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EXTERNAL CHARACTERISTICS OF THE BRAIN OF "HIME-MASU", *ONCORHYNCHUS NERKA* VAR. *NERKA* (WALBAUM)

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It has been generally considered that the external characteristics of the brain reflect some aspects of ecology in fish (Evans, H. E., 1952; Evans, H. M., 1935; Lissner, 1923; Uchihashi, 1953). Accepting such a consideration, Uchihashi *et al.* (1957) have discussed the correlation between the external form of the brain and ecology in the eight salmonid fishes. In spite of their work on the brains of salmonid fishes exclusively, however, no observation was made upon *hime-masu* which have been regarded to be comprehensive of the hierarchical problem of salmonidae in the origin and ecology of this fish.

In the present paper, several noticeable points are mentioned in the features of the lobus olfactorius, saccus vasculosus and valvula cerebelli of *hime-masu*, in addition to the account of the peculiar features of the brain of this fish, in which the results are almost identical with those of the salmonid fishes reported by Uchihashi *et al.*

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Materials and Method

Twenty-two specimens of *hime-masu* collected at Lake Shikotsu, Hokkaido, Japan were employed in the present observation. All the specimens used were adult, three or four years old and 25–26 cm in body length. The materials both fresh and fixed with formalin were subjected to observation. Further, several materials of red salmon, *Oncorhynchus nerka* var. *nerka* (*WALBAUM*), were used in the comparison of the valvula cerebelli with that of *hime-masu*. The observations were made under binocular microscope.

The specimens of *hime-masu* employed in the present study possess some intricated problems in regard to their origin. It has been reported that in Japan

the indigenous form of *Oncorhynchus nerka* var. *adonis* (JORDAN et McGREGOR) which is also called *hime-masu* has inhabitated only the two lakes, Akan and Chimikeppu, both in Hokkaido (Oshima, 1922; Matsubara, 1955; Tokui, 1960). The individuals of *hime-masu* which now live in Lake Shikotsu have originated from the eggs transplanted several times from two different lakes: namely, one is Lake Akan mentioned above, from which the eyed eggs of *O. nerka adonis* were transplanted to Lake Shikotsu in the three consecutive years from 1894; the other is Lake Urumobetsu on Etorofu Island of the southern Kuriles, from which the eyed eggs of *O. nerka nerka* were transplanted also several times from 1920 (Higurashi, 1939; Daito *et al.*, 1951; Tokui, 1960). According to Higurashi (1939), the transplantation of the eggs from Lake Urumobetsu to Lake Shikotsu was done to compensate for an extreme diminution in the number of the individuals of *O. nerka adonis* transplanted formerly from Lake Akan. Therefore, it is judged that in Lake Shikotsu the majority of the individuals belong to *O. nerka nerka*. In view of the circumstances described above, the specimens of *hime-masu* used here seem to belong to *O. nerka nerka*, though regarding to the composition of *hime-masu* population there remains a slight doubt whether or not the other progeny interbred between *O. nerka nerka* and *O. nerka adonis* exists in Lake Shikotsu.

Result of observation

1. Fatty substance

The brain of *hime-masu* is situated in a narrow cranial cavity, and is covered with a relatively small amount of fatty substance which appears to be rather solid. The fatty substance forms a somewhat thick layer on the dorsal surface of the brain, while it is rather thin at its ventral surface.

2. Nervus olfactorius, Bulbus olfactorius, Lobus olfactorius

As is seen in Figs. 1–3 (n), the nervus olfactorius occupies the frontal of the brain. It appears to be rather thick and elliptic in its cross-sectional view, showing about 0.5 mm in thickness in the specimen of 25 cm body length.

The bulbus olfactorius is situated close to the lobus olfactorius. Therefore, the olfactory tracts are invisible externally. When laterally observed, the olfactory bulb appears to be a regular triangle in shape (Fig. 2, b).

