PART II.

Henricus Franque, doctor of medicine and surgery, published his famous monograph, entitled Amiæ Calvæ, Anatomian Descripsit Tabalaque Illustravit, in Berlin in 1847. The pamphlet form of this unique paper, familiar to all anatomists who have worked upon or are interested in the osteology of fishes, now lies before me. It extends through seven pages, written in Latin, upon the skeleton of *Amia calva*, with references to some of the soft parts; description of figures in the plate, and the plate itself. This latter presents eleven figures, four of which are devoted to the skeleton; Fig. 9 to a scale; while the remainder illustrate various things in the soft anatomy. Fig. 1 is an upper view of the skull, with all the "cover-bones" retained in their normal positions. In Fig. 2 we are presented with a left lateral view of the entire skeleton of a moderately sized fish of this species. Fig. 3 gives an inferior view of a part of the cranium, with the entire hyobranchial apparatus removed.

These figures are all well done, and in a style peculiar to themselves, bold and clear, though lacking in some points of minute detail. Three of these figures have been copied for me by Mr. H. L. Todd, and reduced by photograph for the purpose of adding to this article the figure of the lateral view of the entire skeleton. This will be valuable in showing the general relation and arrangement of the bones.

The excellent article of Bridge[48] is good as far as it goes, but he treats of the skull of *Amia* only, and we still have to resort to other works to study the extremely interesting points in the remainder of the skeleton. Moreover, as Mr. Bridge's paper was published in the Journal of Anatomy, it is not particularly available to a very large number of American workers. Indeed, this valuable periodical is not subscribed for by nearly as many of our libraries and institutions as it should be, nor as it deserves to be. To present a good account of the entire history of the skeleton of *Amia* is the principal object I had in view upon undertaking the present paper. Just previous to Dr. Sagemehl's paper, which constitutes Part I of this memoir, Bridge very truly tells us, in his article, when reviewing all that anatomists had done with the skeleton of this Ganoid up to 1877, that "the cranial osteology of living Ganoids has been hitherto but partially investigated; and even those genera that have been described by the older anatomical writers will abundantly repay renewed investigation now that the researches of Parker, Gegenbaur, and Huxley have thrown so much light upon the morphology of the vertebrate skull."

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[48] Bridge, T. W.—The Cranial Osteology of Amia Calva. Jour. of Anat., normal and Pathol. Vol. XI, Pt. IV, page 603. Edinburgh and Lond., July, 1877.

"Agassiz,[49] it is true, has given to us an elaborate account of Lepidostens, and the earlier description of Polypterus by H. Müller[50] has been supplemented by Dr. Traquair's[51] opportune paper; while to Dr. Günther and Prof. Huxley[52] we are indebted for exhaustive accounts of the skeleton of Ceratodus."

"On the other hand, I am not aware that, beyond the more or less brief accounts to be found in John H. Müller's *Vergleichende Anatomie der Myxinoiden*[53] we have any detailed descriptions of Spatularia, Acipenser, or Amia; and the anatomical student who may wish to acquire any complete knowledge of these genera must content himself with the above-mentioned references, or with such facts as he may be able to glean from such anatomical text-books as Huxley's *Manual of Vertebrata*, Owen's *Comparative Anatomy*, or the *Grundzüge der Vergleichenden Anatomie* of Gegenbaur. More especially is this true of *Amia*. The zoological characters of this genus have been described by several Zoologists. Vogt[54] first detected its true position among the Ganoids and removed it from the Clupeoid Teleostei, with which it had been placed by Müller;[55] and Hyrtl[56] and Franque[57] have described the generative organs and visceral anatomy. But I am not aware that there exists any connected account of the osteology of the skull of this genus, or that the skull has been figured."

Jordan and Gilbert place the *Amias* in the order Halecomorphi, and the single species known, the subject of this paper, *Amia calva*, in the only family in the order, Amiidæ. These authors give as the geographical range of this fish the great lakes and sluggish waters from Minnesota to Virginia, Florida, and Texas. In describing the external appearance of *Amia calva*, they state that it is of a "dark olive or blackish above, paler below; sides with traces of dark reticulate markings; lower jaw and gular plate often with round blackish spots; fins mostly dark, somewhat mottled. Male with a round black spot at base of caudal above, this surrounded by an orange or yellowish shade. In the female this spot is wanting."[58]

On the 12th of February, 1883, I took in a seine near New Orleans, La., four specimens of *Amia*. Two of these were alike; they were very dark above, the ocellation at the base of the tail, large, very black, and the emargination a brilliant buff color. But what was still more strik-

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[49] Agassiz, Poiss, Foss, Tom. 11.

[50] *Abhandl, A. K., Wiss.*; Berlin, 1844.

