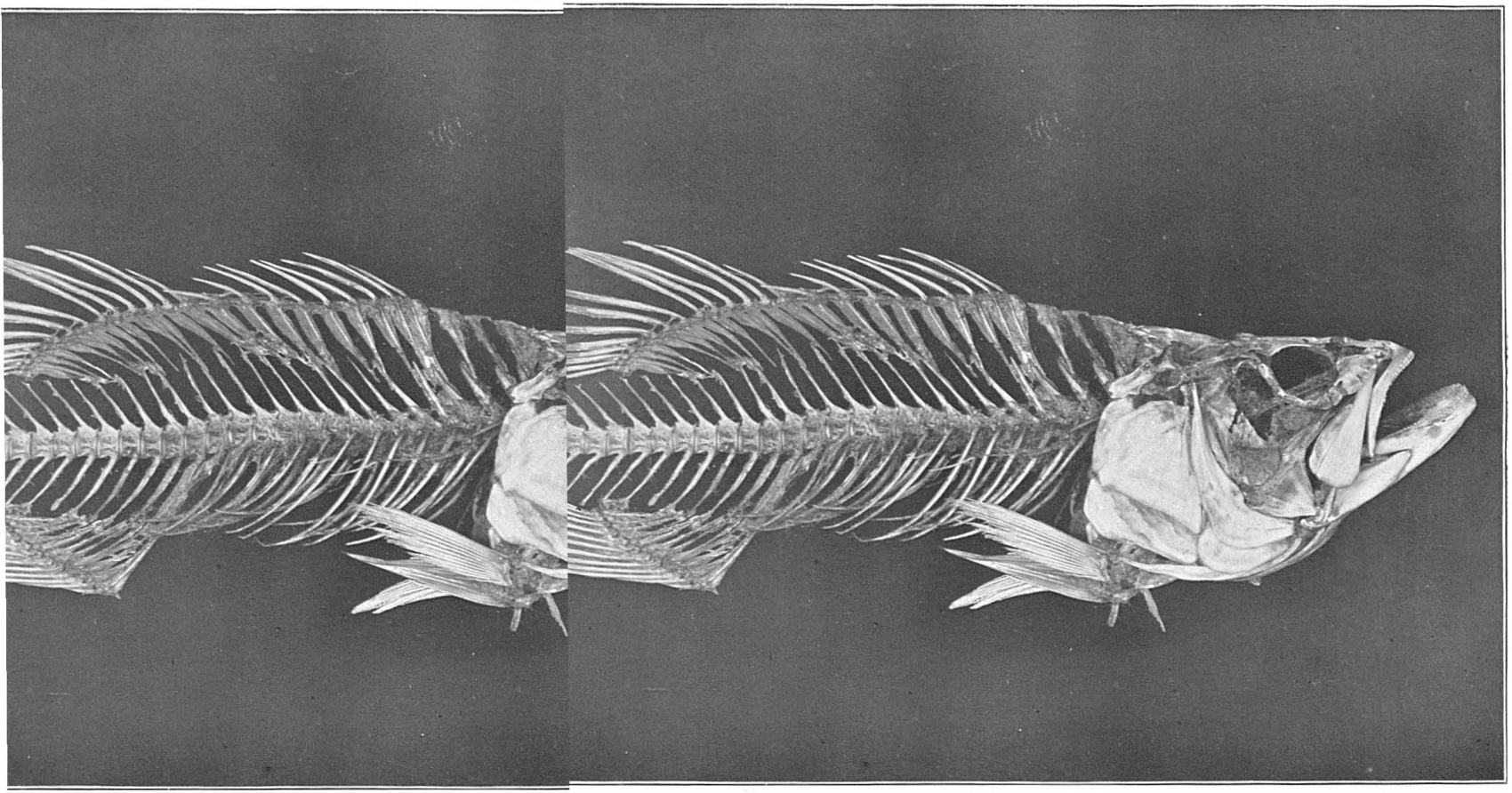

GHT LATERAL VIEW OF THE ENTIRE SKELETON OF *Micropterus dolomieu.*

eproduced from a photograph made by the author from the specimen. In
ı some few cases are slightly dislodged, as may be seen in the dorsal fin-ray

RIGHT LATERAL VIEW OF THE ENTIRE SKELETON OF *Micropterus dolomieu.*

nd reproduced from a photograph made by the author from the specimen. In some places the ligamentous attachments
ies in some few cases are slightly dislodged, as may be seen in the dorsal fin-rays, abdominal ribs, and the ventral fins.

THE SKELETON OF THE BLACK BASS.

By Dr. R. W. SHUFELDT.

Upward of twenty years ago a special interest was taken by me in the osteology of the large-mouth black bass (*Micropterus salmoides*) from having discovered in the skeletons of one or two specimens of that species a pair of free ribs articulating with the base of the skull or occiput. As this peculiar anatomical character had never been noted by me before in any of the true bony fishes (*Teleostei*), it was at the time deemed worthy of scientific record, and so, under the title of "Osteology of the large-mouthed black bass (*Micropterus salmoides*)," there was printed in Science, of Cambridge, Mass., May 2, 1884, a brief account of this interesting point in the skeleton of *Micropterus*.

