With the Compliments of the Author.

ON THE

YOUNG STAGES OF SOME OSSEOUS FISHES.

I. Development of the Tail.

1835-1910

By ALEXANDER AGASSIZ.

[From the Proceedings of the American Academy of Arts and Sciences, Vol. XIII.]

Cambridge, November, 1877.

IV.

ON THE YOUNG STAGES OF SOME OSSEOUS FISHES.

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Presented Oct. 10th, 1877.

I. *Development of the Tail.*

The structure of the tail of bony fishes has been described by Agassiz, Vogt, Owen, Stannius, Heckel, Huxley, Kölliker, and Lotz. The homocercal tails of bony fishes of the present day were contrasted by Agassiz and Vogt, and subsequently by Heckel, with those of the Ganoids, and of other fishes appearing before the Jurassic period, having so-called heterocercal tails; and they attempted to show that the tails of all homocercal fishes pass during their development, through a heterocercal stage. Heckel, Huxley, Kölliker, and Lotz have plainly shown, that, while the external appearance of the tail of bony fishes is homocercal, their real structure is only a modified heterocercal one: so that, as far as we now know, the tail of all fishes is built upon the modifications of the same type; the caudal fin not differing (as I shall show here), in its mode of development from the primitive embryonic fin, from that of the dorsal or anal fins. The theory of Agassiz, that the heterocercal tail of the young of bony fishes passes gradually into a homocercal one, and that the tail of the young of the bony fishes represents an embryonic stage which is permanent in Ganoids, is apparently overthrown by the well-established fact of the heterocercality of the tail of adult bony fishes modified externally so as to assume a homocercal form.

In the following notes, I shall describe the gradual change of the embryonic tail of several species of bony fishes, and call attention to the presence of an embryonic caudal lobe, which has thus far, apparently, escaped the notice of ichthyologists, and which shows remarkably well the identity of growth between the tails of Ganoids and of bony fishes.

As early as 1856, the late Professor Agassiz noticed in Lepidosteus a peculiar fleshy filament (the extension of the vertebral column) above the caudal fin, capable of independent vibratory motion; and compared the young caudal to a second anal, from its position as an appendage of the lower surface of the dorsal column.

This filament still exists in specimens having a length of eight inches. (See fig. 1.) Professor Wilder has lately * followed the transformations of the tail of the Gar-pike, from the time when the tail of the young Lepidosteus is in the stage corresponding to that of Pl. I. fig. 4, of this paper, until the filament has entirely disappeared, and the tail has assumed the rounded outline of the adult. He has also found traces of this filament in very young specimens of Amia, as a slight undulation of the dorsal edge of the caudal at the termination of the supposed notochord.

The stage figured by Wilder agrees very closely to the stage of Pl. I. fig. 10, of this note, and represents — I have not the least doubt, from having traced its gradual disappearance in so many of our bony fishes — the remnant of the fleshy embryonic filament of our bony fishes and of the Ganoids, as was surmised by Wilder.

I have given in Pl. I., quite in detail, the changes gradually taking place in the tail of a Flounder, from the time it leaves the egg until it has nearly assumed the final shape of the adult. On Plate II., I have given figures of a number of young fish tails, of different species, to show how general is the presence of the embryonic caudal fin, even in a comparatively advanced stage of growth. I have also given on the same Plate a figure of a young Lophius (Pl. II. fig. 9), a few days after its hatching from the egg, to show how extensive are the changes our fishes go through before reaching the adult condition; and I hope to give little by little, in papers I am now preparing, the general history of these changes in the principal families of our marine fishes, commencing with the development of the Pleuronectidæ.

In a young Pleuronectes, just hatched from the egg (Pl. I. fig. 1), the caudal end of the chorda is straight. It extends from the anterior arch between the otolites to its posterior extremity, in a line nearly parallel to the dorsal embryonic fin, nearer the dorsal than the ventral side. The embryonic caudal fin is rounded, and nearly symmetrical above and below, the dorsal fold being the narrowest.

In the next stage figured (Pl. I. fig. 2), the caudal extremity of the chorda has become slightly bent upwards, concave towards the ventral side; and then appears the first trace of the division line *f* be-

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* Notes on the American Ganoids. Proc. Am. Ass. Adv. Sc., 1876, p. 153, Detroit Meeting.

tween the embryonic and the permanent caudal fins; also, traces of the principal caudal rays, and of the accessory rays both of the dorsal and ventral side of the tail. In the following stage, the indentation between the embryonic and the permanent caudal has become deeper, the chorda more arched; the caudal fin-rays are well marked, and the permanent caudal now projects well beyond the general outline of the embryonic fin fold. The delicate lines imitating the fin-rays of the permanent fins, are specially prominent in subsequent stages (Pl. I. figs. 5–9). In the tail of the young of Pl. I. fig. 4, the whole tail is thrown up, and has now assumed the regular heterocercal type; the permanent fin-rays of the caudal being all placed on the lower side of the chorda. There is no trace, as yet, of any ossification of the vertebral column; the anterior and posterior supports of the fin-rays, as well as the supports of the accessory dorsal and ventral rays, are all cartilaginous.

In the next stages (Pl. I. figs. 5–7), the embryonic caudal has assumed the shape of a large independent lobe; the permanent fin proper extending entirely below it, and forming an independent fin, like a second anal, entirely on the lower surface of the notochord. The resemblance of the tail, at this stage, to the tail of Lepidosteus is so striking that I have here given, for comparison, a figure of the tail of the young Lepidosteus (eight inches in length), from which the late Professor Agassiz described the fleshy filament extending independently above the permanent caudal.

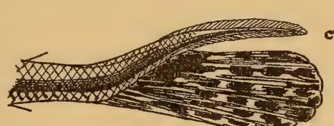

Fig. 1. Tail of young Lepidosteus.

In consequence of the greater arching of the notochord (Pl. I. fig. 5), and the simultaneous growth of the permanent caudal (the embryonic caudal remaining unchanged), the caudal fin is now bilobed. The principal permanent fin-rays of the tail-fin are well developed, but not yet articulated; the dorsal and ventral cartilages of the accessory fin-rays are well separated. In this and the preceding stages, large pigment spots are found between the two principal cartilaginous supports of the fin-rays, and afterwards greatly developed along their outer edge. The large black spot found on the tail of Amia, near the base of the caudal rays, recalls strikingly this space covered by pigment spots. We also find in otner genera (Ctenolabrus), a large pigment spot, remaining more prominent than the others during the whole embryonic growth, and which can still be traced when the young fish has grown to a considerable size. In Ctenolabrus, the large pigment spot is placed on each side at the base of the tail, half-way between the termination of the dorsal and anal fins.

In Plate I. fig. 6, the caudal extremity of the chorda is still more arched upwards, the permanent caudal fin projects as far as the extremity of the embryonic caudal, the lower anterior edge is also separated by a slight indentation from the general line of the primitive embryonic fin-fold, and four or five of the principal caudal rays show a single articulation.

In this and in the subsequent stage (Pl. I. fig. 7), we see the first trace of the gradual disappearance of the embryonic caudal. In Pl. I. fig. 7, the permanent caudal projects beyond the embryonic tail, and there are traces of two articulations in a couple of the principal fin-rays. The permanent caudal has also gradually been thrown more upwards (Pl. I. fig. 8); the fin rays becoming more and more parallel with the axis of the body, until they gradually spread, fan-shaped, on each side (after passing through stage Pl. I. fig. 9) of a central line, as in Pl. I. figs. 10 and 11.

In Pl. I. fig. 8, we have the first sign of the disappearance of the extremity of the notochord, preparatory to the formation of the urostyle. (See Pl. I. figs. 10, 11, and 12.) The permanent caudal is now pointed, projecting far beyond the embryonic caudal, which, in the subsequent stage (Pl. I. fig. 9), is reduced to a slight lobe; it becomes still smaller in the next stage (Pl. I. fig. 10); and is finally reduced to a mere thickened semi-transparent edge, — the last remnant of the original embryonic fin-tail fold to be found in the permanent tail (Pl. I. fig. 11). Accompanying the disappearance of the embryonic caudal, we find a constant increase in the length of the permanent caudal (Pl. I. fig. 9). From being pointed, as in Pl. I. figs. 8, 9, it becomes somewhat rounded; and, with the more symmetrical arrangement of the fin-rays, the edge becomes scalloped as in figs. 10 and 11, and it does not differ materially from that of the adult in its general outline. In fig. 11, we can plainly see the ossification of the vertebræ, with the corresponding apophysis, the urostyle, the two principal cartilages supporting the fin-rays, with the dorsal and ventral cartilages supporting the accessory fin-rays. This is better shown in fig. 12, — a magnified drawing of the base of the tail of fig. 11.

The other genera of bony fishes in which I have traced the presence of this embryonic caudal lobe, or a trace of it, are Atherina, Batrachus, Cottus, Ctenolabrus, Lophius, Gasterosteus, Fundulus, Phycis, Gadus, Menhaden, Temnodon, Labrax, Scomber, six species of Pleuronectidæ, Poronotus, Lumpus, several of the genera of Viviparous fishes (Embiotocoidæ) from San Francisco, and a few other species as yet undetermined. In the very youngest specimens of Syngnathus I have been able to examine (fig. 2), the position of the two supports of the caudal rays, below the upturned termination of the notochord differed in no wise from that of the other bony fishes here mentioned.

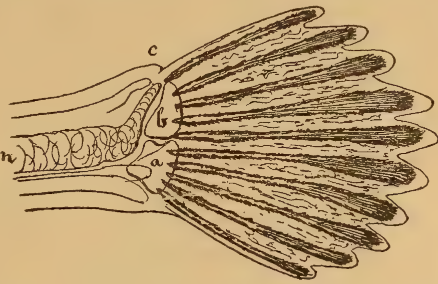

Fig. 2. Tail of young Syngnathus, $\frac{3}{4}$ in. long.

In Atherina, Pl. II. figs. 1–4, the embryonic caudal does not form quite so marked a lobe as in the species figured in Pl. I. Still, the separation between the permanent and the embryonic caudals is sufficiently well-marked to leave no doubt of the existence of the caudal lobe. The same is the case with Batrachus (Pl. II. fig. 5), with Lumpus (Pl. II. fig. 6), and Ctenolabrus (Pl. II. fig. 7). In the young Poronotus (Pl. II. fig. 8), the embryonic caudal lobe is more prominent.

In Lophius, the termination of the notochord remains unchanged quite late in life; the tail of the young Lophius (Pl. II. fig. 10) showing no trace of any ossification of the vertebral column, or degeneration of the extremity of the notochord, at a time when the young fish can readily be recognized as a young Lophius, from the presence of the peculiar appendages of the pectorals and of the anterior dorsal. In Gasterosteus (Pl. II. fig. 13), the embryonic caudal is again very prominent: it can readily be traced in Pl. II. figs. 14, 15, until the tail has assumed the shape it finally takes in the adult. In all the genera thus far described, the tail gradually passes from a strictly ventral appendage, placed below the dorsal column, to that of a terminal tail placed in the continuation of the vertebral column.

In Phycis and in the Cod, the structure of the tail is somewhat different; the accessory fin-rays, both of the dorsal and ventral side, are very numerous (Pl. II. figs. 19, 20), far outnumbering what are usually called the principal rays of the tail. These accessory rays early make their appearance (Pl. II. fig. 18); so that, although the terminal part of the chorda is turned up as in other fishes (Pl. II. figs. 19, 20), and the two principal cartilages of the tail-fin are placed below it, as in other fishes, yet, owing to this, the separation between the embryonic and permanent caudals is never distinctly indicated (Pl. II. figs. 18, 19, 20) — at least, not in specimens I have had the opportunity of examining — by an indentation or a sharp notch, as in other species figured in this paper. The tail of Phycis and of Gadus, therefore, which at first glance are so beautifully homocercal, do not in reality differ from the tails of other bony fishes; having like them a truly heterocercal termination (Pl. II. fig. 17), but completely disguised by the great development of the accessory fin-rays of the dorsal and ventral sides (Pl. II. figs. 19, 20).

In addition to the similarity of structure of the embryonic tail of bony fishes with that of the Ganoids, we find another point of comparison in the fleshy, fringed pectoral fins, which recall Huxley's Crossopterygians. This fleshy pectoral seems to be quite generally present in the embryos of bony fishes. It is represented for Lophius, on Pl. II. figs. 9, 11, 12. I have found similar fleshy, fringed pectorals in the embryos of Cottus and of several other bony fishes. In fact, immediately before the appearance of the rays in the pectorals, all bony fishes may be said to have such fringed, fleshy pectorals. They are, however, not sufficiently large and prominent to affect the general appearance of the young fish, except in the genera Lophius and Cottus, and one or two others; but in these genera they are well developed, and are similar in structure to the fleshy pectoral of young Lepidosteus.

Carus has called attention, in the Leptocephalidæ,* to the peculiar mode of termination of the chorda, — slightly bent upwards. The filament forming the tail-fin of Tilurus, the forked tail of some of the species of Leptocephalus, and the peculiar ending of their tail, recalling heterocercal tails, are certainly embryonic characters, — judging, at least, from similar stages of many of our common osseous fishes. These characters, with others, — such as the unossified chorda, the transparency of the body, the large prominent pigment spots, — all go far towards confirming the view of Carus, that the Leptocephalidæ are only the embryos of other fishes, such as Cepola and Trichiurus.

Both Huxley and Van Beneden † contend that the facts which they bring forward completely refute the theory of the parallelism of the

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* Carus, J. V., Ueber die Leptocephaliden. Leipzig, 1861, p. 13.

† Van Beneden sur le développement de la queue des Poissons Plagiostomes, Bull. Acad. de Belgique, 3me série, xl. No. 3.

embryonic tails of bony fishes with those of fishes preceding the Jurassic period: Huxley, because the bony fishes of the present day are not provided with a structurally homocercal tail (as was supposed by Agassiz and Vogt), but have — as he showed from Gasterosteus, and as I have shown here from many other genera of bony fishes — a truly heterocercal structure; Van Beneden, because in the Plagiostomes the tail of the young fish is at first truly homocercal, this condition preceding the heterocercal one, while, according to Agassiz and Vogt's theory, the young Plagiostomes should possess pre-eminently heterocercal tails; and, taking it also for granted that the oldest fossil fish known possessed truly homocercal tails, the whole theory, according to him, falls to the ground.

Now, while fully admitting, with Huxley, that what Agassiz and Vogt called homocercal, in the modern bony fishes, is only an external delusion, due to a structure of the bones of the tail, which (as I have shown here) is found in a large number of bony fishes of the present day; while also admitting, with Van Beneden, that the young Plagiostomes, which in the adult have a truly heterocercal tail, yet have, in the early stages, a strictly homocercal (structurally also) tail, — yet I think that neither Huxley nor Van Beneden has upset the theory of Agassiz and Vogt; and that, mistaken as they were in the details, the great generalization remains, of the complete accordance between the embryonic growth and the paleontological development: only it must be carried one step farther; and we must, at the same time, give a somewhat different interpretation of the meaning of the heterocercality of the tail, so prevalent among the bony fishes of the present day, from that given to it by Agassiz and Vogt. Let us preface by stating that the heterocercal tail is not the earliest stage; and that neither Von Baer, nor Agassiz and Vogt, stated this, but merely noticed it as one of the early stages in the fish embryo. In fact, as is well known, the earliest stage of the tail in the egg, and immediately after hatching, is nearly symmetrical; the notochord extending in a straight line towards the tail, with the dorsal and ventral embryonic fins forming a rounded tail, the dorsal fin slightly narrower than the ventral. This stage we might call the Leptocardial (Pl. I. fig. 1), — the earliest form of tail assumed by bony as well as other fishes, which precedes that of the heterocercal tail proper (Pl. I. figs. 3, 4).

So that, as far as embryology is concerned, the tail of the Selachians is formed strictly in accordance with the law of development of other bony fishes; and it only remains to be seen how this accords with the paleontological record.

If we examine the tails of the Devonian fishes, — as we know them from the restorations of Agassiz, Hugh Miller, Pander, Heckel, Pictet, Huxley, and others, — we cannot fail to be struck with the exact parallelism of these ancient fishes, as far as the structure of the tail is concerned, with the structure of the successive stages of the tail of the young Flounder, figured on Plate I. of this paper.

We find, among the Devonian fishes, genera with truly leptocardial tails, like those of Pl. I. fig. 1, such as the genera Glyptolæmus, Gyroptichius; also, genera with slightly modified tails (with the least possible tendency to heterocercality), as in figs. 2 and 3, — Holoptichius and Osteolepis; next, such genera as Glyptolepis, where the heterocercal tail is somewhat more marked, approaching nearer the form of Pl. I. fig. 4. But it must be remembered, that in all these genera, although the outline of the tail-fin is much as in the figures here given (Pl. I. figs. 2–4), yet, as in Polypterus and still more in Ceratodus, the scales extended over the dorsal column into the tail, in a triangular shape; and it is only in such genera as Dipterus that the heterocercal character becomes more prominent, as in Pl. I. fig. 4.

This does not by any means conclude the parallelism, which is still more striking when we come to such forms as Phaneropleuron and Tristichopterus, where the tail is lobed, the dorsal column extending into the dorsal lobe exactly as in the stage represented in Pl. I. figs. 5, 6.

In the Old Red, such genera as Acanthodes, Diplacanthus, Cheirolepis, and the like, represent stages corresponding to those of Pl. I. figs. 5, 6, 7, where we find the first indication of the separation of a true caudal and of an embryonic caudal. In the subsequent modifications of the tail of fossil fishes (approaching Lepidosteus), the tendency has been gradually to lessen the upper embryonic caudal lobe, and to give greater prominence to what is to become the caudal proper; although there is not, of course, the difference in structure of the fin-rays of the two sections to separate them, as in bony fishes. It is only when we compare these older forms with such genera as Platysomus, Semionotus, Lepidotus, and finally Pachycormus, that we trace the gradual approach to an externally homocercal tail, much by the same process which we readily follow in the embryo fish through the corresponding changes from Pl. I. fig. 8, to Pl. I. fig. 11. The gradual shortening of the extremity of the chorda dorsalis, until it only extends slightly in advance of the base of the caudal rays, is strictly analogous to the disappearance of the embryonic caudal and the gradual development of the permanent caudal from the lobes of the heterocercal tail of the young fish embryo.

In addition to the parallelism of the embryonic and paleontological development of the tail, we find other embryonic characters in the Old Red fishes. I have already alluded to the old-fashioned structure of the pectorals in the embryo of Lophius and other bony fishes; and would call attention to the innumerable embryonic fin-rays (Pl. I. figs. 5–9) of the embryonic dorsals and ventrals, which recall strikingly the similar numerous rays so characteristic of the fins of the older Ganoids.

So that, while Agassiz and Vogt were undoubtedly mistaken in the details of their explanation and comparison of the homocercal and heterocercal tails, yet the parallelism they attempted to prove, not only exists, but can even be carried out far beyond any thing they conjectured. Their very mistakes regarding the heterocercal structure of what they called a homocercal tail in the bony fishes of the present day being (as I have attempted to show) the best proof of the existence of such a parallelism, and the clearest indication possible of the uniformity of structure of the tails of the fishes of the present day with those of the fishes of the most ancient geological period in which fishes have as yet been found. This parallelism could, however, not be conclusively made out, until it was proved that the extension of the chorda dorsalis into the upper lobe of the heterocercal tail gave us the explanation of the peculiar heterocercal structure still to be traced in the so-called homocercal tails of the bony fishes of the present day, long after the disappearance of the upper caudal lobe, which (as I have shown) exists in bony fishes only during a short embryonic period.

DESCRIPTION OF THE PLATES.

LETTERING.

a. Anterior cartilage on lower side of notochord, supporting principal fin-rays.
b. Posterior cartilage on lower side of notochord, supporting principal fin-rays.
a′. Anterior dorsal cartilage.
b′. Posterior dorsal cartilage, supporting accessory fin-rays.
c. Embryonic caudal fin.
d d. Principal caudal rays.
d′. Accessory dorsal caudal rays, above notochord.
d″. Accessory ventral caudal rays, below notochord.
df. Dorsal fin.
vf″. Ventral fin.
f. Permanent caudal fin.
n. Notochord.
v. Last ossified vertebra.
v′. Dorsal apophysis.
v″. Ventral apophysis.
w. Urostyle.

PLATE I.

Tail of Flounder.

Fig. 1. Tail of young fish, with straight notochord and embryonic fin.
„ 2. Slightly older — the extremity of notochord somewhat arched, and showing first trace of caudal fin.
„ 3. The indentation between the embryonic caudal and the permanent caudal is deeper; fin-rays well defined.
„ 4. Extremity of notochord still more arched than in preceding figures; the separation between the permanent and embryonic caudals somewhat more distinct.
„ 5. In this stage, the permanent and embryonic caudals form a sharp angle; the distinction between embryonic and permanent rays is well shown.
„ 6. The permanent caudal extends as far as the embryonic caudal, which now shows traces of resorption.
„ 7. The pointed permanent caudal extends beyond the line of the embryonic caudal, somewhat decreased in size.
„ 8. The cartilaginous supports of the fin-rays proper have become large; the extremity of the notochord shows traces of the formation of the urostyle.
„ 9. The permanent caudal has increased greatly in length; the embryonic caudal is now reduced to a small rounded lobe.
„ 10. The caudal has become well rounded; a mere trace of the embryonic caudal is left. The urostyle is also more distinct.

Fig. 11. The tail has now the shape of that of the adult; the merest trace of the embryonic caudal remains.

„ 12. Fig. 11 somewhat magnified, to show the cartilages supporting the permanent and the accessory fin-rays of the tail, as well as the urostyle with last ossified vetebra.

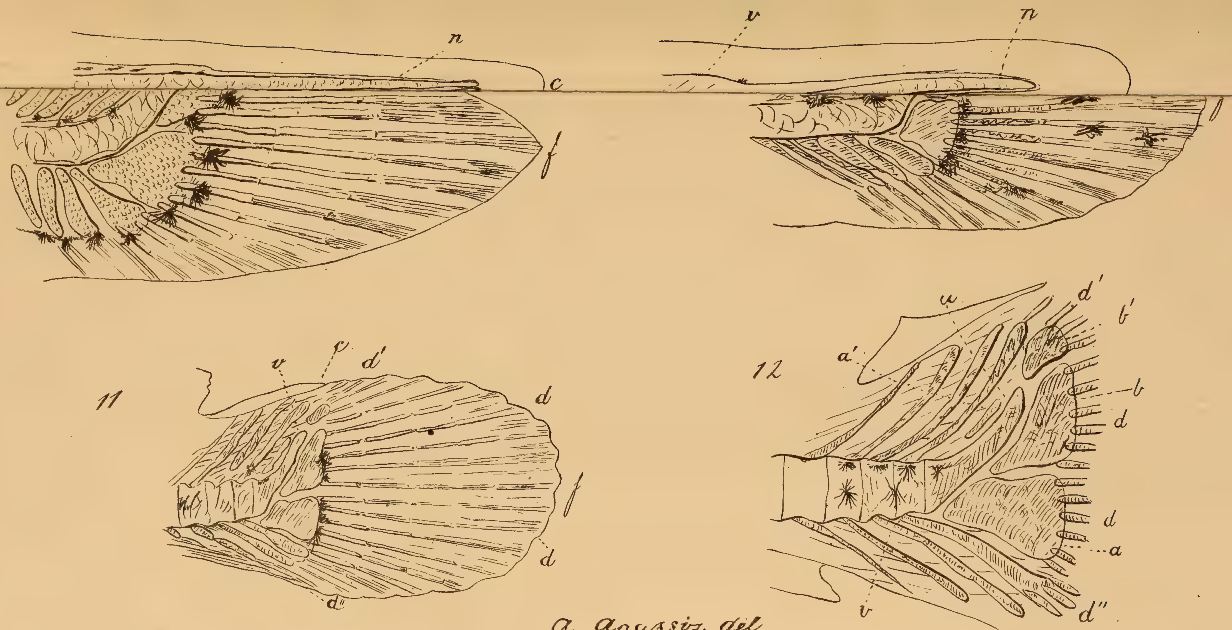
The young Flounder of Fig. 1 measured $6^{mm.}$ in length; that of Fig. 12 measured $18^{mm.}$; the whole change of the tail, from the straight notochord of Fig. 1 to the rounded tail of Fig. 12, took place in about three weeks, judging from the specimens fished up.

PLATE II.

Tails of Embryos of Young Fishes.

Figs. 1–4. Atherina, respectively $5^{mm.}$, $9^{mm.}$, $10^{mm.}$, $11^{mm.}$ long.
Fig. 5. Batrachus. $9^{mm.}$ long.
„ 6. Lumpus. $4^{mm.}$ long
„ 7. Ctenolabrus. $6^{mm.}$ long.
„ 8. Poronotus. $7^{mm.}$ long.
„ 9. Young Lophius with straight notochord. About $5^{mm.}$ long.
„ 10. Heterocercal tail of young Lophius. $20^{m.}$ long.
„ 11. Fleshy pectoral of same, seen from the side.
„ 12. Same seen from above.
Figs. 13, 14. Gasterosteus.
„ 16, 17, 18. Phycis. Fig. 16 *f.* $3^{mm.}$, $8^{mm.}$, $15^{mm.}$.
Fig. 19. Cod. $20^{mm.}$ long.
„ 20 and Fig. 18. Magnified. (Phycis.)

Alex. Agassiz Young Fishes Pl. I.



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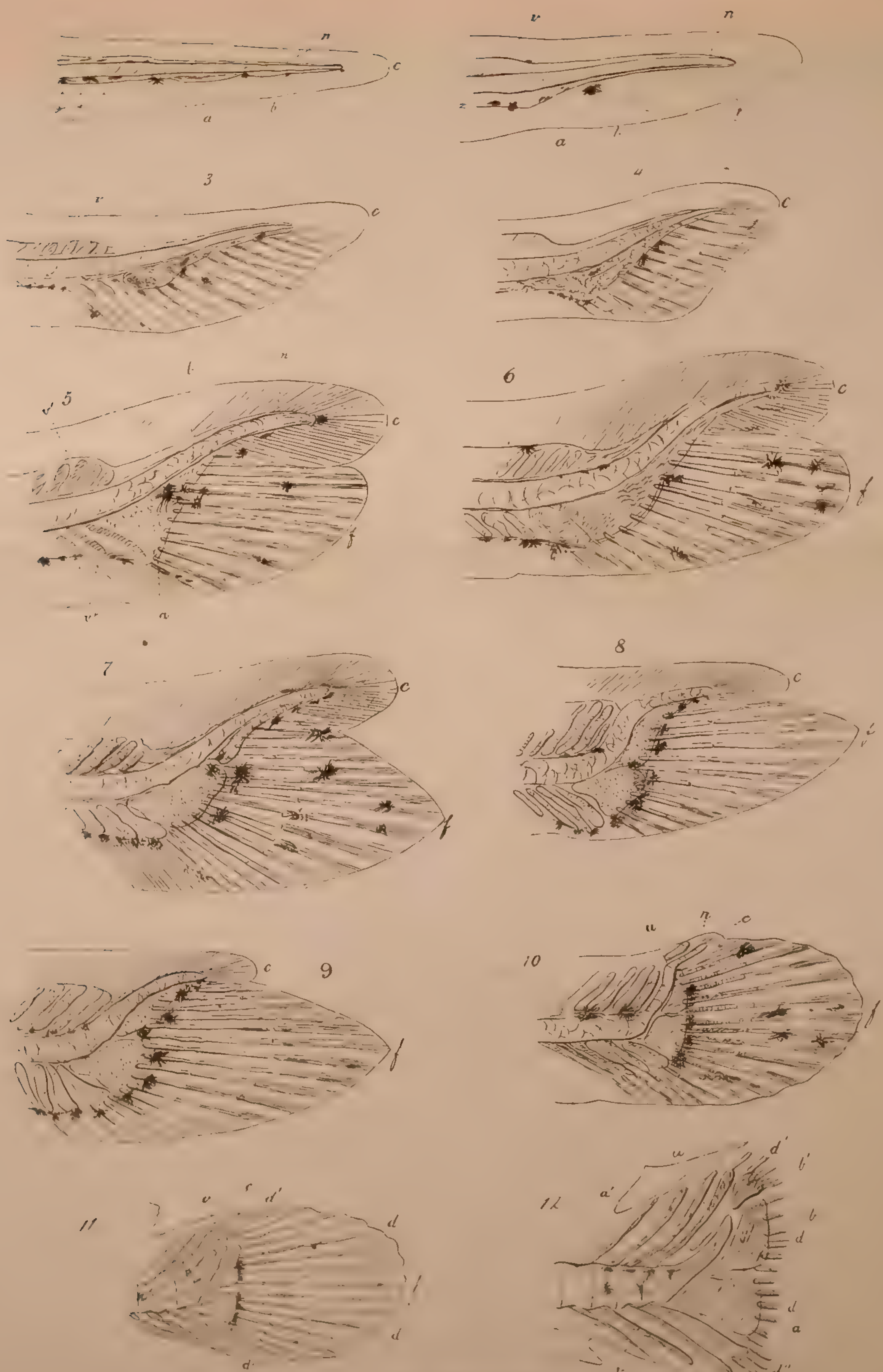
Alex. Agassiz Young Fishes Pl. I.



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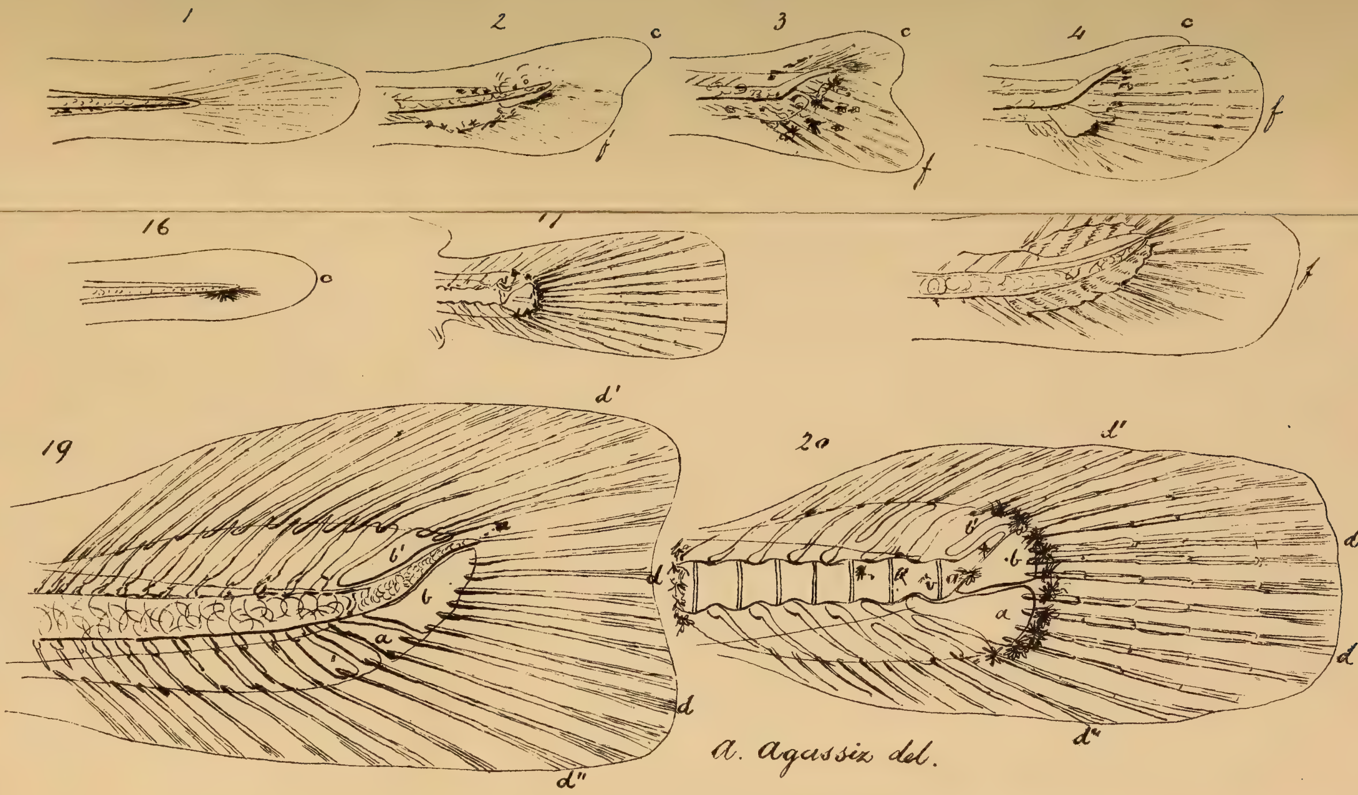
Alex. Agassiz Young Fishes Pl. II



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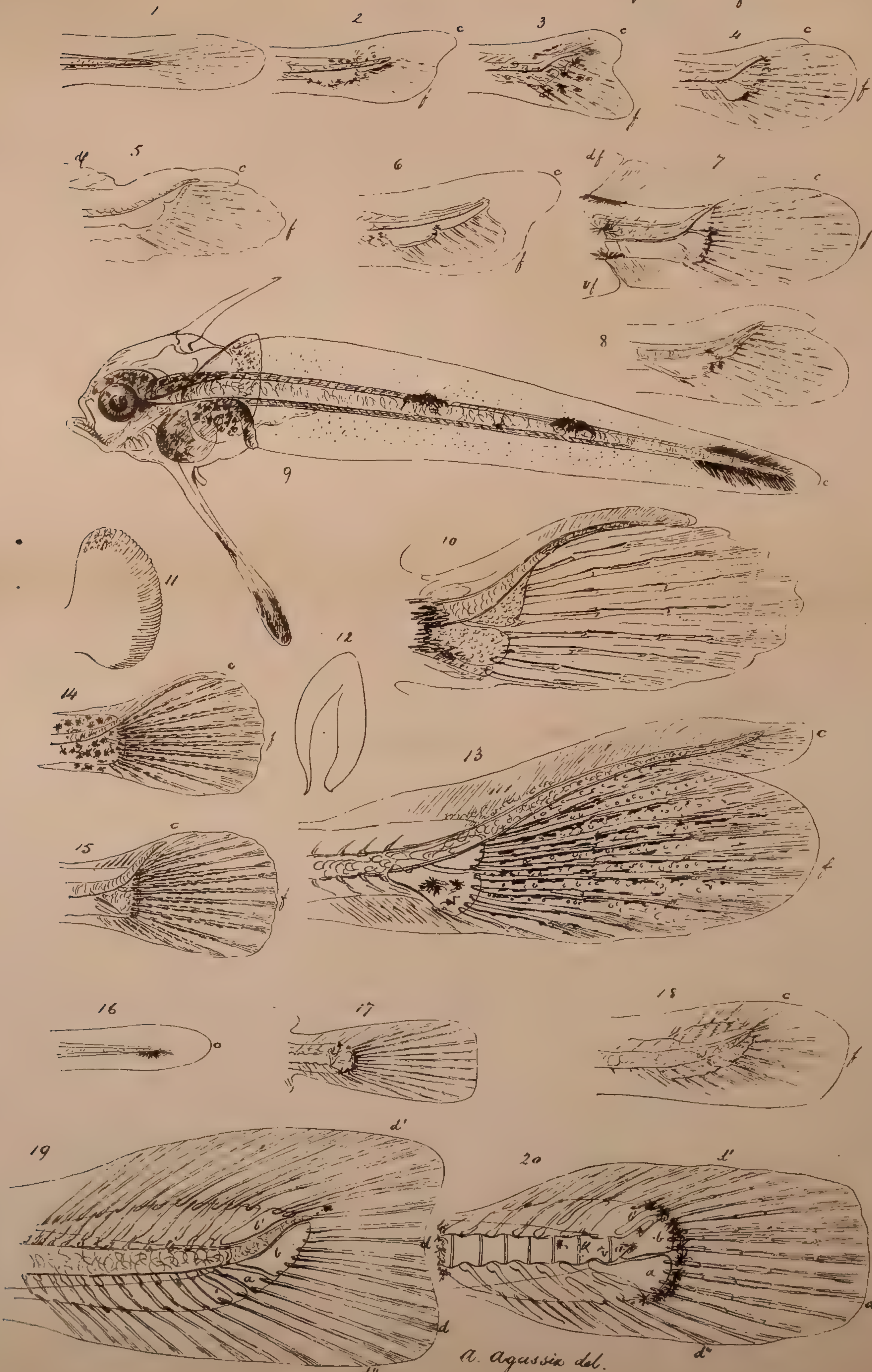
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By ALEXANDER AGASSIZ.

II. Development of the Flounders.

[From the Proceedings of the American Academy of Arts and Sciences, Vol. XIV.]

With 8 Plates.

Cambridge, June, 1878.

PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. XIV.

PAPERS READ BEFORE THE ACADEMY.

I.

ON THE YOUNG STAGES OF BONY FISHES.

By Alexander Agassiz.

Presented May 28, 1878.

II. *Development of the Flounders.*

A young Flounder, immediately after its escape from the egg, presents no special points of difference from the embryos of other bony fishes, in a similar stage of growth. There are, however, in the earlier stages also many points in common, to which but little attention has been paid, thus far; and the study of these characters presents, from an embryological point of view, many features of special and also of more general interest. As I have already treated of the development of the tail and head (in Part I. of these Studies),* the gradual passage from a leptocardial tail, such as we find in Pl. III. fig. 1, to a so-called homocercal tail (Pl. IV. fig. 5), I will not refer to this again, beyond calling attention to the peculiar physiognomy of these young bony fishes, while in the stages (Pl. III. figs. 3–5, and Pl. IV. fig. 1) during which the heterocercal tail is so prominent a feature, and before the fins characteristic of the osseous fishes have become wholly or partially differentiated from the primitive embryonic fin-fold, which extends from the base of the head, and runs more or less parallel with the dorsal chord, round the anal extremity, back toward the anterior

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* Proceedings Am. Acad. Arts and Sciences, xiii. 117. Boston, 1877.

part to the anal opening. Their general resemblance, at this time, to the Ganoid types of older periods, and especially to the Amias of the present day, cannot be too strongly insisted upon. In the Flounders, there is usually but a single dorsal and anal fin, formed from the original embryonic fin-fold. I will only notice, in a general way, the separation of the anal and dorsal from the caudal, by the earlier appearance of the permanent fin-rays; and the more rapid growth of the caudal, during the time when, in the dorsal and anal fin, the embryonic fin-rays, which disappear with the growth of the permanent ones, are still the most prominent feature. Little by little, however, with the increase in depth of dorsal and anal (Pl. IV. figs. 2, 3, 4, 5), the separation between these and the base of the caudal becomes more abrupt; and this, accompanied by the gradual shrinking of the remnant of the embryonic fin-fold at the base of the caudal both above and below, soon brings the relations of the three principal fins of the Flounders to the proportions they bear in the adult (Pl. IV. fig. 5). In another species (Pl. IX.), I shall describe the gradual development of the anterior dorsal out of the primitive embryonic fin-fold. In the bony fishes, neither the development of the ventrals nor the pectorals has yet been traced from a lateral embryonic fin-fold; but, in sharks and skates, the case is different. (See J. Wyman,* in his development of Raja.)

We may perhaps find hereafter, in the development of such forms as Lumpus, Liparis, and the like, a nearer approach to the Selachian mode of development of the paired fin-rays. In those of the bony fishes the development of which I have had an opportunity of following, the pectorals are well developed; early assuming, even while in the egg, the Ganoid (Crossopterygian) type, to which I have already alluded in the first part of this paper.† In some of the earlier stages, the lateral embryonic fold, from which the pectorals are formed, can be distinctly traced, — though never assuming the great prominence which it has in the dorsal or anal embryonic folds, the paired fins early concealing the lateral folds; while it is the reverse with the dorsal and anal folds, from which the dorsal and anal fins are developed late.

The ventrals, on the contrary (Pl. VI. fig. 5, Pl. VII. fig. 4, Pl. IX. fig. 6), make their appearance very much later, and, in our Flounders, at

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* Wyman, Jeffries. Observations on the Development of Raja Batis, in Mem. Am. Acad. Boston, 1864. And also Balfour, F. M. Elasmobranch Fishes.

† Agassiz, Alexander. On the Young Stages of Osseous Fishes. Proc. Am. Acad. xiii. Boston, 1877.

first as a mere swelling of the median line, behind the hyoid bone; this (Pl. IV. figs. 3–5) grows quite rapidly; the permanent fin-rays at once make their appearance, — the anterior ones (the outer) first; and there is nothing special to note in the further development of the ventrals, which soon resemble, on a small scale, the ventrals of the adult. The ventrals possess, at no time, embryonic fin-rays, like those of the dorsal, anal, and caudal fins, formed from the longitudinal embryonic fin-fold. In the pectorals, embryonic fin-rays also precede the formation of the permanent rays; but in many bony fishes (Pl. VI. fig. 5, Pl. X. fig. 1), these permanent rays appear very early, — before those of other paired or unpaired fins, — the Crossopterygian stage being passed while still in the egg.

A striking characteristic of the young of all bony fishes is the extraordinary development of the pigment cells (chromatophores and chromatoblasts), and the great changes they undergo during the growth of the embryo. Pouchet* has more recently called attention to the wide-spread existence of these pigment spots, so well known to all students of Invertebrates. He studied them especially among the Fishes, in connection with the atrophism of the color on the blind sides of Flounders; pointing most plainly to the partial atrophy of the great sympathetic nerve, effected during the passage of the eye from the right to the left, or *vice versa*, as the cause. The power of the nervous system over the complicated system of pigment spots, which produces eventually the coloring of the adult fish, is of course much more readily traced in the younger stages, while the individual cells are still isolated, and before their anastomoses have become so complicated that it is well-nigh impossible, even in quite young specimens, to follow the changes resulting from any special nervous excitement. Compare, for instance, the simple chromatic system of cells of Pl. II. figs. 1–4, with the more and more complex anastomosing branches of Pl. III. figs. 5 and Pl. IV. figs. 1–5. This is still better seen, perhaps, if we compare Pl. VI. figs. 1–3 (young Flounders, just hatched from the egg, and a couple of days old) with Pl. VI. figs. 5–7, showing the gradual passage of the few, large, well-individualized chromatic cells of Pl. VI. fig. 3, into the innumerable system of small cells, closely packed and crowded in spots, so as to form the special design characteristic of this species.†

* Pouchet, G. Des Changements de Coloration sous l'Influence des Nerfs. Archives de Physiologie et d'Anatomie. 1876.

† Pouchet has succeeded in producing a white side in trouts, by destroying the eye of that side. Rev. Scient. xiii. 1877.

The young Flounder has already attained a considerable size, before any signs appear of the change in the position of the eye on the left side (see Pl. III. figs. 3–5 and Pl. IV. fig. 1), and before the young fish shows the least tendency to favor one side over the other. Not until the young fish is fully three-eighths of an inch in length can the first slight difference be perceived in the position of the two eyes (when seen from above), the left eye being somewhat in advance of the other. In this species, the Flounder eventually lies down on the left side, which becomes colorless. In order to prevent repetitions, we shall call this the case of a right Flounder (dextral), — that is, of a Flounder colorless on the left side, and where the left eye has passed over to the right side, — calling the sides, at the same time, either blind or white, and the opposite ocular or colored.

Plates III. and IV. show very well the changes of form through which the young dextral Flounder passes before it finally assumes the appearance of the adult, and habitually rests with its colorless side upon the ground. All young Flounders, even long after they have all the characteristics of the adult, very frequently swim vertically for quite a length of time, or else swim near the surface, with the undulating movement they have when swimming over the bottom, their heads well raised, and bodies carried flat, parallel to the surface. Even quite old Flounders sometimes are caught swimming near the top of the water. Almost all the stages figured in Plates III. and IV. were caught near the surface, swimming vertically, like any other young bony fishes; but this they do only when they come up to feed, while the water is very smooth, about ten in the morning, on very bright sunny days, when they may be seen eagerly devouring swarms of embryo Crustaceans, of all orders. The young of other fishes seem to share this habit; for of the latter I have examined no less than twenty-five species, caught at various times with a hand-net, swimming near the surface of the water, on bright sunny days, when not a ripple ruffled the sea. With the least movement, all the more delicate of these embryos vanish; leaving only the older and more vigorous, which in their turn disappear, and seek shelter in deeper water. Only when the young fishes are old enough to be recognized as the young of their tribes, do they venture to join them in their ordinary haunts.

Pl. V. figs. 7–11, Pl. VI., and Pl. VII., on the other hand, give us in general the changes of form a young sinistral Flounder undergoes from the time it leaves the egg until it assumes the characteristics of the adult. The explanation of the plate will give all the necessary details of the changes, which are mere repetitions of those described in Pls. III. and IV.; with the exception, of course, that the blind, colorless side is now found on the right side of the fish, the left side being the chromatic side. This species, as compared with the dextral species, is remarkable for the greater development of the pigment cells, figured on Pls. III. and IV. The young Flounder (Pl. VI. fig. 7), when not more than three-fourths inches long, is already quite opaque, the whole colored side being thickly covered with minute pigment cells: they extend also upon the dorsal and anal, in irregular blotches, forming only in later stages the patterns which characterize some of the species among our Flounders. It is not uncommon for a peculiar pattern to appear quite early (see Pls. VII. and IX.).

In the present species, the pigments of the dorsal and anal do not appear before the stage figured on Pl. VI. fig. 5.

As will be seen, on an examination of the figures of Pl. VI., the earlier stages (Figs. 1–5) are readily recognized by the total absence of pigment cells in the extremity of the caudal. This feature still persists, in quite well-advanced individuals (Pl. VI. figs. 6, 7, 8). The tail, in this species, passes rapidly through the heterocercal stages, and does not present the striking external resemblance to that of Ganoids, so characteristic of the species figured in Pls. III. and IV.

On Pl. V., additional details have been given of the mode of transfer of the eye from the one side to the other, — either the right eye to the left side, or *vice versa*, — which, with the figures of the embryos, on Pls. III., IV., VI., will show very clearly how the transfer is accomplished, in the ordinary case of a dextral or sinistral Flounder.

