A CONTRIBUTION TO THE STUDY OF THE MORMYRID CEREBELLUM

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TWENTY-THREE FIGURES

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INTRODUCTION

The morphological investigation of the mormyrid brains was accomplished by Ecker (1854), Marcusen (1864), Oeffinger (1867), Sanders (1882) and Franz (1911), and also the detail of the expiration of fibers by Franz (1911, '13), Stendell (1914) and van der Sprenkel (1915). The development of the brain in Mormyridæ is far superior to that of most other bony-fishes. Such developmental gradients of the brain are distintly due to the excessive formation of the cerebellum which overspreads almost all the other cerebral parts.

The hypertrophied cerebellum of Mormyridæ has been often misinterpreted by various authors, that is to say, as a cerebral lobe (Erdel), strikingly developed corpora quadrigemina (Ecker) or a considerably hypertrophied nucleus nervi facialis (Marcusen). Sanders, for the first time, interpreted this organ as a well developed valvula cerebelli. Franz, however, divided this whole cerebellar lobe into two parts, such as the mormyrocerebellum and the ichthyocerebellum, and moreover stated that the mormyrocerebellum may not be homologized with the entire valvula cerebelli of Sanders, but only with the lobus lateralis valuvlæ. Also the ichthyocerebellum of Franz can be separated into both the corpus cerebelli and the valvula cerebelli as generally shown in the teleostean cerebellum.

The causal genesis of the cerebellar hypertrophy may not, however, be adequately satisfied in spite of its being the focus of all intentions.

It, therefore, seems desirable to present a somowhat detailed account of the mormyrid brain, especially the fiber systems in the cerebellum, and also to enter into discussion of the characteristic formation of the mormyrocerebellum of Franz through the microscopical observations in a number of specimens of several mormyrids.

Lastly, I am greatly indebted to Prof. Dr. K. Kudo, Manchuria Medical College, Mukden, for the opportunity to study his collection of serially sectioned mormyrid brains.

MATERIAL AND METHODS[1]

The material for this present report is consisted of stained and serially mounted sections of the brain of mormyrids which were prepared by Prof. Dr. K. Kudo as follows:

Petrocephalus bane (Lac.)

1) frontal plane 30 μ in thickness, stained after Weigert-Pal and Vitalscharlach VIII.
2) frontal plane 25 μ in thickness, stained by hæmatoxylin and eosin (serial sections of the whole of the head).
3) sagittal plane 30 μ in thickness, stained after Pal.

Mormyrus caschive (Hasselq.)

1) frontal plane 30 μ in thickness, stained by Van Gieson's picrofuchsin.

GROSS ANATOMY OF THE MORMYRID CEREBELLUM

The morphological description of the mormyrid cerebellum was well accomplished by V. Franz, but it is not applicable to every case.

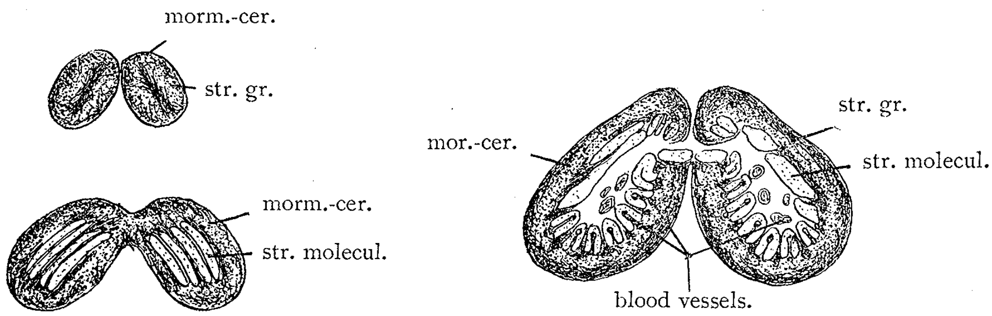
[1] I am much obliged for sending this valuable material to the Wellcome Tropical Research Laboratories at Khartom, for whose generosity I thank to the Director of the Labortories in this opportunity once more.

Most of the material was already cut and stained several years ago, but circumstances have not allowed me to take up the investigation myself. Fortunately Dr. N. Suzuki has consented to my offer to make use of the sections for his study of fish-brains and I am glad to see before me now this one of his contributions to the minute anatomy of the fish-brain.

K. Kudo, Mukden.

So that the somewhat varied formation of the cerebellum in these specimens be understood, it will be necessary to explain the fiber systems of the cerebellum.

In the most frontal segment[2], two ovoidal sections, consisting of the granular layer of the mormyrocerebellum (morm.-cer.) is symmetrically arranged. In this level, the thick and thin fibers are irregularly distributed and reciprocally intermingled, while some of them run somewhat diagonally to the dorso-ventralward and parallel with each other along the median line (fig. 1). When tracing caudally one finds that the molecular layer begins to appear and is surrounded by the granular



Petrocephalus bane

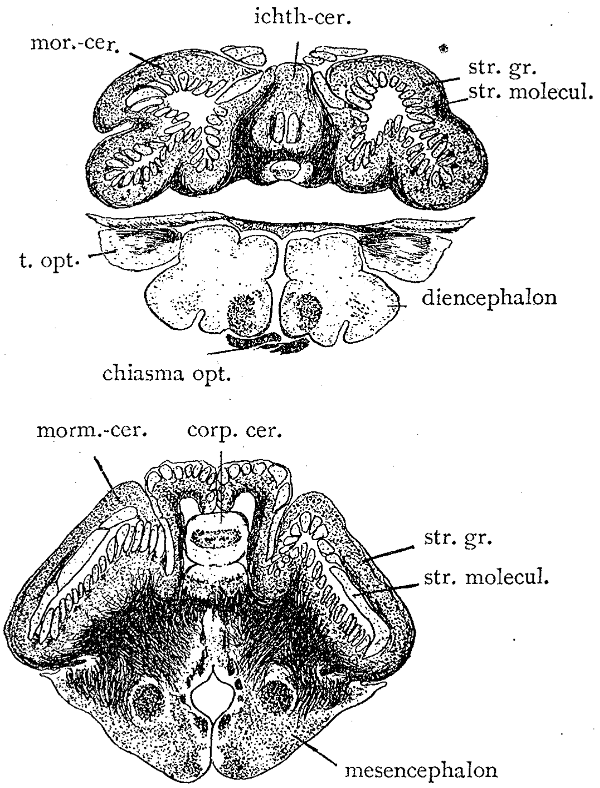
Fig. 1—Transection through the most frontal level of the mormyrocerebellum. (W. P. V. series 2). Fig. 2—Transection (10-th section). Fig. 3—Transection (46-th section).

