

ERRATA.

Page 12, lines 16 and 17, for *one* hundred read *three* hundred and for *one thousand* read *six hundred*.

Page 17, line 2, dele first letter in the line.

Page 168, line 12, page 177, lines 13 and 14, and page 271, line 10, for *Lemna trisulca* read *Spirodela polyrhiza*.

Page 209, line 2 of foot-note, after *but* insert *represents*.

Page 256, line 7, and page 266, line 19: *snowi* n. s. has been shown to be *hieroglyphica*, ♂.

Page 257, insert as line 8 as follows: -ken to the office produced young in ten days. The

Page 272, line 13, for *P. biguttatus* read *Pompilus biguttatus*.

Page 278, Plate V., 16, after *view* insert as follows: *a*, mentum; *b*, labial rudiment; *c*, maxillary palpi; *d*, maxilla; *e*, labrum; *f*, antenna; *g*, eye; *h*, mandible.

Page 286, line 11, drop initial *the* one line.

Page 386, line 1, for *Comstocki* read *Comstock*.

Page 399, line 17, for *specimens* read *specimen*.

Page 411, line 10, for *Michaelson* read *Michaelsen*.

Page 441, line 3 from bottom, for *66* read *68*.

Page 445, line 10 from bottom, for *57* read *58*.

Page 466, line 1 from bottom, for *Cypria* read *Cypris*.

ARTICLE IX.—*Some Notes on the Brain and Pineal Structures of Polyodon folium.* BY H. GARMAN, LEXINGTON, KY.

Some time about 1888 the writer of these notes made several dissections of the brain of this interesting fish and drawings of them were made by Magnus Westergren, at that time Artist of the Illinois State Laboratory of Natural History. Other duties have until recently prevented further prosecution of the study, but I have now to present some of the results of a reëxamination of these dissections, kindly placed in my hands by Professor Forbes, together with some facts gained by a study of fresh material obtained by me from the Ohio River. For purposes of comparison I have dissected out the brain of our common sturgeon (*Acipenser rubicundus*).

As in other sturgeons, the brain of *Polyodon folium* is enclosed by a thick cartilaginous cranium. It rests on the floor of a cavity which it only partly fills, the space above being partly occupied by fatty tissue, but that part dorsal to the mid-brain being almost entirely empty. As if to make up for the deficiency of padding about the brain, the fore- and mid-brains are enclosed in a tough whitish fatty tissue of considerable thickness, which can only be removed by the exercise of great care, so closely and tenaciously does it adhere. A peculiar feature of the brain when first exposed is a dense black fat which encloses the hind-brain and fills a large space surrounding the base of the spinal cord where it leaves the medulla. I have seen nothing just like it in other fresh-water fishes.

The olfactory nerves are very large, indicating that the sense of smell is an important one to the shovel-fish. Each nerve is separated, from its origin on the

walls of the olfactory lobe, into two divisions, with some slight intermingling of fibers at the base. The divisions lie parallel at first, but separate completely at about the middle of their course, and before reaching the nasal sac each divides into a number (seven were counted) of small diverging branches passing into the walls of the sac. One can see in the olfactory nerve of *Acipenser rubicundus* an indication of doubleness, but in *Polyodon* it is carried much further, the divisions being independent except for the slender fibers which cross from one to the other at the base. The nerves have a very slight upward turn as they pass out to the sac.

The olfactory lobe is well developed in both *Polyodon* and *A. rubicundus*, but is not a conspicuous part of the brain in either fish. To ordinary inspection it looks like a slight enlargement of the base of the olfactory nerve. It contains a ventricle of large relative size which communicates with the ventricle of the fore-brain.

