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

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Communicated by Dr. Günther, *F.R.S.*

[Plates 38—41.]

Part I.—Ichthyopsida. Section I.—Pisces. Subsection II.—Plagiostomata.

Introduction.

Among the numerous writers who have turned their attention to the nervous system of Fishes, a list of whom comprises most of the great anatomists of the present and past century, nearly all have confined their investigations to the brain of the Teleostei, to which their attention was almost exclusively directed, and only to a small extent was the nervous system of the Plagiostomata referred to. The names of these writers were given in the first of this series of papers.* Busch † was the first who devoted a treatise entirely to the nervous system of the Plagiostomata, with which he combined the Ganoids. Written in Latin, this is a plain and, upon the whole, accurate description of the external or macroscopic appearance of the brain of the Plagiostomata and Ganoids.

Miklucho-Maclay's ‡ contribution, also macroscopic, appeared in 1870. In it he propounded an entirely new theory as to the arrangement of the various parts of the central nervous system. I have made some remarks on this in a former paper; suffice it here to mention that he describes as the thalamencephalon ("Zwischenhirn") that part of the brain which the majority of anatomists consider to be the optic lobe, and the lobe which almost unanimously has been described as the cerebellum he maintains to be the mesencephalon, while he restricts the term hind brain to the small posterior and inferior tuberosity of the cerebellum.

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* 'Phil. Trans.' (vol. 169, pp. 769—772), 1878, part ii.

† "De Selachiorum et Ganoideorum Encephalo." Berolini, 1848.

‡ "Beiträge zur vergleichende Neurologie der Wirbelthiere." Leipzig, 1870.

The next writer, VIAULT,* turned his attention principally to the microscopic features of the brain of these animals; he was almost the first to do so exclusively to the Plagiostomata. In a general way he was preceded by STIEDA † in the Teleostei, but the investigations of this writer in the Plagiostomata were confined to the spinal cord only.

LEYDIG ‡ had long previously conducted researches into the microscopic anatomy of the Plagiostomata, but they were principally restricted to other organs of the body and were very slightly turned to the brain, in which, however, he succeeded in making a noteworthy discovery.

VIAULT'S treatise, although very voluminous, contains no new facts, and the illustrations leave much to be desired, being stiff and apparently semi-diagrammatic. He did not neglect homology, and refuted MIKLUCHO-MACLAY on one side and ROHON and FRITSCH, in advance, on the other; against the former he asserted the claim of the cerebellum to that name, and also showed how the optic lobes could not be the cerebrum, but were homologous with the corpora bigemina ("tubercules jumeaux"), and therefore belonged to the mesencephalon. The hypoarium he identified with the tuber cinereum.

This writer, then, has adopted the ordinary interpretation of the various segments of the brain in these animals; far otherwise is it with ROHON. § It seems as if the more recent German anatomists were unable to put pen to paper without trying to suggest some new and more or less untenable views. With regard to the cerebrum and the cerebellum he agrees with the majority of the older writers, but in the battle-ground of homology—the optic lobes—he publishes some new views. He considers these lobes not as the mesencephalon alone but as a combination of the mesencephalon with the thalamencephalon; he remarks that this segment of the brain considered histologically consists of two completely differentiated masses, although macroscopically they appear intimately united. The first mass, "Zwischenhirn," according to him, consists of a dorsal part which begins over the posterior part of the "regio ventriculi tertii," and lies as a cover upon the "Mittelhirn," and, further, of a ventral part, which is formed from the infundibulum and lobi infundibuli and their ventricles. Between and behind these two masses the Mittelhirn is inserted. This consists of the roof of the aqueduct of Sylvius (on which the dorsal part of the "Zwischenhirn" is applied), the floor of the same, and the nervous substance beneath.

These authors complete the list of those whom I have been able to discover whose work has been confined to the elucidation of the central nervous system of the Plagiostomata.

* "Recherches histologiques sur la structure des centres nerveux des Plagiostomes." 'Archives Zool. Expér.,' vol. 5, 1876.

† "Ueber den Bau des Rückenmarks der Rochen u. d. Haie." 'Zeitschr. Wissensch. Zool.,' vol. 23, 1873.

‡ "Beiträge zur Mic. Anat. u. Entwickelungsgeschichte d. Rochen u. Haie." Leipzig, 1852.

§ "Das Centralorgan des Nervensystems der Selachier." 'Wien, Akad. Denkschr.,' vol. 38, 1878 (Abthg. 2), p. 96.

Macroscopic Anatomy.

The species which have been investigated for the purposes of this essay are *Raja batis* and *clavata, Rhina squatina, Scyllium catulus* and *canicula,* and *Acanthias vulgaris.*

As the object of this paper is principally the microscopic anatomy, and only in a subordinate way is it devoted to the macroscopic appearance, a short description only of the external aspect of the brain will suffice, especially as good figures of many species are given in the works of ROHON and MIKLUCHO-MACLAY.

The Rays are distinguished by the greater solidity and size of the central nervous system, particularly of the cerebellum. The ventricles are nearly obliterated, while in Acanthias, on the other hand, the ventricles are of great size and have comparatively thin walls, so that the brain has a deceptive appearance of great size. In the Rays the olfactory lobe is attached to the anterior external angle of the cerebrum by a peduncle, which becomes longer as the size, and presumably the age, of the animal increases. In Scyllium and Acanthias the corresponding peduncle is short, and the olfactory lobe is nearly sessile and projects but a short distance in front of the anterior end of the cerebrum; in the former of these two species the olfactory lobe is of large size, almost equalling the cerebrum itself, while in Acanthias and Rhina it is comparatively small, and in the latter it is connected to the hemispheres by a somewhat long but thin peduncle.

The cerebrum in Acanthias and Rhina presents both dorsally and ventrally a longitudinal furrow, which is well developed anteriorly; in Scyllium there is a dorsal furrow, but none on the ventral surface. In the Rays the surface is smooth, but in Scyllium the upper surface presents a pair of tuberosities.

The cerebrum is attached to the anterior end of the optic lobes by a gutter-shaped neck of greater or less length, the thalamencephalon, of which the nervous tissue forms the floor and sides only; the dorsal portion is covered by the pia mater, and gives access to processes from the same which form a veritable plexus choroides. The posterior edge of the thalamencephalon is marked by the attachment of the pineal gland (epiphysis) which in Scyllium is carried at the end of a long stalk, and when in position is placed in contact with the interior surface of the skull above the anterior end of the cerebrum. In Rhina the pia mater forms a vascular sac which covers over and projects above the level of the thalamencephalon.

The mesencephalon, optic lobes, or corpora bigemina are two rounded prominences placed between the thalamencephalon in front and the cerebellum behind; they are separated from each other by a median longitudinal furrow. In Scyllium they are completely covered by the anterior lobe of the cerebellum; in the Rays this lobe projects only partially, and in Acanthias and Rhina scarcely at all over these segments of the brain.

On the ventral or hæmal aspect the hypoaria or lobi infundibuli are seen. They

may be considered as an appendage to the thalamencephalon ; they are not so well developed, comparatively speaking, as in the Teleostei.   In front of them is seen the chiasma nervorum opticorum, while at their posterior end in the furrow between them and the anterior end of the medulla oblongata is situated the hypophysis cerebri or pituitary body ; this is connected with the inferior end of the infundibulum by a glandular tube.   On each side of the hypophysis cerebri is a membranous vesicle, the saccus vasculosus, which differs from the part with the same name in the Teleostei in not being glandular.   The saccus vasculosus of the Teleostei is probably included in the pituitary body in the Plagiostomata, since the posterior part has an arrangement here, corresponding to that in those fishes.   The communicating tube lies between the two lobes of the hypoaria, a position which is the same as that occupied by the sac in question in the Teleostei.   If this is the case the saccus vasculosus in Plagiostomata is a new formation, and has no homologue in the osseous fishes.

The hæmal surface of the medulla oblongata presents a shallow, longitudinal, median furrow, the anterior prolongation of a similar one in the spinal cord, which is the representative of the anterior median fissure of the higher vertebrates.

The cerebellum in Scyllium is cylindrical in its central part, but terminates anteriorly and posteriorly in pointed extremities ; its external surface is smooth, but presents in the midline a longitudinal furrow.

In the Rays, also, there is a longitudinal furrow, and several subordinate furrows give the external surface a more complicated appearance.

In Acanthias and Rhina the cerebellum is comparatively small, oval in shape, and is marked by a longitudinal furrow, which in the former is supplemented by another, placed transversely, forming the figure of a cross.

At the sides the cerebellum is connected to the medulla oblongata by the crura ad medullam ; at the point of junction where these become the restiform bodies,* and for some distance behind, some folds are developed in Scyllium, Acanthias, and Rhina. In the Rays these folds form quite a complicated arrangement.

The medulla oblongata forms a wide shallow trough, the fourth ventricle, or sinus rhomboideus, which contracts gradually behind until it becomes merged in the spinal cord at the calamus scriptorius.   In the Rays the fourth ventricle is much narrower than in the other species.   The open dorsal part is covered by a process of pia mater, which is devoid of nervous tissue, but develops tortuous folds lined by columnar epithelium, enclosing both arteries and veins, and altogether has a glandular appearance.

The spinal cord in Raja has a quadrangular section, its largest diameter being at the posterior end of medulla oblongata ; it gradually diminishes in size towards the posterior end of the body, and extends to within one inch from the extreme end of the tail.   In specimens which I have dissected I did not find the enlargement at its anterior extremity as stated in Owen's ' Anatomy of Vertebrates.'†   In Scyllium, Rhina, and Acanthias, the shape of this part is oval, and slightly depressed on the

* BUSCH, *loc. cit.*, p. 23.   † Vol. 4, p. 271.

ventral surface, on which is a longitudinal furrow, the representative of the anterior median fissure.

Apparent Origin of the Cranial Nerves.

First pair.—The olfactory nerves pass out from the anterior end of the bulbi olfactorii, and passing through the dense connective tissue partitions, are distributed on the pectinated mucous membrane of the olfactory organ; their course and terminations do not come within the scope of this work.

Second pair.—The optic nerves present a well marked chiasma which projects beyond the anterior end of the lobus infundibuli or hypoarium.

Third pair (figs. 1 and 2)—Oculomotorii—rise from the usual position on the inferior surface of the medulla oblongata. Their origins are covered here by the hypophysis cerebri, and there is a slight interval between them and the posterior end of the hypoaria. This fact seems to show that the posterior lobes of these bodies, which are well developed in the Teleostei, are not represented in the Plagiostomata.

Fourth pair—Trochleares—have also a well-defined and constant superficial origin ; they invariably emerge from a furrow between the optic lobes and the cerebellum, marking the point of demarcation between the mid-brain and the hind-brain.

Fifth pair (figs. 1, 2, and 3)—Trifacial—arise by two roots in the Rays, one the anterior from the side of the crura cerebelli, the other more dorsal from the folds of the restiform bodies ; these two join together and pass through the foramen into the orbit, and immediately join the Gasserian ganglion.

The course of the ophthalmic branch is rather peculiar ; it is derived from the upper root in the foramen, and divides into two branches, one of which passes over and the other under the external rectus muscle of the eyeball ; these, uniting again into one trunk, pass over the olfactory sac, and emerging through a passage in the cartilage go on to supply the anterior pointed angle of the body.

In Acanthias (fig. 3) the trifacial arises by one root only from the lower edge of the restiform bodies. It passes out of the skull through its own foramen, and immediately joins the Gasserian ganglion. The three usual divisions arise from this ganglion ; the superior of the three, the ophthalmic, seems here to consist almost entirely of the frontal branch, which passes horizontally through the orbit, crosses above the peduncle of the olfactory lobe, and is distributed to the skin as far as the anterior extremity of the snout. The next division, the largest of the three, emerges from the anterior end of the inferior side of the ganglion, having the origins of the recti muscles between itself and the last branch, and passes downward and forward through the deep part of the orbit to the ventral edge, where it divides into two branches ; of these the inferior supplies the region opposite to and below the foramen of the optic nerve ; the other branch passes forward beneath the peduncle of the olfactory lobe, and supplies the inferior surface of the snout behind the distribution of the frontal. The third division, the smallest of the three, arises from the inferior angle of the

ganglion, and passing directly downward supplies the integument about the angle of the mouth.

In Rhina (fig. 2) the trifacial has a corresponding origin and distribution to that in Acanthias, except that it arises by two roots.

In Scyllium (fig. 1) the arrangement of this nerve is somewhat different, it arises by a single root opposite the posterior end of the crura cerebelli ad medullam. While still within the skull it gives off two branches, each of which passes through its own separate foramen; outside these join together and pursue a course comparable to that of the ophthalmic in Acanthias and Rhina. The root, having given off these branches, passes on through another foramen, and immediately outside it forms the Gasserian ganglion, which gives off the superior maxillary branch from its distal extremity; from the proximal end of the ganglion is given off a trunk which at once divides into two branches, of which one passes beneath the trunk of the superior maxillary nerve, and piercing the floor of the orbit supplies the muscles situated beneath that part, viz., the masticatory muscles. The other branch follows the usual course of the facial; it passes obliquely backward and outward behind the spiracle to the outer margin of the body in front of the branchial chamber.

Sixth pair—Abducentes—arise near the central line of the medulla oblongata on the ventral surface by four bundles, which soon unite into a single strand on each side. AHLBORN[*] describes a small nerve in the Petromyzon, which he thinks is this nerve, but it is evidently only an unusual branch of the trifacial. If it were the abducens, Petromyzon would be an exception to all other vertebrata.

Seventh pair.—Facial.—In the Rays this is inseparably united to the under part of the upper root of the trifacial; it emerges through a separate foramen immediately in front of the ear capsule and, passing over the muscles of the jaws, supplies the cheek.

In Acanthias (fig. 3) also the facial has a separate root, which arises in close juxtaposition to the posterior side of the trifacial. It passes through a foramen separated from that of the former by a very thin plate of cartilage; it supplies the region of the spiracle. In Rhina and Scyllium this nerve is a branch from the Gasserian ganglion. ROHON [†] describes it as a branch of the acusticus, but in all specimens that have been examined by me there have been none in which the two nerves could be said to be joined either at their origins or elsewhere.

Eighth pair—Acusticus.—In all these species this is in juxtaposition to the posterior side of the facial, and arises beneath the upper root of the trifacial.

Ninth pair (fig. 3).—Glossopharyngeal.—In Acanthias this nerve arises from the side of the medulla oblongata on about the same level as the trifacial. It is a small nerve, but is quite independent of the trifacial in front and of the vagus behind; it

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[*] "Untersuchungen über das Gehirn der Petromyzonten." 'Zeitschr. f. Wissensch. Zool.,' vol. 39, 1883, p. 211.

[†] *Loc. cit.*, p. 63.

pierces the auditory apparatus obliquely, passes backward and outward through a channel in the cartilage of the skull, and supplies the first branchial arch.