While still in the egg (Pl. V. fig. 6), and for some time after hatching (Pl. V. figs. 1, 2, 7, Pl. III., Pl. IV. fig. 1, Pl. VI. figs. 1–4), the eyes of the two sides are placed symmetrically on each side of the longitudinal axis. The first change — and the process is identical, whether we take a right or a left Flounder — is the slight advance towards the snout (Pl. V. fig. 3) of the eye about to be transferred; so that the transverse axis, passing through the pupil of the eyes, no longer makes a right angle with the longitudinal axis. This movement of translation is soon followed by a slight movement of rotation; so that, when the young fish is seen in profile, the eyes of the two sides no longer appear in the same plane, — that on the blind side being now slightly above and in advance of that on the colored side (Pl. IV. fig. 2, Pl. V. fig. 5, Pl. VI. fig. 5, Pl. IX. fig. 7). With increasing age, the eye on the blind side rises higher and higher towards the median longitudinal line of the head; a larger and larger part of this eye becoming visible from the colored side, where the embryo is seen in profile (see Pl. IV. figs. 3–5, Pl. VI. figs. 6, 7, Pl. V. figs. 8–12, Pl. VII. fig. 5), until the eye of the blind side has, for all practical purposes, passed over to the colored side (Pl. V. figs. 4, 11).

The rapidity and extent of this translation and rotation of the eye from the blind to the colored side can be best seen on comparing the profiles of the heads (Pl. V. figs. 5, 10) of a dextral and a sinistral Flounder with the profiles seen from the colored sides, before the eyes have begun their movement (Pl. I., Pl. VI. fig. 6, Pl. VII. fig. 5).

As the dorsal, little by little, with advancing age, extends along the head towards the nostrils, it soon, in old specimens, finds its way behind the eye which has come from the blind side (compare the position of the anterior part of the dorsal, in Pl. VI. figs. 5 and 7, in Pl. IV. figs. 2 and 5, and Pl. VIII. fig. 3). This continued advance of the dorsal anteriorly, after the eye has passed to the colored side, naturally gave rise to a great many theories respecting the passage of the eye through the head, under the anterior part of the dorsal fin; and many naturalists, after an examination of the twisted facial part of the skull on the adult, have attempted most ingenious explanations of the mode by which the eye reached its ultimate position.

The facts contained in this paper leave no doubt that, at any rate, in the majority of the Flounders of our coast (I have traced the development of eight species), the transfer of the eye from the blind side to the color side occurs very early in life, while all the facial bones of the skull are still cartilaginous, and that long before their ossification the eye has been transferred, by a combined process of translation and rotation, to the colored side. Let x, y, z be rectangular axes; and, if we call the longitudinal axis of the body twisting x, the transverse axis at the extremity of which the eyes are placed in the plane xy, the first change taking place is that x is no longer at right angles with y, though the eyes are still in plane xy. The next change is that the plane in which the eyes are now placed ($x'y'$) makes an angle with the xy; cutting z at a slight distance above the origin of the coordinate axes, the eye of the colored side forming the apex of the angle. This angle gradually increases, until it passes beyond the plane yz, when the eye from the blind side has reached the colored side.

The subsequent modifications of the frontal bone, owing to the aberrant position of the eye from the colorless side, are interesting on account of their connection with abnormal anatomical features found in the Flounders; but they explain in no wise the mode in which the transfer of the eyes has taken place, this being anterior to any essential changes in the frontal bone. In early life, the strong muscles which control the motion of the eyeball in the young Flounder maintain also a very powerful strain upon the frontal bone while still cartilaginous and readily flexible, and no doubt help to twist it in accordance with the gradual change in the position of the eyes.

While the observations of Malm on the young stages of Flounders tended to show the improbability of the eye passing through the skull from the blind side to the binocular, the observations of Steenstrup on the genus Plagusia, seemed, for that genus, at any rate, to show clearly that the eye did pass through the tissues of the head, during its transfer from the blind to the binocular side. But neither Malm nor Steenstrup, nor subsequently Schiödte, actually traced the changes undergone during the process. Steenstrup's specimens were alcoholic; and, although his theory was substantiated by observations on a number of intermediate stages of the passage of the eye through the tissue, yet, on the other hand, the observations of Malm, making it probable that the eye merely went round the head, in a manner not yet explained, were equally precise. I had myself traced quite a number of Flounders, in all of which the eye was transferred in accordance with the process described in the commencement of this paper, and figured on Pls. III.–VIII., — a process completely in accordance with the suppositions of Malm, and in direct contradiction to the theory of Steenstrup. In the late summer of 1875, however, I traced to my satisfaction the development of a very transparent Flounder (Pl. X. fig. 1), — so transparent, indeed, as to rival the most watery of Jelly Fishes. When placed in a flat glass dish, it could only be distinguished by allowing the light to strike it in certain directions: otherwise, all that was visible were the two apparently disembodied bright emerald eyes, moving more or less actively.

In this Flounder (Pl. X. fig. 1), already of a considerable size, — over an inch in length, — the position of the eyes was perfectly symmetrical. They were placed also at considerable distance from the anterior extremity of the snout; so that, judging from the size of the fish and the position of the eyes, as well as from the extension of the dorsal almost to the nostrils, I inferred that I had a new Flounder, in which the eyes would probably always remain more or less symmetrical, and in which the transfer of the eye from one side to the other was replaced by the exceeding transparency of the body, allowing either eye, owing to the great range of motion of the eyes both in a vertical and horizontal direction, — a feature characteristic of all Flounders, — to be really useful on both sides of the body. A Flounder can move his pupil vertically and horizontally through an angle of at least one hundred and eighty degrees. Thus, our transparent Flounder, which I did not at first recognize as the Plagusia of Steenstrup, could readily, by looking obliquely, see with great distinctness, through the transparent tissues, what was passing on the opposite side of the body.

I made all preparations to watch the changes in this interesting fish, should any such take place; and, a couple of days afterwards, I noticed the first change in the position of the eye (Pl. X. fig. 3) of the right side. No less than fifteen of these transparent Flounders were caught at the surface, with the hand-net, at the mouth of the harbor of Newport, close to the shore, on a very quiet and brilliant morning. They were then swimming vertically, and rushing violently after the minute Entomostraca swarming on the surface; but, as soon as they were confined in shallow glass jars, they turned on the right side, where they would often remain immovable on the bottom for hours. They were rapid in their movements when disturbed; frequently jumping out of the water and over the sides of the dishes, to a considerable distance. Though they appear so delicate, they do not seem to suffer, any more than other Flounders, from their momentary stay on dry land. When swimming vertically, they usually move obliquely, the tail kept much lower than the head; and, when seen endways, are more or less curved, owing to the extreme tenuity of their body (Pl. X. fig. 2).

During the change of the eye from the blind to the binocular side of the body, the outline of the young fish becomes more rounded anteriorly; and the minute, dotlike yellow and black pigment spots, hardly perceptible in Fig. 1, Pl. X., form somewhat more prominent patches on the sides of the body, and radiating lines parallel to the fin-rays on the dorsal and anal fins (Pl. X. fig. 11).

The right eye (Pl. X. fig. 3) could, when the fish was in profile, be seen through the head slightly in advance, and somewhat above the left eye; the right eye in that position, owing to the great transparency of the body, being quite as useful as if it had been placed on the left side. In the following stages, the right eye rises gradually more and more above the left eye, in a somewhat oblique direction towards the fifth or sixth anterior ray of the dorsal, until the fifth or sixth day, when the right eye can be seen entirely clear of the left eye, well above it (Pl. X. fig. 4). Owing to the great size of the orbit, the left eye, when seen from the left side (Pl. X. fig. 3), sometimes appears shot a little behind the right, especially after the motion of rotation has commenced; for we find that in this Flounder, as well as in the others, the transfer of the eye from the right side to the left takes place by means of a movement of translation, accompanied and supplemented by a movement of rotation over the frontal bone. But, in this case, very special conditions attend the transfer, which, at first sight, seem to make the passage of the eyes of this species an exceptional one. I think we can easily show that the present mode of transfer does not differ so radically as would at first seem from the conditions described in the other species, in the beginning of this paper. When the right eye of the young Flounder has reached the frontal bone, and approaches the base of the dorsal, we find, on turning the fish on his left side, that the right eye is no longer on the outer surface of the right side. It no longer occupies, as in the earliest stages, a huge orbit, capable of extensive movements in all directions; but unlike the left eye, which has retained all its former powers of locomotion, as well as its original place, it has gradually sunk deep into the tissues of the base of the dorsal fin, between it and the frontal, — having sunk, indeed, to such an extent that the huge orbit, so characteristic of all Flounders, has gradually become reduced to a mere circular opening. Through this opening, the eye now communicates with the exterior; while, from its position above the frontal (Pl. X. fig. 4), it has, when the pupil turns to the opposite direction, a perfectly unobstructed vision through the transparent left side of the body. Little by little, the opening on the right becomes smaller and smaller; and as, at the same time, the eye pushes its way deeper into the tissues, an additional opening is now formed on the left side (Pl. X. fig. 7), through which the right eye can now communicate directly with the left exterior on the left side of the body. Thus, in the stage intermediate between Pl. X. fig. 4 and Pl. X. fig. 8, we find no less than three orbital openings: one large one, — the original one of the left eye; a smaller one, on the left side also, the new orbit formed for the right eye, as it has pushed its way through the tissues of the base of the dorsal fin; and a small orbit on the right side, the remnant of the original right orbit of the right eye, which, before the right eye has completely passed over to the left side, becomes entirely closed (Pl. X. fig. 8). With the continued sinking of the right eye, the gradual resorption of the tissues, and the closing up of the old orbit, as the eye works its way across the head, we eventually get the right eye entirely over to the left side. It has now, by a movement of translation and of rotation, penetrated through the tissues between the base of the dorsal fin and the frontal bone; having apparently passed through the head, as was suggested to Steenstrup, by his examination of the alcoholic specimens which furnished him the materials for his paper on Plagusia. The present transparent species evidently belonged to this genus (Plagusia); and I had thus succeeded in actually tracing, in one and the same individual, the passage of the right eye to the left side through the head.

If we now compare this method of transfer of the eye through the head with the transfer previously described round the frontal bone on the exterior of the head, we can readily see that the difference is not as great as it would appear at first sight. Were we to imagine this species of Plagusia with a dorsal, stopping in the anterior median line behind the posterior edge of the eyes, the transfer would then take place exactly as in the case of the common Flounders. The right eye would travel round the frontal, without having to sink into the tissues; and, if subsequently to the transfer of the right eye to the binocular side, the anterior portion of the dorsal were to extend in advance of the anterior edge of the eyes to the intermaxillary, we should then obtain a result identical with that described before, and one which actually occurs in precisely this manner as we have seen in a number of Flounders; and the mere resorption of the tissues at the base of the anterior part of the dorsal, while interesting as a short-cut to an end, is not of so great physiological value, or so important as a difference in the method of the transfer of the eye, as appears on a first examination.

Owing to the transparency of this Plagusia, several interesting structural details could readily be followed, which only tedious manipulation would have demonstrated in the other more opaque species, of which the development is here given. Among these were the great length of the optic nerve, which allows, as it were, sufficient slack to be taken in during the transfer of the eye from the right to the left side (Pl. X. figs. 4, 8, 9), so as apparently not to interfere in any way with the sight of the right eye; also, the immense accumulation of muscular bands forming the sheath of the orbits of the eyes, and providing for the great variety and range in the movements of the eyeball and lids (Pl. X. figs. 3, 4, 5, 8, 9); also the direct and very active circulation taking place to and from the heart with the cavity of the orbit of the eyes. (See Pl. X. fig. 9, where the direction of the arrows shows the course of this current.) The presence of this circulation of a so-called ocular heart can be readily traced in the adult of our Halibut.

The Flounders have thus far only been found in the most recent geological deposits: they seem to belong peculiarly to the present period. It is certainly remarkable that no Flounders should have been discovered among the true bony fishes, which date back as far as the Jurassic Period. To whatever cause we may ascribe the peculiar development of the Flounders, it seems to have been inactive during the periods immediately preceding our own; and, in the absence of any plausible explanation of their appearance and development during the present period, we must look to some exceedingly subtle agency, of which we have at present no conception. The causes usually assigned for the development of fishes with a binocular side are all unsatisfactory; and all are invalidated by the fact that similar conditions constantly fail to produce like results. The Flounders are usually said, for instance, to rest on one side, because the great width of the body makes it the most natural position; but there are many other fishes of far greater width which always swim vertically, and never show any tendency to assume the pleuronect mode of locomotion. In fact, the great development of the dorsal and ventral fins gives to Flounders special advantages over other fishes for maintaining a vertical position. The young Flounder also shows a tendency thus to rest on one side, at a time when the young fish is much like any other fish, long before the habit could be of any special benefit or use.

The absence of a swimming-bladder has also been assigned as a principal cause of the peculiar mode of locomotion among Flounders. But there is one of our Flounders in which a swimming-bladder is already well developed in the young fish; and this does not prevent that particular species from adopting, as early as the others, the Flounder mode of locomotion.

The only other cause we can assign is that broad fishes, like the Flounders, find it of course much easier to pursue their prey, if, while swimming close to the bottom, they are protected from detection by a complicated system of pigment cells, for producing colors or patterns within certain limits, so as to resemble sand, mud, or gravel. This would gradually lead to the exclusive use of one side (should the fish lie on either side), and would result in the atrophy of the eye, unless the fish were able to transfer his eye to the other side, and thus retain it; when, as a secondary cause from this, the atrophy of the pigment cells of one side would follow. If this, however, is the natural explanation, why do not we find Flounders in almost all families of fishes, — at least, among the broad forms of the group, — and why were they not as common in earlier times as at the present day? We have also to face a very interesting point of heredity. It would certainly seem far simpler for the Flounders to hand down, from generation to generation, the two eyes on one side of the body, and further to hatch their young, as other fishes do, with the characters of the adult; instead of leaving for a future period (and a period of great mortality among them) the development of the transfer of the eyes to the right or left, — thus transmitting merely the tendency, and not the thing itself, as we find to be the case in Acalephs (Hybocodon), in the Tunicates, Salpæ, in the Gasteropods, in the Polyzoa, &c. Yet this tendency is very well defined; for we rarely meet with dextral forms when the Flounder is sinistral, or *vice versa;* and I have, in our common Flounders, met with no instances of reversal in the course of the development. In Plagusia only did I notice such a reversal, where there was an attempt made in many cases — seven out of fifteen cases — by the young fish to force the left eye to pass to the right side by lying down on the left, but in no case did this prove successful; and, after a while, the young fish showed traces of brain disease, and soon died, usually before the process of transfer of the eye had made much progress, — showing that a violation of the normal mode of transfer cannot readily be made with impunity. This may be the explanation of the rarity of such abnormal cases in the whole family.

The attempts which I made, both in Plagusia and several of the other species of Flounders, to prevent the transfer of the eye by placing the glass dish at a height over a table, and thus allowing the light to come from below, as well as from all other sides, failed in arresting the transfer. This experiment, likewise, produced no effect in retaining the pigment spots of the blind side longer than in specimens struck by the light only normally, from above.

The habits of young Flounders differ greatly from those of the adult: while the latter are generally more or less sluggish, the young Flounders, when measuring less than a couple of inches in length, are remarkably active, bounding through the water, as it were, and, if disturbed, frequently jumping out of the flat dishes in which I kept them. When this happened, falling from the table to the floor, they often remained a considerable time out of water, without appearing to suffer from their exposure, on being put back into water.

Giard has, in the Rev. des Scienc. Nat. for September, 1877, suggested that the fundamental cause of asymmetry in the animal kingdom was due to a difference in the strength of the organs of sense; and he has given, in support of this view, some most ingenious speculations on the asymmetry of Ascidians, of which the Tadpole was transparent, while opaque Tadpoles belonged to symmetrical types; the position of asymmetrical Ascidians being determined by that of the organs of sense of the embryos. We might add here, in favor of this view, the asymmetricals of many Acalephs (Hybocodon), in which the disproportion of one of the organs of sense (tentacles) is very great. He further calls attention to the facts that, in Pteropods, it is the organs of sense which first show asymmetry, and suggests that cyclopism has been an indirect cause of restoration of symmetry; though this point does not seem well taken, — judging, at least, by what we know of the development of cyclopism among Crustacea. At any rate, the action of light upon organs of sense, which in all embryos are developed out of all proportion to their ultimate conditions, must remain an all-important element in its effect upon the nervous system. In embryos so transparent as many young fishes, which seem to be nothing but eyes, brain, and notochord, the action of light must be infinitely more potent upon the nervous system than it can possibly be in older stages, when the muscular system has obtained a so much greater preponderance. The sensitiveness of young fishes to the slightest disturbance of the water, either as a shock or from light, is exceedingly acute; while, when older, they are apparently insensible to the same causes.

I have nothing to add to the explanation of the mechanism of coloration given by Pouchet in his admirable memoir on the change of coloration, to which I have already referred. A recapitulation of the important points may, however, help the reader not familiar with his memoir to understand the changes taking place during the development of our young Flounders. In the coloration of fishes, we must distinguish colors due to interference of light produced by the presence of thin plates, and those due to anatomical elements frequently highly colored, and endowed with sarcodic movements capable of marked changes of form, under special influences, so as to present the shape of extended dendritic surfaces or minute spherical masses through which the pigment is distributed. The changes of coloration due to thin plates are, of course, exceedingly variable, the tints following each other with great rapidity, according to the angle at which we view them. Such lamellar coloration is common among insects, crustacea, and also in some families of fishes. Among the most beautiful examples are those of the dolphin (*Coryphæna*) and of Saphirina; while the second class of colors — those due to the movements of the anatomical elements — are directly connected with the impressions of color received by the eye, and brought about by the reflex action of the nervous system. That this is the case, the rapid change of coloration produced by placing Flounders upon differently colored bottoms sufficiently proves. This has, of course, a direct bearing upon the question of mimicry; but it must be frankly stated that, as far as the causes of coloration among animals have been studied, it is difficult to see how natural selection can have been a factor in producing permanent mimicry; while the rapidity with which many fishes adapt themselves to the color of the bottom upon which they live enables them undoubtedly to produce a protective coloration, which is of advantage to them; and constant habit may develop unequally the capacity of producing certain tints, or patterns even, which in their turn may be transmitted, and thus readily account for the lighter coloring of Flounders living upon sandy bottoms, as compared with those living upon rocky bottoms covered with dark algæ. Yet place the latter upon a light ground and the former upon a dark ground, and they will very soon adopt the proper coloration of their bottom, showing they have not lost their power of changing. As for many of the patterns of coloration of birds and in insects, produced by physical causes, it seems quite impossible to look upon them as the fortuitous product of the action of light, or to regard it as an efficient cause of protective mimicry.

The pigment cells appear early in the egg. In some of the fishes, we have even two color elements in the older stages, immediately before the young fish is hatched, — viz., the black and yellow; but, in the majority of cases, the black alone is present, the yellow element appearing subsequently, and, last of all, the red. The experiments made by Pouchet on pigment elements show that the blue pigments are probably only a dimorphic condition of the red pigments. This would give a ready explanation why Lobsters turn red when cooked, and of the blue Lobsters which are occasionally caught. The same may also be said of green. Violet pigment, which is found in some Crustacea, gives special reactions.

The anatomical elements containing the pigment are greatly changed during growth. The examination of the pigment spots of the youngest fish on any of the Plates here given with more advanced stages shows how great is the capacity for expansion in the black pigment elements, which from mere dots have almost become special organs capable of great expansion and contraction. Pouchet calls the pigment elements chromatoblasts in their embryonic condition, to distinguish them from the chromatophores into which they eventually develop. In addition to the chromatoblasts and chromatophores, Pouchet has also called attention to a third set of bodies, which he calls iridocytes. These are found in Fishes, Reptiles, Mollusks: they are situated near the surface of the integument, and produce the phenomena of iridescence of cœrulescence by interference of light (as shown by Brücke), of solid particles more or less analogous to excessively thin laminæ. By simple combinations of the action of the red, yellow, and black chromatophores with the iridocytes are obtained all the colors which we can produce in Fishes, Reptiles, Crustacea, Mollusks, &c.; these colors resulting mainly from the expansion near the surface, or retraction into an inferior layer of the black chromatophore, which, thus mixed with the yellow and red, or with the iridocytes, at greater or less depths, suffice to produce all the variations of coloring of our young Flounders. An examination of Plate VIII., showing the changes of coloring produced upon young Flounders when placed upon differently colored bottoms, will readily show the process by which the different colorations are produced.

In the Flounders, after the eyes have passed to one side, the connection between the impression produced on the retina and the blind side becomes less and less distinct, until eventually a complete paralysis of the nerves affecting the chromatophores takes place; and little by little the blind side thus becomes white with advancing age.

The pigment cells are of three colors, — black, yellow, and red (Pl. VIII. fig. 6): the black expand nearest the surface, the yellow and red varying greatly in their position, according to the species. The black cells are all more or less dendritic when expanded, concentrating to a mere dot when wholly contracted. The proper mixture of the three colors in various degrees of expansion or contraction, combined with the suitable pattern of position, enables the Flounders to imitate so admirably the general effect of the ground upon which they are accustomed to feed, be it either sandy, gravelly, or muddy. So true is this, that often only a most practised eye could detect them, as, with the head slightly raised, the eyes starting out of their sockets far above the surface of the head, they turn actively in all directions, seeking for prey, or trying to escape the notice of their enemies. The rapidity with which they produce this change of color is quite striking; and, although it was well known that many fishes had the power to change gradually the tint of the body, it had not been noticed that it could be effected rapidly, and apparently at will, before it was recognized by Pouchet. I have not unfrequently removed the jar containing a young Flounder (Pl. VIII. fig. 2) from a surface imitating a sandy bottom to one of a dark chocolate color, and in less than ten minutes I have seen the black pigments obtain such a preponderance (Pl. VIII. fig. 1) that it would hardly have been possible to recognize in the dark, almost black fish the young Flounder, whose yellowish-gray speckled hue had so well simulated sand, a few moments before. On removing him to a gravelly bottom, the spots of the side quickly became prominent (Pl. VIII. fig. 3). During all this time, the pigments of the blind side showed no trace of any sensitiveness; while, if these experiments are made when the eyes are still on both sides, the pigments of the two sides change at the same time in a corresponding manner.

It is well known that Squids and Cuttle Fish, provided as they are with exceedingly sensitive chromatic cells, are also able to imitate, for their protection and disguise, the coloring of the ground upon which they happen to live. But, in Cephalopods, the change of color of these chromatophores is more intimately connected with the nervous system, and appears far more sensitive and less subject to control than among fishes. In Cephalopods, the mere act of moving the mantle, of breathing, or of forcing the water through the siphon, seems sufficient to produce a change of tint; and a sudden disturbance is as likely to bring about a detrimental as a beneficial change of color.*

Among Fishes, Reptiles, and other Vertebrates, as well as among Cephalopods, and the mass of Mollusks, Crustacea, Annellids, Echinoderms, &c., in which we find dermal pigment cells, we can readily imagine how the effect of environments might, by reflex action, bring about a resemblance to surrounding coloring, as has been described by Pouchet and by Bert, thus producing general effects in the pigment cells, which would assimilate within certain limits with the surrounding tone. In all these cases, the explanation based upon mimicry as beneficial presents little difficulty; and we might suppose that by the laws of heredity those colors alone which had been stimulated by continued action through many generations would be transmitted. Thus Flounders, for instance, living on sandy bottom, in which the grayish tint imitating sand had been most constantly produced by the action of the proper pig-

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* See the papers on the chromatophores of Cephalopods, by Hubrecht, Niederland. Archiv f. Zool., II. No. 3, p. 8, Mai, 1875, in which he makes a most interesting comparison of the phenomena of chromatophores and protoplasmic action. Also an important paper by Dr. Hagen, in the American Naturalist, vol. vi., July, 1872, on mimicry in the color of insects. The general results of Dr. Hagen's study of the phenomena of color in insects agree, in the main, with the results obtained by Pouchet from the study of Fishes, Crustacea, and Mollusks; both Pouchet and Hagen recognizing the presence of colors due to action of light, and the presence of colors due to pigments, the hypodermal and dermal layers. Judging from the interesting discussions brought out by the papers of Weismann, of Wallace, and others, on the causes of color in the animal kingdom, we are, however, only on the threshold of a most interesting and novel field of inquiry.

ment cells, would naturally transmit to their progeny in the greatest quantity only such pigment as would most easily reproduce the imitation of sand, while the same might be true of the Flounders living on muddy or gravelly bottoms. Something analogous exists in the common Echini, where dark-green and violet pigment spots closely imitate dark granitic rocks covered with seaweeds; or in the imitation of sand by the grayish-green tint of Mellita and the yellow tint of Amphidetus, &c.: yet the whole theory of mimicry, even in these cases, as a means of protection, is again overthrown by the mass of Clypeastroids, Spatangoids, Echinoids, whose dark coloring, but for their habit of burrowing in the sand in which they live, would make them most prominent objects. We next have the legions of Ctenophoræ, Jelly Fishes, and of other pelagic animals (especially the embryos) so transparent as to be scarcely distinguishable from the water in which they live, many of them are reduced to the merest film. Have they all, little by little, assumed their transparency, in order to escape their enemies? Then why do they swarm in such quantities that their numbers counteract the very object of their transparency? It is common along the seashore, at proper times of tide and wind, to find long lines where all these delicate and transparent animals are accumulated on purpose as it were to provide the food needed by their enemies, who are at hand playing sad havoc among them. Many of the embryos of our common marine animals are gregarious for a short period of their life; for instance, the young of the majority of our Crabs and Shrimps, of many Gasteropods, Annellids, and Radiates, just at the time when they are most delicate, and least capable of escaping the attacks of their enemies. At the time of hatching of the young Prawns (*Palæmonetes vulgaris*), and of the young of our Cancer, sea perch may be seen devouring them by the wholesale while they are swarming close to the shore. Thus, numberless young are destroyed in spite of their transparency, and the same holds good for a host of other embryos.

In the Flounders, we seem to have fair evidence that they are able to produce certain effects in consequence of impressions received upon the retina, and that the changes taking place on the chromatic side of the body are probably due to the capacity of the fish to distinguish certain colors from others. But more accurate experiments than I have yet made are necessary to enable us to decide whether the sense of color is developed so early in the Vertebrate series, or whether we have simply a set of reflex actions. It certainly seems, from a physiological point of view, very hazardous to infer — as has been frequently done on philological grounds — the gradual development of the sense of color in early races of mankind, from the color descriptions of Homer and early Greek writers. It is not an uncommon thing to find children of the lower classes unable to give specific names to the different colors; but, if I am not mistaken, they can always distinguish the primary colors without difficulty, though not able to name them. Certainly, the facility for painting and coloring noticeable in the pottery of the uncivilized races of the world seems unfavorable to this theory.

EXPLANATION OF THE PLATES.

The Plates accompanying this paper are a fair sample of the results to be obtained from the transfer of original drawings by the Heliotype process. The drawings are quite acceptable reproductions of the originals; and this method of illustrating papers on Natural History will prove very useful in many cases. The method described by the younger Sars for obtaining transfers from original drawings is somewhat cumbersome, requiring a great deal of care and a number of processes. The present method simply requires for the naturalist that he should put on thin Bristol board the plate he desires to have transferred, of the size he wishes, and arranged as he desires; the only requisite being that the figures be all drawn with a pen and with a special ink. He may then be assured that he will get a plate nearly as clear as his original; and several transfers being made from the original, — say three or four, — a large number of clear copies can be struck off without reducing the distinction of the impressions, as is invariably the case in all lithographic processes. The delay incident to all lithographic processes requiring a special artist are done away with, and the author has only himself to blame for errors. This method seems to give better results than that employed by Sars. Compare his plates of Brisinga with those of the present paper. The cost of the Heliotype method is moderate; the impression on paper, and whole manipulation, after the drawing is supplied to the patentees of the process, being considerably less than the cost of printing and paper from an ordinary lithographic stone.

Plates III., IV., V., figs. 1–5, illustrate the development of a dextral Flounder, in which the eye passes from the left side to the right side.

Plate V., figs. 6–13, Plate VI., illustrate the development of a sinistral Flounder, in which the eye passes from the right side to the left.

Plate VII. illustrates the development of a sinistral Flounder, in which the eye passes from the right to the left side long before the dorsal, anal, or caudal fins have lost their embryonic character.

Plate VIII. illustrates the changes of color produced in the young Flounders by placing them on differently colored ground.

Plate IX. shows the development of a sinistral Flounder, in which the anterior part of the dorsal becomes to some extent an anterior dorsal.

Plate X. illustrates the passage of the eye through the integuments between the base of the anterior part of the dorsal and the frontal bone.

PLATE III.

Pleuronectes Americanus Walb.

Platessa plana Storer Pl. XXX. fig. 2.

Fig. 1. Young, about 4^{mm} long a few days after hatching. Seen from the left side. The eyes are symmetrically placed at the extremities of an axis at right angles to the longitudinal axis. The pectorals are well developed, the embryonic fin extends unbroken from the base of the brain to the anus, the ventral portion is somewhat broader. The eyes are of a light bright-green, and there are faint yellow patches on the lower sides of notochord along the muscular bands.

„ 2. Somewhat older than fig. 1. The tail has become slightly heterocercal, and the embryo is much less transparent than in the previous stage. The muscular tissue above and below the notochord is of a light-brown color, with yellow patches near the black pigment spots. One or two very indistinct tail-rays have begun to form.

„ 3. In this stage, the principal changes are confined to the increased number of tail fin-rays, and to the segmentation of the vertebral column sending out its dorsal and ventral cartilaginous apophyses. The pigment spots of the embryonic fin-fold (fig. 1), as well as of other parts of the body, seem to become more prominent, when increased activity in the formation of new tissues takes place. See the pigment spots in the tail of this figure.

„ 4. A somewhat more advanced stage, in which the dorsal and ventral embryonic fold has become tolerably separated from the tail-fin. At the base of the dorsal and ventral folds, the basal fin-rays are well developed, but as yet we find no trace of the fin-rays proper.

„ 5. In this stage, the tail-fin is in great part separated from the embryonic fin-fold, which shows here and there traces of the formation of the fin-rays proper; but in other respects it differs from the preceding stage mainly in the greater number of pigment spot patches, in the greater development of the muscular bands, and of the dorsal and ventral apophyses of the vertebral column. The eyes are as yet symmetrical. The length of this embryo is about that of the preceding stage (fig. 4).

PLATE IV.

Pleuronectes Americanus Walb.

Fig. 1. We now come to a series of stages in which the body becomes broader in proportion to the length, and in which the dorsal and anal fins are all gradually isolated from the caudal. In this stage, the fin-rays extend nearly to the edge of the dorsal and anal, the muscular bands are much wider, and there is a slight asymmetry in the position of the left eye, which has moved well forward towards the top of the snout; while in the preceding stages the left barely

extended to point of a vertical passing through the lower extremity of the upper jaw. The patches of color which are to be eventually characteristic of the species first make their appearance in this stage.

Fig. 2. Somewhat more advanced than fig. 1. The left eye, when seen from the right side, projects slightly in advance of the frontal. The dorsal and anal fin-rays are well developed, but still united to the caudal. The tail has become rounded. The patches of coloring are defined. Rudimentary ventral fins have appeared. There are as yet no hard rays in the pectorals.

„ 3. In this stage, the left eye has moved more towards the crest of the snout, the dorsal and anal fins are disconnected from the caudal, and the ventrals are larger than in the preceding stage.

„ 4. More than half the left eye is seen above the frontal ridge; the dorsal and anal still more disconnected from the caudal than in the preceding stage; the ventrals larger, and the pattern of coloration quite marked by prominent pigment cells.

„ 5. In this stage, the left eye has fully passed to the right side, the dorsal fin, extending to the upper edge of the orbit, having gradually extended in that direction from stages represented in Pl. IV. figs. 2, 3, 4. The pattern of coloration of the body and of the fins is like that of the adult, but, of course, more indistinct. The dorsal and anal fins are now completely isolated from the caudal fin: they have both fin-rays fully developed, and have greatly increased in breadth since the last stages figured.

PLATE V.

Figs. 1–5. — Pleuronectes Americanus Walb.

Fig. 1. Head of a young specimen, about in condition of Pl. III. fig. 1. Seen from above, to show the symmetrical portion of the eyes.

„ 2. Head of another specimen, about in the same stage as in fig. 1. Seen from below.

„ 3. Head of a young specimen somewhat more advanced, in which the left eye has changed its position somewhat, and has advanced towards the snout; showing the effect, when seen from above, of the first movement of translation of the eye of the left side.

„ 4. Head of young Flounder, intermediate between figs. 4 and 5, Pl. III., to show the transfer of the left eye above the ridge of the frontal bone.

„ 5. The head of a young Flounder, nearly in the same condition as fig. 4. Seen from the left side, showing the position of the eye during the transfer while projecting above the frontal bone.

Figs. 6–13. — Pseudorhombus maculatus Stein.

Fig. 6. Head of young specimen still in the egg. Seen from above. The eyes symmetrically placed at extremity of a transverse axis at right angles to the longitudinal axis of the Flounder.

Fig. 7. Head of same species, a couple of days after hatching, before any movement of translation or of rotation of either eye has commenced. The two eyes symmetrically placed at the extremities of a transverse axis at right angles to the longitudinal axis of the Flounder.

„ 8. Shows the position of the eyes of the young Flounder from the left side, where the right eye projects beyond the ridge of the frontal bone.

„ 9. Shows the position of the right eye, seen from the right side, at about the time the lower edge of the orbit has reached the summit of the edge of the frontal bone.

„ 10-13. Show in regular succession the gradual passage of the eye from the stage of fig. 9 until it has reached, in fig. 13, the position it retains on the adult entirely on the left side of the body; the space between the eyes separated by the frontal ridge becoming less in each specimen with advancing age.

PLATE VI.

Pseudorhombus melanogaster Stein. Mass. Fish Rep. 1872, p. 47.

Platessa oblonga Storer Pl. XXXI. fig. 2.

Fig. 1. Young specimen, just hatched from the egg. The yolk mass projecting below the outline of the lower surface; the dorsal embryonic fold much wider than the anal embryonic fin; the pigment spots are confined to the dorsal edge of the brain, and to the muscular band above the notochord.

„ 2. Embryo two days old. The yolk mass projects but little beyond the line of the lower surface. Large prominent pigment spots extend over the whole body, with the exception of a small portion of the tail, which is left bare from the earliest stages (fig. 1), and remains bare for some time yet, thus giving an excellent specific distinction for readily distinguishing the young of this species from other species of embryos about in the same stages. The snout has become more pointed than in the preceding stage, the dorsal embryonic fold has lost much of its width, and in consequence the young fish resembles a tadpole much less than in the preceding stage.

„ 3. Represents the same embryo on the fifth day after hatching. The principal changes consist in the form of the head, the prolongation of the lower jaw well in advance of the upper one, the presence of large pectorals, the increase of the stomach, and a very slight tendency to heterocercality in the tail.

„ 4. Somewhat older embryo. The stomach and alimentary canal have greatly increased in size, the air-bladder has become prominent, the body has greatly increased in width, the tail is decidedly more heterocercal than in the previous stage figured, and the right eye shows a slight tendency to move upward and forward towards the anterior edge of the snout.

Fig. 5. In this stage, considerably larger than the previous one, the change in the outline of the young fish is considerable. The dorsal is highest at its anterior extremity, the caudal is well separated from the dorsal and anal fins, in all the fin-rays are fully formed, the profile of the head is more blunt, and the whole body thickly covered with dark pigment cells.

„ 6. The differences of this stage from the younger one (fig. 5) consist mainly in the greater width of anterior part of the body; the distinct pattern of coloration; the increase in width of the dorsal and anal fins, and their disconnection from the caudal, which has become elongated and rounded at the extremity; the presence of small ventrals; and the transfer of the right eye forward and upward, so that one half is visible above the frontal from the left side.

„ 7. Is a young Flounder, taken late in the season, but slightly larger than fig. 6, in which, however, the right eye has passed well over to the left side. The dorsal has extended towards the posterior edge of the right eye, its anterior edge projecting over the eye. The pattern of coloration is similar, in a general way, to that of the adult, and extends into the base of the broad dorsal and anal fins. The ventrals are larger than in fig. 1. The Flounder in this stage and the preceding stages (figs. 4, 5) habitually rests on the right side, but as yet none of these young fishes show any difference in the coloration of the right from the left; the former being still quite as brilliant as the latter in the oldest stage here figured (fig. 6).

PLATE VII.

Rhombus maculatus Mitch.

Pleuronectes maculatus Storer Pl. XXXI. fig. 4.

Fig. 1. Young specimen, with rudimentary air-bladder, few pigment spots, measuring 5^{mm} in length.

„ 2. Somewhat more advanced than fig. 1. The pigment spots greatly developed, but the embryonic dorsal and anal fins show scarcely any advance.

„ 3. The body has become somewhat broader, the tail far more heterocercal, and rudimentary fin-rays appear both in the dorsal and anal fins. Patches of coloring indicating the future pattern are well defined.

„ 4. Somewhat more advanced, but slightly longer, than fig. 3. The base of the fin-rays of the dorsal and anal are well developed. The body, with the exception of a bare space of the tail and adjoining part of the body, is of a uniform grayish-brown color, with patches of yellow, and black longitudinal lines along the upper and lower edges of the notochord, and the base of the dorsal and anal fin-rays, as well as following the muscular bands along the ventral edge. The upper and posterior edge of the stomach is covered by intensely black pigment spots closely crowded together.

Fig. 5. Slightly older than the preceding stage. The eye, from the right side, projects above the line of the snout; the coloring much as in fig. 4. The anal, dorsal, and caudal fins are, however, more advanced.

PLATE VIII.

Rhombus maculatus Mitch.

Fig. 1. Young sinistral Flounder, natural size, showing the color assumed when the fish is placed upon a dark mud-colored ground.

„ 2. The same fish, somewhat enlarged, showing the coloring assumed when placed upon a yellowish sandy soil.

„ 3. Another specimen of the same species, somewhat younger than the preceding stages, showing the coloring assumed when placed upon a mottled ground (partly gravel, partly sand) somewhat darker than the yellowish sandy soil.

„ 4. Black pigment spots forming the blotches along the lines of the rays of the dorsal, when fully expanded.

„ 5. Another portion of the dorsal, showing the spots when contracted.

„ 6. A portion of the pigment spots of the colored side, showing the red, the yellow, and the black pigment spots when fully expanded, the darker tints between the colored pigments representing the masses of iridocytes.

PLATE IX.

Pseudorhombus oblongus Stein.

Platessa quadrocellata Storer Pl. XXXI. fig. 3.

Fig. 1. Egg of Flounder, showing the symmetrical head of embryo.

„ 2. Head of young Flounder, the fourth day after hatching. Seen from above.

„ 3. Head of fig. 4. Seen from below.

„ 4. Young Flounder. Seen in profile. Quite transparent. Remarkable for the great development of the dorsal embryonic fin, 6.5^{mm} in length.

„ 5. Somewhat older than fig. 3. First trace of heterocercal tail.

„ 6. Older than fig. 4. The anterior part of the dorsal is developed before the rest, forming a sort of anterior dorsal. The eyes are still symmetrical.

„ 7. Young Flounder, quite well advanced. The fins are all differentiated. The right eye has, however, moved, thus far, but little forward and upward.

PLATE X.

Plagusia Sp.

Fig. 1. Young Plagusia, slightly over an inch long. Seen in profile. The eyes of the two sides are equally distant from the snout: they are placed symmetrically with reference to a longitudinal axis, and a plane

passing through the transverse axis. This specimen is perfectly transparent, — fully as transparent as the most delicate Hydroid Medusa. The action of the heart, the course of the vessels, can be readily followed, as well as the other structural details, which are usually only visible after dissection. The dorsal fin projects far down the frontal ridge to the nostrils, well in advance of the eyes.

Fig. 2. Young Plagusia (fig. 1). Seen with head on.

„ 3. Shows the relative position of the eyes after the first movements of translation and of rotation have become visible by the slight advance and rising of the eye of the right side. Seen from the left side.

„ 4. Somewhat more advanced than fig. 2. Seen from the right side. The outline of left eye can be traced through the tissues of the head.

„ 5. Head, seen from the left side. The right eye has moved upwards sufficiently to be seen through the tissues of the head, clear above the left eye. We find in this stage the first trace of the opening of the eye on the left. The eye, when turned in the socket, can look through the tissues at the base of the dorsal; and, when thus turned, to see through the left, is nearly as sensitive to approaching objects as the left eye. When looking at the same fish for the other side (the right), we find that the eye has deeply sunk in the tissues between the frontal bone and base of dorsal fin, and that, while sinking and pushing its way to the opposite side, the tissues of the right side have gradually united and narrowed the former large circular orbit to a mere small elliptical opening.

„ 6. The eye of the right side, as turned to the right; the new orbit appearing on the upper edge of the eyeball.

„ 7. The same eye with the ball turned toward the left, showing the commencement of the new orbit forming as a small circular opening on the left side of the fish. The old orbit of the right side being now reduced to a minimum, the fish now having two orbits on the left side and one on the right. The orbit of the right being reduced to a small aperture, and disappearing in a subsequent stage (fig. 9), while the new orbit of the right eye on the left side is as yet much smaller than the corresponding orbit of the left eye.

„ 8. Head seen from the right side, showing the small size of the old orbit of the right eye after it has forced its way partly across the head.

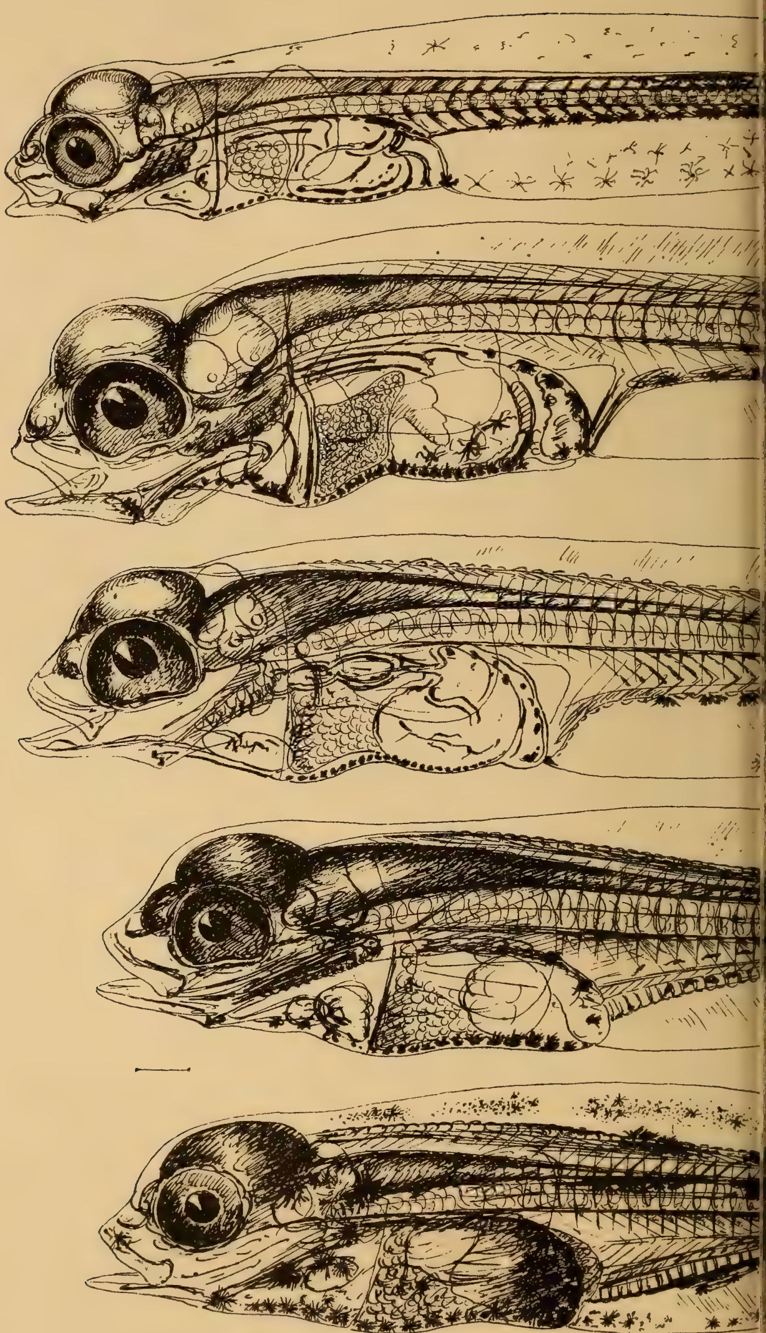
„ 9. The right eye has now passed entirely round the frontal bone, and is held in its hollow curve, and has at same time forced its way through the tissues so far that the original orbit of the right side has become closed, and the new orbit for the right eye on the left side has become nearly as large as the orbit of the left eye.

„ 10. In this stage, the eye from the right side is now completely transferred to the left, and no difference is apparent between the orbits. In this and all preceding stages, the great length of the two optic nerves is readily seen; and we thus understand the possibility of so extensive a movement of either eye without interfering with the visual function. The slack of the optic nerves being only taken in for the eye which happens to be transferred in any genus of Flounder.