The fore-brain presents no outward trace of doubleness. When viewed from above it is oval in general shape, widest at about the middle, and is obtusely angulate medially in front. Viewed from the side it is seen to rise above the level of the olfactory lobes. It appears not to be so well developed in *Polyodon* as in *Acipenser*. The division commonly termed the thalamencephalon can hardly be said to exist, though the constriction of the brain at this region and the positions of the epiphysis and hypophysis definitely locate it. The ventral wall of the fore-brain bears two large, lobed, white, basal ganglia which encroach a good deal upon the ventricle. The front extremity of each lies opposite the opening into the ventricle of the olfactory lobe. A membranous dorsal sac is present which communicates freely posteriorly with the cavity of the fore-brain. It is not as conspicuous in *Polyodon* as in our sturgeon, and is not perceptible from without except as its out-

line is roughly indicated in alcoholic specimens by collapse of its dorsal wall, which usually gives rise to a depressed area on the posterior dorsal surface of the fore-brain. In front of the dorsal sac the dorsal wall of the fore-brain, viewed from within, presents a slight median ridge, while anteriorly, between the olfactory lobes, is a slight membranous fold, these being the only indication of separation of the cavity of the fore-brain into two ventricles. The fore-brain of *A. rubicundus* shows a similar but, I think, somewhat larger trace of a septum between the halves of this division of the brain. The lateral wall of the fore-brain of *Polyodon* is provided within with thin vertical plicæ, resembling those on the inside of the dorsal membrane of the fourth ventricle.

Arising from the dorsal wall of the brain at the junction of the fore- with the mid-brain is a slender white filament having the appearance, to ordinary inspection, of a nerve. At first it is concealed by the dorsal wall of the dorsal sac. By reflecting this wall it appears running along the ventral side of the wall as a whitish line. It emerges to the exterior near the anterior extremity of the dorsal sac and extends thence obliquely upward and forward to the cartilaginous cranium, where it passes into a special channel, along the middle of which it extends in a direct course nearly to the surface. In a fish which must have been about $3\frac{1}{2}$ feet long, the end organ to which this filament passes lies about 1.66 mm. from the outer surface. The stalk expands as it enters the end organ. It is enclosed throughout its course in a membranous sheath, which gives it an appearance of being larger than it really is. It is accompanied by small blood vessels which supply the walls of the passage and eventually give small capillary vessels to the end organ.

The end organ is also enclosed in a sheath continuous with that surrounding the stalk. From the surface of the sheath radiate numerous small slender fibers (muscular?) which pass to the walls of the cavity in which

the organ lies, and thus serve to keep it in place. Some of the fibers arise from the dorsal face of the sheath of the end organ. The essential part of the organ, within the sheath, looks, on ordinary examination with a low-power objective, like a small whitish nervous ganglion. It is somewhat slipper-shaped viewed from the side, but a dorsal view shows it to be a little depressed, with the dorsal side slightly convex. The outline is roughly oval in shape, viewed from above. In the specimen studied most carefully there was a slight rounded anterior projection. From my recollection of some sections prepared by me at the Illinois Laboratory, and of a drawing of one of them made by Mr. Westergren, I can say that the organ contains a cavity, but presents nothing which could be regarded as a lens. The stalk and end organ are sometimes accompanied by pigment, but may show only a slight trace of it, as indicated in my outline figure (Fig. 9) of these structures. In one example studied pigment was much more abundant than in the rest, and was accumulated beneath the end organ somewhat as it is back of the eyes of Vermes and Crustacea.

The channel in which the stalk and end organ lie is in one of the shovel-fish* examined 18.5 mm. in length, and has an average diameter of about two millimeters. Distally it enlarges somewhat, and is rounded at its extremity. A system of smaller passages ramifying in the cartilage of the cranium is in communication with it.

In one of my specimens the cavity about the end organ is more enlarged than in the others and a small passage leads through the cartilage above to the exterior. The passage was plugged with connective tissue similar to that constituting the skin which overlies the cartilage above the end organ. In another example studied I found no trace of an opening to the exterior. Unfortunately I neglected to examine thoroughly, with reference

* This fish was not less than three feet long.

to this point, two other examples dissected, but I am disposed to think such passage could not have been present in them, else it would have caught my attention.