It was there stated that this peculiarity "consists in a pair of freely articulated ribs at the base of the occiput. Their heads are received in a shallow facet on either side situated just above and rather internal to the foramen for the vagus nerve. Immediately below each rib occurs the projection of bone that bears upon its entire posterior aspect one of the pair of articular condyles for the first free vertebra of the spinal column. Still beneath these condyles is seen the conically concave facet for articulation, with a similarly formed surface occurring on the centrum of the vertebra just mentioned, and the one which I believe would be described as the atlas." This pair of ribs is directly in sequence with the abdominal ribs on either side. Their occurrence in this situation might be accounted for by saying that several of the anterior vertebræ of the column had been absorbed by the occipital elements. Mr. Bridge found such a condition in *Amia*, though no free ribs were present (*Journ. Anat. and Phys.*, XI, 611, London, 1877). In further commenting upon this it was added that "in the cranium of *Micropterus*, however, I should think that this would be highly improbable. Both the first and second vertebra of the spinal column of this bass support each a pair of free ribs, and a mid-series of the other abdominal ribs bears epipleural appendages. Dr. Günther states, in his account of the osteology of the *Teleostei*, in the article 'Ichthyology' of the Encyclopædia Britannica (vol. XII, 9th ed.), that 'the centrum of the first vertebra or atlas is very short, with the apophyses scarcely indicated. Neither the first nor the second vertebra has ribs.' I have a yellow perch (*Perca flavescens*) in my possession where both of these vertebræ support a pair of free ribs." In conclusion, I added that "should an examination of the young of the black bass show that none of the anterior vertebræ of the column were included with the occipital segments, but that these ribs are truly occipital ribs, then they become of interest from several points of view."

This discovery was made in March, 1884, and, as has been noted above, was published the following May, and attracted the attention of no less a distinguished

authority than Mr. McMurrich, who at once noticed it in the same periodical (Science, No. 69, 1884), but his remarks possessed upon this point but little value, inasmuch as he had not taken the trouble to examine a specimen before printing them, and therefore had no material before him when he wrote. Nevertheless they were replied to by me in another contribution to Science (vol. III, No. 72, June 20, 1884) under the title of "Osteology of *Micropterus salmoides*," and this time a figure of the left lateral view of the cranium of this species of fish was published that showed the pair of free ribs on the occiput.

Moreover, in this communication the literature of the subject was reviewed, greater detail added in regard to these free *occipital ribs*, pointing out that Mr. McMurrich was entirely wrong in his conceptions of their morphology, and that "Dr. Sagemehl, in his valuable paper on the cranium of *Amia* (*Morphologisches Jahrbuch*, IX), is very explicit in what he says about the coössification of the three vertebræ with the basi-occipital of this ganoid; and if this author had been aware of such a state of affairs as I here figure in any of the Teleostei, he certainly would have brought it forward in connection with

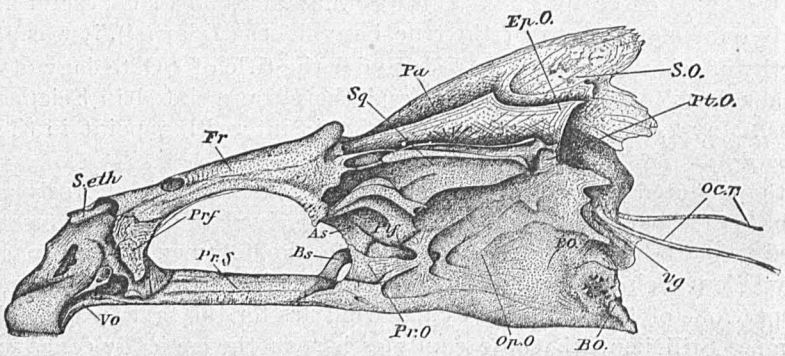

FIG. 1.—Left lateral view of cranium of *M. salmoides*, showing a pair of ribs at the occiput; life size from nature, by the author, from his own dissections. *S. eth.*, supraëthmoid; *Fr.*, frontal; *Sq.*, squamosal; *Pa.*, parietal (not well in sight); *Ep. O.*, epiotic; *S. O.*, supraoccipital; *Pt. O.*, pterotic; *oc. r.*, occipital ribs; *vg.*, foramen for vagus nerve; *E. O.*, exoccipital; *B. O.*, basi-occipital; *Op. O.*, opisthotic; *Pr. O.*, proötic; *Ptf.*, postfrontal; *As.*, alisphenoid; *Bs.*, basisphenoid; *Pr. S.*, parasphenoid; *Prf.*, prefrontal; *Vo.*, vomer.

the discussion of that subject. They are two very significant facts, that these ribs in *Micropterus* articulate *beyond* the vagus foramen and that they are apparently constant. I have since found similar structures in a specimen of *Orcynus thynnus* and this ganoid; and if this author had been aware of such a state of affairs as I here figure in any of the Teleostei, he certainly would have brought it forward in connection with