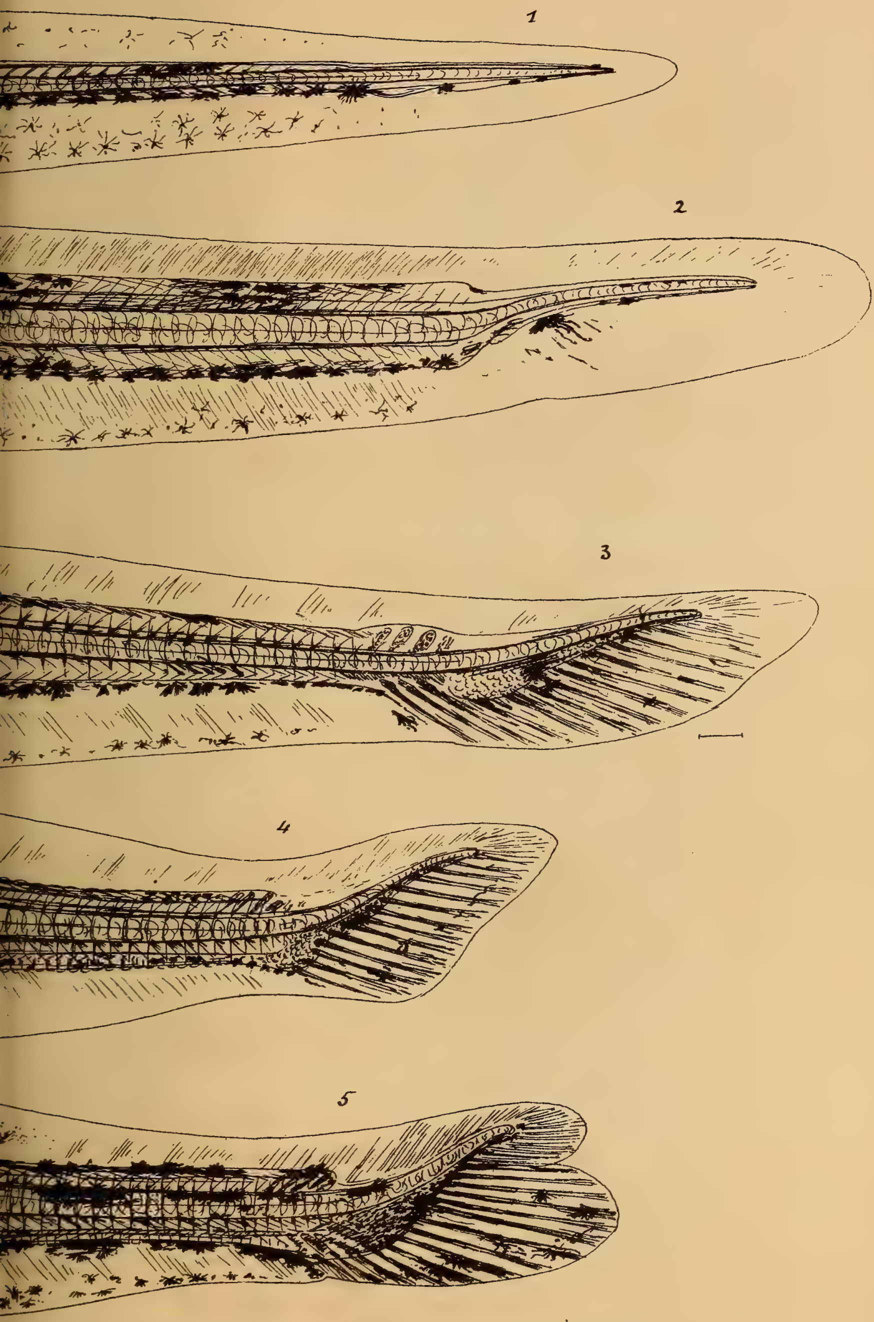
There is in Flounders a most active circulation going directly from the heart to the orbits and back again: this is well shown in this figure by the direction of the arrows along the vessels leading towards the orbits and back again to the heart.

Fig. 11. Is a young Plagusia, after the transfer of the eye, nearly three inches long, showing even at this stage but a slight accumulation of pigment spots along the dorsal and anal fins parallel to the line of the spines. A few yellowish and black pigment spots have also accumulated on the left side, but the young fish has as yet lost but little of its transparency.

What eventually becomes of this species I am not able to say, and it is not improbable that this species is identical with that described by Steenstrup, and it may also be the young of the Plagusia found on the Atlantic coast of the Southern States.



Alex. Agassiz Young Fishes Pl. III



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Alex. Agassiz Young Fishes Pl. III

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Alex Agassiz Young Fishes Pl. IV

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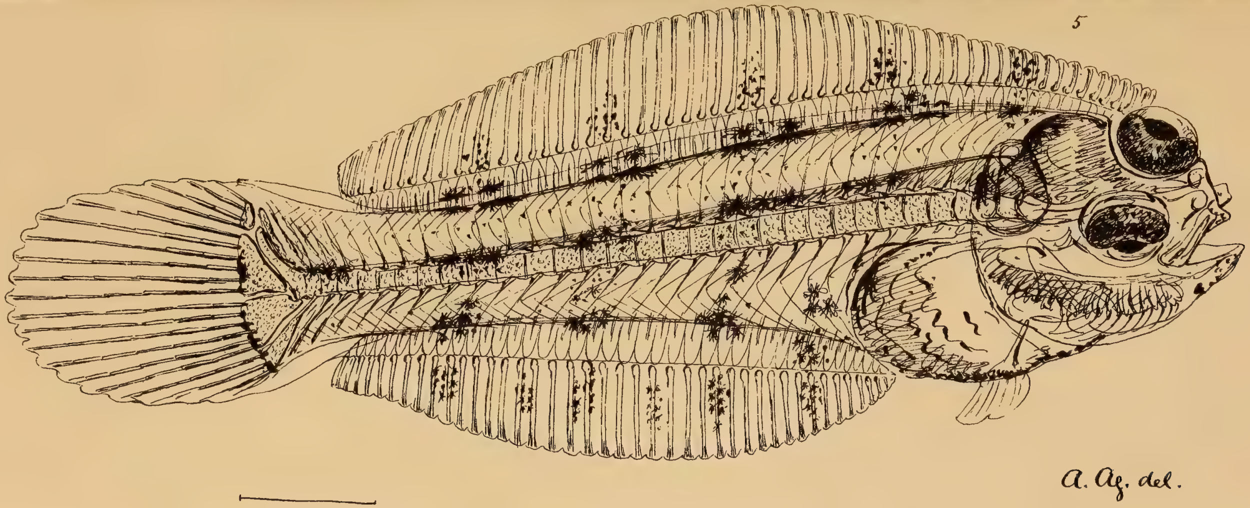

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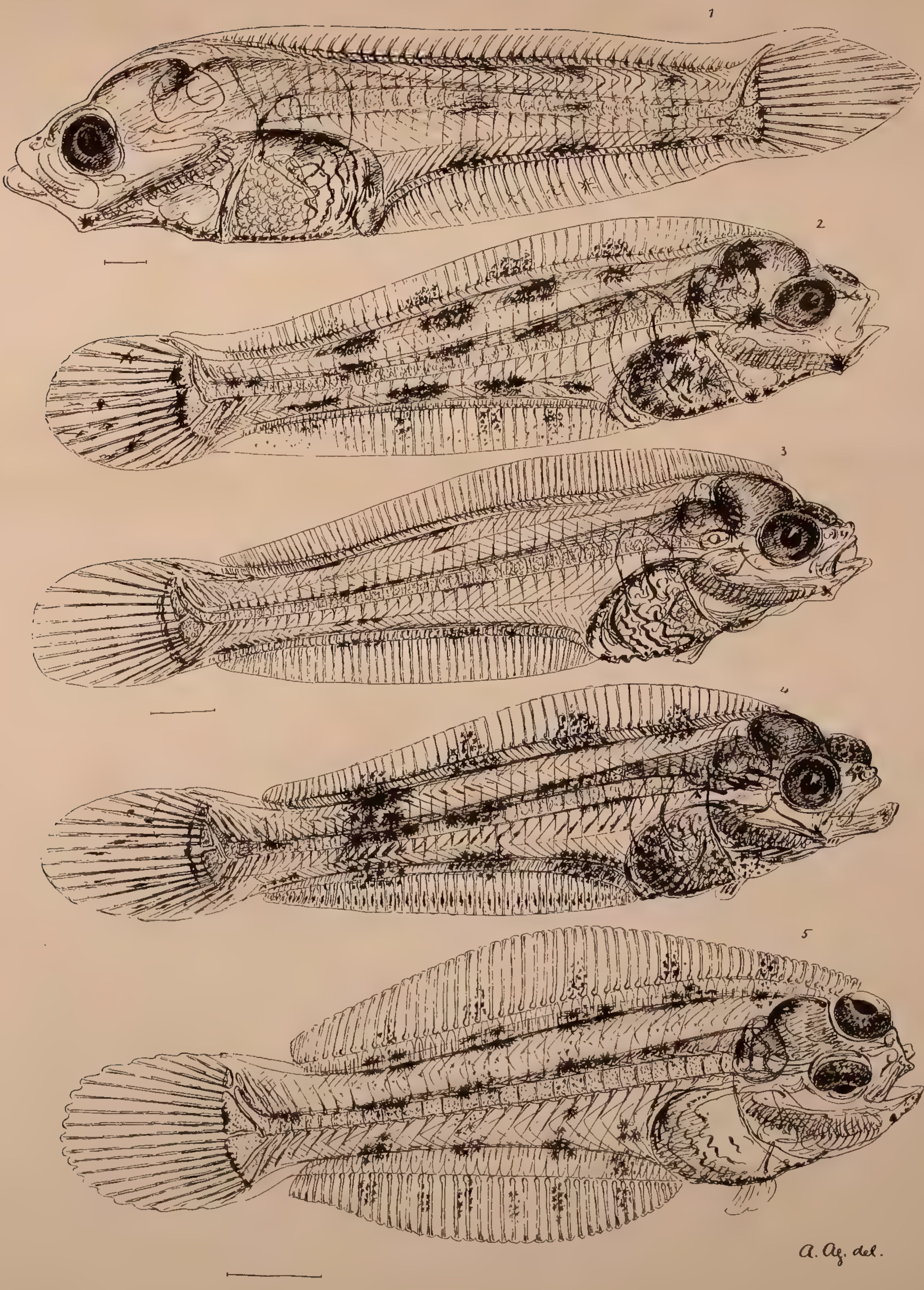
Alex Agassiz Young Fishes Pl. IV



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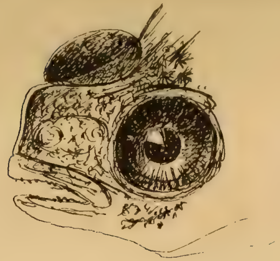

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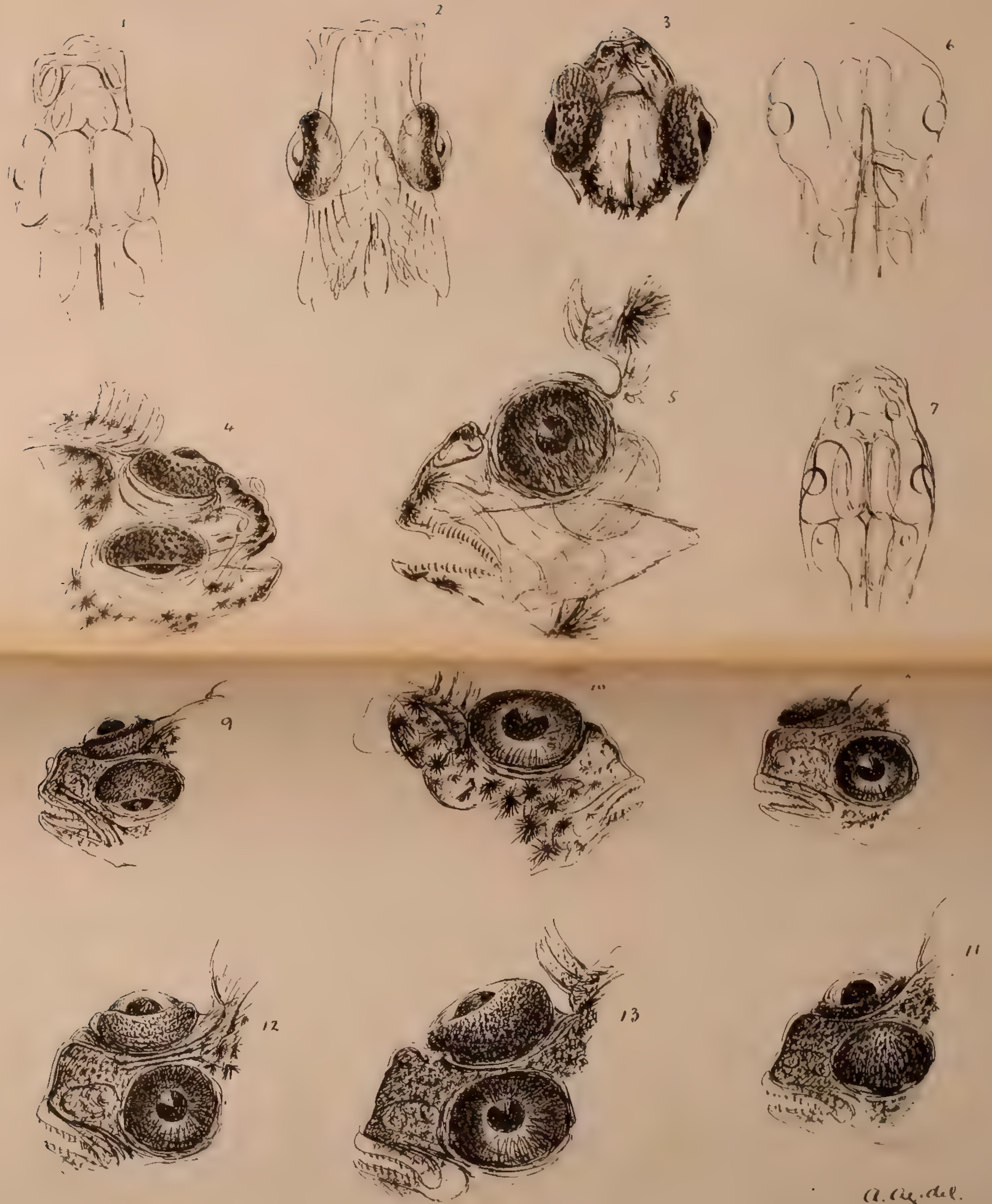
Alex. Agassiz Young Fishes Pl. V

Alex. Agassiz Young Fishes Pl. V



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Alex. Agassiz Young Fishes Pl. VI

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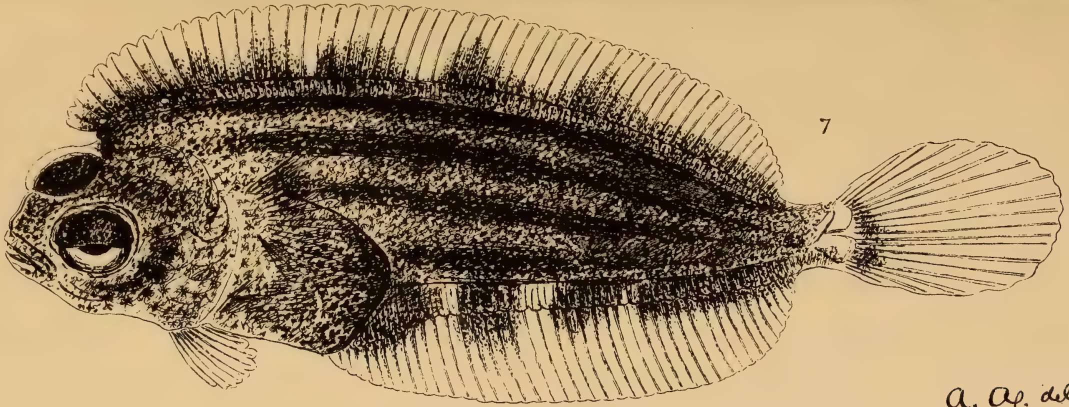

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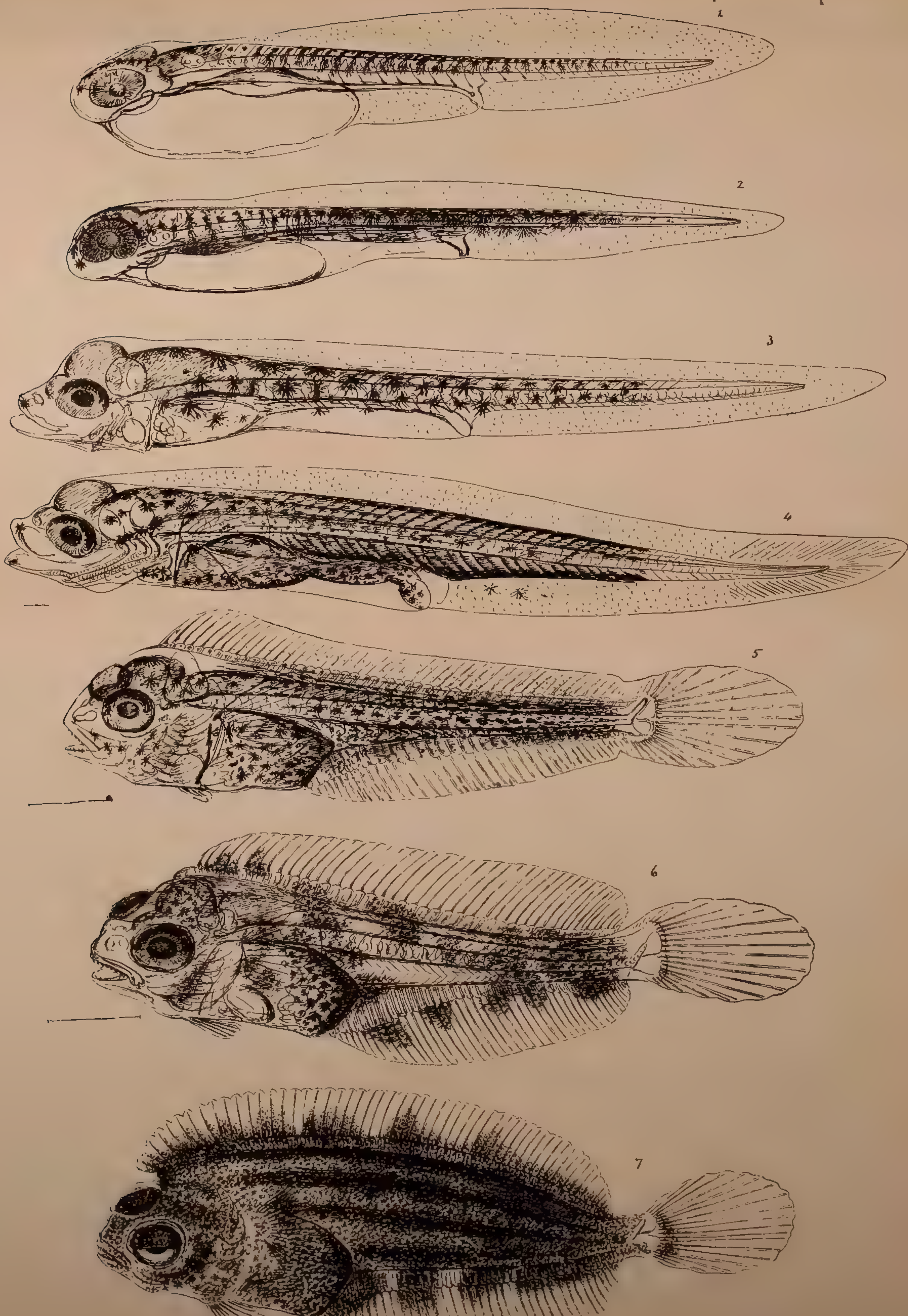
Alex. Agassiz Young Fishes Pl. VI



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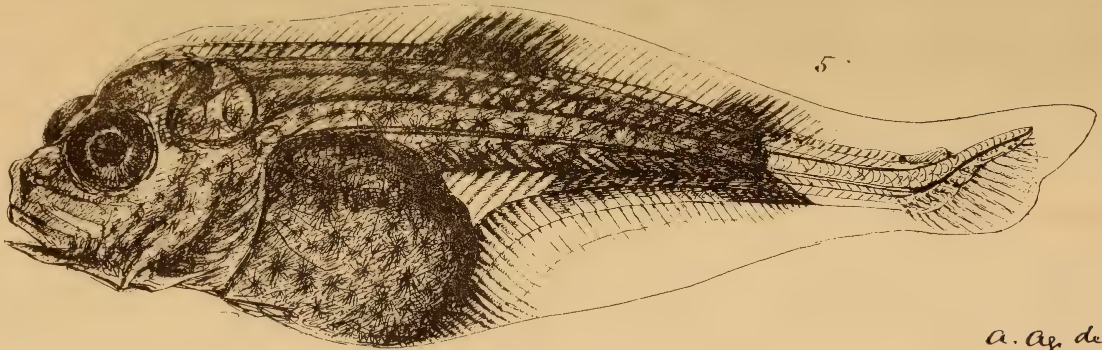

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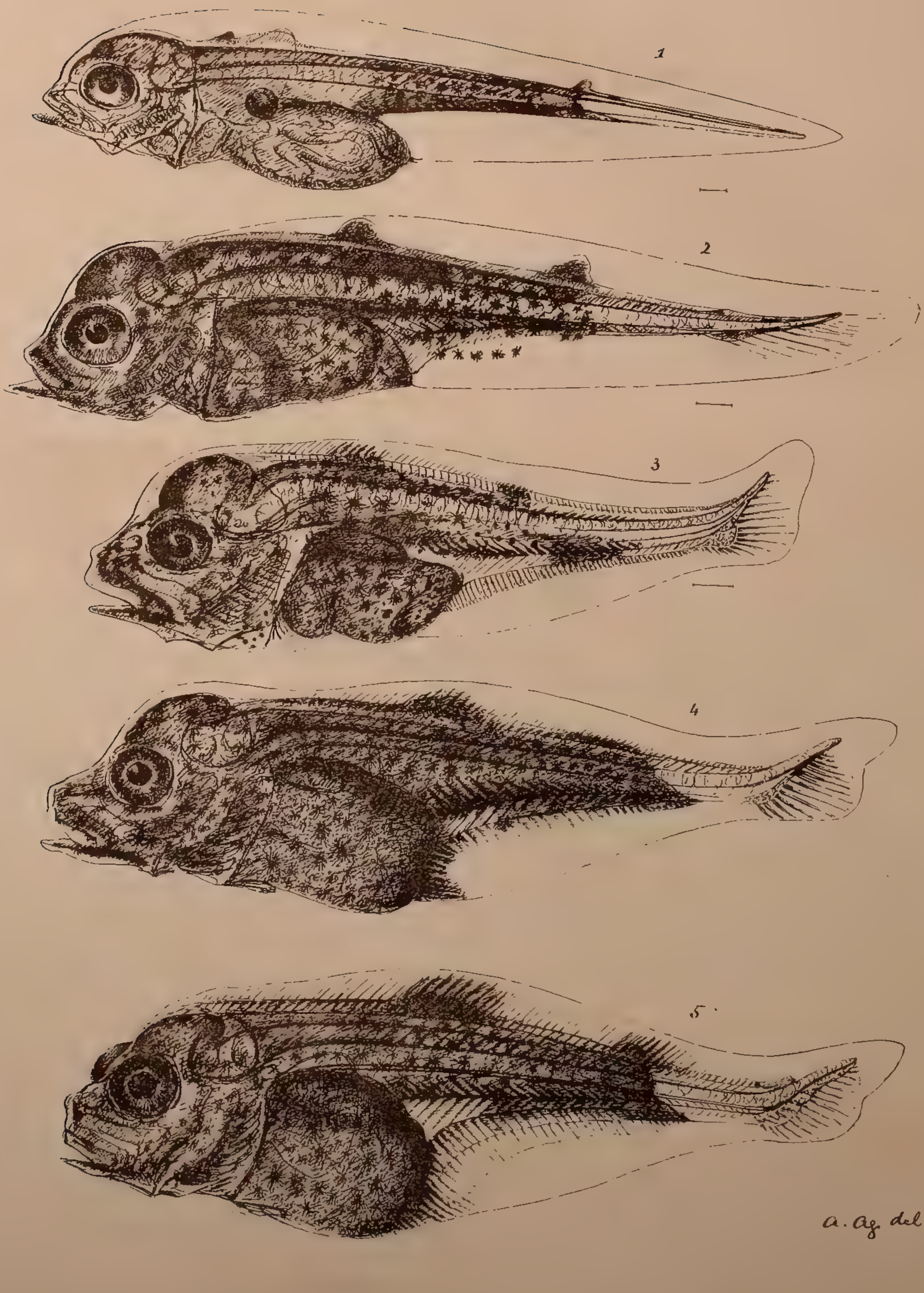
Alex. Agassiz Young Fishes Pl. VII



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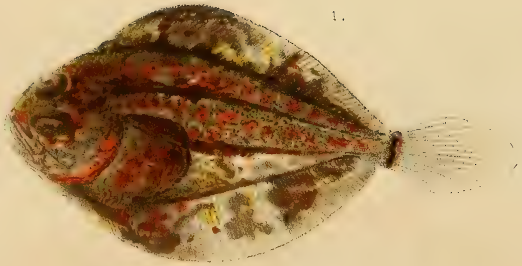

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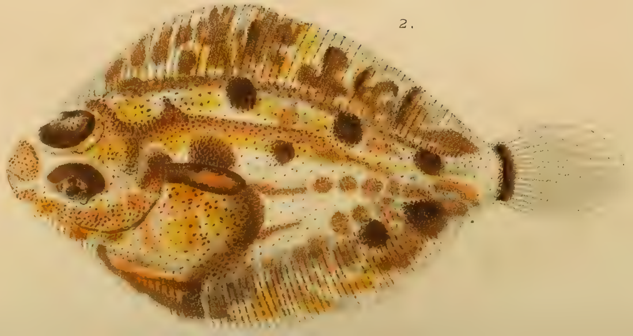

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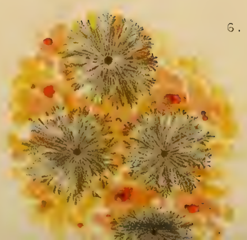

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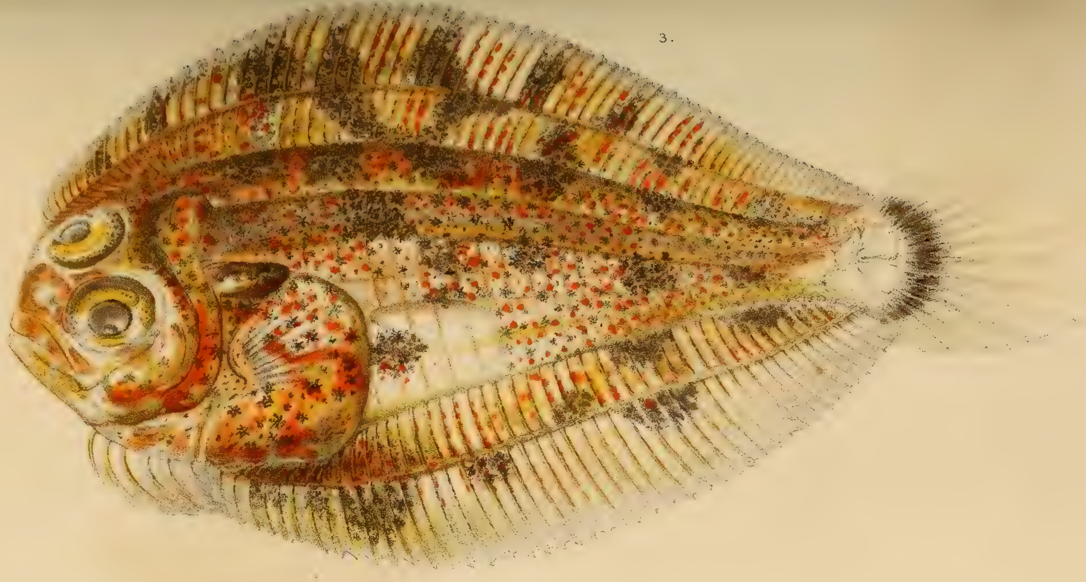

A.Meisel, Lith.

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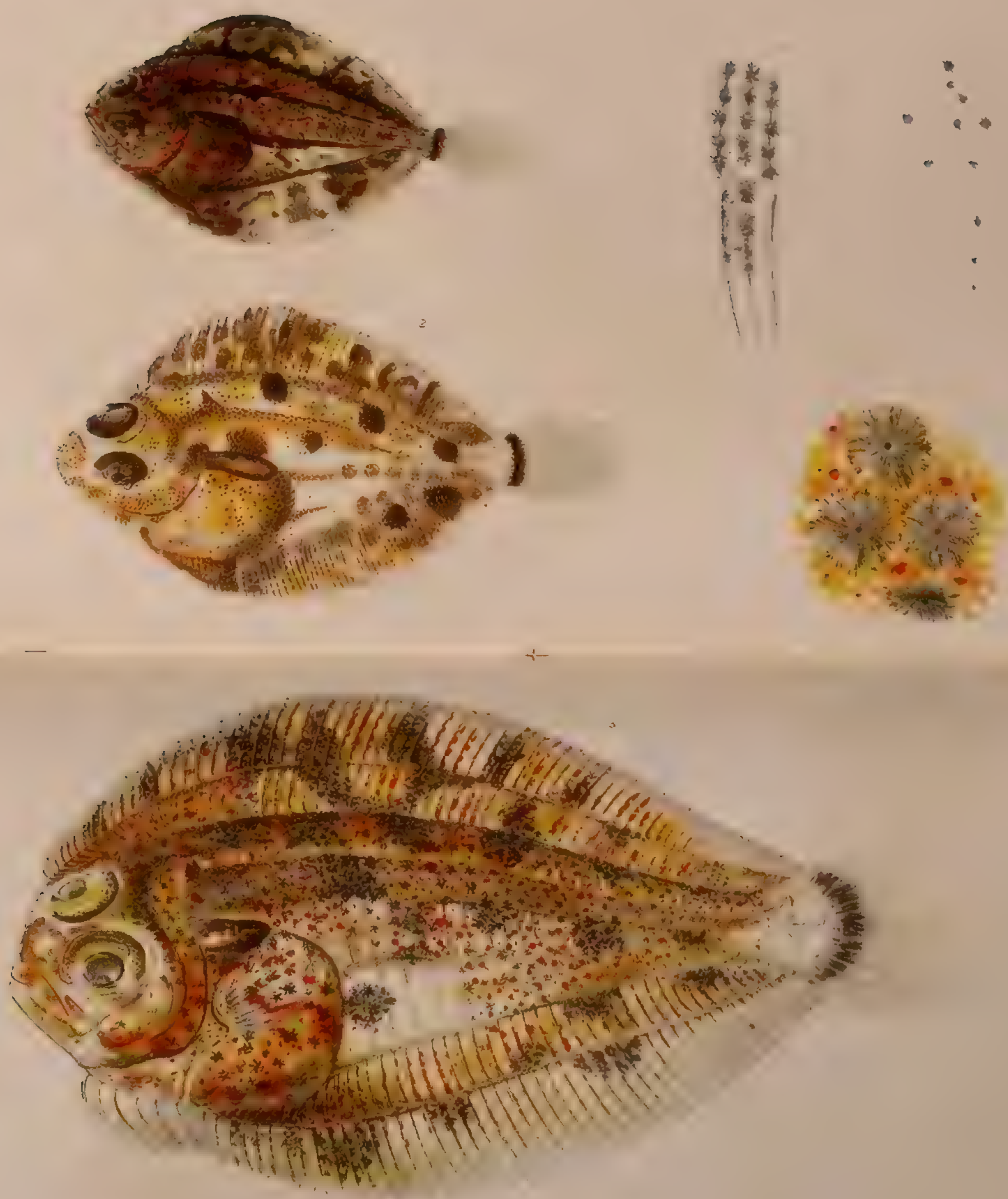

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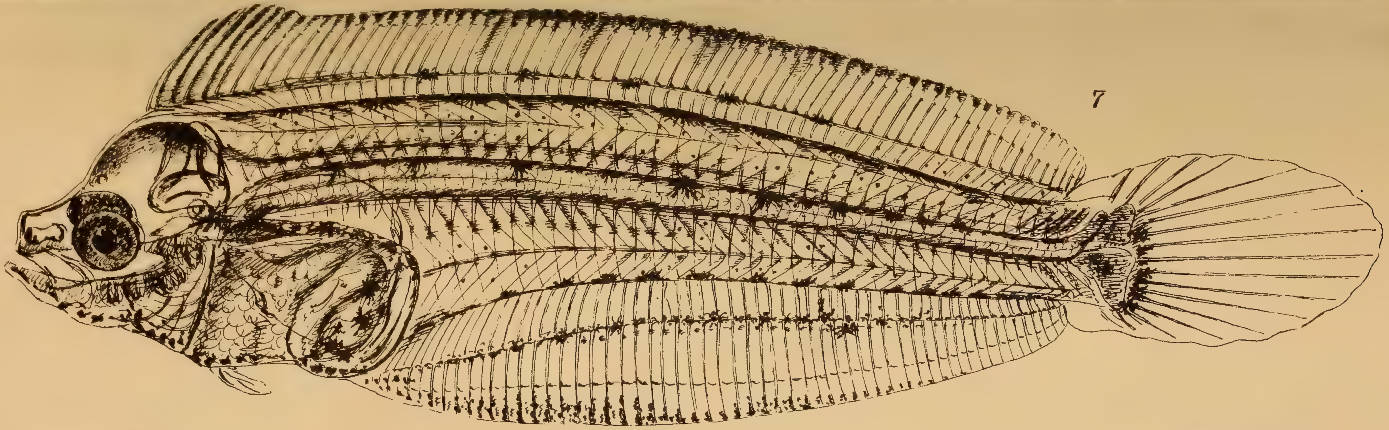

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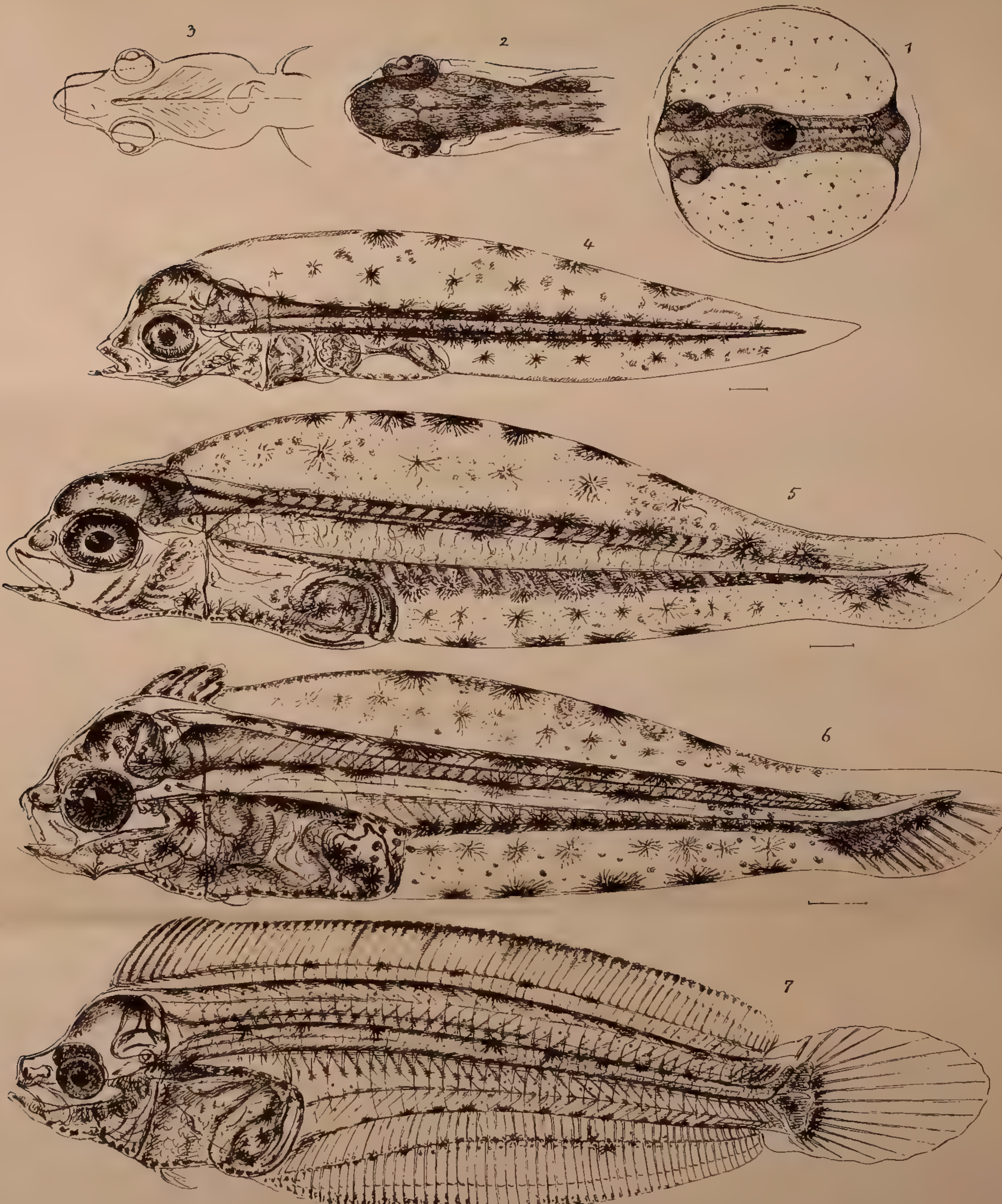
Alex. Agassiz Young Fishes Pl. IX



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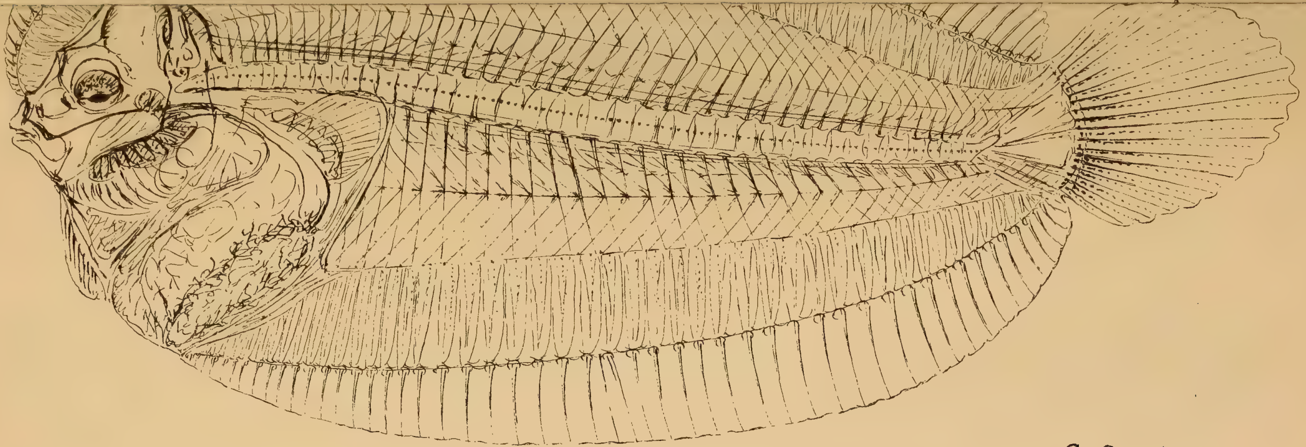

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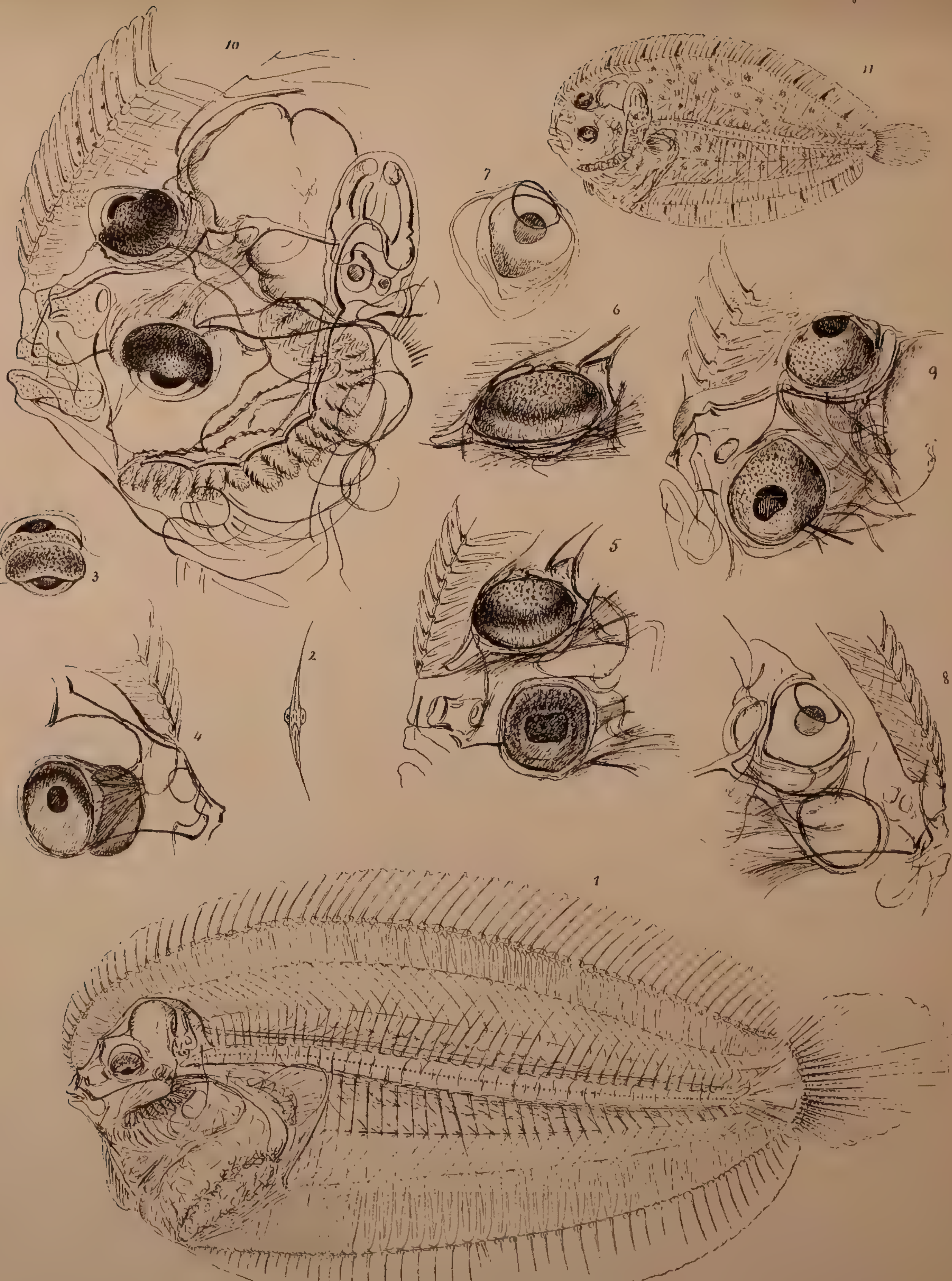
Alex. Agassiz Young Fishes Pl. X



A. Ag. del.

ON THE

YOUNG STAGES OF OSSEOUS FISHES.

By ALEXANDER AGASSIZ.

PART III.

WITH TWENTY PLATES.

[From the Proceedings of the American Academy of Arts and Sciences, Vol. XVII.]

July, 1882.

XVI.

ON THE YOUNG STAGES OF SOME OSSEOUS FISHES.

By Alexander Agassiz.

Presented May 9, 1882.

Part III.*

Many interesting points of relationship between the embryos of osseous Fishes and their fossil representatives have been traced by comparing the structure of the tail of the fish embryo as it passes from the leptocardial stage through the various stages of heterocercality to a so-called homocercal stage. This relationship, as has been pointed out, is very marked, and has led to some important generalizations. The comparison of the pectorals or of the dorsal and anal fins does not, however, lead to such interesting results. It is true that as far as the pectoral fins are concerned, their resemblance in the early stages of the bony fish embryo to the crossopterygian type of pectorals is very striking, but, owing to our imperfect knowledge of the structure of the pectorals of the ancient Fishes, this comparison is at present less complete than that between the tails of the older fossil Fishes and the tails of the embryos of the modern osseous Fishes.

With regard to the comparison of the median fins of the osseous Fishes of to-day with the median fins of Fishes of earlier periods, we do not come to any satisfactory results. If we take, for instance, the change undergone by the embryos of osseous Fishes, we find invariably in the youngest stages a continuous embryonic fold, extending from the head along the dorsal side to the extremity of the tail and around the lower side to the yolk bag. At a later period, when they carry embryonic rays, these embryonic median fins resemble somewhat the

* Part I. Proc. Amer. Acad. XIII. 1877–78, p. 117; Part II. Proc. Amer. Acad. XIV. 1878–79, p. 1.

fins of some of the earlier Ganoids in which the fin rays are very numerous, as, for instance, the Platygnathus of the Old Red. These characters are represented in the Ganoids of to-day both in Ceratodus and Protopterus; indeed even the Blennies, Eels, Murenidæ, and Ophididæ of to-day may be regarded as types of these embryonic stages, of which Phaneropterus with its confluent dorsal and caudal is a representative among the older fossils. But in the one case the fin rays are the permanent rays, while in the other the [embryonic] fin rays disappear with the appearance of the permanent osseous fin rays, as I have shown in my paper on the early stages of Lepidosteus.* The same conditions are repeated also in the young stages of that genus.†

As regards the formation of the dorsals, the posterior dorsal is the first to be differentiated; in the embryos of the osseous Fishes the anterior dorsal appearing only subsequently, and either independently or connected with the posterior one. In those fishes which have these fins separated in the adult, the dorsals are usually united in the earlier stages, but if the anterior dorsal is of a peculiar type, as, for instance, in Lumpus, Trachypterus, and Lophius, the anterior dorsal becomes separated at an early stage, sometimes even while still in the egg, from the posterior dorsal. We can therefore assume that as far as the dorsals are concerned a continuous median fin still connected with the caudal is the earliest embryonic type of fin.

The next stage of development is a type in which the caudal is well separated from the dorsal and anal embryonic fold, with a continuous single dorsal ending finally by the differentiation of the dorsal into one or more independent dorsals. The formation of abnormal types of anterior dorsal to form structures adapted to special uses, as in Lophius, is an embryonic feature, and this development of the dorsal may exist either as a separate dorsal, or the anterior rays of the single dorsal may be developed to an extraordinary degree, forming immense filaments, as in Argyreiscus, Blepharis, and many other fishes.

This anterior dorsal also may exist only in the embryonic stage, as is the case in Fierasfer and Trachypterus. The anal is usually well developed before the appearance of the ventrals, except in the cases of those genera in which the ventrals take an extraordinary development

* Proc. Amer. Acad., 1878, XIII. p. 65.