From the outside the position of the end organ can be made out at once in *Polyodon* by the presence of an elliptical foramen* in the bony exoskeleton which covers the cartilage of the head. It shows as a depressed area when undisturbed, and is occupied by skin in which one can see with a magnifier uniformly distributed pigment specks. In one of my specimens the foramen measures 7 mm. in diameter and 19 mm. in length. It extends lengthwise with the cranium, and lies between the eyes. I can see no change in the character of the skin immediately over the end organ, which lies beneath or a trifle posterior to the center of the foramen. When the skin occupying the foramen is removed the cartilage under it is seen to be gently convex; and when the surrounding bony exoskeleton is also taken away the region is still perceptible, owing to this convexity and to the different color and greater translucency of its cartilage, through which, by close looking, one can see the end organ. The adjoining cartilage is of a more opaque whitish cast. The thickness of the cartilage and skin together just above the end organ measures in one of my examples 1.75 mm., of which each tissue constitutes about one half. The end organ in this specimen lies 0.50 mm. beneath the cartilage, and measures about one millimeter in diameter, excluding the enclosing sheath.

In *Acipenser rubicundus* the pineal structures are in general much like those of *Polyodon*. In this fish the stalk is concealed at first beneath the wall of the dorsal sac and reaches the roof of the brain proper at the same point as in *Polyodon*. It is accompanied into the channel in

*The foramen is completely surrounded by the "frontal" bones of Collinge (Quar. Jour. Mic. Science, Vol. 36, 1894, pp 499-537). These bones are not separate at the middle line, as represented by this author, but meet both in front and behind the foramen, so that the median bone, the "dermo-ethmoid," is excluded from the foramen in front. Collinge may have described the bones of an immature example; otherwise the difference between his account and my own indicates considerable variation.

the cartilage by an extension of the dorsal sac, which can be followed rather more than half the distance to the end organ. The stalk is, however, throughout its course an entirely independent structure, and is made conspicuous by the blood vessels accompanying it, the blood supply here being apparently greater than in *Polyodon*. The end organ lies close under the cartilage, but not quite so near the surface as in *Polyodon*. The cartilage over it, in one example studied, is 1.50 mm. thick. I found no opening through the cartilage, and the bony exoskeleton of the head, which is here about 2 mm. thick, is without a foramen.

The end organ in *A. rubicundus* is somewhat different from that of *Polyodon*. The stalk in its sheath expands gradually at its distal extremity and forms an elongate-ovate or club-shaped organ which is not firmly suspended like that of *Polyodon* by elastic bands. It measures 2 mm. in length and has a diameter of 0.66 mm. near its extremity. A system of minute blood vessels ramifies over the surface of its sheath in such profusion that one cannot help thinking that the organ must be functional. No pigment is apparent about it.

Whether these end organs are to be considered eyes or not they certainly are entirely independent not only of the lateral line system, but of all other nervous structures. In both of these fishes the slender stalk has a very direct and evident course from its origin on the roof of the brain to its end organ, and without receiving or giving off branches expands in the substance of this terminal enlargement. If its present condition is taken into account one must conclude that the structure is, or has recently been, an important sense organ to the sturgeons.

The infundibulum is very large in both *Polyodon* and *A. rubicundus*. It opens freely above into the posterior part of the fore-brain. The cavity extends well down into the organ, but the hypophysis itself, though

somewhat hollowed out within, is a compact, solid, whitish body. The *saccus vasculosus*, also of large size, is noticeable from its dark color. It is completely hollow, and its cavity communicates with that of the infundibulum. In *A. rubicundus* there is on each side of the infundibulum a conspicuous oval swelling, which dissection shows to be a thin-walled sac or pouch opening widely into the cavity of the infundibulum. In *Polyodon* this swelling is scarcely evident.

The optic nerves are small in *Polyodon*, as would be expected from the small size of the eyes. They are of larger relative size in our sturgeon.