[51] Journal of Anatomy, Vol. IV.

[52] Phil. Trans. 1871; 5 Proc. Zool. Soc. 1876.

[53] *Vergl. Anat. d. Myx.*, Berlin, 1835.

[54] *Annales des Sciences Naturelles*, Tom. XXIV, Heart and alimentary canal figured.

[55] Müller's paper, "*Sur les Ganoides et sur las classification naturelle des Poissons,*" is translated by Vogt in the XXV. vol. Ann. Sci. Nat.

[56] *A. K. Wiss. Wien.*, 1855.

[57] *Amiæ calvæ Anatomia*, Berlin, 1847.

[58] Jordan & Gilbert. *Syn. Fishes of North Amer.* Bull. U. S. Nat. Mus., No. 16, 1882.

ing, and what differs from Jordan and Gilbert's description, the pectoral and ventral fins in these two specimens were of a bright Prussian green. The two remaining specimens were smaller fish, much lighter in color, being sort of a clay-brown, with the fins of a similar shade, and less mottled than the others, with the caudal ocellation present, only not so large or brilliant.

OF THE GANOID PLATES.

This series of investing bones of the cranium have been so thoroughly described by Sagemehl above, and by Bridge in the Journal of Anatomy, that I shall content myself with a running review of them, with special references to the fine specimen before me, from which I made my drawing. (Plate IV, Fig. 16.)

The most extraordinary thing about Bridge's description is that he seems to have secured a specimen for his dissection, wherein the parietal dermo-plates were in one piece, without any trace of a suture between them. To the united bone this anatomist gave the name of the dermo-supraoccipital, which is commented upon by Dr. Sagemehl in Part I of this paper.

It seems hardly possible that Bridge could have been mistaken in this matter, as he made special search for the sutural trace dividing them, aware as he was of Owen's already having mentioned that two plates occupied the site of his dermo-supraoccipital. Moreover, the sculpturing would be different on a single plate, as the rugosities would radiate from a single center to the borders as they do in the other plates.

In all the specimens that I have examined, including the one before me, these parietal plates, existed as described by Dr. Sagemehl, even to the detail of the suture not terminating in the median line posteriorly as shown in Plate I, Fig. 1, *Pa*. This was the condition found and described also by Franque, who gives a very good representation of a superior view of the dermal plates in this fish. (Plate II, Fig. 7.)

The arrangement in my specimen is precisely the same as in the specimen drawn by this latter anatomist, the right-hand plate extending more anteriorly and the suture between the bones deflected to this side posteriorly. Figure 7 should show, however, more marked serrations of the margins of the bones anteriorly, as they are invariably found to be so in nature.

External to the parietal plates on either side we find a longer and narrower bone, sculptured as the rest, which is the *squamosal*. (Plate IV, Fig. 16, *Sq*.)

Behind the squamosals and parietals, the hinder margins of which form nearly a straight suture across the skull, we find the *supratemporals*, two rather long, triangular plates placed transversely with their blunted apices meeting in the median line (Fig. 16, *S. tp*.). These two plates shut out from superior view the two forked limbs of the posttemporals upon which they rest.

Of all these plates on the superior aspect of the skull the frontals are by far the largest. Posteriorly they articulate with the squamosals and parietals as already described, while on either side they make room for the postorbitals. (Plate IV, Fig. 16, *Fr.*)

Their anterior bodies are separated from the hinder margins of the nasals by a considerable interspace. This is bridged over by a delicate membrane, which is continuous with a similar tissue that extends across the gap between the frontal and lacrymal on either side (Plate IV, Fig. 16, *jn.*). In prepared skulls where this structure is allowed to remain and dry it becomes very thin, and by cutting through it we expose the posterior narial apertures and the primoidal cranium beneath.

The nasals are oval bones that articulate with each other in the median line by means of a markedly dentate suture. Wedged in between them anteriorly we find the azygos and subtriangular ethmoid (Plate IV, Fig. 16, *Na.* and *Eth.*). Upon the outer side of each nasal, in my specimen, there lies a smaller plate, of a spindle-like form, that corresponds to the plate described by Bridge as the preorbital, although its posterior end occupies a point only about half-way distant between the teeth and the anterior margin of the orbit (Fig. 16, *An.*). This author also figures a small ossification below this preorbital, which does not occur in my specimen. Dr. Sagemehl seems to have found a like structure, but attached no significance to it.

