OBSERVATIONS ON THE CORRELATION BETWEEN THE SURFACE LIVING HABIT AND THE STRUCTURE OF THE BRAIN OF THE FRESHWATER GREY-MULLET, *MUGIL CORSULA* HAMILTON

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Introduction

The study of the correlation of habits of fishes with their anatomical structure is one of the most fascinating subjects in Zoology. This gives a great clue to the structural changes occurring in the animal due to adaptation to any particular environment. The purpose of the present communication is to record a few observations on how far the pattern of the brain structure of *Mugil corsula* Hamilton reflects the general habit of the fish.

Studying the structure of the brain of certain cyprinoid fishes with reference to their feeding habits Evans (1931) and Bhimachar (1935) have classed them into three different groups. The habits and the brain structure of the Grey Mullet, conform, more or less, with the surface feeding cyprinoids. It may be stated that this paper does not attempt to give a detailed account of the brain structure but merely points out the important behaviour patterns as expressed by the habit of the fish.

The investigation of this problem was undertaken at the suggestion of Rai Bahadur Dr. S. L. Hora, Director of Fisheries, Bengal, to whom the author is much indebted. The Bouin fixed material was sent by Dr. Hora. The brain sections are stained with iron hæmatoxylin.

Surface Living Habit

Mugil corsula lives at the surface of water in ponds and rivers of the Gangetic provinces. To describe the surface living habit of this fish I cannot do better than to quote extracts from Dr. Hora's paper on the biology of *Mugil corsula* Hamilton, with observations on the probable mode of origin of aerial vision in fishes (1938). He states:—

"*M. corsula* has the remarkable habit of swimming with its eyes above the surface of water. When the fish is swimming at the surface, the eyes, a portion of the head and the anterior part of the body are entirely out of water, the rest of the body is obliquely inclined to the surface of water. As the fish progresses, ripples of the displaced water are found at the sides of the head.... Thus the fish moves through the water very gracefully and occasionally ducks its head below the surface presumably to keep the eyes moist.... Its eyes are wholly out of water and are no doubt adapted mostly for an aerial vision.... The stomach contents of several adult specimens contained nothing but algæ and a few insects and young molluscs entangled among plants.... When there are swarms of insects, *M. corsula* feeds voraciously on insects.... The stomach contents of small specimens from 6 to 8 cm. in length were found to consist mostly of large number of copepods and sometimes small insects. The almost toothless jaws, the presence of a symphisial knob and convoluted alimentary canal indicate that the observed feeding habits of *M. corsula* correspond with those of the 'Carp-minnows'. Though the mouth of *M. corsula* is situated on the ventral surface of the head, when the eyes and a part of the head are out of water, its position becomes almost anterior and the gape becomes obliquely directed upwards and forwards, as is usually the case with the fishes that feed near the surface.... On the approach of an individual the fish dives under water with great agility but does not stay there for long and comes up to the surface at a short distance from its original position."

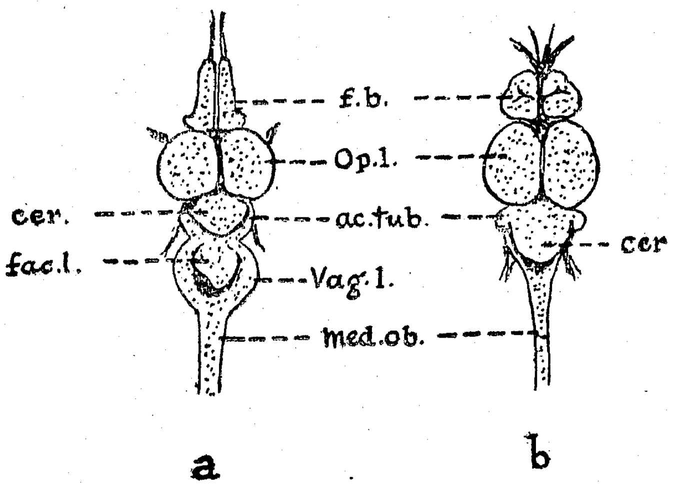
While describing this species Day (1889) observes "These fish swim with their eyes just above the surface of water, giving the appearance of a number of tadpoles. Immediately they are disturbed they dive down with great rapidity".

Sense Organs

It would be necessary to give a brief account of the sensory organs of the fish as they give a clue to (i) the habit of the fish and (ii) the extent of the development of their respective brain centres and connections. The eyes are large and the visual sense is well developed. As the head of the fish projects outside the water for long periods, the eyes are adapted for aerial vision also. Just as in the case of the surface feeding cyprinoids and cyprinodonts the sense of hearing is acute. The lateral line sense organ of the trunk is absent. The gustatory organs namely the taste buds and the terminal buds are highly atrophied. The barbels which bear large number of terminal buds, as found in cyprinoids and siluroids, are absent. The general tactile sense appears to be well developed.