† In my next paper on bony Fishes, I hope to treat of the transformation of the median fins of osseous Fishes from their embryonic stage to that of fins with permanent osseous rays.

and are adapted for special uses, as in the young of some Gadoids, or those genera in which the rays of the ventrals extend into large filaments, which may be of use as tactile organs. The most characteristic of these genera are found among some of the newly discovered deep-sea Fishes dredged by the "Challenger" and by the "Blake."

In the Fishes living at moderate depths and in pelagic Fishes the pectorals or ventrals may be developed into organs of flight, as we find it to be the case in the young of Onus, which certainly mimics to an extraordinary degree in its embryonic stages the Flying-Fishes. The specialized ventrals of the embryonic stages of Lophius and Onus may represent the huge ventral appendages, articulated fins, which exist in Pterichthys and other Devonian Fishes. The absence of ventrals or the presence of small ventrals and the existence of a large anal fin, still more or less united with the caudal and dorsal fin, may thus be regarded as embryonic characters. The differentiation of the anal is the next stage of development, and well-developed, isolated anals and ventrals are generally found to occur with well-developed and isolated dorsals. The existence of abnormally developed ventrals, as in young Gadoids, may also be considered as an embryonic character.

As far as the oldest fishes are concerned, we find in them the same dorsals and anals isolated from the heterocercal tail fin, just as they exist in many of the Fishes of the present day, and there is nothing to show that in the earliest known fossil Fishes the development of the median fins did not take place much in the same manner as it takes place to-day in the young of Lepidosteus.

There is something in the general structure of the youngest embryos of Lumpus which recalls to us the Cephalaspidæ. The position of the mouth in all young bony Fishes is characteristic of the earliest Fishes; they have in common also a cartilaginous skeleton, heterocercal tails, and a rudimentary dorsal and anal, with prominent pectorals, as in some of the fossil genera. With the Dipteridæ, although we have median fins broken up into several distinct fins and a heterocercal tail, yet these fins all belong to the embryonic posterior dorsal and anal. In the next prominent group, the Acanthodida, the heterocercal tail continues and is found to exist with single anal and dorsals, and small ventrals with well-developed pectorals. While in the Palæoniscidæ, the Dapedidæ and Pycnodonts, we find the representatives of embryonic types in which the tail becomes much less heterocercal, the anals and dorsals are each one long continuous fin with numerous rays, recalling the embryonic stages of Poronotus figured in this memoir. When, however, we reach the Jurassic, Cretaceous, and Tertiary, we come upon types more closely allied to the older stages of our bony Fishes, embryos in which an anterior dorsal is found, of which the anterior part is more or less developed, as in *Platax semiophorus* and the like, having also heterocercal tails. We also meet in these later formations genera in which the fin rays of the ventrals are still excessively developed, as in embryo Gadoids, and finally find the Fishes of the youngest formations agreeing more closely than any of their predecessors with the adult forms found in the seas of the present day.

The number of scattered papers in which various young stages of osseous Fishes are described is large, but, with the exception of the memoirs of Sundevall, of Lütken, and of an interesting chapter on Young Fishes by Günther in his Introduction to the Study of Fishes, these papers are usually limited to a single stage of development. As the present communication is mainly devoted to the study of young stages which have not as yet been described, I have quoted only those papers which had special reference to the genera here studied. I propose to incorporate the bibliography covering this subject with that of the Embryology of Fishes now in preparation for the "Selections from Embryological Monographs" to be published in vol. ix. of the Memoirs of the Museum of Comparative Zoölogy.

Labrax lineatus. *Bl. & Sch.* (*Roccus*, Gill).

(Plate I. Plate II. figs. 3, 4.)

In very young striped Bass, measuring about 3.5^{mm} in length (Plate I. fig. 1), the eye is of a bright blue color, with an emerald green band above the pupil. This, with the prominent silvery swimming bladder and the long line of large chromatophores extending from the vent along the base of the embryonic anal fin nearly to the extremity of the body, renders it easy to recognize the young stages of the Bass. All the stages here figured were collected on the surface with the tow-net. The eggs I have not found.

In the next stage (Plate I. fig. 2) the head has become proportionally larger, the mouth is placed more anteriorly, and the embryonic caudal rays are also more prominent. The muscular bands, the brain as well as the stomach, are colored a light yellowish-brown.

In the next stage (Plate I. fig. 3) the head is comparatively still larger, the body has become stouter, and the embryonic caudal is better separated from the dorsal and anal fin folds. The jaws are larger, the lower jaw projecting well beyond the upper one. In the next stage (Plate I. fig. 4), the permanent caudal is forming, and the original muscular bands around the body are more distinct than in the previous stage, otherwise the young fish does not differ materially from the stage of Plate I. fig. 3. In the next stage (Plate I. fig. 5) the caudal is almost terminal, and the posterior dorsal as well as the anal are indicated by the rudimentary permanent rays along the dorsal and anal lines.

In Plate II. fig. 3, the young Bass has a symmetrical rectangular caudal, well-developed pectoral and ventral fins, with anal and posterior dorsal completely separated from the caudal, the permanent rays large. The anterior dorsal is low, and still united with the posterior dorsal; the line of pigment spots extending along the ventral side is the only prominent one. A young Bass in the stage of Plate II. fig. 4, shows a forked caudal comparatively larger than in the adult, while the outline of the dorsal and anal is lobed, and the anterior dorsal distinct from the posterior one, and fully as high. The head has also become more elongated, and the little Bass assumes somewhat the coloring of the adult. In addition to the original ventral line of pigment spots, two prominent stripes of elongated black spots extend along the lateral line, and a less distinct line runs along the base of the dorsals. The line at the base of the dorsals is sometimes present in much younger specimens (Plate I. fig. 3 *a*) not older than those of Plate I. fig. 3. In a younger stage than Plate I. fig. 3 *a*, this dorsal line was interrupted, consisting of three patches along the base of the dorsals. The pigment spot which appeared at the base of the caudal rays as early as in stage Plate I. fig. 2, now extends as a short line across the base of the permanent rays.

TEMNODON SALTATOR, *Lin.* (*Ponatomus saltatrix*, Gill).

(Plate II. fig. 5.)

Of the Carangidæ I have only found on the surface one small Blue fish (Plate II. fig. 5) measuring 9^{mm} in length. The tail fin was but slightly forked; the anterior dorsal rudimentary, but the base of the permanent fin rays already present; permanent fin rays existing in the posterior dorsal as well as the anal; large pectorals, rudimentary ventrals. Teeth of upper and lower jaw already quite prominent; body elongate, angular. Prominent line of black pigment spots extending from the top of the head to the end of posterior dorsal along upper side of stomach and base of anal and caudal. Eye bright blue, bluish silvery body with a few faint pigment cells uniformly scattered over the flanks. The Carangidæ with rudimentary ventrals and no anterior dorsals are evidently genera representing the embryonic stages of this family.

STROMATEUS TRIACANTHUS, *Peck* (*Poronotus triacanthus*, Gill).

(Plate VI.)

The more advanced stages of the Butterfish (from 10–20^{mm} in length and larger) are frequently found within the tentacles of our common Dactylometra. The younger stages were, however, all fished up from the surface with the hand-net.

The youngest stage of Poronotus observed measured 7^{mm} in length (Plate VI. fig. 1). The body in this stage is comparatively stout, the head large. The caudal is already developing, though the embryonic lobe is still present; the urostyle is quite large. The dorsal and anal embryonic fins are narrow. The pectoral is large, rounded, transparent, the permanent rays well developed. The eye is large, and has the peculiar greenish-brown metallic lustre of the adult; this makes it comparatively easy to recognize the embryo Butterfish in the early stages.

There is a line of large chromatophores along the base of the anal, extending from the vent along the ventral line to the operculum, a few large pigment cells (four to five) on the digestive cavity, and a large patch over the swimming bladder. There are four comparatively small pigment cells along the lateral line, three to four along the dorsal line behind the head, and eight to ten irregular pigment spots on the head above the eye, with three or four small pigment cells in advance of the eye and on the jaws. In the following stage (Plate VI. fig. 2) the anterior part of the body and the head have a light brownish tint, the tail fin is nearly symmetrical, it has permanent fin rays with three articulations, the body is somewhat more elongated, there are the first traces of the permanent dorsal and anal fin rays along the dorsal and ventral lines. The general distribution of the pigment spots is very similar to that of the previous stages; the cells are, however, somewhat more dendritic. In the following stage figured (Plate VI. fig. 3) the chromatophores have greatly increased in number and size, especially on the upper part of the head and along the flanks of the anterior part of the body. There is now a double line of dendritic cells extending along the base of the anal and of the dorsal, and a few small cells at the base of the caudal rays. The dorsal and anal fins are separated from the caudal by a deep cut, but the caudal embryonic fin fold is still quite broad, and extends well beyond the base of the tail.

In the next stage (Plate VI. fig. 4) the young Poronotus has assumed, though faintly, the general coloring of the adult. The whole body is slightly tinted with yellowish brown, the head and anterior part of the body being darkest, with patches of carmine between the eye and base of the brain. The upper part of the head, the anterior part of the dorsal line, and the flanks of the body are well covered with large dendritic chromatophores closely packed together. Large and more distinct cells cover the sides of the body behind the digestive cavity. A row of longitudinal bars of pigment extends along the whole base of the dorsal, while delicate dendritic cells extend along the base of the anal and at the base of the caudal rays. The caudal in this stage has become slightly forked, the dorsal and anal are high, still better separated from the caudal than in the previous stage. The mucous pores of the head are already quite numerous along the operculum and near the nostrils. When the young Butterfish has reached a length of 16^{mm} (Plate VI. fig. 5) the body has become much broader, the mucous pores of the head have greatly increased from the previous stage figured, the chromatophores of the anterior part of the body, above the head, along the dorsal region, and over the stomach have become very numerous, they extend over the anterior part of the dorsal, with a double line of rectangular spots along the base to the extremity, and a similar double line extends along the base of the ventral. The dorsal and anal, as well as the caudal, have assumed very nearly the outline they have in the adult; the permanent rays are well articulated in the median fins.

ATHERINICHTHYS NOTATA, *Günth.* (*Chirostoma,* Gill).

(Plates X., XI.)

The youngest specimens of Atherina (Plate X. fig. 1) are striking for their coloring, a light yellow tint extending over the whole embryo. The young Atherina is readily recognized from its light-blue eye, with greenish-emerald band above the pupil, and large otoliths, the patches of large chromatophores along the upper and lower side of the stomach, and three lines of rectangular pigment cells extending, the one along the whole base of the embryonic anal, the second along the lateral line, the third along the base of the posterior extremity of the embryonic dorsal. The next stage figured (Plate X. fig. 2) is characterized by its proportionally larger head, by the presence of a large dendritic pigment cell over the base of the brain, with five rounded spots in front of it over the principal lobe of the brain, and similar spots behind extending into the dorsal line of pigment spots, which in this stage runs along the whole base of the embryonic dorsal, and forms a line fully as marked as the other two already existing in the younger stage. In this stage the yellow coloring of the body is more intense along the upper part of the head, over the stomach, and along the dorsal line, than in the younger stages. The large dendritic pigment cells on the top of the head are sometimes found in specimens quite as young as Plate X. fig. 1. In the stage of Plate X. fig. 2, the caudal fin is forming.

In the next stage figured (Plate X. fig. 4) the head has become somewhat lengthened, the caudal fin more terminal, the embryonic caudal lobe quite rounded; the yellow coloring of the body and head is more marked, and has assumed at the same time a somewhat greenish tinge. The embryonic dorsal and anal are slightly lobed; the first trace of the base of the permanent dorsal and anal rays can be seen along the dorsal and ventral lines. There are very rudimentary ventrals as slight projections, one on each side of the anterior part of the embryonic anal. The diagonal muscular bands are well marked. The three lines of pigment cells are more prominent than they were in the preceding stage.

In a somewhat older stage (Plate XI. fig. 5) the head is proportionally more elongate than in younger stages. The caudal fin is nearly symmetrical, but with a slight trace of the embryonic caudal lobe; the dorsal and anal are well separated from the caudal; their permanent fin rays have commenced to form, though not as well advanced as those of the caudal.

In the next stage figured, when the young Atherina has attained a length of about 16^{mm} (Plate XI. fig. 6), the general outline of the head and body is much that of the adult; but the tail fin is still rounded; there is but a trace of the anterior dorsal; the dorsal and anal are still quite low, though completely separated from the caudal; the anterior part of the anal embryonic fin, in which no permanent rays are formed, has not entirely disappeared; the ventrals have greatly increased in length since the stage of Plate XI. fig. 5. The caudal rays are edged with rows of narrow pigment cells, while in the preceding younger stage the pigment spots of the caudal were limited to the base of the rays (Plate X. figs. 3, 4), or there are but a few irregularly scattered along the fin rays (Plate X. fig. 5). There is a marked line of pigment cells along the base of the dorsal and anal; in the anal an additional line of pigment spots runs near the outer edge of the fins. The general coloring of this stage approaches quite nearly that of the adult, though the body and the lateral line do not have quite as silvery a lustre as in the older stages.

In the oldest Atherina here figured the snout has become quite pointed (Plate XI. fig. 7). The anterior dorsal has made its appearance, the caudal is forked, the dorsal and anal are high, having much the shape they have in the adult, the pectorals are quite pointed. The permanent rays of all the fins are now edged with narrow pigment cells. The pigment spots of the lateral line consist of three or four irregular lines of minute dendritic chromatophores, while the dorsal line is made up of two irregular lines of large spots extending from the snout to the base of the tail. The ventral line extends only from a point slightly in advance of the base of the anal to the caudal fin; it also consists, like the dorsal line, of two irregular lines of elongated pigment spots. In this stage the young Atherina has fairly assumed the principal characteristic features of the adult.

Batrachus tau, *Lin.*

(Plate XVI. fig. 1.)

Dr. Storer has given a figure of a young Batrachus (Mem. Amer. Acad. v., Plate XIX.) measuring about 2^{mm} in length. It differs but slightly from the large specimens, the more rounded outline of the head, as seen from above, and the greater elongation of the head characterising this younger stage.

A young specimen (Plate XVI. fig. 1), measuring only 8^{mm} in length, was slender, the pectorals fully developed; the openings in the mucous membrane of the head were well developed, the ventrals small; the dorsal and anal fins were still connected with the embryonic caudal, the separation between the anal and caudal being but little marked. The tail fin was still in an embryonic stage, with a well-marked trace of the ganoid lobe. The whole fish was dotted with small pigment spots, with a few larger cells scattered irregularly over the surface; the pectorals were similarly covered. The general tint of body and fin was gray, with blackish and yellowish pigment cells.

Lophius piscatorius, *Lin.*

(Plate XVI. figs. 2–5; Plates XVII., XVIII.)

The eggs of Lophius are laid embedded in an immense ribbon-shaped mucous band, from two to three feet broad and from twenty-five to thirty feet long. This gelatinous mass is often found floating on the surface of the sea during the last part of August. It looks at a short distance like an immense crape. The mucous mass is of a light violet gray color, and the dark black pigment spots of the young Lophius, still in the egg, give to the mass a somewhat blackish appearance. The eggs are laid in a single irregular layer through the mass, usually well separated by the mucus in which they float (Plate XVI. fig. 2).

When just hatched (Plate XVI. fig. 4) it would be difficult to recognize the young as the embryo of Lophius. It has but a single first dorsal element, a narrow short spathula-shaped ventral, and a small circular pectoral. These characters, with its transversally flattened body and head, seem in this stage to have no relation to the vertically flattened adult Lophius. The embryo in this stage, as well as while still in the egg (Plate XVI. fig. 3), and until it is far more advanced (Plate XVI. fig. 5, Plate XVII. fig. 7), is remarkable for the great width of the embryonic fin fold along the dorsal and ventral lines, the very straight notochord, and the three or four prominent patches of intense black pigment cells placed at equal distances along the lower, upper, and terminal parts of the chord. The tail pigment spots extend on both sides of the notochord, and form the largest of the three patches. This is the case from the earliest stages, until the body of the young Lophius is completely covered by pigment cells, as in the oldest stage here figured (Plate XVIII. fig. 2). I have already on a former occasion figured some of the changes which the tail undergoes as the embryo passes from the stage of Plate XVII. fig. 3, to the oldest stage of the young Lophius (Plate XVIII. fig. 2).

The principal changes of form of the body of the young Lophius consist in the gradual flattening of the head, and at the same time the increase in the proportion of the head as compared to the rest of the body, — a feature in which Lophius and the Cottoids differ somewhat from the post-embryonic changes of other osseous Fishes, where the head loses in later stages the comparatively huge size which characterizes nearly all the younger stages of bony Fishes soon after they leave the egg.

The yolk bag of the young Lophius when just hatched is comparatively small (Plate XVI. fig. 4), being almost entirely absorbed while still in the egg, and it soon disappears entirely (Plate XVI. fig. 5). In a somewhat younger stage, taken out of the egg (Plate XVI. fig. 3), it is quite globular, and the first trace of the pectorals and of the ventrals as a mere fold of the embryonic fin fold, which extends over the yolk bag, is still well shown.

In these earlier stages (Plate XVI. fig. 3, and Plate XVI. fig. 1) the embryonic fin folds are covered with minute round black pigment spots. It is only in much more advanced stages (Plate XVIII. fig. 1) that we begin to find traces of the ordinary dendritic pigment spots which eventually cover the dorsal, anal, and caudal fins (Plate XVIII. fig. 2).

The young a few days after hatching (Plate XVI. fig. 5) differ from the preceding stage mainly in the greater elongation of the head, the disappearance of the yolk bag, the comparatively larger pectorals, and in the position of the eye, which is somewhat higher. In the next stages (Plate XVII. figs. 1–3) the head has become still more elongated, the lower jaw projects well beyond the upper jaw, the branchiæ are well developed, the eye has assumed a still higher position in the head, the pectorals have greatly increased in size, the single anterior dorsal element is more than double what it was in the size figured before, and the ventrals have become greatly lengthened, showing a trace of the second ray at the base of the larger ones. The alimentary canal is well circumscribed, and the pigment spots over the remainder of the yolk bag, the top of the brain, and the base of the chorda are of an intense black, with a slight tinge of yellow over the alimentary canal.

The outline of the body has somewhat lengthened, the embryonic dorsal and ventral fins remain of great width, showing as yet no trace of separation of an anal or dorsal or caudal fin, beyond the presence of embryonic fin rays in the large caudal pigment spot (Plate XVII. fig. 3), already present in younger stages.

In somewhat older stages the original dorsal ray shows a trace of a second ray behind its base (Plate XVII. fig. 4), which in a still older stage attains half the length of the original ray (Plate XVII. fig. 5.). The second ray of the pectorals of this same stage (Plate

XVII. fig. 4) has also greatly increased in length from that of Plate XVII. fig. 3, the original pectoral ray at the same time having become so bent that the extremity forms an obtuse angle with the base. The separation of the anterior from the posterior dorsal takes place at a very early stage, already within the egg (Plate XVI. fig. 3), the first ray of the anterior dorsal pushes its way through the embryonic dorsal fold in a slight depression formed above the head, and thus forms the separation of the anterior part of the dorsal embryonic fold from the posterior. In a view from above of the young Lophius within the egg, the derivation of the pectorals and of the ventrals from the embryonic fin fold which covers the yolk bag is well seen. The paired fins are formed in the same manner on the yolk fold. They belong to the original embryonic fin fold, which splits, so as to cover the yolk bag.

Plate XVII. fig. 6, represents the embryo Lophius in a somewhat older stage than when the dorsals and ventrals are in stage figured on Plate XVI. figs. 4, 5. The dorsal and ventral embryonic folds are somewhat more opaque, both from the greater number of pigment spots, which, however, are of lighter tint than in younger stages, and from the additional number of embryonic fin rays. These are now very closely placed together on the dorsal side; they are somewhat less numerous and more distant on the ventral side. This stage is remarkable also for the great size of the lobed fleshy pectorals, with rows of light gray dendritic pigment cells along the line of the embryonic rays. There is a rudiment of a third dorsal ray, and the second ray of the ventral is more than half as long as the original ray. Teeth are well developed on the lower jaw. In the next stage figured (Plate XVIII. fig. 1) the principal differences consist in the increased length of the anterior dorsal rays (there are three rays now, and the rudiment of a fourth), the increase in length of the two ventral rays and the appearance of a rudiment of a third ray. Muscular bands are now more distinct along the body than in the younger stages; the three principal pigment spots have become broken up into smaller dendritic pigment cells, and we have the first trace of the formation of a caudal fin in the widening of the body immediately below the anterior part of the caudal pigment spots. The fleshy pectoral has become still larger than in the last stage figured; the dendritic stellate chromatophores of the head and of the ventral region of the pectoral side of the body are more numerous; the head has greatly increased in size, it is colored light yellow; the muscular bands and the tissues below the patches of the chromatophores along the body line are of the same color. The broad flat fin rays, dorsal and ventral, are of a grayish tint; the eye is blue. In the oldest of the young Lophius which I have had occasion to examine (Plate XVIII. figs. 2, 3) the changes from the preceding stage are very great. Although the body is still laterally compressed, the head, which has greatly increased in size, as well as the body anterior to the anal opening have become somewhat flattened vertically, the first trace of the great flattening so characteristic of the genus. The anterior part of the head projects proportionally far in advance of the orbits, the head sloping less from the base of the anterior dorsal ray than in preceding stages. The pectorals have now become enormous, they extend across the whole width of the body of the young Lophius, they are lobed at the edge, the rays articulated, well marked, and edged with rows of elongated dark pigment spots. The tail fin is well formed, though it still retains its ganoid shape, and the posterior dorsal and anal, though well formed, are still connected by a distinct remnant of the dorsal and ventral embryonic fin fold with the caudal fin. The anterior dorsal now has five rays, with a rudimentary one anterior to the first formed ray. These rays are connected at the base by a fin fold at a much higher point than in younger stages; they extend far beyond the fold; the extremities curve down about a quarter of the length of the ray. The increase in length of the ventral rays has been still more remarkable. The original ventral ray is now nearly twice as long as the body of the fish, and the second ray extends fully as far as the extremity of the caudal fin. There are two shorter exterior rays and one interior ray; they are joined by a membrane extending nearly to the base of the caudal, so that when expanded and seen from above the ventrals appear like regular wings. Their great size and the shape of the peculiar pectorals is well seen in the figure from above (Plate XVIII. fig. 3). The general color of the body of the largest specimens here figured is of a very light, dirty violet tint, of an olive green along the dorsal line; the body and head are covered by darker violet gray pigment spots. The pigment spots of the ventrals are of an intense black, as well as a few of the spots along the extremity of the urostyle. The pigment cells, of a violet gray, are especially numerous along the line of the pectoral rays, with a row of darker cells at their base (fig. 10). The dorsal, anal, and caudal fins are still very transparent, with a delicate tinge of violet. The young Lophius is very active during its embryonic stages, in striking contrast to the sluggish habits of the adult. The adult is comparatively a deep-water fish. I have dredged it in the "Blake" as low down as 320 fathoms off Newport. The females undoubtedly come to shallower waters to spawn, as they are not an uncommon fish during July and August, being frequently found left by the tide on the flat where they come to spawn.

The young in the stages here figured are pelagic Fishes; they were all collected, during July, August, and September, on the surface both at Newport and in Massachusetts Bay. The young hatched from the egg were only raised as far as the stage represented in Plate XVI. fig. 4. The young fishes frequently assume, when at rest, an inclined position, much as the young Garpike, and do not float horizontally as other bony Fishes do. See the figure in my former paper on the development of the tail in Plate II. Vol. XIII. Proc. Amer. Acad. 1877–78.

Günther* has figured (on p. 471, Introduction to the Study of Fishes) a young Lophius measuring over 70^{mm} in length, in which there are three long anterior dorsal filaments. The older of the young stages I figure resemble somewhat Melanocetus. The general resemblance of the more advanced stages of Lophius (Plate XVII. figs. 3, 6, Plate XVIII. fig. 1) to the Ophididæ and Macrouridæ is very striking.

Somewhat similar to the egg ribbons of Lophius are the masses of eggs laid by Fierasfer described by Risso and Cavolini, and also well figured by Emery,† who has followed the development of the young and given excellent figures of different stages; see Emery, Plate I. fig. 2, Plate II. figs. 5–7. They assume also, as do the young of Lophius, a peculiar slanting attitude characteristic of certain stages of growth. It is most interesting that such distant types as Lophius and Fierasfer should in their embryonic stages show such close resemblances. Compare the figures of this paper and figs. 5 and 6 of Plate II. of Dr. Emery's Memoir. It is not extraordinary that these forms should have been described under the different generic names of Vexillifer, Helminthostoma, and Porobranchus. The temporary dorsal appendage which is so prominent in the young Fierasfer (Emery, Plate I. fig. 2) is developed much in the same way as the

* See also Ann. and Mag. of Nat. Hist. 1861, vii. (3), p. 190.

† Fauna u. Flora d. Golfes v. Neapel. II. Monographie. Fierasfer, v. Dr., Carlo Emery, 1880.

permanent dorsal appendages of Lophius, which are eventually changed to the appendages used for fishing by the adult. What part this temporary dorsal appendage plays in Fierasfer is not known, but Emery supposes it to have the same function as in Lophius.

Cottus grœnlandicus, *C. & V.*

(Plate III., Plate II. figs. 1, 2.)

The eggs of this species (Plate III. fig. 1) are found floating on the surface; they are readily recognized from the number of small oil globules (from 10–12) which the yolk contains. Other Cottoids lay their eggs in bunches attached to the bottom, or singly between stones in shallow water. The young immediately on hatching (Plate III. fig. 2) are characterized by the great width of the anterior part of the body, the breadth of the embryonic dorsal fin toward the head, and the great size of the fleshy pectorals. Viewed from above, when slightly older (Plate III. fig. 3), the pectorals are seen to project far beyond the general outline as thick fleshy flaps; their formation as a fold of the primitive lateral embryonic fold is well shown in the stages within the egg (Plate III. fig. 1*a* 1*c*); in the last stage (Plate III. fig. 1*c*) they appear to stand independently of the body upon the yolk mass. In the stages of Plate III. figs. 4, 5, the rapid increase in the size of the head and of the pectorals can be traced. In the stage of Plate III. fig. 4, the permanent pectoral fin rays are commencing to form, and in Plate III. fig. 5, what we may call the crossopterygian stage of the pectorals is very striking.

The development of the anterior part of the body goes on, as in Lumpus, much more rapidly than that of the posterior, and at a stage (Plate II. fig. 1) where the Cottoid characters of the head and pectorals are already very striking, the embryonic dorsal and anal folds are still united with the caudal fold, and the tail only shows, as yet, a rudimentary caudal fin and the beginning of the ventrals.

In the next stage (Plate II. fig. 2) the spiny processes of the operculum and head of the young Cottus are well developed, and the pectorals fins have all the appearance of that of older specimens; the ventrals are well advanced, the dorsals and anals are separated from the caudal fin, the permanent fin rays are quite prominent, and the anterior dorsal exists as a low fin.

The general coloring of this stage of the young Cottus is of a dirty yellowish brown, with patches of darker pigment cells and black spots along the base of the anal fin, of the pectorals, and of the upper part of the stomach and head. In the youngest stages (Plate III. figs. 2, 3) there are two large patches of yellowish brown along the dorsal embryonic fin, four along the ventral, and the outer edge of the pectorals is colored in the same manner. In the subsequent stages (Plate III. fig. 4, and Plate II. fig. 1) the young have the general coloring of the older stages. This seems characteristic of other Cottoids, as in a young *Hemitripterus acadianus* corresponding to Plate III. fig. 4; the brilliant red coloring so characteristic of the adult is the prevailing tint of the pigment spots of that early stage.

Cyclopterus lumpus, *Lin.*

(Plates IV. V.)

In the youngest stage of this species I have had occasion to examine (Plate IV. fig. 1), measuring 4^{mm}, the caudal fin was already partly separated from the dorsal and ventral embryonic fin. The spiny rays were also indistinctly indicated in those fins. The pectorals were large, the rays gradually diminishing in length towards their junction with the sucking disk (the modified ventrals on the abdominal side). The anterior dorsal is formed evidently, as in Lophius, at an early stage, and separates, as in that genus, the anterior and posterior parts of the embryonic dorsal fin. The younger stages of Lumpus (Plate IV. figs. 1–4) are noted for the great length of the urostyle. The head of the younger stages is remarkable for its great length and breadth (Plate IV. figs. 1–4). The great prominence of the pigment spots on the anterior part of the young fish, as far as the base of the dorsal and ventral embryonic fins, gives the young Lumpus a very striking appearance. It resembles somewhat the armored Fishes of the Old Red, and we are strongly reminded of the restorations of Coccosteus in such stages as those of Plate IV. figs. 1 and 3. With increasing age and size (Plate IV. figs. 3, 4) the young Lumpus is more uniformly covered by pigment cells, the posterior part of the body becomes less transparent, more fleshy, and it loses its ancient look, resembling more, at this stage (Plate IV. fig. 4), the young of Batrachus, which may, indeed, be said to be a permanent condition of this stage of Lumpus (with the exception of the absence of the sucking disk in Batrachus). The posterior dorsal and the ventral have become well separated from the caudal fin, which in Plate IV. fig. 4, has nearly completely lost its ganoid shape, having become almost symmetrical. The urostyle, however, is still marked by its great length. The permanent rays of the median fins are well advanced (Plate IV. fig. 4); the paired fins have not changed materially since the last stage (Plate IV. fig. 3). There is great diversity in the coloring of the young of Lumpus. In the youngest stages (Plate IV. figs. 1–3) the head, in a line drawn nearly vertically below the base of the anterior dorsal, is of a light chocolate brown, with a darker brown band extending from the nostrils above the eye to the base of the anterior dorsal. A light blue band extends from the rear of the eye to the top of the operculum, and in front of the eye to the nostrils. A blue spot of similar tint is found at the posterior base of the dorsal and at the base of the caudal extremity of the posterior dorsal. The rest of the body is straw colored. The young of stage represented in Plate IV. fig. 4, were usually of a bright olive green, darkest towards the dorsal side, with the same blue band extending towards the operculum from the rear of the orbit, with one or two round blue spots above the level of the pectorals along the lateral line. Other specimens were of a bluish neutral slate tint, uniformly spotted with darker pigment cells, with the same blue band between the eyes, above the nostrils, and behind the eyes. This was also the coloring of the oldest of the young specimens caught (Plate V. figs. 1, 3), resembling in general the bluish coloring of the adult, only of a darker tint.

The intermediate stages varied greatly in coloring; some were of a yellowish brown spotted with chocolate-colored patches, with light greenish bands behind the eyes, and five roundish spots of the same color along the lateral line, and a similar number of larger spots along the base of the posterior dorsal, extending, in some specimens, along the median dorsal line of the body to the colored band extending between the eyes. Other stages, with a similar arrangement of elliptical spots of a bluish tint along the dorsal and lateral lines, were of a reddish brown color with pigment patches of a darker greenish or of a brownish color, the abdominal region being of a lighter color.

In the stage of Plate V. figs. 1, 2, the anterior part of the body already assumes somewhat the angular outline characteristic of the adult, though these young stages are all more elongated than the adult, having also the head comparatively well separated from the posterior part of the body. The young in the stages of Plate V. figs. 1, 2, do not as yet show any traces of the prominent rows of spiny tubercles formed in the adult. These were developed to a slight extent in young Lumpus measuring 34^{mm} in length (Plate V. figs. 3, 4): a line commencing to form along the anterior slope of the anterior dorsal, a less prominent horizontal row on a level with the line of the orbits close to the eyes, a third lateral one along the body at the level of the upper extremity of the operculum. This, the most prominent of the rows, consisted of large, elliptical protuberances, through which spiny processes projected (Plate V. figs. 3 *a*, 3 *b*), and a last row of somewhat smaller tubercles along the median line of the abdomen behind the ventrals. The anterior dorsal fins of these young stages (Plate V. figs. 3, 4) resemble greatly such permanent anterior dorsals as exist in Chironectes, for instance.

In the older stages (Plate V. figs. 1–4) the anterior dorsal has become well separated from the posterior, the median fins are entirely isolated, with well-developed fin rays, and the caudal has become symmetrical. The pectorals are somewhat larger, but otherwise they and the ventral fin disks (Plate V. fig. 3 *c*) do not differ much from their condition in younger stages. The early development of the pectorals seems a marked characteristic of all embryos of osseous Fishes.

These young stages of Lumpus were all collected close to the shore; they were found living among the eel-grass at Nahant, near low-water mark. Günther has figured* the young of *Cyclopterus spinosus.* Of these stages, the youngest correspond to the oldest stage of *Cyclopterus lumpus* here figured, the oldest measuring over 45^{mm} in length.

GASTEROSTEUS ACULEATUS, *Lin.*

(Plate IX.)

The changes due to growth in Gasterosteus closely resemble those of Fundulus. The principal differences consist in the longer persistence of the embryonic tail lobe, which is still very prominent (Plate IX. fig. 1) at a stage when in Fundulus the tail has become nearly symmetrical. The notochord continues to extend into the tail as late as the stage of Plate IX. fig. 4. The chromatophores are in the shape of irregular spots during early stages; they become more and more dendritic as the young fish grow older (Plate IX. figs. 2, 3, 4). In the stage of fig. 4 they begin to assume the arrangement forming the vertical bands of the adult, and in the oldest stage here figured (Plate

* An Introduction to the Study of Fishes (1880), p. 485.

IX. fig. 5) the general pattern is similar to that of the adult. In subsequent stages the spiny processes of the operculum are developed as well as those of the large ray of the ventrals. The ventrals make their appearance at about the time of the disappearance of the yolk bag (Plate IX. fig. 3), somewhat later than the formation of the rudimentary anterior dorsal spine (Plate IX. fig. 2). The outline of the young fish becomes more compact with age, passing gradually through the changes represented in Plate IX. figs. 1–5, from an elongated slender fish to one with a comparatively broader and stouter body.

Pelagic Fish Eggs.

The number of species of marine Fishes of which the eggs are pelagic is probably quite large. Scarcely a summer passes without some new egg being brought to light by the surface-fishing carried on at Newport. The eggs of the majority of our species of Flounders, those of Ctenolabrus, of Tantoga, of several species of Cottus, I know, from my own observation, to float on the surface of the water. Häckel has called attention to the pelagic eggs of Lota or some Gadoid which he had observed as early as 1866. Sars has shown the same to be the case with the eggs of the Cod. Mr. Ryder has figured the eggs of the Spanish Mackerel (Bull. U. S. Fish Com., i. Pl.) Both he and E. van Beneden, who also has observed pelagic fish eggs (Quarterly Journal Mic. Soc. 1878), have called attention to the value of these pelagic fish eggs for embryonic investigations. Mr. Ryder has also made observations of the spawning of Zeus, and suggests that many of the marine Fishes are nocturnal spawners. That this is the case with many of the Fishes I have named above seems probable from the state of segmentation in which they are found to be on the morning following the day on which they were collected. The pelagic eggs collected during the day were invariably well advanced, and the experiments for artificial fecundation which I have made with Ctenolabrus and Tautoga to obtain the very earliest stages of the development of the egg were invariably made late in the afternoon, towards dusk. I have long known the eggs of Lophius to occur floating on the surface as a gigantic mucous band, and they have also been subsequently collected by the U. S. Fish Commission. The eggs of Fierasfer are also pelagic; see Emery's monograph. I have myself also collected the eggs of the Spanish mackerel on the surface, and have observed a couple of stages of the young considerably more advanced than those figured by Mr. Ryder. The youngest of the stages I have observed correspond very closely with the stage figured by Mr. Ryder on Plate IV. fig. 16, Bull. U. S. Fish Com. It was remarkable, however, for having a lateral anal opening close to the notochord, the anal embryonic fin extending unbroken beneath it from the operculum to the extremity of the tail. The older stages are very readily distinguished from other fish embryos by the large pigment spots which are formed one above the other, and by three large patches dividing the posterior part of the body into nearly equal parts, from the extremity of the anal opening to the tail.

Ctenolabrus cœruleus, *Dek.*

(Plates XIII. XIV. XV.)

The egg of Ctenolabrus floats on the surface immediately after being laid, and the eggs in all stages of development are fished up with the hand-net from June to the last part of August. The greater number of the eggs appear to be laid in July. The segmentation of the egg is rapid; in less than twelve hours after fecundation there are sixteen segmental spheres. In fifty hours the embryonic cap is well formed; in fifty-two hours the eyes are blocked out; and the young fish is hatched in from four and a half to five days in the stage of Plate XIII. fig. 1, measuring about 2^{mm} in length. The yolk bag is large, elliptical, and it (as well as the embryonic fin fold) is free from chromatic cells, which cover only the dorsal part of the body, and stop a little way short of the extremity of the notochord. On the second day after hatching (Plate XIII. fig. 2) the young Ctenolabrus is about 3^{mm} in length, the body is much more elongated, the head especially has lengthened, the distance between the eyes and the otoliths is nearly double, the rudimentary pectorals are better marked, and the distance of the vent from the yolk has greatly increased. The black chromatic cells have also increased in number, and are proportionally smaller than in the preceding stages. On the third day after hatching (Plate XIII. fig. 3) the young Fish presents a totally different appearance: the chromatophores characteristic of the early stages within the egg immediately after hatching have disappeared, there are left but a few large cells in the anterior part of the head, behind the pectorals along the dorsal, while there are in this and the subsequent stage (Plate XIII. fig. 4) large patches of pigment cells, and large chromatophores at the base of the anterior termination of the notochord below the level of the eyes. We find also along the body a large patch at the posterior extremity of the stomach, a second at the end of the intestine near the vent, with a smaller patch between this and the anterior one, and a third prominent patch extending across the body half way between the vent and extremity of tail, with a couple of smaller spots in front and one behind this patch. In the stage of Plate XIII. fig. 3, the opening of the mouth is still inferior, the pectorals have greatly increased in size since the preceding stage, the body has much lengthened, the vent is placed about half way between the anterior and posterior extremity, and the embryonic fin folds are comparatively much narrower. In a stage but slightly older (Plate XIII. fig. 4) the chromatophores are larger and more prominent, the pectorals have increased in size, the head has increased in length, the mouth is more anterior, the yolk bag has become much reduced, and the heart and alimentary canal have greatly increased in size. In the next stage (Plate XIII. fig. 5), the fourth day after hatching, the young Fish measures about 4^{mm} in length, and has greatly changed from the preceding day. The opening of the mouth is anterior, the branchial rays have been formed, the heart is divided into chambers, the stomach proper has greatly increased in size, and the intestine is better specialised than in the younger stages. The muscular bands appear well defined above and below the notochord, embryonic caudal rays are quite distinct, the permanent pectoral rays are blocked out, and the pigment cells are reduced to the three large patches described in the previous stage and a few smaller cells round the eyes and on the head. A small but prominent pigment spot has made its appearance near the end of the notochord on the lower side of the body. The stages intermediate between Plate XIII. fig. 1, and Plate XIV. fig. 1, were not traced. In Plate XIV. fig. 1, the caudal is well developed, showing but a slight trace of its ganoid lobe. The head is much larger, the body comparatively stouter, the mouth anterior, the branchiæ well developed, and important changes have taken place in the size of the stomach. In the next stage (Plate XIV. fig. 2), measuring 6^{mm} in length, the snout has become more pointed, and the body is quite broad and comparatively much flattened.

The spinal apophyses, of which a few could be seen in the preceding stage, are large and well developed, the dorsal and ventral muscular bands have become most prominent, there is a trace of the origin of the ventrals, the anal and dorsals are separated from the caudal embryonic lobe by a deep narrow slit, and in both these fins, as well as the caudal, the permanent rays have begun to be formed, being most advanced in the caudal fins. There are two gigantic black chromatophores extending over the dorsal part of the stomach, three prominent chromatophores of the same color in the posterior flanks of the body immediately in the line of separation of the dorsal and anal from the caudal lobe, and the remnant of a small black pigment patch at the base of the caudal rays. On the top of the cerebrum there is a patch of black pigment, and also on the anterior part of the dorsal line near the base of the brain. The general color of the young fish at this stage is yellowish, with brilliant yellow patches surrounding the dark patches of black chromatophores; the eye is of a dull blue color, with a black band above the pupil. In the next stage (Plate XIV. fig. 3), measuring 6.5^{mm} in length, the caudal fin has lost its ganoid lobe and has become symmetrical; the cleft separating the dorsal and anal from the caudal lobe has completely isolated them from the caudal; the snout has lengthened somewhat, the pectorals and ventrals have become larger. The principal difference in the appearance of these two stages consists in the great development of closely packed chromatophores, which cover uniformly the whole body and the posterior part of the head. The fins alone are as yet free from them; but at the base of the dorsal and anal there is a prominent continuous line of black pigment cells, and a few small inconspicuous chromatophores at the base of the caudal rays. The next stage (Plate XIV. fig. 4), but slightly older than Plate XIV. fig. 3, measuring 7^{mm} in length, differs from it mainly in the absence of the coating of chromatophores. There are, as appears from this stage (Plate XIV. fig. 4), from that of Plate XIV. fig. 3, and from the subsequent stage figured, three sets of coloring characterized by the extremes here figured. One as in the stage of Plate XIV. fig. 3, with densely packed dendritic chromatophores; the other, fig. 4, with only a few prominent patches of large chromatophores, and the intermediate stage (Plate XIV. fig. 5), measuring 11^{mm} in length, in which we have the large prominent patches (Plate XIV. fig. 5), with the band of continuous pigment cells along the base of the dorsal and anal, and the body uniformly covered with comparatively small pigment spots. This will probably account for the great differences already noticed in the youngest stages (Plate XIII. figs. 4, 5, 6, and Plate XIII. 1, 2, 3) in the presence or absence and distribution of the dendritic chromatophores. We might naturally expect such a difference from the innumerable variations in coloring noticed in the adult Ctenolabrus. During a single season at Nahant, the late Professor Agassiz had no less than sixty colored sketches made of specimens of this species, measuring from three to four inches in length, illustrating differences in the coloring or markings. In younger stages, when the young Ctenolabrus measures not more than 15^{mm} in length, I have found fully as great a variety in the types of coloration as among the adult; the principal types of coloring varying from a perfectly uniform light green tint to a mottled and banded pattern, which recalls far more Julis than the usual pattern of design and coloring found in our Ctenolabrus. The next stage figured (Plate XV. fig. 1) is but slightly more advanced than Plate XIV. fig. 5; it belongs to the light-colored type. The principal differences to be noticed are the nearly complete disappearance of the caudal embryonic fold and the formation of a rudimentary anterior spiny part of the dorsal. In a young Ctenolabrus (Plate XV. fig. 2) measuring 11^{mm} in length, this anterior part of the dorsal is somewhat more developed; the urostyle is much smaller. This specimen belonged to a type of coloring of which the adult has patches of darker color along the dorsal and ventral lines, these patches also extending over the anal and dorsal fins. The darker chromatophores are black, those of the dorsal fin and along the dorsal are of a light-brown color, and the whole upper part of the body and head is colored a brilliant yellow. In a young Ctenolabrus measuring 15^{mm} in length the anterior part of the dorsal has greatly increased in height, the posterior ends of the dorsal and anal have become rounded, and there is no trace of the rudimentary caudal embryonic fin. Young specimens of the same length were either uniformly covered by closely packed brownish or black chromatophores on a reddish-brown or greenish background, or else the darker chromatophores were arranged in bands, slanting from the median line towards the tail, with irregular patches at the base of the dorsal fin and along the dorsal side, or else they were of the pattern figured here (Plate XV. fig. 3) upon a light yellowish background.

In a somewhat more advanced stage (Plate XV. fig. 4) of about the same length as Plate XV. fig. 3, the body and head of the young Ctenolabrus have become quite compact, the fins resemble in outline those of the adult, and the young Ctenolabrus has practically assumed the principal characteristic features of the older and larger fish. Fishes in the stages of Plate XV. figs. 2–4, are still pelagic, though many of them can be caught in the eel-grass or kelp along with the older fishes.

The young Ctenolabrus at a very early age assume the peculiar slanting of the body which the older fish take specially when feeding or when coming up to examine any object.

Motella argentea, *Rhein.*

(Plate VII. Plate VIII. figs. 1–3.)

The youngest specimen of this species I have seen (Plate VII. fig. 1) measured 4^{mm} in length. It was remarkable for the comparatively strong coloring for so young a stage. The head dorsal and ventral muscular lines, as well as the sides of the stomach, are of a dark dirty yellow. The pectorals are large and transparent, but the ventrals, already well developed, are of a dark maroon color. The lower part of the eye is light blue, the pupil of a dark crimson. About half way between the tail and pectorals there are two large pigment cells, one in the dorsal, the other in the ventral side of the notochord. A smaller cell indicates the position where the embryonic caudal fin rays are forming.

There are three pigment cells on the brain, the largest in front, two smaller ones at the extremity of the snout, one on the lower and one on the upper jaw, with a still smaller cell at the base of the operculum. Four to five larger cells form a black edge to the upper side of the stomach. In a somewhat older stage (Plate VII. fig. 2) the principal differences consist in the greater size of the pectorals, the larger ventrals, the increase in size of the chromatophores on the head and stomach, and the greater elongation of the snout. Seen from above (Plate VII. fig. 3) the ventrals appear like wings proportionally as large as the pectorals of the young Flying-Fish. In a young fish measuring 7^{mm} in length (Plate VII. fig. 4) the pectorals have increased but little in size since the preceding stage. The ventrals are nearly one third the length of the fish. The head, quite rounded above, is proportionally larger, and the body much wider and less elongate than in the younger stages (Plate VII. figs. 1–3).

