectum. The small cells which do not show such elongated processes as in the species just cited, are scattered irregularly among the fibrillæ which traverse this body in all directions through the upper section of the tuberosity. They measure from about 0·005 millim. to 0·0035 millim. in diameter, and each shows a well defined nucleus and nucleolus, the latter being a mere speck.

The larger cells occur sparingly; they have a clear space round them, and are of moderate size, being about 0·019 millim. by 0·0093 millim.; the nucleus generally measured 0·006 millim. in diameter, and the nucleolus 0·0017 millim.; with these which were smooth and rounded or oval in outline, occurred others which were of irregular shape, with three processes; these latter are rather smaller, measuring 0·012 millim. by 0·008 millim., with a nucleus 0·003 millim. in diameter; some other cells which are still smaller, measuring 0·006 millim. by 0·007 millim., seem to form a transition to those of the smallest category mentioned above.

Cerebellum.

The cerebellum (fig. 1) has the usual structure of this lobe in Teleostei; here it is a tongue-shaped process directed forward, in which respect it differs from that of most Fishes, where as a rule it is turned backward, unless it is not sufficiently developed to

* Arch. f. Anatomie, 1835.

form more than a small tuberosity bridging over the fourth ventricle. It resembles, however, the form of the cerebellum in Fishes of the family Siluridæ, of which *Schilbe Hasselquistii*, found also in the Nile, may be taken as an example, but in comparison to the size of the brain it is much smaller, since in *S. Hasselquistii* it predominates over the other lobes in size, while here it is overshadowed and compressed by the enormous size of the wings of the valvula cerebelli. In structure it agrees with that of the cerebellum in all Vertebrata.

DENISSENKO*, in his interesting paper on the anatomy of this lobe, divides it into three layers, viz.: the molecular, which is external; the granular coming next, and the fibrous occupying the centre of the lobule; but MEYNERT† makes a separate layer for the Purkinje cells, which is more in accordance with the state of affairs in the Teleostei; I have never found these cells so irregularly dispersed through the molecular layer in those Fishes which I have examined as is described by DENISSENKO. The nerve fibres also do not form a distinct layer, except quite at the root of the organ.

Adopting MEYNERT's idea, I shall therefore speak of the Purkinje cells as forming a distinct layer, and term it the intermediate layer.

Thus we have in the cerebellum of the *Mormyrus* three layers, counting from the outside towards the centre, viz.: the molecular, the intermediate, and the granular layers; the fibrous layer may be looked on as part of, and diffused through, the last mentioned one. These correspond to the first three layers in *M. cephalus*, and the fibrous stratum in the parts where it forms a distinct layer would in like manner correspond to the fourth.

The radial striation which characterises the molecular layer is very strongly marked in this species. This appearance is caused by prolongations from the single layer of epethelial cells which cover the whole surface of the cerebellum; each cell sends a process for a considerable distance into this layer. STIEDA‡ has published a good description of these cells, to which he has given the appropriate name "stiftzelle;" BOLL§ showed how they were developed from the so-called "Deiters," or connective tissue cells, so as to form a membrane beneath the pia mater. These peculiar cells appear to exist on and form a covering for most parts of the brain, *e.g.*, the cerebrum, and the tecta lobi optici, but they do not form such well marked and distinct striations in other organs as they do in the cerebellum. This layer is not formed entirely of connective tissue, although these processes do occupy a considerable part of it, and cause the striated appearance which gives it such a characteristic aspect; there is a large quantity of molecular matter as well as small cells in it. These small cells are extremely scarce, although occasionally met with; they resemble the cells of the granular layer, and have a nucleus and a nucleolus, which latter is a mere

* Zur Frage ü. den Bau der Kleinhirnrinde, &c., Arch. f. Mikroskopisce Anatomie, Bd. xiv., 1877.

† STRICKER's Handbook, Sydenham Society, vol. ii.

‡ Studien ü. d. Centralnervensystem der Wirbelthiere, p. 154.

§ *Loc. cit.*

speck; they are usually pear-shaped, and have a process at each end; they measure about 0·006 millim. long by 0·0045 millim. broad. There is probably also a network of fine fibres in the molecular layer of the cerebellum, such as is found in the corresponding layers of the wings; but I have not been able to add anything to what I remarked on this subject in my paper on the brain of the Teleostei.*

The intermediate layer consists of the Purkinje cells and a bundle of longitudinal medullated fibres of small size, which appear to join eventually the crus cerebelli. The Purkinje cells resemble those of the Teleostei in general, in being arranged parallel to the long axis of the lobe: they are shorter and thicker than the corresponding cells in *M. cephalus;* their usual size is 0·018 millim. long by 0·016 millim. broad; some are as long as 0·022 millim.; the nucleus is about 0·009 millim. in diameter, and the nucleolus 0·002 millim.; there is a circular space round the nucleolus, which is clearer and smoother than the remainder of the contents of the nucleus: these cells then resemble those of the motor horn of the grey matter of the spinal cord, in the disk-like nucleolus and the clear space which surrounds it. Each Purkinje cell has two processes, one thicker, corresponding to the protoplasmic processes of the cells of the spinal cord; the other finer, corresponding to the axis-cylinder process of the same. I never could perceive any prolongation of this into the nucleus, but on the other hand, the axis-cylinder process was in one case distinctly traceable into one of the medullated fibres of the longitudinal bundles belonging to the intermediate layer. This fact confirms the statement of KOSCHENIKOFF,† and also accords well with the theory which I suggested in the description of the cerebellum in *M. cephalus,* and which only required this arrangement to complete the statement.

It now remains to consider the granular layer of the cerebellum; DENISSENKO described a method by which he thought he had demonstrated the existence of two different species of cells in this layer. During the process of double staining with eosin and hæmatoxylin, he maintained that one kind of cell takes up one colour and another kind absorbs the other colour; he thus had the so-called eosin cells and the hæmatoxylin cells. Whatever may be the case in higher animals, in Fishes there exists only one species of cell in this layer; I tried the experiment several times, carefully following DENISSENKO's directions; but I never could find that the cells of this layer exercised any selection as to the material they took up, but the result was that all the cells assumed a more or less light purple uniform tint according as the eosin or hæmatoxylin solutions were the stronger: from this one must infer that there is no difference of composition in the cells forming this layer in Fishes. In shape they resemble those of the third layer of the cerebellum in *M. cephalus;* they belong to the smallest category, generally measuring about 0·004 millim. in diameter; they mostly possess a nucleus and nucleolus; some are even still smaller, being 0·0034 millim. long by 0·003 millim., but the nucleus is of the same size as that of the larger specimens.

* *Loc. cit.*

† Axencylinder Vortsatz der Nervenzellen im Kleingehirn, &c., Arch. f. Mik. Anatomie, Bd. v., 1869.

They have a tendency to be arranged in distinct rows, the spaces between which are occupied by nervous fibrillæ.

There has been a good deal of dispute as to the nature of these cells. Some histologists think that they are connective tissue cells, others that they are nervous elements; with these latter I must throw in my lot; there seems to be no manner of doubt but that they are nervous; and it is difficult to imagine that a whole lobe of a brain should be almost entirely made up of connective tissue, or what object could be fulfilled by such an arrangement; it would not be required to support the few remaining elements which would then consist of little else than the Purkinje cells which one would suppose might be better packed up in a smaller compass.

Valvula Cerebelli.

I hope to prove eventually that the wings described at the commencement of this paper are nothing more than the lateral parts of the valvula cerebelli enormously developed; but for the present I will confine myself to a description of their structure. They consist of two parts: a central portion, which is simply a continuation of the cerebellum, containing precisely the same elements arranged in precisely the same manner; and a pair of wings.

In many Fishes this part forms nearly the whole of the valvula cerebelli, the wings not being much developed; but here, although it is much more extensive than in many Fishes in which it forms the greater part of the valvula, it occupies but a small portion of the entire structure.

It consists of three tubercles (fig. 1) arranged one in front of the other, diminishing in size from behind forward; of these the most posterior appears actually to be part of the cerebellum. They each present the molecular, intermediate and granular layers. The first of these three layers can be traced continuously from the cerebellum over these tubercles and ends in front of the foremost with an undulating free edge as if an indefinite development of these bodies might take place. The wings arise from each side of this central portion and cover more or less the remaining lobes of the brain according to the age of the animal. The greater part of their mass is formed by an accumulation of minute cells which closely resemble those of the granular layer of the cerebellum; with these are found numerous bundles of fibrillæ. This accumulation of cells takes the form of thick plates which are bent and folded as formerly explained. On one side of these plates a series of closely arranged ridges are placed (fig. 3). Each of these ridges is a cerebellum in miniature and consists of the regular number of layers, the molecular, the granular, the intermediate, and the fibrous. They are so placed that the molecular layers of a pair of ridges are arranged in close contact, with only a process of the pia mater between them, then comes the granular and the intermediate, and finally the fibrous layer is interposed between a pair of ridges on the other side, one fibrous layer serving for two contiguous ridges; the fibrillæ

belonging to this layer are of extreme fineness and are unprovided with a medullary sheath, being at these parts merely axis cylinders.

Each ridge is inserted into the main body of the wing, like a nail into a plank, with a conical insertion consisting only of the molecular layer. The granular-basal part of the wings forms a conical projection between each pair of molecular layers, and the pia mater passes down between these, forming a double membrane which at the summit of this conical process of the basal part divides into two, one accompanying each molecular layer to the extremity of its insertion where it disappears.

We have thus a series of ridges in alternately reversed positions, occurring in fact in pairs back to back. Where the wings are comparatively straight, the only contact that the ridges have with their basal portion is by the insertion at one edge; but where curves and foldings occur the ridges become more or less distorted, and may be in contact with those parts by the sides as well as by the edges. With regard to the minute structure of these ridges and the remainder of the wings we will begin with a consideration of the molecular layers. These are generally separate from each other at the summit of the ridge, but in some parts this layer of one ridge is continuous with that of the next; but in those parts where the wings end in a free edge, and the ridges are on the external surface, the end of each ridge where it abuts on this free edge, goes round to join the next, forming a loop. The striated arrangement of the molecular layer is very apparent and the palisade cells (as one may translate STIEDA's term "stiftzelle") are very well developed. The pia mater generally penetrates between each pair of molecular layers, and where this is so the striations are directed at right angles to the width of the ridge as seen in section, or in other words parallel to its thickness; but in the ridges along some parts of the dorsal surface of the wing, where they are external, the pia mater does not penetrate between them but simply covers their free edge; in this case the striations are not directed at right angles but parallel to the width of the ridge; this seems to show that the striation is due to the palisade cells and not to the ramifications of the protoplasmic processes of the Purkinje cells, to which I was formerly inclined to attribute it. Besides this, the prolongations of these cells may very often be seen actually sending processes into the molecular layer. I can also confirm BOLL's statement that the palisade cells forms a membrane distinct from the pia mater; for this latter membrane can be torn off leaving the layer of palisade cells intact.

As previously mentioned, the arrangement of the layers in these ridges is not quite the same as in the cerebellum; the granular layer becomes interposed between the molecular and the intermediate layers, instead of the reverse being the case; this granular layer is continuous with the basal portion of the wings, but differs somewhat in this, that in the basal portions of the wings the cells are more uniform in size, whereas in the ridges the cells vary more in dimension; the smaller ones (fig. 17, *b*.) are oval or rounded, with nucleus and nucleolus; generally they are provided with two or three processes; they measure usually about 0·004 millim. or less; one of those figured is

0·004 millim. long by 0·003 millim. wide, and the nucleus is 0·002 millim. in diameter; the other is 0·0034 millim. in diameter with a nucleus of the same size as that of the one first mentioned. The cells of the larger size seem to be transitional forms to the Purkinje cells. The one figured (fig. 17, *c.*) measures 0·006 millim. long by 0·0054 wide, the nucleus is 0·003 in diameter, and the nucleolus, which in this case is rather larger than is usual in this species of cell, measures nearly 0·001 millim. in diameter. These two kinds of cells are irregularly mingled with each other, but the smaller sort are more often found nearer the molecular layer and extend some distance into it. The basis of this granular layer contains a fine network of fibrillæ (fig. 17, *h.*) which connects the cells together and extends into the molecular layer.