The mid-brain is a compact rounded mass of small size, whitish in color when the pigmented connective tissue is all removed, and without any decided outward trace of separation into two lobes. There is a very slight median impression in front, but beyond this the mid-brain shows little appearance of doubleness, either inside or out. In *A. rubicundus* this division of the brain is more extensively and deeply impressed along the dorsal middle line, but even in this fish the mid-brain is a single structure with one undivided cavity. Its ventricle is occupied in part by an extension of the cerebellum, called by Goronowitsch the *valvula cerebelli*.

The oculo-motor nerve arises on the ventral side of the mid-brain close to its junction with the hind-brain.

The trochlear nerves are exceedingly small and slender, and their origin is so concealed by the adjacent structures and so covered up by connective tissue that one must follow them up with care in order to find where they leave the roof of the brain. Both nerves, in both *Polyodon* and *A. rubicundus*, seem to arise at the dorsal middle line, and originate so close together that they look like a single nerve passing over the roof of the brain and joined to the latter at the middle line. In the sturgeon there is a small whitish lunate swelling just in front of the point where they leave the brain.

The hind-brain is the largest division of the brain in *Polyodon*. It is large also in *Acipenser rubicundus*, but the disproportion is not so great in the latter. In the shovel-fish it is, in front, more than twice the width of the mid-brain. The extensive fourth ventricle is completely covered dorsally by a thick, tough, black epithelial membrane, with strongly plicate inner surface. When this membrane is removed the ventricle is seen to be widely open and bounded largely by the conspicuous restiform tract. The lobe of the cerebellum, already mentioned as the *valvula cerebelli*, can be seen extending into the ventricle from the front, its forward extension, already noted, occupying the posterior part of the ventricle of the mid-brain.

The trigeminal group of nerves, arising from the lateral wall of the medulla, is made up of three well-defined parts in *Polyodon*. The most anterior division is a slender nerve* about as large as the oculo-motor, which extends obliquely outward and forward, crossing over the oculo-motor and passing out towards the snout. It seems to be throughout entirely independent of the other divisions of the fifth nerve. The second division is much larger and, arising just behind the first, extends outward and forward, parallel with the first, until it joins the third division. The latter is the largest division of the three, and arises from the restiform tract, some distance behind the second division and well up on the side wall of the medulla. At first it extends downward and forward, then outward over the large second division.

The seventh nerve (facial) looks in *Polyodon* like a posteriorly directed branch of the trigeminal. It arises from the side of the medulla beneath the third division of the fifth, with which it is at first very closely bound up, extends forward and outward, and then turns abruptly backward, leaving the fifth at once.

*Ramus ophthalmicus superficialis, according to Collinge.

The auditory (eighth) is a strong nerve which arises just behind the facial and on a level with it, but is completely independent. It divides into two branches at once, and these subdivide before being distributed to the ear.

A considerable space separates the ninth nerve (glossopharyngeal) from the eighth. It is slender in *Polyodon*, and extends backward parallel with the spinal cord at first, lying beneath the tenth nerve (vagus), so that it is not visible from above. A short distance posterior to the medulla it turns outward and then becomes distinguishable.

A slender nerve arises above the ninth and extends back over it to the side of the tenth with which it joins and merges, though not entirely losing its identity as far as followed. I take this to be the lateral line nerve. Near its origin it exchanges fibers with the ninth.

One of the largest cranial nerves in *Polyodon* is the vagus, although it is not as large as in *A. rubicundus*. It arises well back on the side of the medulla, on a level with the nerves just mentioned. Its fibers separate into bundles where it joins the medulla, of which I count eleven, the two hindmost being smallest and turning abruptly out of the general course to join the medulla.

The sixth nerve (abducens) I have not studied in *Polyodon*. In *A. rubicundus* it is very small, and arises by two roots near the ventral middle line, about midway between the eighth and ninth nerves.

Further explanation may be left to the figures accompanying these notes.

Looking at the brain of *Polyodon* as a whole, and as compared with that of the sturgeon and other fishes, it may be said that it impresses one as that of a fish of inferior rank, although the peculiar snout and other features of the anatomy speak of a somewhat special development. The large relative size of the medulla oblongata and the undivided and poorly developed fore- and

mid-brains justify this impression, as do the condition of the pineal structures and their relation to the exterior.