layer (str. gr.) (fig. 2). The thick fibers are somewhat densely arranged in the layer of the Purkinje cells which lies between the molecular and the granular layers. Passing in a more caudal direction, the mormyrocerebellum shows a W-shaped fold in section view (fig. 3), so that the extraordinarily well developed and elongated cerebellar lobe seems to be folded back dorso-medially with the conversed arrangement of three cerebellar layers, such as the granular (outside), Purkinje cells (middle) and the molecular (inside). The inside molecular layer makes fine folds all over the inner surface which run longitudinally, and ar-

2 For convenience of description, the entire cerebellar body was put under three segments, the oral, middle and the caudal. The first segment consists of the serial sections from the most rostral part of the cerebellum to the most frontal level of the united or fusion area of the cerebellum and the mid-brain. The above mentioned united part of the cerebellum and the mid-brain may belong to the middle segment. The remaining posterior cerebellar body is treated as the caudal segment.

ranged like teeth of a comb in transection. Such a formation of folds of the molecular layer can continuously be traced to the caudal end of the cerebellum.

At the posteriormost level of the oral segment, the mormyrocerebellar lobe is divided into three lobules by the formation of folds in the lateral and ventral cerebellar wall (fig. 4). The lateral lobe of the mormyrocerebellum of Franz which was dorso-medially folded back is quite free from that of the opposite side with a a certain interval between them. At the middle segment, they keenly unite to each other and overspread the corpus cerebelli which is almost enveloped with the whole mormyrocerebellar lobe (fig. 5).

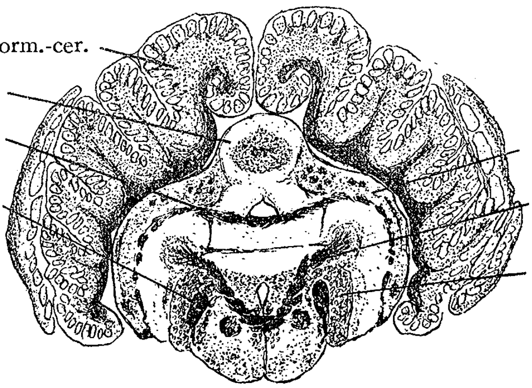


Petrocephalus bane

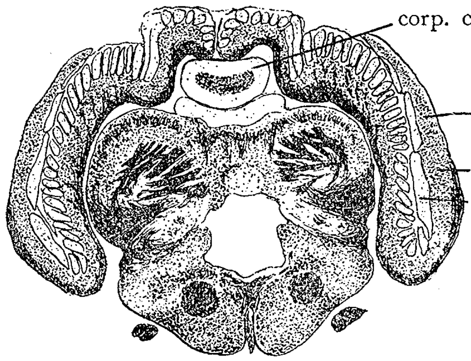
Fig. 4—Transection through the level of the chiasma opticum (W. P. V. series 178). Fig. 5—Transection through the united region of the cerebellum and the mid-brain (W. P. V. series 207).

From the middle segment to the caudal one, the ichthyocerebellum of Franz (ichth.-cer.) shows a normal development and also the identical type of the piscian cerebellum, while the mormyrocerebellum of Franz is gradually reduced in volume, and the lobus lateralis valvulæ is in contact with the dorsal margin on the mid-brain (fig. 6). In the most caudal region, the lateral mormyrocerebellar lobe hangs down ventro-laterally in a single plate (fig. 8).

In my own specimens, the appearance of the ichthyocerebellum and the mormyrocerebellum are almost identcal in priniciple, except for a certain variation. The mormyrocerebellar lobe in *Mormyrus* *caschive* folds in the more complex formation, compared with that of *Petrocephalus bane* (fig. 7).



Lastly, the rich and systematic distribution of the blood vessels in the space of the formation of the fold, or among the molecular ridges which are arranged like teeth of a comb, will be far more characteristically recognized in these specimens than in those of most other teleosts.



Petrocephalus bane

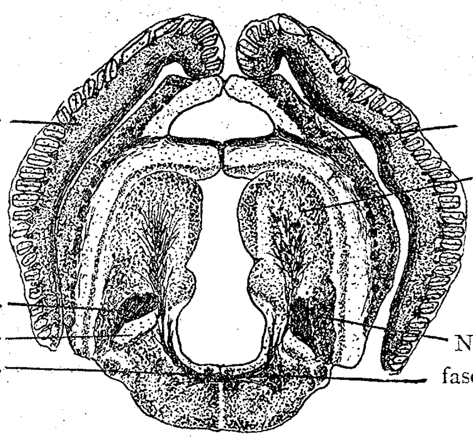
Fig. 6—Transection through the level of the fasciculus longitudinalis lateralis (W. P. V. series 303). Fig. 7—Transection through the caudal segment of the cerebellum (W. P. V. series 312).

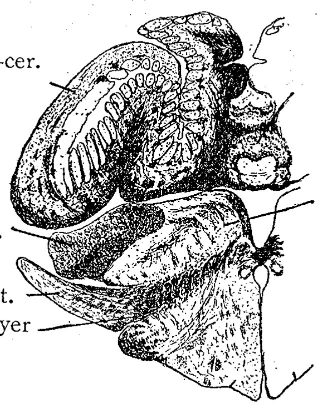
MINUTE ANATOMY OF THE MORMYRID CEREBELLUM

The fiber systems of the cerebellum are generally divided into two groups, such as the afferent and the efferent (Edinger and others). The efferent fiber system in Mormyridæ is recorded as follows: the tractus cerebello-præeminentialis, tractus cerebello-tegumento-bulbaris, and the tractus mormyrocerebello-thalamicus. And the following fiber bundles belong to the afferent systems: the tractus spino-cerebellaris or tractus bulbo-cerebellaris, tractus mesencephalocerebellaris, tractus tecto-cerebellaris, tractus diencephalocerebellaris and the tractus tegumento-mormyrocerebellaris.