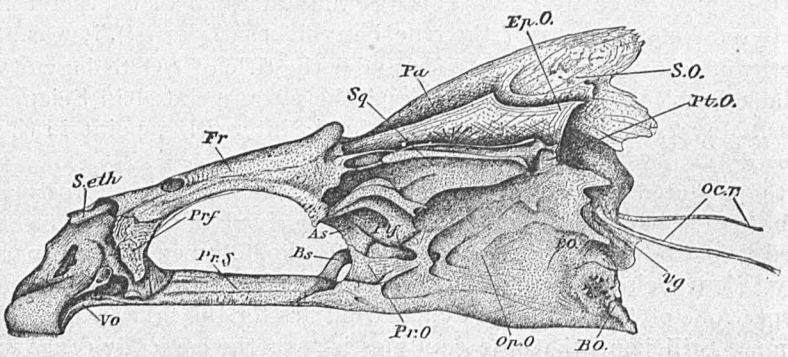

FIG. 1.—Left lateral view of cranium of *M. salmoides*, showing a pair of ribs at the occiput; life size from nature, by the author, from his own dissections. *S. eth.*, supraëthmoid; *Fr.*, frontal; *Sq.*, squamosal; *Pa.*, parietal (not well in sight); *Ep. O.*, epiotic; *S. O.*, supraoccipital; *Pt. O.*, pterotic; *oc. r.*, occipital ribs; *vg.*, foramen for vagus nerve; *E. O.*, exoccipital; *B. O.*, basi-occipital; *Op. O.*, opisthotic; *Pr. O.*, proötic; *Ptf.*, postfrontal; *As.*, alisphenoid; *Bs.*, basisphenoid; *Pr. S.*, parasphenoid; *Prf.*, prefrontal; *Vo.*, vomer.

the discussion of that subject. They are two very significant facts, that these ribs in

paper as a whole was devoted to the osteology of *Amia*, and what I had to say there about that of the black bass was only by way of comparison. While I shall take advantage of those previous researches, the present memoir is primarily intended to give an account of the skeleton of this well-known bass in its entirety, and, as will be observed, a full-page plate is likewise here given which presents a side view of the entire skeleton of the small-mouthed black bass (*Micropterus dolomieu*). This is from a photograph made from a specimen prepared by Dr. Jacob L. Wortman. Fig. 27 of my *Amia* paper gives a left lateral view of the skull of *Micropterus salmoides*, natural size, being reproduced from a drawing made by me from my own dissections. This figure is here reproduced as fig. 2 of the present memoir There is also given in

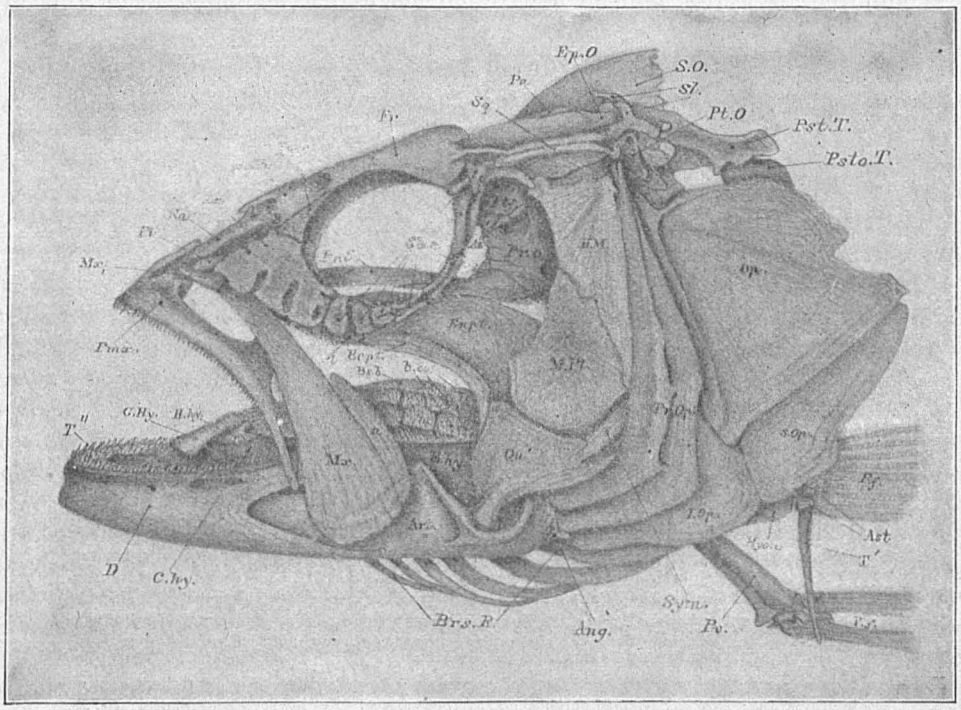

FIG. 2.—Left lateral view of skull of *M. salmoides*, with the skeleton of other parts connected with it posteriorly.