The chromatophores are more numerous in the upper part of the head and on the upper part of the stomach, while the single cell of the dorsal region half way to the tail has increased to a large patch of chromatophores, and forms in this stage the largest accumulation of pigment cells. The permanent rays of the caudal fin are well advanced, and at the base of each is placed a minute pigment spot. The permanent rays of the dorsal and anal are also commencing to form, but they are far less advanced than those of the caudal. The embryonic fin rays are still to be traced in that part of the fin fold which unites the caudal lobe with the dorsal and anal. The coloring of this stage is greener than in the preceding stages; the greenish tint is especially marked on the upper part of the head and near the dorsal patch of chromatophores. The ventrals are somewhat darker colored than the younger stages. In all the stages thus far figured the young fish swims mainly by means of the powerful stroke of the ventrals, which they spread like wings laterally to their fullest extent at right angles to the body. In a somewhat more advanced stage (Plate VII. fig. 5), measuring 12^{mm} in length, the body has increased greatly in length, the pectorals are longer, the ventrals are less than one-fourth the length of the body; the caudal has become terminal and rounded, and quite well separated from the dorsal and anal; the permanent fin rays are well developed in the three median fins; the head has become lengthened, and the pigment spots of the upper part of the head and anterior part of the body are smaller and more numerous than in the preceding stages.

The chromatophores along the dorsal line and base of the dorsal and anal are now arranged in longitudinal lines. The coloring of the body behind the anterior base of the dorsal, as well as the head, has assumed a yellowish-green tint slightly bluish towards the ventral side.

In a subsequent stage (Plate VII. fig. 6), but slightly older, the greenish color of the dorsal part of the fish has become more marked, and there exists a principal lateral line of black chromatophores extending from the operculum nearly to the posterior extremity of the dorsal; the extremity of the body near the caudal is still quite transparent, of a yellowish tint, showing the ganoid termination of the notochord. The ventrals in this stage are proportionally longer again than in Plate VII. fig. 5, being somewhat more than one quarter the length of the fish. Viewed from above, the young fish is often seen with ventrals spread at right angles, as in Plate VIII. fig. 1 *a*, or flapping them violently up and down when excited, or as in Plate VIII. fig. 1, when swimming rapidly. In a somewhat older stage (Plate VIII. fig. 2) the dorsal and anal fins are well separated from the caudal; the anterior dorsal has commenced to form; the ventrals have lost somewhat their wing-like character, they are usually carried folded, and appear more like long fin rays; the head has lengthened, is more rounded, sloping anteriorly; the pectorals are elongated, and the greenish blue color of the body is limited to the dorsal regions, the sides being silvery; a colored belt, slightly greenish, extends along the base of the anal. In the oldest pelagic specimen of young Motella (Plate VIII. fig. 3) the barbel of the lower jaw is well formed, the anterior dorsal is higher than the posterior dorsal, the ventrals are long fin rays equalling in length one third of the length of the young fish, the greenish blue color of the dorsal region is more intense than in the younger stages, and extends in slightly lighter-colored diagonal bands across the flanks; the posterior part of the dorsal, of the anal, and the base of the caudal are marked with small black pigment spots at the base of the permanent fin rays. In this stage and in the one immediately preceding (Plate VIII. fig. 2) the young fish make but little use of their ventrals while swimming. The extremity of the caudal is cut quite sharply at right angles to the longitudinal line, with slightly rounded corners. At this stage the resemblance to Bregmaceros is striking.*

Gadus morrhua, *Lin.*

(Plate VIII. figs. 4, 5.)

The only other Gadoid of which I have found the young by fishing on the surface is probably our common Cod; when only 28^{mm} in length it has in this early stage (Plate VIII. fig. 5) assumed all the characteristic features of the genus. The only other young stage I have seen is a young Cod measuring 20^{mm} in length (Plate VIII. fig. 4), which differed from fig. 2 in not having a barbel, and in having the median fins still connected, although the three dorsal and two anals were quite distinct. The pigment cells were not arranged to form any definite pattern, but covered uniformly the dorsal region. The breaking up of the continuous embryonic dorsal and anal into separate fins is admirably seen in the stage represented in Plate VIII. fig. 4.

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* Emery in his monograph of Fierasfer has also figured the pectorals of the young Merlucius and Motella. There is still some uncertainty with regard to the genus to which the specimens I have here referred to Motella belong; they may prove to be one of the species of Onus described by Collet.

Fundulus nigrofasciatus, *C. & V.*

(Plates XIX. XX.)

Sundevall has already given the principal changes of form which Cyprinus undergoes while passing from its leptocardial stage to that of the adult. I have traced the principal changes of growth in one of our species of Fundulus, and find they agree fairly with the stages figured by Sundevall. That in the youngest stages the crossopterygian nature of the pectorals is owing to their large size is perhaps as striking as in any other embryo of osseous fish known to me. (See Plate XIX. figs. 5, 6, in which are given a view of the pectorals, fig. 6, from above; partly in profile, fig. 5; and a side view of a large pectoral (fig. 4), in which the fleshy base and the embryonic rays of the fin are best developed just previous to the appearance of the first trace of the permanent fin rays.) The gradual change of the pigment cells from a linear arrangement to the characteristic pattern of the adult is readily traced in the oldest specimens figured on Plate XX.

Osmerus mordax, *Gill.*

(Plate XII.)

The egg is pelagic, quite transparent; the young on hatching are about 5^{mm} in length (Plate XII. figs. 1, 2), with a comparatively small yolk bag, very rudimentary head, huge eyes, the vent placed at about three quarters of the length of the body near the posterior extremity, pectorals quite rudimentary. There are no pigment cells in this stage in any of the young I have collected. In the next stage figured (Plate XII. fig. 3) the young fish has greatly changed, the head is quite elongate, branchiæ are present, the lower jaw projecting beyond the upper one, pectorals large, eye brilliant emerald green, the yolk bag has completely disappeared, the caudal embryonic fin rays are very marked; we can also see the first trace of the separation between the caudal, anal, and dorsal. A prominent row of large pigment cells extends along the base of the anterior anal embryonic fin fold, with a smaller line extending along the upper side of the intestines, a few small pigment cells at the extremity of the notochord, along the base of the posterior anal and of the operculum, with two or three pigment cells along the dorsal line about half way from the head to the tail.

In the next stage figured the young Osmerus is considerably older, measuring already 22^{mm} in length; the caudal is completely separated from the dorsal and anal, in both of which the permanent fin rays already exist; there are rudimentary ventrals present in this stage. The general coloring of the body is a light dirty yellow, with patches of more brilliant yellow along the lateral line and base of the head. There is one line of greyish pigment spots along the dorsal side of the notochord, a very prominent line of large pigment cells running somewhat below the notochord, extending from the base of the pectorals to the vent, with four or five large pigment cells along the base of the anal and the ventral line towards the base of the caudal. Small pigment spots extend along the base of the caudal fin rays, with three or four larger spots at the base of the caudal fin. The oldest stage I have found (Plate XII. fig. 5) was not larger than Plate XII. fig. 4, but the caudal, anal, and dorsal were in a more advanced condition, the permanent fin rays better marked, the head less elongate, the body behind the ventrals comparatively broader. The great resemblance of this stage of Osmerus to Scomberesox and Belone in the general arrangement of the median fins and the great elongation of the body is striking. Mr. H. J. Rice has, in the Report of the Commissioner of Fisheries of Maryland for 1877 (Plates III. V.), given excellent figures of several young stages of the Smelt. The figures here given complement the stages already known, and with those of Mr. Rice give a fair sketch of the principal changes of the Smelt due to growth. The resemblance of the development of Osmerus to that of the Herring as given by Sundevall is very striking. Sundevall figures young fishes, which he calls embryo Herring, from 8 to 38^{mm} in length, but he does not state whether they were actually raised from eggs of known origin. Before the publication of Mr. Rice's paper I had already supposed the young fishes figured on Plate XII. to be the young of some Clupeoid, but the figures given by him seem to leave no doubt that the young I figure on Plate XII. belong to the Smelt.

EXPLANATION OF THE PLATES.

PLATE I.

LABRAX LINEATUS, *Bl. & Sch.* (ROCCUS, *Gill.*)

Fig. 1. Young Labrax measuring 3.5^{mm} in length.
" 2. Slightly older than fig. 1, measuring 4^{mm} in length.
" 3. Still more advanced, measuring nearly 5^{mm} in length.
" 3*a*. Tail of young Labrax somewhat older than stage of fig. 3, with a dorsal line of pigment spots.
" 4. Young Labrax in which caudal is forming, 8^{mm} in length.
" 5. Somewhat more advanced than fig. 4.

PLATE II.

Fig. 1. Young COTTUS GRŒNLANDICUS, somewhat older than stage of Plate III. fig. 5, measuring 8^{mm} in length.
" 2. Profile view of young Cottus measuring 11.5^{mm} in length.
" 3. Young Labrax 16^{mm} in length.
" 4. Young Labrax 26^{mm} in length.
" 5. Young Blue Fish (TEMNODON SALTATOR) measuring 9^{mm} in length.

PLATE III.

COTTUS GRŒNLANDICUS, *C. & V.*

Fig. 1. Egg of Cottus found floating on the surface.
" 1*a*. First trace of pectorals of young Cottus still within the egg.
" 1*b*. Somewhat older stage of lateral fold.
" 1*c*. Still older stage than fig. 1 *b*, still within the egg.
" 2. Young Cottus just hatched, measuring 2.5^{mm} in length.
" 3. Slightly older specimen, third day after hatching, seen from above.
" 4. Young Cottus, somewhat older than preceding stage, measuring 3^{mm} in length.
" 5. Young Cottus eleventh day after hatching.

PLATE IV.

CYCLOPTERUS LUMPUS, *Lin.*

Fig. 1. Young Lumpus, seen in profile, measuring 4^{mm} in length.
" 2. Same seen from above.
" 3. Young Lumpus, somewhat older than preceding stage, seen in profile.
" 4. Profile view of young Lumpus measuring 5^{mm} in length.
" 5. Profile of young Lumpus measuring 10^{mm} in length.

PLATE V.

CYCLOPTERUS LUMPUS, *Lin.*

Fig. 1. Young Lumpus 20^{mm} in length.
" 2. The same as fig. 1, seen from above.
" 3. Profile of young Lumpus still older, measuring 34^{mm} in length.
" 3*a*. Spiny protuberances along anterior dorsal line of anterior dorsal.
" 3*b*. Largest spiny protuberances of lateral line.
" 3*c*. Pectorals and ventrals seen from the abdominal side.
" 4. Same as fig. 3, seen from above.

PLATE VI.

PORONOTUS TRIACANTHUS, *Gill.*

Fig. 1. Young Butterfish 7^{mm} in length.
" 2. Somewhat older stage than fig. 1.
" 3. Older stage than fig. 2; 9^{mm} in length.
" 4. Slightly more advanced than fig. 3; 10^{mm} in length.
" 5. Young Butterfish having principal characters of the adult, 16^{mm} in length.

PLATE VII.

MOTELLA ARGENTEA, *Rhein.*

Fig. 1. Young, measuring 4 in length.
" 2. Somewhat older than fig. 1, 5^{mm} in length, seen in profile.
" 3. Same as fig. 2, seen from below to show rays of ventrals.
" 4. Young, measuring 7.5^{mm} in length.
" 5. Young, measuring 12^{mm} in length.
" 6. Slightly older than fig. 5, measuring 14.5^{mm} in length, seen in profile.

PLATE VIII.

MOTELLA ARGENTEA, *Rhein.*

Fig. 1. View from above of same embryo as Plate VII. fig. 6.
" 1*a*. Same as fig. 1, seen from above, with its ventrals fully expanded and spread out.
" 2. Young Motella with small anterior dorsal, measuring 15^{mm} in length.
" 3. Considerably older than fig. 2, measuring 34^{mm} in length.
" 4. Young Gadus measuring 25^{mm} in length.
" 5. Young Cod measuring 28^{mm} in length.

PLATE IX.

GASTEROSTEUS ACULEATUS, *Lin.*

Fig. 1. Young Gasterosteus with prominent ganoid tail fin measuring 7^{mm} in length.
" 2. Older stage, 12^{mm} in length, in which the embryonic fin lobe has disappeared, the tail fin has become symmetrical, and the permanent rays of the dorsal and anal are well developed.

Fig. 3. Slightly older than preceding stage. Rudiments of anterior dorsal spines and of ventrals have made their appearance, 15^{mm} in length.

" 4. In this stage the rudimentary anterior dorsal spines, as well as ventrals, have increased somewhat in length, the dorsal and anal are both higher, and the chromatophores of the body are arranged in bands somewhat as in the adult, 22^{mm} in length.

" 5. Young Gasterosteus, in which the principal characteristics of the adult are fairly developed, 27^{mm} in length.

" *5a.* Anterior spine of ventral of young Gasterosteus, somewhat older than preceding stage.

PLATE X.

Atherinichthys notata, *Günth.* (Chirostoma, *Gill*).

Fig. 1. Young Atherina measuring 5^{mm} in length.

" 2. Somewhat older stage, measuring 6.5^{mm} in length, seen from above.

" 3. About in stage of fig. 2, seen in profile.

" 4. Older than preceding stage, 9^{mm} in length.

PLATE XI.

Atherinichthys notata, *Günth.*

Fig. 1. Somewhat more advanced than preceding stage (Plate X. fig. 4) $10,5^{mm}$ in length.

" 2. Young Atherina measuring 16^{mm} in length.

" 3. Young Atherina, having the principal characters of the adult, of about the same length as fig. 2.

PLATE XII.

Osmerus mordax, *Gill.*

Fig. 1. Young Osmerus just hatched, measuring 5^{mm} in length, seen in profile.

" 2. Same seen from above.

" 3. Young Osmerus measuring 9^{mm} in length.

" 4. Considerably older than fig. 3; 22^{mm} in length.

" 5. Oldest Osmerus found swimming on the surface, measuring 22^{mm} in length.

PLATE XIII.

Ctenolabrus cœruleus, *Dek.*

Fig. 1. Young just hatched from the egg, 2^{mm} in length.

" 2. Young, on the second day after hatching, 3^{mm} in length.

" 3. Young on the third day after hatching.

" 4. Young on the third day after hatching, somewhat older.

" 5. Young hatched four days, about 4^{mm} in length, seen in profile.

" 6. Young same as fig. 5, seen from above.

PLATE XIV.

CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young 5^{mm} in length, fished up at the surface. Caudal fin forming.
" 2. Young 6^{mm} in length, anal and dorsal fins separated from the caudal, ventrals commencing to form.
" 3. Young 6.5^{m} in length, somewhat more advanced than fig. 2.
" 4. Young measuring 7^{mm} in length, the dorsal and ventrals somewhat better separated from the caudal fin than in the preceding stage.
" 5. Young 10^{mm} in length.

PLATE XV.

CTENOLABRUS CŒRULEUS, *Dek.*

Fig. 1. Young somewhat more advanced than the stage of Plate XIV., fig. 5, of about the same length.
" 2. Young 11^{mm} in length.
" 3. Young 15^{mm} in length.
" 4. Young of same size as preceding figure, but somewhat more advanced.

PLATE XVI.

Fig. 1. Young BATRACHUS TAU, measuring 8^{mm} in length.

LOPHIUS PISCATORIUS, *Lin.*

Fig. 2. Three eggs embedded in the gelatinous membrane in which they are laid; magnified.
" 3. Young Lophius taken out of the egg just previous to hatching.
" 4. Young Lophius just after hatching.
" 5. Somewhat older stage; the yolk bag has entirely disappeared.

PLATE XVII.

LOPHIUS PISCATORIUS, *Lin.*

Fig. 1. Slightly older stage than fig. 5, Plate XVI.
" 2. Same as fig. 1, seen from above.
" 3. Older than fig. 1; the second ray of ventrals commences to form.
" 4. Anterior dorsal of slightly older stage, showing the beginning of the second ray.
" 5. Anterior dorsal rays of specimen somewhat older than fig. 4.
" 6. Older stage than fig. 5, with longer dorsal rays in anterior fin and rudiment of third; two large ventral rays.
" 7. Ventral rays of specimen somewhat older than fig. 3, about in the stage of fig. 5.

PLATE XVIII.

Lophius piscatorius, *Lin.*

Fig. 1. Young Lophius showing still greater increase in length and number of anterior dorsal and ventral rays.
" 2. Oldest pelagic stage, measuring 30^{mm} in length, seen in profile.
" 3. Same seen from above, slightly less magnified.

PLATE XIX.

Fundulus nigrofasciatus, *C. & V.*

Fig. 1. Young, measuring 7^{mm} in length.
" 2. Same seen from above.
" 3. Older than fig. 1; dendritic pigment cells more numerous in the upper part of the head; the nearly unbroken lines of chromatophores are broken up into separate cells; the permanent rays of the dorsal and anal fins make their appearance.
" 4. Crossopterygian stage of pectoral of young Fundulus about in stage of fig. 1, from the side.
" 5. Same fin seen from above, slightly bent laterally when in motion.
" 6. Same fin seen from above, at rest.

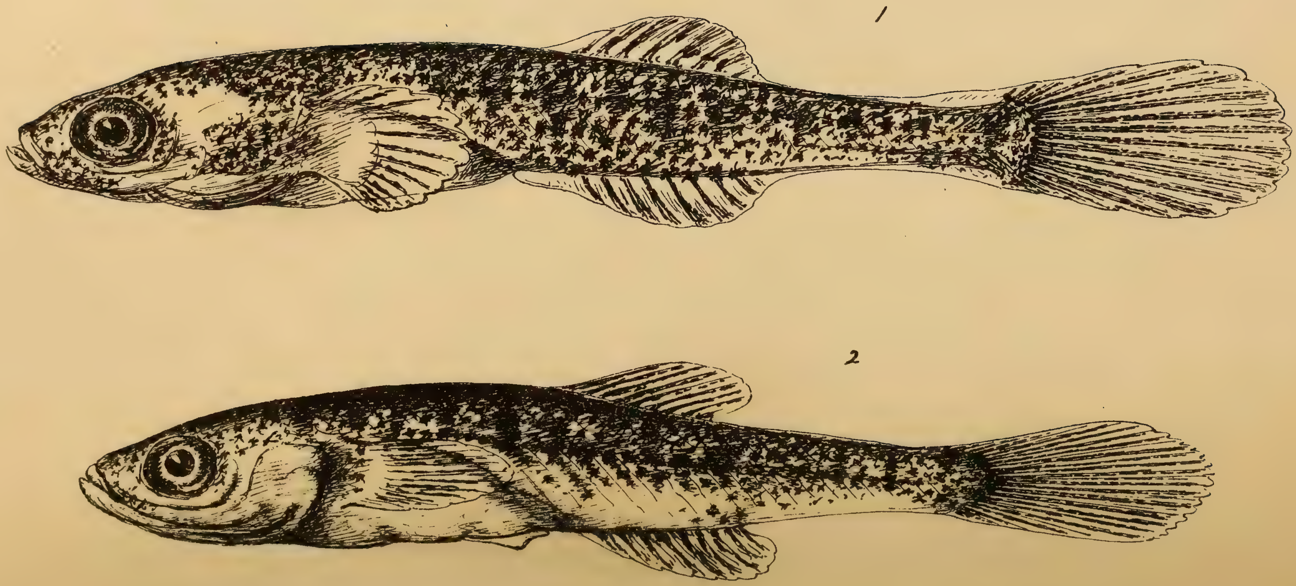
PLATE XX.

Fundulus nigrofasciatus, *C. & V.*

Fig. 1. Young measuring 11^{mm} in length and uniformly covered with dendritic chromatophores, dorsal and anal quite high, well separated from the caudal; first trace of ventrals.
" 2. Young measuring 16^{mm} in length, body more compact, ventrals quite distinct, anal and dorsal slightly lobed, caudal rounded, pectoral elongated, whole body covered uniformly by closely packed dendritic chromatophores.
" 3. Young measuring 20^{mm} in length; although the head is still comparatively larger than in fig. 4, yet the anterior part of fish has assumed the characteristic sloping outline of the adult. The scales are already well developed in this stage. The pigment cells are comparatively smaller than in younger stages, and very closely packed over the whole surface, especially on the dorsal side.
" 4. Same as fig. 3, seen from above.

Agassiz Young Osseous Fishes

Pl. XX



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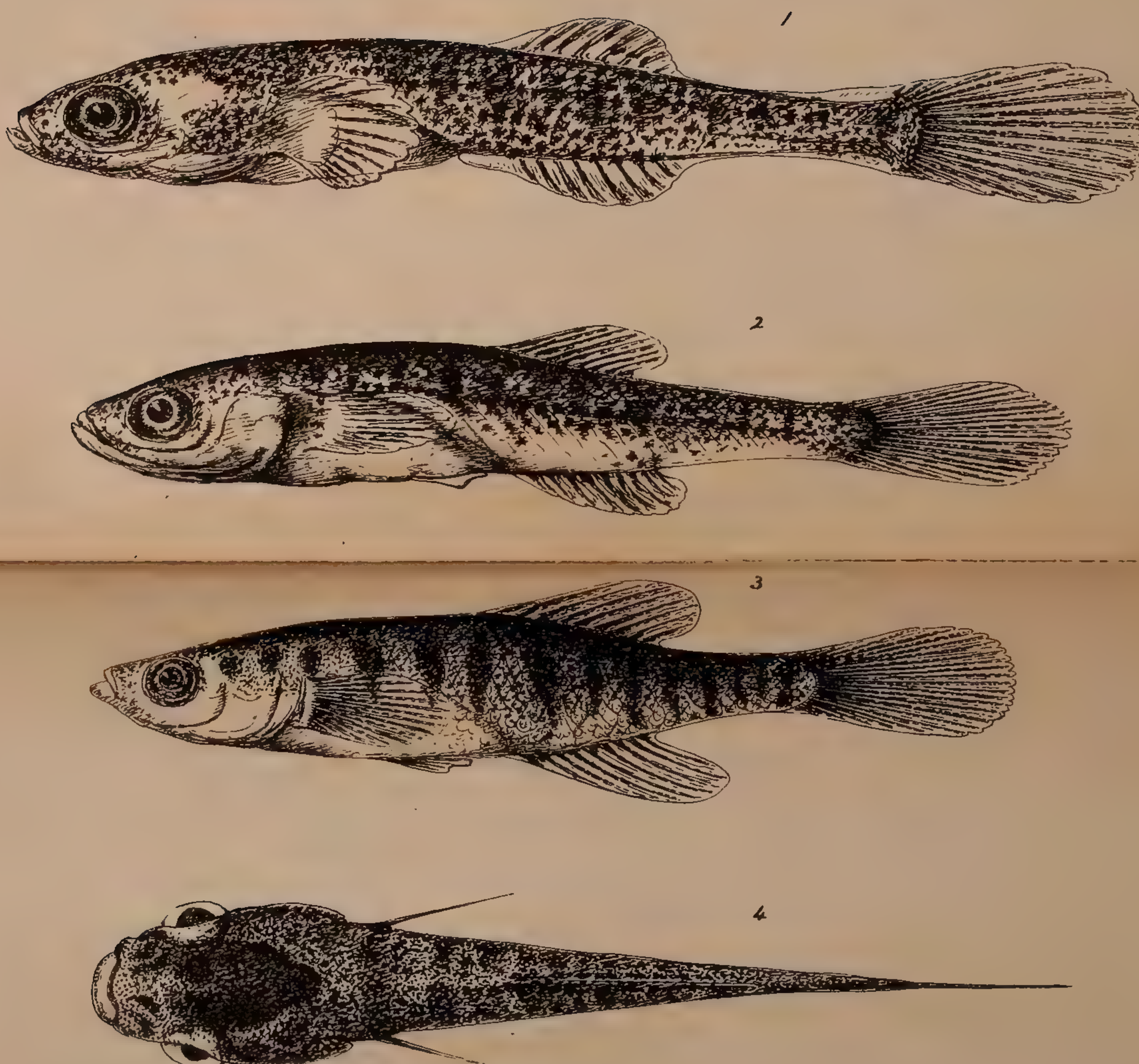
Agassiz Young Osseous Fishes

Pl. XX



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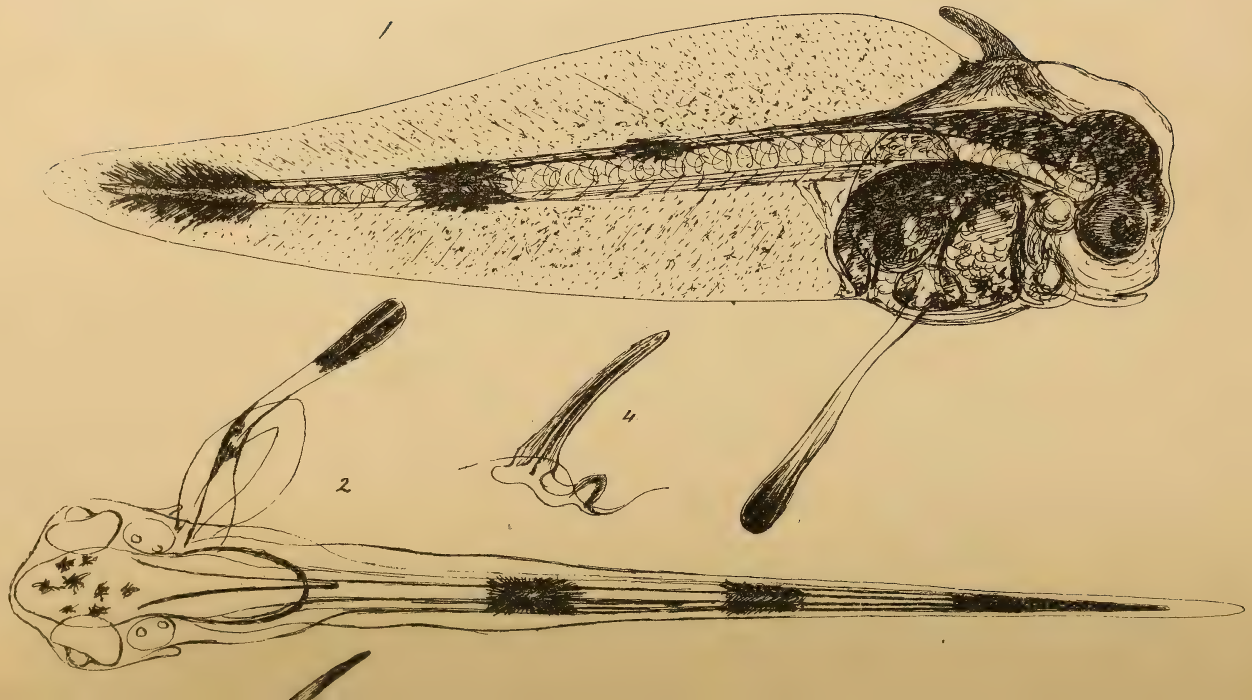
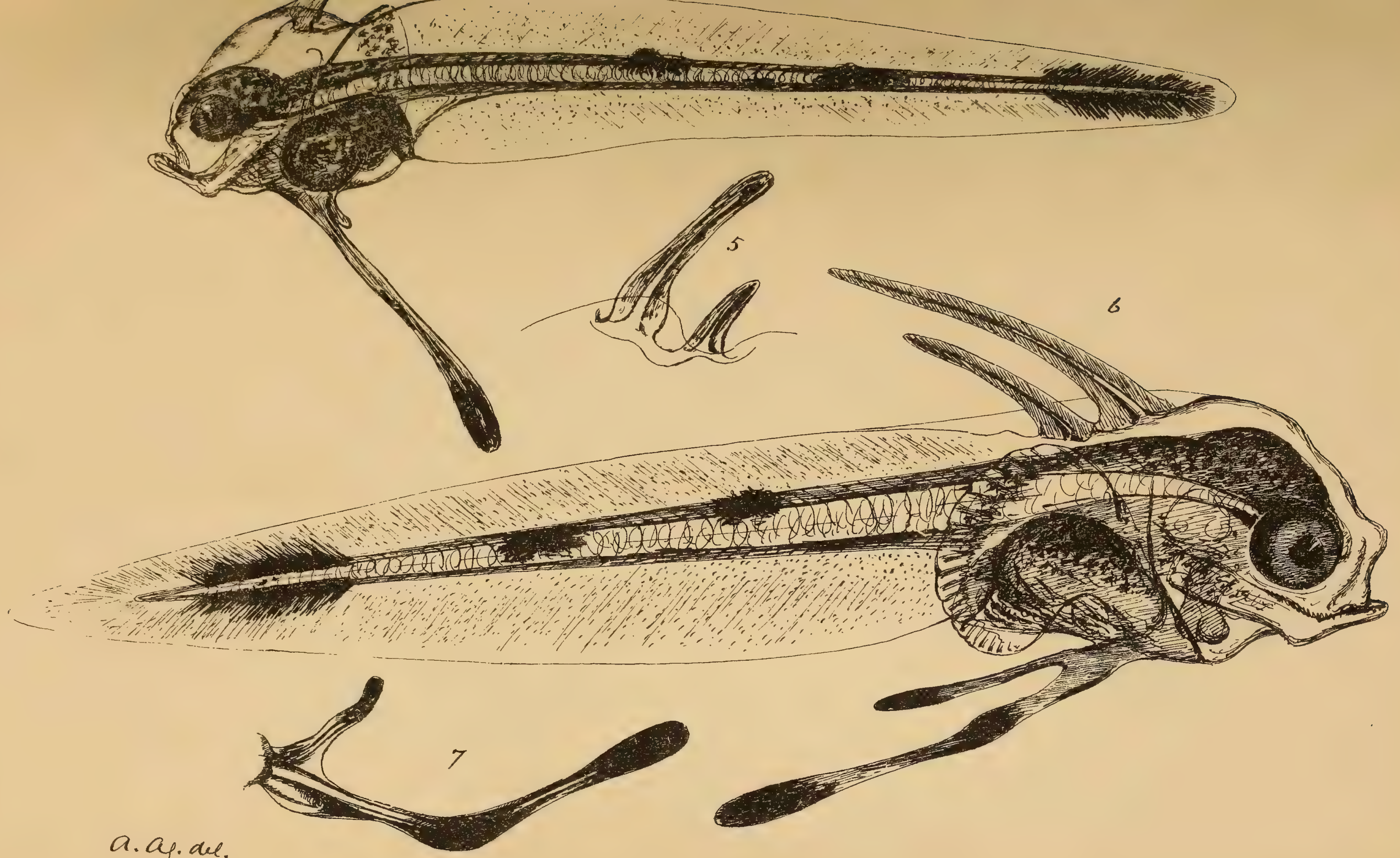
Pl. XVII

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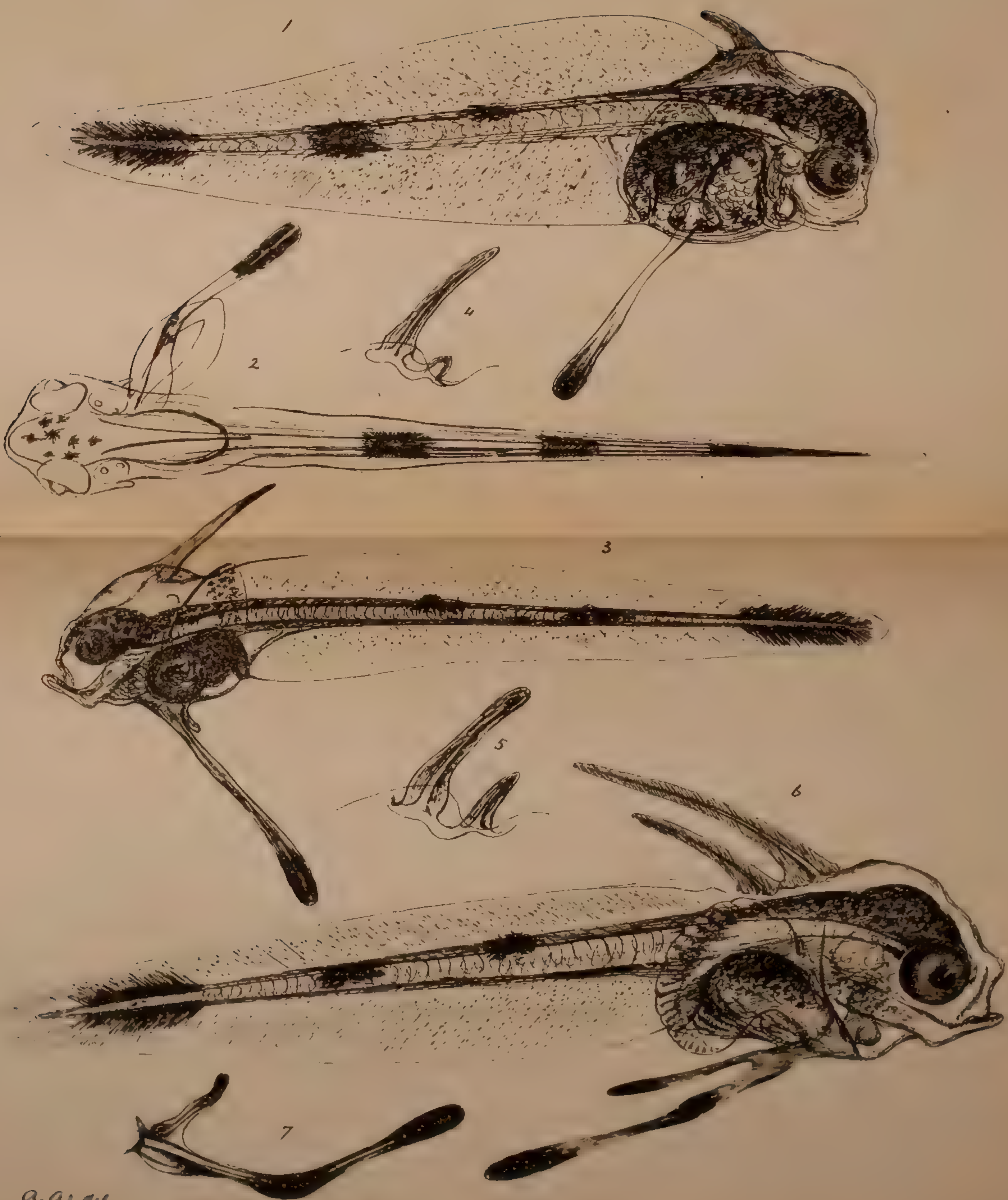

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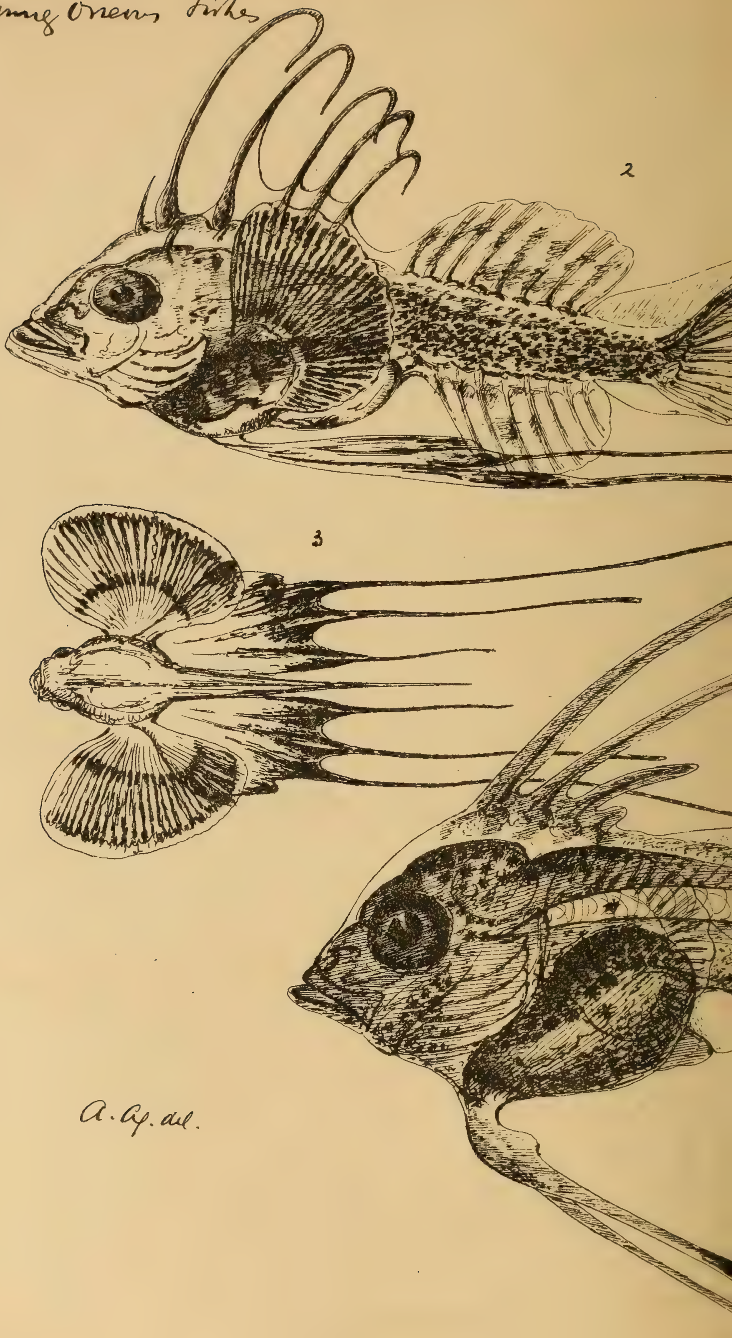

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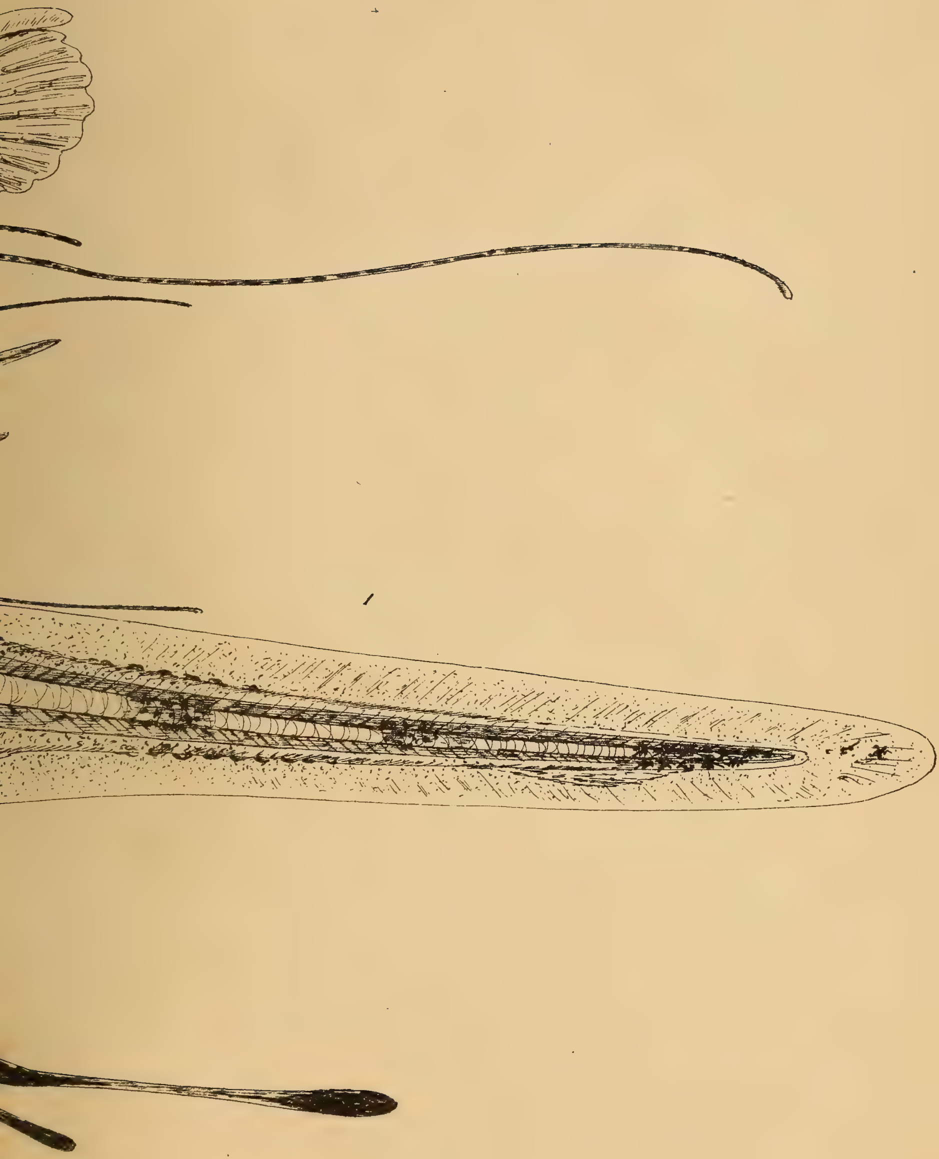
The Helioty

Pl. XVIII



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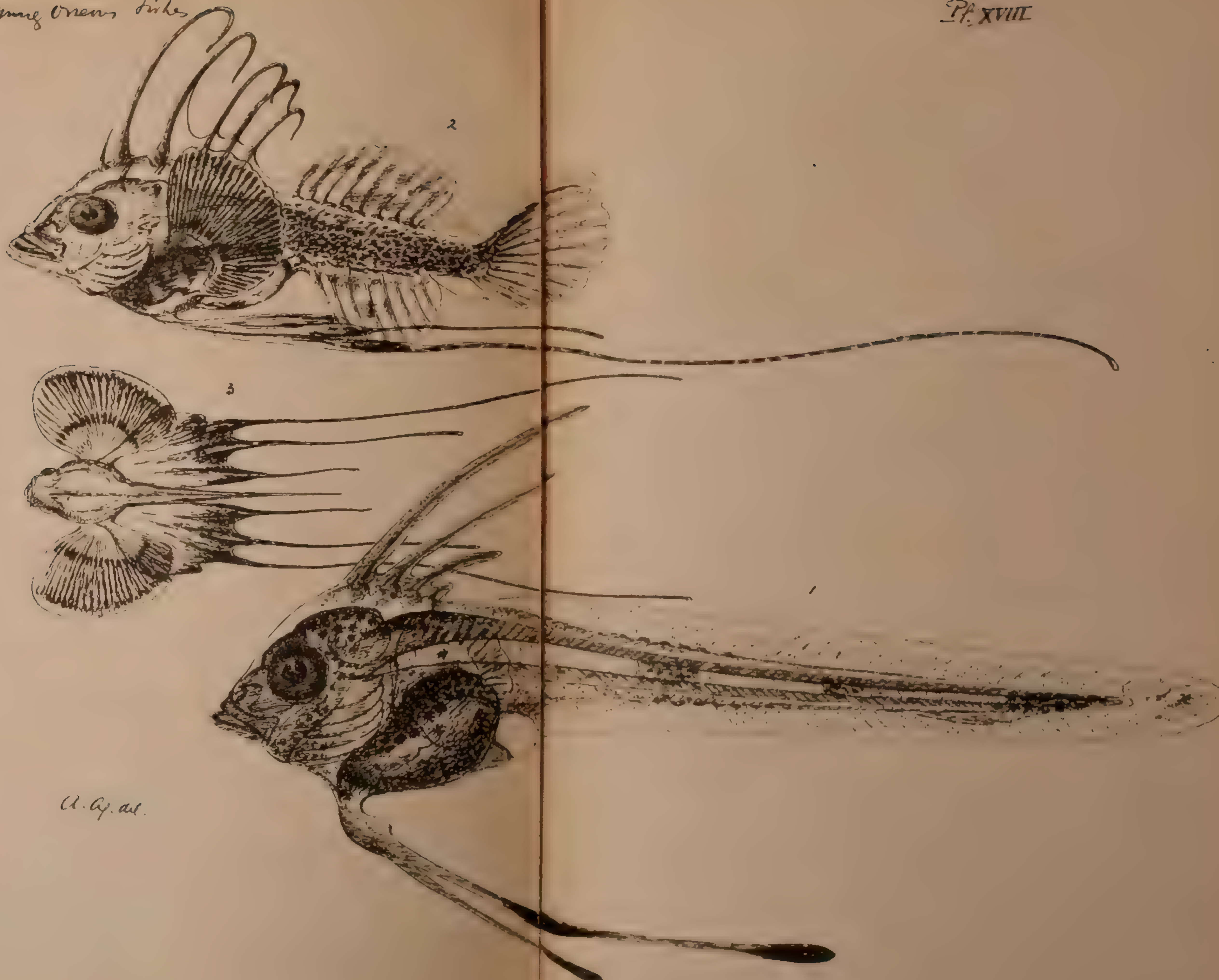
Pl. XVIII



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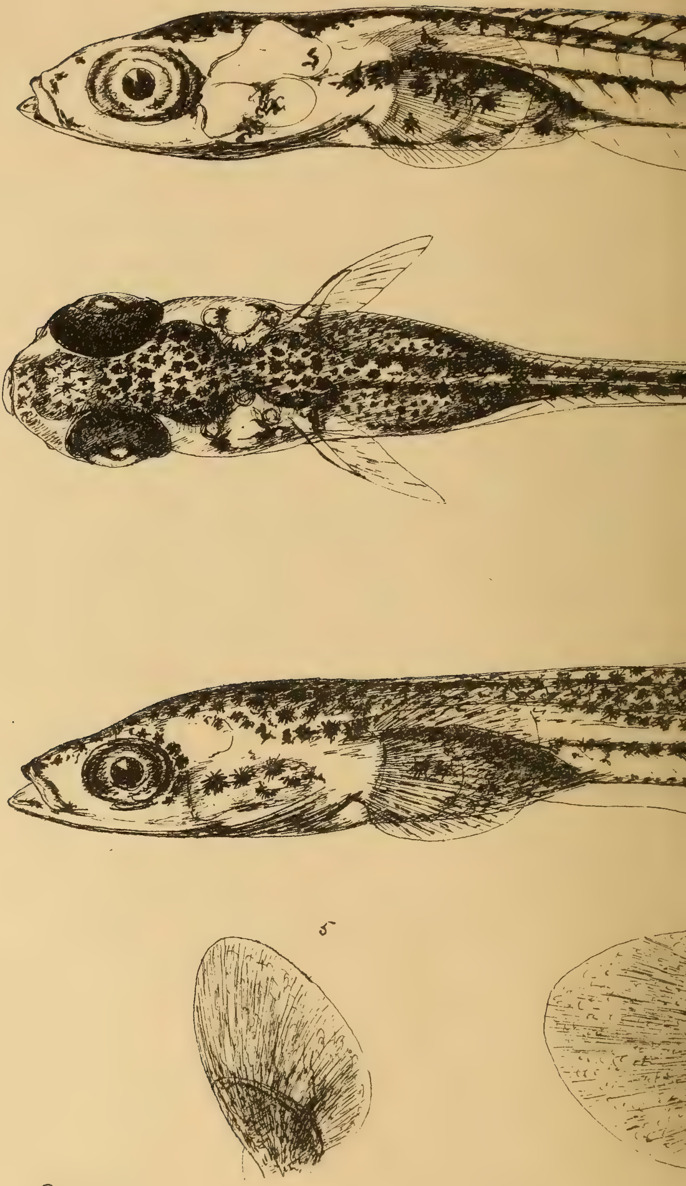

