

A Transformation of Brain Form Following the Growth of *Chasmichthys gulosus* (GUICHFNOT)

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It is admitted by the general phenomenon of animate creation that a behaviour and a form would be transformed in keeping with the growth of *Chasmichthys gulosus*. Up to the present, many of research workers have made a special study of transformation of outside form and digestive structure accompanying ecological adaptation. However, with the growth of transformation of brain form, the sense-centre, a question concerning ecological adaptation remains untouched, but as to the said question nobody but a writer UCHIHASHI ('53, '55) is to the point.

Upon this, we turned our attention to a fact that in the early days of *Chasmichthys gulosus* they live a swimming life and then turn to living in the bed as they grow older. From this point of view, we made a special study of transformation on the connection between brain form and behaviour respectively in their growth phase.

The growth of *Chasmichthys gulosus* and its behaviour

Chasmichthys gulosus, as a rule, swims among the reef in the shore and belongs to a goby family of fishes. Ecological adaptation, from hatching to their growth, explains as follows:

(a) A young fish after hatching, in general, live a swimming life until side of 25 millimeters in the total length, (b) from the total length of 20 millimeters or thereabout, it takes an action after the fashion of creep once in a while, (c) from the total length of 30 millimeters or so it turns to living in the bed of water, (d) as regards a food fad, preys upon Copepoda while leading a swimming life and when turned to a bed living it will be turned into omnivora, (e) up to the total length of 20 millimeters or so it lives gregariously but when grown up over 20 millimeters, gregarious living will go down, by degrees, and it will perfectly be vanished in the phase of bed living and (f) on the other hand, there are positive phototaxis as far as about 15 millimeters in the total length, grows weak with the growth and will completely be vanished over 35 millimeters.

Brain form of adult *Chasmichthys gulosus*

With respect to an external brain form of adult fish, a goby family of fishes has a distinctive form of optic lobes. As writer UCHIHASHI explained on that point of *Chaeturichthys hexanema* BLEEKER and *Boleophthalmus pectinirostris* (GMELIN),

fatty matter to cover the brain of *Chasmichthys gulosus* is comparatively abundant, whole brain will more or less be depressed lengthways, a straight line which to knot the apex of olfactory lobes and corpus cerebelli will be inclined forward in some degree, and the apex of optic lobes is a little shorter than this straight line.

All conspicuously big olfactory lobes, with the exception of olfactory bulbs resemble a bottle in shape and are small, and stick to olfactory lobes. Respective hemisphere of olfactory lobes are remarkably jut out to the outer side, the dorsal view of respective hemisphere is analogous to triangularity without corner and has three projecting points at the rear of the back. Olfactory lobes are larger than optic lobes. Epiphysis is short as well as small.

Just in front of thalamus, a right side nerve of chiasma opticum places upwards in decussate nerve, optic nerves are comparatively thick, section is almost ellipse, additionally thick.

In the respect of thickness, this cannot stand comparison with that of olfactory nerves. Infundibulum is large, while inferior lobes are corpulent ones and spread forward especially expanded in the rear. Saccus vasculosus is located along the lower part of median line and well developed in a shape of an obtuse angle and a wedge. Hypophysis is a cone and small.

Optic lobes viewing from the rear presents an oval shape and are small and its two shapes of blades are not perfectly spread in the direction of rear.

Corpus cerebelli is small, its back-viewing is almost similar to a rectangle without corner and nothing but to extent to the rear only.

Eminentia granularis is small, valvula cerebelli is a small projection in shape and is omnipresent in the optic ventricle. Medulla oblongata is long and expanded. Crista cerebelli enlarges like a levee in shape and both leaves come in touch with each other.

Ventriculus quartus is long and slender unfolding at the mouth just a bit, both sections in which facial lobes and vagal lobes located are incorporate, the two in one and enlarges a little on both sides of ventriculus quartus. Viewing the brain from its all aspect, telencephalon is the largest and comes next in order of optic lobes, infundibulum + inferior lobes, medulla oblongata and corpus cerebelli.