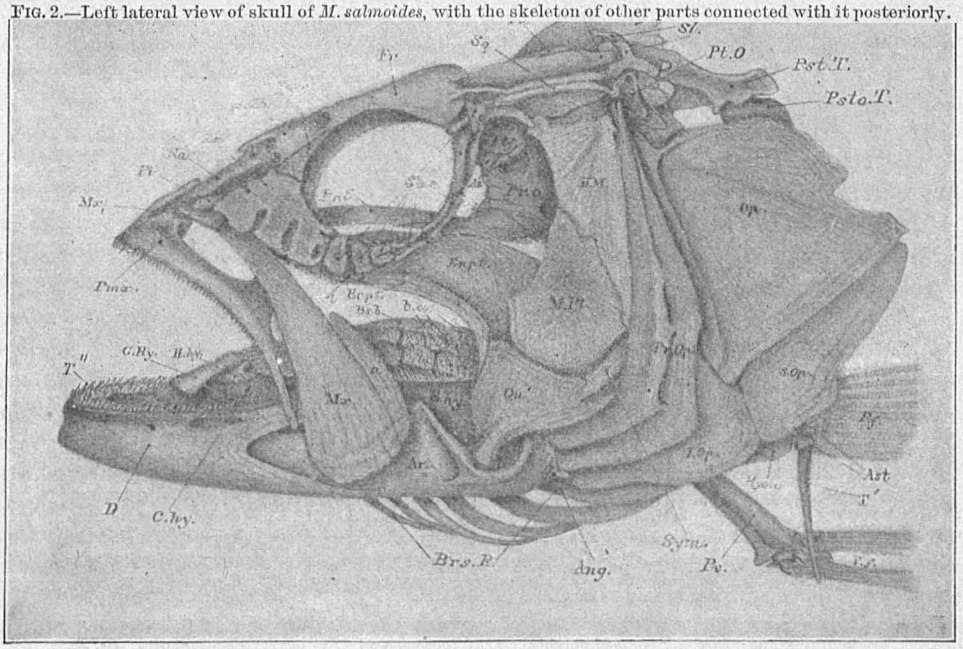

FIG. 2.—Left lateral view of skull of *M. salmoides*, with the skeleton of other parts connected with it posteriorly.

The late Sir Richard Owen, in his celebrated work on "The Anatomy and Physiology of Vertebrates," said:

> It may well be conceived, then, that more bones enter into the formation of the skull in fishes than in any other animals; and the composition of this skull has been rightly deemed the most difficult problem in comparative anatomy. "It is truly remarkable," writes the gifted Oken, to whom we owe the first clue to its solution, "what it costs to solve any one problem in philosophical anatomy. Without knowing the what, the how, and the why, one may stand, not for hours or days, but weeks, before a fish's skull, and our contemplation will be little more than a vacant stare at its complex stalactitic form."

Now, from this it will be easily appreciated that to write the "what," the "how," and the "why" of the entire skeleton of *Micropterus* would simply make a volume of several hundred pages, an achievement by no means contemplated when this brief

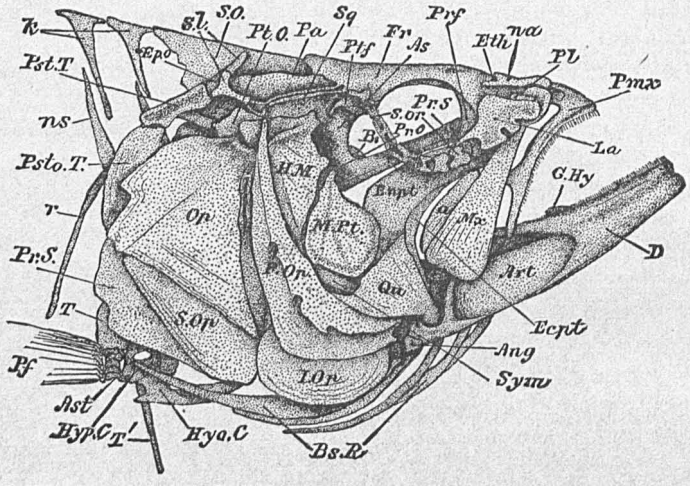

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FIG. 3.—Right lateral view of skull of *M. dolomieu*, with other bones; natural size, by the author. *Pmx*, premaxillary; *Pl.*, palatine; *na.*, nasal; *Eth.*, ethmoid; *Prf*, prefrontal; *As.*, alisphenoid; *Fr.*, frontal; *Ptf.*, postfrontal; *Sq.*, squamosal; *Pa.*, parietal; *Pt. o.*, pterotic; *S. O.*, supra-occipital; *s. l.*, supralinear; *Ep. o*, epiotic; *k*, interneural spines; *La.*, lacrymal; *Pr. s.*, para-sphenoid; *S. or.*, suborbital; *Pr. o.*, proötic; *Bs.* basisphenoid; *G. Hy.*, glossohyal; *D.*, dentary; *Art.*, articular; *Mx.*, maxillary; *a*, admaxillary; *Enpt.*, entopterygoid; *Ecpt.*, ectopterygoid; *M. Pt.*, metapterygoid; *Pst. T.*, posttemporal; *Pr. S.*, proscapula; *Pf.*, pectoral fin; *Hyo. C.*, hypocoracoid; *Op.*, operculum; *S. Op.*, suboperculum; *Ang.*, angular; *Sym.*, symplectic; *n. s.*, neural spine; *Psto. T.*, posterotemporal; *T.*, teleotemporal; *T'.*, lower teleotemporal; *Bs. R.*,

pare them in the following manner: One head is to be macerated in warm water until all the soft parts can be removed and the bones separate from each other, except those in the cranium. Each bone should be removed by itself, laid out to dry in a relative position it occupied in the skull, and identified if possible. For this latter operation the second skull is intended, and this one should also be partially macerated, but only so far as to moderately soften the tissues; then by the most careful dissection, *all* of these should be removed, and the entire osseous structure of the head left precisely as it is in life, in so far as the bones are concerned, the latter being held together only by their ligaments. This prepared skull is then properly dried. The third head, prepared exactly like the second, is longitudinally sawed in two by means of a very fine saw, passing to one side of the crest of the supraoccipital. By means of these two halves we are enabled to study the osseous parts of the interior of the brain case and the bones at the anterior extremity of the skull.

Fig. 3 of the present paper, as well as the illustration of the skull of the large-mouthed black bass in fig. 2, will give an idea as to how the bones are normally related to each other, and as shown in the heads of the two species of *Micropterus* prepared by the second method. Fig. 21 of my memoir on *Amia calva* shows the head, or rather the cranium, of a yellow perch (*Perca flavescens*) longitudinally bisected in order to bring into view the bones in the brain case.

