ON THE STRUCTURE OF THE BRAIN IN SOME ENGYSTOMATID FROGS.

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1. Introduction.

Though the nervous system of anuran amphibia has been the subject of a large number of memoirs, there are several points of interest in the anatomical features of the brain of these narrow-mouthed burrowing frogs which have not been noted before. In a previous communication on the subject of Conus Arteriosus, attention has been drawn by the writer to the peculiarities in the mode of origin of the principal arches in Microhyla and Ramanella* which differ from those of Rana and Bufo. These peculiarities do not, however, characterize the entire family of Engystomatidae. On an examination of the brain of the former two genera one finds the occurrence of characters which distinguish them from the other South Indian forms, and in most respects they do not appear to have been recorded till now in any amphibian. In a few directions they cross the path of Gymnophiona and in a few others, the Urodela but in most respects the features seem to be peculiar to the two genera, as, for example, the extent and disposition of Corpora Striata, which is a combination of piscine and amphibian characters. Moreover the

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* Dr. Malcolm Smith treats this genus as synonymous with Kaloula and is of opinion that an examination of all the known species of Kaloula would be necessary before Ramanella could be established as a distinct genus. In this paper I am retaining the name Ramanella.
extremely variable nature of most of these features within the limits of a single species must point to a more archaic and generalized position occupied by these two genera.


The following genera of the Engystomatid family have been examined:— *Microhyla ornata*; *M. rubra*; *Ramanella symbiotica*? (Kaloula variégata) and *Cacopus systoma*. For purposes of comparison the brain of *Rana tigrina*, *R. hexadactyla* and *Bufo melanostictus* has also been sectioned. The larvae of all these forms except *R. symbiotica* have been utilized for the purpose of tracing the development of such characteristics as occur in the adults selected for study.

In almost every case the adult brains and the tadpoles were fixed in Bouin’s picro-formol followed by Iron-alum and Eosin. The sections have been photographed for lantern slides and camera lucida tracings have been made. Serial drawings have been used for the purposes of reconstructions which have enabled the tracing of the actual relations of the parts under investigation. Bielschowsky’s Method (DaFano’s modification) has been employed to investigate the paths of the nerve fibrils in the adult brains of *Microhyla* and *Ramanella*.

3. The Structure of the Brain.

I shall now proceed to record some of the exceedingly interesting features in the adult brain of *Microhyla* and *Ramanella* for which there is hardly any parallel among the amphibia. There is a fairly complete literature on the subject of amphibian brain cited by Susanna Phelps Gage in her monograph on the Brain of Diemyctilus viridescens and none of the amphibia seem to possess these characters. More than *Ramanella*, *Microhyla* is widely variable and in the course of the following description, the limits of variations will also be indicated.

*The Brain of the Adult.*—Even in general outline and relative proportions of the different parts, the Engystomatid brain differs from that of *Rana*. The olfactory lobes are divided deeply on the ventral surface by a deep median groove, while the dorsal aspect is nearly flat, and the division of the cerebral lobes into two halves is superficial and is not pronounced.
Text Fig. 1 is a free-hand drawing of the surface view of the brain of *R. tigrina* (A) and of *Cacopus* (B) and it will be noticed that the posterior portions of the hemispheres in the latter case extend backwards till they embrace the optic lobes and the consequent greater divergence of the cerebrum in this region exposes a more extensive area of the twixt brain. It will be further noticed that the cerebellum is not confined to a narrow bridge of transverse tissue, but is produced in the median line into a definite lobe which lies over the choroid plexus investing the fourth ventricle. On the dorsal aspect
of the diencephalon, there is a parapineal body. In Ramanella, the pituitary apparatus is extraordinarily developed and underlies the whole of the ventral surface of the middle brain and is solid.

The Cerebral and Olfactory Lobes.—In the Engystomatidae as a rule, the olfactory lobes are solid and the rhinosep is abolished. In other respects the brain of Cacopus resembles that of Rana and Bufo which conform to the description given by Ecker for Rana temporaria and therefore I do not propose to make any comment on them in the following paragraphs which will deal exclusively with Ramanella and Microhyla. In these genera and even in Cacopus the olfactory lobes which arise superficially are short and dorso-ventrally compressed and at the anterior end terminate in small rounded bulbs. The olfactory nerves have dorsal and ventral origins, the discs at the base of the latter are inconspicuous in Cacopus but absent from Microhyla and Ramanella.

Text Fig. 2 is a transverse section of the olfactory lobes of Ramanella where they are united together, though the bulbs in front are divided by a deep and broad groove, whose extension in the caudal end partially divides the lobes also.

Text Fig. 2.

Camera Lucida tracing of the transverse section of the Olfactory Lobes near the transverse sulcus of Ramanella. The solid nature is noticeable.

C.—Fibre tracts. Kg.—Koppen’s Glomeruli.
Each lobe bears on its dorsal margin on either side of the dorso-median fissure, a large number of nuclei and fibres which are prominently developed in the left half, which are deeply affected by the stain, but the outlines of the cell membranes are not easily made out. These nerve tracts from which the dorsal roots of the olfactory nerves arise, form conspicuous swellings behind and are continued on to the surface of the head end of the hemispheres. The entire substance of the rest of the rhinencephalon is composed of fine fibrils and granules of which the larger bodies are aggregated towards the middle and the finer to the peripheral regions. In Fig. 2 which is a transverse section of the olfactory lobes, both on the dorsal and ventral aspects, are seen large, dark-looking cell aggregations which represent "Koppen's glomeruli" composed of fibrils also. These are conglomerates of fibrils and nerve cells supported by a granular matrix. A few such conglomerates are shown on the right hand margin of the dorsal olfactory lobe of Figs. 2 and 3.

Transverse section of the anterior region of the cerebral lobes of *Rana*.

The cerebral ventricles (Cv.) are greatly contracted. The fibres (C), Koppen's Glomeruli (Kg.) and the nerve band (nb.) are shown.

and the superficial mass of nerve tissue is continued behind in the form of a swollen band, which at about the middle of the anterior half of the cerebral lobes becomes part of the corresponding hemisphere, entering the ventricle as a distinct
Text Fig. 4.

This section passes behind that delineated in Fig. 3. The accessory cerebral lobe (al.) is shown on the left-hand side of the Fig. The floor of the cerebral ventricles (V) is occupied by the forward extension of the club-shaped organ (CS.). The Olfactory tract (ot.) is well marked.
Text Fig. 5.