Gross Morphology of the Brain

The brain of *Mugil corsula* is relatively well developed. The medulla oblongata is narrow indicating hypertrophied condition of the visceral centres such as the vagal, glassopharyngeal and the facial lobes. The acousticolateral tubercles, cerebellum, optic lobes and the forebrain are very well developed. Fig. 1 is intended to show how the brains of two



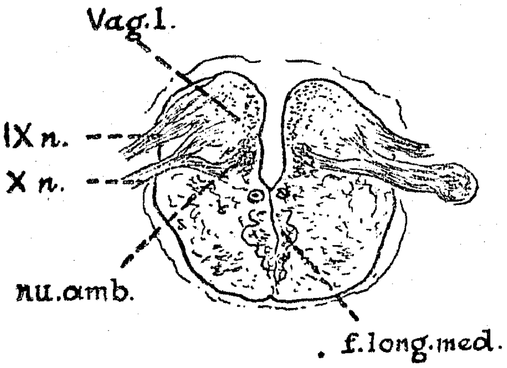
1. FIG. Dorsal view of the brain of (*a*) *Nemachilus beavani*, (*b*) *Mugil corsula*

fishes with different habits—*Mugil* which lives at the surface of water and feeds mostly by sight and *Nemachilus* which lives at the ground and feeds by groping and grubbing, differ in their general structure.

MICROSCOPIC ANATOMY OF THE BRAIN

The brain structure is examined from behind forwards. Fig. 2 represents transection of the medulla oblongata in the region of the vagal lobes. Two small hypertrophied vagal lobes can be seen, one on either side of the ventricle. A few sections caudally the lobes just fuse with each other over the ventricle. The nucleus ambiguus (motor vagus nucleus) consists of large spindle-shaped cells and lies ventromesial to the visceral nucleus. There are decussating fibres passing down the vagal lobes. At the rostral end the two vagal lobes are connected with each other by commissura infima. The brain in this region is narrow. The nerve roots of the IX and the X nerves can be seen entering the brain. The cerebellum is cut in transection at the level of the facial lobes as represented in Fig. 3. The facial lobes are comparatively very small and remain independent instead of fusing with each other as in many cyprinoids. The motor sensory column or the V lobe which is the brain centre for tactile sensation is prominently developed. Thick bundles of descending fibres from the V lobe are noticed. The secondary gustatory tracts are feebly developed.

About the rostral end of the medulla oblongata is seen a spindle-shaped mass of rounded deeply stained cells between the somatic sensory



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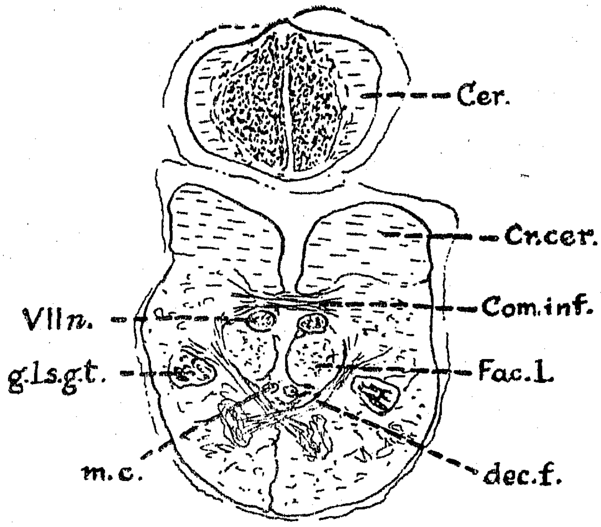

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FIGS. 2–3.—Fig. 2. Cross-section through the medulla oblongata of *Mugil corsula* showing the vagal lobes. ×30. Fig. 3. Cross-section through the medulla oblongata of *Mugil corsula* in the region of the facial lobes. ×30.

column and the cerebellum which is designated by Evans (1932) as the central acoustic lobe. The central acoustic lobe contains a mass of grey composed mostly of rounded cells taking deep hæmatoxylin stain just as the cells of the stratum granulosum of the cerebellum. As the sections are examined rostrally, in the region where the acousticolateral tubercles appear the molecular layer of this lobe fuses with the molecular layer of the cerebellum and the rounded grey cells disappear in the middle region, leaving two masses of cells one on either side near the lateral recess of the ventricle. Communicating fibres from these cell masses can be seen passing laterally to the respective acousticolateral tubercles. A few sections rostralwards even these cells disappear. Just before the disappearance of this cell mass a branch of the VIII nerve can be seen entering this nucleus. The fact that these cells neither join the cell mass of the stratum granulosum of the cerebellum nor send any fibres to that area clearly indicates that it is not, in any sense, a part of the cerebellum.