A. THE AFFERENT FIBER SYSTEMS

1) The tractus mesencephalo-cerebellaris (tr. mes.-cer.); this tract is one of the chief afferent fiber bundles of the mormyrid cerebellum. In the oral segment, the fibers of this tract come out from the whole area of the ganglion mesencephali laterale (g. mes. lat.) which lies on the dorso-lateral part of the mid-brain in a large ovoid body consisting of the small cells. The fibers of this tracts, then run horizonto-caudally to the beginning level of the middle segment, being intermingled with the fine terminal fibers of the fasciculus longitudinalis lateralis (fasc. long. lat.) or the lemniscus lateralis which is considerably well developed in this specimen. In the posterior part of the oral segment, the ganglion mesencephali extro-laterale (g. mes. extrolat.) begins to appear on the dorso-lateral edge of the ganglion mesencephali laterale. This body consists of the thick and



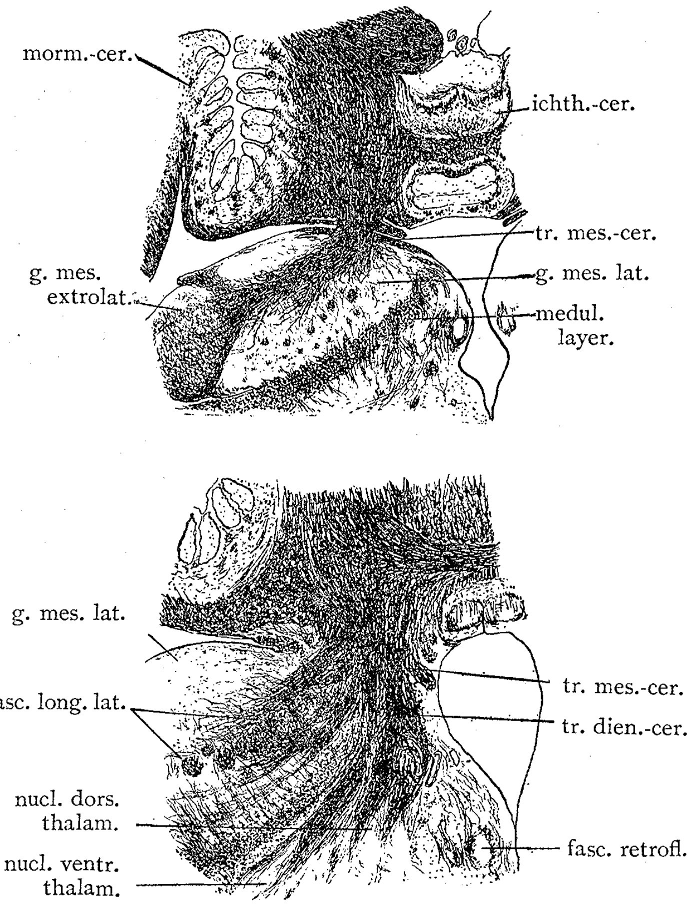


Petrocephalus bane

Fig. 8—Transection through the level of the lobi nervi laterales (W. P. V. series 432). Fig. 9—Transection through the level of the ganglion mesencephali laterale (W. P. V. series 228).

thin fibers being densely tangled with each other in Pal-carmine preparation (fig. 9).

At the frontal level of the middle segment, the fiber bundle of the tractus mesencephalo-cerebellaris efferent from the ganglion mesencephali laterale chiefly ascends dorso-medially showing a concave course, and ends without decussation in the maze of fibers of the medial granular layer situated between the mormyro- and ichthyocerebellum (fig. 10). In the more caudal part of the middle segment, the tractus mesencephalo-cerebellaris, consisting of the fibers of the ganglion mesencephali laterale et extrolaterale, ascends dorso-medially, and intersects with the thick fibers of the tractus diencephalo-cerebellaris at the transitional region of the mid-brain and the cerebellum. Some of the peripheral fibers of this tract changes its course medio-horizontally, intermingling with the ascending fibers of the tractus diencephalocerebellaris (tr. dien.-cer.), and soon radially ends in the granular layer of the opposite side, after the decussation with the fibers of the contra-lateral root



Petrocephalus bane

Fig. 10—Transection through the tractus mesencephalo-cerebellaris (W. P. V. series 233). Fig. 11—Transection through the level of the tractus diencephalo-cerebellaris (W. P. V. series 244).

(fig. 11). This course has not distinctly been indicated by Franz or Stendell. So, this fiber bundle does not only consist of the fibers efferent from the ganglion mesencephali extro-laterale as described by Franz or Stendell, but also from the ganglion mesencephali laterale. The tractus mesencephalo-cerebellaris in these specimens can not be considered the same as the tractus tecto-cerebellaris of Goldstein (tr. t.-cer.) in *Gadus*, or *Acipenser* by Johnston. Because, there is a sharp distinction between these two bundles (fig. 12).

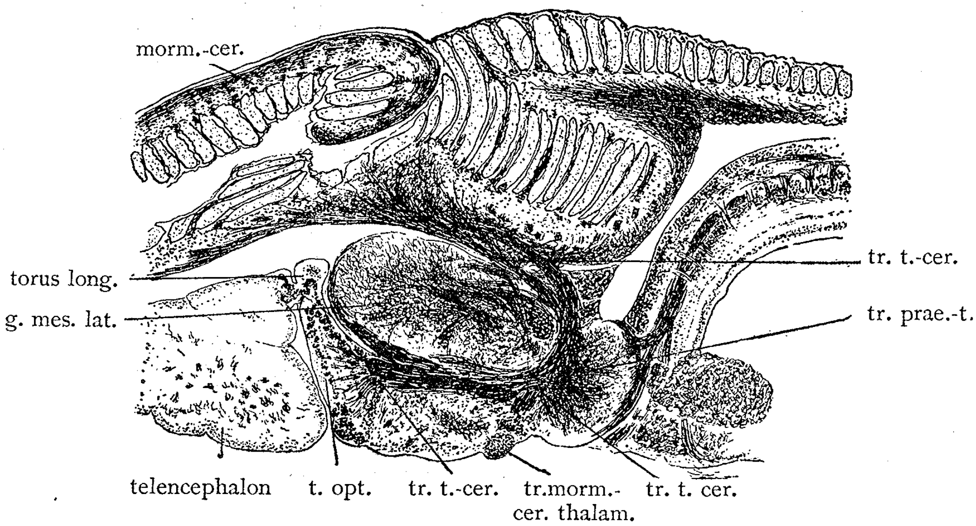


Fig. 12—Sagittal section through the median line in *Petrocephalus bane* (P. series 81).