The lobus olfactorius lies between the bulbus olfactorius and the lobus opticus, exhibiting an ovoidal shape in dorsal view (Figs. 1–3, l). The volume of the lobus olfactorius proceeds that of the bulbus olfactorius. The dorsal surface of the olfactory lobes are covered by a simple, epithelial membrane, so-called pallium or tela, which reaches laterally to the middle margins of the olfactory lobes. The

proper sulci of the olfactory lobes are seen to be vestigial; the fissura endorhinalis is recognized only as a very shallow furrow on the lateral surface of the olfactory lobe, and the sulcus ypsiliformis is observed to be lacking.

3. Nervus opticus, Chiasma opticum, Lobus opticus

Both the lateral and ventral views of the chiasma opticum are seen in Figs. 2 and 3 (o). The chiasma is a predominant component at the ventral portion in *hime-masu*, lying in the area nearest in front of the inferior lobes. The nervi optici persist to occupy the greater part of the antero-ventral area of the optic lobes, and are the largest components among the cranial nerves. The thickness of the optic nerve is, at least, 1.5 mm, being as much as three times that of the olfactory nerve.

The lobus opticus is well-developed, providing the largest part in volume of the brain of *hime-masu* (Figs. 1–3, t).

4. Epiphysis, Saccus vasculosus, Hypophysis, Lobus inferior

The epiphysis appears to bulge out superficially from the connected portion of the olfactory lobes and the optic lobes; it stretches rostrally to the middle portion of the olfactory lobes (Figs. 1 and 2, e). It exhibits a swollen shape being surrounded with the fatty substance at its basal portion. When the epiphysis is observed *in situ* in the cranial cavity, it is seen to extend antero-superiorly into the covering of cartilage which encloses the telencephalon dorsally.

The saccus vasculosus situated behind the infundibulum appears to be a red patch (Figs. 2 and 3, v). The general shape of the saccus is elliptic in ventral view. However, so far as the present specimens are concerned, the saccus showed a considerable variation in shape; for instance, it was very elongate in some cases, while it was rather nearly square in others. When the outer membrane of the saccus is removed, it is observable that this component is composed of ten small sacs. These sacs are arranged bilaterally along a median line forming five pairs. The arrangement of these sacs appears to be very similar to that of the olfactory rosset in nares of fish. The colouration of the saccus vasculosus was also found to be highly variable according to the specimens used. Further observation revealed that the variation in colouration was closely associated with the amount of blood supply in the saccus. Usually the saccus was found to contain a not very large amount of blood which appeared to be distributed as a network-like blood supply. In some specimens, however, the saccus was found to be completely filled with blood, presenting the existence of several large sinus in it. Further, in other cases, it was faintly reddish or colourless owing to scanty supply of blood.

Behind the chiasma opticum and in front of the saccus vasculosus, the hy-

pophysis is found to protrude below the infundibulum (Figs. 2 and 3, h). The hypophysis of this fish is chestnut-like in shape and is very voluminous. It appears that the height and width of this component are larger than its length.

The lobus inferior lies just beneath the optic lobes and envelopes both the infundibulum and the saccus vasculosus (Figs. 2 and 3, i). The lobus inferior attains about half the length of the optic lobe, and is more voluminous than either the infundibulum or the saccus vasculosus.

5. Corpus cerebelli, Eminentia granularis, Valvula cerebelli

As is seen in Figs. 1 and 2 (c), the corpus cerebelli is also a comparatively larger component in the brain, lying close to the posterior end of the optic lobes. The corpus shows a bow-like shape bending its distal end to the postero-dorsal surface of the medulla oblongata in lateral view (Fig. 2). Two, shallow and parallel fissures furrow the surface of the corpus, though they soon disappear.

The valvula cerebelli is a prolongation of the cerebellum into the ventricle of midbrain. Although this component is not observable externally, it is disclosed on the surface of the diencephalon when the optic roofs are cut off (Fig. 4). In *hime-masu*, it presents the appearance of two pairs of the foldings. In contrast with such number of the valvula in *hime-masu*, the valvula of the red salmon is composed of three pairs of foldings (Fig. 5). It is noticed that on the dorsal surface of the posterior valves of *hime-masu*, there are found a pair of small bilateral eminences which are connected with each other at the median line (Fig. 4). However, in the present observation, it could not be ascertained whether or not these eminences in *hime-masu* were homologous to the pair of the second or of the third folding in the red salmon.