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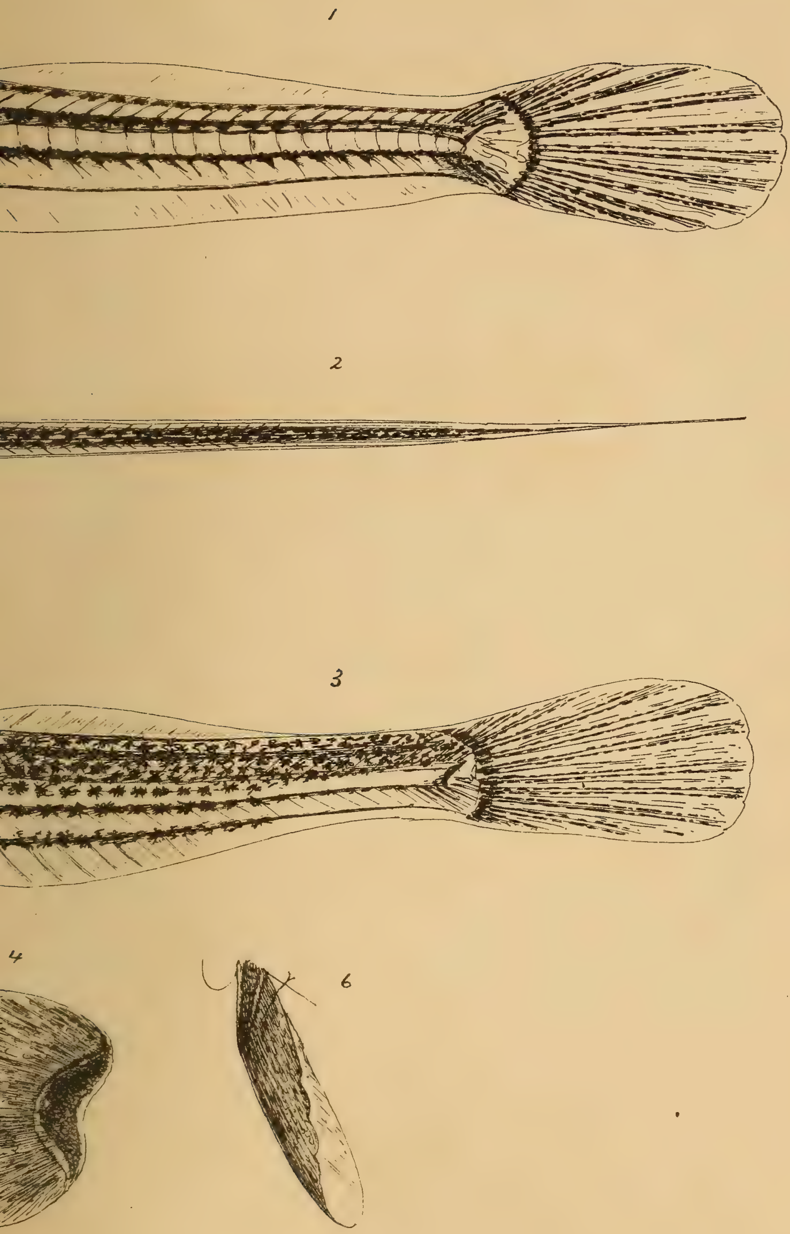
The Helio

Pl. XIX



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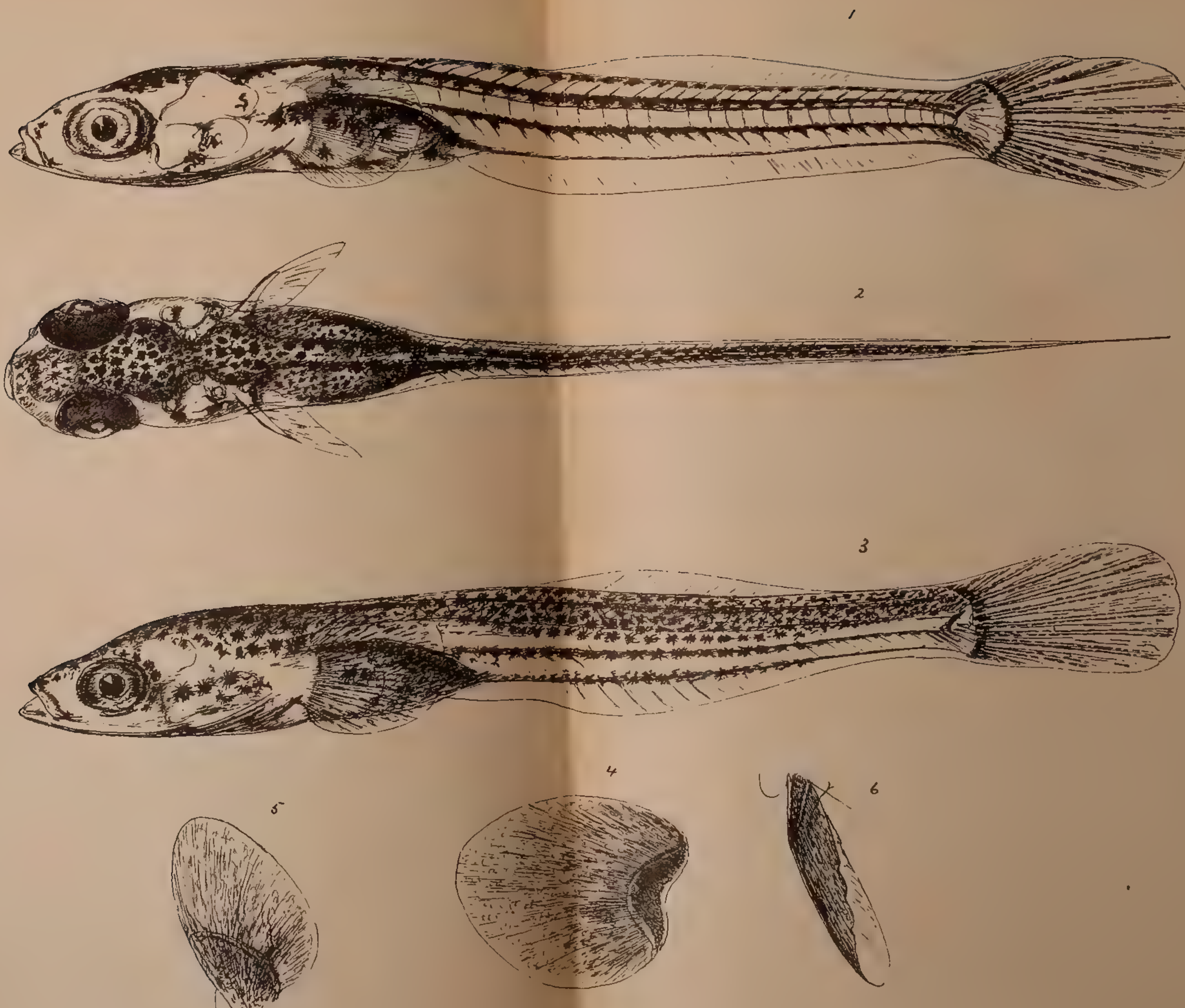
Pl. XIX



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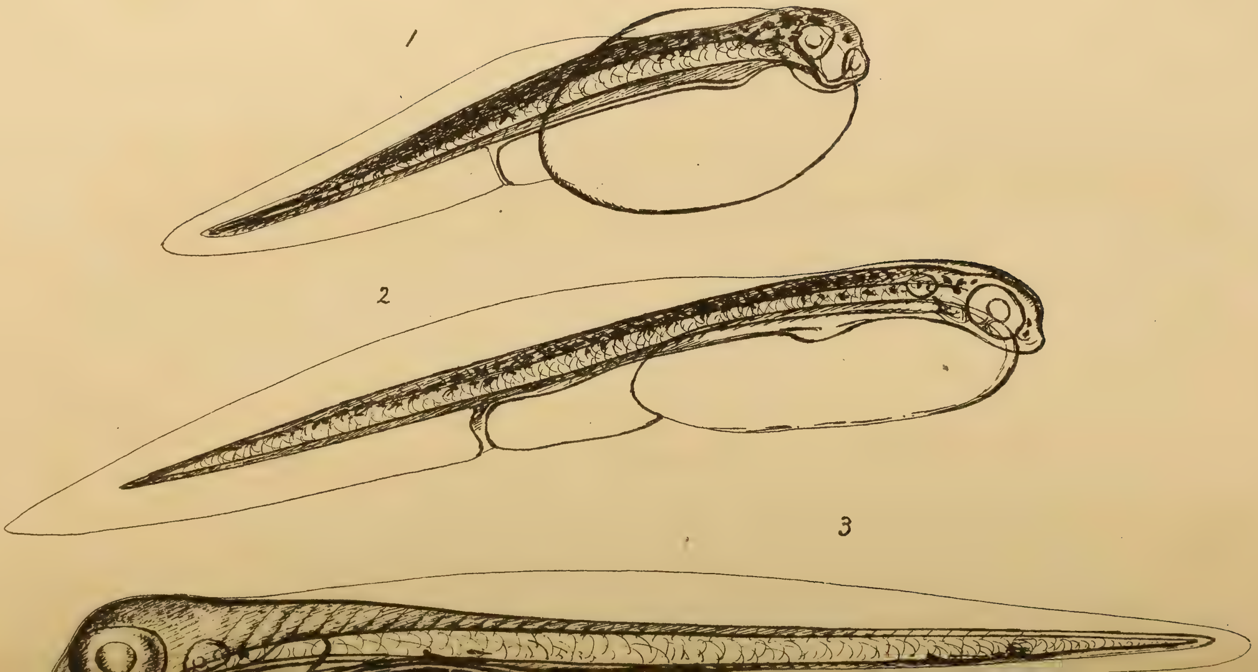
Pl. XIII



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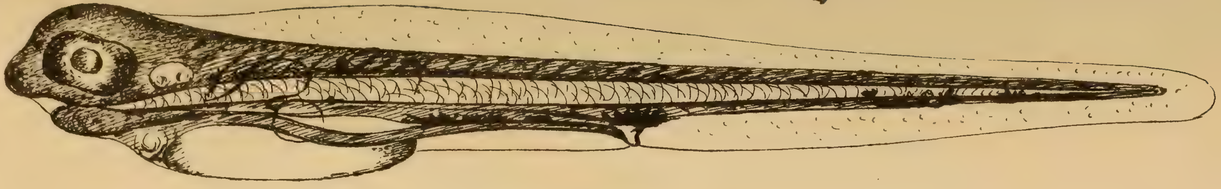

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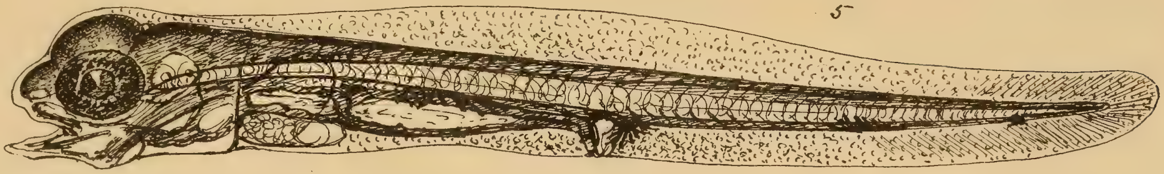

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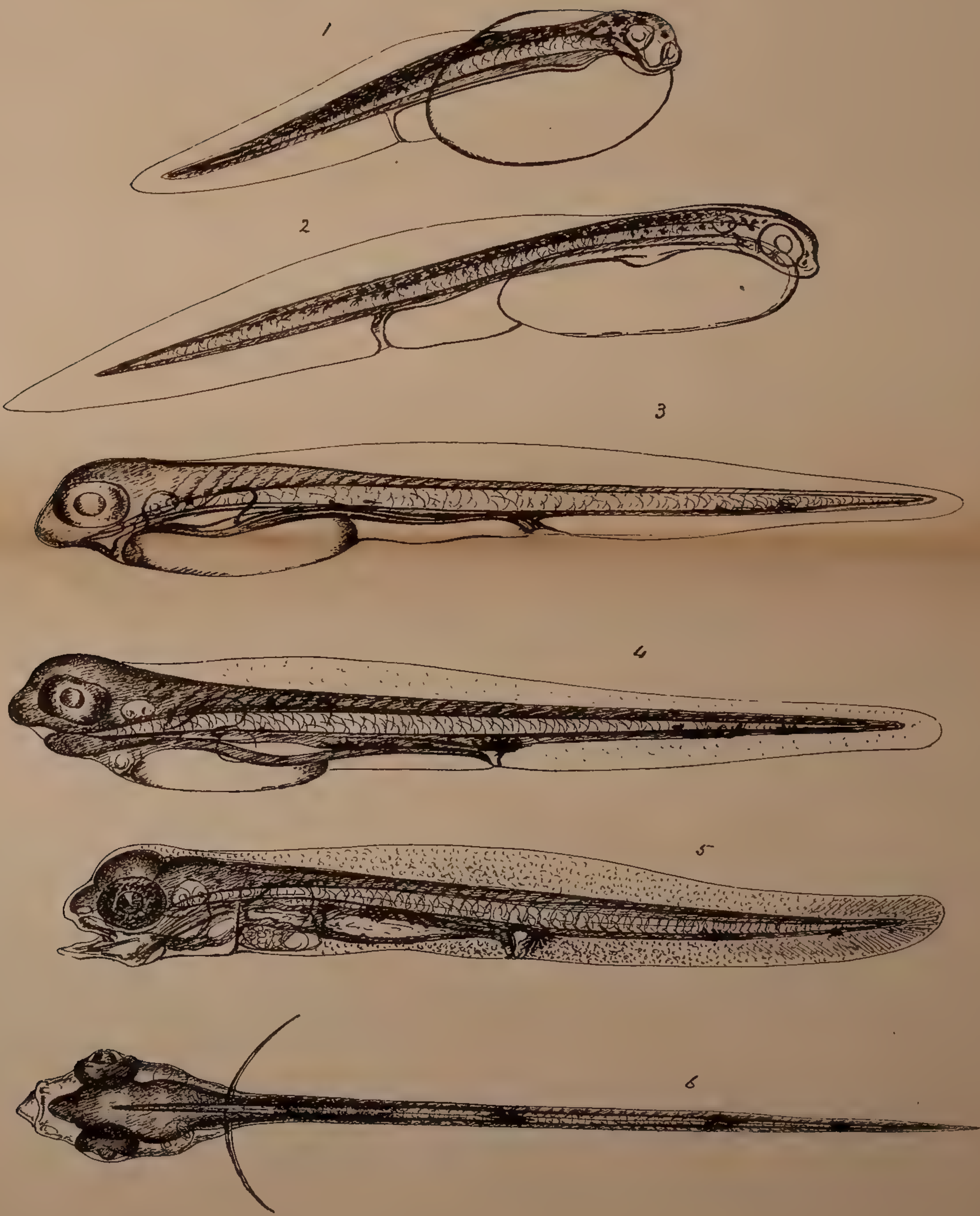

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Pl XIV

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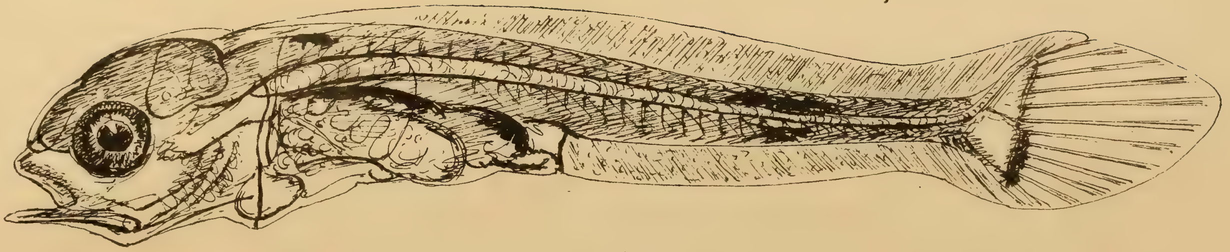

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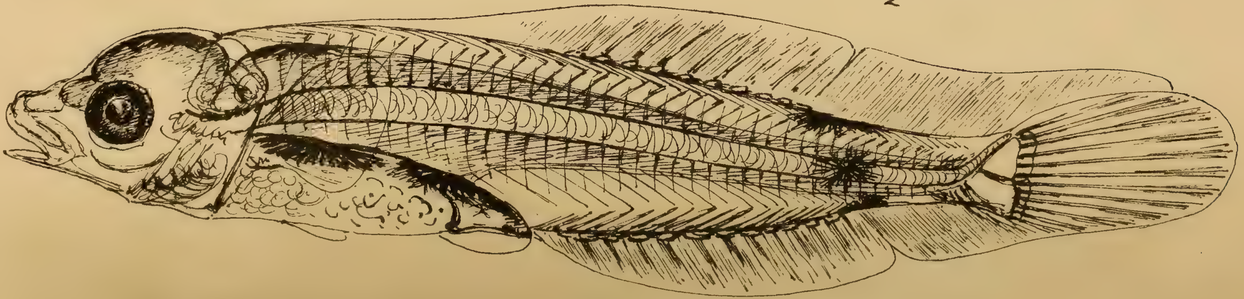

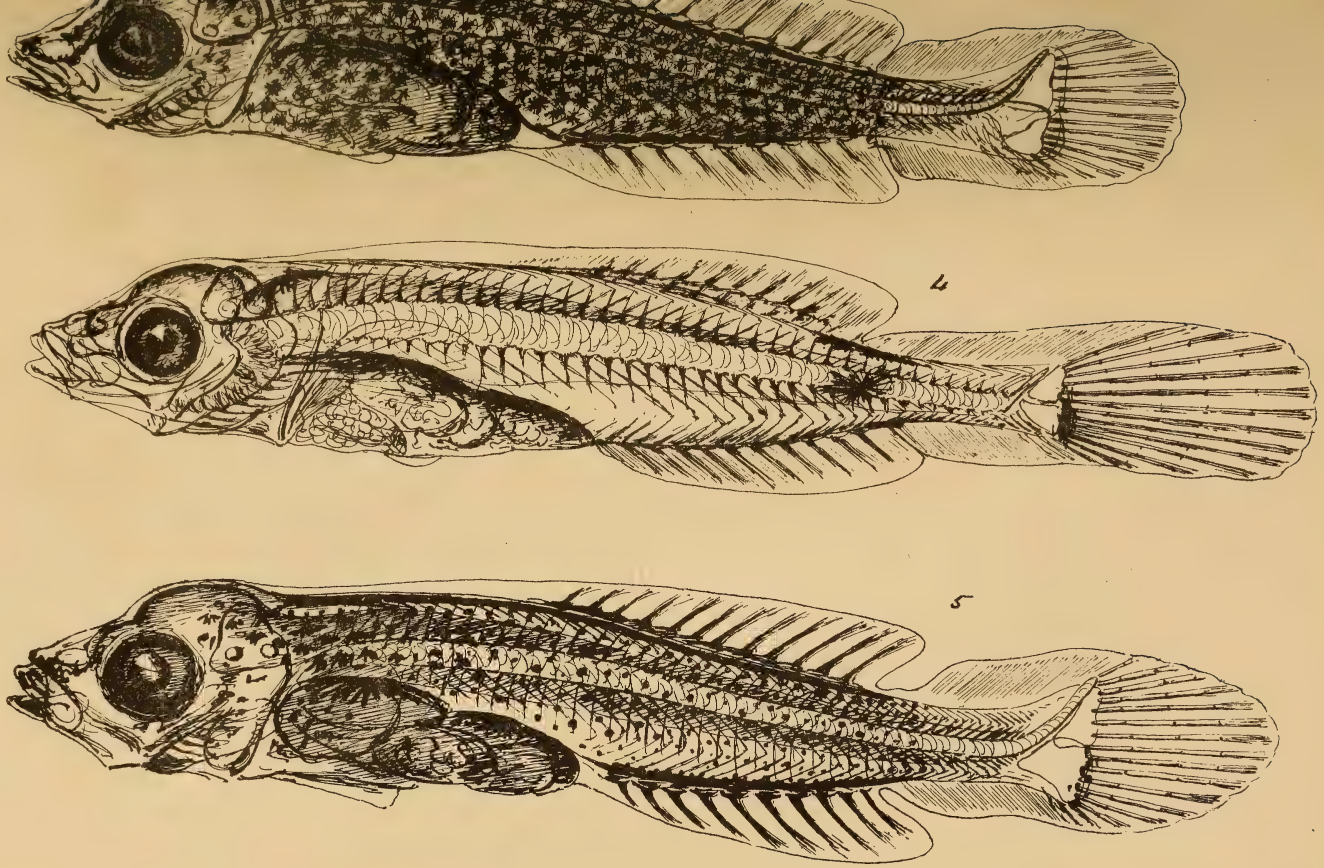

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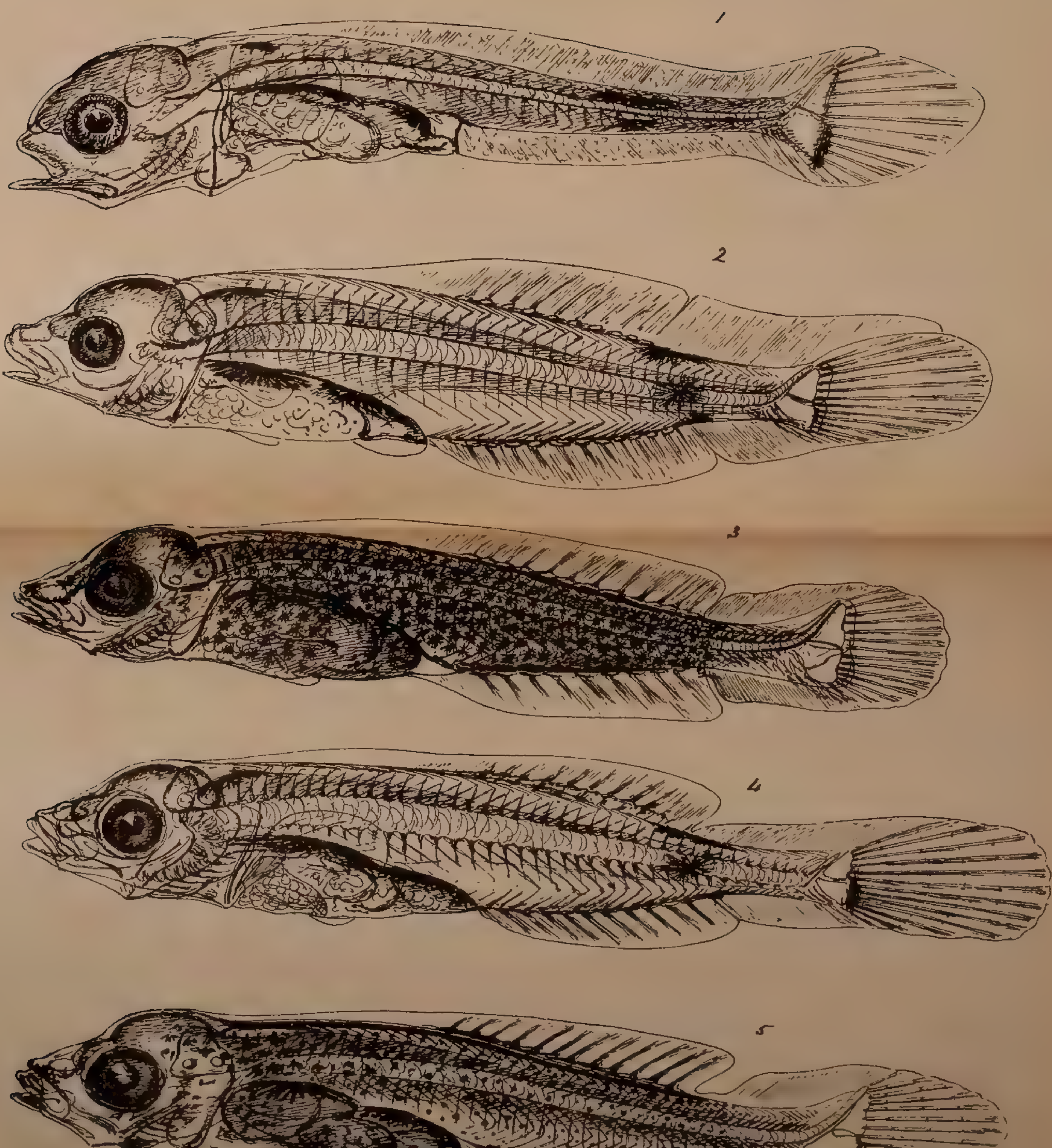
Agassiz Young osseous Fishes

Pl XIV



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Agassiz Young Osseous Fishes

Pl. XV

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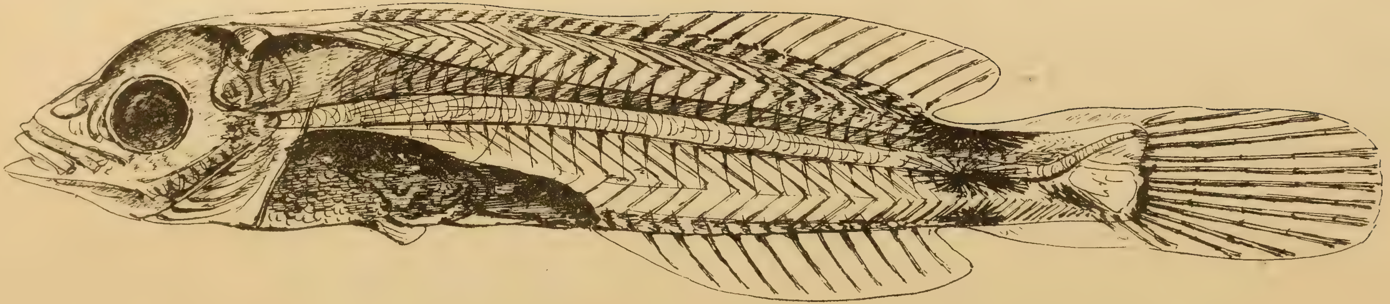

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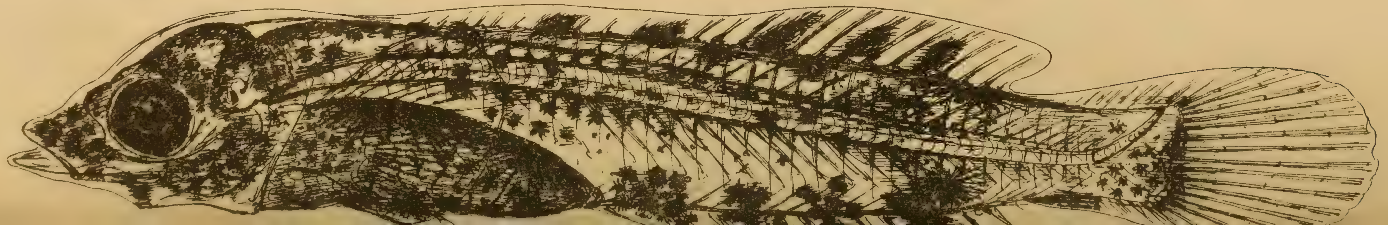


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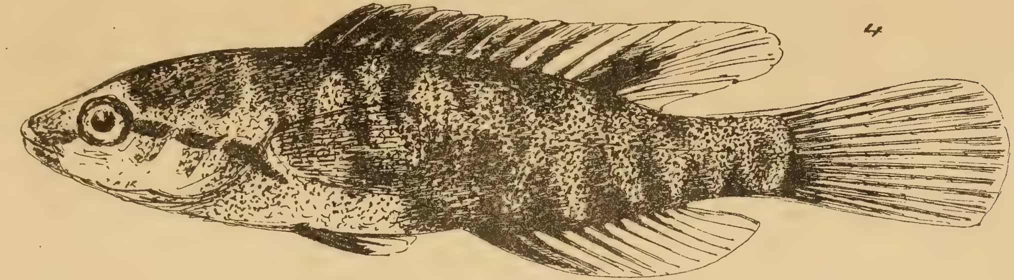
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Agassiz Young Osseous Fishes

Pl. XV

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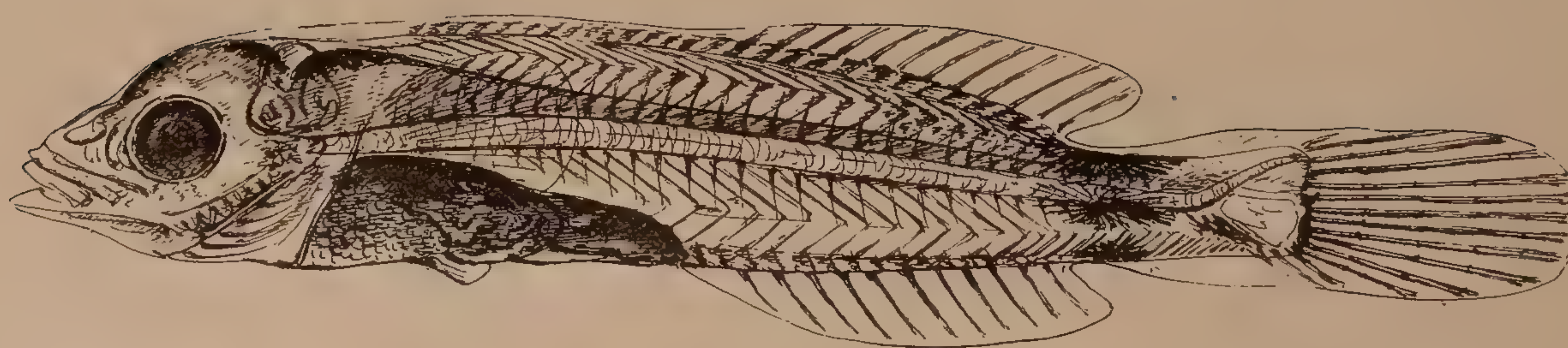

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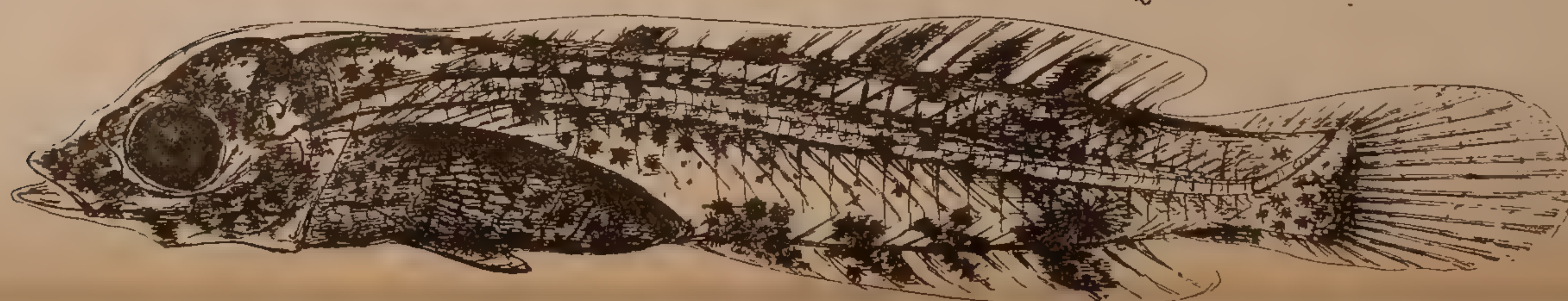

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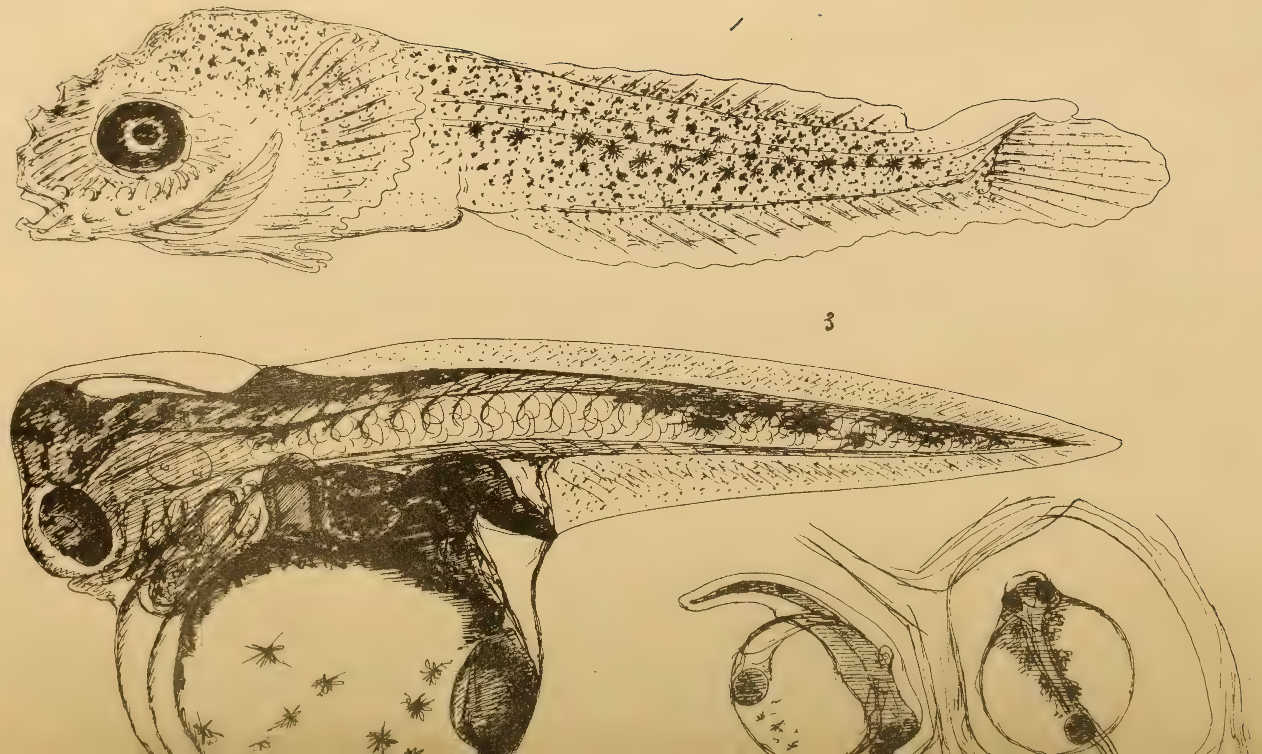
Agassiz Young Osseous Fishes

Pl. XVI



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Agassiz Young Osseous Fishes Pl. XVI

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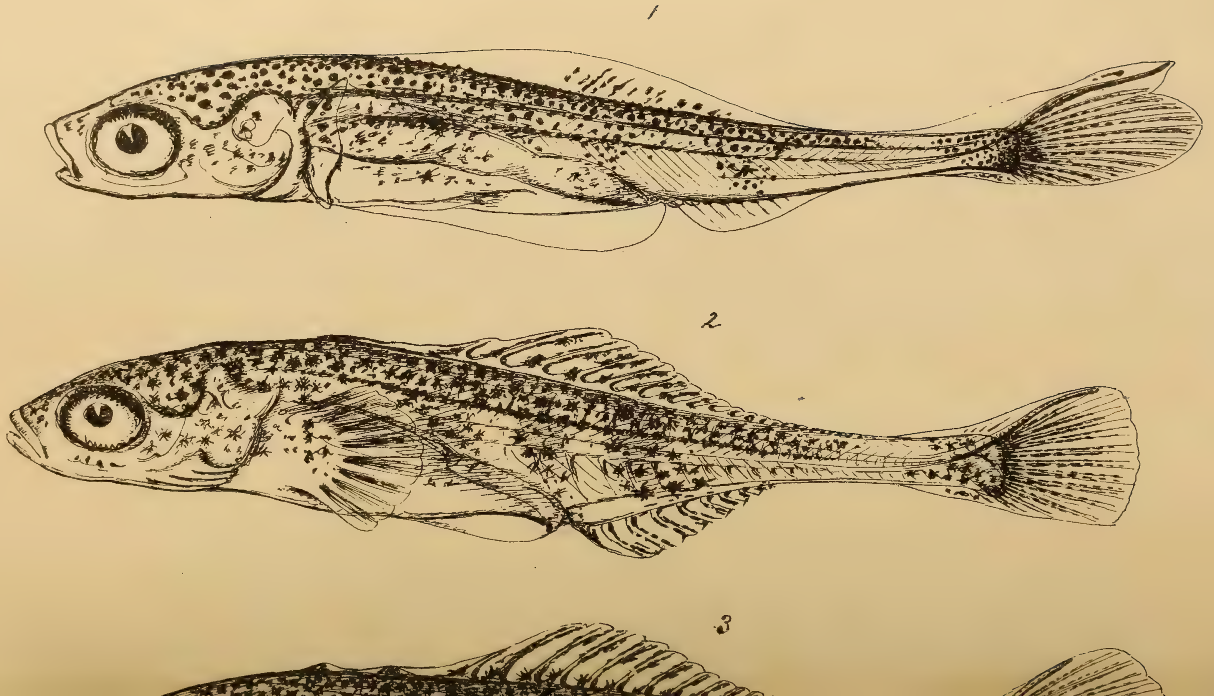
Agassiz' Young Osseous Fishes

Pl. IX

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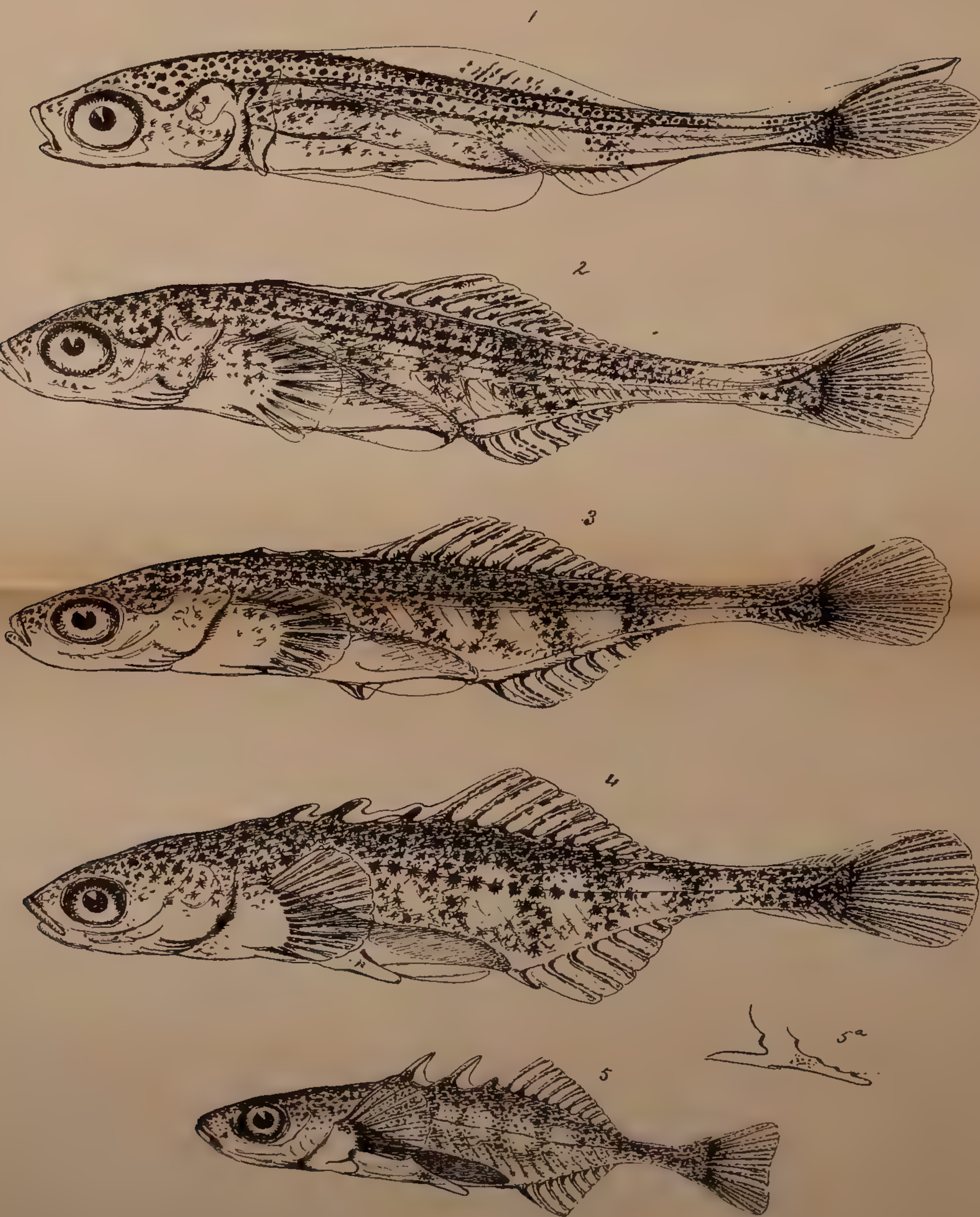

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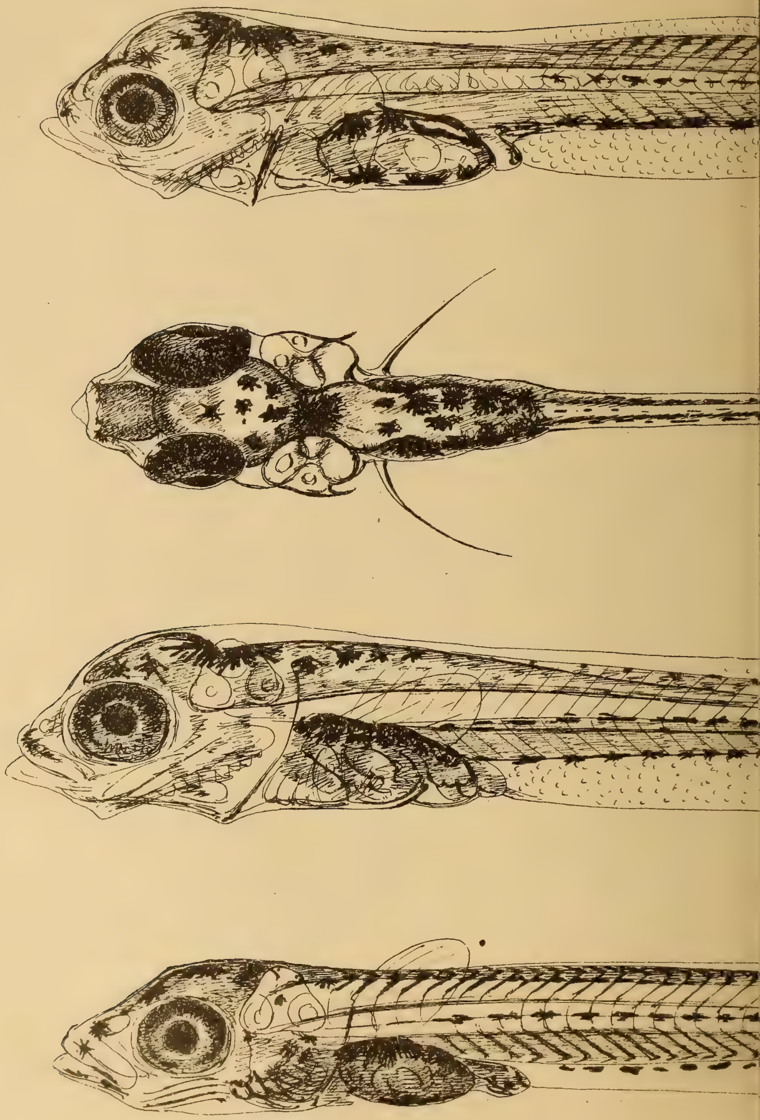
Agassiz' Young Osseous Fishes



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Pl. X

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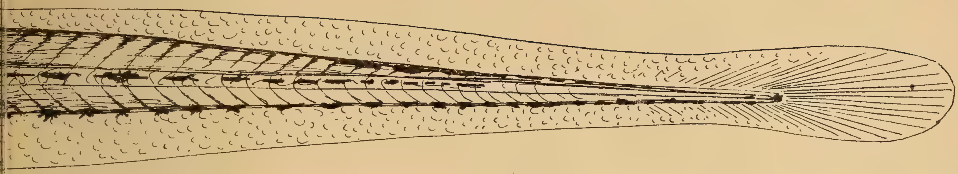

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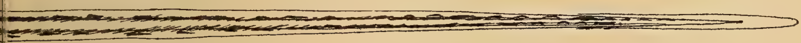

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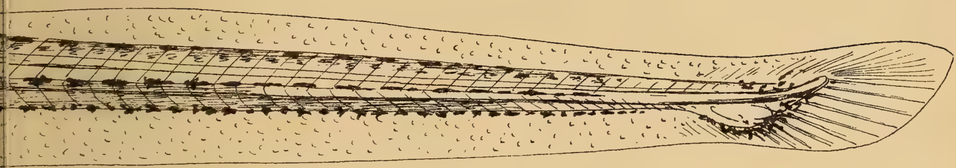

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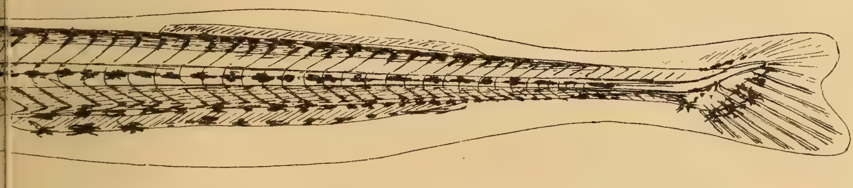