Bridge describes the ethmoid very concisely when he says, "The dermo-ethmoid (*Eth.*) is somewhat T-shaped, with its anterior transverse part slightly concave from side to side. It overlies the prenasal process and the premaxillæ. Each end of the transverse part is in contact with the preorbital bone, while the stem of the T passes backwards between the nasals, separating them for about a third of their extent."[59]

The periphery of the orbit is subelliptical in outline, and six of the dermo-plates contribute to its boundary. The upper half of the circumference is formed by the free margin of the frontal, as the vault of the orbital cavity is made by this bone. Its lower half is bounded by the five remaining plates, of which the superior postorbital is the largest, and the rear suborbital the smallest, though the latter contributes the greatest share to the peripheral circumference.

The most anterior bone of this suborbital chain, I call, in common with other anatomists, the *lacrymal*, as it is quite constant in the class, both in the position it usually occupies and its occurrence. The two smaller plates, immediately beneath the orbit, are true suborbitals, and their number and arrangement vary greatly throughout all fishes.

Behind the large triangular *postorbitals*, we find a group of small bone-plates, forming a vertical chain, that fills in the space between these bones and preoperculum (Plate IV, Fig. 16 *k*, *k′*, *k″*). These small plates seem to vary in their size, form, and number, for on the opposite

[59] Jour. of Anatomy, July 1877, page 608.

side of my specimen I find but one of them, which is situated just below the squamosal and shaped like the one marked *k''* on the right side.

All four of the *opercular bones* are present and thoroughly developed. (Fig. 16, *Op.*, *S. op.*, *I. op.*, *and Pr. op.*)

The *preoperculum* is a long, narrow, crescent-shaped bone, that touches the squamosal above and contributes to the articulation for the mandible below. Only a narrow strip of its external surface, just within the posterior border, along its entire length, shows the sculpturing common to the other bones. Beyond this its surface is smooth, and its anterior border makes a very intimate union with the hyomandibular and symplectic.

The three remaining opercular bones are beautifully sculptured all over their external surface, and remind one not a little of those rugose surfaces as seen in some of the handsome marine shells. Of these bones the *operculum* is by far the largest; it articulates with an elongate facet, placed upon the upper and posterior angle of the hyomandibular. In common with the remaining two of the group, its anterior border is overlapped by the preoperculum. The upper and lower margins of the *suboperculum* are closely applied throughout their entire extent to the opposed margins of the operculum and interoperculum. This element is of a more irregular form than either of the others, its upper border being deeply concave to admit the rounded lower anterior angle of the operculum, while the inferior one is quite straight. Against this last, the base of the *interoperculum* is applied, this latter plate having somewhat the form of an isosceles triangle, with its rounded apex directed below. The inner surfaces of these three last opercular bones are smooth and unmarked by any sculpturing, as their opposite sides are. A rounded ridge crosses the suboperculum obliquely, extending from its upper posterior angle to the lower anterior one. Anteriorly, the extremity of the *maxillary* (Fig. 16, *Mx.*) is bent towards the median line, and articulates in a socket immediately behind the outer end of the premaxillary, being covered over above by the preorbital and lacrymal plates. Its entire lower margin is armed with a single row of thickly set teeth. These decrease in size from before, backwards, and, like the larger ones on the premaxillary are very sharp and gently curved inwards. The hinder half of the upper border of the maxillary supports an additional thin plate of bone, as seen in so many of the Teleostei. This is the *admaxillary*, and its form is very much the same as in bony fishes (Fig. 16, *a*). Both the maxillary and admaxillary are sculptured on their outer surfaces after the fashion of the other ganoid plates described above.

Bridge says: "In comparing the skull of *Amia* with the skulls of certain of the Siluroidei, and notably with that of Clarias, it is interesting to notice that, in addition to the more obvious and less important points of resemblance between the two genera necessitated by the flattened condition of the head and a foreshortening of the prefrontal region, there is a close agreement between them in the number and relations of their ganoid plates."[60]

Of the Mandible.—A lateral figure of this very complex bone presents us with a partial view of four of the elements that enter into its composition (Fig. 16). As usual, the chief part of the ramus is made up by the *dentary* (Fig. 16 and Pl. V, 17, *D* or *d*). This bone expands behind to articulate with the angular and surangular on lateral view, while internally this expanded part is broadly concave, which concavity is arched over by the splenial. Anteriorly, it meets the fellow of the opposite side in a rather strong symphysis, the two bones developing a single row of powerful teeth. These are of a conical form, curved backwards, and very sharp at the apices. In Fig. 16 is shown where two of these teeth have been shed, and the shallow pits they leave behind them. The row of smaller teeth beyond, as shown in this figure, belong to the splenial or the plates connecting it with the symphysis. Upon lateral view we may also see the angular and surangular to the extent shown in Fig. 16, as well as the ossification marked *z* to be described further on.

The *angular* is the next in point of size to the dentary. Its outer surface is convex and sculptured in the same manner as the ganoid plates, while posteriorly it forms part of the articulation of the jaw.