The ridges are bounded on the other side by a single row of cells which appear to correspond to the Purkinje cells of the cerebellum; their stratum may therefore have the same denomination of intermediate layer (fig. 17), and the term is still appropriate, for although they are not intermediate between the granular layer and the molecular—the former having encroached more on the latter than in the cerebellum—they are still intermediate between the granular and the fibrous layer, which latter is common to two contiguous ridges. As just mentioned, these cells are arranged in a single row in ordinarily formed ridges, *i.e.*, in ridges which occupy the straight parts of the wings, and are bounded on one side by the granular layer, and on the other by a space which separates one ridge from the other, and in which the fibrils from the fibrous layer are found, which presumably join the axis cylinder processes of these cells, although I have not actually been able to see the junction.

These cells are generally pear-shaped or oval, and usually have two processes, one at each end; one of these is the protoplasmic process, which can often be traced through the granular into the molecular layer. This process usually runs straight; but in the cell which formed the subject of the drawing (fig. 17, *a.*) it had accidentally become bent; the other process is probably the axis cylinder process, and it is not difficult to understand that it may join the fibrillæ from the fibrous layer. Occasionally cells occur which are more or less triangular in shape, in which case the apex is turned towards the granular layer, and two processes are given off from the broad end, which probably join the fibrils. All these Purkinje cells are of larger size than the largest of those belonging to the granular layer, although smaller than the Purkinje cells of the cerebellum. Their measurements are as follows (fig. 17, *a.*):—length, 0·01 millim.; width, 0·0068 millim.; nucleus, 0·0048 millim. in diameter; and nucleolus 0·0015 millim. Another cell is rather longer and larger, being 0·016 millim. long and 0·012 millim. wide, with a nucleus 0·006 millim. in diameter; but the nucleolus is smaller, being only 0·0005 millim. in diameter. The arrangement of these cells in those ridges which are placed on the straight part (either horizontal or perpendicular) of the wings is shown in the figure (fig. 17); but where there are curves and foldings, as at the angles of junction of horizontal with perpendicular wings, other cells are added to the single row of Purkinje cells so as to form groups filling up the depressions

caused by these foldings. These cells are of about the same size as the others, but differ in shape, being multipolar instead of bipolar. In other respects they belong to the same class, having a large oval or rounded nucleus and an easily distinguishable nucleolus. The specimen shown in the figure (fig. 17, *f.*) is a representative cell, having six processes, none of which can be singled out from the others as an axis cylinder process. This cell measures 0·01 millim. long by 0·008 millim. wide; the nucleus measures 0·006 millim. by 0·004 millim., and the nucleolus about 0·001 millim. in diameter.

These cells are situated among a network of fibrillæ, which fills up the space between them; but I could not trace any of the processes of the cells into this network.

In other respects the ridges at these curves and foldings have the same structure as elsewhere, the only difference being that at these places there is a larger space than ordinary between two contiguous ridges, which is consequently filled in with the cells resembling those just described.

The basal portions of the wings, which form the greater part of the whole mass to which the ridges appear merely as appendages, are entirely composed of extremely small cells which correspond in every respect with those of the granular layer of the cerebellum in structure, together with very fine nerve fibres, which are accumulated in greater numbers towards the outer side. The fibres run in a direction from the roots of the wings towards the apex, and give a longitudinally striated appearance to the part especially near the outer surface. In places where a sufficiently thin section has been obtained to see their arrangement, these cells are found to be placed in long, narrow groups, one or two deep, following the direction of the fibres, which form a network of elongated meshes. The cells are attached to them by short stalks in the same way as is represented in the figure of the torus longitudinalis (fornix) in my paper on the brain of the Teleostei.* This arrangement becomes less apparent, and the cells are more irregularly scattered towards the inner side of the wing, where the fibrillæ take a less decidedly longitudinal direction. The cells themselves are round, oval, or fusiform, sometimes with three, sometimes with two processes, one from each end, and occasionally with only one (fig. 17, *g.*); they measure about 0·003 millim. long by 0·0026 millim. broad, one larger than those figured was 0·0034 long, with a nucleus of the same size as that of the other.

MARCUSEN was of opinion that the anterior lobes of the wings had a different structure from the remainder, but such is not the case. The anatomical arrangements are precisely the same throughout the whole extent of this very extensive organ, which might be considered extremely complicated were it not that it is entirely made up of repetitions of the same structures.

The difference to be remarked between the anatomy of the ridges on the wings of the valvula cerebelli and that of the cerebellum is reduced to three points: first, the arrangement of the layers comes in a different order; secondly, the Purkinje cells are

* Fig. 18, *e.* Phil. Trans., 1878.

directed with their long axis towards the molecular layer, instead of parallel with it; and thirdly, the granular layer itself contains cells of various sizes instead of all being uniform in dimensions.

Medulla Oblongata.

We now come to the consideration of the medulla oblongata. This contains an extraordinarily developed tuberosity, which MARCUSEN* took to be the cerebellum, and which he was puzzled to find had not the histological character of that organ. That it is not the cerebellum is certain; what its real homology is will appear presently. In the meantime we can turn our attention to its minute structure. A reference to the figure (fig. 1) shows that it is an immensely developed tuberosity of a rounded shape placed immediately above the medulla oblongata and behind the cerebellum. It appears as a new development superadded to the usual elements of the Teleostean brain. It may be denominated for the present "Tuberculum Impar."

A section, either longitudinal or transverse, shows that six layers from outside inwards may be distinguished by the different degrees in which they absorb the colour of the staining fluid.

The first layer consists of small cells which become deeply coloured by the staining fluid.

The second layer contains sections of obliquely directed bundles of nerve fibres.

The third is a smoothly-granular layer which does not become so highly coloured as the outside, but which shows faint indications of radial striation.

The fourth layer is a narrow stratum of variously-sized cells which become intensely coloured by the staining fluid.

The fifth layer is occupied by a complex of medullated fibres, which form a complicated felt-like mass of intricate texture.

The sixth layer exists only at the anterior end of the tuberculum impar, and consists of finely granulated matter. This is replaced at the posterior end by a circular hollow space which seems a mere gap in the tissue, and is not a ventricle properly speaking, since it is not lined by epithelium.

Further inspection shows that the first or outer layer is not continuous throughout. Behind, it is deficient on the dorsal surface, the layers of each side ending within a short distance from each other in a club-shaped termination (fig. 8), but towards the anterior end of the tuberculum impar they meet in the mid line (fig. 7), while quite at the front of that tubercle they are continuous with a part (fig. 1) which is intercalated between the cerebellum and the tubercle in question. Both in the club-shaped dorsal termination at the posterior end of this layer, and at the anterior end, where the layers of the two sides meet in the mid line, the thickness is increased by the introduction of a new material consisting of a granular basis through which numerous cells of a very large size are interspersed, and the portion which is intercalated between

* *Loc. cit.*

the tubercle and the cerebellum is entirely formed by this material together with fibres running from the base to the apex.

The remainder of the first or external layer is found to be composed of a very fine network of fibrillæ, together with cells in considerable numbers, which are enclosed in a mesh-work of connective tissue. These cells are of two different sizes (fig. 18, *d*, *e*.), and are either round, oval, or pear-shaped. The smaller kind measured about 0·0045 millim. long by 0·004 millim. wide, with a nucleus 0·003 millim. in diameter, and a nucleolus which is a mere speck. Some of these cells are seen to give off several very slender processes which join the fine network of fibrillæ forming the basis of this layer. This class of cell is the most numerous, but others of a larger size occur more sparingly, these are often pear-shaped, with two processes, one from each side; they measure about 0·01 millim. long by 0·006 millim. wide, the nucleus being 0·004 millim. long by 0·003 millim. wide, and with a disk-like nucleolus measuring about 0·001 millim. Besides these cells and the net-work of fine fibrillæ, bundles also of these latter are seen penetrating this layer principally running in a longitudinal direction; some also are transverse and others oblique. The smaller class of cells are found throughout, but predominate in the posterior part of this layer, while the larger ones are found mostly in the anterior portion.

The granular basis of the club-shaped dorsal termination of this layer and the anterior end of the same, might be looked upon as a separate layer, but it does not extend over the whole tuberculum impar, but is confined to the dorsal and anterior portions only, where it forms a sort of crest. This granular portion of the outer layer contains, in addition to the elements already mentioned in describing that layer, viz.: small-sized cells and fibrillæ, cells of a very large kind, equal to, if not surpassing, those of the spinal cord in magnitude; these occur principally in the dorsal accumulation, where they form a special ganglion, but they are also found in the anterior process. One of the largest measures 0·052 millim. in length and 0·02 millim. in width; the nucleus, oval in shape, is 0·013 millim. long by 0·01 millim. broad (fig. 18, *f*.); it contains a distinct disk-like nucleolus, 0·003 in diameter, which has a circular clear space round it; this cell passes off gradually at one end into a broad protoplasmic process, and at the other more sharply into a narrower, probably axis-cylinder, process. This cell seems to be of an exceptional size; most of them are smaller, not much exceeding 0·03 millim. in diameter, but all show the same characteristics—broad, disk-like nucleolus, and usually two processes. Some of the cells also show distinct traces of striation of the cell-contents.

If these cells may be looked upon as motor corpuscles, they seem to form an exception to the rule that motor elements occur only on the ventral surface—a rule which is perhaps not of universal application, as there are exceptions to it, even in the spinal cord in Fishes.

The second layer requires no comment, as it consists simply of bundles of nerve-fibres, belonging, according to their position, either to the trifacial or the vagus. They

are cut off obliquely as they descend from above downwards; they extend over the dorsal edge of the third layer, even where the first layer is deficient; and here they form what may be looked upon as a commissure.

The third layer (figs. 7 and 8) is the widest of all of them, and consists of a finely granular material, showing distinct traces of radial striation, which is more apparent in some places than in others. It seems to have the same sort of composition as the molecular layer of the cerebellum; the absence of palisade cells would account for the striation being very slightly indicated, and would seem to show how much of these markings might be attributed to the presence of the palisade cells, and how much to the nature of the material itself and to the direction of the nervous fibrillæ.

The fourth layer (figs. 7 and 8) consists of cells of two sizes arranged in an arch equally curved in both directions. The smaller cells form a continuous line which is always conspicuous, in whatever direction the sections are made, on account of the intense colour which they take up from the staining fluid. They are generally bipolar and are so placed that their processes run in a radial direction, in apparent continuation of the striæ of the third layer; they thus seem to be a medium of communication between the fifth layer and those layers situated more externally.

These cells have all well-marked nuclei and nucleoli, and are of three sizes; the largest, generally spherical, measure 0·0143 millim. long (fig. 18, *a.*) by 0·013 millim. wide, nucleus 0·008 millim., and nucleolus 0·002 millim. Of the middle-sized cells the length of one representative cell (fig. 18, *b.*) is 0·009 millim. long by 0·006 millim. broad, the nucleus is oval, 0·0045 millim. long by 0·003 millim. wide; there is here also a disk-like nucleolus measuring 0·0015 millim. in diameter. A process is seen to be directed from the small end of this cell towards the third layer; the comparative breadth and appearance of this prolongation characterise it as a protoplasmic process. A fine fibre coming from the other side of this cell, if it existed, is not visible. This kind of cell seems to form a transition between the larger kind resembling motor cells of the spinal cord and the smaller cells which some writers consider to be connected with sensation, but they have more affinity to the former, as is shown by their large circular nucleoli.

The smallest species of cells (fig. 18, *c.*) in this layer range from 0·006 millim. to 0·004 millim. in diameter; they are generally nearly round or oval; they have a nucleus and nucleolus; their processes are directed radially; the thicker is turned towards the third layer, and the other, which is finer, towards the fifth layer. The smaller cells are arranged in groups, irregularly scattered through the granular basis of the layer; the larger ones either occur singly or in groups, or else in some places occupy a curved row: these are placed at the edge of the fourth layer between it and the third.