In Scyllium (fig. 1) also this nerve arises independently of the vagus, but nearer to it than the corresponding one in Acanthias; it pursues a course through the auditory apparatus resembling that in Acanthias, and like it is distributed to the first branchial arch.

In the Rays it has a similar distribution, but arises beneath the anterior roots of the vagus.

In Rhina (fig. 2) this nerve has a somewhat different arrangement. It arises in connexion with the anterior side of the anterior root of the vagus, and after having passed through the chamber containing the otolithic vesicle, enters a long channel in the postero-external angle of the skull, in which it enlarges into an elongated fusiform ganglion, and continuing in the same outward and backward direction eventually divides into two branches, of which the anterior supplies the membrane bounding the gill cavity, and runs along the anterior surface of the branchia attached to it; the other supplies the anterior border of the first branchial arch and passes round its outer edge towards the pharynx.

Tenth pair (fig. 2).—Vagus.—In Rhina this nerve rises by seven roots. The two anterior roots are thickest; they arise close together and join immediately. The third root, which was only found on one side, comes out close behind the posterior of these. Then follows an interval, after which occur three fine roots, which immediately join together to form a single fine cord, which after a short course joins the third root in the foramen of exit ; so that the nerve emerges from the skull in two divisions, which close outside and, under cover of the projecting process containing the glosso-pharyngeal, develop a large ganglion. Close outside the foramen a large branch, which appears as a continuation of the two anterior roots, is given off from the outer edge of the proximal end of the ganglion, and passing outward and backward, bifurcates at the edge of the branchial arches ; one branch goes along the posterior border of the first and the other to the anterior border of the second branchial arch.

The ganglion at its distal end divides into three branches ; the outer of these passes backward and divides into two nerves, which are distributed in the same manner as the last, one going to the posterior border of the second, and the other to the anterior edge of the third branchial arch. The middle one of the three terminal branches of the ganglion is the largest, and passes backward to form the ramus intestinalis of the vagus ; before entering the abdominal cavity it gives rise to a branch, which goes towards the outside and, dividing into two, supplies the posterior border of the third branchial arch and the anterior border of the fourth, precisely in the same manner as the others. The ramus intestinalis gives off another branch beyond, but this I failed to trace to the posterior border of the fourth branchial arch, which it probably supplies. The remaining division of the ganglion passes down the back between the muscles and forms the ramus lateralis.

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This arrangement corresponds to that described by GEGENBAUR* in Hexanchus, although there is a slight difference in detail in the distal distribution. In Hexanchus there appear to be a greater number of branchial arches, so there are a greater number of these rami branchiales. Moreover, the third branch, the ramus pharyngeus, seems to be absent in Rhina, as I did not find it.

In Scyllium (fig. 1) this nerve arises by six roots, which are placed close together with no interval between; the most anterior of these roots is the largest and folds over the others, forming nearly half the nerve. After passing through the foramen the nerve develops an elongated ganglion, from which four branches are given off, corresponding to those in Rhina. In the distal arrangement, however, the rami branchiales differ in not bifurcating; but each branch goes direct into the base of the posterior gill of its respective branchial arch, so that they are represented solely by the rami pharyngei; in other respects the distribution in both species is alike. Acanthias differs from the other species in this that the vagus, instead of arising by several small roots, arises by one large one placed some distance behind the origin of the glosso-pharyngeal.

Eleventh pair.—The hypoglossal does not appear to be present in any of the specimens examined by me.

The spinal nerves have the usual dorsal and ventral roots; in the Rays only do they present any peculiarity, the anterior nerves, to the number of seventeen or more, come off close together in a small space beyond the skull. This arrangement, of course, has reference to the largely developed lateral fins, which they supply; they are much larger in size and closer together than in the other species examined.

The Central Cavities.

The central cavities, canals, and ventricles are lined throughout by a layer of endothelium, which is also termed ependyma by some writers.

The shape of the central canal in the spinal cord (figs. 6, 7, and 8) varies somewhat in Scyllium, but usually it is oval in section with the long axis placed transversely; the transition to the fourth ventricle is indicated by a deficiency of the endothelium on the dorsal edge of the canal. The lumen gradually enlarges, in some cases becoming triangular or in others lozenge-shaped, the upper angle gradually extending to the dorsal surface, so that the canal at last becomes open at the top, forming the calamus scriptorius. There is often found a small quantity of granular material in the canal, which presents the appearance of being a coagulation; it corresponds to the rod occasionally found in the central canal in the Teleostei, and shows perhaps that the cerebro-spinal fluid coagulates more firmly in the latter than in the former.

The fourth ventricle (figs. 9, 10, 11, 12, and 13) is a broad shallow trough, extending from the calamus scriptorius to the anterior end of the crura cerebelli ad medullam,

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* " Ueber die Kopfnerven von Hexanchus." 'Jenaische Zeitschrift,' vol. 6, 1871, p. 524.

where it passes into the aqueduct of Sylvius. The anterior end is continuous directly with the posterior extremity of the ventricle, the widest part being immediately behind the crura cerebelli ad medullam, thus differing from the arrangement in the Teleostei, in which the anterior end forms a distinct chamber beneath the cerebellum, communicating with the posterior part by a narrow passage. Behind the cerebellum the fourth ventricle is covered by the processes of the pia mater. BUSCH[*] terms it the arachnoid, but adds that it differs essentially from the arachnoid of the human brain, inasmuch as it abounds in numerous vessels. He speaks of a third membrane as the pia mater dipping into all the cavities. It does not appear from my dissections to be different, but both seem to be the same membrane.

The walls of the fourth ventricle (figs 1, 2, 3, and 5) are formed on each side by an elongated and anteriorly-folded ridge which becomes merged into the lateral parts of the cerebellum. These may be looked upon as the restiform bodies. On the floor (figs. 1 and 5) may be seen two longitudinal cylindrical prominences separated by a furrow occupying the central line ; these are the funiculi teretes. They indicate the position of the ventral longitudinal columns, which may be considered to correspond to the anterior pyramids. BUSCH [†] also considered them to be so, but in the figure he makes them extend as visible protuberances quite up to the posterior commissure, an arrangement which was not found in my specimens, although they are traceable thus far, but are not apparent on the surface. Laterally the floor is occupied by a row of hemispherical beadlike tubercles, which form the origins for the roots of the vagus. Immediately behind the crura cerebelli ad medullam the funiculi teretes disappear, and the place of each is taken by a shallow longitudinal trough, the external margin of which corresponds to the external limit of the ventral longitudinal column. Towards the anterior end of the crura a deep furrow appears in the central line of the floor of the ventricle ; it extends into the aqueduct of Sylvius and gradually deepens until it joins the third ventricle. In the optic lobe the aqueduct of Sylvius becomes somewhat enlarged and forms a ventricle of a concavo-convex form, the concavity being directed upward ; near to its anterior end a passage, the continuation of the furrow on the floor above mentioned, leads into the third ventricle beneath the posterior commissure.

The third ventricle, or thalamencephalon, is not closed in superiorly by nervous tissue, but gives entrance to processes from the pia mater which intrude through its roof to form the choroid plexus. It communicates by a gutter-shaped passage with the ventricle of the cerebrum, which ventricle at the posterior end is single, the foramen of MONRO, but at the anterior end becomes double, the lateral ventricles ; each lateral ventricle communicates by a small round foramen with a passage leading into the peduncle of the olfactory lobe ; this passage passes forward in the tuberosity situated on the outer side of the cerebrum, close to the outer wall, and soon becomes a mere slit, which enlarges when the peduncle is free of the cerebrum, and takes on a

[*] *Op. cit.*, p. 20, tab. iii., fig. 8.

[†] *Op. cit.*, p. 23.

rounded form; it penetrates only a short distance into the posterior end of the olfactory lobe so that the ventricle of this is but small.

Prof. BURT. G. WILDER* gives a different interpretation to these facts. He considers that the ventricles in the olfactory lobes are the true lateral ventricles, that the apertures by which they communicate with the ventricles of the cerebrum are the foramina of MONRO, and that the walls of the cerebrum are what he proposes to call the "prothalami," connected by the crura thalami with the optic lobes, and that the ventricles which they contain are simply the forward continuation of the third ventricle. There are many objections to this mode of interpretation; the ventricles in the cerebrum and their continuation backward into the third ventricle fulfil all the requirements of the case; but principally the structure of the olfactory lobes would forbid their being interpreted as cerebral hemispheres, which would have to be the case if their cavities were to be looked upon as lateral ventricles.

The third ventricle extends inferiorly into the ventricles of the hypoaria, which in the species under consideration, viz., Scyllium, is broad from side to side, and narrow from above downward; posteriorly it ends in two lateral pouches, between which, in the midline, is a communication with a cavity in the interior of the hypophysis cerebri, which cavity is lined by a continuation of the endothelium lining the ventricle of the hypoarium.

The arrangement in Rhina and Acanthias resembles that of Scyllium, but in the former all the cavities are more extensive. On the other hand, in the Rays all the ventricles are smaller and more contracted; the fourth ventricle is a comparatively narrow deep fissure, the ventricle of the optic lobe is a small triangular enlargement of the aqueduct of Sylvius, and communicates by a narrow passage with the third ventricle. The lateral ventricles are non-existent, only a single very small cavity extending for rather less than one quarter of its length into the parenchyma of the posterior inferior margin of the cerebrum remains as the representative of the foramen of MONRO (fig. 18).

Microscopic Anatomy of the Brain.
Lobi Olfactorii.

The olfactory lobe may be looked upon as consisting of two parts, the lobe proper and the peduncle, but this classification is merely superficial, as in structure they pass gradually into each other. The lobe itself is more or less pear-shaped, broader at the anterior end, where it abuts on to the olfactory organ, and narrower behind, where it is attached to the peduncle.

The olfactory lobe may be described as consisting of three layers placed one in front of the other. The internal, which is also the posterior layer, occupies more than half of the lobe at the posterior extremity, and consists entirely of a mass of small cells embedded in a network of fibrillæ and granular neuroglia. In front of these is seen

* 'Philadelphia, Acad. Nat. Sci. Proc.,' 1876.

the middle layer which consists of glomeruli olfactorii. These occupy all the anterior side of the mass of small cells, and extend a short distance both above and below along the sides ; the posterior contour of this middle layer is not however regular, but is rather concavo-convex in outline.

The glomeruli olfactorii (fig. 23) were first discovered by LEYDIG.* He gives a figure which differs considerably from mine, and shows only granular neuroglia and no fibrillæ ; at one end is a compact bundle of unseparated fibres going to the olfactory organ, at the other end a group of uncleated cells attached to the glomerulus by fibrils. The difference in the mode of treatment usual at that time would account probably for the non-separation of the fibrillar network.

The anterior layer consists of interlacing bundles of fibres passing from the anterior end of the glomeruli in a more or less curved course to the connective tissue framework which supports the follicles of the olfactory organ.

The most conspicuous difference to be observed in this lobe, as compared with the corresponding part in the Teleostei, is the much higher development of the glomeruli, which in the osseous fishes are represented by merely an undifferentiated mass of neuroglia.

The peduncle has also three layers. The interior is occupied by a layer of small cells which surround the lumen of the peduncular passage. Outside these is a stratum of glomeruli which extends round the internal layer on all sides, except one very small gap. They are placed thicker at the anterior end of the peduncle, and gradually thin out on approaching the cerebrum ; they cease entirely within one section from that body. The outer circumference of the peduncle is occupied by the fibres derived from these glomeruli, which also become more numerous, and occupy a larger space on proceeding more forward.

The description above given is taken from specimens of Scyllium ; in the other species examined essentially the same disposition of the layers is found.

We now go more particularly into the minute structure (fig. 23), commencing with the third or internal layer. This layer is composed of a granular neuroglia, in which ramify fibrillæ of extreme tenuity forming an extensive network. In this are embedded numerous small cells ; these are oval, pear-shaped, or spherical, and in many cases show a nucleus and nucleolus ; they give off processes which join the network. In Scyllium and Acanthias they are of about the same size. The larger ones measure about 9μ long by 7μ broad ; from these to the smaller ones of 5μ there is every variety of dimensions. In the Rays also they are of about this size. In Rhina are a trifle larger, varying from 13μ by 8μ to 8μ in diameter. Cells of these different sizes are seen scattered thickly throughout the layer.

The glomeruli (fig. 23) are elongated pear-shaped or oval masses arranged generally with their long axes in the direction of the nerve fibres ; that is to say, one end is turned toward the internal and the other toward the first or external layer. They

* 'Beiträge z. Mikr. Anatomie u. Entwickelungsgeschichte d. Rochen u. Haie,' Leipzig, 1852.

consist of a central core of granular material, which in fortunate preparations is seen to be composed of closely intertwined fibrillæ of very fine dimensions; externally fibrils of a larger size are to be observed running parallel to the long axis of the glomerulus, in the course of which elongated cells are developed. These fibrils occupy the outside of and the space between the glomeruli; they converge towards the outer or anterior end of these bodies, and go to form a flat bundle of fibrils emerging from that end of the glomerulus; at the inner extremity a fibrillar network, a continuation of the central core, connects these structures with the internal or third layer.

The course of the fibrillæ would seem to be from the cells occupying the internal layer into the centre of the glomeruli, where they form a much closer network; then by some means not quite apparent they would seem to join the fibrils, enveloping the exterior surface of those bodies to form the bundles which pass out to join the nerves which supply the Schneiderian membrane.

In Scyllium the cells which occur in the course of the external fibrils of the glomeruli are rather larger than in the other species, and the cells of the internal layer which are found in the neighbourhood of the glomeruli are larger (18μ by 14μ) than those in the interior of the internal layer, which is not the case in the other species. With this exception the above account applies equally to all the species investigated.

The ventricle of this lobe is lined by an endothelium, consisting of a single layer of cells; this is a continuation forward of the layer which lines the other ventricles of the brain and the central canal of the spinal cord.

The structure of the peduncle gradually merges into that of the cerebrum without any distinct or obvious line of demarcation; neither are there to be seen any bundles of fibres or any crura connecting the one with the other.

Cerebrum.

On examining a transverse section through the cerebrum of Rhina, it will be observed that externally beneath the pia mater the cerebral parenchyma is composed almost entirely of a granular neuroglia, through which a few small cells are sparsely dispersed; these measure generally from 7μ to 8μ in length and from 5μ to 7μ in width; they give off processes which join the network of fibrillæ which pervades the neuroglia. This layer occupies about one-sixth of the whole thickness of the cerebrum between the external surface and the lateral ventricle. Many capillaries penetrate the brain from the pia mater through this part.

Internal to this layer the whole extent of the remaining five-sixths of the cerebral wall is occupied by a mass of cells; these, in addition to cells more or less spherical or oval, resembling those in the outer layer in size and appearance, consist of a great number of larger cells, measuring from 10μ to 12μ in diameter, together with others more or less oval in shape and measuring from 13μ to 8μ in long diameter and from

8μ to 6μ broad. Towards the internal surface the smaller cells again predominate in number and are more scattered than in the central portions occupied by the larger cells, but are yet closer together and more numerous than in the outer layer. The ventricles are lined by an endothelium composed of a single layer of columnar cells.