2) Tractus diencephalo-cerebellaris (tr. d.-cer.); this is also a well developed tract with a typical expiration of fibers and is often known as the tractus cerebello-lobaris (Ariens Kappers). The greater part of the fibers, however, comes out from the nucleus ventralis thalami, and the remainder from the nucleus dorsalis thalami. Both of them immediately unite into a compact fiber bundle at the direct dorsal region of the nucleus dorsalis thalami (fig. 13), and then gradually ascend dorso-medially to the fusion area of the middle segment, curving a concave arc (fig. 14). Just at the entrance of this tract to the cerebellum, this fiber bundle is longitudinally pierced by the well-developed fiber bundle of the tractus tecto-cerebellaris (fig. 11). The somewhat twisted fibers of the tractus diencephalo-cerebellaris thus

run into the granular layer with the vertical course, being mixed with the fibers of the tractus mesencephalo-cerebellaris. The terminal fibers is missed not only in the basal region of the granular layer of the mormyrocerebellum as shown by Stendell, but some of them apparently expirate medio-transversally to the opposite side after the decussation in the median line (fig. 13).

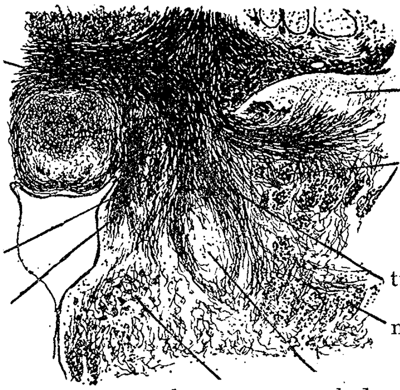


Fig. 13—Transection through the level of the tractus tegumento-mormyrocerebellaris in *Mormyrus caschive* (P. c. series 158).

3) The tractus tegumento-mormyrocerebellum (tr. teg.-morm.-cer.); the fiber of this tract, which was for the first time described by Franz, efferent from the nucleus prætegumentalis in a thick fiber bundle, ascends dorso-laterally curving a convex arc, along the dorsal ridge of the mid-brain, and then reaches the transitional region of the middle segment. The peripheral fibers terminate in the granular layer of the mormyrocerebellum in these specimens as shown by Stendell (fig. 13).

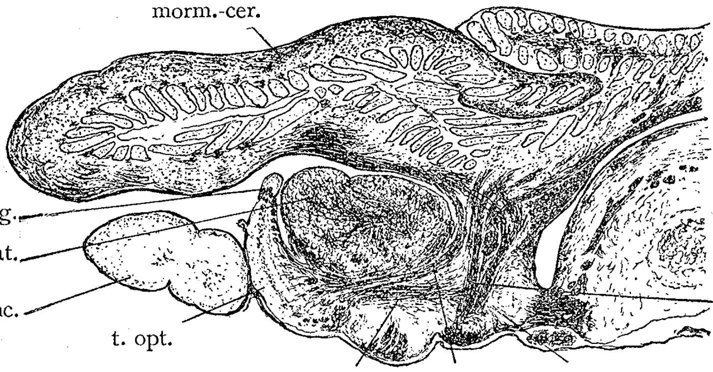
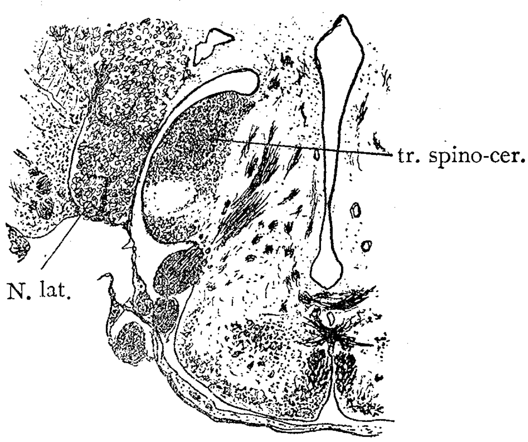


Fig. 14—Sagittal section through the level of the tractus tecto-cerebellaris in *Petrocephalus bane* (P. series 80).

4) The tractus tecto-cerebellaris (tr. t.-cer.); this tract was also described as the tractus mesencephalo-cerebellaris anterior by Goldstein in *Gadus* or Johnstone in *Acipenser*. In teleosts, this tract is generally shown as a short connective fiber bundle between the cerebellum and the mid-brain. In Mormyridæ, the fibers of this tract originate from the internal layer of the tectum opticum which is relatively ill-developed. This tract runs, for a while, horizonto-caudally and then ascends dorsally to the transitional part of the middle segment. In this region the fibers of this tract unite in a single thick fiber bundle (fig. 11 and 12), and then gradually expirate dorso-frontally along the dorsal margin of the mid-brain. Finally, the fibers of this tract radiate in the granular layer of the mormyrocerebellum (fig. 12). In this sagittal section it can distinctly be observed that the fibers of this tract in the beginning of the fiber-expiration are intermingled with the fibers of the tractus præ-eminentio-tectalis.