Transformation of brain form with the growth

An early stage of swimming (total length 5~10 millimetres)

Optic lobes are large in particular as compared with the respective parts of brain. Telencephalon comes next in this point, however, olfactory bulbs are extremely small. A back-viewing of olfactory lobes presents a long ellipse,

optic lobes and olfactory lobes are not conjoin with each other, front part of diencephalon would be seen from the rear, moreover, ganglion habenulare would also be seen.

Optic nerves are extremely large, a right-side nerve is placed on the top and crosses in front of infundibulum. A small one in comparison is infundibulum and interior lobes are at once small and long ellipse. As for saccus vasculosus, its fixed location is only enlarged, but its outline is not ascertained yet. To see from back, corpus cerebelli is nearly round shape and small and project only in the upward direction.

Valvula cerebelli, of optic ventricle, is a three-cornered projection in small shape and is omnipresented in the rear part of optic ventricle. Eminentia granularis is large and long ellipse: in addition, an expansible one. Medulla oblongata, from the back-view, is thickly protruded and almost elliptical.

As stated above, it would be recognized that among the brains, the largest one is optic lobes and come next in order to telencephalon, infundibulum + inferior lobes, medulla oblongata and corpus cerebelli respectively in respect of dimensions.

A middle stage of swimming (total length 11~15 millimeteres)

As well as in an early stage of swimming, optic lobes are of the largest among respective parts of brain. The largest one, second only to optic lobes, is telencephalon but dimensions of olfactory bulbs against olfactory lobes is extremely increased.

On the other hand, the back-view of olfactory lobes is six to eighteen in contrast to the previous stage of swimming, but it has a slight fissure extending from 2 to 3 in the rear of the back. In the previous stage of swimming, there are substantial aperture between rear end of olfactory lobes and front end of optic lobes, where we can see ganglion habenalare, but an excessive change in this stage of swimming is that a rear end of olfactory lobes and a front part of optic lobes are associated with each other.

Though, optic nerves, infundibulum and inferior lobes have no remarkable transformation, especially inferior lobes are beginning to expand as well as enlarge. An outline of triangular saccus vasculosus would be able to recognize clearly.

Optic lobes are enlarged to some extent from the previous stage and have projected in the direction of the rear.

The back-viewing of corpus cerebelli, in the previous stage, was round shape, but in the middle stage it is extended a little to the rear. Also in this stage, as for valvula cerebelli, a hollow would be formed on the end of its rear, and eminentia granularis would only be an oval shape without any growth, however,