In Scyllium the cells of the inner layer appear to average a smaller size than in Rhina, being from 5μ to 6μ in diameter, the smaller ones predominating; they are arranged in elongated groups parallel to the endothelium. The fibrillæ have principally a tendency to a radial direction. On the outer side the cells are more sparingly distributed, they are generally about 7μ in diameter; in the central portions some cells have a tendency to be arranged in groups of four or five; sometimes so many as nine occur in one cluster, but these are of the smaller kind. Large cells resembling those of Rhina are not so numerous as in that species; they usually occur singly, and measure about 10μ or 11μ; some of them are elongated or pear-shaped. The neuroglia is of the same nature as in Rhina.

In Acanthias the parenchyma of the cerebrum resembles that of Rhina. On the outer side there is the usual space of granular neuroglia and network of fibrillæ, in which very small cells are scattered. Then comes the layer of cells of greater size, which are generally more elongated than in Rhina; their dimensions vary from 14μ to 7μ in length and from 10μ to 6μ in width. Towards the inner surface smaller cells predominate; as a rule the cells occur singly, but small groups, consisting of two or three cells, are sometimes to be found. This brain, therefore, forms a transition between Scyllium and Rhina.

At the base of the cerebrum (fig. 19), even with or slightly above the floor of the ventricles, there are four elongated groups of the larger cells agglomerated together with little if any neuroglia between; they are placed one in each outer wall and one in each inner wall, all running longitudinally; they are situated at one-third of the thickness from the outer and inner wall respectively. The remainder of the section is composed of neuroglia, with cells scattered through it resembling the arrangement at the dorsal part of the brain. In the space between the outer margin and the groups above described the neuroglia is more compact and presents a smaller number of cells, which, however, are more abundant on the side nearer the ventricles, where the neuroglia is also of a looser texture. The anterior commissure is principally derived from the outer edge of the group situated in the external wall, but some few fibres are derived from the inner edge of the same; they cross over to the opposite side of the brain and bear the same relation to the group on the other side.

This commissure, which I think must homologize with the anterior commissure of mammalia, appears to correspond to what BELLONCI[*] terms the olfactory commissure in *Anguilla vulgaris*; but in these fishes there are no visible bundles connecting it with the olfactory lobe.

[*] "Intorno alla struttura e alle connessioni dei Lobi Olfattorii, &c. 'Roma, R. Accad. Lincei Mem.,' vol. 13, 1882.

The crura cerebri are derived from both edges of the groups situated in the inner wall, the two origins being more equal than is the case with the anterior commissure. The nucleus in each half of the cerebrum gives out a separate column, which goes to form the crus of its own side, and has no communication with that of the opposite side.

The anterior commissure is confined to the ventral region of the cerebrum, and is not found above the level of the nuclei above described. A third bundle of fibres is mentioned by ROHON * as descending from the dorsal and middle cerebral regions obliquely towards the crura cerebri in Raja ; these he considered to represent the "fasciculi longitudinales tegmenti posteriores." These bundles were not found in any of my specimens.

In the Rays there is no continuous belt of neuroglia existing round the circumference ; in some places, the cells extend close to the external surface, in others the neuroglia is deficient in cells. In the interior of the cerebrum the cells are arranged still more decidedly in groups than in Scyllium ; there are a larger number of cells collected together, generally from nine to twenty-one, but the individual cells are smaller, not exceeding 4 μ or 5 μ, and most of them are spherical. These clusters are separated from each other by small masses of neuroglia, and in some parts they are in contact forming an irregular network. At the base of the cerebrum there is a continuous stratum of cells which follows the curve of the posterior margin. These correspond to the groups described in Acanthias, and, as in that species, the crura cerebri are in relation to them, and pass through the posterior end of the group.

Hypoaria.

In Rhina the parenchyma of the hypoaria consists of an irregular network of minute fibrillæ, resembling that found in the corresponding parts in the Teleostei. In this parenchyma numerous cells are scattered irregularly throughout the mass ; they are of various shapes, spherical, pyriform, oval, or fusiform ; they give off one, or more, generally several processes, which join the above mentioned network ; they differ in size from 13μ by 7μ to 6μ in diameter. They are not so regularly pear-shaped as in the Teleostei, neither do they present a distinct chamber or space surrounding them ; they also give off a greater number of processes.

The absence of a chamber surrounding the cells here, and also the presence of a greater number of processes, may possibly have been conditioned by a difference in the mode of treatment. Chromic acid was used in preparing the brains of the Teleostei, this probably caused a greater contraction of the parenchyma, and so may have broken off the processes, while at the same time it formed the space round each cell, and as the parenchyma is softer in the hypoaria, so the effect would be greater. The process followed in preparing the brains of the Plagiostomata, which was the

* Op. cit., p. 71.

same as that employed for the nervous system of Mormyridæ, avoided this contraction of the tissues.

The ventricle in Rhina is of great size, and occupies nearly the whole of the lobe, leaving only very narrow walls. This ventricle is lined by an endothelium which consists for the greater part of its extent of one layer of columnar cells, the internal end of which sends processes into the interior of the parenchyma; they are backed up by a layer one, two, or three deep of spherical cells of an endothelial nature, which sometimes project more or less into the substance of this lobe. Next to these cells is found a layer comparatively free from cells; here the general direction of the fibrillæ is longitudinal, but the direction of the processes from the endothelial cells is radial, crossing the former at right angles; the result being that this layer has a squared striation; the cells, which are occasionally present in this layer, are spherical in contour, resembling in this respect the inner cells of the endothelium. At the posterior portion, where the hypophysis cerebri is attached, the endothelium is composed of the rounded cells only, which are extended from four to seven deep; they are continuous with the endothelial cells of the hypophysis cerebri. The processes from the endothelial cells resemble those from the " Stiftzelle " of the cerebellum; they are present even when the endothelium consists only of the spherical cells, but they are not so well marked as when the columnar cells are found. In the layer of parenchyma, which is next to the endothelial lining of the ventricles, there are more cells to be found in that part where the endothelium consists of spherical cells than where it is composed of columnar cells only; which seems to show some connexion between the two kinds of cells, that is to say, between the spherical cells which go to form the endothelium, and those which are dispersed through the ventricular part of the parenchyma.

Scyllium and Acanthias resemble Rhina in the arrangement of the endothelium and parenchyma in this lobe. The cells in both these species are on an average smaller, and the smaller cells predominate.

In the Rays (fig. 18) the parenchyma is more compact, the fibrillæ form a closer network, and the cells are scattered with larger intervals between them. There are no ventricles in the hypoaria in the Rays, and consequently no endothelial layer; the shape of the cells is more generally fusiform than in the other species, and their average size is greater.

In order to conclude the description of the region of the third ventricle (fig. 18), a tuberosity may be mentioned which exists in the dorsal part of the wall of this ventricle and in front of the anterior end of the optic lobe. In it are found numerous small cells embedded in a granular neuroglia, but no ganglion cells are to be seen. A well-defined bundle of fibres proceeds from it backwards and slightly downwards, but disappears at the ventral side of the longitudinal columns. This tuberosity corresponds to the tuberculum intermedium of GOTTSCHE.* AHLBORN† describes similar structures

* MÜLLER's ' Archiv,' 1835.

† " Unters. über das Gehirn d. Petromyzonten." ' Zeitschr. Wissensch, Zool.,' vol. 39, 1883.

in Petromyzon; the ganglion he looks upon as corresponding to the ganglion habenulæ, and the bundle of fibres to MEYNERT's fibres. This interpretation may possibly be correct; the relation of the parts is not antagonistic to, but rather favours this view, but the ganglion interpedunculare is not to be found in any specimens examined.

Lobi Optici.

The ventricle of the optic lobe in Scyllium (figs. 15 and 18) is partially divided into two by a longitudinal depression of the roof, corresponding internally to the external longitudinal furrow, which gives to the outer contour the appearance of a double lobe (the corpus bigeminum), an appearance which is not verified by the internal construction, the ventricle being single; in this respect the optic lobe of the Scyllium resembles the tectum lobi optici of the Teleostei. There are, however, considerable differences between the two, more especially in the macroscopic aspect. The torus longitudinalis is absent, the transverse commissure which crossed its base alone remaining; the thickness of this lobe exceeds that of the tectum actually and proportionately. On the other hand, in compensation, the structure is simplified.

The tori semicirculares, which are well developed in the bony Fishes, are wanting in the Plagiostomata, so that in the latter the floor of the ventricle is slightly concave; the furrow in the central line is common to both.

There are three layers to be made out more or less clearly in these lobes. The first or external layer contains numerous cells embedded in a granular neuroglia; they attain their maximum in this layer, but extend also into the next in diminishing numbers. Toward the outer edge a few scattered cells only are to be seen, but they gradually increase in number, and in the centre they attain their maximum. These cells are mostly spherical in shape, and measure on an average about 8μ in diameter; in addition to these, there are found in this layer, in much smaller numbers, fusiform cells placed with their long axes in a radial direction. These cells correspond in every respect with the fusiform cells which are found in the tectum lobi optici of the Teleostei. Like all the bodies here distinguished by the term cell, they have a nucleus and a nucleolus; the nucleus is not coloured so deeply as the remainder of the cell contents by the staining fluid. This shows their correspondence in structure with the cells of the cerebrum, hypoarium, and the granular and molecular layers of the cerebellum, and differentiates them from the motor cells of the spinal cord and the medulla oblongata and other ganglion cells, in which the nucleus is stained of a deeper tint than the remainder of the cell contents. They are generally broader, but not so long as those of the Teleostei; one end gives off a comparatively thick fibre going toward the inner surface of the lobe, the other end, being pointed, probably gives off a fine process, judging from the analogy with the cells in Teleostei, but if so it escaped notice from being broken off in the sections. The position of the nucleus varies, sometimes being near the pointed, at others near the broad end of the cell.

In Acanthias, cells which have a decidedly fusiform shape are rare, the greater number being oval or rhomboidal. They occur in or on the radial fibres as in Scyllium. Most of the cells, however, are spherical, and are arranged in longitudinal groups, separated by intervals of granular neuroglia, in which are found fibres from the optic tract running from before backward; but in the second layer they are divided by bundles of fibres belonging to the transverse commissure. Occasionally, but very rarely, a fusiform cell is found in the course of a longitudinal fibre. The fusiform cells are generally 20μ long by 6μ broad, from this they vary to 12μ by 7μ; they are thus larger than the corresponding cells in Scyllium. The oval or round cells are usually about 8μ by 7μ. There is a gradation between the extremely elongated cells, and those which are nearly spherical.

In Rhina (fig. 22) the fusiform cells are more numerous, they are also larger than in Acanthias. The rounded cells are also very numerous; as in the other species they give off processes to the surrounding network.

The greater scarcity of cells in the optic lobe of the Rays is compensated for by its greater thickness. The fusiform cells are very scarce, most of those present being rounded, but some oval ones occur. They are on an average smaller than those which are found in Acanthias, and about equal in size to those present in the optic lobe of Scyllium.

The second layer consists principally of bundles of transverse fibres, derived partly from the commissura ansulata, and to a small extent from the lateral columns of the medulla oblongata; these transverse fibres form many bundles, which are separated from each other by granular neuroglia, into which the rounded cells from the first layer penetrate; so that these two layers may be looked upon as overlapping each other, the cells of the first layer encroaching on to the territory of the second; thus the limits of the two divisions are not strictly defined. In this stratum there occur also cells intermediate in character between the fusiform and the spherical cells.

The third layer lies immediately internal to the endothelial lining of the ventricle; in it are found at the posterior end only some fibres which come forward from the cerebellum; they do not extend far, and are not visible at the anterior end of the lobe. The small cells from the first and second layers also penetrate into this one, and occur quite close to the endothelium at parts. In addition to these elements, large cells (fig. 22, *Dachkerne*, ROHON) occur, which are nearly equal in size to the motor cells of the ventral horns in the spinal cord, but they differ in shape and in the number of processes, and also probably in composition, since they much more easily become crumpled and lose shape. They are spherical or oval, and sometimes pear-shaped. They are provided with a conspicuous nucleus and nucleolus; the cell contents are usually smooth, or only finely granular, the nucleus has a coarser appearance, and contains large granules, and the nucleolus is seen as a large granule with a dark border and lighter centre. They generally give off one process only, or very rarely

two. Rohon * imagined that he saw several processes cut off close to many of these cells, and therefore came to the conclusion that they were multipolar cells, but such is not the case. I have examined them very minutely, and in good preparations the contour has always appeared perfectly smooth, but in preparations that have not succeeded well their outline becomes irregular, and this no doubt misled Rohon.

The single process, when only one is present, passes towards the outside, so that of the cells on each side of the mid-line each sends its process in an opposite direction; they always join the transverse commissure which constitutes the second layer. The average length of these cells is $55\,\mu$, and the width $35\,\mu$. Viault does not appear to have seen these cells, as no mention is made of them in his account of the histology of the optic lobes.†

In Scyllium these cells first appear rather suddenly as a large circular group in that part of the roof of the aqueduct of Sylvius which corresponds to the valvula cerebelli opposite the exit of the fourth nerve; in the next section in advance the number of cells grouped together is not so large, and still farther forward they spread out into a single row laterally, while still keeping more closely clustered together in the mid-line. They extend as far as the anterior end of the optic lobe, where they terminate with a few scattered cells.

In the Rays these cells commence behind also opposite the exit of the trochlearis, not, as in Scyllium, by a large group, but by a single cell on each side close to the anterior termination of the granular layer of the cerebellum. These two cells are rather isolated; in the next three sections in advance only one is to be found; in front of this they gradually increase in number until they form a layer, one or two, and, in some places, three cells in thickness, extending some distance laterally. Anteriorly they diminish in number and terminate with two outlying ones some distance behind the transition of the optic lobe into the third ventricle. In these fishes occurred the only instance of an exception to the rule of each cell having but one process; in this case a process was seen emerging from each end. There was also a single instance only of a cell sending its process toward the mid-line instead of toward the outside.

In Rhina these cells are restricted to the mid-line and do not spread out laterally. They commence as a group of four or five cells immediately in front of the exit of the trochlearis; they rather suddenly increase in number, and are restricted to the projection of the roof into the ventricle; on the edge of the group one or two outlying cells are occasionally found. They extend forward for about half the length of the ventricle. In another specimen there was a slight variation. They commence in this specimen in the valvula cerebelli by three groups, one on each side and one situated superiorly in the mid-line; this latter disappears, and the two former coalesce centrally and extend forward nearer the anterior end of the ventricle than in the last specimen, and terminate in a few stragglers.

* *Op. cit.*, p. 78.
† *Op. cit.*, p. 501.

In Acanthias the arrangement resembles very much that found in Rhina; these cells begin suddenly some distance in front of the trochlearis and are restricted as a group in the centre of the roof of the optic ventricle; anteriorly they terminate over the posterior edge of the posterior commissure, which in this species is some distance behind the anterior termination of the ventricle.