Transverse section of the anterior region of the Cerebral lobes. The club-shaped organs (CS.) are larger occupying almost the entire floor of the Ventricle (V). The accessory lobe (al.) on the left-hand side is still a separate structure attached to the main hemisphere by a delicate membrane (m.). The olfactory nucleus (on.) and the tract (ot.) extend as far back as this region.
tongue-like valve. The solid nature of the olfactory lobes is a point of special interest. It is almost impossible to describe the "normal" features of the structure of the hemispheres in Ramanella or Microhyla, for no two specimens agree in all details and in some cases the variations are extremely wide. I have therefore selected two sets of slides in order to show the structures which vary, each represents transverse sections in a serial form and also a series of sagittal sections for purposes of studying the disposition and relations of the new features.

Text Fig. 4 is intended to show that the floor of the ventricles in this region which is behind that depicted in Fig. 3 shows the anterior part of the club-like elevations and the left hand outer margin of the hemisphere bears ventrolaterally an accessory lobe which commences here and is continued backwards. The olfactory glomerulus is asymmetrical, in being confined to the left lobe. The disposition of the cells and fibres is normal and the accessory lobe on the left has precisely the same structural details as the main hemisphere, except the fact that it is solid.

Text Figs. 5 and 5a represent the views of the hemispheres in the same region of different specimens of Ramanella. In Fig. 5 the ventricles are symmetrical in proportion and

![Text Fig. 5a.](image)

Represents the transverse section of the cerebral lobes of another specimen of Ramanella in the region corresponding to Fig. 5. The club-shaped organ (CS) occurs only on the right-hand side. The shape of the ventricle in the sectional view is in perfect contrast to Fig. 5. The lateral thickening (CS') on the left-hand side represents the true corpus striatum.
form, being crescentic owing to the club-shaped structures occupying their floor, though both do not present the same degree of development in this region. Further in Fig. 5 the accessory lobe is separated from the main hemisphere by a membrane passing obliquely on the ventral margin of the latter. In Fig. 5a (also of the adult brain) the two ventricles differ in proportion and form; the one on the right is bell-jar-like while the left one is nearly rectangular. It will be also noticed that the club-shaped structure is conspicuously developed on the right and practically absent from the left,—a feature totally opposed to Fig. 5. The accessory lobe also is lacking. On the other hand, the inner wall of the left hemisphere shows a thickening (the corpus striatum) not met with in the right hand division. Now in point of histological details of the ventricular outgrowths, mention may be made of the fact that they are composed of a fine reticulum on the free convex border, the central and basal portions comprise very deeply staining large nuclei and stronger fibrils. The cell outlines are sufficiently clearly indicated; the basal fibres pass below and diverge on either side of the lobes. So far as the lobes and the ventricles are concerned, Fig. 5 may be assumed to be symmetrical while the hemispheres are not and in Fig. 5a the hemispheres present an outward symmetry while the internal parts and cavities follow an asymmetrical disposition.

Text Figs. 6 and 6a are from corresponding portions of the cerebrum of the same specimens of Ramanella as Figs. 5 and 5a. In Fig. 6 the lobular ventricular elevations are confined to the floor and are directed inwards and present equal proportions. The ventricle of the right hemisphere is deeply crescentic. The accessory lobe on the left hand side has fused with the ventral surface of the substance of the main lobe and the dividing membrane is shifted to the more dorsal region. The olfactory glomerulus on this side hangs freely in the ventricle which, on account of this structure, is converted into S-shape. On the right hand lobe the glomerulus still persists as a distinct structure without being incorporated into the hemisphere. Fig. 6 bears no resemblance to 6a, in which the club-shaped elevation of almost the same dimensions arise from the inner walls of the ventricle. Tracing these structures from Fig. 5a, in which one is ventral in position, it has manifestly passed over to the inner lateral face in the caudal end of the cerebrum. It will be further noticed that Fig. 6
Text Figs. 6, and 6a.

Are series belonging to Figs. 5, and 5a, respectively, and represent sections of corresponding portions of the hemispheres belonging to two different sections of Rana terminalis. The accessory sulci, and finally disappear. The difference in the shape of the cerebral hemispheres, the size, and the venous in position and they are noticeable feature.
is extraordinarily asymmetrical both externally and in the arrangement of the internal parts, while Fig. 6a is perfectly symmetrical in both respects. In the succeeding sections the ventral accessory lobe on the left gradually fuses with the hemisphere of that side, the dividing line of fibres seen more anteriorly disappears. In some cases I have noticed that this dividing mass of fibres separates enclosing a space which posteriorly, as the fibres separate, becomes confluent with the ventricle, in which case the tongue-like projection in the area

Text Fig. 6a.

between the two bands forms a broad lamellar plate entering freely into the lumen of the left cerebral lobe. The valvular folds become now double; the inner one is a continuation of the left olfactory conglomerate, the outer formed by the fibres and cells of the accessory lobe on its fusion with the cerebral mass. The latter in the caudal regions of the brain, gradually shifts over to the dorsal aspect until finally it fuses with the glomerulus.

Fig. 7 gives a picture of the cerebral lobes well behind the fore part where they arise from the Lamina terminalis. The dorsal longitudinal fissure divides as in the case of Rana and Bufo, the cerebral lobes into two separate portions with, however, one pronounced difference, viz., the lateral margins are not vertical but slope down from the dorsal groove; they are broadly oval, the smaller angle directed downwards and outwards. The dorsal surface of the cerebrum is strongly convex throughout its extent, thus fitting into the concavity
presented by the under-surface of the strongly arched frontoparietal bone. Out of the six sets of slides of *Ramanella* which I possess this mode of disposition of the cerebral hemispheres can be detected only in two series, but absent from others. In the latter case the lobes continue to be fused well over the diencephalon as is illustrated in the following

**Text Fig. 7.**

Transverse section of the cerebral hemispheres belonging to the series to which section 5 belongs and is intended to show the position where the club-shaped organ meets the corpus striatum.

figures. In Fig. 7 it will be noticed that each lobe is perfectly symmetrical in all respects and the ventral club-shaped elevations have passed over to the inner walls to become incorporated with the corpus striatum of that side, and the position (P) where the fusion has taken place is still distinguishable in both the lobes.

**Text Figs. 8 and 8a.**

The true corpora striata with the longitudinal groove (lg.) are shown in the corresponding regions of two examples of *Ramanella.*

lt.—lamina terminalis.
Text Figs. 8 and 8a are sections of the cerebrum passing through corresponding regions of the two examples of Ramanella continued from the previous figures. Besides differing in external configuration which may not be of any great importance, Fig. 8a shows the anterior extensions of the diacœl and the third ventricle. The ventricle of each lobe in both the figures is reduced to a narrow slit, on account of the prominent growth of the corpora striata, the longitudinal groove (ventriculi lateralis cornu internum) is as clearly marked as the symmetry of parts. Fig. 8 which is a continuation of Fig. 7, shows the continuity of the hemispheres, dorsally and ventrally, over the lamina terminalis.