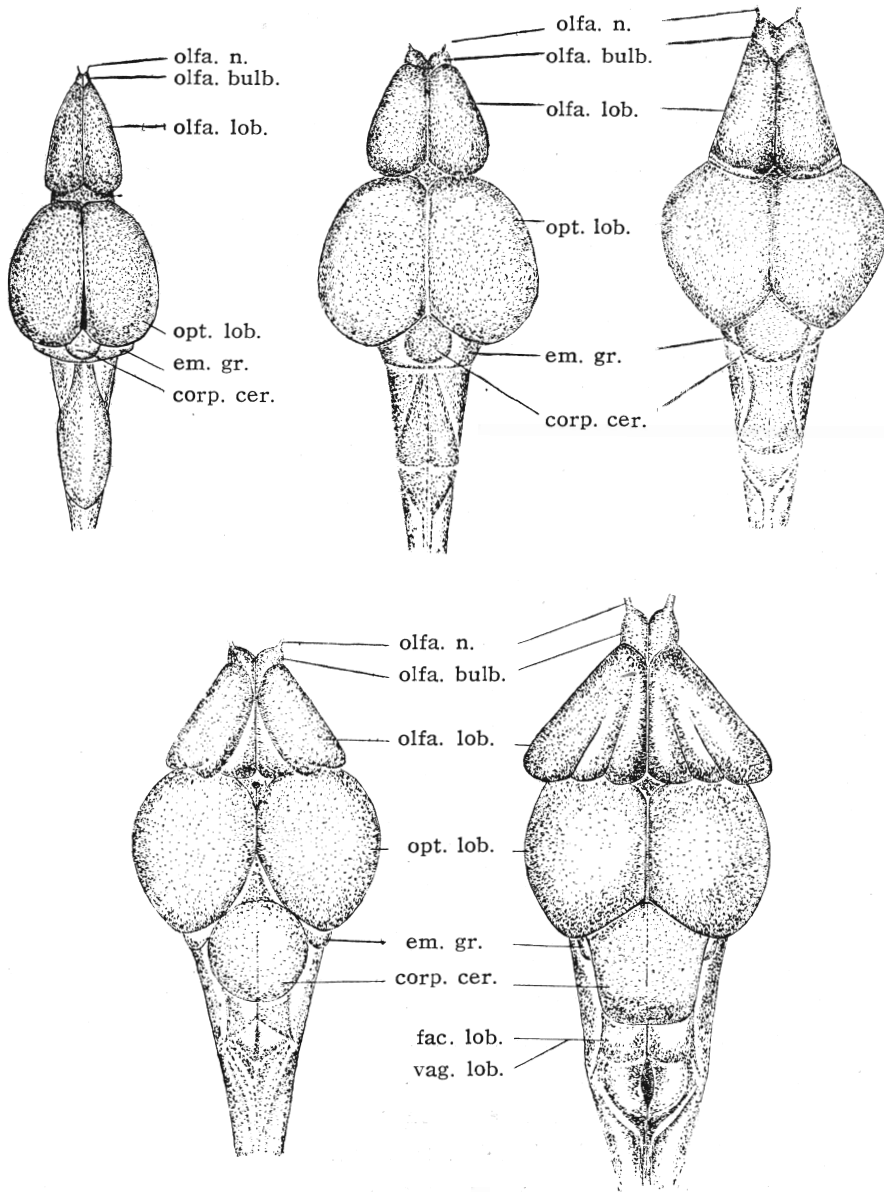


Fig. 1. Development of brain of *C. gulosus* (dorsal view)

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| (1) Total length 7mm × 40 | olfa. n., olfactory nerve, olfa. bulb., olfactory |
| (2) Total length 10mm × 40 | bulb; olfa. lob., olfactory lobe; opt. lob., optic |
| (3) Total length 15mm × 20 | lobe; em. gr., eminentia granularis; corp. cer., |
| (4) Total length 30mm × 20 | corpus cerebelli; fac. lob., facial lobe; vag. lob., |
| (5) Total length 100mm × 20 (adult) | vagal lobe. |

as other parts grows older so eminentia granularis will not be marked little by little in comparison with the grown-up other part.

In contrast to the previous stage, medulla oblongata also differentiate together

with corpulence, but a part to be recognized as crista cerebelli hereafter is enlarged a little only.

When turned to a total length of 15 millimetres a rear side of olfactory lobes enlarges a little. Its back-view nearly assumes a triangular gimlet in shape and optic lobes also make a growth gradually and assumes an ellipse in the back-view. Corpus cerebelli will extend gradually to the rear and forms an appearance to cover the upside of crista cerebelli.

Both infundibulum and inferior lobes will expand gradually. However the rear part of each hemisphere of inferior lobes will not come in contact with, and saccus vasculosus assumes a triangle in shape along the median line between the two leaves.

Out of medulla oblongata, facial lobes, vagal lobes and crista cerebelli, crista cerebelli will narrowly be able to distinguish as a projecting part.

The latter stage of swimming (including creeping period) and the
early stage bed living in the water

When turned to a total length of 20 millimetres it is a time that young fishes make a creeping action, but leading characteristic in this phase indicates that olfactory lobes gradually expand adding globular shape as a whole and nearly presents a triangle in the back-viewing. More than half of the rear side of crista cerebelli will be covered by corpus cerebelli in extending backwards gradually.