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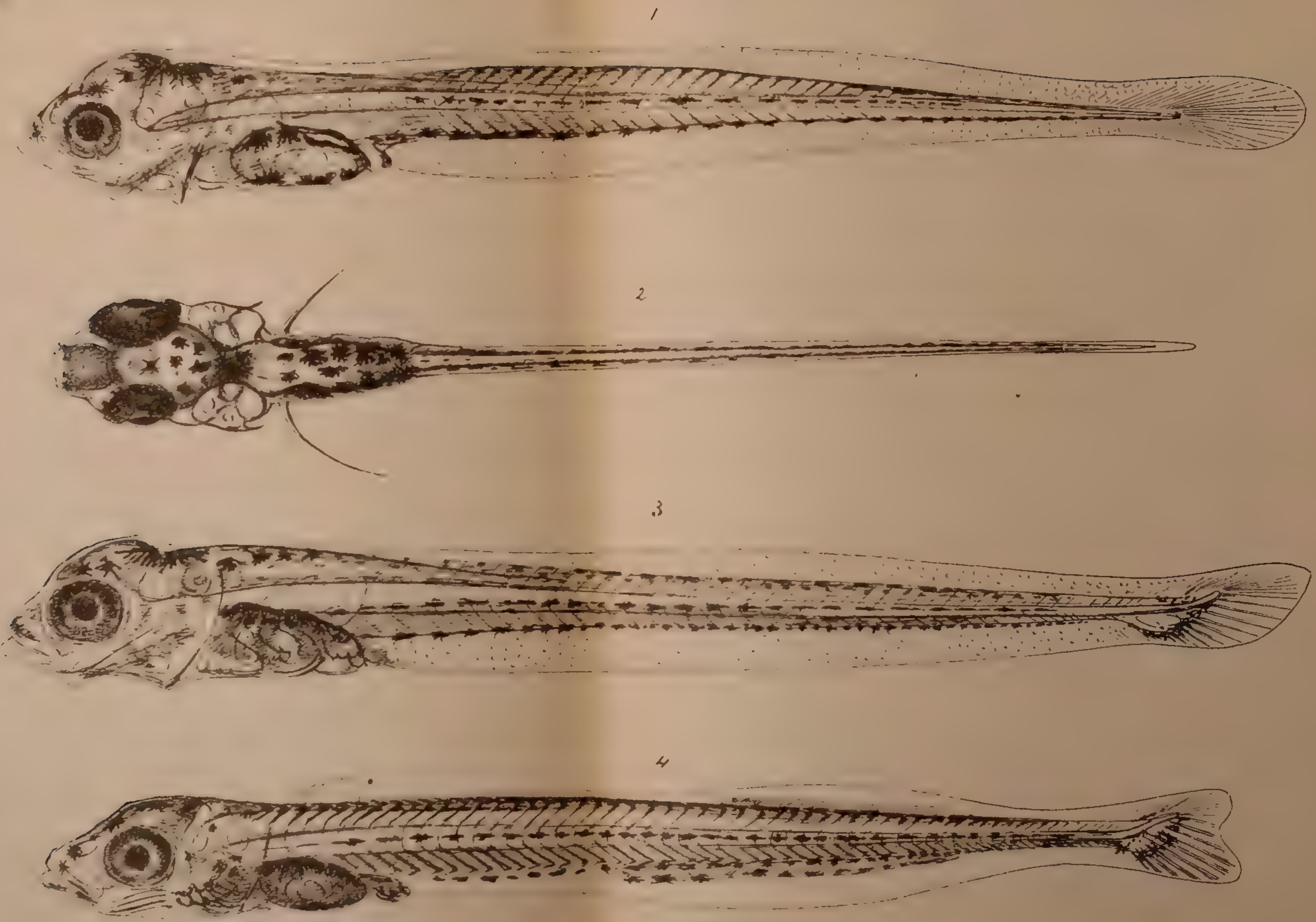
Agassiz Young Osseous Fishes

Pl. X



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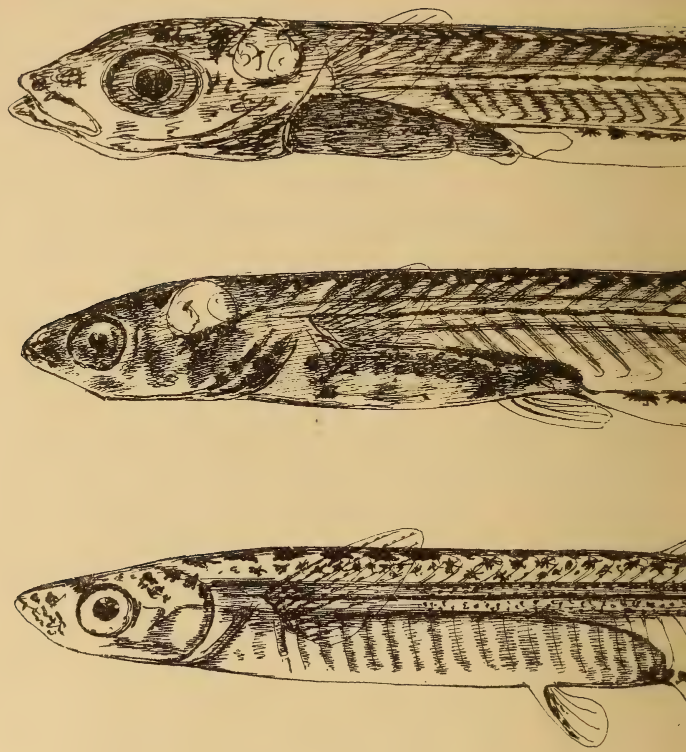

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Pl. XI

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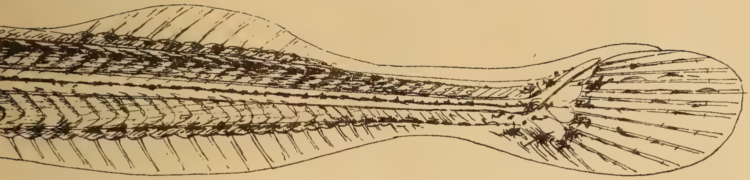

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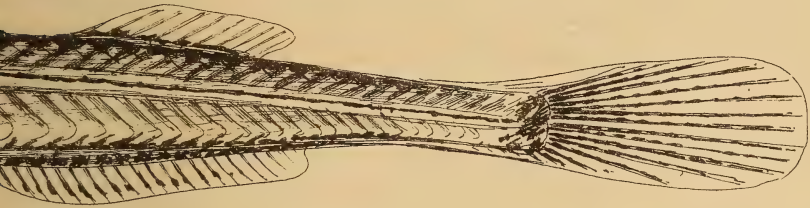

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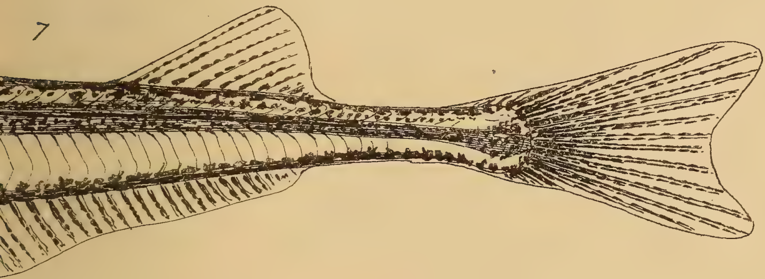

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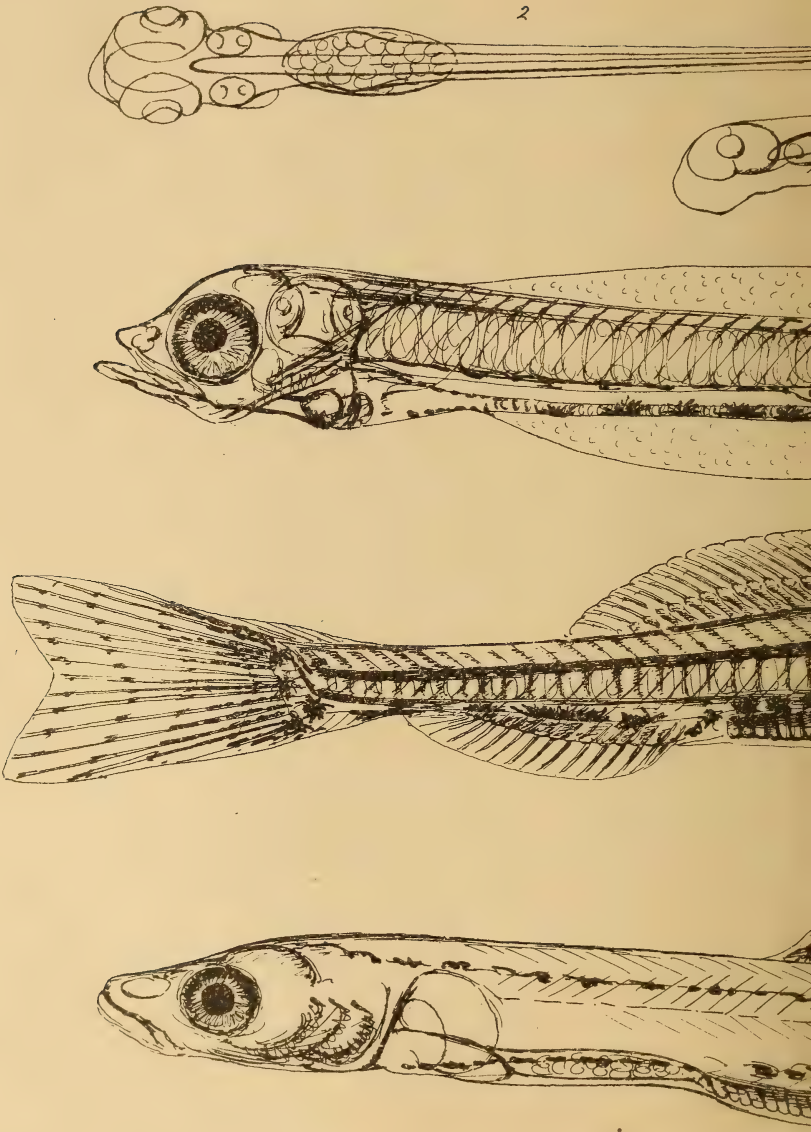
Agassiz' Young Osseous Fishes



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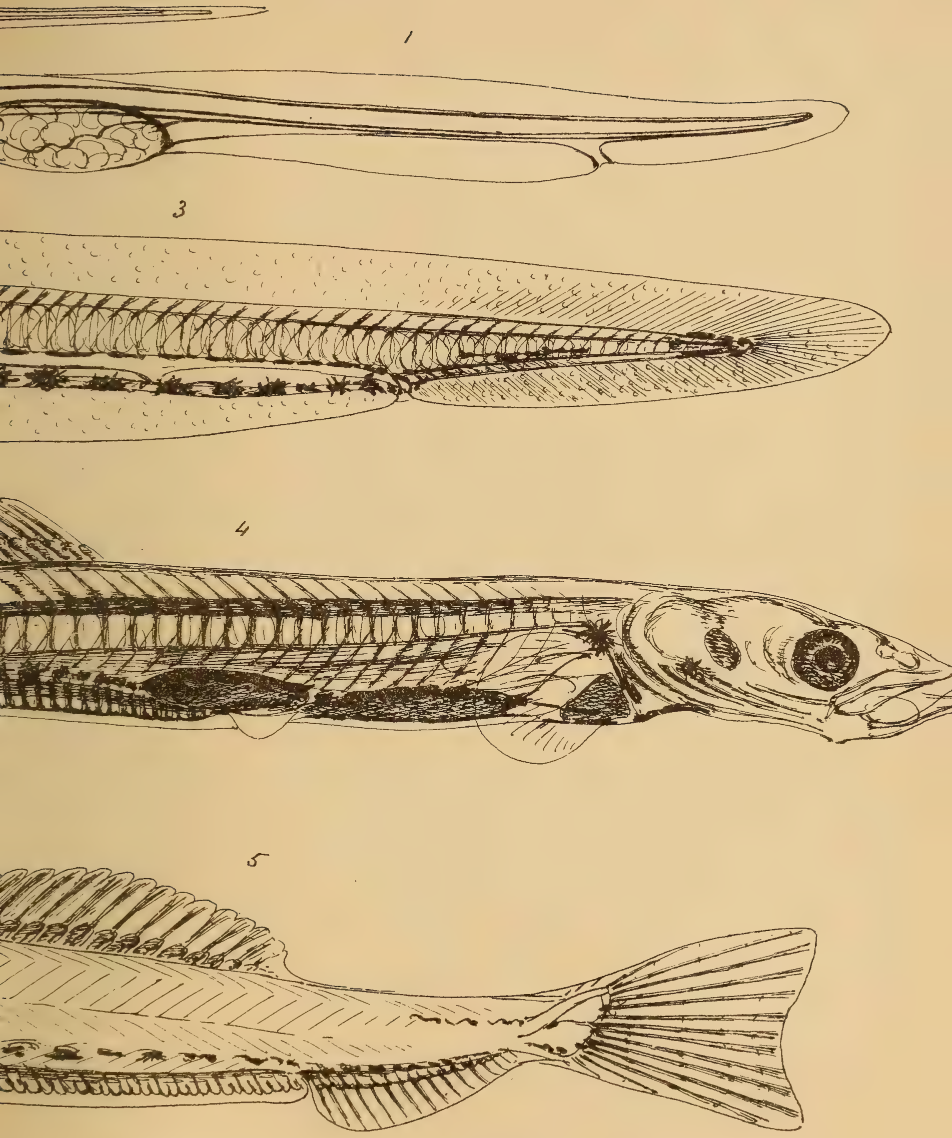
Pl. XII



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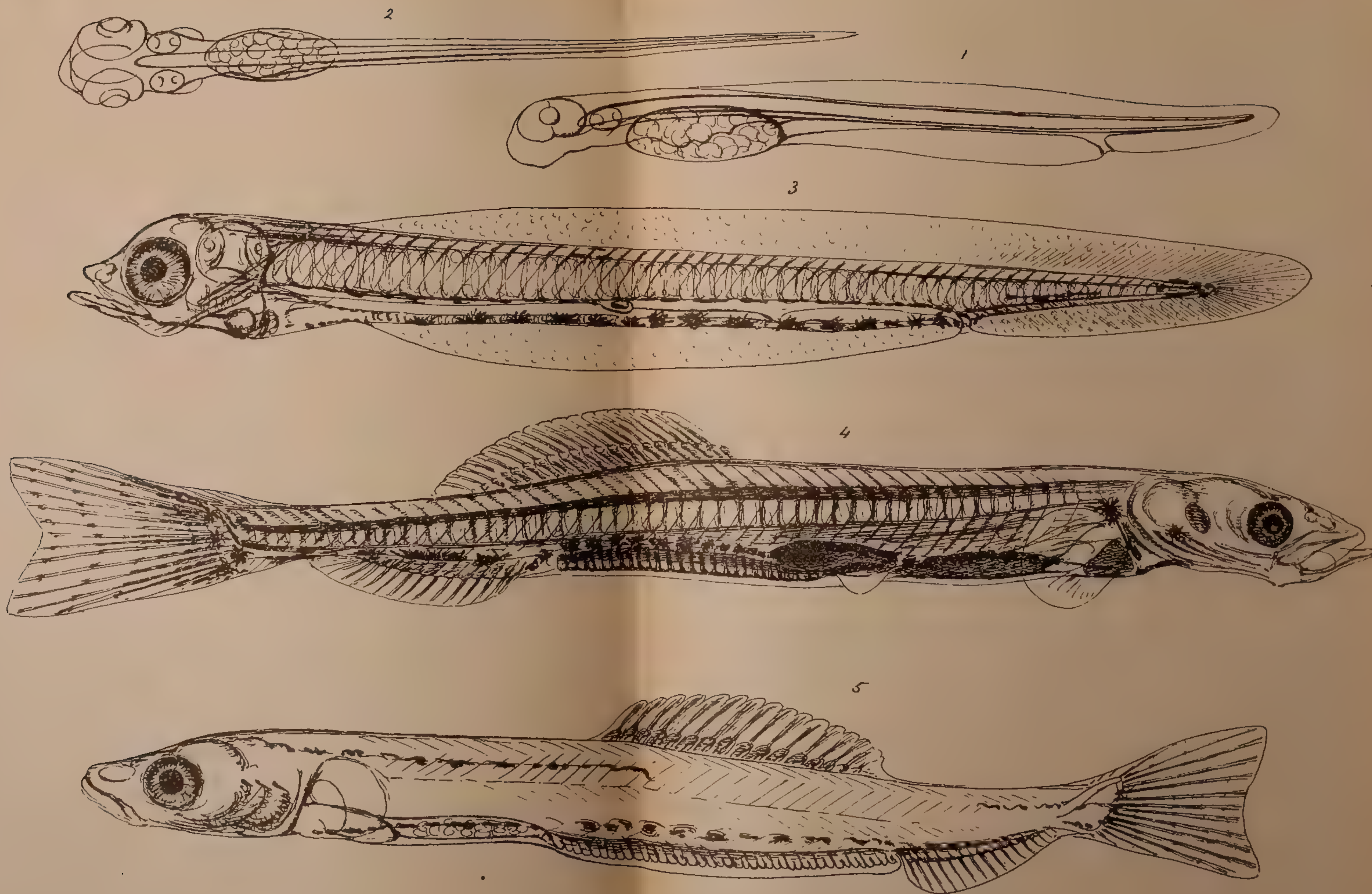
Agassiz' Young Osseous Fishes



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Agassiz' Young Osseous Fishes

Pl. VI

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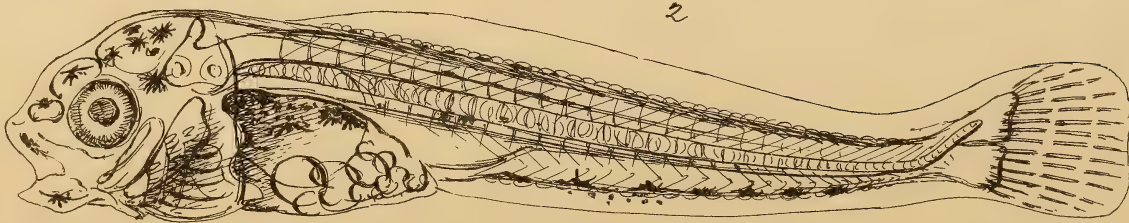

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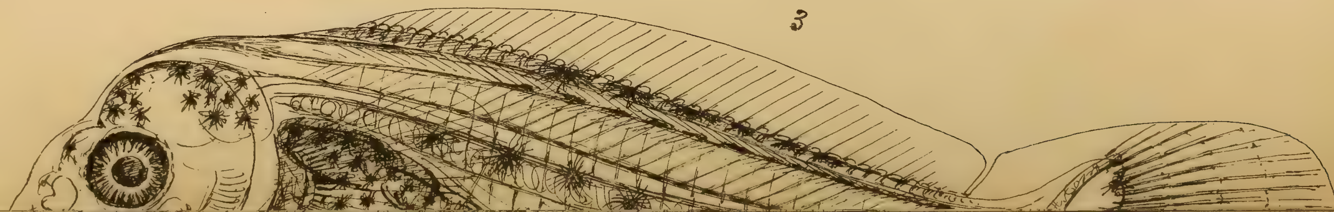

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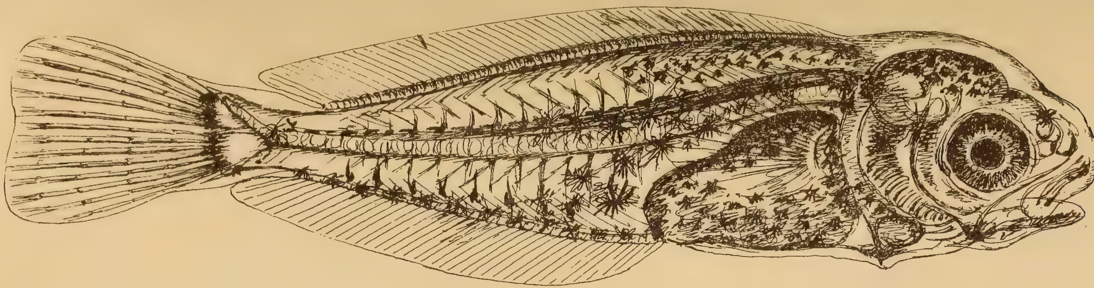

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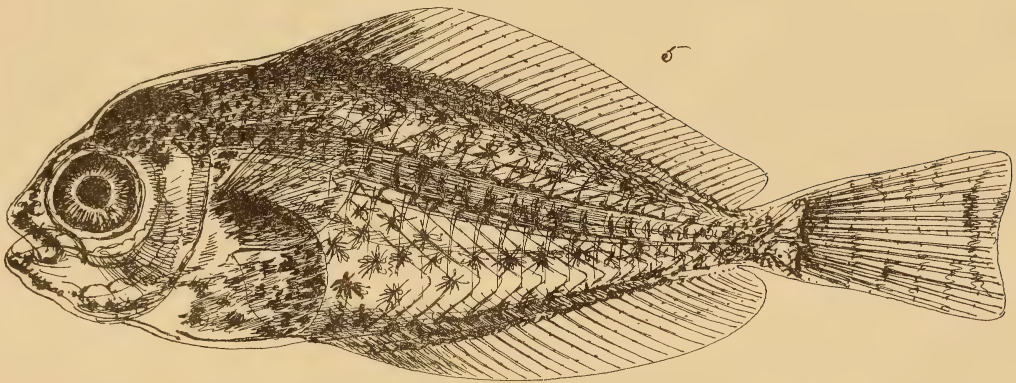

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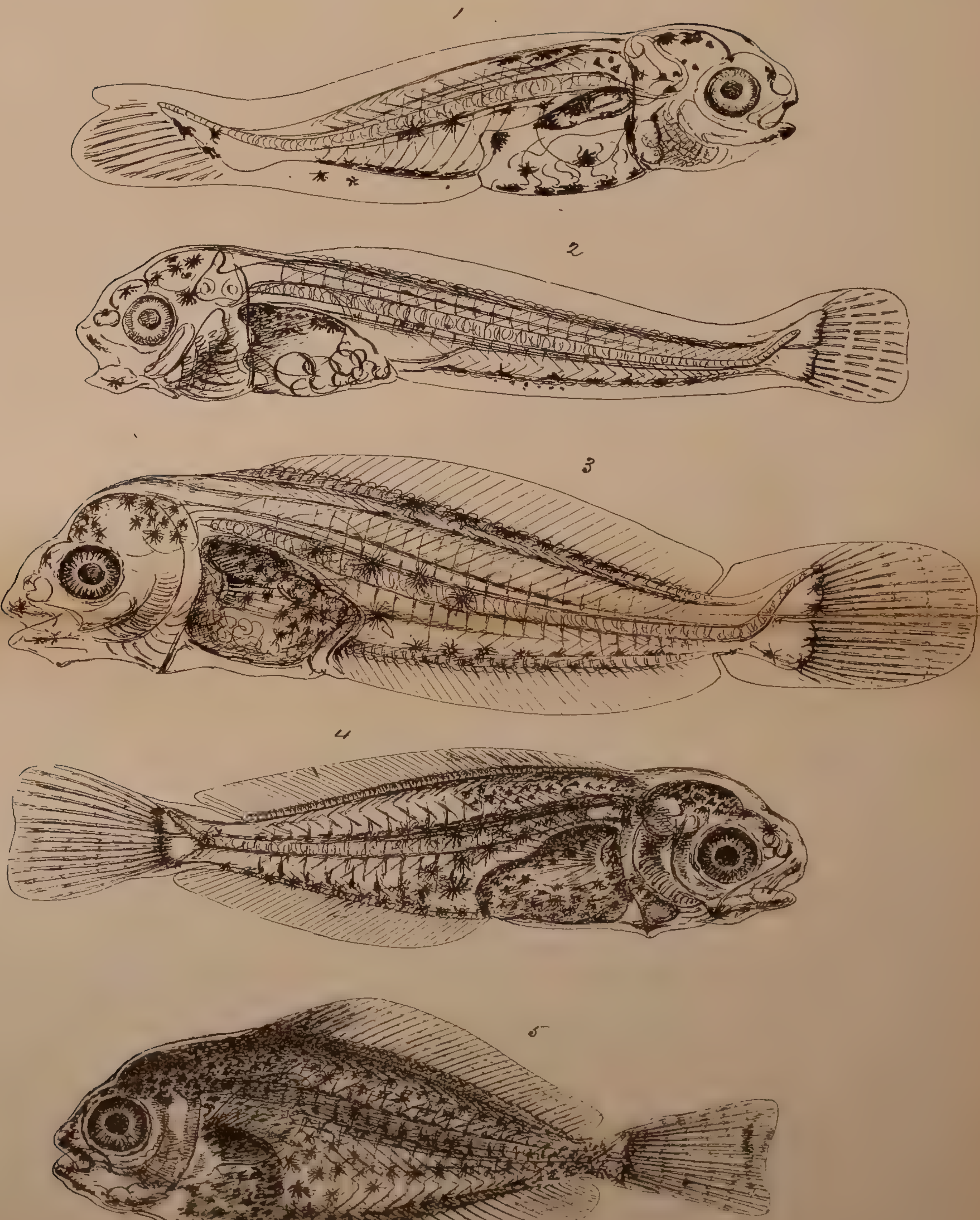
Agassiz' Young Osseous Fishes

Pl. VI



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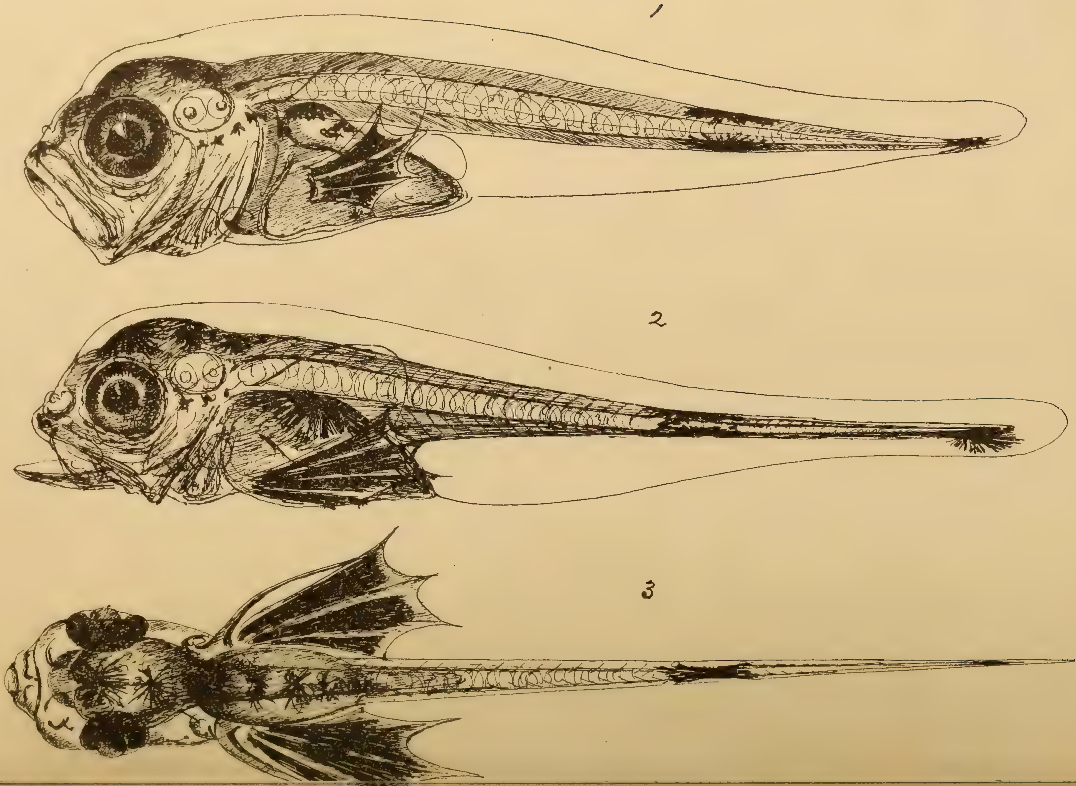
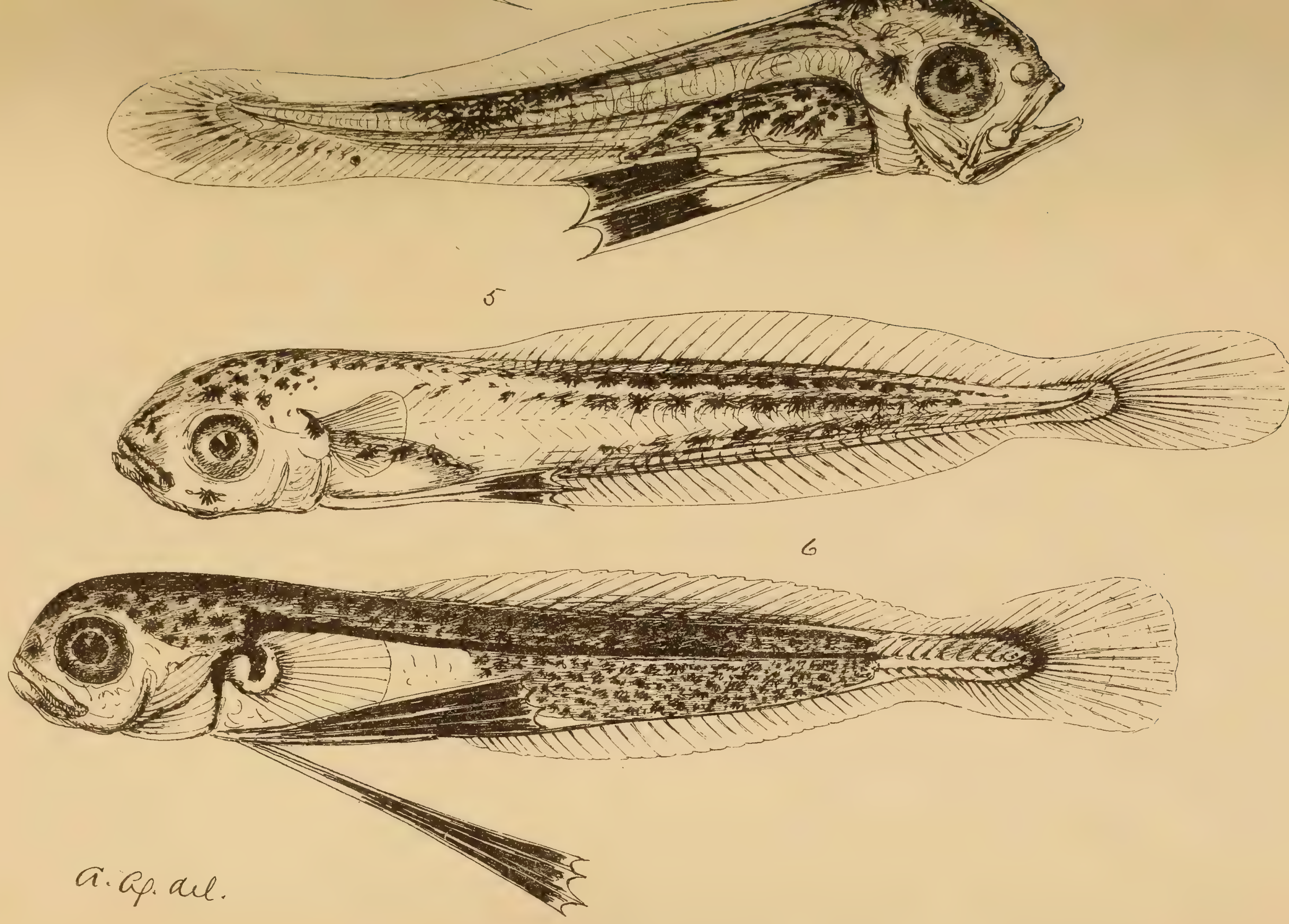
Pl. VII





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Pl. VII

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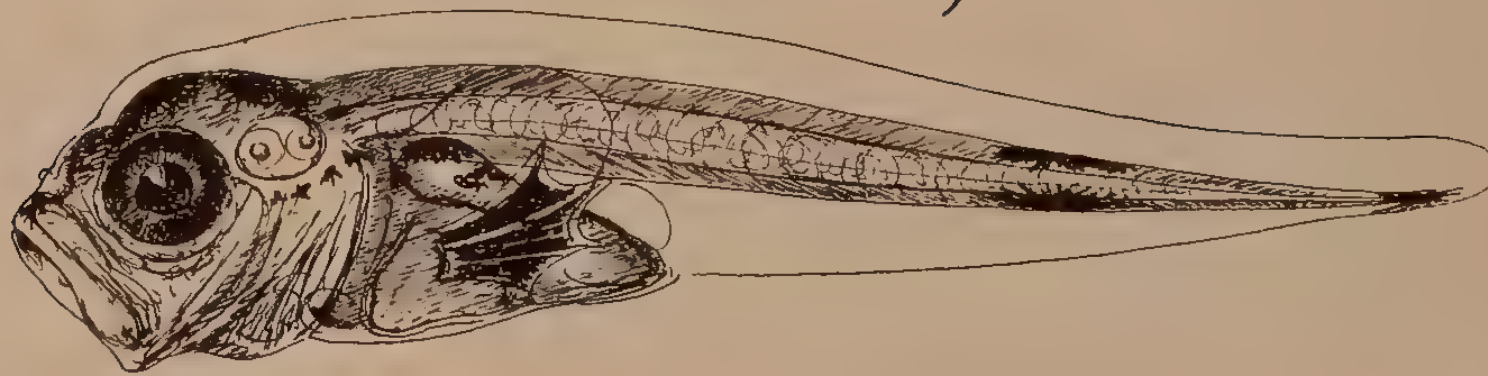

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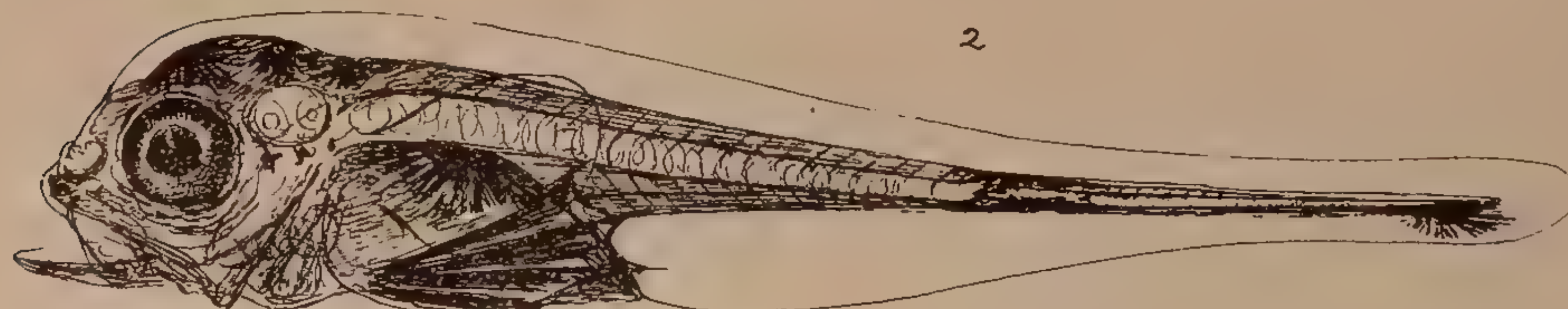

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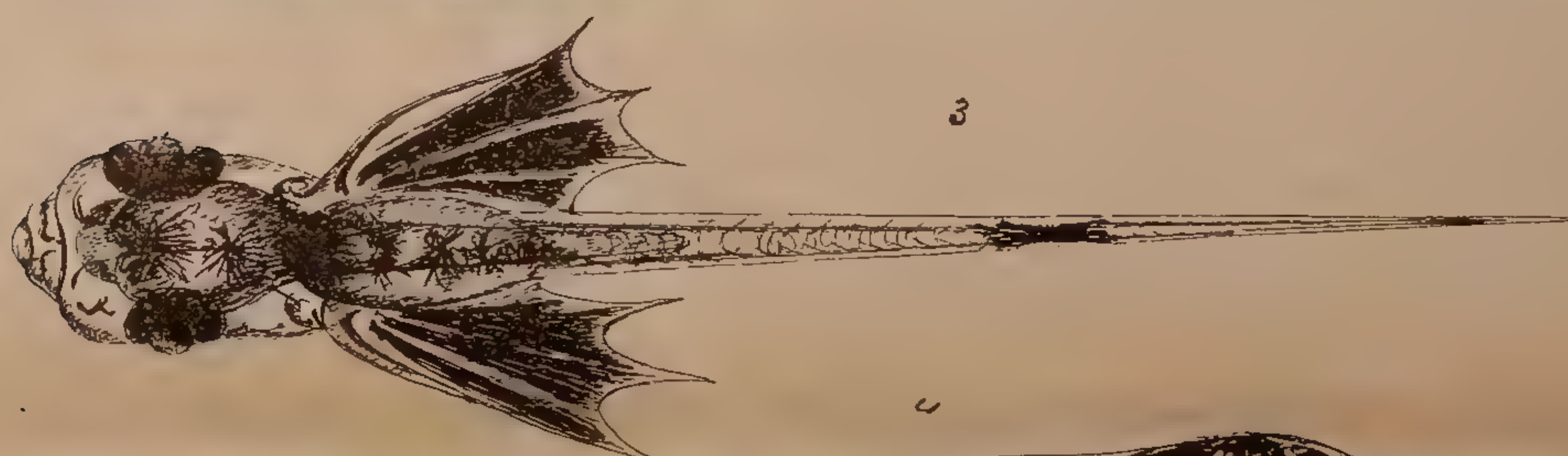

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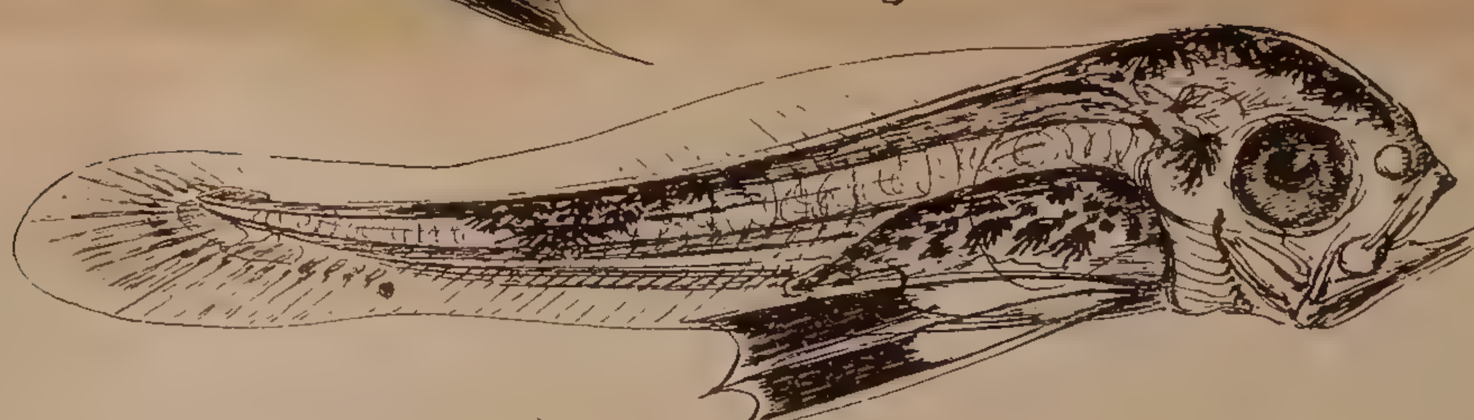

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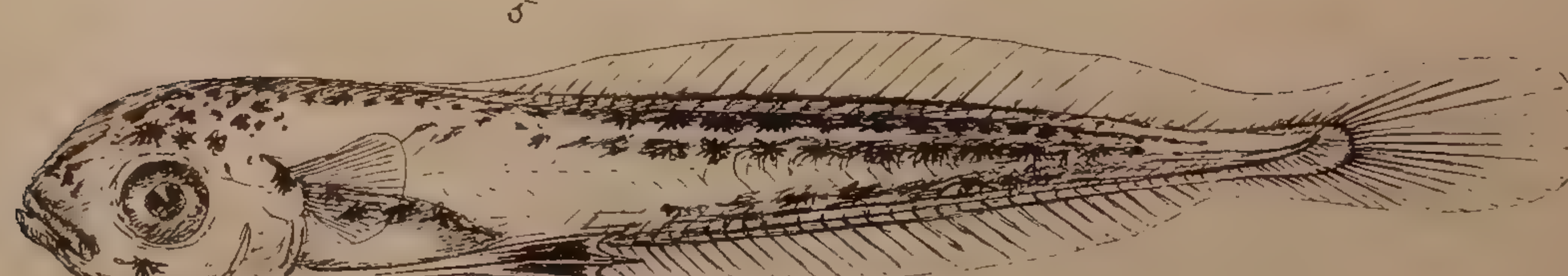

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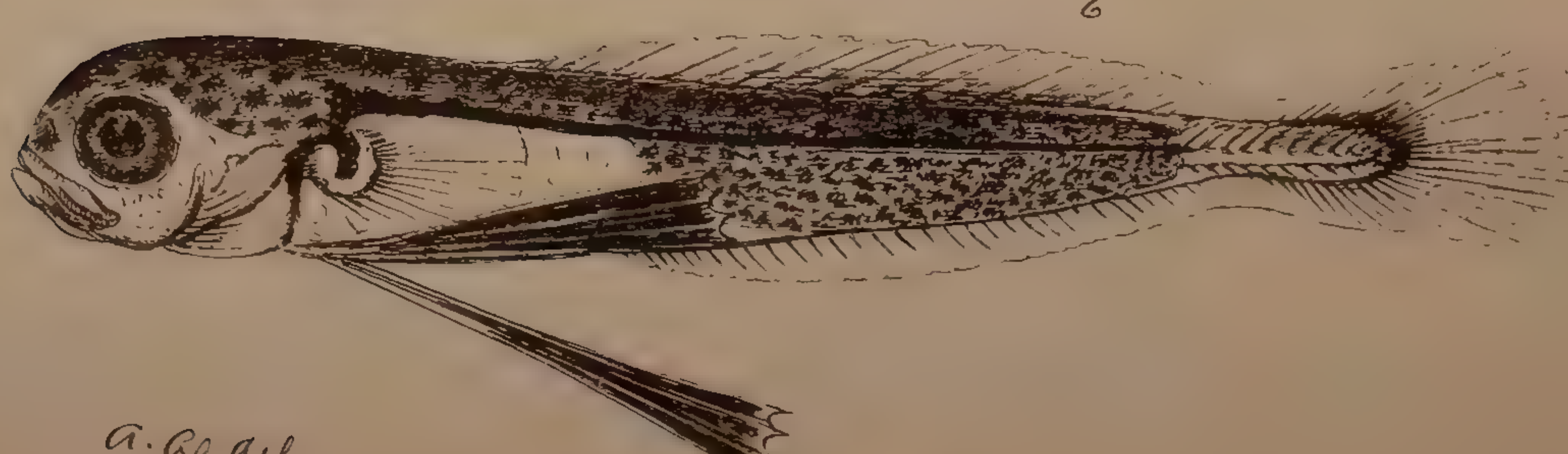

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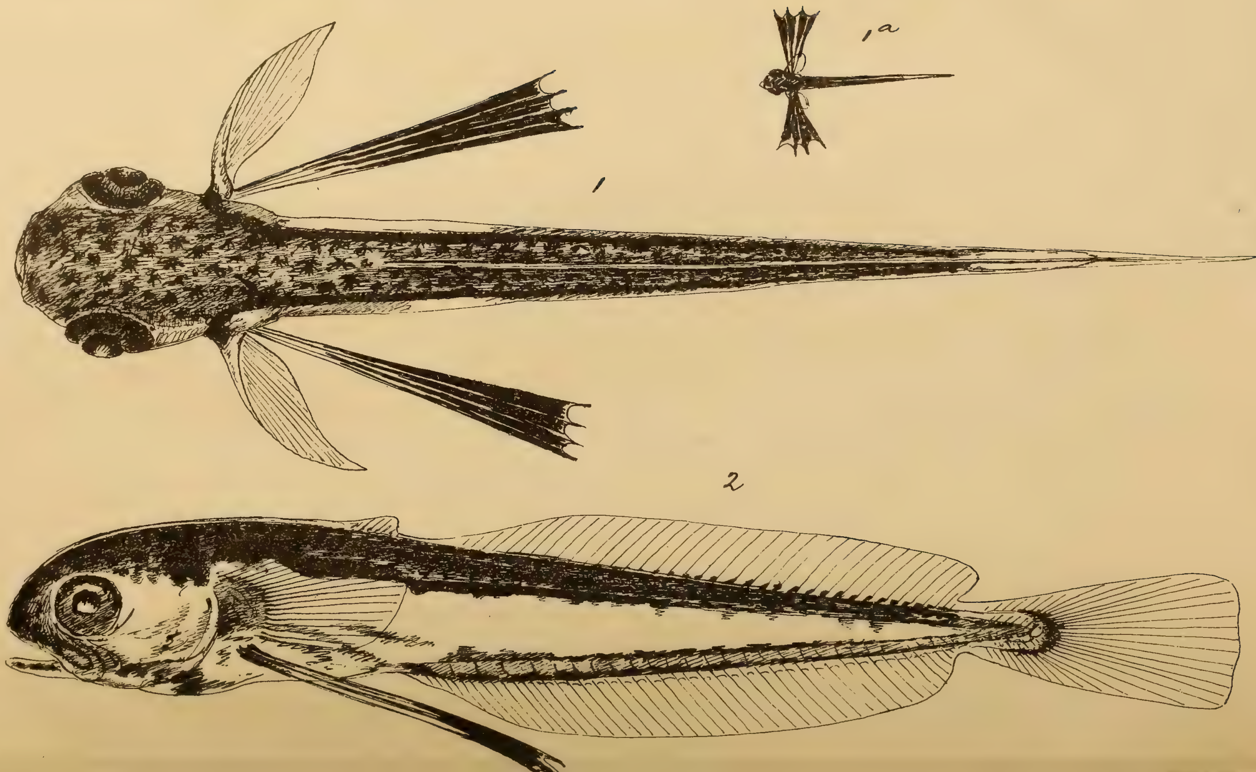
Agassiz' Young Osseous Fishes

Pl. VIII



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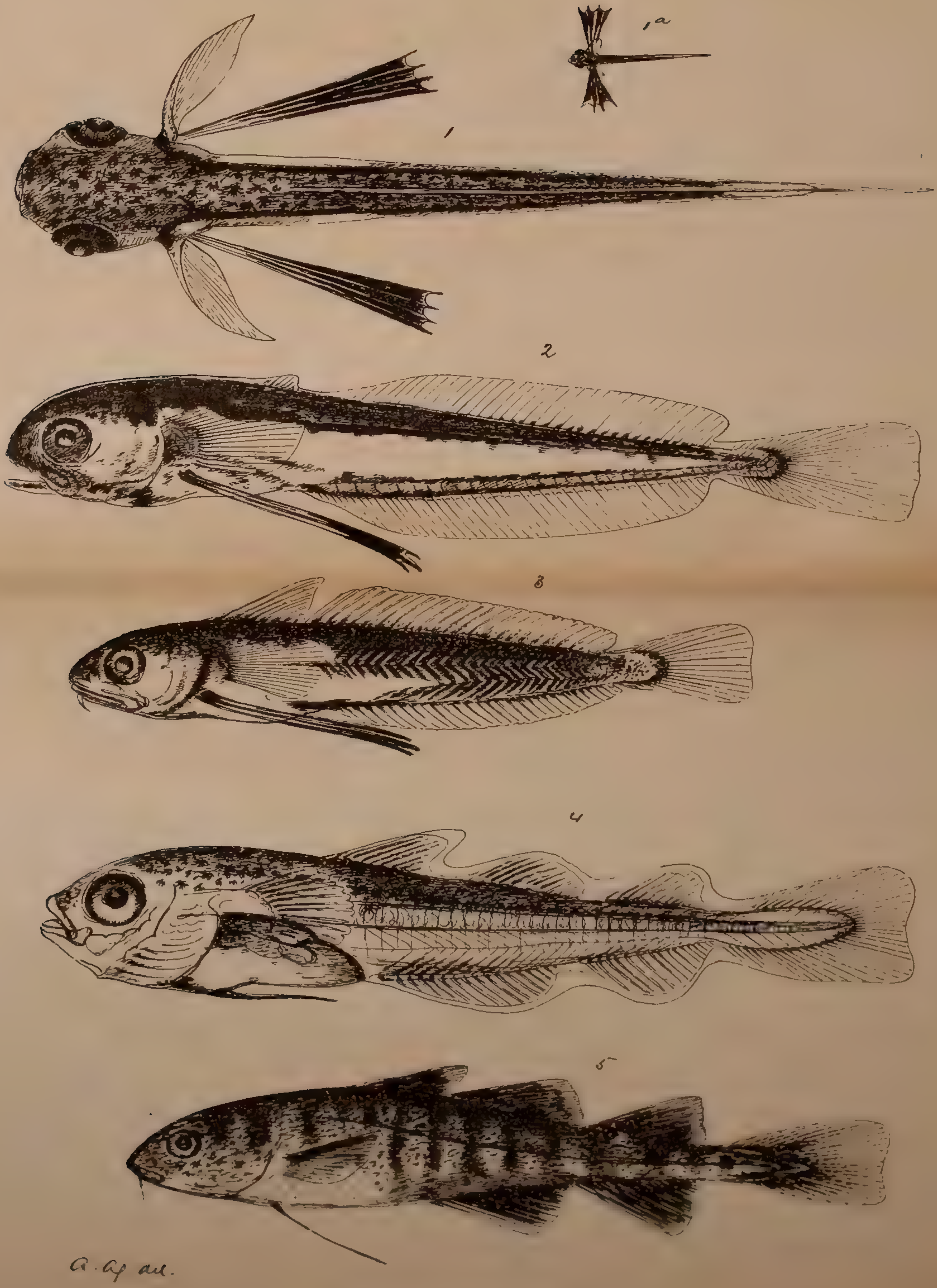
Pl. VIII.