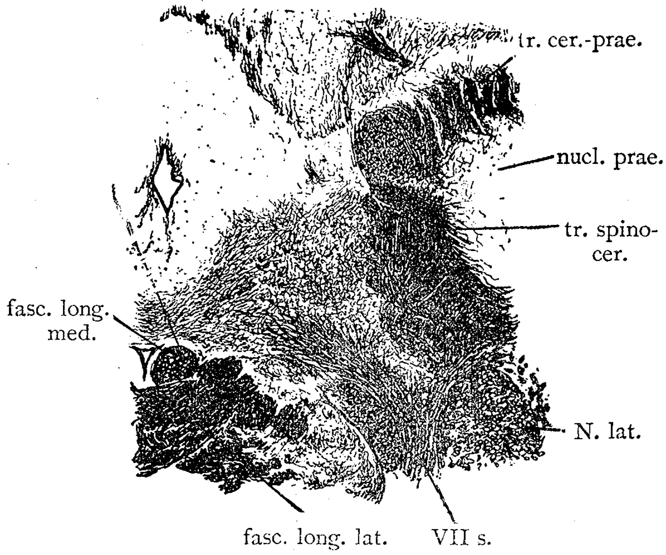
5) The tractus spino-cerebellaris or tractus bulbo-cerebellaris (tr. spino.-cer.); this fiber bundle is considerably well developed. It appears in a thick fiber bundle at the dorso-lateral summit of the medulla

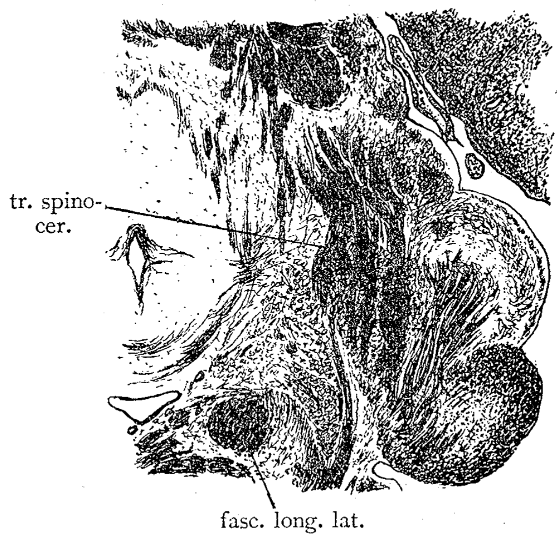


Mormyrus caschive

Fig. 15—Transection through the level of the tractus spino-cerebellaris (P. c. series 269). Fig. 16—Transection through the level of the fasciculus longitudinalis lateralis (P. c. series 275).

oblongata or almost at the identical region of exite of the nervus vagus (fig. 15). This tract gradually goes up dorso-medially along the nervus lateralis which is especially well developed in Mormyridæ (fig. 15). Passing in a more frontal direction, the thick fiber bundle by and by takes the dorso-frontal expiration, and then meet with the intermittent pieces of the thick fibers of the tractus cerebello-præeminentialis (tr. cer.-prae.) (fig. 17). In the eminentia granularis, the intermittent fiber bundles of the tractus spino-cerebellaris take a vertical course to the dorso-medial district of the corpus cerebelli (fig. 18). Finally, this fiber bundle decussates with the fibers of the contra-lateral root on the vertex of the tegumental eminence or at the frontal level of the tractus mormyrocerebello-mesencephalicus (fig. 18).





Mormyrus caschive

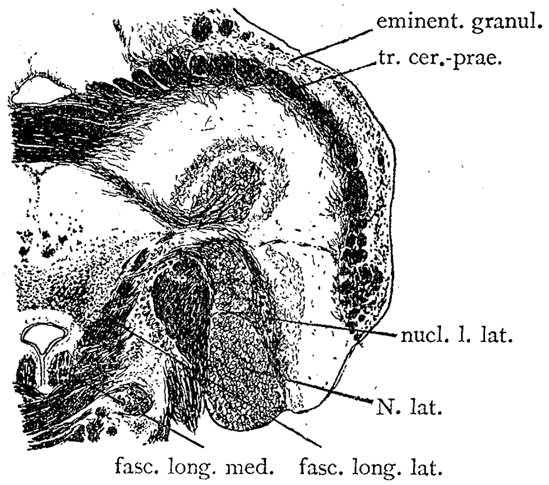
Fig. 17—Transection through the level of the entrance of the sensory facial nerve (P. c. series 215). Fig. 18—Transection through the level of the ascending fibers of the tractus spino-cerebellaris (P.c. series 207).

The running course of the tractus spino-cerebellaris in *Mormyrus caschive* or *Petrocephalus bane* most likely appears as the description made by Stendell or Franz. The tractus olivo-cerebellaris which is generally efferent from the nucleus oliva inferior and goes into the cerebellum with the fibers of the tractus spino-cerebellaris cannot be well-defined in these specimens as shown by Ariens Kappers in Siluridæ (Arius).

B. THE EFFERENT FIBER SYSTEMS OF THE MORMYRID CEREBELLUM

In fishes, the afferent fibers of the cerebellum are usually far superior to those of the efferent (Goldstein, Ariens Kappers and others), while the reverse can be noticed in Mormyridæ. The efferent fiber bundles in Mormyridæ are the tractus cerebello-præeminentialis, tractus cerebello-tegumento-bulbaris, tractus cerebello-tegumento-mesencephalicus, tractus mormyrocerebello-mesencephalicus and the tractus mormyrocerebello-thalamicus.

1) The tractus cerebello-præeminentialis (tr. cer.-præ.); the original fibers of this tract can be seen everywhere in the middle layer of the eminentia granularis. This short and thick fiber bundle which is remittently distributed runs medio-



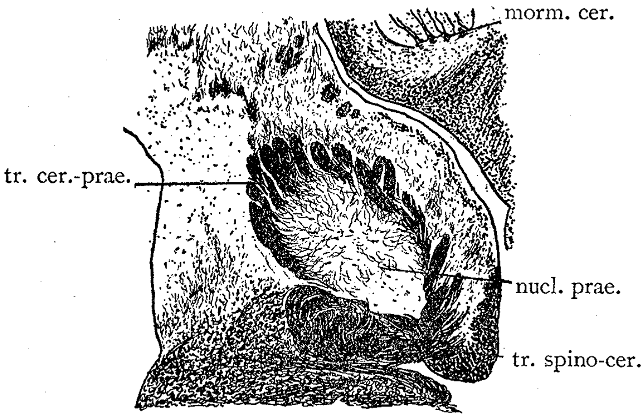


Fig. 19—Transection through the level of the tractus cerebello-praeeminentialis in *Mormyrus caschive* (P. c. series 239). Fig. 20—Transection through the level of the nucleus præeminentialis in *Petrocephalus bane* (W. P. V. series 353).