The acousticolateral tubercles receive nerve fibres from the internal ear and the lateral line sense organs. The caudal ends of these tubercles are seen about the region of the commissura infima. They gradually increase in size rostrally and coalesce with the cerebellar grey at their anterior extremity. The cerebellum which is the brain centre for the static and the muscular tone is well developed.

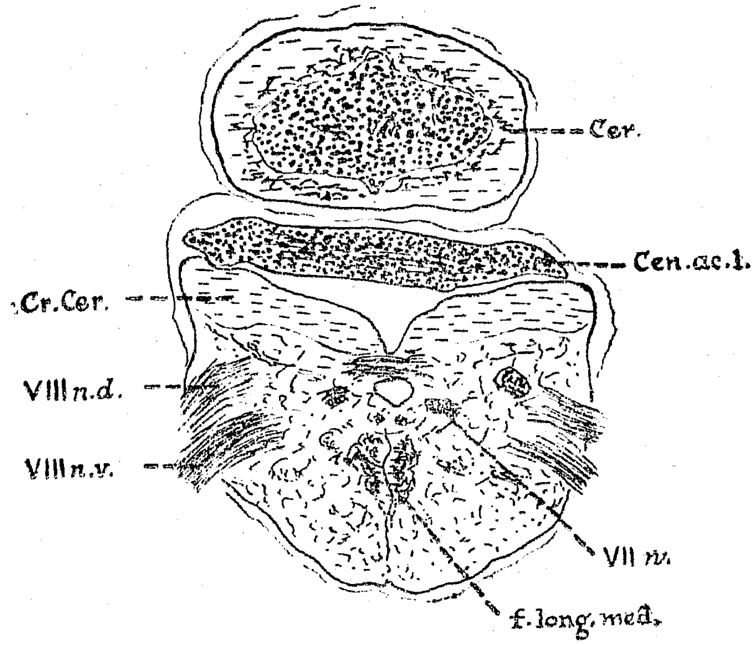


FIG. 4. Cross-seciton of the medulla oblongata of *Mugil corsula* showing the central acoustic lobe. ×30.

Fig. 5 represents the transection about the middle region of the optic lobes. The optic tecta are prominently developed. Fishes with atrophied eyes such as *Trypanchen vagina* and *Amphipnuous cuchia* have been noticed

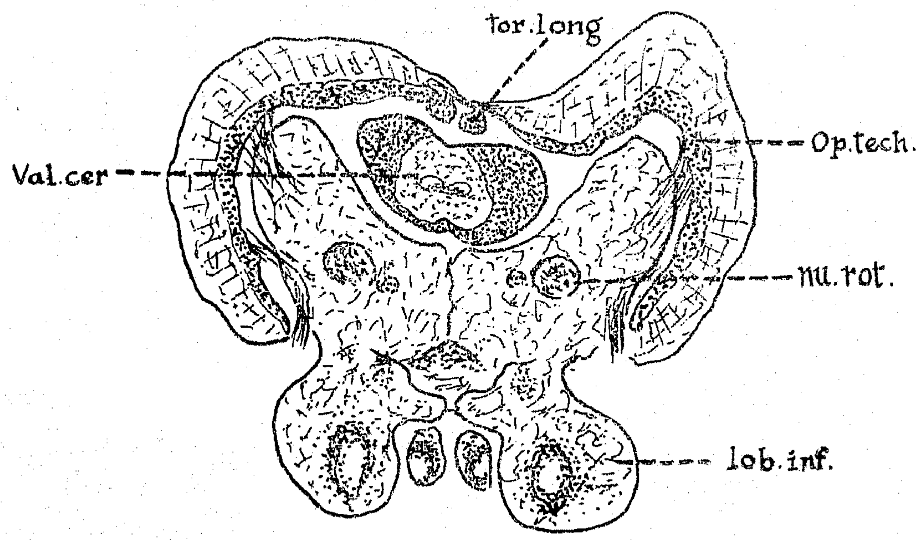


FIG. 5. Cross-section of the mid-brain of *Mugil corsula* in the region of the valula cerebelli. ×30.

to possess relatively small optic tecta. The usual Teleostean mesencephalic nuclei and nerve fibres are noticed in the Mullet. There is a well-developed valvula cerebelli. The torus longitudinalis is remarkably well developed.