These cells occur also in turtles, in which their arrangement resembles that described in the last two species; in these animals they are grouped together in the projecting roof of the ventricle of the optic lobe in precisely the same manner as in Acanthias or Rhina.

The function of these cells is not at first sight apparent; according to the theory that assigns motor functions to the larger cells and sensory functions to the smaller cells, these ought to be motor cells; but their position is adverse to this view, the motor cells being usually, though not always, placed on the ventral side of the nervous centres. They may be probably looked upon as corresponding to the large cells in the nerve cell layer of the retina. These latter have been considered by some authors as refuting the above-mentioned theory, but, according to Professor M. Foster,* there is a residual motion in the eye after all the nerves have been severed, which he attributes to these cells in the retina. The cells in the optic lobe have probably some such function, and it would be interesting to know whether the retina in the Plagiostomata differ in any respect from the retina of those animals, e.g., Teleostei, which do not possess these cells in the optic lobe.

Cerebellum.

Two lobes may be distinguished in the cerebellum of Scyllium: one, anterior, projecting over the surface of the optic lobe for quite half its length, and ending in front in a pointed extremity; and one behind, which in like manner extends over the fourth ventricle; dorsally these coalesce and form one indistinguishable substance. Corresponding to the external shape, there is internally a ventricle which occupies the whole length of the lobe. Slightly in front of the central point there is a communication below with the general cavities of the brain through the dorsal wall of the aqueduct of Sylvius.

In structure the cerebellum (fig. 17) presents the four layers found in the brain of the Teleostei, that is to say, externally the molecular layer characterized by the striation directed perpendicularly to the external surface, then the layer of Purkinje cells or intermediate layer, internal to which occur the stratum of fibres, principally longitudinal, but in some places transverse, the fibrous layer, derived from the crura cerebelli ad medullam to a great extent; finally the granular layer is the most internal and projects into the ventricle.

The aggregate foldings of these four layers constitute the cerebellum, and in a

* 'Textbook of Physiology,' p. 408.

longitudinal section are seen to be as follows. Commencing at the posterior end of the optic lobe, with which they are connected by a narrow isthmus (the sole representative of the structure so highly developed in Teleostei), they all pass forward to form the ventral wall of the anterior lobe; arrived at the anterior point they turn back and constitute the dorsal wall of the anterior and posterior lobes, between which there is often found a small fissure; from the posterior end they again pass forward and form the ventral wall of the posterior lobe. Arrived at the foramen of communication with the fourth ventricle they turn towards the ventral surface, and then backward, supplying the posterior part of the roof of that passage, and finally turn upward to end close beneath the lower surface of the posterior lobe; here they form a curved free process which may be termed the inferior lobe. BUSCH* did not recognise the cerebellar structure of this lobe, and considered it as merely an appendage to the restiform bodies, "Fimbria ex corpore restiforme orta."

The four layers are not equal either in superficial extent or in mass (fig. 17). The external or molecular layer is deficient both at the anterior and posterior end for a small space; behind it continues from the under surface of the posterior lobe into the upper surface of the inferior lobe; at the point of junction of the two it forms a fold of its own, not participated in by the other layers (except the intermediate), which fills up the angle between the lower surface of the one and the upper surface of the other lobe.

The intermediate or PURKINJE cell layer is scarcely separable from the molecular, and may be looked upon as part of the same, it follows all its windings, and is deficient where that is deficient.

The third or fibrous layer may be traced at the junction of the anterior end of the cerebellum with the optic lobe into the posterior end of the latter, where it enters the third layer close to the endothelium; it consists of a longitudinal bundle of fibres, which passes along the ventral wall of the posterior lobe, and is dispersed and disappears in the anterior end of the granular layer. It may, perhaps, be looked upon as the representative of the crura cerebelli ad cerebrum. In the dorsal wall this layer forms two subordinate strata, the external of which consists of transverse or oblique, while the internal is formed of longitudinal fibres; in some parts there is a longitudinal layer external to as well as internal to the transverse fibres; these latter are derived directly from the crura cerebelli ad medullam, whereas the longitudinal gain their position more indirectly; they disappear in the granular layer anteriorly and posteriorly. Both sets of fibres are traceable into the inferior lobe.

On inspecting a transverse section of the cerebellum (fig. 13), it is seen that the granular layer consists of four longitudinal tuberosities or tori, which project into the ventricle of the cerebellum; they are placed one on each side of the central line of the dorsal wall, and in a corresponding position on the ventral wall. In the interval between these tori this layer is absent, and the wall at these parts is formed only by

* *Op. cit.*, Tab. 1, fig. 4.

the molecular layer with the PURKINJE cells and the fibrous layer. Anteriorly each torus commences by a rounded projection into the roof of the aqueduct, then passes dorsad along the anterior wall of the channel forming the communication between the ventricle and the aqueduct; and, passing forward along the floor of the anterior lobe, amalgamates at the anterior end of the cerebellum with the dorsal tuberosities, forming a mass of granular layer occupying the whole thickness of the lobe at that point; the two tori then pass along the whole length of the dorsal wall to the posterior end of the cerebellum, where an arrangement is found resembling that at the anterior extremity; hence the tori are to be traced into the ventral wall of the posterior lobe, and from there downward along the posterior wall of the channel above mentioned, then backward along the roof of the sinus rhomboidalis; finally, they turn upward, and end in a club-shaped free extremity as it appears in a longitudinal section. A consideration of the description just given would seem to show that, properly speaking, there are only two tori in the granular layer, since the dorsal and ventral are continuous at each end of the cerebellum.

Transverse sections (fig. 13) show that the inferior lobe is the medium of communication between the cerebellum and the medulla oblongata through the restiform bodies. The junction is effected at the lateral part of this lobe. Through the connecting link the fibres of the crura cerebelli ad medullam pass from one to the other. Owing to the folding of this lobe the section passes through the granular tori twice, giving the appearance as if there were four, two projecting into the ventricle of the cerebellum and two into the roof of the fourth ventricle. At the point of junction of this lobe with the restiform columns, the crura cerebelli part into two divisions, one, the external, passes upward along the outer wall of the cerebellum to the dorsal angle, then turning inward joins that of the other side in the mid-line, crossing through the bases of the two dorsal tori of the granular layer. In the central line, at the bottom of the fissure which divides the two tori from each other, the wall of the cerebellum consists only of the commissure in question, and a modified molecular layer, much narrower than at the other parts of the cerebellum. The internal division of the crura goes partly upward, and forms a commissure through the bases of the upper tuberosities of the inferior lobe, and partly downward to make a corresponding commissure through the lower tuberosities. At both the upper and lower central points the wall is composed only of the transverse fibres, and a small portion of the molecular layer.

The inferior lobe (fig. 17) is the only part which MIKLUCHO-MACLAY allows to belong to the hindbrain, all the remainder of the cerebellum belonging in his view to the midbrain or mesencephalon. But this view is untenable, the inferior lobe is clearly nothing more than a fold of the cerebellum with no independent characteristic whatever; it has no ventricle, nor any indication of relationship to the primitive vesicles of the brain, as a glance at the figures given by BALFOUR* would show.

* 'Development of Elasmobranch Fishes,' Plate xv., fig. 7a.

In Raja (fig. 12) the cerebellum has the same fundamental arrangement as in Scyllium, the four layers, the molecular, the PURKINJE cells, the fibrous and the granular, are all present. Externally there is a deep transverse furrow formed by the molecular layer; in the lateral walls also there are two involutions of the molecular layer all followed by that of the PURKINJE cells. Internally the ventricle is occupied by the four tori of the granular layer, which nearly fill it, leaving only a comparatively small cruciform fissure between them. The inferior lobe is well developed, and the fold of the molecular layer therein is larger than in Scyllium.

The total outcome of the difference is that in Raja the cerebellum is more solid and massive; there is a larger quantity of material. The molecular layer is more extensive, being folded into several furrows, and the granular layer forms larger tuberosities. These facts seem to show that the greater activity of life, in conjunction with the lighter and less muscular but more agile body, of the dogfish, does not require the quantity of nervous substance to start it that is necessary to move the more massively muscular and heavier carcase of the sluggish Ray, so that it would appear that quantity of muscle requires more nervous activity than quickness of motion.

The case of Rhina seems to contradict this theory, for with a massiveness of body less, certainly, than that of the Rays, but much greater than that of Scyllium, it is provided with a brain possessing less nervous tissue than that of Scyllium. How to reconcile this incongruity is more than I can say. Both in Rhina and Acanthias the cerebellum resembles that of Scyllium, except that it is lighter and thinner, and contains a larger ventricle.

The tuberosities, the arrangement of which has been just described, correspond to the granular layer in the solid cerebellum of the Teleostei ; the form here, as has just been explained, is that of four, or rather two, discrete longitudinal, more or less cylindrical, tuberosities or tori. The fundamental structure is the same both in the Plagiostomata and the Teleostei ; there is the network of fibrillæ (fig. 20), in which minute cells are thickly scattered in an irregular manner; these cells are rather larger than those found in the corresponding part in the Teleostei ; they average 6μ by 4μ, and 5μ or 4μ in diameter, their outline is more irregular, and they give off on all sides processes which join the network of the neuroglia.

The arrangement of the network differs somewhat from that found in the Teleostei. The general direction of the fibrils is longitudinal; but in addition to this the fibrillæ form small knots or little masses of neuroglia in which the fibrils are inextricably wound together so as to be almost indistinguishable. These knots might almost be compared, on a small scale, to the glomeruli of the olfactory lobe. There is every gradation of closeness, between some in which the fibrils are scarcely more compacted together than in the remainder of the layer, to others which have almost the appearance of cells. They are best seen in the Acanthias, in which they are more developed than in the other species. The cells are, on an average, of larger size in Rhina than in either Acanthias, Scyllium, or Raja, in all of which they are about equal.

The intermediate layer of PURKINJE cells follows the folds and involutions of the molecular layer, except a small tract along the central line of the dorsal portion. In it are seen not only the true characteristic PURKINJE cells, but also smaller cells; between the two there is a gradation in size.

The larger PURKINJE cells (fig. 21) are about 27μ long by 14μ broad, and the smaller 15μ by 10μ; they are generally elongated and triangular in shape; two molecular processes are given off from the side turned towards the molecular layer, and one finer process from the narrower end is directed towards the granular layer. Occasionally these cells are broader at the end turned towards the granular layer, as if they had been truncated; sometimes fusiform cells are found with a process emerging from each extremity, resembling those found in Teleostei. The processes which pass into the molecular layer may often be traced nearly as far as the external surface, their course is nearly direct, and they give off branches which preserve the same general direction as the main trunk; they thus contribute to a greater extent to the striation of the molecular layer than in Mormyrus. The smaller cells mentioned above are found in the neighbourhood of the PURKINJE cells, and their processes join the fibrillar network of the molecular layer.

The outer or molecular layer of the cerebellum (fig. 21) consists, in addition to the processes of the PURKINJE cells, also of a fibrillar network, the general tendency of the striation of which is in a longitudinal direction; the fibrils composing this are not so broad as those which go in a course perpendicular to the surface. Near the external edge the network becomes irregular. Cells of small size are found sparingly scattered through the central and outer portions of the layer; they are more numerous than in Mormyrus, and still more so than in Mugil Cephalus, in which they were seldom found; they are rather larger in size than in the Teleostei, averaging 6μ or 7μ in diameter; they are spherical or sometimes slightly triangular in shape, and give off processes on all sides which join, some the longitudinal and some the radial fibrils. In Rhina they appear to be fewer in number, but somewhat larger than in the other species examined. In other respects this description applies equally to all.

The ventricle of the cerebellum is lined by a layer of endothelium derived from the general endothelial lining of the brain cavities.

Restiform Bodies.

The crura cerebelli (fig. 12) in their descent on to the medulla oblongata, are accompanied by the molecular and granular layers, which extend in Raja nearly as far as the posterior end of the fourth ventricle; so that the tuberosities which bound that ventricle laterally appear as if they were the continuation of the cerebellum; the absence, however, of the PURKINJE cells marks a substantial difference in organization; for these cells may be considered as characteristic of the cerebellum, structures more

or less resembling the granular or molecular layers are found in other parts, but PURKINJE cells occur nowhere else. In Scyllium the granular layer does not extend so far back as the molecular. The same may be said of Rhina and Acanthias.

Spinal Cord.

The grey matter of the spinal cord (figs. 6, 7, and 8) has somewhat the shape of a goblet with its foot. The dorsal horns spread out towards the dorsal surface in a way to make it resemble a Lucernaria ; this resemblance is more apparent in Acanthias than in the figure. The ventral horns are extremely well defined and distinct, they extend horizontally on each side of the central canal, in shape like a pair of clubs. Surrounding the central canal there is a single-celled layer of endothelium to be observed ; and external to that a space of connective tissue which may be compared to the substantia gelatinosa centralis. In a transverse section one may reckon four columns of longitudinal fibres. Those beneath the ventral horns of grey substance may be termed the ventral columns, situated between the central canal and the ventral surface of the cord, and bounded on each side by the ventral roots of the spinal nerves. The lateral columns extend from the outer sides of the ventral roots to the external side of the dorsal horns. The remaining two columns are the dorsal situated above the dorsal cornu, and a small pair of fasciculi placed immediately dorsad of the central canal above the connecting link between the two ventral cornua. In addition to these there are a few small bundles running longitudinally through the dorsal cornua, which are the dorsal roots of the spinal nerves. The ultimate destination of these columns will be seen presently, as far as I have been able to unravel their course. Each ventral horn of grey substance contains about nineteen or twenty cells in one section. These cells are of a larger size than those found in the ventral horns in the Teleostei ; they are generally elongated, and give off several processes ; they are arranged in an imbricated manner, with their long axes directed obliquely from the ventral to the dorsal surface. As the spinal cord passes on to merge into the medulla oblongata, the ventral cornu becomes depressed towards the ventral edge of the cord, so that instead of being placed in a horizontal position, it gradually comes to form an angle of about forty-five degrees. Immediately behind the posterior end of the fourth ventricle it begins to disappear, but some of the cells may be traced in the corresponding position for a few sections farther forward, and they finally disappear at the posterior end of the medulla oblongata. At this point another ganglion becomes apparent, which is not a continuation forward of the ventral cornu, but is situated nearer the central line and the dorsal surface in the grey matter of the floor of the fourth ventricle, rather to its outer side. It forms part of the origin of the vagus. The fibres of the ventral column vary in size, but they are larger than those of the lateral and dorsal columns ; their average diameter is less than that of the corresponding fibres in the spinal cord of the Teleostei.

Although in the Plagiostomata the gigantic fibres discovered by MAUTHNER in the Teleostei are not present, and thus a difference is found to exist between these groups in the structure of the spinal cord, yet in Ceratodus, which perhaps presents an archaic form of nervous system, a form of nerve fibre is seen, which is in all likelihood the primitive form of this kind of fibre. In this nerve fibre, instead of one very large axis cylinder, there are several, which are all enclosed in a separate and distinct medullary sheath ; they occupy a position in the spinal cord and medulla oblongata corresponding to MAUTHNER's fibres.