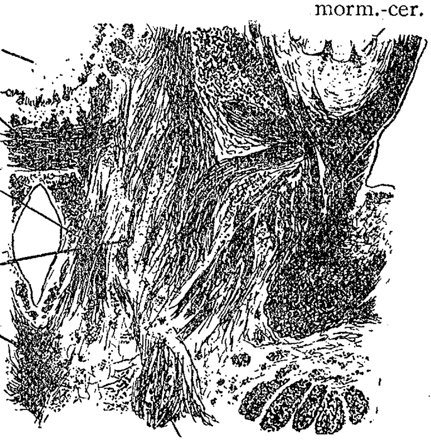
horizontally, and gradually increases its content of fibers when one traces frontalward, and finally decussates with the contralateral root on the medio-dorsal tuberosity of the frontal section of the eminentia granularis (fig. 19). The intersected fiber bundles, moreover, descend somewhat ventro-laterally to the front, and then terminate in the peripheral area of the nucleus præeminentialis (fig. 20). Some fibers of this tract, however, terminate in the opposite middle layer of the eminentia granularis. The tractus cerebello-præeminentialis was erroneously described by Franz as the commissura vestibulo-cerebellaris, and the appearance of the fiber-expiration of this tract can not always be true in every case as described by Stendell in Mormyridæ. The reference of this kind can be quite distinctly explained in the sagittal section in my own preparation (fig. 12). In the same section, it seems that the tractus præeminentio-tectalis which has an intimate relation with the tractus cerebello-præeminentialis efferent from the nuelcus præeminentialis (nucl. præ.) takes a frontal course having a slight concave arc, while the greater part of the fibers terminate in the inner layer of the tectum opticum. Some fibers of the tractus præeminentio-tectalis, however, run into the peripheral zone of the ganglion mesencephali laterale, contrary to the suggestion made by Stendell.

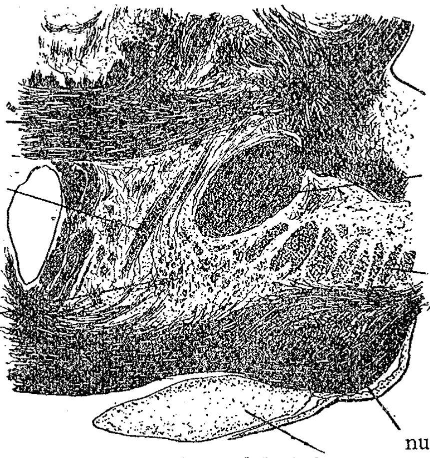
2) The tractus cerebello-tegumento-bulbaris (tr. cer.-teg.-bulb.); the fibers of this tract emanate from the whole of the corpus cerebelli, especially from its granular layer and the layer of the Purkinje cells, but the source of these fibers cannot be distinctly determined as stated by Ariens Kappers. This fiber bundle is composed of the two kinds of fibers efferent from the lateral side of the corpus cerebelli and from the granular layer of the mormyrocerebellum. The fiber bundle descends ventro-caudally and the greater part of them decussates in the upper region of the ganglion interpedunculare or lower region of the fasciculus longitudinalis medialis, and the other ends in the nucleus reticularis without the decussation.

3) The tractus cerebello-tegumento-mesencephalicus (tr. cer.-teg.-mes.); this tract is also made up of fibers efferent from the middle layer of the corpus cerebelli. The remittent fibers of the tractus cerebello-tegumento-mesencephalicus descend caudo-ventrally to

the somato-motorial area of the mid-brain along the ventricular wall. The greater part of fibers decussate at the somewhat fronto-ventral region of the fasciculus longitudinalis medialis or the dorsal area of the beginning of the ganglion interpeduculare. Some of them run caudo-ventrally and end in the nucleus reticularis or the special cell-group (fig. 21). The fibers of the tractus cerebello-tegumento-mesencephalicus cruciatus, after the decussation, respectively terminate in the nucleus reticularis, the nucleus ruber tegumenti or in the commissura ansulata (fig. 22).

4) The tractus mormyrocerebello-mesencephalicus (tr. morm.-cer.-mes.); this tract is a strong fiber bundle which connects the cerebellum, especially the mormyrocerebellum and the mid-brain. The greater part of fibers will be efferent from the broad area of the granular layer of the mormyrocerebellum, probably from the layer of the Purkinje cells. These fibers descend ventro-medially being





Petrocephalus bane

Fig. 21—Transection through the level of the tractus cerebello-tegumento-mormyrocerebellaris (W.P.V. series 271). Fig. 22—Transection through the level of the tractus cerebello-tegumento-bulbaris (W. P. V. series 277).

gathered into a single broad bundle of fibers at the transitional region of the middle segment (fig. 22). After intersecting with the contra-lateral root on the dorsal region of the ventricle, these fibers cross to the opposite side and distribute in the maze of fibers or perhaps in the homologized area of the nucleus lateralis cerebelli of the reptilian cerebellum. With the more caudal tracing, one part of them consisting of the thick fibers terminate in the dorso-medial summit of the ganglion mesencephali laterale (fig. 22), but it is doubtful if it may be introduced into this ganglion as shown by Stendell.