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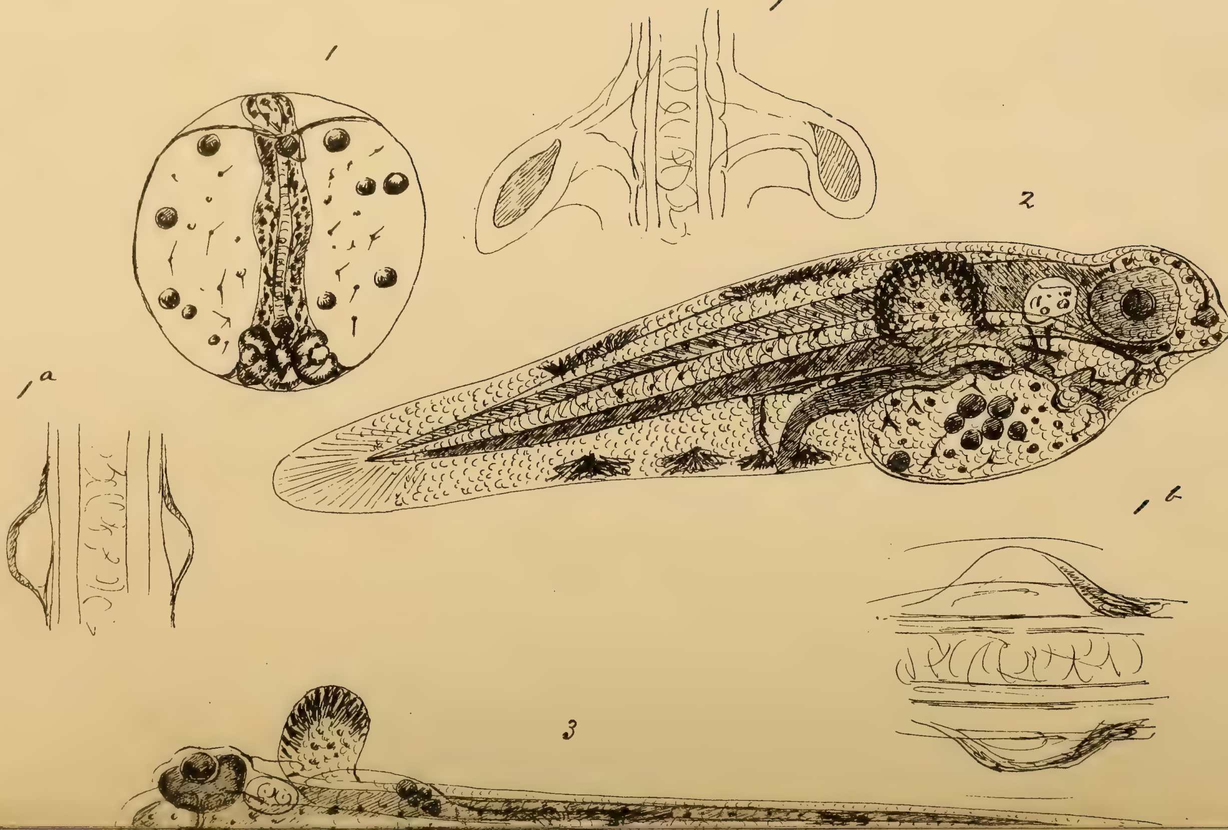
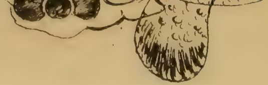
Agassiz' Young Osseous Fishes. Pl. III





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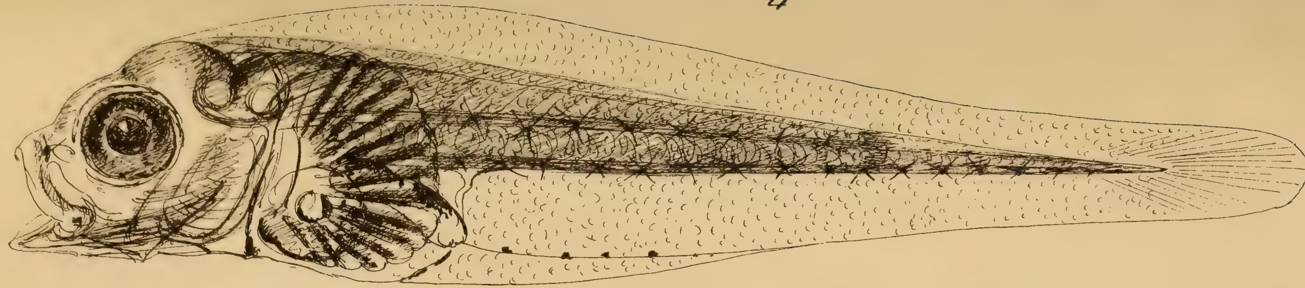

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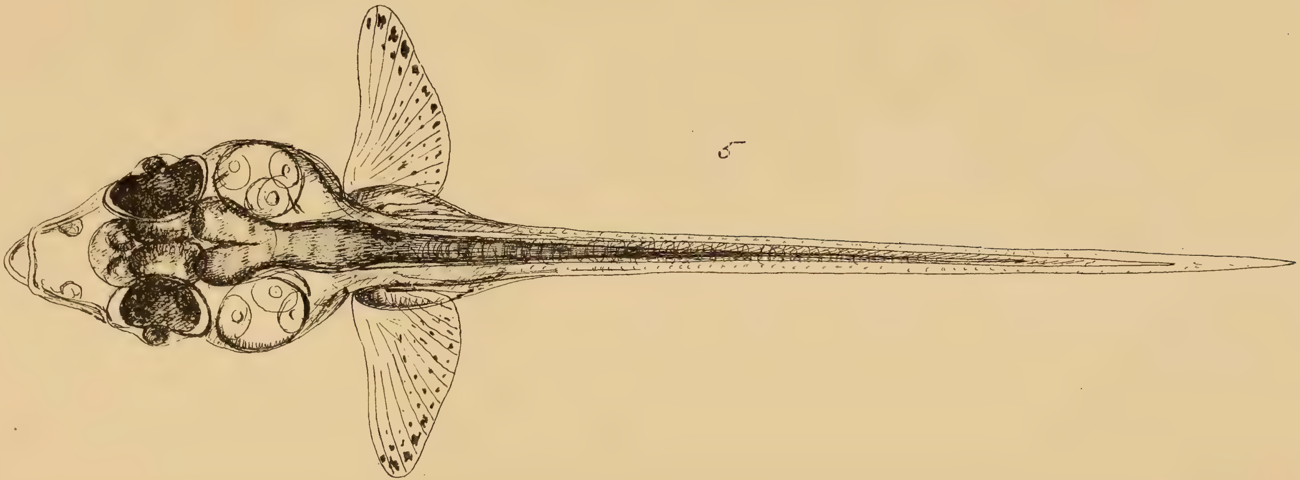

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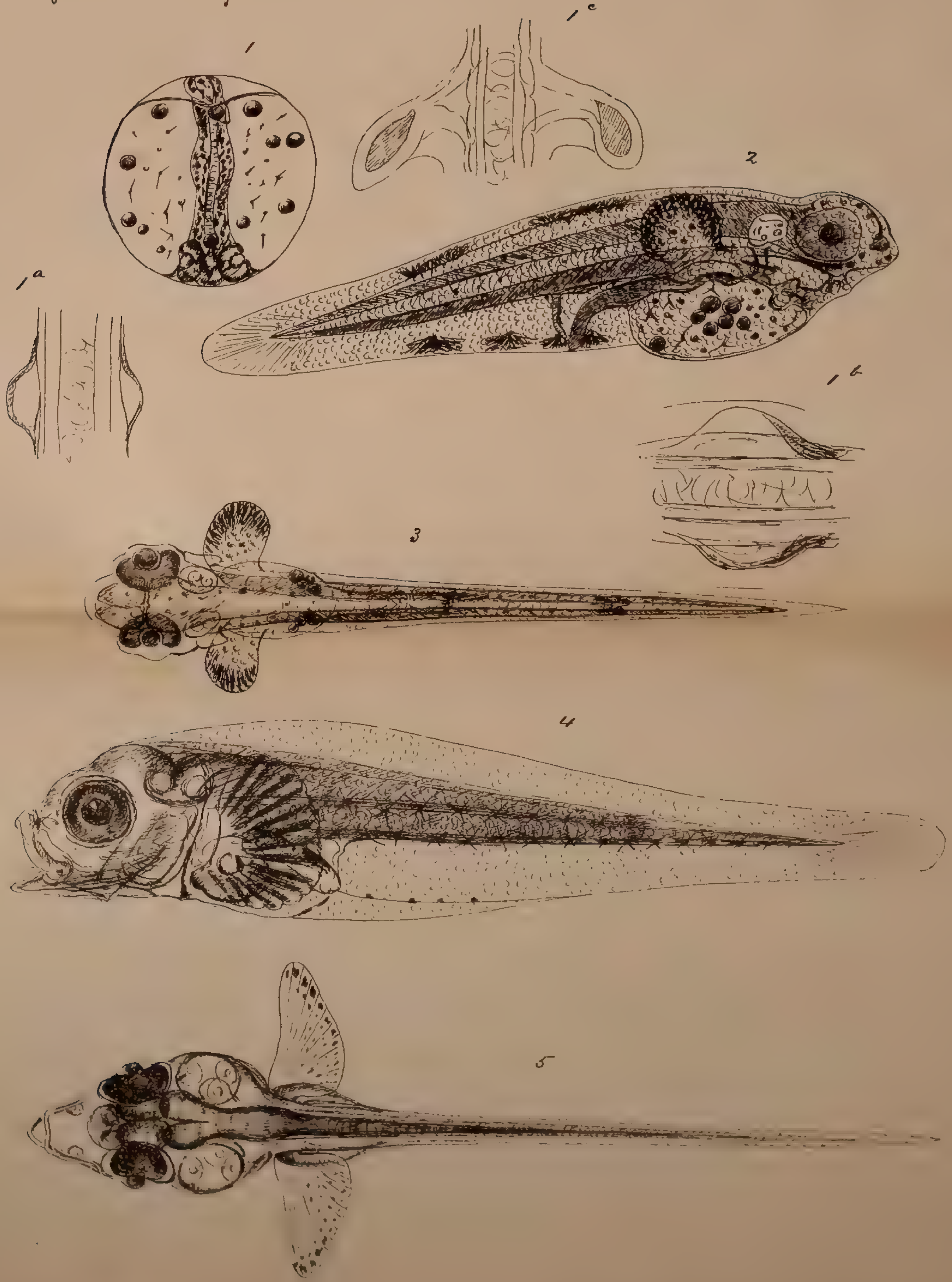
Agassiz' Young Osseous Fishes. Pl. III



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Agassiz' Young osseous Fishes

Pl. IV

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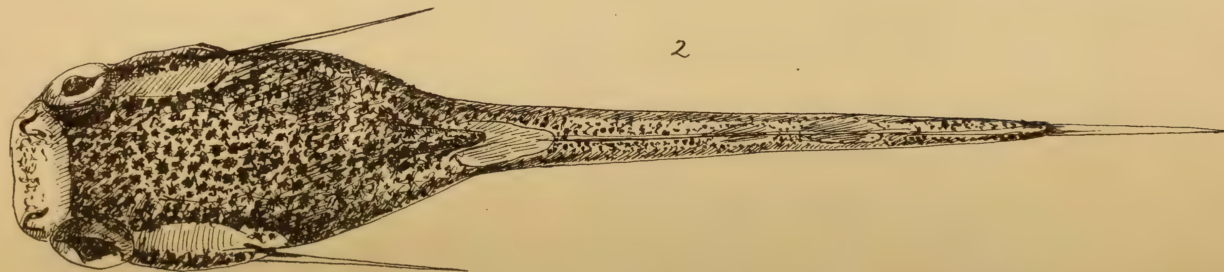

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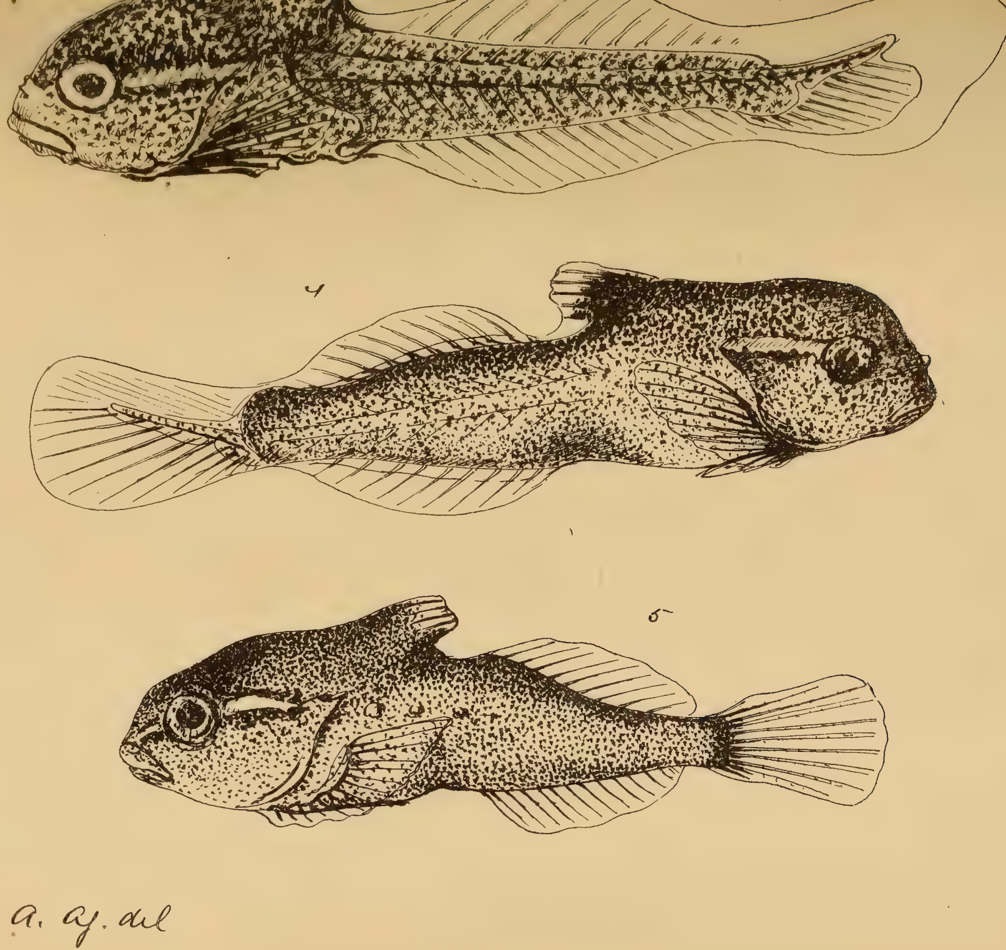

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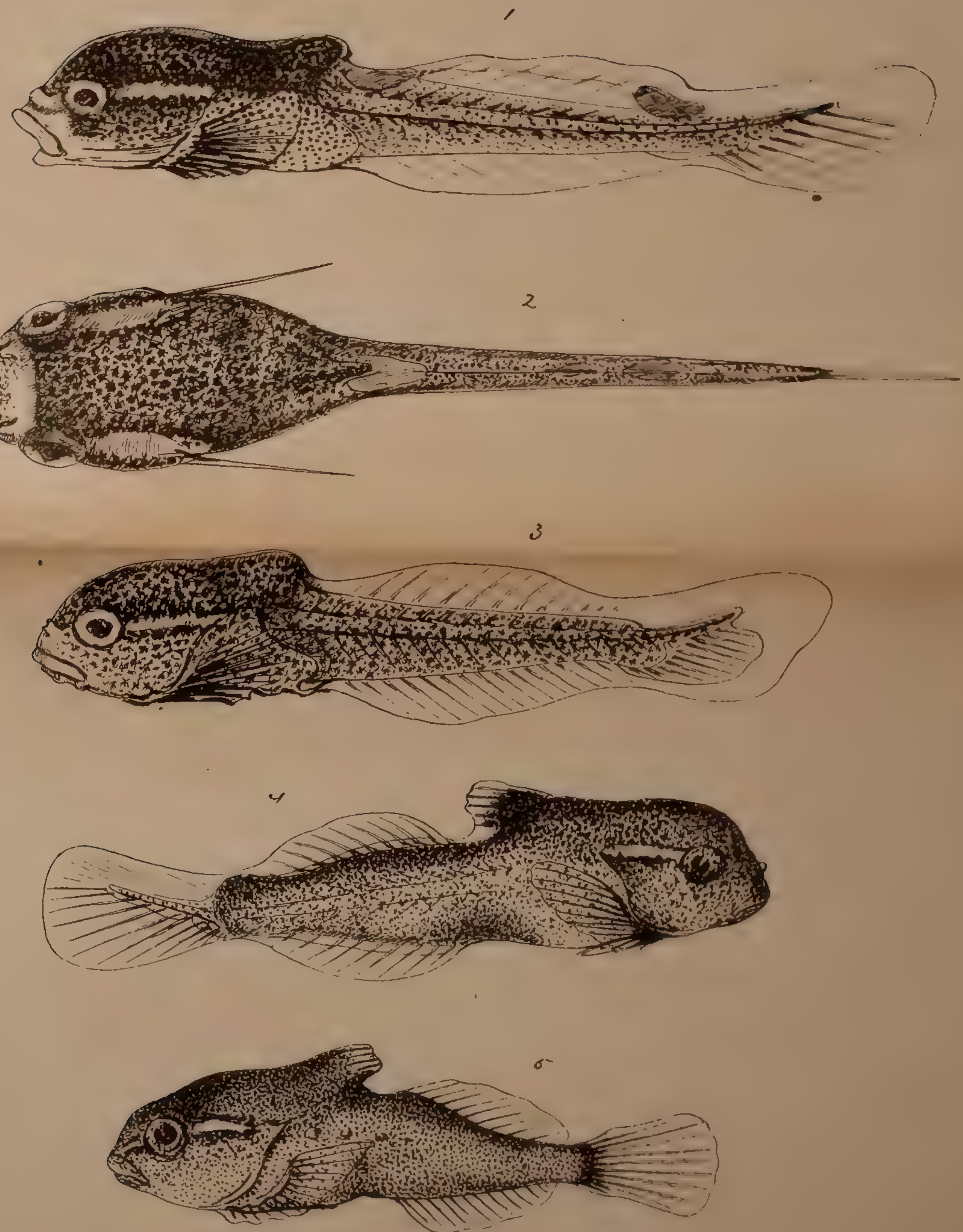
Agassiz' Young osseous Fishes

Pl. IV



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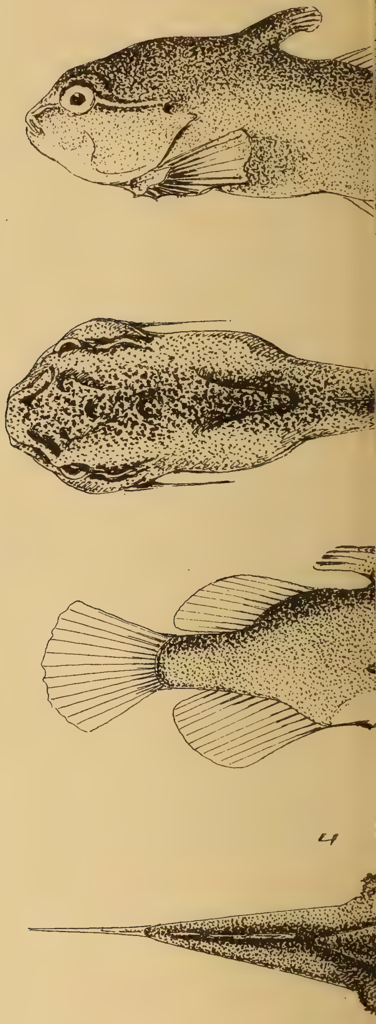
Agassiz' Young Osseous Fishes



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Pl. V

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Agassiz' Young Osseous Fishes

Pl. V

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Agassiz Young Osseous Fishes Pl. I

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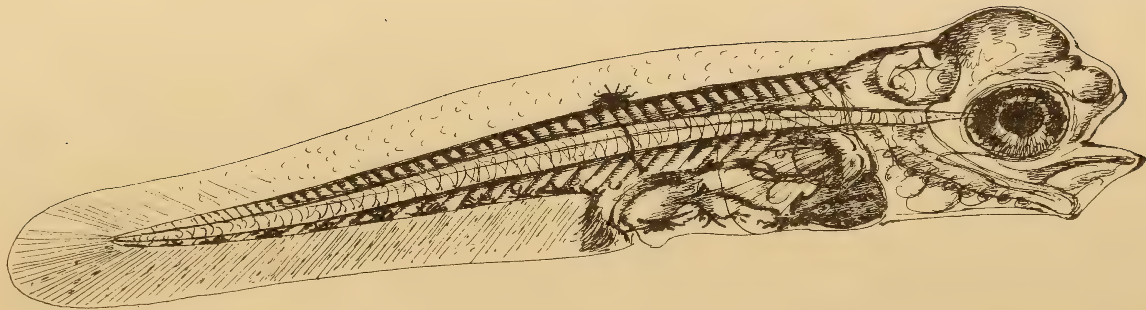

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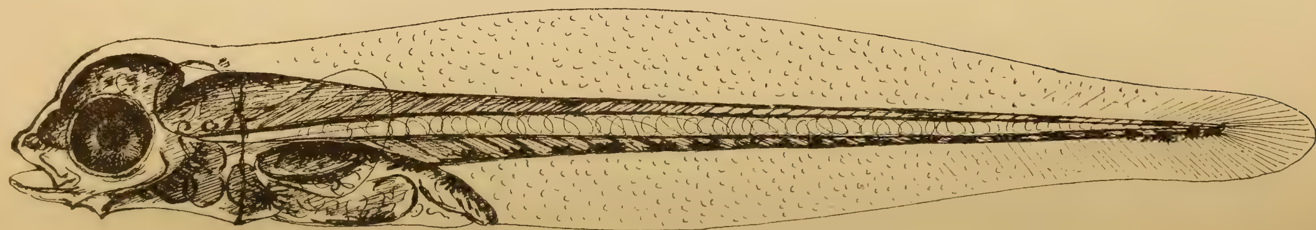

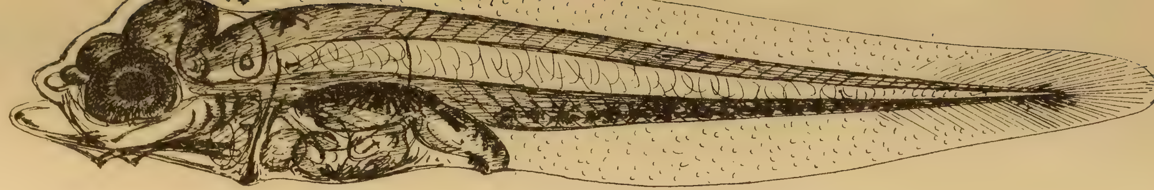

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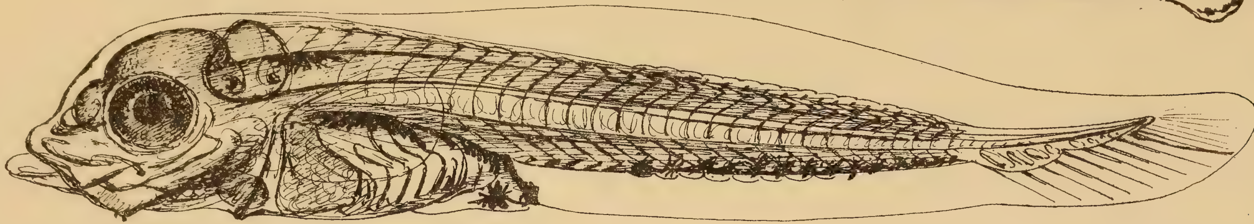

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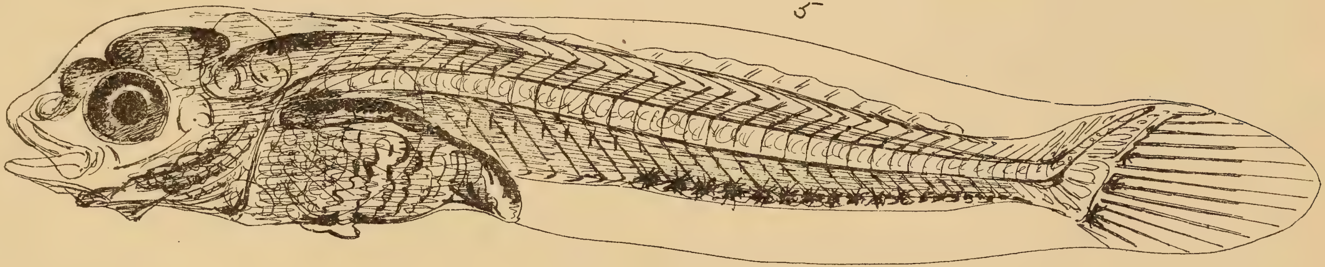

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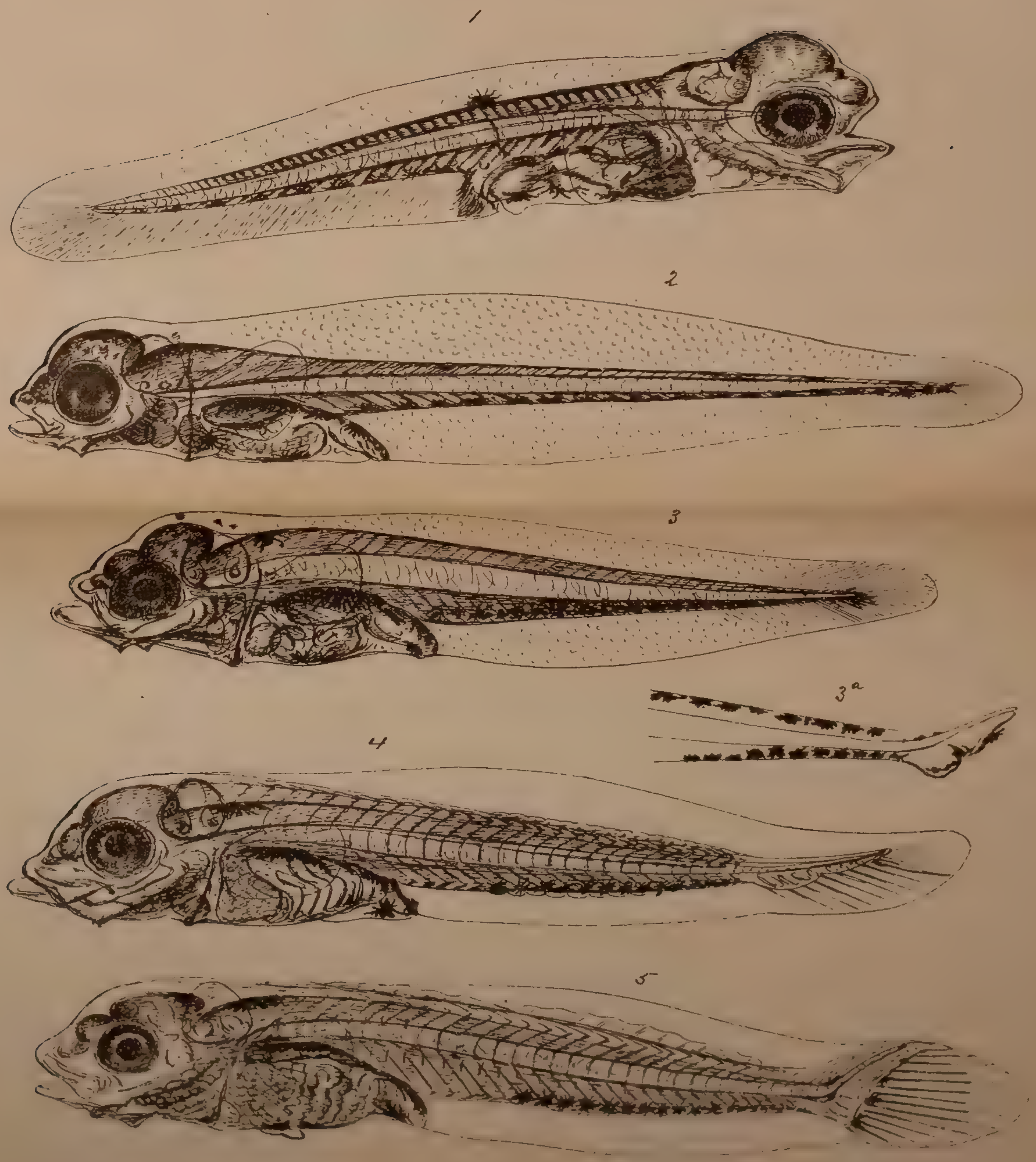
Agassiz Young Osseous Fishes Pl. I



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Agassiz Young Osseous Fishes

Pl. II

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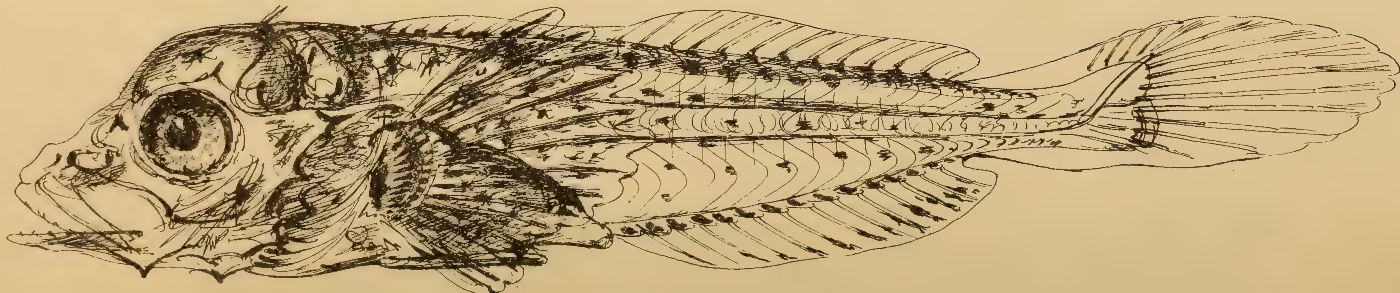

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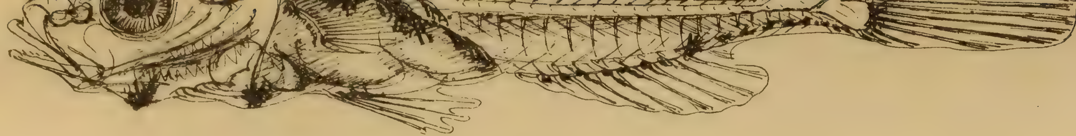

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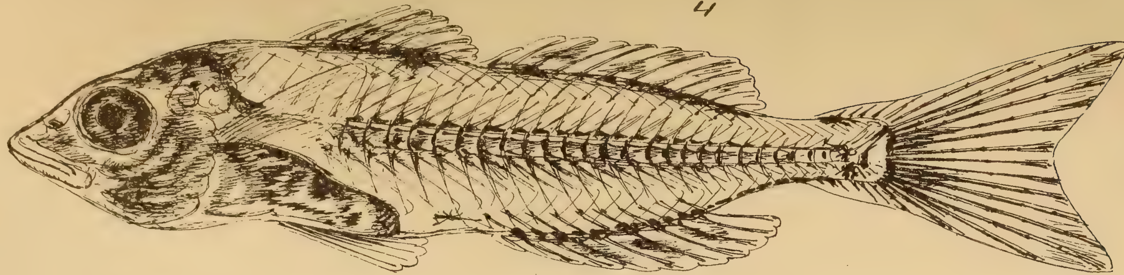

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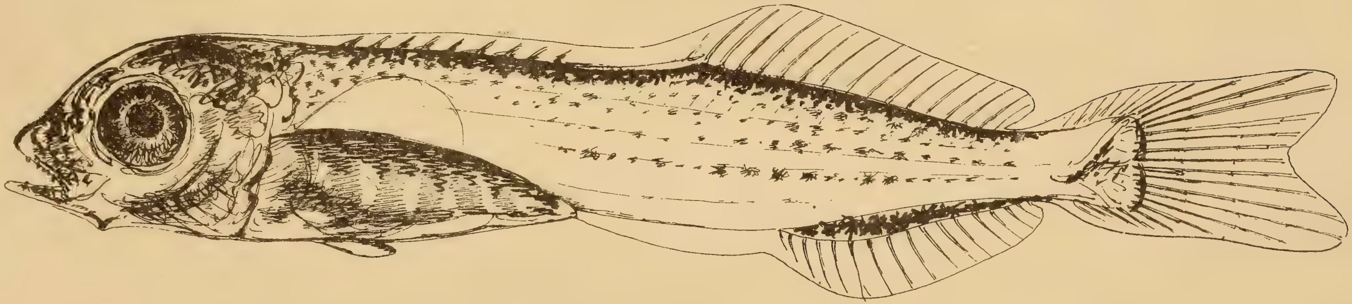

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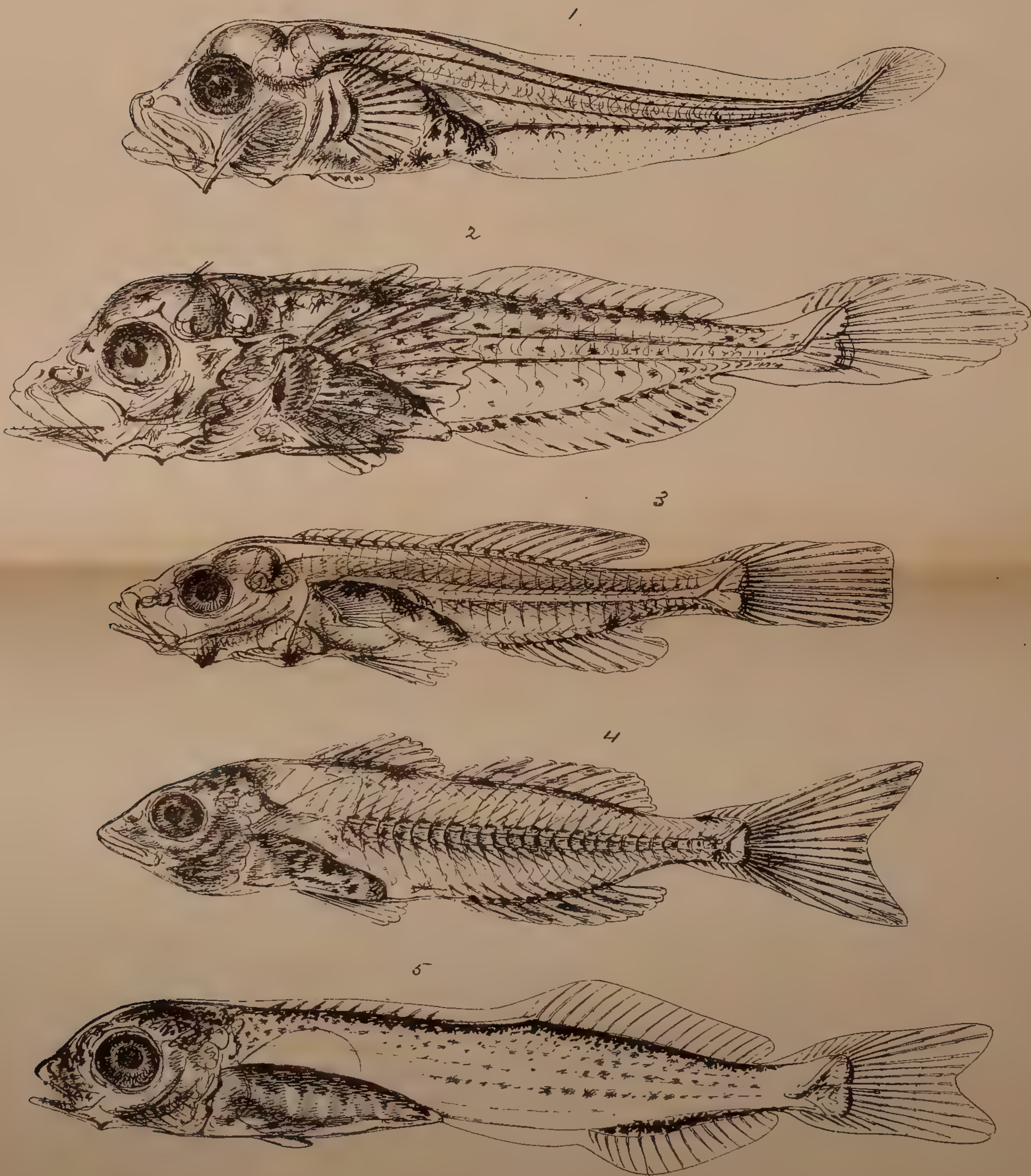
Agassiz' Young Osseous Fishes

Pl. II



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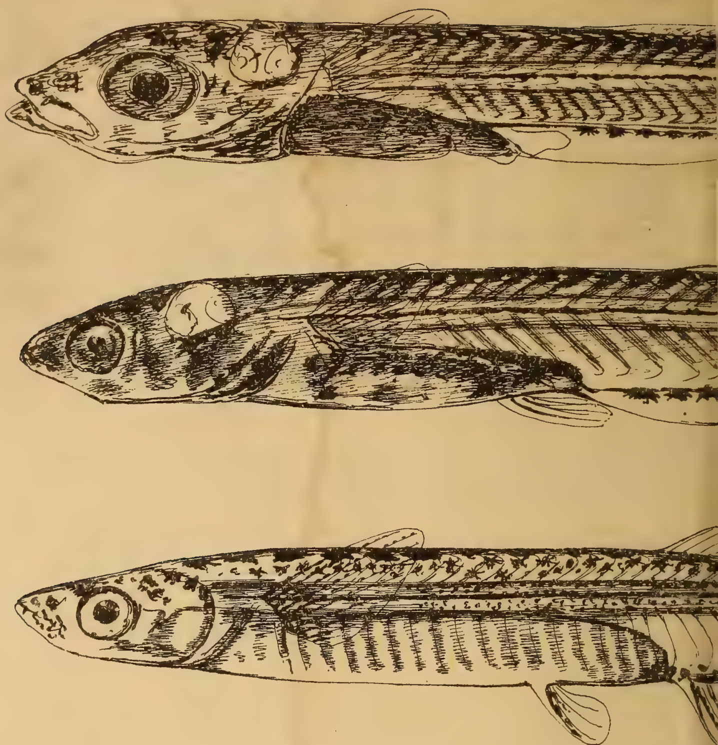

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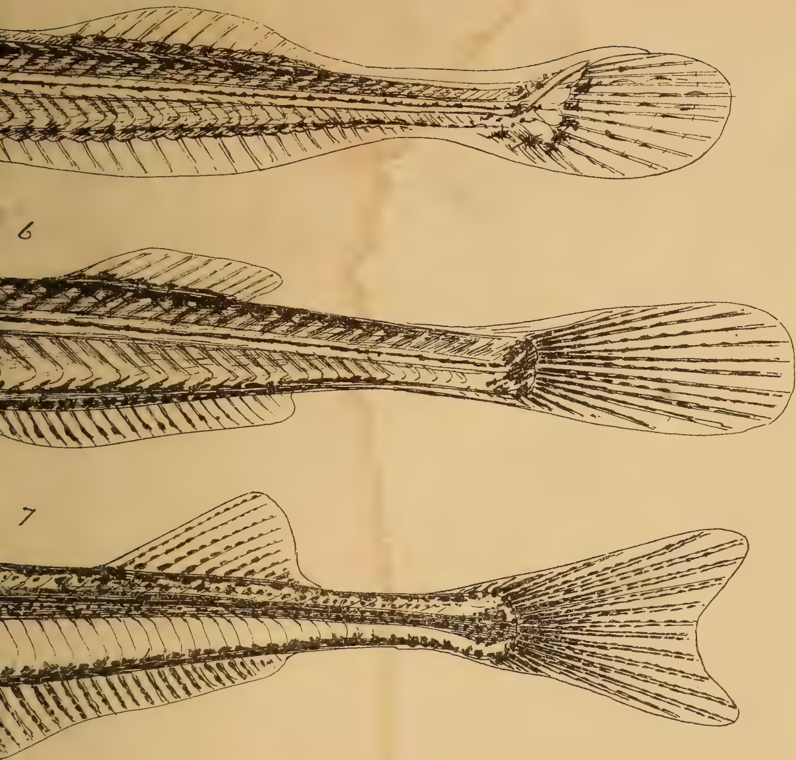
Pl. XI.



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211 Tremont St. Boston.

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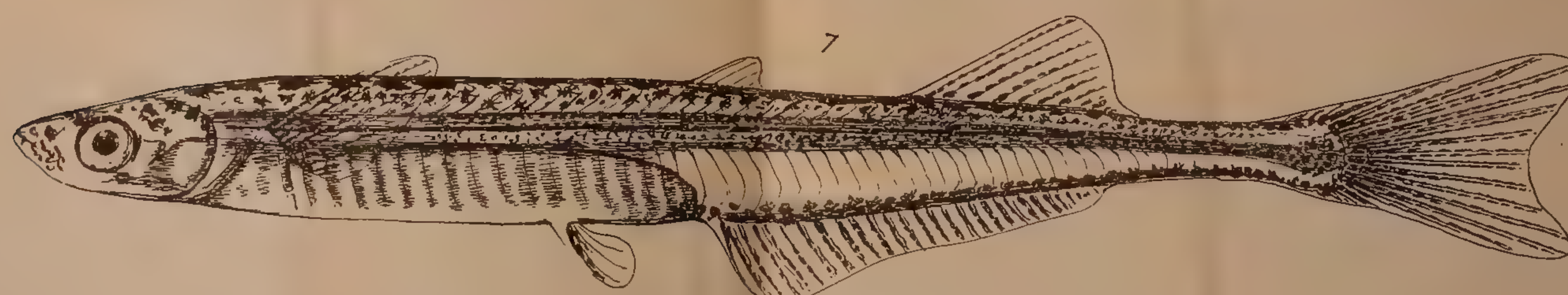

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