The ventral columns on arriving at the fourth ventricle form two distinct longitudinal projections in the central line of the floor of the same ; anteriorly these projections become smaller and disappear at the anterior end of the fourth ventricle ; they disappear as such, but the columns themselves are traceable farther forward much diminished in size. Along the floor of the aqueduct of Sylvius they gradually break up into a number of smaller bundles which recede from the floor of the aqueduct toward the outer side. They can be traced, much diminished in size, into the ventral part of the posterior commissure. The lateral columns also diminish greatly in the number of fibres which they contain in their course forward. Those bundles which are internal and nearer the ventral columns become lost in the region of the posterior commissure, while some of the more external seem to join the transverse fibres which form the second layer of the optic lobe. Those between the two disappear in the region above the hypoarium, some crossing the fibres of the crura cerebri, which disappear in the same region. ROHON * describes these columns as the continuation backward of the pedunculi cerebri, with which he thinks they are continuous, and he identifies the ventral columns with a system that he has traced in the cerebrum,† and which he has homologized with the fasciculus longitudinalis tegmenti posterior. This sort of thing is a mere *tour de force* of the imagination ; these columns may homologize in a general sort of way, but to pick out the particular fasciculi in the human brain to which they correspond is going a little too far. I am unable to confirm his assertions, as neither of these connexions were to be traced in my sections (fig. 18).

Deep Origin of the Cerebral Nerves.

First pair.—The olfactory nerves are derived from the olfactory lobe, a description of which has already been given.

Second pair.—The optic nerves form a distinct and well-formed chiasma. They do not show the pectinated arrangement characteristic of the Teleostei. At the lower portion of the chiasma the fibres of the nerve of one side intersect those of the other in layers as they cross, like the intertwined fingers of the two hands ; but dorsad, more than half of the nerve of one side crosses over that of the other, forming a simple

* *Op. cit.*, pp. 72 and 77, fig. 51.
† *Op. cit.*, p. 79, fig. 42.

decussation. I could discover no fibres that remained on the same side, neither are there any which traverse the chiasma from one nerve to the other without passing on into the brain ; neither does the commissura transversa HALLERI, which is stated by GOTTSCHE* to be present behind the chiasma in Teleostei, appear to be present here.

With regard to the deep origin of the nerve (figs. 18 and 22), the principal part is derived from the anterior end of the optic lobe, where the fibrils of origin occupy nearly two-thirds of the width, comprising in fact the whole of the first or external layer. The fibrils appear to be derived from the cells mentioned in the description of the lobe in question. In addition to this origin some of the fibres are derived from the hypoarium. BELLONCI† denies this origin, and is of opinion that bundles belonging to the anterior and posterior commissura transversa have been credited to the chiasma by mistake ; but, unfortunately for this idea of BELLONCI, these structures do not exist in specimens of Plagiostomata that I have examined. My reason for including the hypoarium as part of the origin of the optic nerve is this ; if very thin horizontal sections of the chiasma be examined at the point where its posterior margin abuts on the hypoarium, several fibres are to be seen passing into it, dispersing through that body, and not returning into the chiasma. If they were simply passing through to some other part they would retain their formation as bundles and would not separate into single fibrillæ. I have not actually traced any of them into a cell, but, nevertheless, as it is, I think this arrangement shows that they end, or begin rather, in the hypoarium.

Third pair (fig. 15).—The oculomotorii nerves are derived from a small group of nerve cells situated on each side of the fissure on the floor of the ventricle of the optic lobe ; from these ganglia a well-defined bundle passes downward and outward, and emerges from the inferior surface, one on each side of the raphé. AHLBORN‡ however describes a decussation, or, as he prefers to call it, a chiasma of the roots of this nerve in the Petromyzon. It seems hardly probable that a decussation should be present in this animal and not in the Plagiostomata, but of course it is just possible that he is right ; if so, the Petromyzon is differently organized to the other members of the class Pisces. It is true that there is a decussation of fibres in the neighbourhood of this nerve, which might have deceived AHLBORN, but it is a distinct formation, and has nothing to do with the oculomotorii ; it extends for some distance both before and behind them, and appears to homologize with the commissura ansulata§ in the Teleostei. In the region between the roots of this nerve there are apparently two sections of this commissure : a dorsal part the fibres of which decussate, and a ventral part the fibres of which simply pass over from one side to

* *Op. cit.*, p. 442, fig. 8.

† " Ueber den Ursprung des Nervus Opticus, &c." 'Zeitschr. f. Wissensch. Zool.,' vol. 35, 1880, p. 24.

‡ " Untersuchung über das Gehirn der Petromyzonten." 'Zeitschr. f. Wissensch. Zool.,' vol. 39, 1883, p. 271.

§ GOTTSCHE, *op. cit.*, p. 439.

the other; they all cross the roots of the oculomotorii at right angles and plainly do not join them. The greater number of the fibres entering into the composition of this commissure are derived from the second layer of the optic lobe. In fact it may be considered as the commissure of the optic lobe, but in addition to these fibres some few appear to be derived from the lateral columns of the cord.

In the Rays this commissure is not so well developed as in Scyllium and Acanthias. In the latter it extends farther behind the oculomotorii than in the others. It seems as if, in these latter, the extent of these association fibres compensates for the size of the ventricles and the consequent thinness of the walls of the optic lobe, cerebrum, and the other parts of the brain.

Fourth pair.—The trochleares are very difficult to trace; they have a distinct decussation in the region of the valvula cerebelli, which is represented by a narrow neck of tissue between the cerebellum and the optic lobe, and is not nearly so well developed as in the Teleostei. I have not been able to trace the roots of these nerves to any ganglion, but in one specimen they were seen turning forward by the side of the aqueduct of Sylvius. In the region of the ganglion of the oculomotorius, there are no collections of cells to be found from which they might be supposed to have been derived. Rohon,* in his account of the origin of this nerve, appears to have fallen into a slight mistake; he describes it as arising from a swelling which is in direct connexion with the cortical part of the anterior tuberosity of the cerebellum. A consideration of his figure convinces me that the section has been made through the restiform bodies behind and not in front of the crura cerebelli ad medullam; if so, the bundle of fibres which he looks upon as the root of the trochlearis must have some other signification. Acanthias is a very good subject for this investigation, because its cerebellum being small does not extend forward and obscure the relation of the parts between it and the optic lobe. Fig. 14 is taken from this animal, and shows the narrow valvular portion extending as a tent over the anterior part of the fourth ventricle at the point of its transition into the aqueduct of Sylvius. It shows also the decussation of the fibres and the commencement of their course along the side of the aqueduct.

Fifth pair (fig. 11).—The trifacial is derived from three roots. One comes forward from the posterior part of the medulla oblongata from the lateral columns of the cord. This evidently corresponds to the ascending root in Mammalia. Another comes backward from the anterior part of the tuberosity of the trifacial, into which it penetrates from the formatio recticularis; these two bundles pass in opposite directions until they arrive at the point of exit of the nerve, when they turn directly outward and cross each other to join the emerging root of the nerve. The third origin comes from a group of cells situated on the lateral part of the floor of the fourth ventricle; in addition to the fibres from the ganglion, others are derived from the raphé.

* *Op. cit.*, p. 80, fig. 49.

There are extensive commissures or arcuate fibres in the region of this nerve, which cross the ventral surface and other parts in the formatio reticularis; they appear to join the restiform bodies.

Sixth nerve.—The abducentes arise by about four small bundles from each side of the raphé. They can be traced from the external surface of the ventral side of the medulla oblongata at about the middle of its length to the lower edge of the ventral columns, where they are lost. They resemble in their arrangement the oculomotor nerves, but unlike them they could not be traced to any nerve cells, unless they have anything to do with some large cells which are sparingly scattered through the formatio reticularis in this region.

Seventh (figs. 6, 7, 8).—The facialis, which in Rhina and Scyllium is a branch of the trifacial, and in Acanthias has a separate root, arises from a bundle which comes forward from the spinal cord. This fasciculus appears above the central canal, between the dorsal and ventral cornua; in its course forward it lies internal to the ascending root of the trifacial. This bundle is described by ROHON* (who apparently missed its connexion with the facial) as the fasciculus longitudinalis lateralis, which he considers as a new formation especially confined to the Plagiostomata, but it corresponds to the root of the facial in the Teleostei; it was described in my paper on the brain of the Teleostei † under the name of the upper column of the trifacial.

Eighth.—The Acusticus appears to arise from the grey matter of the floor of the fourth ventricle.

Ninth pair.—The glossopharyngeal also appears to arise from the grey substance of the floor of this same ventricle.

Tenth pair.—The vagus arises from the series of rounded tubercles which are situated on the floor of the fourth ventricle. GEGENBAUR‡ compares these tubercles to the swellings on the surface of the medulla oblongata in Trigla, and explains the fact that they are situated outside, by supposing that the sinus rhomboidalis in that species is too small to receive them, whereas in Hexanthus the presence of a larger ventricle affords space for them within it.

These tubercles contain a few cells of medium size, from which the roots of the nerve appear to be derived; each tubercle seems to give rise to a separate root, which, passing out of the medulla, joins the others to form the nerve in a manner formerly described.

ROHON,§ who has gone minutely into the relations of the roots of this nerve, has come to the following conclusions. The lobus vagi corresponds to a collection of nerve ganglia, and each root, arising from a single ganglion, corresponds to a posterior (dorsal) root of a spinal nerve; and, further, the roots that emerge behind the lobus

* *Op. cit.*, p. 101.
† 'Phil. Trans.,' 1878, vol. 169, p. 765, fig. 9.
‡ *Op. cit.*, p. 520.
§ "Ueber den Ursprung des Nervus Vagus." 'Wien, Zool. Instit. Arbeiten,' Heft 1, 1878.

vagi represent a mixed system of anterior and posterior roots, which correspond partly to the anterior and partly to the posterior roots of spinal nerves: thus confirming a conclusion previously arrived at by GEGENBAUR.

Spinal nerves (figs. 6 and 7).—The ventral roots of these nerves emerge as a bundle on each side of the raphé, from the internal inferior surface of the ventral horn of grey substance, and, taking a direction nearly downwards, pass out to form the ventral roots of the spinal nerves.

The dorsal roots enter the cord obliquely, and there divide into two cords: one cord from the anterior part of the root passes backward, the other cord from the posterior part of the root passes forward; they cross over the next nerve both in front and behind, and join the lateral columns of the cord.

I am unable to do more than confirm the account which STIEDA* (who was the first to describe this arrangement) gave.

Conclusion.

A comparison of the brain of the Plagiostomata with that of the Teleostei brings out several differences in detail; but the general scheme is the same in both.

In the Plagiostamata the lobi olfactorii have a well marked ventricle, communicating by a passage through the peduncle with a ventricle in the cerebrum, which anteriorly is double, but behind is single. There can be no doubt that these correspond to the lateral ventricles, while the posterior single part, which is continuous with the third ventricle, can be no other than the Foramen of Monro. The position of the anterior commissure, which connects the two sides of the ventral part or floor of these ventricles, would seem to indicate that the corpora striata should be looked for here. The Teleostei possess none of these structures, with the sole exception of the anterior commissure; in them the olfactory lobe and the cerebrum are solid.

The theory of RABL-RÜCKHARD † is scarcely applicable to the Plagiostomata. His conclusions are that the cerebrum in Teleostei is homologous to the island of Reil and the corpus striatum only; while a layer of endothelium which lines the pia mater and forms a shut sac, communicating with the third ventricle, is genetically homologous with the unthickened wall of the cerebral hemispheres, "Grosshirnbläschen," and the space it encloses is the "ventriculus communis." Other writers have compared the hemispheres in the Teleostei with the corpora striata, e.g., TIEDEMANN,‡ but of course this does not detract from the merit of this writer, whose reasoning and detailed exposition of the homology of these structures are worthy of attention. It remains only to be considered how far a layer of endothelium may be taken to represent

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* 'Zeitschr. Wissensch. Zool.,' vol. 23, 1873.

† "Das Grosshirn der Knochenfische u. seine Anhangsgebilde." 'Archiv Anat. Physiol.' (Anat. Abth)., 1883, p. 307.

‡ "Anatomie und Bildungsgeschichte des Gehirns im Fœtus des Menschen." 1816.

nervous substance. It is not to be overlooked that VON BAER* described these hemispheres in the embryo of the Teleostei, as being hollow and containing a small tubercle occupying the position of the corpora striata. In the Plagiostomata, how-ever, the walls of the cerebral hemispheres are thickened, and two ventricles are present, so that we have here a considerable advance in structure. The theory that these represent the lateral ventricles of Mammalia is not universally received. Prof. BURT. G. WILDER† looks upon them as implying an extension forward of the third ventricle, and the real Foramina Monroi he finds in the openings on each side which lead into the ventricles of the olfactory lobes, which latter he considers to be the true lateral ventricles. This view seems to me to be scarcely tenable ; not only is the structure of these lobes incompatible with this opinion, but the position of the so-called Foramina Monroi themselves is against it, the true foramen being a single passage, and not one in each lateral wall, which would be the case if this opinion should be received.

With regard to the homologies of the remaining tuberosities of the brain, except the optic lobes, there are no great difficulties.

The hypoaria, lobi infundibuli or inferiores may be considered to belong to the thalamencephalon, which may be defined as the space between the anterior com-missure in front and the posterior commissure behind, and includes the above-mentioned lobe together with the infundibulum. Thus the thalamencephalon is pushed under the mesencephalon to a great extent in the Plagiostomata.

To the question, how much if any part of the thalamencephalon is represented in these fishes ? I should be inclined to reply, probably no part of it. The only consideration which would seem to favour the idea of its presence would be the position of the posterior commissure, the homology of which is generally conceded ; but this does not necessarily carry with it the homology of the part which it connects, and even if it does so, the posterior commissure does not solely nor even principally connect the two thalami optici. But it is probable that the territory between the anterior end of the optic lobe and the chiasma nervorum opticorum corresponds to the corpus geniculatum externum, or, as MAYSER‡ suggested, the corpus geniculatum internum, for the torus semicircularis in Teleostei.

ROHON, whose ideas generally seem worthy of respect, has rather gone beyond the mark in his theory of the optic lobe ; a combination of the thalamencephalon and the mesencephalon in this lobe is an idea that will not bear inspection. In the first place there is not the slightest appearance in any sections that I have seen of a difference in structure in the optic lobes ; on the contrary, the difficulty was to distinguish any separate layers for description, the characteristic cells extended without a break in greater or less numbers from the external to the internal surface.

* ' Ueber Entwickelungsgeschichte der Thiere.' Zweiter Theil, p. 307.
† ' Philadelphia Acad. Nat. Sci. Proc.,' 1876.
‡ ' Zeitschr. Wissensch. Zool.,' vol. 36, 1881.