The brain of *A. rubicundus* is certainly that of a more active and intelligent fish. The corresponding nerves are larger in the sturgeon; its fore-brain is larger relatively; the mid-brain is larger and with an evident suggestion of doubleness; the medulla is smaller relatively; and, finally, the pineal end organ is less evidently placed and surrounded to receive impressions from without.

EXPLANATION OF FIGURES.

— 801
PLATE I.

Fig. 1. Side view of brain and pineal structures of *Polyodon* as they appear when the cartilage is cut away from one side. Natural size. *Magnus Westergren del.*

PLATE II. 802

Fig. 2. Dorsal view of brain of *Polyodon*, with the connective tissue and fat removed from the fore- and mid-brains and the cerebellum, but with membrane roof of 4th ventricle left in place. A, nasal sac; B, olfactory lobe; C, pineal stalk; D, fore-brain; I, mid-brain; J, cerebellum; M, medulla oblongata; O, spinal cord; 1, olfactory nerve; 3, oculo-motor nerve; 10, vagus nerve. From a photograph.

PLATE III. 803

Fig. 3. Dorsal view of brain of *Polyodon*. B, olfactory lobe; C, pineal stalk; D, fore-brain; I, mid-brain; J, cerebellum; K, valvula cerebelli; L, restiform tract; O, spinal cord; P, part of membrane roof of medulla oblongata, turned aside; 1, olfactory nerve; 2, optic nerve; 3, oculo-motor nerve; 4, trochlear nerve; 5, 5, trigeminal nerves; 7, facial nerve; 8, auditory nerve; 9, glosso-pharyngeal nerve; 10, vagus nerve. *H. Garman del.*

Fig. 4. The glosso-pharyngeal and vagus nerves, completely uncovered and drawn apart so as to show the lateral line nerve at R. *H. Garman del.*

Fig. 5. Side view of brain of *Polyodon* turned so as to show the infundibulum. F, hypophysis cerebri; G, saccus vasculosus. Other letters and figures as in Fig. 3. *H. Garman del.*

XIX
PLATE IV.

Fig. 6. Side view of brain of *Acipenser rubicundus*. B, olfactory lobe; C, C, pineal stalk terminating distally in the pineal end organ; D, fore-brain; E, infundibulum; F, hypophysis cerebri; G, saccus vasculosus; H, swelling on side of infundibulum; I, mid-brain; J, cerebellum; M, medulla oblongata; O, spinal cord: 1, olfactory nerve; 2, optic nerve; 3, oculo-motor nerve; 4, 4, trochlear nerves; 5, 5, origin of trigeminal nerve; 7, origin of facial nerve; 8, origin of auditory nerve; 9, origin of glosso-pharyngeal nerve; 10, origin of vagus nerve. The small enclosed area connected with 10 by an arrow, marks the origin of the lateral line nerve, a part of 10. *H. Garman del.*

PLATE V.

Fig. 7. The exposed channel in which the pineal end organ and its stalk lie in *Polyodon*. A, aperture to the exterior. (The skin covering the cartilage has been removed.) B, end organ; C, cut end of stalk. *H. Garman del.*

Fig. 8. Pineal end organ and a part of its stalk in *Polyodon*, removed from the channel in cartilage, and the end organ turned so as to show the surface presented to the exterior. A, end organ enclosed in sheath and with part of the elastic bands remaining attached; B, cut end of stalk. *H. Garman del.*

Fig. 9. Pineal end organ and stalk of *Polyodon* shown in place. A, end organ; B, cut end of stalk; C, sheath

enclosing stalk; D, line representing boundary of channel.
H. Garman del.

Fig. 10. Pineal end organ and stalk of *Acipenser rubicundus*. Letters as in Fig. 9. *H. Garman del.*

PLATE XXI.

Fig. 11. Part of the bony exoskeleton of head of *Polyodon*, with the elliptical foramen under which the pineal end organ lies. Natural size. From a photograph.