A distinction between vagal lobes and facial lobes of medulla oblongata is not clear, but a section in which both lobes to be formed is a projection. An opened section of ventriculus quartus is small and to be a diamond shape on the whole. Dimensions of respective brain parts in precedence in this growth phase does not differ from that of previous.

When in excess of an overall length of 30 millimetres, a back-viewing of olfactory lobes presents a triangular form, reveals a streak in its rear and its outside section expands to a high degree. In other words, it has two projecting sections, a streak in the inner part is small and the other one in the outside is large.

Both infundibulum and inferior lobe expand in a marked degree and respective lobe of inferior lobes come in touch with each other at their rear. The extremity of saccus vasculosus extends more than the rear part of inferior lobe and is about the same as the sharp of adult fish, at the same time, corpus cerebelli and valivula cerebelli are also come up to the shape of adult fish. A straight line to tie a top of corpus cerebelli and olfactory lobe inclines forwards a little.

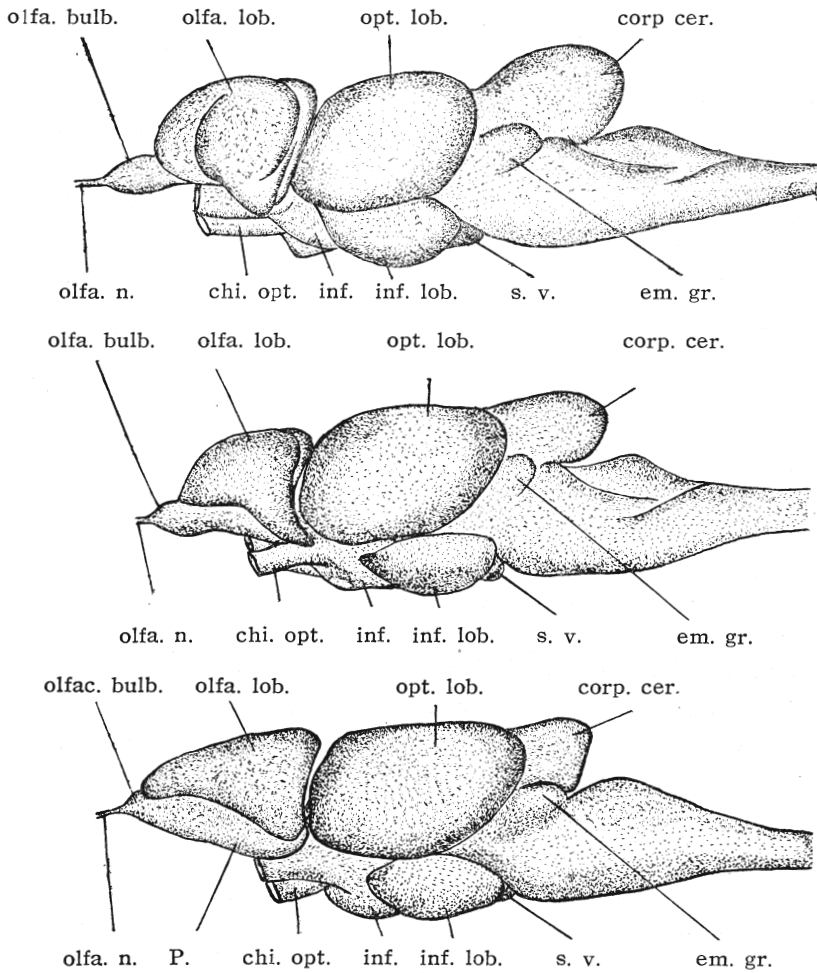


Fig. 2. Development of brain pattern of *C. gulosus* (Lateral view)

- (1) Total length 100 mm × 10 (adult)
- (2) Total length 30 mm × 20
- (3) Total length 15 mm × 30

olfa. n., olfactory nerve; olfa. bulb., olfactory bulb; olfa. lob., olfactory lobe; p., parathalamus; chi. opt., chiasma opticum; inf., infundibulum; inf. lob., inferior lobe; s. v., saccus vasculosus; opt. lob., optic lobe; em. gr., eminentia granularis; corp. cer., corpus cerebelli

In this phase they move into a swimming life in the depth from that on the surface. Three projecting points would be recognized on the back of olfactory lobes in a gradation of 45 millimetres in the total length. However, while in this phase olfactory lobes are still smaller than optic lobes, but respectively other brain parts would be an adult fish type on the whole.