Text Figs. 9 and 9a are posterior sections of the cerebrum and diencephalon of the specimen to which Fig. 8 belongs and they illustrate two strongly marked features not met with in the other slides. One of them is that corpus striatum on the right division is still well marked together with the longitudinal groove. The second set of facts relates firstly to the reintroduction of asymmetry and the total absence of the Foramen of Monro which, besides communicating the ventricles with one another, forms a passage
between them and the diaccel, and the outgrowth of a tongue-like process from the outer wall of the optic thalamus on the left hand division projecting freely into the cerebral ventricle of that side. These characters are confined to two specimens of Ramanella, but absent from the other four which I have examined. The tongue-like process when traced forward, becomes shorter, while behind it attains its maximum growth at about the middle of the optic thalamus, gradually diminishing in size posteriorly. Approximately it extends over one quarter of the median portion of the diencephalon. It will be further noticed that the cerebral ventricle on this side is considerably larger for the reception of this accessory lobe from the optic thalamus. The absence of the Foramen of Monro, which negative future is confined to two specimens; is due to the fact that the posterior divisions of the cerebral lobes are continued behind in the form of tubular prolongations, beyond the optic thalamii and the passage is obliterated on account of the extension of the corpus striatum and its fusion with the wall of the diencephalon beyond the foramen. Moreover it will be seen from Figs. 9 and 9a that the inner wall of the cerebral lobes in this region is incomplete and

Text Figs. 9 and 9a.

Are sections which belong to the same series and 9a is posterior to 9. In the latter the optic thalamus forms the inner wall of the cerebral ventricle on each side and at the point X it almost opens outside. In Fig. 9a the wall of the hemisphere on the right-hand side has come together, while on the left the optic thalamus besides forming the inner wall of the ventricle, bears the tongue-like flange (CS.) which is only an extension of the corpus striatum of that side.
formed by the optic thalamii. In Fig. 9a on the right hand side, the lobe has its own inner wall which is absent from the left side. The tongue-like process is only a slip of corpus striatum.

Text Fig. 9a.

CP.—Chovoid Plexus.

CS.—Slip of corpus striatum which have not completely fused with the optic thalamus. Here the inner wall of cerebral which is formed by the compound structure and its ventricle opens outside; on the right hand the inner cerebral well occurs normally.

Text Figs. 10, 10a and 10b form a series which are a continuation of Fig. 8a and illustrate the formation of the Foramen of Monro which occurs in the four series of slides belonging to specimens of Ramanella, in the form of independent tubes which are thrown together posteriorly at different levels into the diacœl and springing anteriorly at different levels from their respective ventricles. In Fig. 10 it will be noticed that while in the right division the longitudinal groove of the corpus striatum persists, it is absent on the left side and in this respect the section is comparable with Fig. 9. The dorsal half of corpus striatum unlike Rana and Bufo has grown at the expense of the ventral half. Besides the groove marks the position where the inner division of the cerebral ventricle becomes pinched off, by the union of the upper lip of the longitudinal groove with the floor of the cerebral cavity. This has taken place on the left hand division of Fig. 10. In Fig. 10a the portion of the cerebral ventricle which has been separated off from the main cavity on the left side has fused with the diacœl and on the right hand division the
process of pinching off a portion of the ventricle has occurred, the completion of the process indicating the absence of the longitudinal groove of the corpus striatum of that side and in Fig. 10b the confluence of the right hand division of the

Text Figs. 10, 10a and 10b.

Show the formation of the Foramen of Monro (iv, Fm.) and the disposition of the anterior (ac.), middle (mc′.) and posterior (pc.) commissures.

ac. . . . . Anterior Commissure.
CS . . . . Dorsal division of Corpus Striatum.
CS′ . . . . Ventral division of Corpus Striatum.
CP . . . . Choroid plexus dipping into the diacœl.
iv . . . . Inner division of Cerebral ventricle pinched off to be converted into Foramen of Monro.
mc . . . . Mesœœl.
mc′ . . . . Middle Commissure.
pc . . . . Posterior Commissure.
LG . . . . Longitudinal groove.
x . . . . Position where the longitudinal groove has fused with the Optic Thalamus.

pinched off portion of the ventricle with the diacœl of the corresponding side has taken place. These figures provide the evidence in support of the view expressed previously to account for the disappearance of the Foramen of Monro.
Text Fig. 10a.

FM—Left half of Foramen of Monro has been formed. The other half is in the process of formation on the right side. Other letters as in Fig. 10.

Text Fig. 10b.

FM—Foramen of Monro is completely established. Other letters as in Figs. 10 and 10a.
We can easily follow the process of abolition even in these figures. If the fusion of the ventral division of corpus striatum on the left hand side of Fig. 10 were complete instead of retaining the inner portion of the cerebral ventricle marked iv., then the whole ventricle becomes isolated without a passage or communication with the diacoel, a condition which has been reached in the two specimens of *Ramanella* as shown in Figs. 9 and 9a. But this does not account for the open nature of the ventricles in this region unless we assume that the entire corpus has been bodily detached from the lobes in the process of fusion with the optic thalamus. In the seventh set of slides dealing with the longitudinal sections of the *Ramanella* brain, a new series of structural facts is disclosed. Both the cerebral hemispheres are perfectly symmetrical as regards external and internal arrangement of parts.

Text Fig. 11 represents the sagittal section of the outer margins of the right hand division and from the posterior end of the outer wall of the cerebral hemispheres, a blunt process projects into the ventricle and the ventral club-shaped elevation to which reference has been made in connection with the

![Diagram](image)

**Text Fig. 11.**

Sagittal section of the brain passing along the outer margin. In this Fig. is shown the posterior lobe (ol.) of the corpus striatum whose peculiar disposition is illustrated in the succeeding figures.

al.—Accessory cerebral lobe.
transverse sections delineated in Figs 5—6, is not noticeable in this region. The accessory lobe present in this case only on the right hand division, which internally becomes incorporated into the hemisphere, is marked by the deep groove on the ventral aspect of the figure. The ventral olfactory disc is clearly made out, but not the dorsal one. The disposition of the posterior lateral lobe can be traced in Figs. 15 and 15b. It will be noticed that the lobe passes over to the dorso-median wall of the hemispheres and depends from above into the ventricle from a deep ridge which converts the chamber (Fig. 15) into a bill-hook-like form. In Fig. 15a the growth of the ventral lobe is shown, which is more median in position and is distinct from the dorsal organ which is more rounded in this figure and is continuous with the ridge. Fig. 15b is a section which is more internal and the ventral lobes lie freely in the ventricle, which shows that it is formed by bending over bodily towards the inner wall before becoming attached ventrally and to the dorsal ridge. This double fusion is completed in Fig. 16 which is still far from the median line. The transverse sections of the cerebral lobes of this specimen must present a picture totally different from Figs. 7—13b. This specimen offers us with a set of facts which, except the ventral club-shaped organ, it is difficult to homologise with what we know of the other six examples dealt with above. The choroid does not extend into the cerebral ventricles.