Von Baer's theory, although subsequent researches proved it to be untenable, was nevertheless much more reasonable, for there was some ground for it, in the projection of a part of the cerebellum into the ventricle of the optic lobe.

Next the dilemma, which our author propounds on p. 99, as to the trochlearis, has no existence except in the imagination. This nerve does not arise so far back as he supposes; if one inspects his fig. 49 it will be at once seen that one has to do with a section taken behind the crura cerebelli ad medullam, and that the structure represented could not be the roots of this nerve. The true point of decussation of this nerve has been described in the account of the origin of the nerves.

There is no question here of any physiological consequences, either good or bad, in consequence of its fibres passing through the optic tract, since the case does not occur, the two sets of fibres being some considerable distance apart.

In addition to these considerations I may cite Rabl-Rückhard,* who states that at no time during the development of the embryo does the thalamencephalon pass or project behind the point of attachment of the epiphysis cerebri. Neither does Balfour † give any indication of any such occurrences.

If we should abandon the landmarks of homology as Rohon and Fritsch would have us do, we shall be plunged into a sea of doubt; science would be reduced to a mere system of guesswork, and we should become like those natives in South Africa whom a recent traveller described, as amusing themselves over the camp fire by discussing the question as to which fingers of their hand the toes of an ostrich corresponded.

EXPLANATION OF PLATES.

The following letters have the same signification throughout :—

a.c. 5	Ascending root of trifacial.
a.c.ce.	Anterior commissure.
a.l.	Anterior lobe of the cerebellum.
aq.Sy.	Aqueduct of Sylvius.
b.	Nervi branchiales.
c.a.	Commissura ansulata.
c.c.	Crura cerebri.
c.ca.	Central canal of the spinal cord.
c.cbl.	Crura cerebelli ad medullam.
c.cbl.c.	Crura cerebelli ad cerebrum.
cbl.	Cerebellum.
ce.	Cerebral lobes.

* *Loc. cit.*

† 'A Monograph on the Development of Elasmobranch Fishes.' London, 1878.

ch.op.	Chiasma nervorum opticorum.
ch.pl.	Choroid plexus.
d.h.	Dorsal horn of grey substance.
d.r.	Dorsal roots of the spinal nerves.
f.a.	Fibræ arcuatæ.
f.f.	Fasciculus of the facial nerve.
f.l.	Fibrous layer of the cerebellum.
f.m.	Foramen of Monro.
gl.	Glomerulus olfactorius.
g.l.	Granular layer of the cerebellum.
gn.ce.	Collections of cells at the base of the cerebrum.
gn.mo.	Ganglion of the oculomotorius nerve
gn.r.op.	Ganglion of the roof of the optic lobe.
gn.tri.	Ganglion of the trifacial nerve.
gn.v.	Ganglion of the vagus.
hy.	Hypoarium.
i.l.	Internal layer of the olfactory lobe.
i.m.	Inferior maxillary nerve.
i.n.	Infundibulum.
l.c.	Lateral columns of the cord.
l.i.cbl.	Inferior lobe of the cerebellum.
l.op.	Lobi optici.
l.v.	Lateral ventricles.
m.f.	MEYNERT's fibres.
m.l.	Molecular layer of the cerebellum.
m ob.	Medulla oblongata.
n. 2.	Optic nerve.
n. 3.	Oculomotorius nerve.
n. 4.	Trochlearis nerve.
n. 5.	Trifacial nerve.
n. 6.	Abducens nerve.
n. 7.	Acusticus nerve.
n. 9.	Glossopharyngeal nerve.
n. 10.	Vagus nerve.
o.	Ophthalmic nerve.
ol.	Olfactory lobe.
op.tr.	Optic tract.
p.c.	Posterior commissure.
p.i.	Hypophysis cerebri.
p.l.	Posterior lobe of the cerebellum.
p.m.	Pia mater.

r.c.	Restiform column.
r.i.	Ramus intestinalis.
r.l.	Ramus lateralis.
s.g.c.	Substantia gelatinosa centralis.
s.m.	Superior maxilliary nerve.
s.r.	Sinus rhomboidalis or fourth ventricle.
t.c.op.	Tranverse commissure of the optic lobe.
th.	Thalamencephalon.
t.i.	Tuberculum intermedium, GOTTSCHE.
t.tri.	Tuberosity of the trifacial.
t.v.	Tuberosity of the vagus.
v.cbl.	Ventricle of the cerebellum.
v.h.	Ventricle of the hypoarium.
v.h.g.	Ventral horn of grey substance.
v.l.c.	Ventral longitudinal column.
v.op.l.	Ventricle of the optic lobe.
v.r.	Ventral root of the spinal nerve.
v.th.	Third ventricle.
v.v.	Valve of Vieussens, valvula cerebelli, or anterior medullary velum.

PLATE 38.

Fig. 1. Dorsal view of the brain of Scyllium Catulus, the pia mater covering of the third and fourth ventricle removed.   Natural size.

Fig. 2. Dorsal view of the brain of Rhina Squatina, showing part of the distribution of the cranial nerves.   Pia mater not removed.   Natural size.

Fig. 3. Dorsal view of the brain of Acanthias vulgaris.   Pia mater not removed. Natural size.

Fig. 4. Side view of the brain of Acanthias vulgaris.   Natural size.

Fig. 5. Dorsal view of the fourth ventricle and the optic lobes.   Pia mater and cerebellum removed.   × 2.

Fig. 6. Transverse section through the spinal cord of Rhina Squatina.   × 22.

Fig. 7. Transverse section through the spinal cord of Rhina a little more in advance. × 22

Fig. 8. Transverse section through the spinal cord immediately behind the fourth ventricle.   Rhina × 22.

Fig. 9. Transverse section through the posterior end of the Medulla oblongata. Rhina.   × 22.

Fig. 10. Transverse section through the middle of the fourth ventricle.   Rhina.   × 22.

PLATE 39.

Fig. 11. Transverse section through the fourth ventricle at the posterior end of the cerebellum. Rhina. × 22.

Fig. 12. Transverse section through the roots of the Acusticus. Raja Batis. × 22.

Fig. 13. Transverse section through the Crura cerebelli ad medullam. Rhina. × 22.

Fig. 14. Transverse section through the valvula cerebelli and the trochlear nerves, at the transition of the fourth ventricle with the aqueduct of Sylvius. Acanthias. × 22.

PLATE 40.

Fig. 15. Transverse section through the region of the oculomotorius nerve. Acanthias. × 22.

Fig. 16. Transverse section through the anterior end of the optic lobe and the posterior commissure. Acanthias. × 12½.

Fig. 17. Longitudinal section through the cerebellum. Scyllium. × 7.

Fig. 18. Longitudinal section through the mesencephalon and the third ventricle. Raja.

PLATE 41.

Fig. 19. Horizontal section through the third ventricle and the base of the cerebrum. Acanthias. × 12½.

Fig. 20. Transverse section through part of the granular layer of the cerebellum. Acanthias. × 450.

Fig. 21. Section through part of the molecular layer of the cerebellum. Scyllium. × 450.

Fig. 22. Longitudinal section through part of the optic lobe. The section was composed from two separate pieces. Rhina. × 65.

Fig. 23. A glomerulus olfactorius and the adjacent part of the internal layer. Acanthias. × 325.
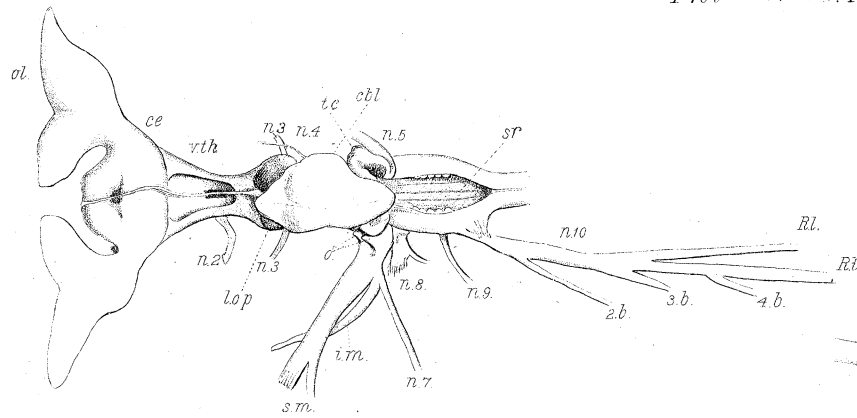
Fig 1