In the total length of 70 millimetres or so, size ranking of respective brain parts are transformed into an adult fish type.

Explanation mentioned above is a summary concerning transformation of the

brain form attending on growth, but a remarkable section of transformation is olfactory lobes of telencephalon and expand more and more immediately after incubation.

Just as respond to this transformation, medulla oblongata will also make progress. Eminentia granularis which had developed in the early stage will be shaken in its development together with the growth and when they enter upon a swimming life in the depth of the water, an eminentia granularis will barely be distinguished on the ground of excessive development of the other brain parts. In addition, a transformation of saccus vasculosus, as states below, is conspicuous, too.

Saccus vasculosus, as stated before, is located on the end of median line of inferior lobes. JHONSTON ('06), DAMMERMAN ('10), KAPPERS ('21) and UCHIHASHI ('53) its process.

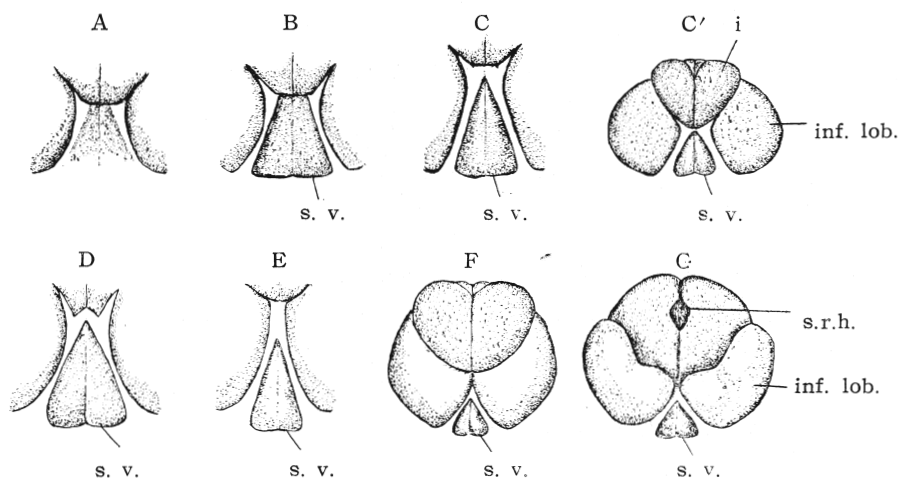


Fig. 3. Ventral view of inferior lobes and succus vasculosus

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|---------------------------|---------------------------------|
| (A) Total length 9~10 mm | (D) Total length 17~20 mm |
| (B) Total length 11~12 mm | (E) Total length 25 mm |
| (C) Total length 14~15 mm | (F) Total length 30 mm |
| (C') Total length 15 mm | (G) Total length 100 mm (adult) |

s. v. succus vasculosus; inf. lob., inferior lobe; i., infundibulum; s.r.h., sulcus recessus hypophysis

In an investigation on this organ's form and organism, UCHIHASHI recognized 13 kinds about 72 kinds of adult teleosts which perceive hydraulic water pressure and its form and size indicate a depth living in water, he concluded. With respect to *Chasmichthys gulosus*, we can not recognize externally about 9~10 millimeters, but when it reached total length of 11~13 millimetres, we can recognize its protuberant part only and its outline is not clear. When reached to total length of 14~15 millimetres we can recognize its existence clearly. Form