The fifth layer consists almost entirely of a complicated interlacement of medullated fibres; those at the anterior end belong to the trifacial, and those at the posterior end to the vagus. Anteriorly they enclose the sixth layer, while posteriorly they

surround a central vacant space. In addition to these fibres there are also a few cells scattered throughout the layer; they resemble the largest sized cells of the fourth layer, but are on an average of slightly larger dimensions; sometimes they have three processes, one of which can be traced for some distance into the complex of fibres forming the exit of the nerve. The sixth layer is formed of finely granular material resembling that of the third layer; it occupies the anterior end of the tuberculum, and forms a sort of kernel round which the other layers are placed.

We have now described those parts of the brain of *Mormyrus* which differ from, and are in fact additions to, the nervous centres of an ordinary Teleostean; the remaining portions show very slight variations from the general plan.

The Central Cavities.

In tracing the central canal of the spinal cord and its prolongations forward, it is to be remarked that the cavities show a tendency to contraction and almost obliteration. At a very short distance in front of the point where the central canal of the spinal cord merges into the fourth ventricle, this latter cavity (fig. 10) becomes plugged with a mass of finely granular material, which in the central line shows indications of its original separation into two halves; this contains part of the ganglion of the vagus. Farther forward this ventricle exhibits an extremely deep narrow fissure (fig. 9), which owes its depth and narrowness to the great development of the vagal tuberosities. At a point beneath the posterior end of the tuberculum impar the ventricle (fig. 8) becomes again plugged by a development of what appears to be connective tissue, corresponding to that material which surrounds the central canal of the spinal cord. There are, however, two spaces left one above the other, the lower one lined by an endothelial layer of cells. They both lie beneath the space which occupies the centre of this part of the tuberculum impar. Towards the anterior end of the tuberculum impar the fourth ventricle (fig. 7) becomes reduced to an extremely small canal, triangular in outline, with the apex directed downward; in some specimens the lumen is scarcely perceptible. This corresponds to the narrower portion of the fourth ventricle in *M. cephalus;* after this it again enlarges (fig. 6) beneath the cerebellum, and shows a triangular lumen which seems to correspond to the anterior end of the fourth ventricle in other Teleostei; beyond this it again becomes contracted as the aqueduct of Sylvius (fig. 4) into a very small perpendicular slit, which soon extends through the hypoarium nearly to the inferior surface of the brain (fig. 3). This slit is occupied in its centre by a small coil of an epithelial tubular structure, which appears to correspond to the saccus vasculosus of the ordinary Teleostei. After this the aqueduct opens into what would be the ventricle of the optic lobe, were it not that it is quite open to the external surface, and by the peculiar position of the tecta, has come to be above instead of below them. The growth of the wings in fact has quite forced open this ventricle and separated the valvula cerebelli and themselves from the tori semicirculares and the

tecta, so that when a transverse section is made there is nothing to prevent their falling apart.

Spinal Cord.

A section of the spinal cord shows the same features as in *M. cephalus*. The grey matter here forms a figure like a St. Andrew's cross (figs. 13 and 14). The dorsal horns are not very much developed, while the ventral horns have about the usual appearance. These latter show the ventral ganglion with from six to ten cells in one section, together with the central ganglion with seldom more than two, but these of a larger size.

Three pairs of columns may be distinguished—the dorsal columns, situated between the two dorsal horns of grey matter; the lateral columns placed between the dorsal and ventral horns: these are characterised by the nerve fibres having a tendency to fall into separate bundles, thus differing from the corresponding columns in *M. cephalus*, where they form a more undivided mass; and finally the ventral columns, situated in the space between the two ventral horns; these have the same sort of large fibres as in ordinary Teleostei, and contain also the characteristic Mauthner's fibres. RANVIER* considers that there is no physiological significance in the various sizes of the nerve fibres, but still it is a curious circumstance that the ventral columns should always contain fibres of so much larger calibre than the others.

The dorsal columns are traceable forward through the tuberosities of the vagus and the outer and inferior angle of the tuberculum impar into the posterior and outer part of the cerebellum; they, together with the tuberosity of the vagus, probably homologise with the restiform columns or bodies and contain finer fibres than either the lateral or ventral column.

The lateral columns are also composed of fine fibres, finer than those of the ventral columns, except at the part where they border on the dorsal horns. Here some of the fibres are of a larger size. When they arrive at the medulla oblongata, these lateral columns are arranged as just mentioned in separate bundles slightly resembling the formatio reticularis of that part in the Elasmobranchii. They can be traced forward as far as the large transverse commissure of the tuberculum impar, which some of them appear to join, others go forward as far as the inner side of the torus semicircularis, being joined by some fibres from the central portion of the above-mentioned commissure, but many of them are dispersed in the grey matter of the medulla.

The ventral longitudinal columns are divided into two bundles by the ventral transverse commissure, as in *M. cephalus*. In the medulla oblongata further forward, they are separated by the immensely developed transverse decussating commissure (fig. 7) of the tuberculum impar. The Mauthner's fibres accompany the upper or central longitudinal column and decussate immediately under the angle formed by the posterior root of the trifacial as it turns outward towards its place of exit from the medulla

* Leçons sur l'Histologie du Systeme Nerveux. Paris, vol. i, p. 100.

oblongata. At the point of their crossing, the Mauthner fibres present the appearance as if the axis cylinder had broken up into fibrillæ. The medullary sheaths are entire, and in them are seen several blue dots* like sections of fibrillæ; in the next section forward both medullary sheaths and blue points have completely disappeared, while in the few sections behind this part, the axis cylinder is seen gradually breaking up into these fibrillæ, the lower one becoming decomposed at a point behind the upper. This confirms what I have long suspected: that the axis cylinders of the Mauthner's fibres are really composed of fibrillæ, and as the Mauthner are merely gigantic nerve fibres it might confirm the views of MAX SCHULTZE,† who was of the opinion that ordinary nerve axis cylinders are made up of fibrillæ, united together into a single fibre.

The central longitudinal columns disappear at a very short distance in front of the decussation above mentioned, and the ventral longitudinal columns take their place beneath the floor of the fourth ventricle, at the anterior end of the commissure of the tuberculum impar. At about the position of the ganglion of the oculomotorius these disappear as compact bundles, but can be traced forward as isolated fibres and small fasciculi as far as the region of the posterior commissure to which they appear to contribute fibres.

Transverse Commissures of the Central Nervous System.

In the spinal cord two transverse commissures are present, corresponding to those of *M. cephalus*; they connect the dorsal and ventral horns of grey matter of each side; the former is placed close to the dorsal edge of the central canal and the latter occupies its usual place between the ventral and central columns (figs. 13, 14, and 15).

More anteriorly an immense decussating commissure (fig. 7) is met with which is connected with the tuberculum impar, and is developed in like proportions. This is evidently the continuation forward of the ventral commissure of the cord; it occupies the same level and separates the two ventral columns in the same manner. It exists only at the anterior part of the tuberculum where it forms a communication between one side of that lobe and the opposite side of the medulla oblongata. Its bundles are seen to arise from the complex of fibres of origin of the trifacial in the central portion of the tuberculum, then to wind round the central nucleus of finely granular matter or sixth layer, to pass beneath what there is of the fourth ventricle and finally to pass beneath that ventricle to the other side, where they are lost quite close to the lateral and inferior edge of the medulla oblongata. This commissure is traceable in the myelencephalon as far forward as the posterior side of the cerebellum.

The commissura ansulata (fig. 6) occurs further back than in *Mugil*, being placed beneath the cerebellum instead of beneath the middle of the valvula cerebelli. That it is the commissure which is displaced backward, rather than that the cerebellum is displaced forward, is I think indicated by the fact that the root of the oculomotorius

* The staining fluid was rosaniline.

† STRICKER'S Handbook, Sydenham Society.

is directed obliquely backward from its ganglion to its exit, whereas in ordinary Teleostei it passes directly downward; I speak here of course in reference to the position which these animals habitually assume. The commissura ansulata consists of the same two divisions as in *M. cephalus*, but the parts which it connects are slightly different. It derives its lateral fibres from the base of the wings to which it acts as a commissure; the upper part of its decussating bundles, instead of going to the torus semicircularis as in *M. cephalus*, goes into and is lost in the granular layer of the anterior end of the cerebellum. Upon further consideration I find that the homology which I gave for this commissure in the brain of *M. cephalus* was most probably wrong, and the fact that some of its fibres in this animal are derived from the cerebellum seems to confirm its determination, as the pons varolii, which was also adopted by FRITSCH.*

The posterior commissure (fig. 3) occupies its usual position behind the third ventricle and the infundibulum, but here it is more isolated, for the posterior wall of the infundibulum appears to be wanting, so that the fissure in the floor of the aqueduct of Sylvius communicates with it without any partition; it forms a communication between regions corresponding to those united by this commissure in *M. cephalus*.

The anterior end of the dorsal commissure of the tecta (figs. 2 and 3) is all that remains of that commissure which in Teleostei generally extends for the whole length of those bodies. This is placed immediately above the posterior commissure and even extends in front of it; this relation contributes material for forming an opinion as to the homology of the tecta, which will be touched upon presently.

The deep transverse commissure, and with it the nucleus rotundus, have completely disappeared in this family, and have left not a trace behind.

Deep Origins of the Cranial Nerves.

In the *Mormyridæ* all the nerves can be easily found except the trochleares and the abducentes; these, probably from the great degradation of the muscles of the eyeball, have become reduced to such extreme minuteness as readily to escape detection.

The optic nerves, although of small size, present, at their entrance into the optic tract, a true chiasma nervorum opticorum, formed by bundles which decussate, and at the same time form a felt-like structure. The optic tract, at its entrance, forms a thick layer of fibres surrounding the trigonum fissum and the hypoarium on three sides (figs. 2 and 3). I am sorry to have to differ from BELLONCI † as to the origin of the optic nerve. The family of the *Mormyridæ* present rather good subjects for investigating the derivations of this nerve, as the tecta have been pressed forward and downward, so as to be placed immediately above the exit of the nerve in question, and consequently the optic tract passes directly upward into the tecta. I find that I cannot subscribe to the opinion that these latter bodies form the only origin of the optic nerves; on the contrary, some fibres are distinctly seen to emerge from the inferior part of the trigonum fissum and from the region containing the small cells which line the infun-

* *Loc. cit.*, p. 74, fig. 44, *p.v.*

† *Loc. cit.*

dibulum, and to join the optic tract. As to these fibres being derived from the posterior commissure, this is very unlikely, since this commissure is situated at a considerable distance away from this particular part.* The optic tracts are seen going upward and entering the roots of the tecta in two separate portions; the inferior portion curves over the angle formed by their junction with the hypoarium and streams into the outer layer of those bodies, while the upper portion enters them by numerous small radiating bundles, which cross the bundles of the commissure of the tectum at a large angle and are lost in the internal layer; that is to say, the layer which corresponds to the third and fourth layers in the tectum of *M. cephalus.* The inferior portion (fig. 2) of the optic tract presents a peculiar arrangement of fibres which form a mass of decussations projecting above the dorsal edge of the optic tract in the central line, from which two or three bundles emerge, going obliquely upward and outward, crossing the crus cerebri to join the main body of the optic tract at the point where a complex of fibres is about to be formed, previous to their entrance into the tecta as above described. I could not make out with certainty that any of the fibres were derived from the tori semicirculares. These bodies are displaced further back in comparison to the tecta than in *M. cephalus,* or rather have retained to a greater extent their proper position, the latter having, as it were, moved forward, so that no part of the optic tract passes beneath their base. But there is a bundle of fibres (fig. 3) which passes downward along their inner edge, and appears to join the complex of fibres of the optic tract.

The oculomotorius (figs. 4 and 5) is derived from a ganglion situated on the floor of the ventricle of the optic lobe corresponding to its origin in *M. cephalus.* The only peculiarity about this nerve is that the fibres run obliquely backward towards their point of exit near the commissura ansulata instead of perpendicularly downward.