6. Medulla oblongata

The medulla oblongata in *hime-masu* surpasses the cerebellum in volume (Figs. 2 and 3, m). The crista cerebelli is dominant in this component, though the facial and vagal lobes remain unobservable.

Discussion

As has been reported by Tuge (1929), both the fissura endorhinalis and the sulcus ypsiliformis in *Carassius auratus* (L.) retain the appearance of distinct sulci. In addition to such distinct main sulci, the other four branched fissures exist on the surface of the lobes. The lobes are apparently divided by these furrows into the four tubercles. Tuge has further stated that each tubercle is approximately composed of respective diverse cell groups so that such a situation offers a convenience to judge the cell configuration in the lobes. In the case of *hime-masu*, however, there only occurs the fissura endorhinalis, and neither the

sulcus ypsiliformis nor any branched fissures exist on the surface of the lobus olfactorius. Such a difference in the external appearance of the olfoctory lobes between the crucian carp and *hime-masu* suggests a diverseness of development in the internal structure of the brain component concerned. It is also probable that such a difference of development in the brain component is ecologically related to difference in degree of dependency upon olfactory perception between these two species of fishes, though it is acceptable that the respective appearance of the lobes is under influence of the development of the cranial bones.

It is found that both the shape and the colouration, i.e., blood supply, of the saccus vasculosus in *hime-masu* are highly variable. The author has observed that such a similar high variability of these characteristics in the saccus vasculosus is also found in the other three salmonid fishes, *Oncorhynchus keta, Salvelinus miyabei* and *Salmo irideus*. Concerning the variation in the shape of the saccus vasculosus, Lissner (1923) has already stated, "Er ist in seiner Grösse bei den einzelnen Arten sehr verschieden". However, he has not made any note about the variation of the blood supply of the saccus, which might be considered to be closely associated with any physiological significance in this component.

The folding of the valvula cerebelli is composed of three pairs in red salmon, *O. nerka* var. *nerka* (*Walbaum*), while that of *hime-masu*, a landlocked form of the former species, is of two pairs. Uchihashi *et al.* (1957) have also reported that the folding of the valvula in red salmon is composed of three pairs. In view of the function of the valvula cerebelli which has been regarded to correlate with the acoustico-lateral line system, the small number of foldings in *hime-masu* may be suggestive of some insufficient activity in this system under consideration when compared with red salmon, though no ecological difference has been proved with regard to the above system between these two kinds of fish. The causation of such a difference in this component between these two species still remains unclarified. At the same time, further observation should be made concerning the number of the foldings of the valvula cerebelli in *O. nerka* var. *adonis* (*Jordan* et *McGregor*), an indigenous form of *hime-masu*.

Summary

1. Observations were made on the external structure of the brain of *hime-masu*, a landlocked form of red salmon, *Oncorhynchus nerka* var. *nerka* (*Walbaum*).

2. In the olfactory lobe, the fissura endorhinalis remains as a vague furrow, and the sulcus ypsiliformis does not exist.

3. Both the shape and the colouration of the saccus vasculosus are highly

variable according to the specimens. The colouration is considered to be closely associated with the amount of blood supply to this component.

4. The folding of the valvula cerebelli is composed of two pairs in *hime-masu*, while it is of three pairs in red salmon.

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Explanation of Plate

EXPLANATION OF PLATE

Fig. 1. Dorsal view of the brain of *hime-masu*. ×7

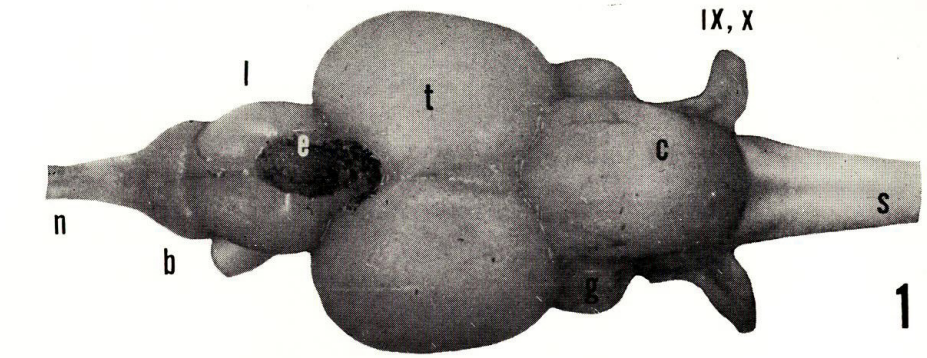
Fig. 2. Lateral view of the brain of *hime-masu*. ×7