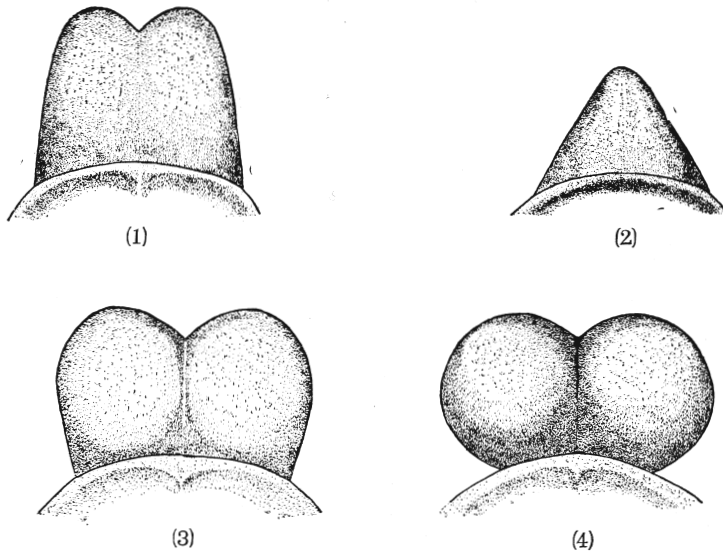


Fig. 4. Dorsal view of "Valvula cerebelli"

- (1) Total length 10 mm
- (2) Total length 20 mm
- (3) Total length 30 mm
- (4) Total length 100 mm (adult)

is similar to heart type, its front end comes in touch with infundibulum and back end is placed in front of the back end of inferior lobes.

Meanwhile, with the growth, it extends to the back with the development of inferior lobes. And form of saccus vasculosus is changed into wedge type.

According to UCHIHASHI's classification, ('53) it means an acute-angled wedge type.

Relations with ecological adaptation

With respect to relations between change of external form of brain and ecological adaptation is stated as per enclosure. Until 10 millimetres or so of total length, its swimming power is weak and leads a swimming life in a throng among seaweeds or reef of the nearest shore. Gill raker, in this phase, is a beginning of formation and the digestive organ advances in a bee line. The brain form, in this phase, is especially large at optic lobes as compared with the respective brain parts and considerably large is eminentia granularis. While vagal lobes or facial lobes are not well developed and is entirely brain form of a visual type.

In the next, in the phase of surface swimming in a throng, a sucking-disk of the abdomen is formed, gets a tooth through, extension in the intestines and

Table 1. Relation Between Transformation of Brain Form and Organism By the Growth of *Chasmichthys gulosus* (GUICHENOT)