As has been stated, if the head of this bass is allowed to macerate in water for a sufficient length of time all the more loosely attached bones, including the occipital ribs (fig. 1, *oc. r.*), will come away and separate from each other. This leaves the *cranium* all in one solid piece as shown in fig. 1. This, as has likewise been said, is composed of its own bony cranial segments, which require more protracted maceration to separate them. This *cranium*, and many fish possess one a good deal like it, is of a pyramidal form, the base being formed by the occiput and the apex by the vomer (*vo*), which is here produced downwards as a prominent beak, being rounded in front, and thickly studded with fine teeth upon its inferior surface.

A very noticeable feature of the cranium are the orbits. These are large and in no way separated from each other by an osseous medio-longitudinal plane standing between them. Above, they have a wide, arched roof, concave from before, backwards; while below there is but the median rod, composed principally of the vomer (*vo.*) and the parasphenoid (*Pr. S.*). Other bones entering into the bounding walls of the orbits are the frontals above (*Fr.*), the prefrontals anteriorly (*Prf.*), the alisphenoids (*As.*), and the postfrontal (*Ptf.*). On top of the cranium, behind, and occupying its hinder half, there are five conspicuous crests, a median one and two lateral ones on each side. These are well shown in fig. 1, and have been fully described in my *Amia* memoir. They vary greatly in the crania of different species of fishes, being entirely absent in some species and very prominent in others.

In the common cod (*Gadus*), for example, the median crest is thick, strong, and high, and produced far backwards and to the front to a point over the center of the orbits. Again, in the black sea-bass (*Centropristes striatus*), of which I have prepared one or two perfect skeletons, these crests are more as in *Micropterus*, but by no means exactly the same, as these two species belong to very distinct families. At the back of the cranium there are to be noticed chiefly the circular, conically concave facet for the atlas vertebra, with above it, one upon either side, the pair of zygapophysial facets for the corresponding ones on the same vertebra. These have above them

again, in the middle line, the somewhat small subcircular foramen magnum, inclined to be subcordate in outline in some specimens. Often in the common cod, always in old individuals, I believe, this first or atlas vertebra fuses with the base of the cranium, and its long neural spine runs up nearly to the top of the supraoccipital crest, being in contact with the posterior margin of the same for the entire way.

Apart from the cranium the chief features of the skull consist in the jaws, the upper one being formed by the maxillary (*Mx.*) on either side, and the præmaxillary and its fellow in front bearing the teeth (*Pmx.*) (fig. 3). These structures have been fully described in the *Amia* memoir, and the two figures there devoted to them are here reproduced as figs. 3 and 4. Attention is also invited to fig. 5, for that, taken in connection with fig. 3 of the present paper, will clearly show the relations of another group of bones of the skull, namely, the opercular bones, or those of the gill-covers (*Op.*, *P. Op.*, *S. Op.*, and *I. Op.*). Considerable attention has already been paid to these in the *Amia* contribution. In connection with them will be found the *symplectic*, a very interesting element in many bony fishes (fig. 3, *Sym.*). Then there are the bones of the *suspensorium*, connecting the cranium with the lower mandible (*H. M.*, *Sym.*, and *Qu.*). Of these, through the intervention of the *interhyal*, the hyomandibular arch has also suspended from its lower extremity the hyoid arch, while its upper and posterior extremity also articulates with the *operculum*.

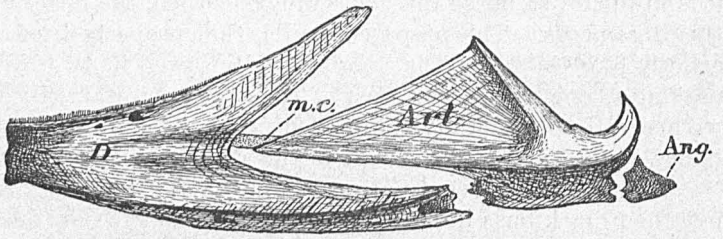

FIG. 4.—Left lateral view of mandible of *M. salmoides*. Natural size, by the author, from his own dissections, the various bones having been pulled apart to show their entire shape. *D*, dentary; *m. c.*, Meckel's cartilage; *Art.*, articular; *Ang.*, angular.

Again, in the *pterygo-palatine* arch of this bass we meet with the *metapterygoid*, the *ento*, and *ectopterygoid* and the *palatine*, and the relation of these bones to each other are shown in fig. 3 of the present paper and devoted to them are here reproduced as figs. 3 and 4. Attention is also invited to fig. 5, for that, taken in connection with fig. 3 of the present paper, will clearly show the relations of another group of bones of the skull, namely, the opercular bones, or those of the gill-covers (*Op.*, *P. Op.*, *S. Op.*, and *I. Op.*). Considerable attention has already been paid to these in the *Amia* contribution. In connection with them will be found the *symplectic*, a very interesting element in many bony fishes (fig. 3, *Sym.*). Then there are the bones of the *suspensorium*, connecting the cranium with the lower mandible (*H. M.*, *Sym.*, and *Qu.*). Of these, through the intervention of the *interhyal*, the hyomandibular arch has also suspended from its lower extremity the hyoid arch, while its upper and posterior extremity also articulates with the *operculum*.