Diencephalon (Thalamencephalon).—In the Engystomatidæ the twixt brain is comparatively wider and larger than in Rana and Bufo; the lamina terminalis extends far forward. Laterally the optic thalami are completely covered by the posterior ends of the cerebral hemispheres which partially embrace the optic lobes also. The diacœl is covered with a dense matting of choroid plexus which depends into the third ventricle. In some examples this cavity forms a narrow slit, in others it is wider than the cerebral ventricle in this region; in the latter the narrow part of diacœl is confined to the ventral region where the third ventricle is reduced to a slit in the posterior region.

Text Figs. 14a and 14b show the form of the diacœl and it is roofed not only by choroid plexus, but by a nervous substance into which the commissural fibres pass forming a loop. The cavity is almost rectangular dorsally and wider than the cerebral ventricle and in the Fig. 14a the ventral
narrow slit presents the aqueductus sylvius. The anterior extension of the mesial portion of the mesocele is found in Fig. 14a, but is constricted in the hinder portion as in Fig. 14b. The optic chiasma does not divide the ventral part of the thalamencephalon into two divisions as in Rana and Bufo. The distribution of the white and grey matter is indicated by light and dotted areas in the figures. The structure usually described as the pineal body in the frogs is a thickened part of the choroid plexus forming the roof of the third ventricle arising from the convolutions of the vessels, but the true pineal body lies outside the fronto-parietals. The pineal stalk, however, remains and is more clearly visible in the sagittal sections (Fig. 20) to which reference is made in the

Text Figs. 14a and 14b.

Cross sections of the Optic thalamus and the Cerebral hemispheres.

The roof of the diacoeel (nr.) is composed of nervous substance into which the commissures (ac, mc, and pc) extend. The ventricles (v.) are continued far behind the Foramen of Monro. The dorsal section of the inter (mtc.) is thrown into the diacoeel (Di) and the median portion (mc.) stops short in Fig. 14a, but is met with in 14b.

On.—Optic nerve.
Op.ch.—Optic Chiasma.
ac.—Anterior Commissure.
mc.—Median Commissure.
Pe.—Posterior Commissure.
Ch.p.—Choroid plexus.
nr.—Nervous roof over a part of the diacoeel.
mtc.—Anterior extension of the metaceel, thrown into the diacoeel.
Di.—Diacoeel.
succeeding paragraphs. The pituitary apparatus in *Ramanella* and *Microhyla* is extraordinarily complex and is best studied in the vertical sections (Figs. 15b, 16, 20, 21 and 21a and also 15 and 15a which are transverse). The tuber cinereum
is degenerate and is represented by a conical process closely attached to the infundibulum (Fig. 20). The floor of the third ventricle does not extend to the base, on account of the forward extension of the mesocæl and consequently the infundibulum arises as a solid mass divided posteriorly into two lobes, meeting in front to form a bi-lobed structure. There is a deep longitudinal groove on the anterior dorsal aspect (Fig. 15c) which completely divides the infundibulum into two halves behind (Fig. 15d). Each lobe bears a dorsal transverse groove also which is indicated in Fig. 21. In the median line dorsal to the infundibulum, there is given off another finger-shaped process from the base of the thalamencephalon, a pair on each side (Figs. 15, 15b and 21a), the inner ones are more conspicuously developed. The lateral accessory lobes perhaps represent the saccus vasculosum and the median ones lobi inferiores of the fishes. In Fig. 21a, the terminal part of the infundibulum is curved

Text Figs. 15, 15a and 15b.

Are intended to show the formation of corpus striatum which in this case is postero-dorsal and its relation with the ventral club-shaped organ (vl). The secondary lobe (sl.) of the hypophysis is best seen in two Figs.

Fe.—Continuation of the outer posterior lobe.
Ol.—Outer posterior lobe of corpus striatum.
On.—Optic nerve.
Hy.—Hypophysis.
Sl.—Secondary lobe of hypophysis.
Vl.—Ventral lobe arising from the floor of ventricle.
forwards and this ectal end represents the hypophysis cerebri. In Fig. 15d the sacci, the lobi and the two divisions of the posterior half of the infundibulum are separately indicated.

**Optic Lobes and Crura Cerebri.**—The anterior margins of corpora bigemina do not diverge in the Engystomatidae generally and in *Ramanella* and *Microhyla*, the two lobes are not differentiated by the superior fissure. On the other hand, they form a continuous mass, with a feebly developed dorsal groove and in transverse sections, the two lobes appear roughly quadrilateral. The front half of each lobe is enveloped by the posterior extension of the corresponding cerebral hemisphere. In the anterior portions of the optic lobes, the median cavity or aqueductus sylvius, is traversed by two
transverse bands of nervous tissue dividing the aqueductus into three parts, the upper two of which enter the optic thalamus to various extents, the more dorsal, farthest. Slightly behind, one of these transverse septa disappears and the median cavity is divided into two (Fig. 15c), further behind (15d) there is a single median slit, owing to the disappearance of the hindmost septum. This is not however the rule, for in various positions, there is a constriction of cavities leading to their entire disappearance in certain sections and their emergence in others. The extent of the optocæl is greatly limited and in the median plane it is thrown into the aqueductus sylvius illustrated in Figs. 16a and 16b where the entire system of cavities assumes the T-form. It is to be noted further that the optocæl is not circular in outline in the cross section nor tubular in the longitudinal section. In Figs. 16a and 16b, the cavity of the lobes is a horizontal slit and the aqueductus sylvius is a comparatively

Text Figs. 15c, 15d, 16a, 16b, 18, 18a and 19.