The trifacial (fig. 7) presents the same number and derivation of its roots as in *M. cephalus,* and in addition derives a large number of its fibres from the anterior end of the tuberculum impar.

The acusticus (fig. 7) also shows a complete concordance with the arrangement in *M. cephalus.* It passes forward in close contact with the central longitudinal column† and turns outward with the upper column of the trifacial, both forming an angle. FRITSCH has suggested that the latter presents the marks of the facialis root in the brain of Mammalia, to which I would add that the acusticus root passing in close contact with it tends to increase the resemblance.

The vagus (figs. 8, 9, 10) also presents roots of origin corresponding to those in *M. cephalus,* with the exception, perhaps, of the one from the cerebellum, which does not seem to be present. Some addition to its fibres is derived from the posterior part of

* There does not appear to be anything extraordinary about this fact, since the trigonum fissum homologises with the tuber cinereum, and this part in the human subject sends fibres into the optic tract. ('Human Anatomy,' QUAIN, latest edition.)

† In the figure 7 this does not show well, the parts being too small, but in the original proparation three distinct bundles of fibres are apparent here.

the tuberculum impar. The only peculiarity about it is that the ganglion of origin of the posterior root is situated higher than the corresponding part in *M. cephalus*, being placed above, instead of below, the floor of the fourth ventricle.

The spinal nerves (figs. 13 and 14) take their origin very much in the same way as in the case of *M. cephalus.* The dorsal roots, after running a short distance dorsad along the edge of the section, pass downward and inward to enter the apex of the dorsal horn of grey matter by two bundles, and there they are soon quite lost to view. The ventral roots are derived from two sources—one from the transverse commissure, which separates the two ventral longitudinal bundles; the other comes from the ventral horn of grey matter of the same side. These two bundles join at the ventral edge of the cord and emerge together as a single root. The fasciculus from the transverse commissure is probably derived from the ventral horn of the opposite side.

Homologies of the Brain in the Mormyridæ.

We have now to consider what relation the brain of *Mormyrus* bears to that of the ordinary Teleostei. What are the homologies of those highly developed wings which MARCUSEN, in despair of finding their signification, termed the "peculiar organ" (Eigenthümliches Organ)? What the homology of the tuberculum impar? If we examine a longitudinal section (fig. 1) we see at once that they are new formations. We have only to remove them and to allow the displaced organs to resume their proper position, and we have a brain like that of any other Teleostean. There is a slight difference in the direction of the cerebellum, but that occurs in other families, such as the Siluridæ. In order to solve this problem we have examined the characteristics of this "peculiar organ," and we have found, in the first place, that it contains all the elements of the cerebellum arranged in a slightly different manner; secondly, we have found that it is not the cerebellum, since that organ exists, presenting the ordinary form and arrangement of tissue; thirdly, that its roots are derived from that part of the brain which lies immediately in front of that organ; the tecta lobi optici occupy this position in ordinary Teleostei, but here they are pressed towards the base of the brain without being otherwise deformed. The only organ then occupying this position that remains for comparison is the valvula cerebelli. This part is highly developed in the Ballan Wrasse (*Labrus maculatus*), and if we examine a transverse section through it (fig. 15), we find in the centre a double layer of the molecular layer indicating the fold of cerebellum by which it is formed; on each side we see that the organ stretches out into a wing, which is composed of a folded stratum of the molecular layer, below which the remainder of its bulk is made up of the granular layer. Even here it looks as if an attempt had been made to pack a large amount of tissue into a small space.

We now turn to a section (fig. 3) through the brain of a *Mormyrus,* taken perhaps a little farther in advance. We find here the same arrangement; in the centre there is a double molecular layer below and a single layer above; this is accounted for by the greater number of foldings undergone by the molecular layer, and would explain

itself by a reference to the longitudinal section (fig. 1), and obviously this is a difference of degree and not of kind; next we have on each side a wing which goes out into a much more complicated arrangement than in *L. maculatus.*

We are now in a position to explain the morphology of the "peculiar organ" in *Mormyrus.* It is easy enough to imagine that the ancestors of the *Mormyridæ* had a brain resembling that of the Ballan Wrasse, possessing a valvula cerebelli of no larger size; but there is nothing to prevent this valvula being endowed with a capacity for indefinite growth. It may be seen that the external extremity of the molecular layer on the right side in the figure (fig. 15) has begun to turn down; it might go on growing, and might form another fold like the one already present, and after that another, and so on until it breaks through the tecta lobi optici, and this going on to an indefinite extent in every direction would eventually produce such a brain as is possessed by the *Mormyridæ* of the present day.

To solve the problem of the tuberculum impar we must turn to an entirely different genus of Fishes; the well-known Gold Carp, such favorites with some people as ornaments for ponds and fountains, present the key to this difficulty.

These Fishes have a tubercle placed in the fourth ventricle behind the cerebellum; in the species that I investigated there were two tubercles in this position, one placed in front of the other. On examining the figure (fig. 16), which is a section across the medulla oblongata of a Gold Fish (*Cyprinus* sp. ?), it is found that there is a tubercle in the centre, and on each side a sharp ridge; the composition of these beginning on the outside of the ridges, which are the vagal tuberosities, is as follows:—

First, there is a layer of small cells.
Secondly, a layer of finely granular material.
Thirdly, a layer of nerve fibres.
Fourthly, a granular layer with large cells dispersed in it.

All these are in the vagal tuberosities; then comes the tuberculum, which occupies the space between them; it consists of—

Fifthly, a layer of small cells; and
Sixthly, a layer of granular material, which occupies the greater part of the tubercle in the centre.

At the junction of this tubercle with the vagal tuberosities there are sections of a few bundles of nerve fibres.

We have now to consider how the tuberculum impar of the *Mormyrus* may be explained by a consideration of these facts.

The organ in question is, as we have seen, placed immediately behind the cerebellum, and at first sight this seems to be the only circumstance that it has in common with that of the Carp, since there are in the *Mormyrus* no sharply projecting ridges, and the succession of tissues does not apparently correspond; but a little consideration will

show that with a slight alteration all these layers may be made to do so. In the Carp we find that the fourth layer is composed of a granular material in which large cells are dispersed; we have only to imagine these cells to be collected at the summit instead of at the sides, when they would homologise with the club-shaped dorsal end of the outer layer and the anterior side of the tuberculum impar of the *Mormyrus.* After this our course is plain, and making allowance for its enormous development, we have layers in tolerably exact correspondence with each other. The outer layer in the vagal tuberosities of *Cyprinus* is evidently the homologue of the outer layer of the *Mormyrus,* then comes the finely granular layer; the third and fourth layers in *Cyprinus* being by some means displaced, we immediately come upon the outer granular layer of the tubercle, which in the places where it is free, extends round the whole circumference: this would correspond to the fourth layer of the tuberculum impar. It may be supposed that the inferior fibres have become developed at the expense of the upper ones, and so would come to be derived from the inner side of this granular layer, and thus correspond to the fifth layer in *Mormyrus.* We have now only the finely granular interior of the tubercle remaining to be accounted for: this would answer to the sixth layer, which is the finely granular material forming the central portion of the anterior part of the tuberculum impar, and which presents the same relation to the remains of the fourth ventricle, and to the central longitudinal columns of the medulla oblongata in both Fishes. From these considerations, the conclusion is obvious, that the tuberculum impar of the *Mormyridæ* corresponds to the tuberculum impar situated in the fourth ventricle of *Cyprinus* together with the tuberosities of the vagus; the three bodies which are nearly separate in *Cyprinus* having become indissolubly united in *Mormyrus.*

I have thus, as far as I am able, explained the special formations in the brain of the *Mormyrus;* but while it is comparatively easy to account morphologically for these peculiarities, it becomes very much more difficult, if not impossible, with our present amount of knowledge, to account for them physiologically. What can possibly be the function of this enormously developed organ and of the innumerable repetitions of the same structure? As far as I could learn there was nothing extraordinary about the habits of these Fishes that could throw any light on it. It is true that their eyes are very small, while their organs of hearing are comparatively highly developed, as was shown by FISCHER,* but there does not seem to be any connexion between these two series of facts. Other Fishes have complicated organs of hearing, and, as far as I know, neither these nor the blind or semi-blind Fishes inhabiting caves have any such peculiarity in the structure of their brain. But the most curious fact about these Fishes is, that notwithstanding the enormous development of the brain, the nerves emerging therefrom have nothing like a corresponding amount of development; most of them are quite small, some escape detection, and the only nerves of any size, the trifacial and the vagus, do not present anything out of the common, either in extent or dis-

* Ueber d. Gehörorgan der Fischgattung Mormyrus. Freiburg, 1854.

tribution. These Fishes certainly have organs placed along the side near the tail, which by some writers have been looked upon as electric lobes, and which, although presenting some of the structure of those bodies, yet show that they are pseudo-electric organs, since they give no shocks when the Fish is handled. This fact, however, seems to have no connexion with the development of the brain, for the lateral line and dorsal nerves which supply those structures are by no means of enormous size. This subject must therefore remain in obscurity until some competent person may be in a position to throw light on it by means of physiological experiments, to which the formation of the brain lends itself with great facility, because it is placed close beneath the skull, which is very thin, and the wings form plates of nervous matter easily removable without injury to other parts of the organ.

Conclusion.

Although the brain of the *Mormyridæ*, being squeezed almost out of all recognition, does not throw much light on the problem of the homologies of the various parts of the central nervous system in Fishes, yet I must take this opportunity of making some remarks on the interpretations put forward by FRITSCH* in his great work, which I had not time to study before my paper on the brain of the Teleostei was finished. As far as I can make out from his rather involved style, he considers that the tecta lobi optici† taken together represent the persistent cortex of the primitive anterior vesicle of the embryo ;‡ nevertheless, he recognises in the commissure of the tecta the homologue of the corpus callosum§ and in the torus longitudinalis that of the fornix of the Mammalian brain. Both these structures are developed from what FRITSCH terms the secondary vesicles,|| from which the cerebral hemispheres arise. How they get transferred to the primary vesicle this author does not explain. Further, he homologises the tori semicirculares with the thalami optici, and certain undefined regions lying to the inside of them with the corpora quadrigemina.

It seems to me that there are two fixed points in the brain of Fishes from which it would be possible to deduce the homologies of all the remainder. The first of these is the pineal gland or epiphysis, together with the infundibulum, which opens beneath it, and the pituitary body or hypophysis which is placed at the inferior extremity of the latter.

EHLERS¶ has shown that the epiphysis is a structure universally present in the Vertebrata, and that it invariably occupies a corresponding position throughout. The probability is that the infundibulum is a channel older even than the Vertebrate stock itself ; and in reference to this subject perhaps I might be permitted to express my gratification

* *Loc. cit.*

† *Loc. cit.*, pp. 22 and 54.

‡ Primäres Vorderhirn.

§ *Loc. cit.*, p. 51, fig. 42.

|| "Secundäres Vorderhirn."

¶ Die Epiphyse am Gehirn d. Plagiostomen. Zeitsch. f. wiss. Zoologie, Bd. 30 (supplement), 1878.

that the suggestion thrown out by me in 1878, that the œsophagus of the primitive ancestors of the Vertebrata passed through the infundibulum, should also have occurred to Professor OWEN, who, in a paper recently read before the Linnean Society, entitled "Homology of the Conario-Hypophyseal Tract, or the so-called Pineal and Pituitary Glands," showed that in the embryo there are indications of there having been a communication between the primitive intestine (before the permanent mouth appeared) and the canal going through the infundibulum and the third ventricle to the present dorsal surface of the brain, so that the lateral walls of the third ventricle and the crura cerebri in Sharks and (consequently in Teleostei) homologise with the commissures between the supra and infra-œsophageal ganglia of insects.

The second fixed point would be the ganglion of origin and the place of exit of the oculomotorius. If the foramen of exit of a cranial nerve be sufficient to fix the homology of the bone of the skull through which it passes, then it must be conceded that the ganglion of origin of a nerve ought to fix the homologies of the parts of the brain lying near it.