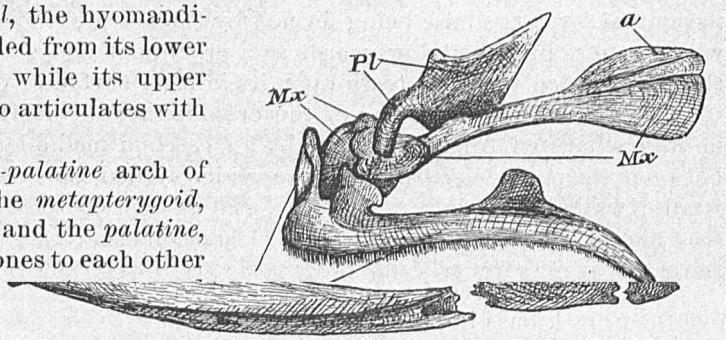

FIG. 4.—Left lateral view of mandible of *M. salmoides*. Natural size, by the author, from his own dissections, the various bones having been pulled apart to show their entire shape. *D*, dentary; *m. c.*, Meckel's cartilage; *Art.*, articular; *Ang.*, angular.

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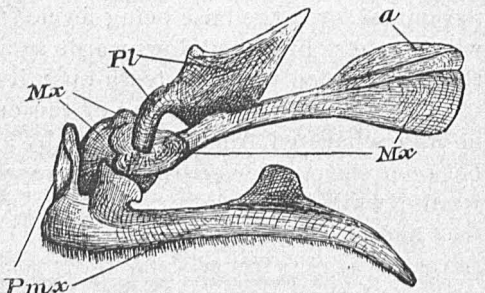

In the latter, in *Micropterus*, we have a *posttemporal* (*Pst. T.*), a *posterotemporal* (*Psto. T.*), a *teleotemporal* (*T.*), a *lower teleotemporal* (*T'.*), a *hypocoracoid* (*Hyo. c.*), a *hypercoracoid* (*Hyp. c.*), and a *proscapula* (*P. Sc.*). Now the lateral or the *pectoral fins* in this bass are connected with the shoulder girdle through the intervention of four little bones, called *actinosts* (fig. 7, *Ast.*); they are very small, graded in size, and are formed somewhat like little hour-glasses or dice-boxes, being enlarged at their articular ends and constricted at the middle. Anteriorly these actinosts articulate with the posterior border of the conjoined hyper- and hypo-coracoids, while posteriorly they afford support and attachment for the bony rays of the pectoral fin (*Pf.*). In the several specimens of black bass I have dissected and others I have examined,

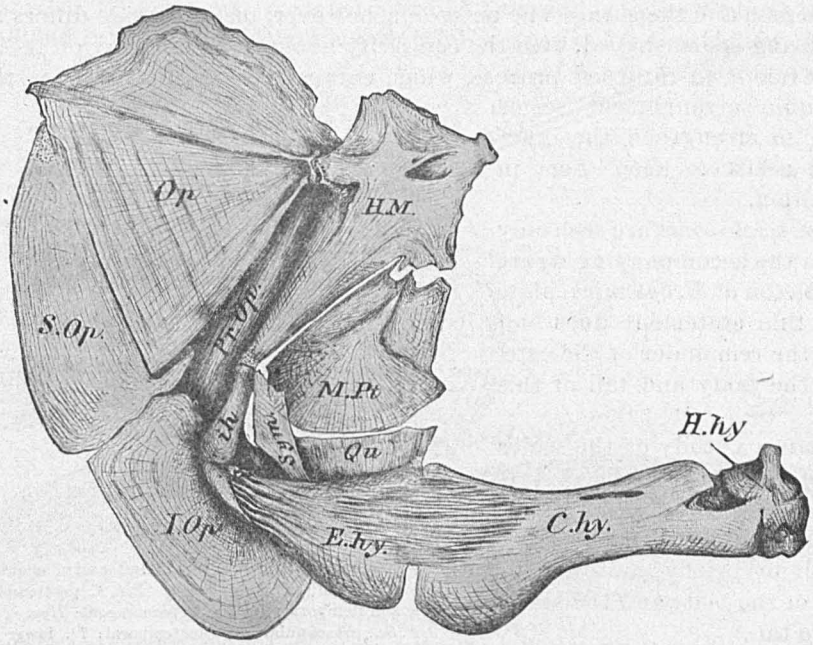

FIG. 6.—Inner aspect of opercular bones, hyoid, symplectic, and other elements of *M. salmoides*. Left side, natural size, by the author, from his own dissections. *Op.*, operculum; *S. Op.*, suboperculum; *Pr. Op.*, preoperculum; *I. Op.*, interoperculum; *H. M.*, hyomandibular; *M. Pt.*,