5) The tractus mormyrocerebello-thalamicus (tr. morm.-cer. th.); this fiber bundle may probably have the same origin with that of the above-mentioned tract. This tract is a strikingly well developed connective fiber bundle between the mormyrocerebellum and the thalamus (fig. 14). In the middle segment, this tract descends caudo-ventro-medially along the basal region of the mid-brain (fig, 23) in a number

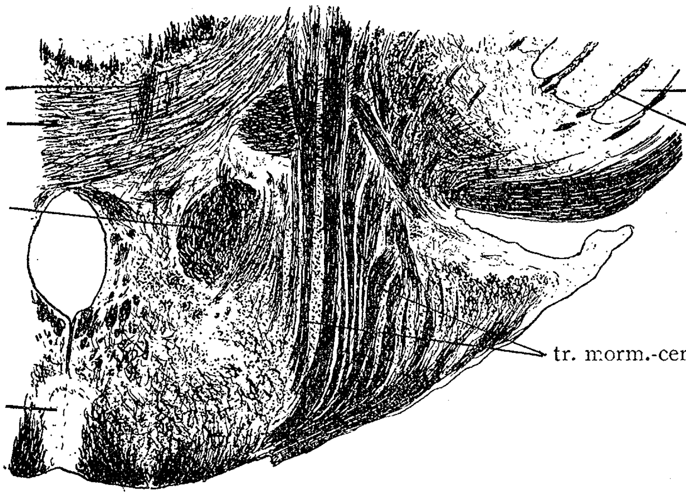


Fig. 23—Transection through the level of the tractus mormyro-cerebello-thalamicus in *Petrocephalus bane* (W. P. V. series 288).

of fiber bundles which are parallel to each other. Some of them are missed in the thalamus, while the greater part of fibers run medio-horizontally with the compact fibers of the commissura ansulata, and then terminate in the nucleus postventralis thalami of Stendell, after the decussation with the fibers of the contra-lateral root at the frontal level of the ganglion interpedunculare (figs. 22 and 23).

C. SOME NOTICEABLE FEATURES

The two strong fiber systems in the medulla oblongata in Mormyridæ, the nervus lateralis and the fasciculus longitudinalis lateralis or lemniscus lateralis are worthy of attention.

1) The fasciculus longitudinalis lateralis (fasc. long. lat.); the origin of this tract may lie in the lobus n. lateralis as shown by van der Sprenkel and Stendell. The fibers at first descend vertically to the dorsal level of the tractus spino-cerebellaris being fused into a thick fiber bundle (fig. 8). This azygos bundle then changes its course ventro-medio-frontally along the ventricular edge, until it decussates with the contra-lateral root beneath the fasciculus longitudinalis medialis (figs. 8 and 16). The greater part of them, after the decussation, run frontally and then somewhat latero-dorsally. The part of this fiber bundle is plainly found to end in the ganglion mesencephali laterale, and some of them in the ganglion mesencephali extro-laterale (figs. 11 and 13.) Some fibers of this tract, however, can be noticed to terminate in the nucleus præeminentialis (fig. 19), while Stendell uncertainly suggested this fiber-expiration in Mormyridæ.

2) The nervus lateralis (N. lat.); the most remarkable structure in the medulla oblongata of these specimens is the special development of the nervus lateralis missunderstood as the nervus facialis by Franz and others. In these specimens, the nervus lateralis is distintly divided into two groups in the total-sectioned preparation, such as the ramus anterior and the posterior. The fiber-expiration of the nervus lateralis anterior which shows a complex fiber bundle with the ascending fibers of the nervus vestibularis and the facialis enters farthest frontally as described by van der Sprenkel. There is the considerable difference between the nervus lateralis and the nervus facialis, while the former and the nervus vestibularis are difficult to differentiate. The fibers of the nervus lateralis anterior thus ascend dorso-medially in order to terminate in the dorsal gray substance of the lobus n. lateralis.

The nervus lateralis posterior which is far superior to the ramus anterior enters the bulb farthest laterally in the considerably frontal level of the caudal segment (fig. 19), and then the majority of the fibers ascend dorsally to the lobus n. lateralis as a very large coarse-fibered tract (fig. 16), while some terminate in the bulb. The detail of this fiber-expiration was adequately explained by van der Sprenkel.

3) The visceral sensory facial nerve is rather poorly developed in Mormyridæ; its delicate fibers apparently enter the bulb at the medial side of the nervus acusticus consisting of the coarse fibers as already described by van der Sprenkel and Stendell (fig. 17).

SUMMARY DESCRIPTION

The results obtained by the present work may briefly be summarized as follows:

1) The mormyrid cerebellum is extraordinarily well-developed, so this organ may just recall the cerebral lobe of the mammals which overspreads the remaining parts of the brain. The latetal lobe in the mormyrocerebellum of Franz or the lobi laterale valvulæ shows a far greater complex structure as denoted by Franz or Stendell. The lateral lobe, therefore, folds back dorso-medially with the reversed arrangement of the three mormyrocerebellar layers, such as the granular (outside), Purkinje cells (middle) and the molecular layer (inside). The formation of fold in the lateral lobe of the mormyrocerebellum is simple in the oral segment, complex in the middle and more caudally gets into a simple structure. The mormyrocerebellar layer is radially and longitudinally arranged with so many ridges of the molecular layer, that it forms teeth of a comb in transection. The structure of the mormyrocerebellum is relatively complex in the specimen of *Mormyrus caschive* in comparison with that of *Petrocephalus bane*.

2) In these specimens, the middle larger blood vessels on the space of fold, or among the molecular ridges are rather more plentifully and systematically distributed than those of the other piscian species.

3) The afferent fiber systems are superior to those of the efferent in Mormyridæ, while the reversed condition of the cerebellar fiber systems is generally found in teleosts.

4) The tractus mesencephalo-cerebellaris which is a chief fiber bundle between the cerebellum and the ganglion mesencephali laterale et extro-laterale is relatively well developed in this specimen. The

fibers of this tract take a general expiration as shown by Franz or Stendell, but this fiber bundle consists not only of the fibers efferent from the ganglion mesencephali extro-laterale as described by Stendell, but also from the ganglion mesencephali laterale which end radially in the granular layer of the opposite cerebeller lobe, after the decussation with the contra-lateral root. This fiber bundle is not proved to be the same as the tractus tecto-cerebellaris of Goldstein in *Gadus* or of Johnstone in *Acipenser*.

5) The tractus diencephalo-cerebellaris which is a well developed afferent fiber bundle is made up of two kinds of fibers efferent from the nucleus ventralis thalami and the nucleus dorsalis thalami. Although the expiration of fibers takes the general form, the terminal fibers may never be missed only in the basal region, but some of them apparently pass through the granular layer medio-transversely to the granular layer of the opposite side.

6) On the tractus tegumento-mormyrocerebellaris, there is no characteristic change in the fiber expiration.