The rostral end of torus longitudinalis (Fig. 6) which joins the commissura posterior is particularly thick. This structure is also small in blind fishes (Kappers and others, 1936).

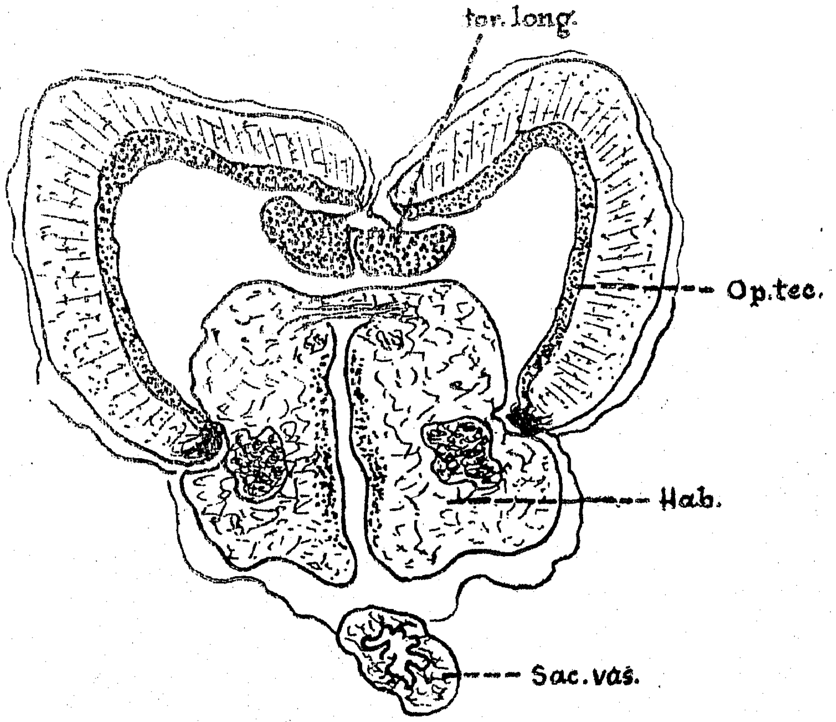
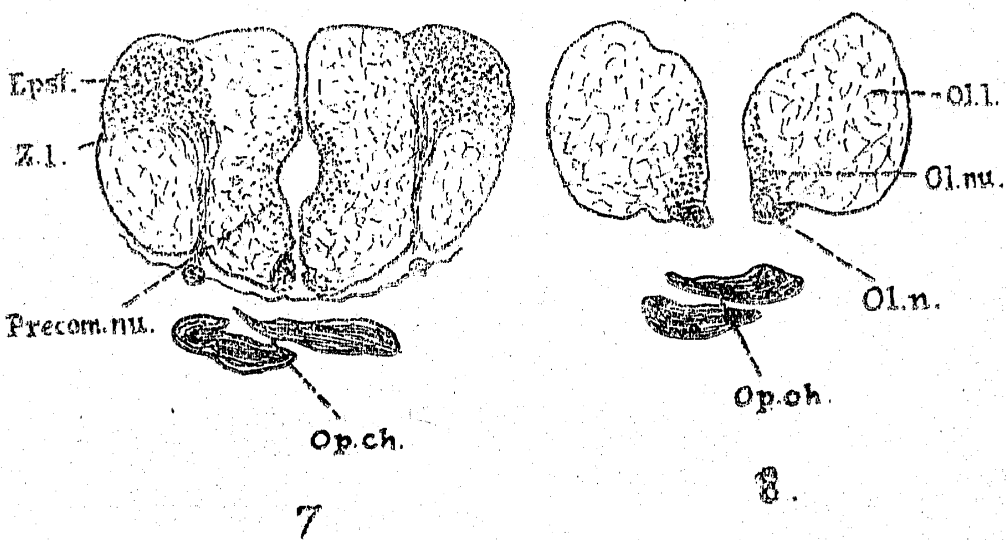


FIG. 6. Cross-section of the rostral part of the mid-brain of *Mugil corsula* showing prominent torus longitudinalis. ×30.

The telencephalon or the forebrain is seen in Fig. 7. The epistriatum or the primordial hippocampi is well developed. The fibre connections of this



FIGS. 7–8.—Fig. 7. Cross-section of the fore-brain of *Mugil corsula* showing well-developed epistriatum. ×30. Fig. 8. Cross-section through the olfactory lobes of *Mugil corsula*. ×30

important structure could not be investigated as the material fixed in Bouin's fluid was not well suited for the study of fibre tracts. A few sections rostrally is seen the transection of the olfactory bulb as in Fig. 8.