We have then these two fixed points, and applying them to the central nervous system, we find that the first indicates the third ventricle or thalamencephalon, and consequently the posterior commissure, which two parts have always a fixed relation to each other. The determination of the posterior commissure incidentally involves that of the corpus quadrigeminum; for FOREL* shows that this commissure is in juxtaposition to the transverse commissure of the anterior corpus quadrigeminum; so in Fishes the posterior commissure is in close relation to another commissure which FRITSCH marks *c. anterior*, but which is nothing more than the continuation forward of the transverse commissure of the tecta lobi optici. This line of argument is supported by the consideration of the position of the ganglion of the oculomotorius, which in the Mammalia is placed immediately beneath the aqueduct of Sylvius and the anterior corpus quadrigeminum. In Fishes the corresponding ganglion is placed beneath the ventricle of the optic lobe and the tectum lobi optici.

In one of his figures† FRITSCH has made it appear as if this ganglion were at the side of the aqueduct of Sylvius instead of beneath it, as it ought to be.

This converging line of argument is supported by another mode of reasoning based upon structure, which although taking a subordinate position is yet of use, as supporting considerations derived from other sources. Thus MEYNERT‡ has shown that in the human subject the anterior corpus quadrigeminum contains radial fibres on which fusiform cells are developed. The tecta lobi optici in Fishes have radial fibres with fusiform cells developed thereon.

The united force of these arguments compels me to homologise the tecta lobi optici

* Beiträge z. Kentniss des Thalamus Opticus, &c. Sitzber. d. k. Akad. der Wiss., Wien, Bd. lxiii. Math. Nat. Classe, fig. 4; also MEYNERT, fig. 249, *l.c.*

† *Loc. cit.*, fig. 32.

‡ *Loc. cit.*

of Fishes not only with one of the pairs of the corpora quadrigemina but especially with the anterior pair, as STIEDA long ago pointed out. The ventricle of the optic lobe would be simply the remains of the ventricle which is always found in the mesencephalon of the embryo in Vertebrata. It does not seem to me that FRITSCH's homologies have any force as against these arguments.

The torus semicircularis could not homologise with the thalami optici, but would seem more likely to correspond to the corpus geniculatum externum,* a ganglion in the course of the optic tract, which according to FOREL† becomes larger in the lower Mammalia.

The region round about the posterior commissure in Fishes homologises better with the thalami optici; the part which extends behind that commissure in Mammalia becomes much less developed, as FOREL‡ has also pointed out, in descending the scale.

The torus longitudinalis, if this line of argument carries any force, could not homologise with the fornix, as the former is a nervous centre, closely resembling the granular layer of the cerebellum in structure, and the latter is simply a set of longitudinal commissural fibres. With these principal points, the minor interpretations of FRITSCH of course fall to the ground. Finally it seems to me that as Fishes retain so many marks of being in an embryological position, they would possess a brain in accordance with these conditions, and to find all the parts of a Mammalian cerebrum even in a rudimentary state, much more in the comparatively developed form insisted upon by FRITSCH, would be, so to speak, an anachronism. The brain would not be in accordance with the rest of the organisation.

EXPLANATION OF PLATES.

The following letters have the same signification throughout:—

a.	Arteries.
aq.Sy.	Aqueduct of Sylvius.
a.v.c.	Ala of the valvula cerebelli.
a.w.	Anterior wings of the valvula cerebelli.
c.a.	Commissura ansulata.
c.c.	Crura cerebri.
c.ca.	Central canal of the spinal cord.

* I have only just received the interesting article by P. MAYSER on the brain of Teleostei (Zeitsch. f. Wiss. Zool., Bd., xxxvi., 1881.) I am glad to find that in most cases he is in accord with me. Curiously enough, he compares the tori semicirculares with the corpus geniculatum internum.

† *Loc. cit.*, pp. 29 and 30.

‡ *Loc. cit.*, p. 30.

cbl.	Cerebellum.
c.cbl.	Crura cerebelli.
ce.	Cerebral lobes.
c.g.	Central ganglion of the spinal cord.
ch.o.	Chiasma of the optic nerves.
c.l.c.	Central longitudinal column.
com.w.	Commissure of the wings of the valvula cerebelli.
c.w.	Central wing of the valvula cerebelli.
d.c.	Dorsal columns of the spinal cord.
d.h.	Dorsal horn of grey matter in the spinal cord.
d.r.	Dorsal roots of the spinal nerve.
d.t.i.	Decussating fibres from the tuberculum impar.
d.w.	Dorsal wing of the valvula cerebelli.
f.l.	Fibrous layer of the cerebellum and of the valvula of the same.
f.r.	Formatio reticularis of the medulla oblongata.
g.l.	Granular layer of the cerebellum and of the valvula of the same.
gn.mo.	Ganglion of the oculomotorius.
gn.tf.	Ganglion of the trifacial.
gn.v.	Ganglion of the vagus.
gn.vh.	Ganglion of the ventral horn of the spinal cord.
hy.	Hypoarium.
i.l.	Intermediate layer of the cerebellum and of the valvula cerebelli.
in.	Infundibulum.
i.n.t.i.	Internal nucleus of the tuberculum impar.
l.c.	Lateral columns of the spinal cord.
l.c. 5.	Lower column of the trifacial.
l.w.	Lateral wing of the valvula cerebelli.
m.	Medulla oblongata.
m.f.	Mauthner's fibres.
m.l.	Molecular layer of cerebellum and valvula cerebelli.
n. 3.	Oculomotorius.
n. 5.	Trifacial.
n. 7.	Facial.
n. 8.	Acusticus.
n. 9.	Glossopharyngeal.
n. 10.	Vagus.
op.tr.	Optic tract.
p.c.	Posterior commissure.
p.m.	Pia mater.
p.w.	Posterior wing of the valvula cerebelli.
r.	Raphé.

r.c. Restiform column.
s.g.c. Substantia gelatinosa centralis.
s.r. Fourth ventricle or sinus rhomboidalis.
s.v. Saccus vasculosus.
t. Tectum lobi optici.
t.c. Transverse commissure of the cerebrum.
t.c.t. Transverse commissure of the tectum.
t.c.v. Transverse commissure at the root of the vagus.
t.f. Trigonum fissum.
t.i. Tuberculum impar.
t.l. Torus longitudinalis.
t.s. Torus semicircularis.
t.v. Tuberosity of the vagus.
u.c. 5. Upper column of the trifacial.
v.c. Valvula cerebelli.
v.g. These appear to correspond to the vincula gelatinosa centralia of FRITSCH, *l.c.*, p. 44.
v.h. Ventricle of the hypoarium.
v.h.g. Ventral horn of grey matter in the spinal cord.
v.l.c. Ventral longitudinal column.
v.op.l. Ventricle of the optic lobe.
v.r. Ventral root of the spinal nerves.
v.t.c. Ventral transverse commissure in the medulla oblongata and the spinal cord.
v.th. Third ventricle or thalamencephalon.

PLATE 59.

Fig. 1. Longitudinal and vertical (sagittal of authors) section through the brain of a young *Hyperopisus dorsalis*, close to the central line. × 8½ diameters about. The dorsal part of the lateral wing is left in outline. The anterior wing has become slightly bent upward; it ought to be parallel to the long axis of the brain.

** Show the line of section taken in fig. 3.

Fig. 2. Transverse section through the anterior part of the optic tract and the tecta lobi optici of another specimen of the same species. The lateral and dorsal wings of the valvula cerebelli have been left in outline. × 15½ diameters nearly.

Fig. 3. Transverse section through the centre of the tectum lobi optici at a point slightly behind the last, taken from the same specimen. × 15½ diameters nearly.

PLATE 60.

Fig. 4. Transverse section through parts slightly behind the last. Taken from an older specimen of *H. dorsalis.* × $15\frac{1}{2}$ diameters nearly.

Fig. 5. Transverse section through the aqueduct of Sylvius and the trigonum fissum of a younger specimen. × $8\frac{1}{2}$ diameters nearly.

Fig. 6. Transverse section taken farther behind, and falling through the main part of the commissura ansulata and the posterior part of the cerebellum. Taken from the same specimen as fig. 4. × $15\frac{1}{2}$ diameters nearly.

PLATE 61.

Fig. 7. Transverse section through the anterior part of the tuberculum impar. Taken from the same specimen as the last. × $15\frac{1}{2}$ diameters nearly.

Fig. 8. Transverse section through the posterior part of the tuberculum impar. Taken from the same specimen. × $15\frac{1}{2}$ diameters nearly.

PLATE 62.

Fig. 9. Transverse section through the posterior part of the fourth ventricle. The extreme posterior end of the tuberculum impar, which projects over it, is not represented. This is taken from another specimen of the same species. × 37 diameters.

Fig. 10. Transverse section through the posterior end of the fourth ventricle. Taken from the same specimen as fig. 8. × 37 diameters.

Fig. 11. Transverse section taken close to the point of transition of the spinal cord into the medulla oblongata. Taken from the same specimen as the last. × 37 diameters.

Fig. 12. Transverse section taken from the same specimen at a point a short distance behind the last. × 37 diameters.

Fig. 13. Transverse section through the spinal cord of a younger specimen of the same species, to show the origin of the ventral roots of the spinal nerves × 37 diameters.

PLATE 63.

Fig. 14. Transverse section through the spinal cord of an older specimen of the same species, to show the origin of the dorsal roots of the spinal nerves. × 37 diameters.

Fig. 15. Transverse section through the valvula cerebelli of the Ballan Wrasse (*Labrus maculatus*). × 23 diameters.

The tecta lobi optici and the upper part of the tori semicirculares are represented in outline.

Fig. 16. Transverse section through the posterior part of the fourth ventricle of a species of Gold Fish (*Cyprinus* sp. ?), to show the origin of the vagus and the tuberculum impar. × 23 diameters.

Fig. 17. A section through one of the ridges of the wing of the valvula cerebelli from a *Mormyrus oxyrhynchus.* × 450 diameters. The molecular layer of the twin ridge is seen in close contact, the only separation being by a process from the pia mater. The fibrous layer on the side next the Purkinje cells is omitted, having dropped out of the section.

p.c. Purkinje cells.

Fig. 17. *a.* A Purkinje cell from the single layer. × 1140 diameters; the axis cylinder process had been broken off, and is therefore not represented.

e.f. Other Purkinje cells. × 650 diameters.

e. Taken from a part of the intermediate layer where only one row of cells is to be found. Both the axis cylinder and the protoplasmic processes are to be seen.

f. Taken from a part where the cells occur in groups.

b.c.d. Cells taken from the intermediate layer. × 1140 diameters.

g. Cells from the granular layer forming the basal portions of the wings. × 1140 diameters.

h. Section through the junction of the molecular with the intermediate layer, showing the network of fibres. × 430 diameters. *m.* indicates the side towards the molecular layer.

Fig. 18. Transverse section through the posterior end of the tuberculum impar. × 50 diameters.

a. One of larger cells of the fourth layer. × 450 diameters.

b. Another larger cell of the fourth layer. × 1140 diameters.

c. A small cell of the same layer. × 1140 diameters.

d. Two cells of the first layer taken from the posterior end of the tuberculum impar. × 1140 diameters.

e. Cells from the anterior part of the same layer. × 1140 diameters.

f. Largest sized cells from the club-shaped process. × 450 diameters.

PLATE 62.

Fig. 19. Ventral surface of the brain of *H. dorsalis* twice the natural size.

Fig. 20. Side view of the brain of *Mormyops* (sp. ?) part of the skull being removed.

Fig. 1.