7) The tractus tecto-cerebellaris takes the general course of afferent fibers from the internal layer of the tectum opticum. The fibers of this tract in its beginning are tangled with the thick fibers of the tractus præeminentio-tectalis.

8) The tractus spino-cerebellaris appears in a thick fiber bundle at quite the same level of exit of the nervus vagus and gradually goes up dorso-medio-frontally with the nervus lateralis to the cerebellum. This fiber bundle takes the general course of fibers in Mormyridæ. The tractus olivo-cerebellaris which is generally efferent from the nucleus oliva inferior and goes with the fibers of the tractus spino-cerebellaris into the cerebellum cannot be recognized in these specimens as shown by Ariens Kappers in Siluridæ.

9) The tractus cerebello-præeminentialis was incorrectly described by Franz as the commissura vestibulo-cerebellaris. The fiber-expiration of this tract can not always be applied in every case as shown by Stendell. The considerable development of the tractus præeminento-tectalis shows the intimate relation with the tractus cerebello-præeminentialis. Some fibers of the tractus præeminentio-tectalis run into

the peripheral zone of the ganglion mesencephali laterale, contrary to the conclusion of Stendell.

10) The greater part of the tractus cerebello-tegumento-mesencephalicus efferent from the middle layer of the corpus cerebelli descends caudo-ventrally to the somato-motorial area of the mid-brain along the ventricular wall. The fibers of the tractus cerebello-tegumento-mesencephalicus cruciatus respectively terminate in the nucleus ruber tegumenti and in the commissura ansulata.

11) Both tracts of the tractus mormyrocerebello-mesencephalicus and thalamicus have the same origin in the cerebellum, probably in the whole area of the layer of the Purkinje cells of the mormyrocerebellum. The greater part of the tractus mormyrocerebello-mesencephalicus terminates in the maze of fibers in the confused area of the nucleus lateralis cerebelli of the opposite side, after the decussation at the dorsal region of the ventricle, while some of them terminate in the dorso-medial summit of the ganglion mesencephali laterale. But it is doubtful if it may be introduced into this ganglion as shown by Stendell. The fibers of the tractus mormyrocerebello-thalamicus have the most characteristic course. This tract, therefore, descends caudo-ventro-medially along the basal region of the mid-brain in the several group of fiber bundles which are parallel with each other. Some of the mend in the thalamus and the greater part of fibers terminate in the nucleus postventralis thalami of Stendell with the dense fibers of the commissura ansulata, after the decussation at the frontal level of the ganglion interpeduculare.

12) On the excessive development of the fasciculus longitudinalis lateralis and the n. lateralis and also on the special fiber expiration of both fiber bundles in the bulb, these are probably in accord with the description made by van der Sprenkel, excepting some of the termination fibers of this tract fasciculus longitudinalis, namely, the fine fibers of this tract apparently enter the nucleus præeminentialis in opposition to van der Sprenkel.

According to my own results briefed above, they are in most respects, more satisfactorily in accord with the statements made by van der Sprenkel and Stendell in comparison with those of Sanders and Franz.

Contrary to the normal condition in teleosts, the efferent fiber systems of the mormyrid cerebellum are rather well developed than those of the afferent, especially strong in the tractus mormyrocerebello-thalamicus et mesencephalicus. The most remarkable feature of these tracts may be probably due to the secondary connection of the excessive enlargement of the layer of the Purkinje cells in which the fibers of these bundles have their root. The sensory systems of the branchial nerves are generally ill developed as shown by van der Sprenkel, but the nervus lateralis, especially the ramus posterior, is extraordinarily well developed in these specimens.

The greater development of the nervus lateralis posterior, which was misinterpreted by Franz and Sanders as the n. facialis, has been suggested by van der Sprenkel to have the intimate correlation with the excessive hypertrophy of the lobi laterales valvulæ in Mormyridæ, and also the primary center of this nerve may be related to the cerebellar development. Van der Sprenkel, moreover, has noticed the occurrence of the special glandular sense organ in the lip and ascertained the positive correlation to the development of the mormyrocerebellum. In my own total-sectioned preparations of the head, such a sense organ innervated by the ramus anterior nervi lateralis can also be found. The n. lateralis anterior, however, is far inferior to the posterior, so it is probably premature to state definitely that this organ is closely correlated to the hypertrophied mormyrocerebellum, and also that it belongs to the group of the acustico-lateral organ.

The development of the n. lateralis which has the intimate relation with the somatic sensibility and the fasciculus longitudinalis lateralis which is the secondary tract of the n. lateralis may, in fact, have the intimate correlation to the excessive development of the lobus n. lateralis. The considerable development of the tractus spino-cerebellaris which probably has the cervical sensibility as in Triglidæ and Lophiidæ (Ariens Kappers) may also be in some correlation.

Despite the fact that the excessive hypertrophy of the mormyrocerebellum has the greater correlation to the special development of the lobus n. lateralis, due to the secondary and tertiary connections of the n. lateralis (Stendell and van der Sprenkel), there is a considerable interval between this characteristic structure and the causal genesis of the cerebellar hypertrophy.

The valvula cerebelli of teleosts has in general, a various developmental gradient in species, and the dimension of the teleostean cerebellum is partly due to the effect of the pressure of skull among the larval stages as the suggestion made by Ariens Kappers (1908) in *Gadus*, Selachians, *Galeus*, *Hexanchus* and others.

Besides, the considerable development of the tractus mesencephalo-cerebellaris with the well developed ganglion mesencephali laterale et extro-laterale, the strong feature of the tractus diencephalo-cerebellaris and also the plentiful supply of blood in the mormyrocerebellum of Franz may have some positive correlation to the cause of this cerebellar hypertrophy.

Resuming the general observations on the entire course of this work, the writer suggests that the explanation of the frontal and then the total enlargement of the mormyrid cerebellum is as follows: the anlage of the cerebellum may perhaps be situated more frontalward in the early larval stage, and at the same time, the excessive formation of the cerebellum, especially in the mormyrocerebellum of Franz, under the condition of the considerable reduction of the visual apparatus in bottom feeders, may have occurred accompanied by the special development of the correlated fiber tracts in secondary and tertiary connections.

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