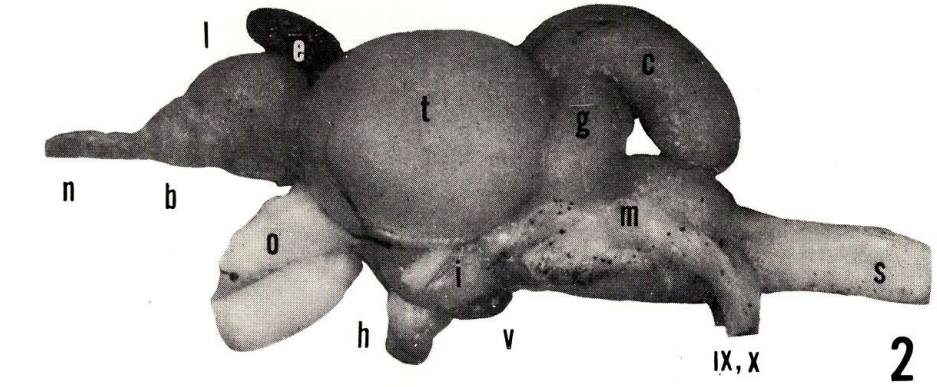
Fig. 3. Ventral view of the brain of *hime-masu*. ×7

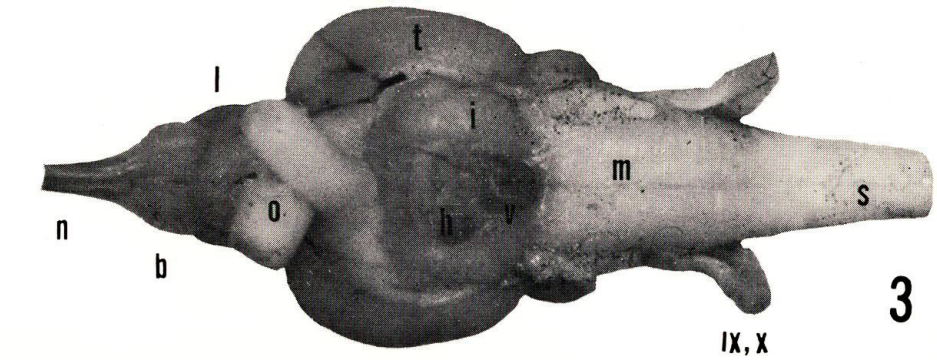
Abbreviations in Figs. 1–3: b, *bulbus olfactorius*. c, *corpus cerebelli*. e, *epiphysis*. g, *eminentia granularis*. h, *hypophysis*. i, *lobus inferior*. l, *lobus olfactorius*. m, *medulla oblongata*. n, *nervus olfactorius*. o, *chiasma opticum*. s, *medulla spinalis*. t, *lobus opticus*. v, *saccus vasculosus*. IX, X, *ninth and tenth nerves*.

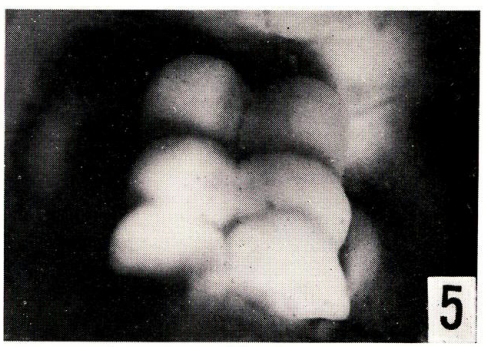
Fig. 4. Dorsal view of the valvula cerebelli of *hime-masu*. ×10

Fig. 5. Dorsal view of the valvula cerebelli of red salmon. ×7.5









T. Nishiyama: Characteristics of the Brain of "Hime-masu"