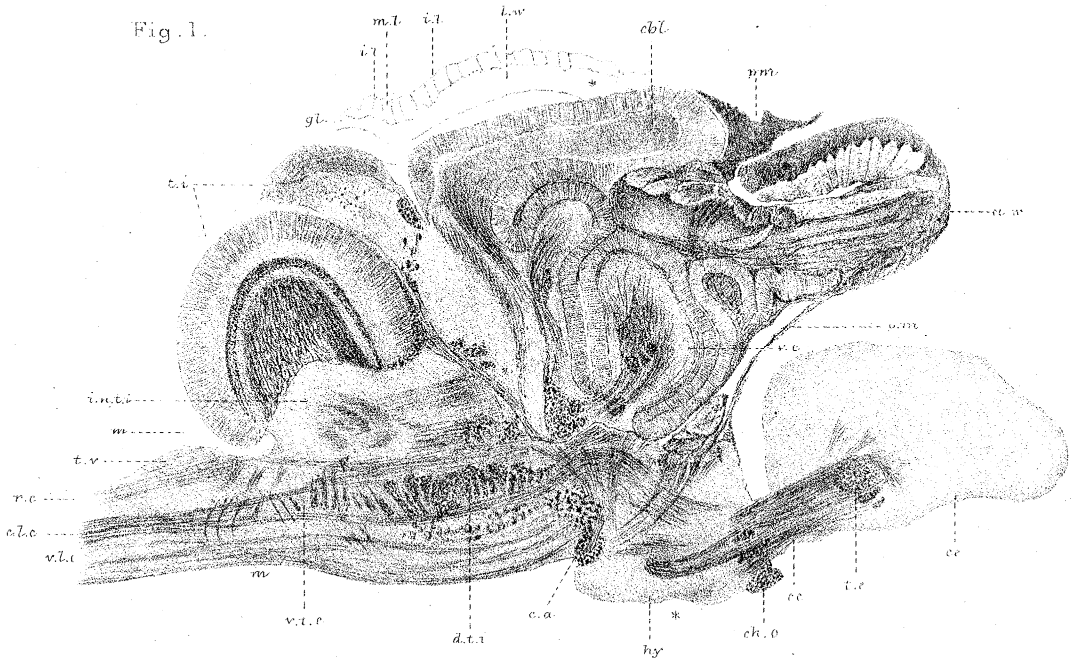


Fig. 2.

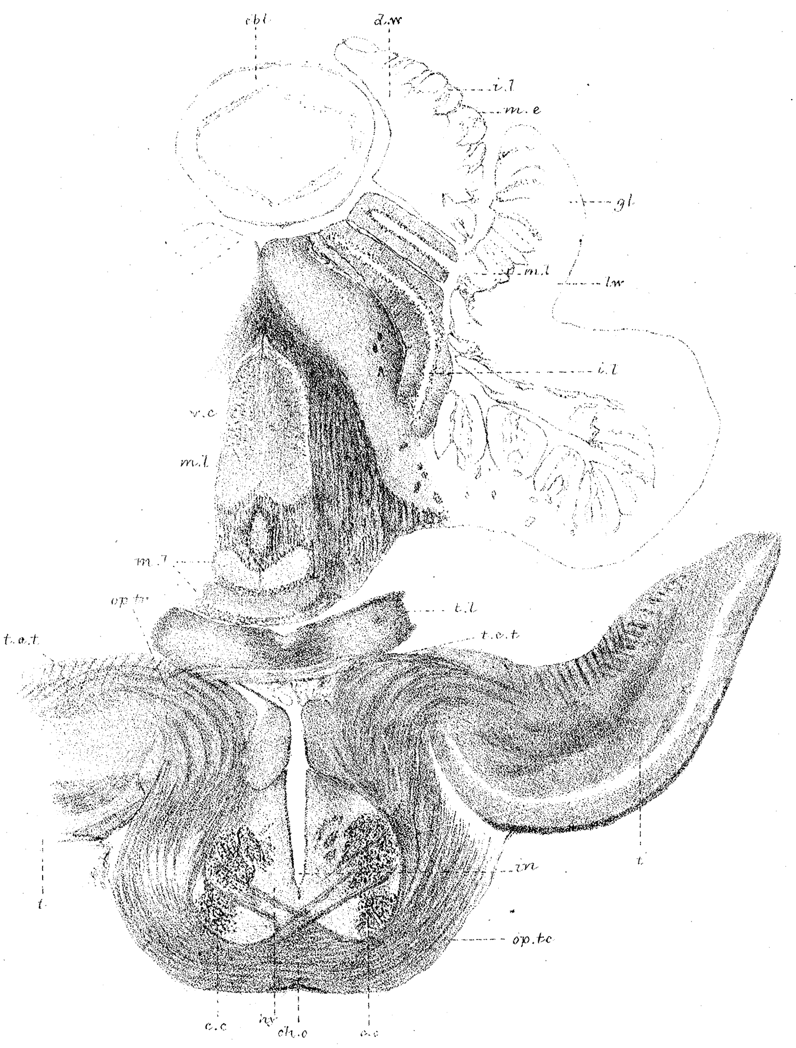
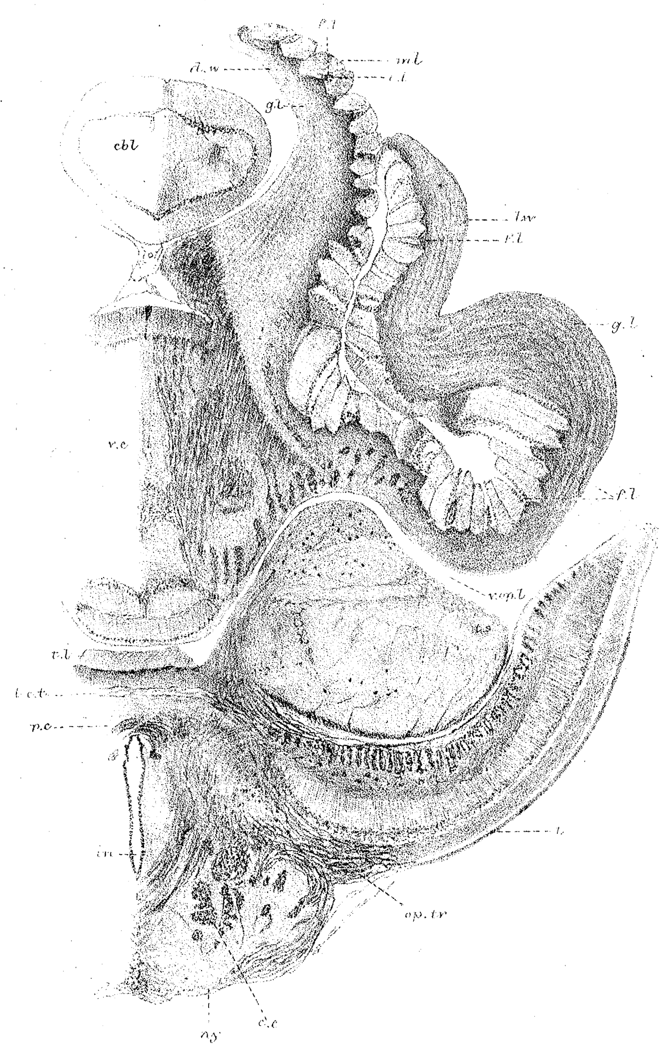


Fig. 3.



A. Sanders del.

West, Newman & Co. lith.

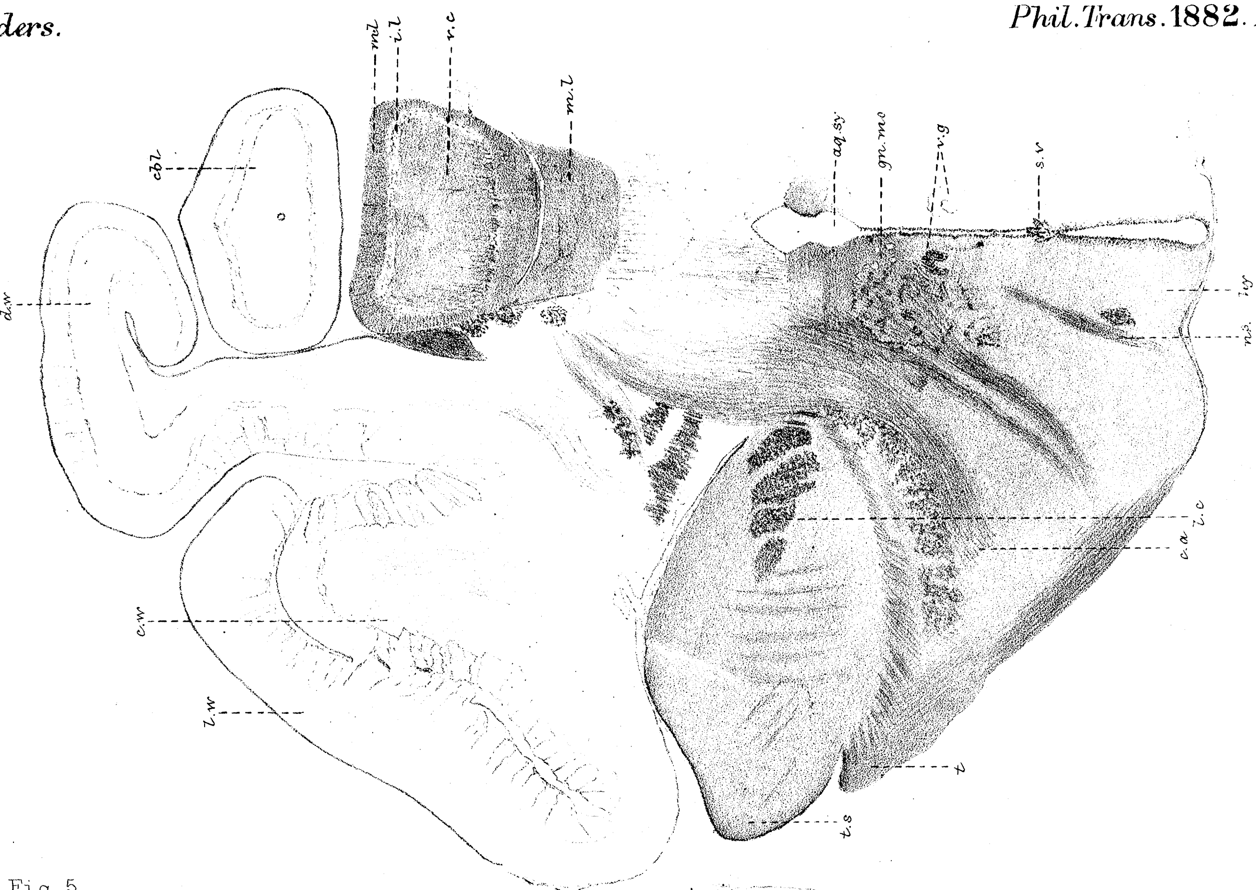


Fig. 4.

Fig. 5.

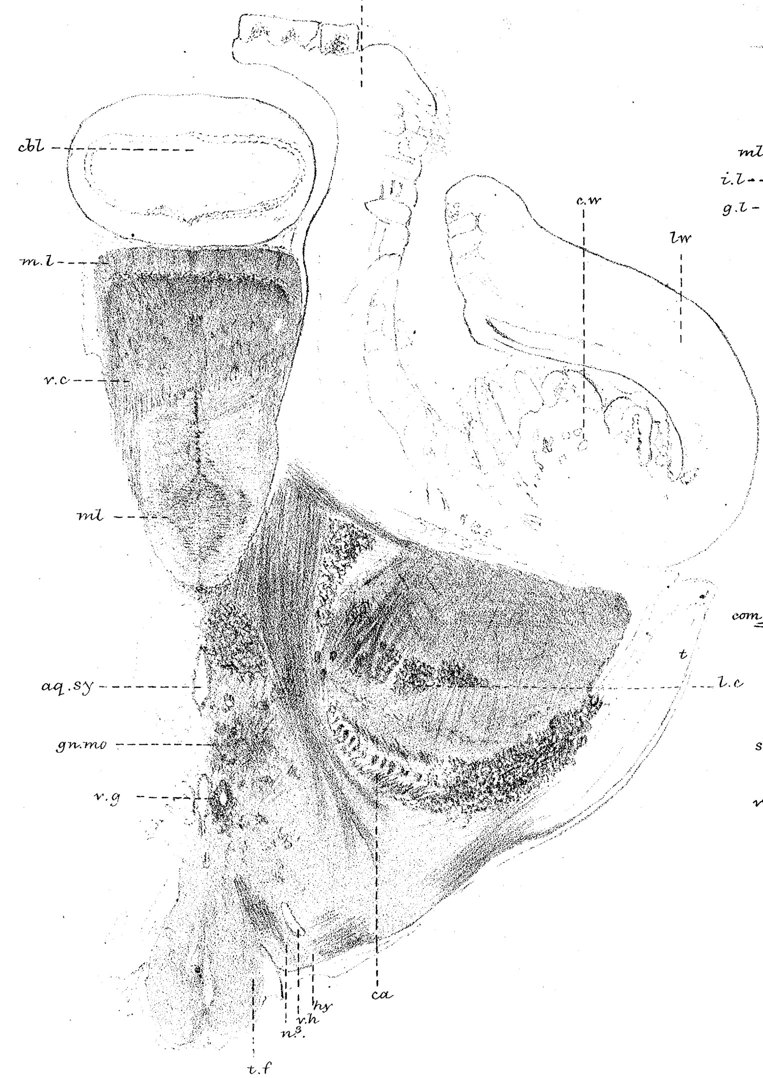


Fig. 6.