Are sections through the optic lobes showing the relation of the optocæl (opt.) with iter (mc.) on the one hand and on the other the divisions of iter into dorsal and ventral moieties by transverse septa. The septa are produced by the fusion of the lateral walls of the crura in different positions. The longitudinal groove (lg.) of hypophysis (Hy.), the lobi inferiores and saccus-like (sv.) bodies are also shown. The cerebrum extends as far as Fig. 15c.
wider chamber. This is a condition unknown in *Rana* and *Bufo*. In Fig. 21a the lobe is cut practically in the median line, and the cavity is a crescentic slit, due to the projection into it of a large rounded mass arising from the posterior wall of the lobe. This character is confined to a single specimen, absent from the specimen whose brain is shown in transverse sections. In Figs. 18 and 18a which are sections from the posterior region of the lobes, the aqueductus sylvius is detached from the optococela which in the first figure are continuous and in the second have disappeared. The distribution of grey and white matter and of the commissural bands is indicated in Fig. 16b. The roof is comparatively thin in the median line but the floor is thicker, and the former is heavily pigmented.

*Cerebellum.*—Of all the Anuran amphibians, *Rana* and *Microhyla* present an interesting condition of cerebellar development. In Fig. 19a which is a transverse section of the optic lobes, the cerebellum has a width more than half that of the mesencephalon and in Fig. 21a it is quite as high
Text Figs. 16, 20, 21 and 21a.

Arc sagittal sections in continuation of the series 15. 15a and 15b and show the fusion of the club-man to the outer outgrowth of the corpus of the cup-shaped nature of the ophidian hypophysis (Hy.) and the transverse groove of the secondary of the ophidian hypophysis (Hy.) and the transverse groove of the latter (fg.). The optic tracts (opn.), the occurrence (i.e.). Other figures and previous figure.
Text Figs. 16a–19. Lettering as previously.

Text Fig. 16b.
as the optic lobes. Laterally the cerebellum diminishes gradually in height and becomes confluent with the anterior margins of the Medulla oblongata. In *Cucopus*, the median portion of the cerebellum which is large compared with *Rana*

and *Bufo* where it is a narrow transverse bridge of nervous tissue, overhangs the fourth ventricle. Springing from the posterior base of the cerebellum in the median line is a secondary finger-shaped process having the same histological characteristics as the main structure. Such a conical process
is confined only to a single specimen. The lateral folds of the cerebellum extend posteriorly on the lateral margins of the Medulla only in *Ranellula* and *Microhyla* but not in *Cacopus*, a feature which shows the possible limits of development even though as a case of individual variation.

Text Fig. 18.

Text Fig. 18a.
Medulla Oblongata.—The fourth ventricle is roofed by the choroid which sends below into the chamber, numerous vascular ingrowths. In Fig. 20, the sides of the medulla are partially covered by the hinder extensions of the cerebellum.

Nuclear Centres and Commissures.—The nuclear centres and the tracts of nerve and commissural fibres have been studied in Bielschowsky preparations. In Plate I Fig. 1 practically all the cranial nerve centres are made out. The central nuclei of the medulla is composed of large spherical cells distributed on the ventral and dorsal horns around the fourth ventricle. These cells are continued both ways into the cerebellum and the spinal cord. The pneumotogastric nucleus is composed of larger lenticular cells in the posterior ventrolateral margin of the medulla. The fibres are derived from these and other cells lying in front of the grey matter. Some of these fibres become continuous with those in the white matter, where all difference is lost. For instance, in Plate I Fig. 1, there is a median bundle of fibres which cannot be easily separated into pneumogastric and other fibres. In some sections, however, the fibres are gathered into two bundles, one of these belongs to the white matter but ultimately passes into the grey matter. Between these
Cross section of mesencephalon in the region where the cerebellum partially covers it. The relative proportions of the two structures must be a point of interest.

Ce.—Cerebellum; ms.—mid-brain.

bundles smaller nerve cells occur. But in none of the preparations could I trace the fibres to cells of the white matter, though here they occur in bundles more or less isolated into two parts. The glossopharyngeal nucleus, composed of fusiform cells, lies close to the pneumogastric nucleus and the fibres get mixed up with the latter. The nucleus of the auditory nerve is an aggregation of a large group of rounded cells which are disposed in two parts, in the dorsal and ventral regions of the medulla, connected by small fibrils. This two-fold origin of the auditory nerve is in contrast with its three-fold origin in *Rana*. The abducens nucleus forms part of the central nucleus from which it can be made out only in one or two sections in which it appears as a small mass of fusiform cells which character distinguishes them from the rounded cells of the central nucleus. It is dorsal to the trigeminal nucleus. The trigemino-facialis nucleus
Text Fig. 20.
Lettering as in Figs. 21 and 21a.

Hyp........Anterior lobe of Hypophysis.
Oph........Optic nucleus.
Ep...........Vestiges of Epiphysis.
is a group of cells which, on account of being placed very closely, cannot be differentiated into separate centres. The cells are crowded. The fibres of these two nerves are in two separate bundles, having a similar course. A sort of loop is produced by the dorsal bundle which curves down to meet the lower bundle. I cannot make out separate cell aggregations in correspondence with these separate groups of fibres which arise indiscriminately from the cells. If the bundles of fibres were regarded as sensory and motor, the nuclear clump of cells do not occur in a state of physiological differentiation occupying distinct dorsal and ventral positions. The Trochlear and Occulomotor nuclei occur as little clumps of small rounded cells at the base of the anterior margin of the medulla oblongata. Some of the cells of the trochlear group extend into the valvula cerebelli. The fibrils arise directly from the cells and judging from their positions, they must be distinctly motor. The optic tracts arise in a large group of spindle-shaped cells in the crura and the fibres pass the hinder part of the optic thalamus before being sorted out in the chiasma.