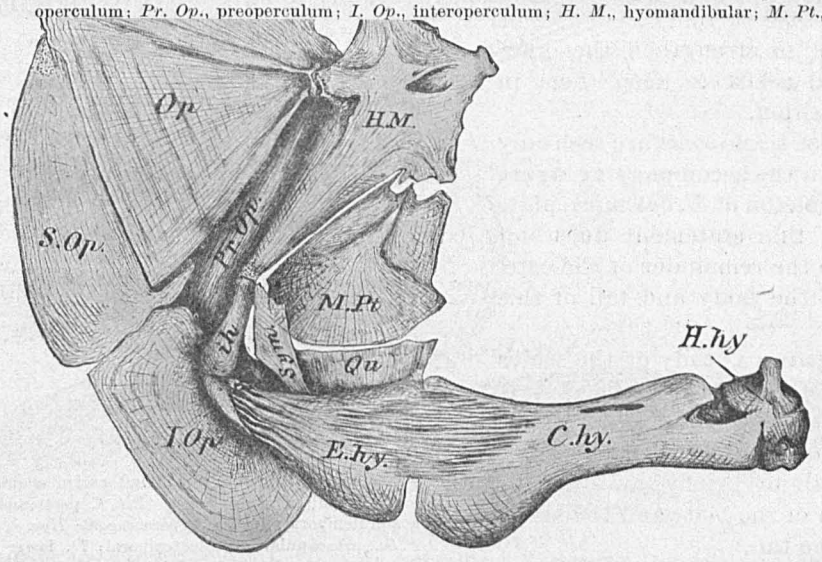

FIG. 6.—Inner aspect of opercular bones, hyoid, symplectic, and other elements of *M. salmoides*. Left side, natural size, by the author, from his own dissections. *Op.*, operculum; *S. Op.*, suboperculum; *Pr. Op.*, preoperculum; *I. Op.*, interoperculum; *H. M.*, hyomandibular; *M. Pt.*, metapterygoid; *Sym.*, symplectic; *ih.*, interhyal; *Qu.*, quadrate; *E. hy.*, epihyal; *C. hy.*, ceratohyal; *H. hy.*, hypohyal. These represent the actual arrangement and relations of these bones in teleostean fishes generally.

borders develop a raised rim, and the planes of the surfaces, contributed by the two bones superiorly on either side, look upward and outward, the reverse being the case, of course, beneath. The postero-external angles, as well as the hinder border, are thickened and undulating for the articulations of the heads of the ventral fin-rays. There is, also, a characteristic process developed mesially on this border, into the formation of which each pelvic bone takes an equal share; above it is bifid, directed upward and backward, and compressed anteroposteriorly; below it is peg-shaped and directed in the same degree forward and downward.

I fail to find any bony nodules representing the actinosts between the ventral fin-rays and the pelvic bones in this fish; and the rays themselves seem to be constructed upon the same plan as the pectoral ones, being retained in their positions by firm ligaments and the skin. The outer one, however, on either side differs materially in form, being spoon-shaped, with the concavity against the next ray on its inner side. It also develops an inturned process, which curves over the next two or three rays. This double arrangement seems designed to strengthen the inner rays and assist to keep them in their position.

These *pelvic bones* are seen only in part in the accompanying figure of the skeleton of *M. dolomieu* (plate 44), but this statement does not apply to the remainder of the osteology of the body and tail of this bass.

Omitting a study of the scales of *Micropterus*, which closely resemble those of most other forms of the higher teleostean fishes, we have still to briefly consider the skeleton of the body and the skeleton of the tail.

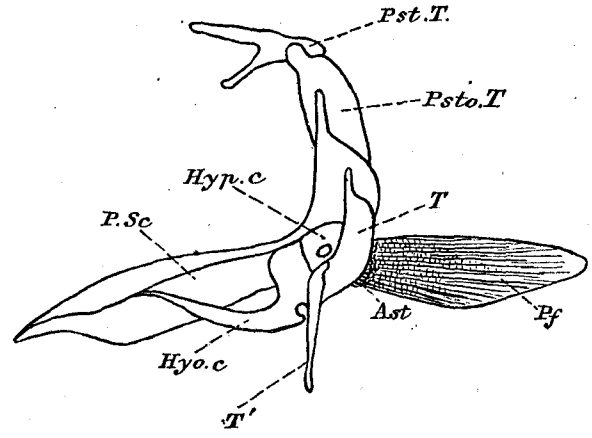

FIG. 7.—Sketch of the inner aspect of left half of shoulder girdle and pectoral limb of *M. salmoides*. *Pst. T.*, posttemporal; *Psto. T.*, posterotemporal; *Hyp. c.*, hypercoracoid; *Hyo. c.*, hypocoracoid; *P. Sc.*, proscapular; *T.*, teleotemporal; *T'.*, lower teleotemporal; *Ast.*, actinosts; *Pf.*, pectoral fin.

Counting the one from which the *urostyle* springs, *Micropterus* seems invariably to have *thirty vertebræ* in its spinal column. When I make this statement I am aware of the fact that in my paper on *Amia calva* thirty-two was the number reckoned, but after carefully recounting these on two perfect skeletons now before me, representing both species of the genus, I am satisfied that there are but thirty of these bones. Fifteen of these vertebræ belong to the abdominal portion of the column, and each one supports a pair of ribs, all of which in their turn, save the last *five pair*, have *epipleural appendages*. The atlantal pair articulate with the vertebra at the very base of the neural arch, but as we proceed backward they gradually recede from this position so as to finally spring from *beneath* the transverse processes on the under side of the vertebra. This condition is characteristic of a great many of the osseous fishes. The neural and hæmal arches of this form are completely anchylosed with the vertebral elements, and in the best-developed segments, both superior and inferior, post- and pre-zygapophyses are present.

As the accompanying figure, shown in plate 44, of the skeleton of this bass is reproduced from a photograph of a carefully dissected and dried skeleton, it will be observed that a little ligamentous material is remaining, and some of the bony fin-rays and spines are very slightly unparallel, but this fact will lead no one astray, as it is quite evident which bones have become so while the skeleton was drying. The arrangement of these *osseous fin-rays* and *interspinous bones* practically agrees with those elements as we have long known them to exist in all ordinary bony fishes, as in the common yellow perch for example (*Perca*).