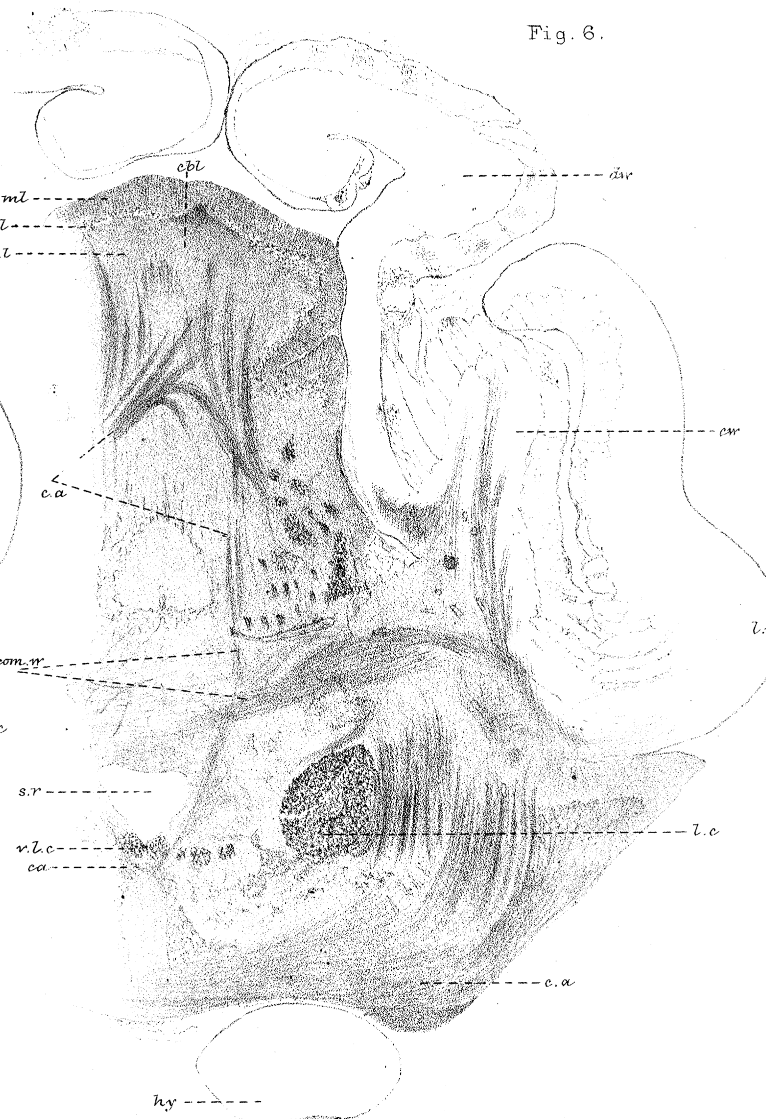
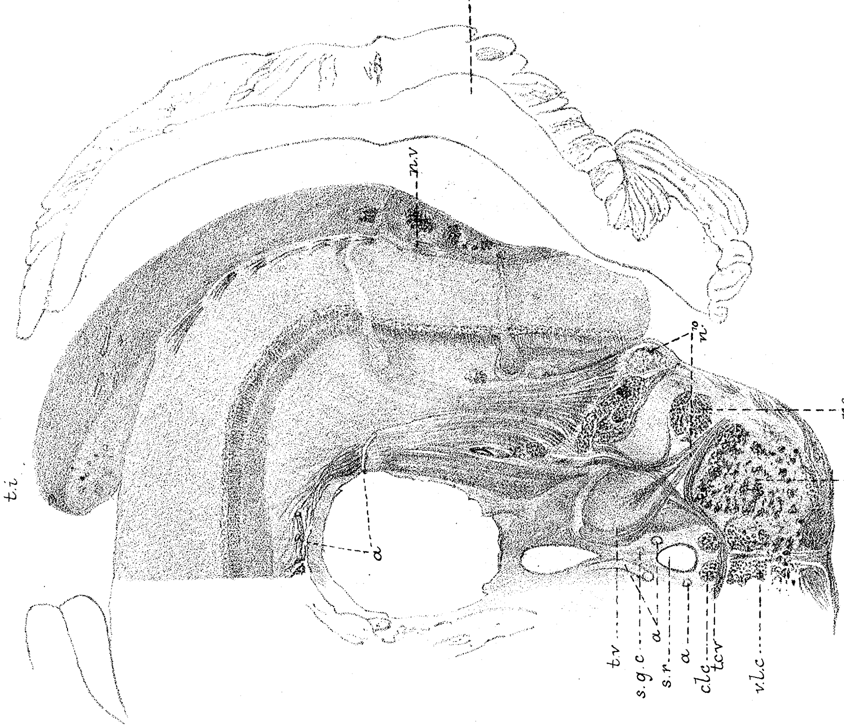


Fig. 8.


p.w
n.v
n°
r.c
l.c
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a
t.v
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a
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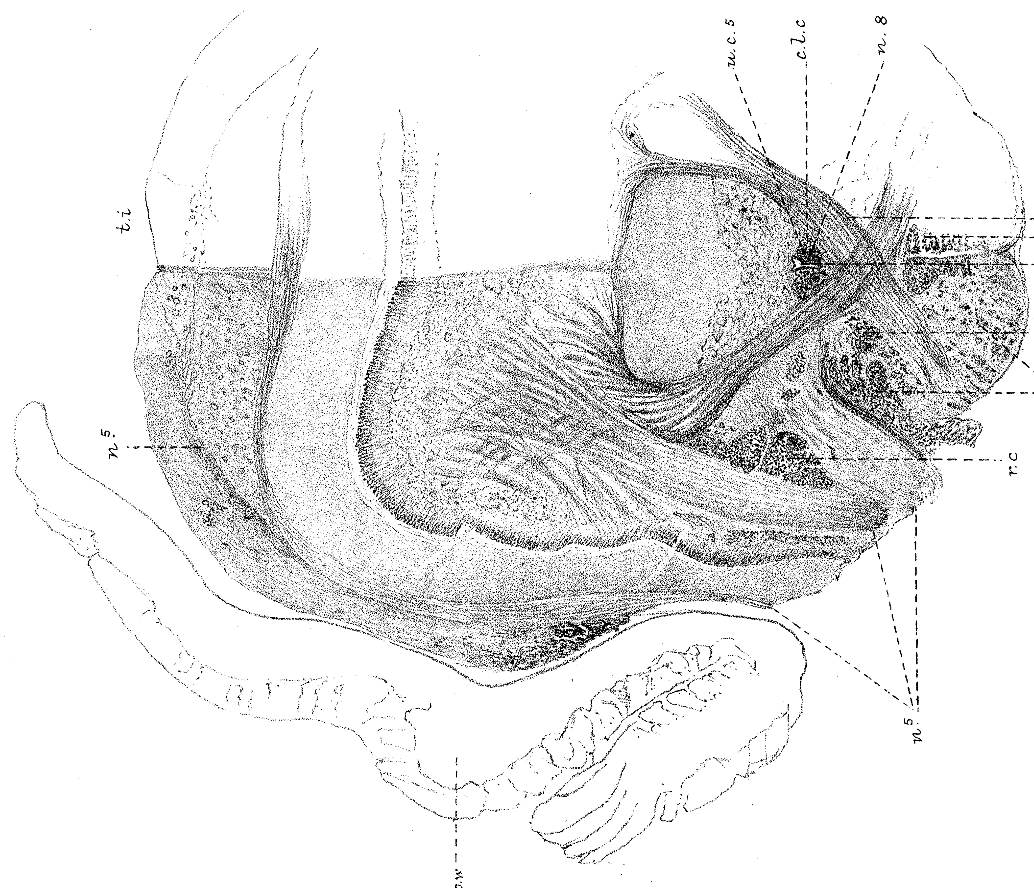
v.l.c

Fig. 7.


t.i
u.c.5
c.l.c
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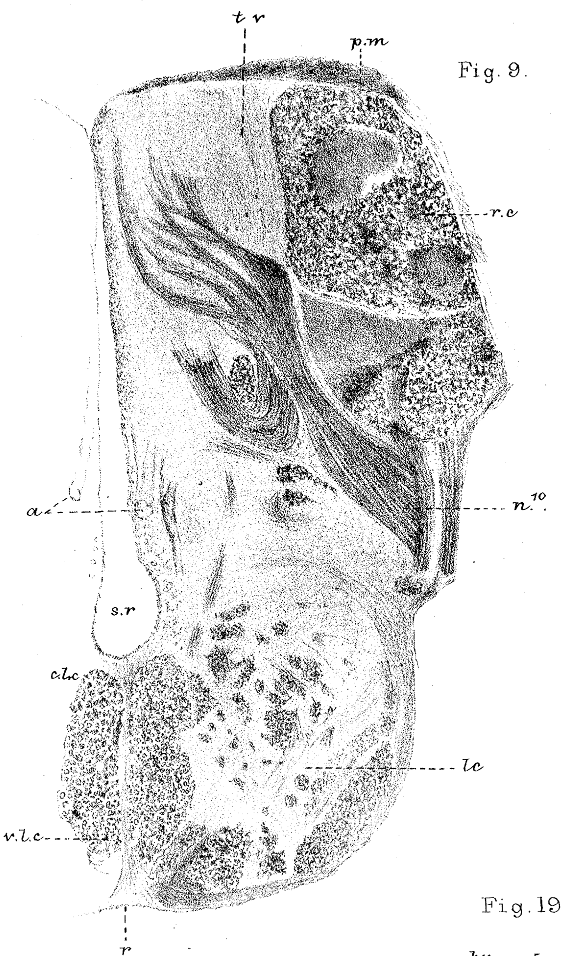
l.c.5
l.c
r.c
n5
n5
p.w

Fig. 9.