Fig 2

Fig 3

Fig 4
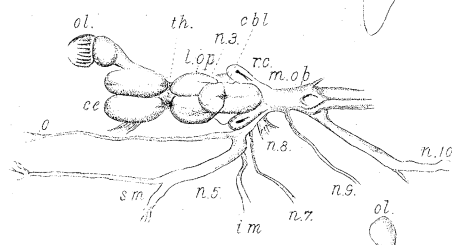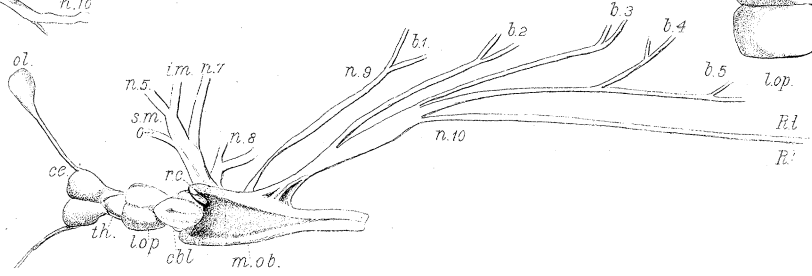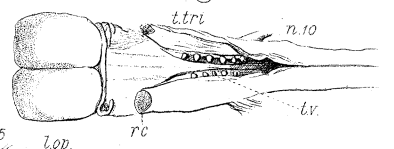
Fig 5 ×2
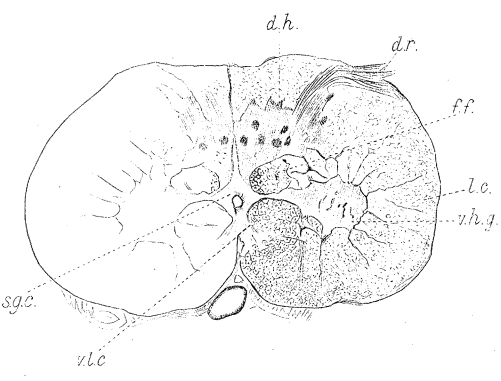
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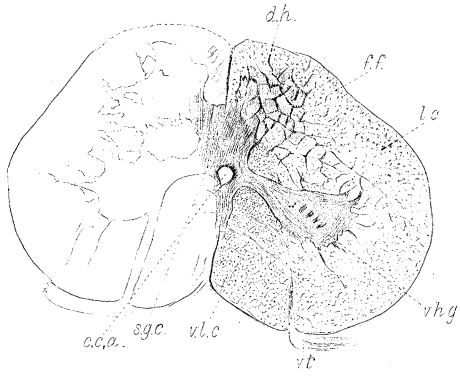
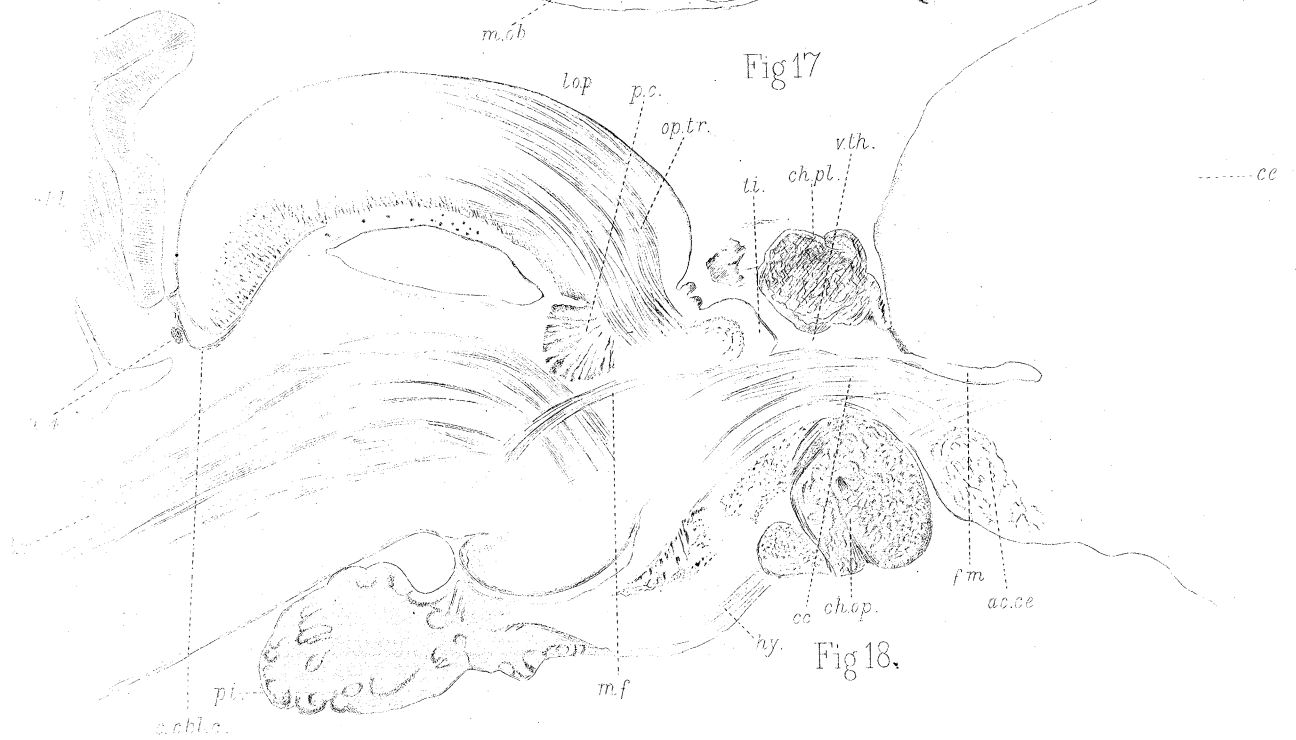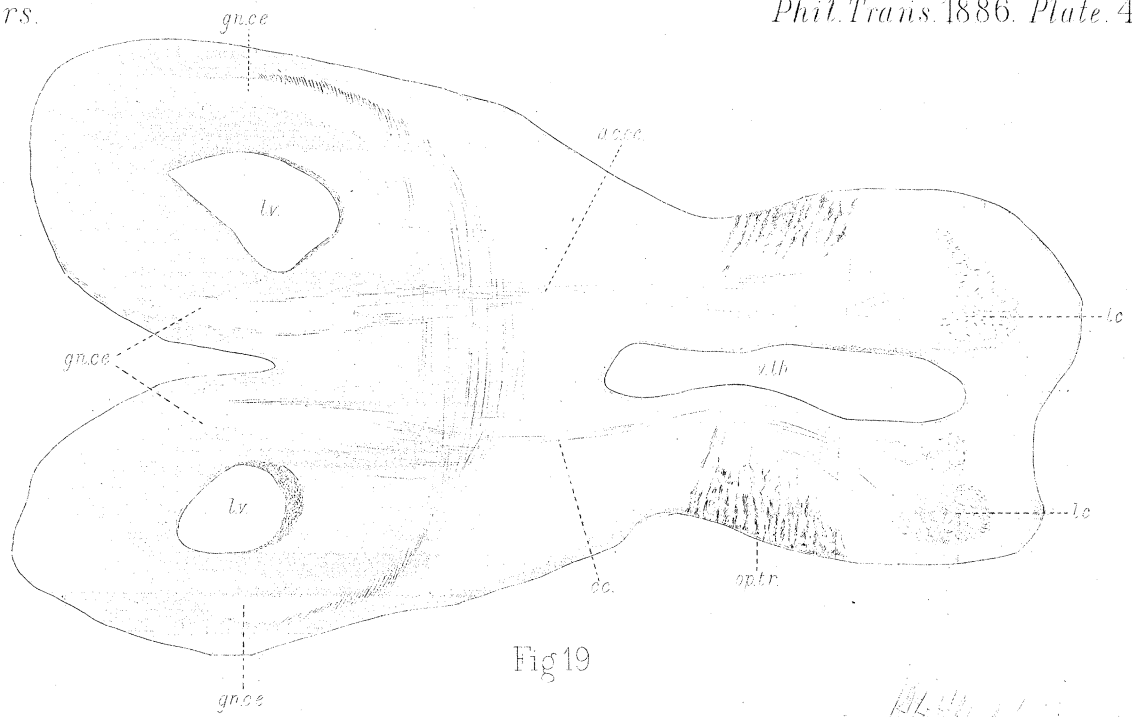Fig 7
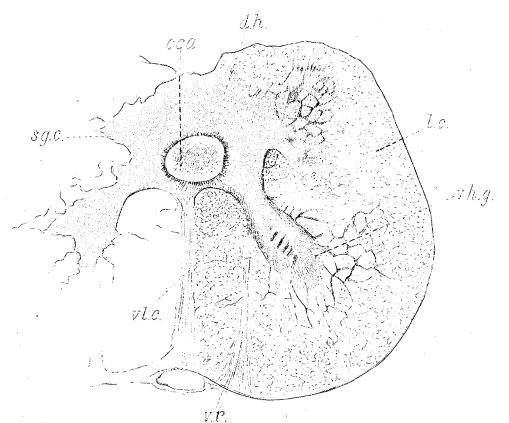
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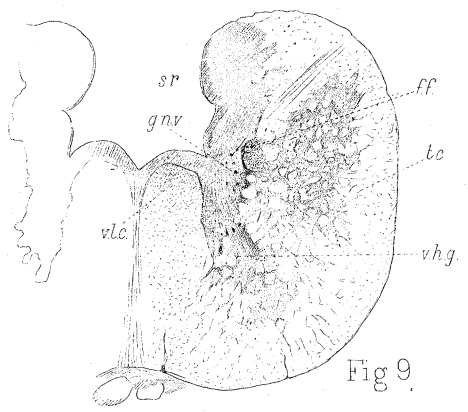
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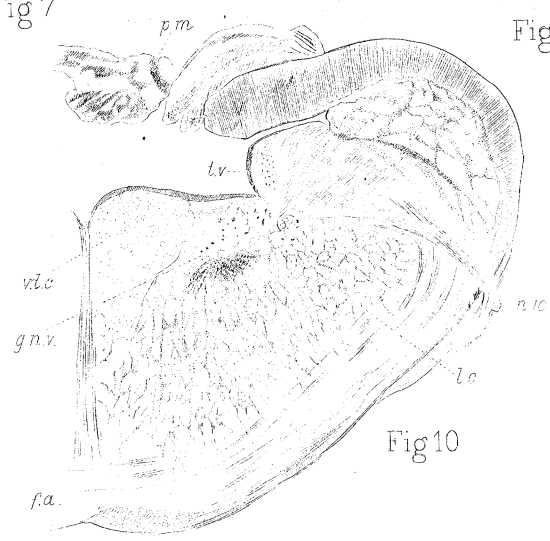
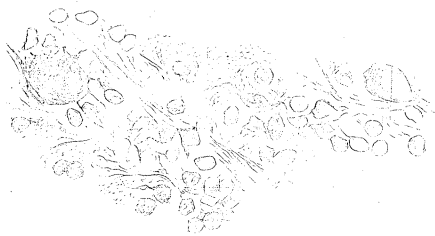Fig 10
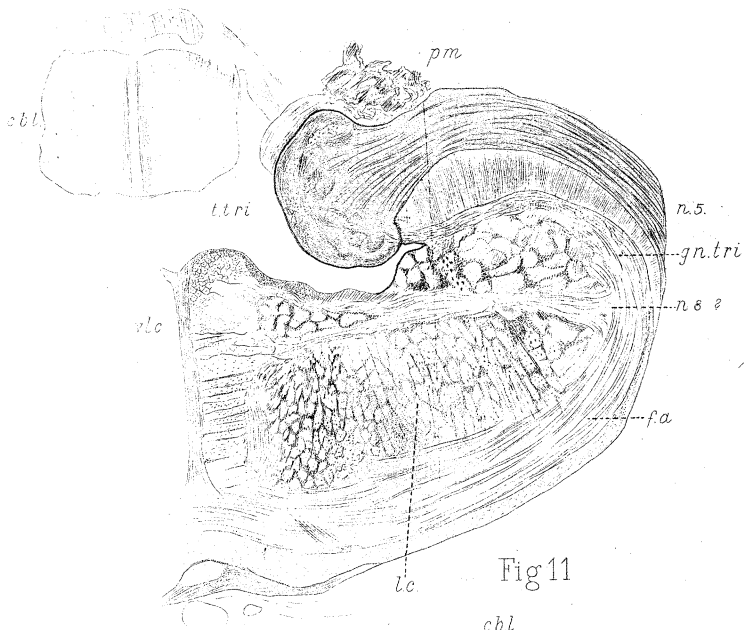
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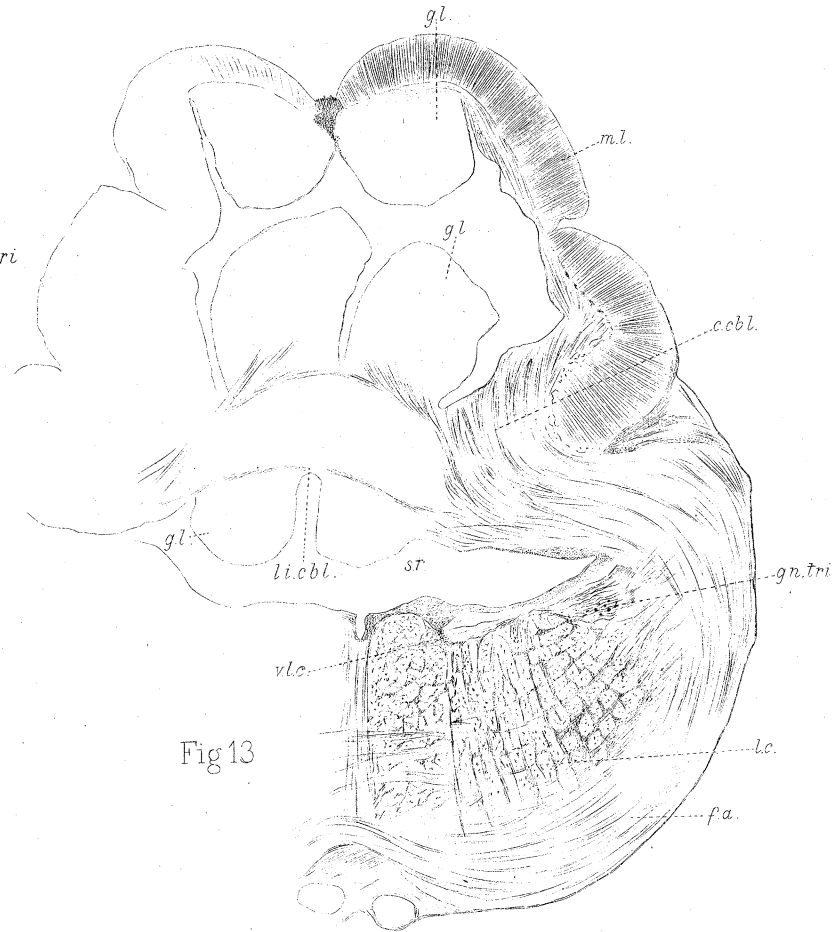
Fig 12

Fig 13
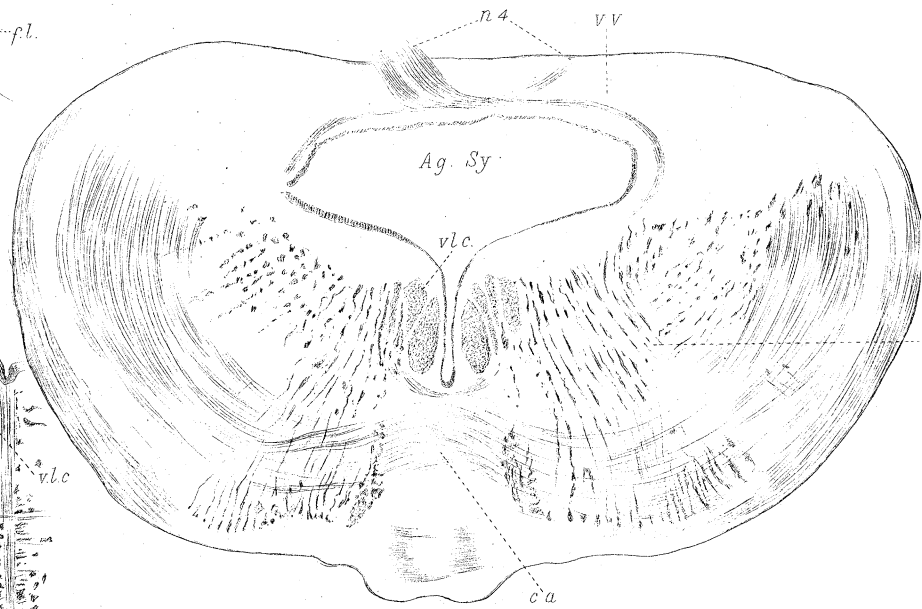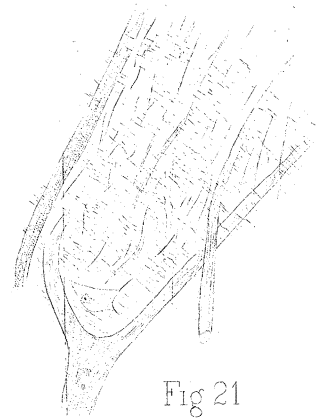
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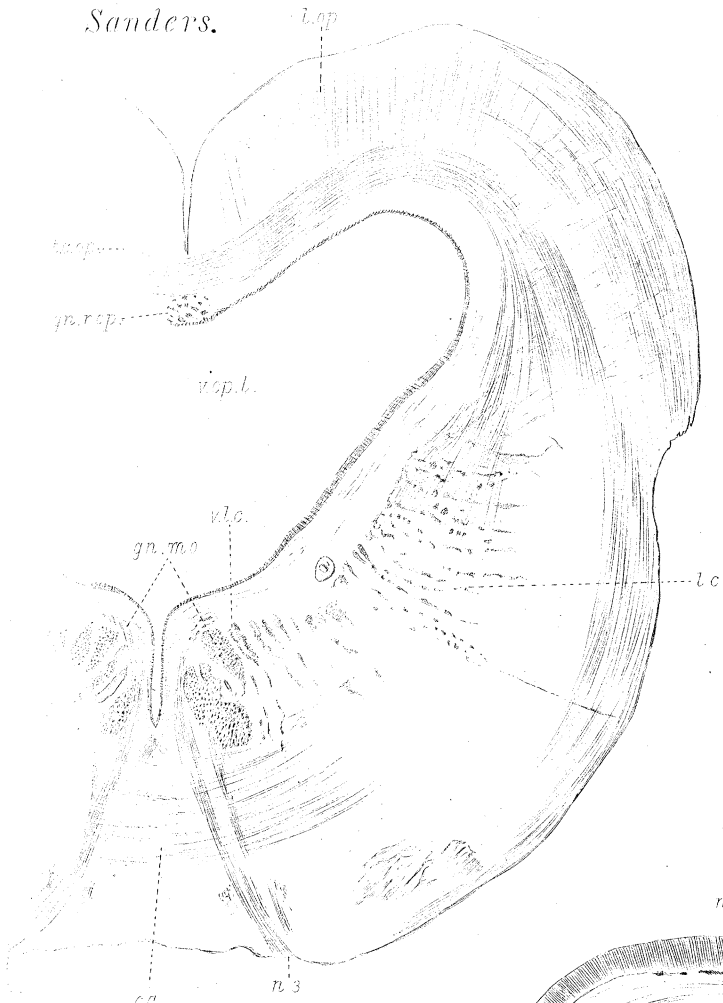
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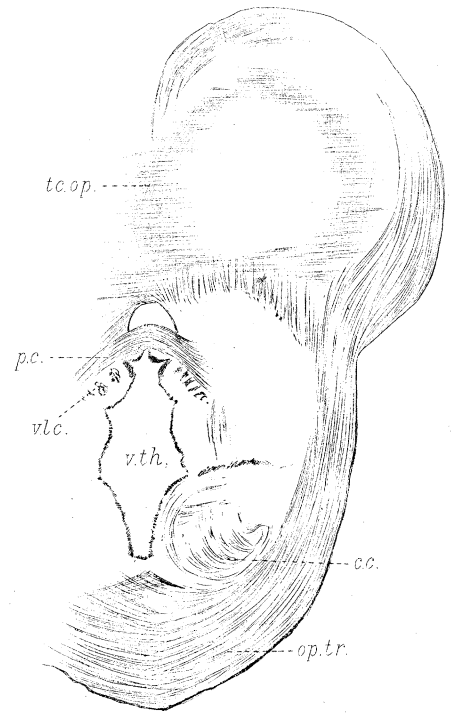
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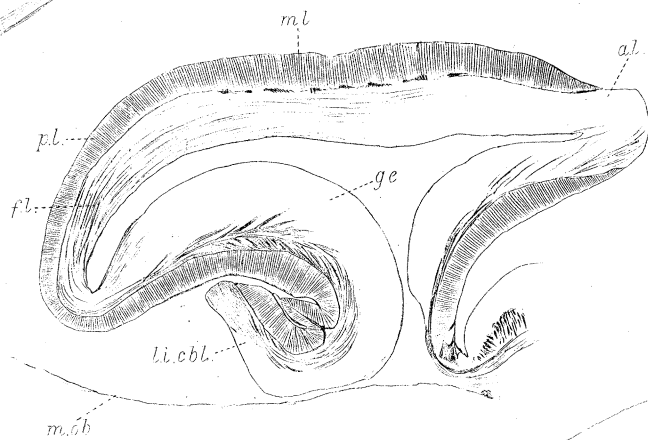
Fig 17

Fig 18.