Full Length	Form of Brain	Swimming Region	Feed	Remarks
7 ~ 10 mm	Optic lobe is considerably large in comparison with respective brain parts. Eminentia granularis is markedly protruded. Saccus vasculosus is not clear. The vagal lobe and facial lobe of medulla oblongata is not distributed and is a single thick protuberant part. Valvula cerebelli is a triangle small cupola.	Among reef or marine plants. Intensely positive phototaxis	Unknown	
11 ~ 15 mm	Corpus cerebelli is only expanded to the rear. Eminentia granularis is gradually getting unclear. Saccus vasculosus is narrowly recognized. Valvula cerebelli forms a circular cupola. Crista cerebelli is getting clear.	Group swimming on the surface region. Intensely positive phototaxis	Nauplius larva <i>Setella sp</i> <i>Cionene sp</i>	Forms sucking-disk. Early stage of formation of the teeth. Things in the stomach are getting clear.
16 ~ 20 mm	Side part of the rear of olfactory lobes gradually make their growth. Corpus cerebelli extends toward rear little by little. Inferior lobe become fat and large. Medulla oblongata finally expand.	Group swimming on the surface region. Intensely positive phototaxis	Copepoda Isopoda	Respective fin completed. Digestive organ is almost same as that of adult fish.
21 ~ 25 mm	Olfactory lobes make growth little by little and lobes posterior cover more than half part of the crista cerebelli. Medulla oblongata become fat and large. Saccus vasculosus become the same with the grown-up fish as a whole.	Sometimes take a creeping action. Separate from group swimming by degrees. Positive phototaxis is gradually getting unclear.	Copepoda <i>Chasmichthys gulosus</i> (young stage)	Teeth form as that of adult fish. Digestive organ is same as that grown-up fish.
26 ~ 30 mm	The order of the size of respective brain parts through all stage of not-grown-up fish follows. Optic lobes, infundibulum and inferior lobes, olfactory lobes, Medulla oblongata, corpus cerebelli.	Removes gradually to the depth of the water.	<i>Chasmichthys gulosus</i> (young stage) Small shaped shell (top-shell)	Gill rakers are complete shape of adult fish.
31 ~ 40 mm	Two projecting parts would be recognized in a grown-up olfactory lobes. Infundibulum and inferior lobes are remarkably expanded. Corpus cerebelli and valvula cerebelli are become the shape of grown-up fish. There are three projecting parts at respective lobes of olfactory lobes. But they are smaller than optic lobes. Others are almost the shape of adult fish.	Bottom	Same as above Small shaped shell (top-shell) Green algae <i>Ligula exaltata</i> Amphipoda	Fin and speckle are complete shape of adult fish.
Adult fish	When exceed 70 mm olfactory lobes are become larger than optic lobes, and the order of respective brain parts of adult fish are olfactory lobes, optic lobes, Infundibulum + inferior lobes, Medulla oblongata and corpus cerebelli.	Bottom	Same as above	

distinction of the stomach and bowels becomes clear. By degrees eminentia granularis is getting unobvious existence, corpus cerebelli extends backward more or less and valvula cerebelli increases its capacity but is omnipresent in optic ventricle. At last the the outline of crista cerebelli is to be recognized and at the same time, saccus vasculosus will also make rapid progress. However, optic lobes keep hold the larges size, positive phototaxis is strong, and prey upon plankton in the near of the surface of the water.

In the second place, following the grope swimming life on the surface of the water, the stage gets into creeping action at times. The total length in this stage is 25 millimetres or so, in which medulla oblongata grows gradually, also

olfactory lobes make similar growth and saccus vasculosus is transformed into an adult fish. In an over-30mm-stage both outside shape and digestive canal are transformed into adult fish on the whole, change into omnivorous from plankton of bait and get into the depth swimming life from the group swimming life and at the same time, positive phototaxis is gradually ceased to exist.

More than two fissures appear of the backside of olfactory lobes as well as the projecting part olfactory lobes which is marked by goby family of fish would be formed and to become in the shape of adult fish generally. Other respective brain parts, on the other hand, are also transformed into the same shape in general.

Viewing from the point of ecological adaptation it goes into the deep swimming life in the stage of 40mm-total length. However, judging from the point of brain form, olfactory lobes are smaller than optic lobes.

On an average the growth medulla oblongata follows that of olfactory lobe but has not yet displayed a brain form of adult fish living in the depth of the water.

Summary

(1) Observed on the outside form of the brain and ecology which to transform itself with the growth of *Chasmichthys gulosus* and investigated the relations between the two from the viewpoint of ontogeny.

(2) With respect to the brain form in swimming stage, both optic lobes and eminentia granularis are grown up well simultaneously it has the brain form similar to the vascular fishes.

(3) Both telencephalon and medulla oblongata are keeping their growth in the brain form living in the depth of the water and goes into change of the gustatory and smell brain form.

(4) Immediately after incubation the nature of strong group living and positive phototaxis are going to move into negative phototaxis and not-in-group living little by little with a remarkable growth of olfactory lobes and medulla oblongata which would be seen in the swimming stage of total length 20 millimeters.

(5) Though in an aspect of growth in solid form both ecological adaptation and transformation of brain form are well-matched with each other, however, so far as time is concerned, it is the tendency of *Chasmichthys gulosus* that the former goes in advance of the latter.

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