The commissures are well developed. The fibres composing the superior and inferior commissures of the medulla oblongata occupy the white matter and the inferior group is better developed. The fibres usually follow a parallel course with very little decussation. In Plate I Fig 1, the bundle of fibres represents the inferior commissure and the transverse commissure which, in the anterior region of the medulla oblongata, run forward. These fibres enter the cerebellum and the nucleus magnus. The pars peduncularis arises as the anterior extension of the pars commissuralis below the optic lobes where the fibres form a network interspersed by minute nuclei. The fibres are not grouped, but are arranged in strands, especially in the middle. They do not extend further than the crura cerebri. In Plate II Fig. 2, the commissural fibres of diencephalon are shown. The Hallerian transverse commissure occurs in the form of a decussating system of fibres occupying the hinder portions of the optic thalamus. Behind, these fibres are connected with a group representing the forward extension of pars peduncularis. The Hallerian fibres are connected with the optic tract of the crura cerebri and the optic fibres which arise in the optic thalami. The optic commissure composed of fibres arising from large spindle-shaped cells in the thalami cross over in
the median line to form the chiasma. Here they are joined
by the fibres of the optic tract from the crura; this bundle is
interesting on account of the fact that some of the fibres join
the Hallerian commissure as well. It is difficult to describe
the latter as a separate commissure in view of the fact that
the fibres pass into the optic commissure on the one hand and
on the other the optic tract. The optic commissure may have
two centres of origin or the Hallerian commissure may be
only a part of the optic commissure. In front of the optic
commissure there is a second separate bundle of fibres divided
by a large column of cells, representing the pre-commissura
chiasma opticorum whose presence in Rana is doubtful. The
fibres of this commissure extend anteriorly into the base of
the optic thalamus and behind into the infundibulum. On
the course of these fibres both ways, rows of spherical cells
occur; the fibres do not enter, however, the hypophysis
cerebri. The fibres of the transverse commissure in the roof
of the diencephalon are disposed obliquely, running from above
downwards and outwards. This course is marked in Plate II
Fig. 2 and in Plate I Fig. 1, all these commissural fibres are
cut across. These fibres are not continued into tuber
cinerium into which pass the anterior extensions of pre-
commissura chiasma opticorum and a decussation, therefore,
occur between these two sets of fibres in front. The dis-
position of the larger spindle and the smaller circular cells in
the different parts of the optic thalamus is interesting; those
in the dorsal portions follow an oblique tract and in cross
sections assume an arch, while others in the ventral regions
follow a longitudinal course. The principal cell areas, fibres
and commissures can be followed in Plate II Fig. 2. The
nucleus through which the corpus callosum passes, forms a
group of fairly large spindle cells occupying the posterior
division of the ventricle. The median cell area is met with
on the floor of the ventricle in the more anterior portion,
through which the fibres from the tuber cinerium pass. Both
the cells and these fibres enter and constitute the character-
istic club organs of Ramanella and Microhyla. In fact, the
lower internal or median cell area forms the base of these
structures and may be continued far behind, following the
organ till it merges into the corpus striatum, where the cells
of this area and those of corpora striata actually commingle.
This combined mass of cells forms a conspicuous area occup-
ying a position between the anterior commissure and the
corpus callosum. The corpus striatum of Ramanella is
exceedingly complex and from a number of slides examined, it is seen to fall into two distinct categories. In one group, the cell mass which is also composite (though not arising from a fusion of median cell area and the definite corpus cells) arises from the posterior outer margin of the ventricle, thus fusing with the upper internal cell area as the corpus striatum, gradually shifts over to the inner wall in the form of a longitudinal ridge described already. The extreme anterior lobe of this ridge meets internally the club organ which, as we have already noticed, is composed of cells of the lower internal or median area into which the fibres from tuber cinereum enter. Thus there is a direct cell continuity between the lower and upper internal cell areas through the oblique dorsal corpus striatum. On the other hand, the second type of corpus striatum does not enter the upper internal cell area, for between these two cell groups, a large mass of white matter intervenes. Again the lower internal cell area extends into the accessory cerebral lobe which attains greater proportion in the brains possessing the second kind of corpora striata. I have not been able to detect any fibres in the accessory lobes. In the base of the cerebral hemispheres, there is a second bundle of fibres ventral to those of tuber cinereum, called the round bundle which can be traced into the diencephalon. The chief commissures are the corpus callosum, the anterior commissure and the hippocampus. The first of these is a large bundle of fibres best seen in Text Figures 13—14b occurring at the point of junction between the lamina terminalis and cerebral lobes. The fibres pass over dorsally into the roof of the third ventricle which in *Rana* and *Microhyla* is not formed entirely of choroid plexus. It is composed of nervous substance in which cells of different sizes and fibres of the commissures occur. In *Rana*, this commissural bundle passes over the Foramen of Monro, and in such forms of *Ramanella* as do not possess the foramen, the fibrous bundle simply courses through the inner parts of the hemispheres and arches over the third ventricle. From the borders of the arch on either side arise the olfactory fibres from the clumps of cells situated all along its course. Behind the corpus callosum receives fibres from the superior transverse bundle occurring in the dorsal portion of diencephalon. The position and the relations of the anterior commissure are variable, depending on the mode of the formation of corpus striatum. Where it arises from the outer posterior wall, the anterior commissure is dorsal to it as in Plate I Fig. 1 and
if it were to arise from the inner cerebral wall, it is ventral to it. In fact, the former can be imagined to be derived from the latter by assuming that the whole structure has undergone a twist towards the inner margin, in which case the dorsal anterior commissure which is unusual would come to occupy the normal ventral position and with it is restored the usual position of the corpus striatum also. In both cases, the posterior portion of the anterior commissure is found below the floor of the common ventricle and ventral to the corpus callosum. At this point it meets the round bundle to which reference has already been made as running at the base of the cerebrum, and still more posteriorly the fibres of tuberceranium. From here a large bundle of fibres is given off anteriorly proceeding in front to the olfactory lobes which derive fibres from two sources, viz., from corpus callosum and from the arch of the anterior commissure. The hippocampal commissure is poorly developed in Rana but in Ramanella, it forms quite as conspicuous a bundle as the corpus callosum or the anterior commissure. It starts from the upper internal cell area and the fibres being disposed ventral and outwards, course side by side along the external margins of the anterior commissure. In the transverse section the bundle is seen finally to occupy a position ventral to the anterior commissure. At the point where the three commissures enter the roof of thalamencephalon, they decussate, so that the corpus callosum is the most posterior, the middle is the anterior commissure and the front one the hippocampus. In the hinder portions of these commissural bands of fibres, there are intercalated a few nerve cells of the smaller round variety. In other places the fibres merge into each other so that all distinction is lost.

Discussion.