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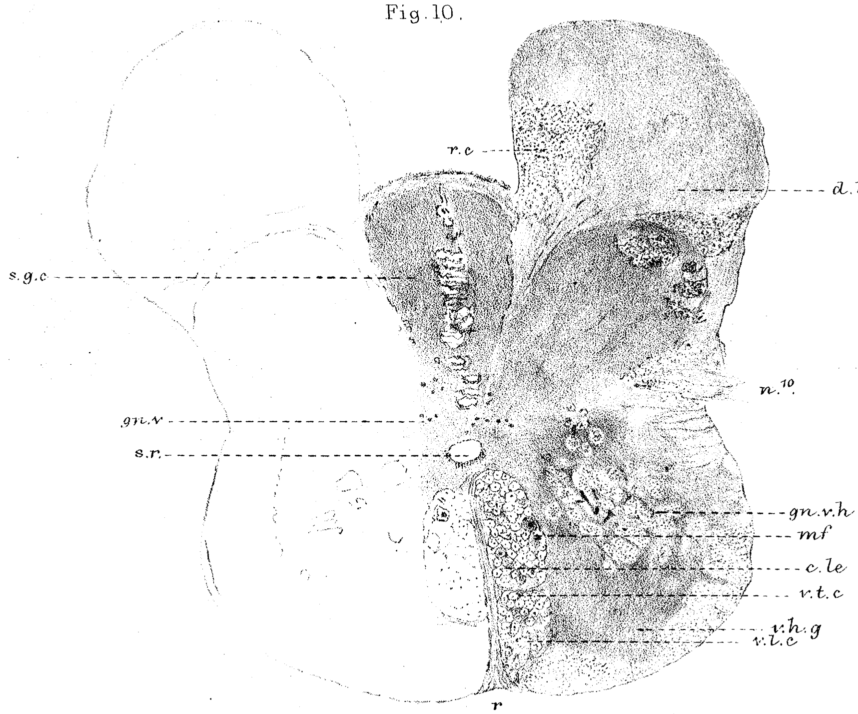

Fig. 19.

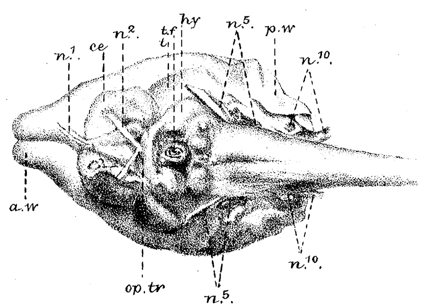

Fig. 20.

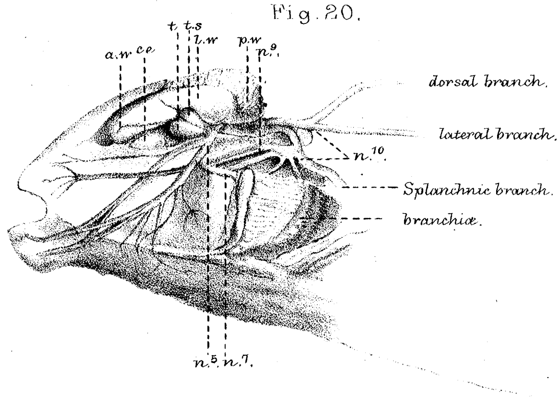

Fig. 11.

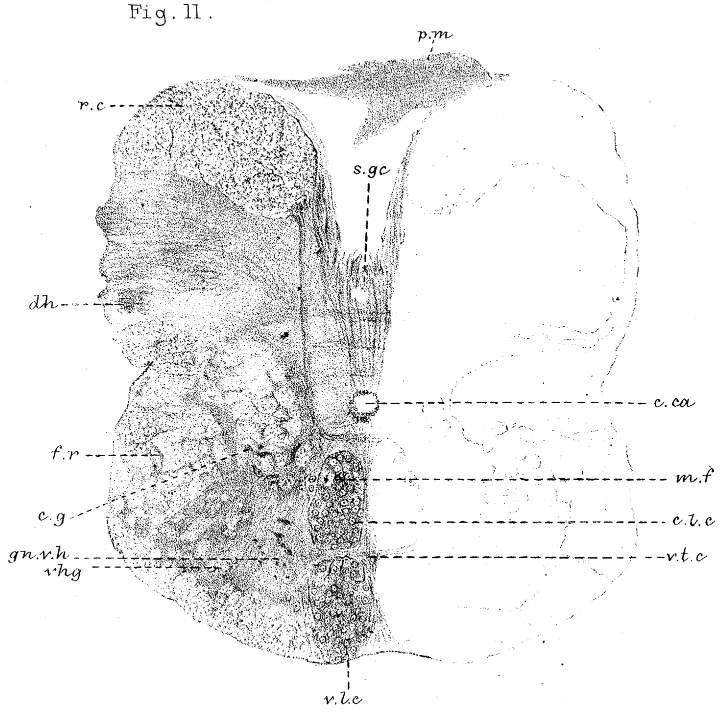

Fig. 12.

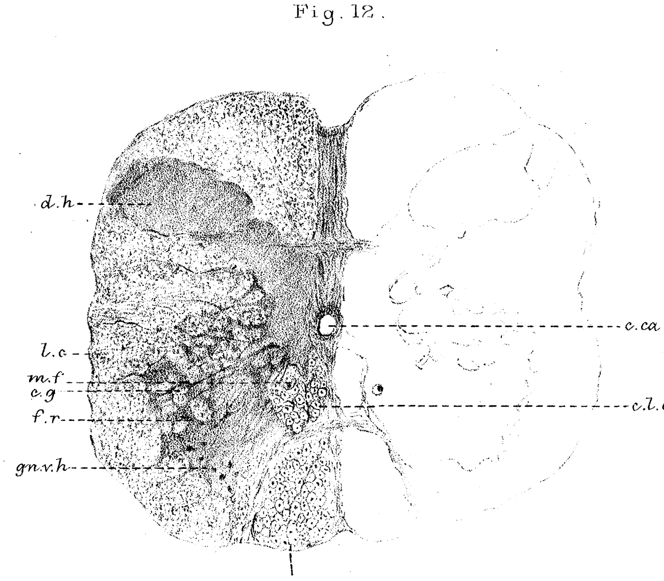

Fig. 15.

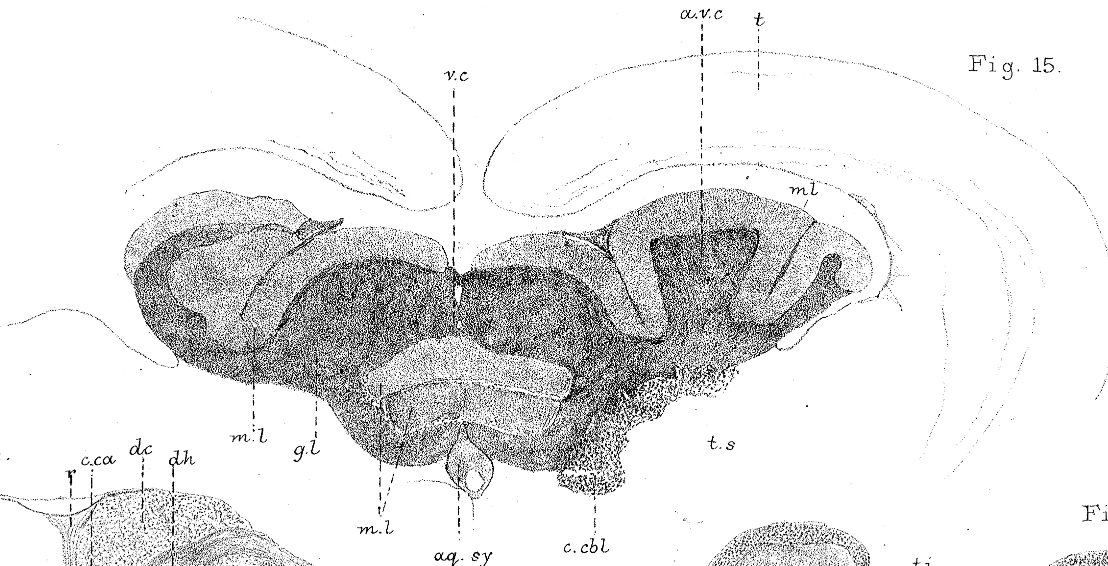

Fig. 14.

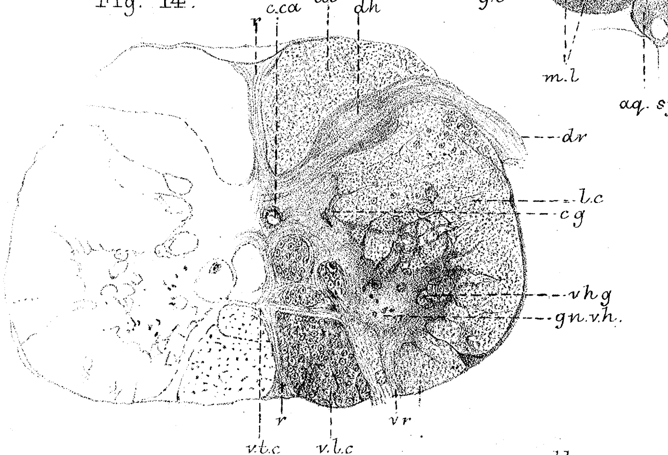

Fig. 16

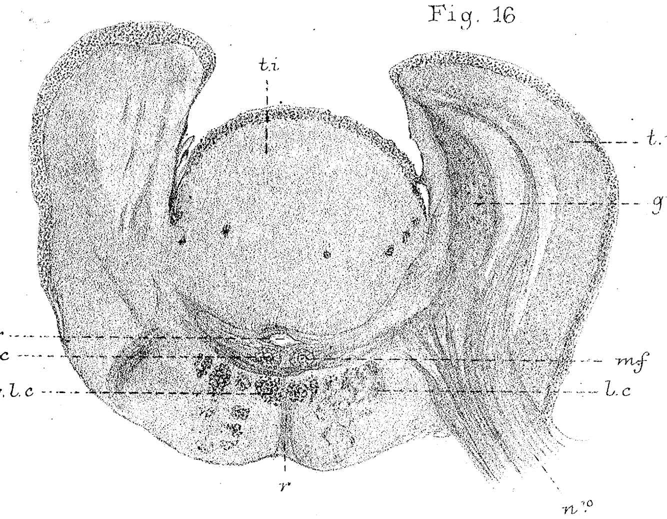

Fig. 13.

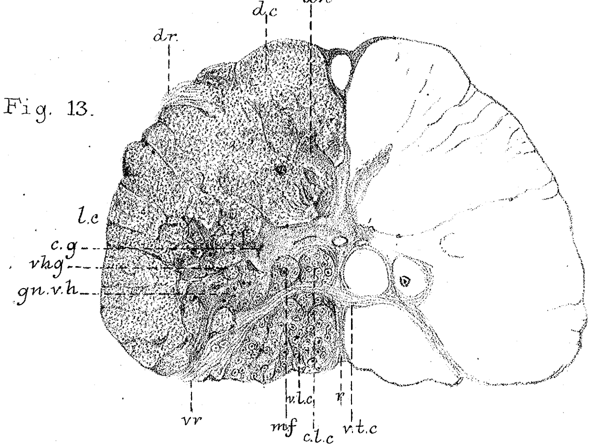

Fig. 17.

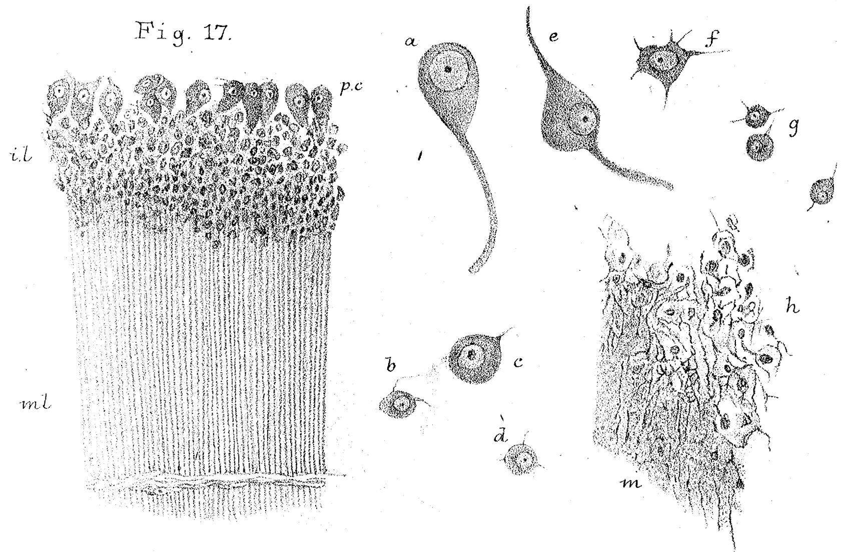

Fig. 18.