Discussion

As the Mullet has acquired a surface feeding habit it feeds largely by sight and therefore the gustatory organs, namely the tastebuds in the mouth and on the body, particularly abundantly found on barbels of fishes which grub and grope for food at the ground level, are practically absent. Correlated with the hypertrophy of the gustatory mechanism, the vagal and the facial lobes which are the brain terminals for the nerve fibres of this system are feebly developed. These lobes are remarkably well developed in carps and catfishes which possess a highly organised gustatory system. The gustatory tracts are also poorly developed in the Mullet. The general tactile sense is well organised and as such there is a well-developed somatic sensory or the V lobe.

The sense of hearing is more acute in the surface living fishes as they are constantly exposed to the external atmosphere, than in the case of those which habitually live at the bottom (Bhimachar, 1935). Correlated with the better development of hearing the central acoustic lobe is well developed in the brain of the Mullet.

It is clear from Dr. Hora's account (1938) of the habits of the grey mullet that it is a very active fish. Correlated with the active habits of the fish the cerebellum is well developed as the cerebellum is intimately connected with all the sensory centres which are concerned with the adjustment of the body in space and motor control in general. The maintenance of the muscular tone and of bodily posture are the most important functions of the cerebellum (Herrick, 1931).

As a result of the remarkable development of the visual apparatus which is adapted for ærial vision also, the optic tectum and the associated structures in the midbrain are very well developed.

The presence of a well-developed epistriatum (Fig. 7) in the forebrain is significant. There has been a great confusion regarding the exact function of the epistriatum. It is generally agreed by majority of workers that this structure in fishes has gradually lost its primary olfactory function and has become differentiated into a higher correlation centre, more or less representing a structure related to the pallium or cortex of higher vertebrates. It is to signify the higher co-ordinating nature of this structure that it is termed epistriatum by Kappers, primordium hippocampi by Johnston, paleostriatum by Sheldon and primordium pallii by Holmgren (Kappers, Huber and Crosby, 1936). But still fishes are regarded as devoid of intelligence. They are even termed "reflex machines" (Norman, 1931). Whether to treat the epistriatum of fishes as a true cortical centre of their brains is still a matter of controversy. It may be pointed out that many of the Indian fishes, especially those with partial terrestrial habit as in the case of air-breathing fishes, offer excellent material for solving this problem.

It is only in recent years that it is definitely established that fishes do "hear". Just as the sense of hearing was denied to fishes for a long time because they did not possess a counterpart of the cochlea of higher vertebrates, it is equally erroneous to deny them "intelligence" because there is not a true cortex in their brain.

It must be admitted that for an active fish like the Mullet, a surface feeder which thrusts its head outside water for considerable periods, the visual and the auditory senses are of vital importance both from the point of view of feeding and defence. With the greater development of these organs there should necessarily be higher co-ordination with various centres in the brain. Dr. Hora has pointed out that while chasing caddis flies the grey mullet makes a determined effort to catch them. Such an action cannot be dismissed as a stereotyped reflex action. It certainly constitutes intelligent behaviour.

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ABBREVIATIONS

ac.tub. .. Acoustico-lateral tubercle.
Cen.ac.l. .. Central acoustic lobe.
Cer. .. Cerebellum.
Com.inf. .. Commissura infima.
Com.post. .. Commissura posterior.
Cr.cer. .. Crista cerebelli.
Dec.f. .. Decussating fibres.
Epist. .. Epistriatum.
Fac.l. .. Facial lobe.
f.b. .. Fore-brain.
F.long.med. Fasciculus longitudinalis medialis.
g.l.s.g.t. .. Great longitudinal secondary gustatory tract.
Hab. .. Habinula.
lob.inf. .. Lobi inferioris.
m.c. .. Methuner's cell.
med.ob. .. Medulla oblongata.
nu.amb. .. Nucleus ambiguus.
nu.rot. .. Nucleus rotendus.
ol.blb. .. Olfactory bulb.
ol.n. .. Olfactory nerve.
ol.nu. .. Olfactory nucleus.
op.ch. .. Optic chiasma.
op.l. .. Optic lobe.
op.tec. .. Optic tectum.
precom.nu. Precommissural nucleus.
Sac.Vas. .. Saccus Vasculosus.
Tor.long. .. Torus longitudinalis.
V. .. Ventricle.
Vag.l. .. Vagal lobe.
Val.cer. .. Valvala cerebelli.
Z.l. .. Zona limitens.
VII n. .. VII nerve.
VIII n. .. VIII nerve.
IX n. .. IX nerve.
X n. .. X nerve.