The outstanding structural features in the brain of Ramanella and Microhyla are of interest as showing the degree of their departure from the normal amphibian condition and in some few of these examples both primitive and advanced states may be detected. For purposes of discussion it would be convenient to set forth here those features which are peculiar to Ramanella. In the cerebral hemispheres the occurrence of club organs springing from the base of the ventricle, and rarely from the top, the non-extension of the ventricle beyond the sulcus transversus, the nervous roof of the diencephalon in the rear portions, the infundibulum being
solid, the large cerebellum with large posterior pair of lobes and non-separation of the optic lobes and the occurrence of accessory bodies in relation to the infundibulum may be mentioned. I do not propose to introduce into the discussion structures which seem to be less important like the accessory cerebral lobe on one side, thus giving the brain an external asymmetrical arrangement of parts. Now in order to find a parallel to the club-like elevations from the anterior region of the ventricle, we must go back to the teleostean fishes in which the corpus striatum arises as a ventral thickening of the undivided prosencephalon. It is doubtful, however, if this is homologous with the lobe of Ramanella as in the closely allied form Microhyla, it arises in the embryo as an excavation of the outer wall of the cerebrum. From the view point of development, therefore, there can be very little relationship, though in the adult condition they occupy almost identical positions. Between the anterior ventral lobe in Ramanella and the true corpus striatum there is a distinct gap which marks the posterior and anterior terminal portions of the respective structures. There is hardly anything in the cerebral hemispheres of the Urodeles, comparable with the club organs nor in other Anura and the only conclusion to which we can come is that they represent the piscine type of corpora striata. If so, we have in Ramanella, the persistence of primitive with a more advanced character, since the cerebral hemispheres present two distinct and separate kinds of corpora striata. The amphibian type of corpus striatum while it occurs in some examples on the inner wall of the ventricle, is in others formed from the outer wall. Such a formation, which is not an individual variation, but occurs in more than two examples, is difficult of interpretation. That the swelling is really in the nature of a corpus striatum is evidenced by the fact that in the inner reaches of the hemispheres, it gradually turns so as to occupy the normal position in which it is met with in the other examples of Ramanella. In both Ramanella and Microhyla we are really dealing with a group of Anura which is really plastic, in the sense that the structural stability has not been reached. This view is supported by the facts of the circulatory arches and the structural details of the Conus. The great divergence of the hinder portions of the cerebral hemispheres, uncovering the greater part of the diencephalon and thus embracing the anterior third of the optic lobes is interesting as combining two sets of opposite characters.
The exposure of a large area of diencephalon is a primitive feature and the posterior extension of the cerebral hemispheres so as to cover a part of the optic lobes must represent a forward departure from the normal anuran brain.

The non-extension of the ventricle beyond sulcus transversus converts the olfactory lobes into solid structures. Even in the very early stages of embryos it is so. The lobes must, therefore, be in the nature of olfactory bulbs and in this case the lobes are not present or are absorbed into the cerebral hemispheres. I am unable at present to find any evidence from my embryological material in support of this. The evidence that one finds in the embryos freshly hatched goes to show that bulbs are present even in these stages and not hollow bulbs. Even in the Selachii, the olfactory peduncles and lobes are hollow, the rhinocel extending almost to the extreme anterior end. In the reptiles the rhinocel stops well behind the lobe, giving the greater part of it a solid character. In Ramanella the part of the brain between the cerebral hemispheres and the commencement of the olfactory bulbs, into which extension of the ventricle occurs, must be looked upon as the lobes which, if so, is confined to the sulcus area.

The roof of the diencephalon is partially composed of choroid plexus in the front regions and a strongly marked nervous tissue behind. In consequence of the great diminution of the choroid, it does not extend forward into the cerebral ventricles of Ramanella as in other anura. Into the nervous roof extend the fibres of the cerebral commissural bands as in the Reptiles. There is, however, no velum transversum. The former character brings Ramanella and Microhyla nearer to the Reptilia. If to the corpus callosum and the anterior commissure, we add the occurrence of well developed hippocampus, the approximation of Ramanella brain to the Reptiles becomes closer. On the other hand the presence of lobi in connection with the infundibulum is a Selachian feature and this persistence in the frog is remarkable. Finally, the diacel does not extend into the infundibulum which is comparatively a large structure. In the anurous examples hitherto investigated, the extension of diacel into the infundibulum has been made out and described. In the fishes it is so. In the lizards, the infundibulum is partially solid. Here in Ramanella we have
a case of a completely solid infundibulum, retaining yet a primitive character in the presence of lobi inferiores. Between the greatly enlarged infundibulum and the ventral wall of the optic thalamus, occurs a finger-shaped process which possesses nerve cells and granules. This is not a rete mirabile and therefore cannot be compared with the saccus vasculosum of fishes. I have not succeeded in tracing the hippocampal fibres into this small body which, I think, is the forerunner of corpus mammillate of the higher vertebrates like the mammals. The fairly uniform occurrence of this structure gives to the *Ramanella* brain an interest unique among the amphibia. In some examples of *Ramanella* where this structure is not present as an independent organ, it is marked off from the base of the infundibulum by a dorsal transverse groove, which separates the superior aspect of it into a proximal and distal portion. The nerve fibres which enter the infundibulum pass into the distal division while the proximal portion is only composed of nerve cells. But by far the most interesting feature of the diencephalon is the absence of Foramen of Monro in some examples and in others its formation as tubes arising at different levels from the cerebral ventricles. Both these characters are peculiar to *Ramanella* and *Microhyla* and hardly any vertebrate is known in which the absence of Foramen of Monro or its formation by backwardly directed tubes has been reported so far. In the transverse sections of the brain, the origin of the foramen can be made out in each stage and it must be in the nature of a curved tube, with the concavity directed forwards in both the cerebral hemispheres.

Not less remarkable is the pair of optic lobes, which in some examples are not separated throughout their length. The wall of the optocœl in most examples studied by me is not of uniform thickness, the posterior surface presents a large swelling which converts the optocœl into a cup-like cavity. In longitudinal sections, the cup appears like a crescentic slit. The crura cerebri are ventral thickenings of the mesencephalon and it is doubtful if the swellings of the optic lobes could represent the crura and if so, it is a very unusual position for them to arise from. In the larval brain, the crus occupies the usual position and in my material it is difficult to follow whether any shifting has taken place. The cerebellum is far better developed in this frog than in any other anuran. It is a conspicuous lobe, stretching across,
behind the corpora beigemina, and quite as high as the latter. There is a uniform character distinguishing the Engystomatidae and in Ramanella and Microhyla attains further enlargement. A point of further interest is the presence of a pair of short lobular structures arising from the posterior base of cerebellum, one on each side of the median line and overhanging the fourth ventricle. It is composed of a few nerve cells and fibres and perhaps they represent the flocculi of the cerebellum of the birds. If not, they can be compared only with the lateral lobes of the cerebellum of the mammals, while the main portion of the Ramanella cerebellum would represent the Vermes.