Fig 19

Fig 20

Fig 21
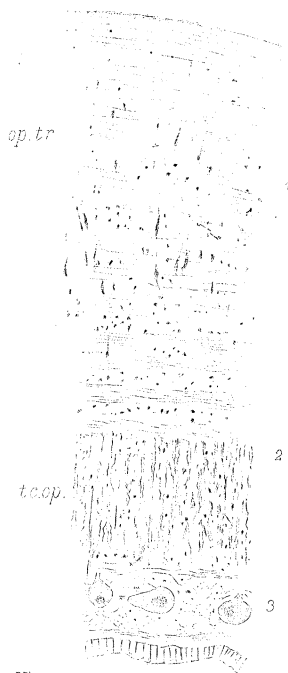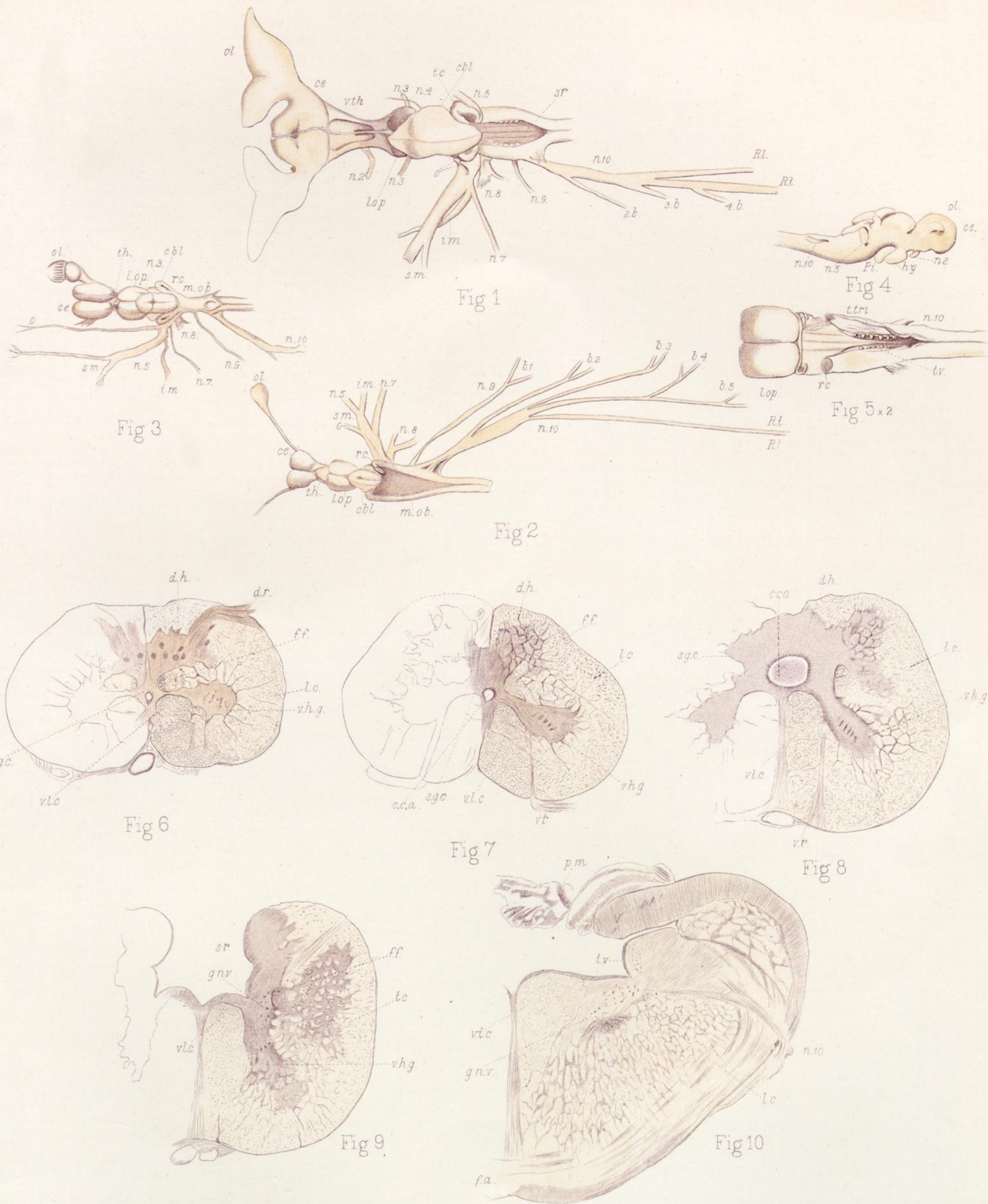
Fig 22

Fig 23.

PLATE 38.

Fig. 1. Dorsal view of the brain of Scyllium Catulus, the pia mater covering of the third and fourth ventricle removed. Natural size.

Fig. 2. Dorsal view of the brain of Rhina Squatina, showing part of the distribution of the cranial nerves. Pia mater not removed. Natural size.

Fig. 3. Dorsal view of the brain of Acanthias vulgaris. Pia mater not removed. Natural size.

Fig. 4. Side view of the brain of Acanthias vulgaris. Natural size.

Fig. 5. Dorsal view of the fourth ventricle and the optic lobes. Pia mater and cerebellum removed. × 2.

Fig. 6. Transverse section through the spinal cord of Rhina Squatina. × 22.

Fig. 7. Transverse section through the spinal cord of Rhina a little more in advance. × 22

Fig. 8. Transverse section through the spinal cord immediately behind the fourth ventricle. Rhina × 22.

Fig. 9. Transverse section through the posterior end of the Medulla oblongata. Rhina. × 22.

Fig. 10. Transverse section through the middle of the fourth ventricle. Rhina. × 22.
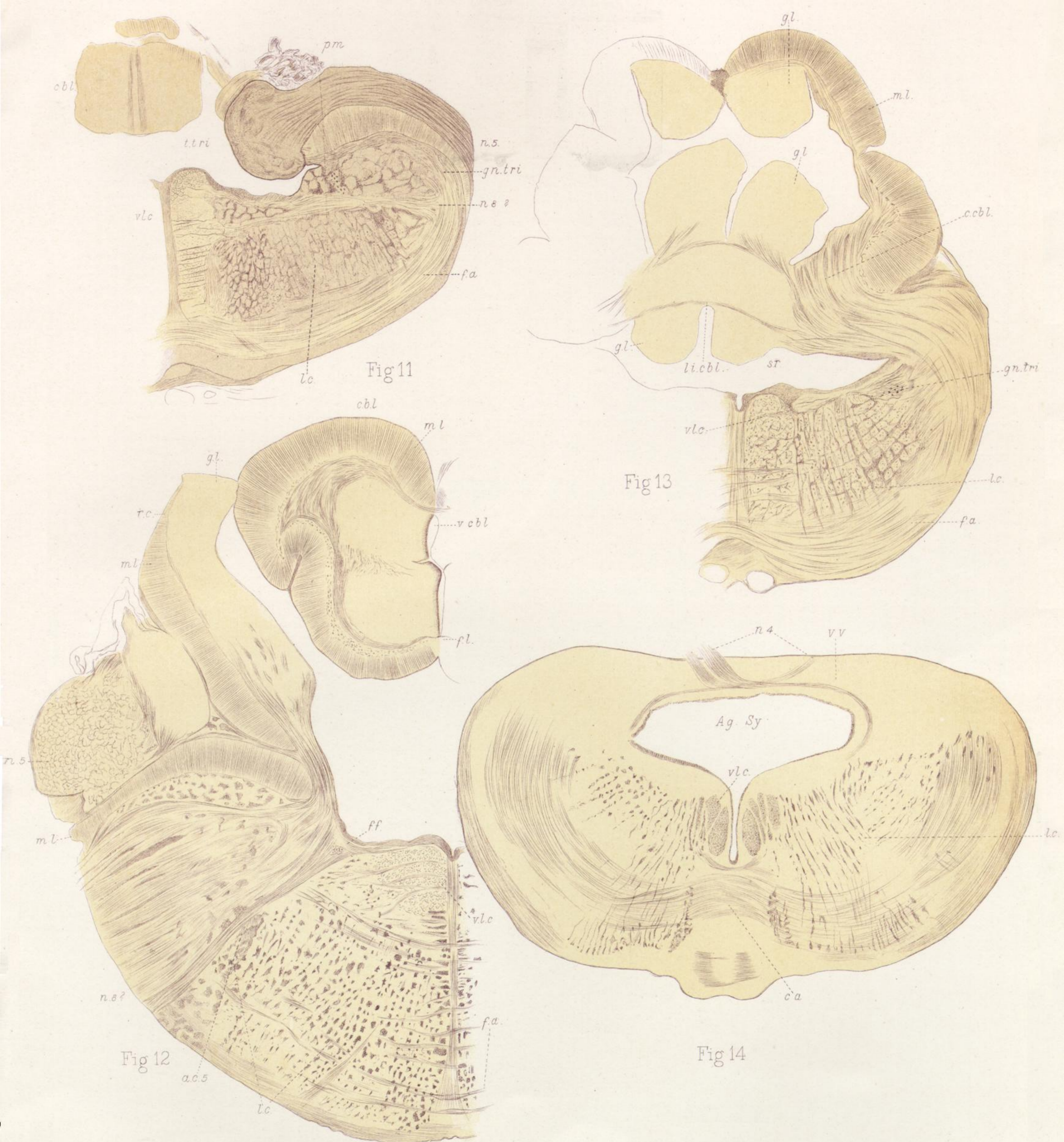
Fig 11

Fig 13

Fig 12

Fig 14

PLATE 39.

Fig. 11. Transverse section through the fourth ventricle at the posterior end of the
cerebellum. Rhina. × 22.

Fig. 12. Transverse section through the roots of the Acusticus. Raja Batis. × 22.

Fig. 13. Transverse section through the Crura cerebelli ad medullam. Rhina. × 22.

Fig. 14. Transverse section through the valvula cerebelli and the trochlear nerves,
at the transition of the fourth ventricle with the aqueduct of Sylvius.
Acanthias. × 22.

PLATE 40.

Fig. 15. Transverse section through the region of the oculomotorius nerve. Acanthias. × 22.

Fig. 16. Transverse section through the anterior end of the optic lobe and the posterior commissure. Acanthias. × 12½.

Fig. 17. Longitudinal section through the cerebellum. Scyllium. × 7.

Fig. 18. Longitudinal section through the mesencephalon and the third ventricle. Raja.
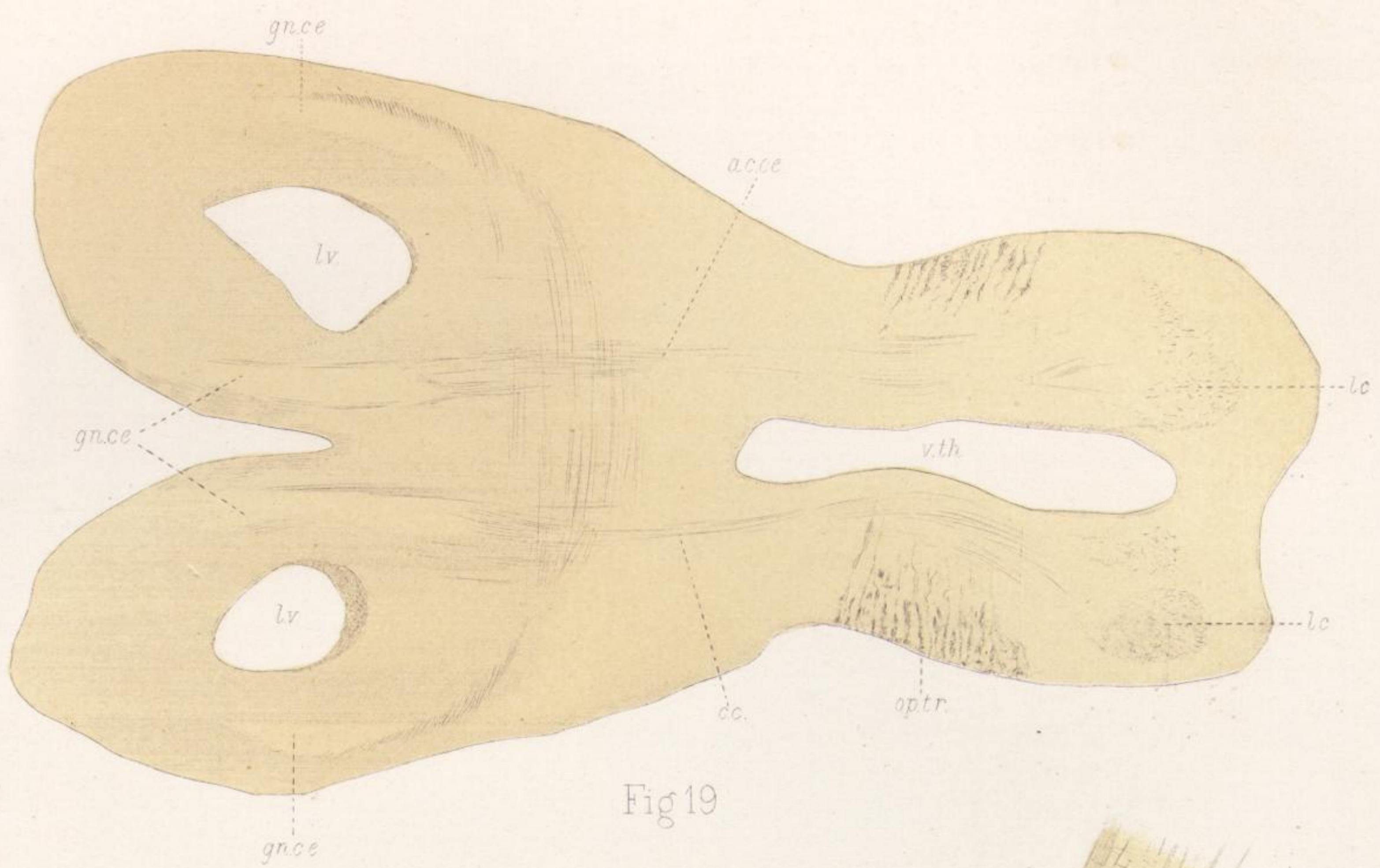
Fig 19

Fig 20

Fig 21

Fig 22

Fig 23.

PLATE 41.

Fig. 19. Horizontal section through the third ventricle and the base of the cerebrum. Acanthias. × 12½.

Fig. 20. Transverse section through part of the granular layer of the cerebellum. Acanthias. × 450.

Fig. 21. Section through part of the molecular layer of the cerebellum. Scyllium. × 450.

Fig. 22. Longitudinal section through part of the optic lobe. The section was composed from two separate pieces. Rhina. × 65.

Fig. 23. A glomerulus olfactorius and the adjacent part of the internal layer. Acanthias. × 325.