The skeleton of the tail in *Micropterus* is of the typical *homocercal* type, and develops a very completely ossified *urostyle*, directed upward and backward at an angle of about 45 degrees, with a markedly straight vertebral column, as is plainly to be seen in plate 44. The osseous expanded portion of the tail is in the vertical plane, and is thus modified in order to give support to the bony rays of the caudal fin. Possibly

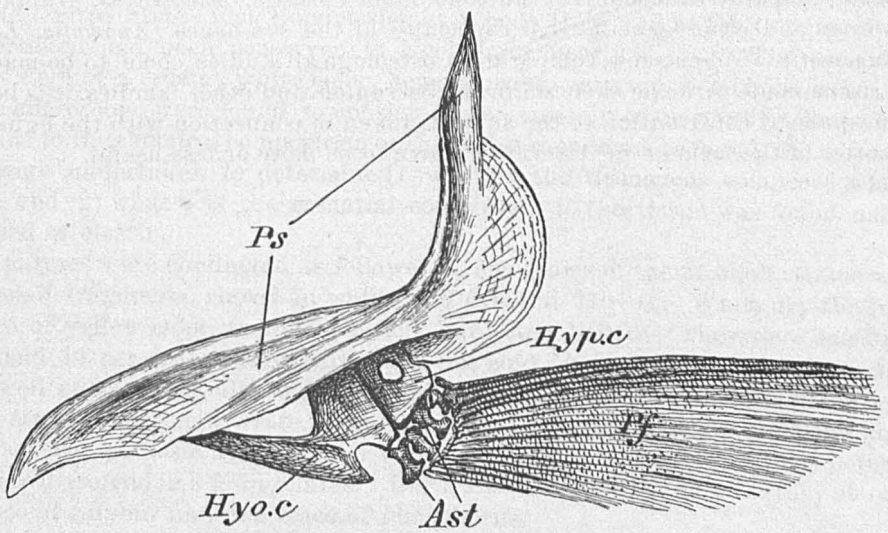

FIG. 8.—Outer aspect of part of shoulder girdle and pectoral fin of *M. salmoides*. Natural size and drawn by the author from his own dissections. *Ps.*, proscapular, with other lettering the same as in fig. 6.

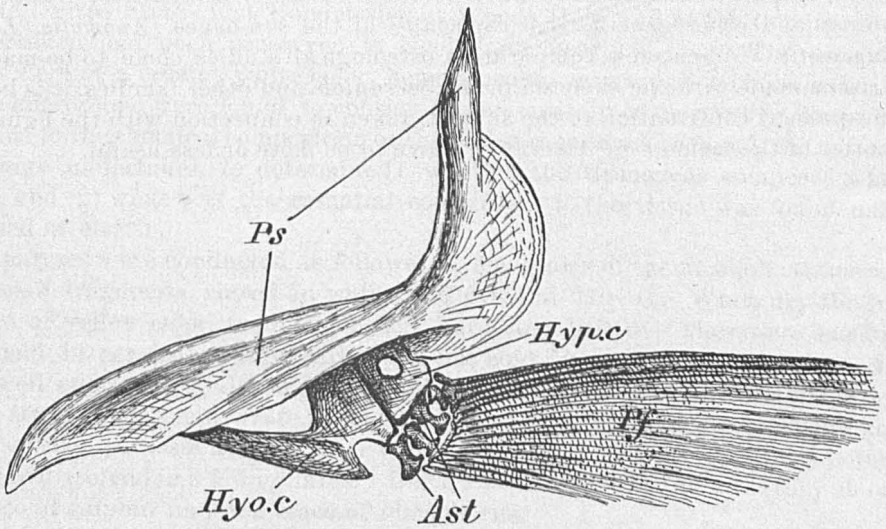

FIG. 8.—Outer aspect of part of shoulder girdle and pectoral fin of *M. salmoides*. Natural size and drawn by the author from his own dissections. *Ps.*, proscapular, with other lettering the same as in fig. 6.

I may formerly have considered that this expanded portion contained *two vertebræ*, and it may. In this case the count for *thirty-two* vertebræ in the column would be

seems designed to afford additional surface and leverage for the origin of the muscle that controls the movements of the caudal fin or tail.

This is all that need be said in the present paper in regard to the osteology of *Micropterus*. My object in writing this contribution has been to collect together the scattered accounts of the various parts of the skeleton previously given by me in different publications, and to review and correct any errors that may have crept into my previous work upon this form. The paper, it is hoped, will prove useful in connection with a general study of the comparative osteology of the entire family of the *Centrarchidæ*, which some day may be either undertaken by myself or some other anatomist. That such a research should be made and published no one has any doubt.

Doctors Jordan and Evermann, in their Fishes of North and Middle America (Part I, pp. 984–1012), have treated quite fully of the species and genera of this group, and have given us a very useful classification of them. Nevertheless we stand much in need of full and comparative accounts of the skeletons of *Pomoxis*, *Centrarchus*, *Acantharchus*, *Ambloplites* and other genera, and especially of the sun-fishes, *Apomotis*, *Lepomis*, and *Eupomotis*. When such comparative osteological studies come to be made, and comparisons made with the skeleton in the *Serranidæ* and other families, it is believed that the present contribution to the subject, taken in connection with the figures and text matter of the memoir on *Amia*, will prove to be more or less useful.