**Embryonic Brain.**

I shall now proceed to trace briefly the development of some of the interesting cerebral features which I have described in the previous paragraphs. Transverse and horizontal sections of the head of tadpoles of Microhyla have been used for the purpose. Fig. 23 is a transverse section of the olfactory lobes of a young tadpole which has budded the hind limbs and the absence of rhinocel even at this early stage is an interesting feature. In other tadpoles of corresponding age belonging to the family Ranidae and Bufonidae, the lobes are hollow outpushings. Text Figs. 23a and 23b are cross sections of the cerebral lobes of two tadpoles of slightly different stages, 23a being the earlier. The hemispheres are

![Text Fig. 23.](image-url)

Transverse section of the olfactory lobes of the Microhyla tadpole without limbs. The cerebral ventricles do not enter them. Ol.—Optic lobe.
elongated and are widely separated posteriorly though in front they come together more intimately. In these figures, the origin of the ventral lobes which has been described as extensions of corpora striata, is noticeable. From their position it is evident that they can have no relation with the true corpora striata. In Fig. 22 which is a later stage, the

Text Figs. 23a and 23b.
Sections of tadpoles of different ages. The latter which is younger shows the formation of the club-shaped organ (CS.) which in 23a is surrounded by a cavity. (Op.f.) optic fibres. (CS.) outer portion of hemisphere becoming part of corpus striatum. (nc) nerve cells forming wall of the cerebral ventricle (V).
lobe is distinctly larger and Fig. 17 corresponds with 23a, 23b in point of age. The hind limbs had grown in all these cases. In Fig. 23b, the outer ventro-lateral border immediately behind the olfactory lobes, there is a histological differentiation of the nerve cells along the tract where the cerebral ventral lobes develop. The completion of this process is indicated by the appearance of a space in the nervous substance as is seen in Figs. 23a and 17. At this stage there is no communication between the slit and the ventricle, which

![Text Fig. 22.](image)

Sagittal section of the brain of the fully developed tadpole and the club-shaped organ has become an internal structure.

is, however, soon established as in Fig. 22 by the increasing growth of this supplemental lobe, which pushes in front of it, the secondary cerebral slit. At the same time the wall of the cerebrum grows over the outer base of the triangular bodies. The result is that the lobes become internal and occupy the cerebral floor and the cavity surrounding them becomes confluent with the ventricle. If in the later stages of growth, these structures were to acquire connection with corpora striata, it is purely secondary. In the discussion of the probable relationship of these lobes to structures known in
Horizontal section of the brain of a tadpole with only hind limbs. The crura cerebri (opl.) and the lobes (opl') which convert the opticocel into a cup are already formed.

Other vertebrates, it was suggested that they may correspond with the corpora striata of the bony fishes, but their origin as separate parts of the outer surface of the hemispheres, precludes the possibility of any such comparison. Consequently these anterior lobes appearing to arise from the floor of the
cerebral ventricles, are really external structures for which homologues in other animals are difficult to find unless considered, as I have done, as piscine. Figs. 22a and 22b which are horizontal sections of the tadpoles of different stages, are intended to illustrate the development of certain cerebellar characteristics to which reference has been made. Fig. 22b represents an earlier phase. On each side the optic lobes are duplicated, the posterior division probably represents a larval phase which disappears during metamorphosis as is seen in Fig. 22a which is a section of the tadpole with four limbs. There is practically a quadrigeminal structure in the mesencephalon of the Microhyla tadpoles, and the bigeminal form is assumed by the adult by the disappearance of the hinder lobes during metamorphosis. The walls of the cerebellum come near each other at two points in Fig. 22b, which, by a fusion, give rise to a transverse septa. The occurrence of such septa accounts for the division and distribution in isolated cavities of the iter depicted in the adult brains in Figs. 15d—19.

4. Summary.

The outstanding features of the structure of the brain of Microhyla and Ramanella may be summarised as follows:—
The non-extension of the cerebral ventricles into the olfactory lobes is a characteristic confined to these two genera only among the members of the Engyostomatidae examined. Generally speaking, the other features are very variable. In some examples the ventral portion of the left hemisphere bears a forwardly directed lobe, which springs, from the dorsal aspect of the cerebral wall of that side. The anterior half of the floor of each hemisphere is occupied by a club-shaped organ which posteriorly becomes incorporated with the corpus striatum of the side. This latter structure is equally variable. In a few cases, it arises from the outer wall of the caudal end of the lobe and passes over the roof and then descends to the sides and the floor where it meets the club-shaped organ. This organ arises in the larva in the form of a body triangular in horizontal section, and is included into the ventricle by the overgrowth of its walls. The absence of Foramen of Monro is an interesting feature in a few cases, and is due to the fact that the corpora striata become fused with the optic thalami and in such examples, the ventricle of the hemisphere opens externally on the dorsal aspect in close apposition to the diencephalon. In all other cases, the foramen is tubular and is situated at different positions. The posterior margins
of the cerebral hemispheres extend as far as the middle of the optic lobes. Though the mode of origin of the club-shaped organs does not justify the supposition, the only organs of the vertebrate brain with which they may be compared, are perhaps the prominent corpora striata of the teleostomian fishes. The brain of Microhyla and Ramanella, therefore, combines both primitive as well as advanced features.

The roof of the diencephalon in the posterior portions where the commissures form a loop, is composed of nervous matter and in this respect, these two genera come nearer to the Reptiles. An individual variation of no great significance is the presence in one form of a plate of nervous tissue arising from the left thalamus and projecting freely into the cerebral ventricle. The occurrence of all the three commissural bands together with a rudimentary hippocampus really must point to state of advance over the other anuranous examples.

The hypophysis is greatly developed and bears accessory structures which can be compared with saccus vasculosum and lobi inferiores of fishes and in addition is incompletely divided into four parts by longitudinal and transverse grooves. In addition, there is a pair of secondary lobes dorsal to the infundibulum, which have no homologues in the brain of other vertebrate animals.

The middle brain is interesting, partly because the optic lobes are not clearly differentiated into corpora bigemina and partly because the aqueductus is divided into dorsal and ventral halves by the approximation of the walls, which form septa in different regions. The optocel in sagittal sections is crescentic in outline, owing to the great thickening of the posterior walls of the optic lobes, so as to constitute distinct lobular bodies.

The cerebellum is far better developed in the Engystomatidae in general than in other families so far examined and it is possible that it may be a piscine character. In most examples of Microhyla and Ramanella, the cerebellum bears posteriorly a pair of finger-shaped small lobules which may be compared with the flocculi of other vertebrate brains. Such secondary structures have not been noticed in any examples of Ranidae and Bufonidae occurring locally.
ENGYSTOMATID FROG'S BRAIN

BIBLIOGRAPHY


22. Wiedersheim, R. Comparative Anatomy of Vertebrates. and Parker, W.N.

PLATE II FIG. 2
Plate I—Fig. 1.


Plate II—Fig. 2.