Above this element we find the *surangular* splint, which is carried up to form the coronoid process, to be tipped with cartilage at its apex.

Bridge, after his careful investigation of the mandible, says, in his paper quoted above, that it "is an unusually complex structure, as each ramus consists of not fewer than fourteen distinct elements. Meckel's cartilage persists as a thin axial band of cartilage. Its distal end is ossified, and forms a small cylindrical mento-meckelian ossicle (Plate V, Fig. 17 of this paper, *mt. mk.*), which lies in a groove on the inner side of the symphysial end of the dentary (*d*). The proximal end of the cartilage is the seat of at least four distinct ossific centers. Of these, three are arranged in a linear series proceeding from the angular extremity of the mandible. These are referred to in the annexed plates [figures] as *a*, *b*, and *c*. Of these the ossicles *a* and *b* form the anterior and posterior boundaries of the articular cup for the quadrate, and are separated from each other by that portion of Meckel's cartilage which forms the bottom of the cup. The bone marked *c* is much smaller than the other two. That part of Meckel's cartilage adjacent to the articular cup is produced vertically upwards and forwards into a well-marked 'coronoid process' (*cr*). The base of this process is the seat of an ossification (*b*) which forms the outer side of the articular cup, and fits into the cup-shaped distal end of the preoperculum. Thus these three bones, *a*, *b*, and *c*, contribute to the formation of the concave articular surface for the quadrate."

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[60] *Ibid.*, page 609.

"Hitherto it has been currently stated in anatomical text-books that the mento-meckelian bone at the distal end, and the articular bone at the proximal end of Meckel's cartilage, were the only elements of the mandible really formed by ossification of the cartilage itself, yet in Amia there can, I think, be but little doubt that at least four, and probably five, ossific centers are developed in the axial cartilage. Whether one of the centers *a*, *b*, *c*, and *d* represents the os articulare of the Teleostean mandible, or whether the latter bone is really a compound bone resulting from the coalescence of the persistently distinct elements of Amia, is not very evident; but I am inclined to think that the os articulare is not so simple a bone as it has hitherto been supposed to be. As the Meckelian cartilage is the distal, or ventral half of the first postoral visceral arch, though it may not be possible to point out the special homologies of the mento-meckelian, and the ossicles *a*, *b*, *c*, and *d*, with the ossifications found in the ventral halves of the remaining postoral arches, yet I think that we may roughly correlate those ossicles with the interhyal, epihyal, ceratohyal, and hypohyal of the hyoidean series."

"It may also be that the cartilaginous 'coronoid process' is another instance of the tendency manifested by the first postoral arch to develop forward connective outgrowths, of which the orbitar process and the palato-pterygoid arcade are conspicuous examples in the proximal half of this arch. In addition to the mandibular elements above referred to there are, in addition, several membrane bones. The ossification *a* has a small ganoid plate (*d. a*)[61] attached to it, which appears at the extreme tip of angle of the jaw."

I show in Plate V, Fig. 18, the large triangular splenial *in situ*. This bone does not run out to the symphysis of the rami anteriorly, but is indirectly connected with it on either side through a chain of five very much smaller plate-like bones. These each support a tuft of good, strong teeth, and very much remind one of the dental plates arranged along on the superior aspect of the branchial arches. I am surprised that Bridge did not notice this when he compared the numerous ossifications of Meckel's cartilage with these arches, as the simile is equally striking. Teeth are found also over quite an extensive area on the upper part of the splenial, though here they are very fine indeed (Fig. 18). When the splenial is in position, a large subcompressed conical space is inclosed between it and the outside bones. The base of this cone is directed inwards and forms the opening to the sulcus in question. Both the symplectic and the preoperculum contribute to form the cup for articulation with the mandible, and the quadrate supplies an articular semi-globular head for the same purpose. As already described, the opposed surfaces on the jaw are developed from special ossific centers.

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[61]This is the ossicle marked *x* in Fig. 16 of this paper

A large azygos *gular plate* partially fills in the inter-ramal space (Pl. VI, Fig. 20, *G. pl.*). This plate, occupying as it does the same position as the paired structures of similar description in Polyterus, is held to the surrounding bone by the skin and other soft parts. Its anterior end develops an expanded tip, which is connected by stronger ligament to the symphysis of the jaw. Externally, the surface is sculptured like the ganoid plates on the roof of the skull, while its internal surface is quite smooth. The homology of this plate is still unsettled. It has been spoken of as replacing the urohyal. A very long, osseous gular plate is found in the inter-ramal space among the Elopidæ.

Of the Cranium.—So minutely has Dr. Sagemehl described this part of the skeleton of *Amia calva*, that I will here but hastily view the points for examination, and introduce them merely as a recapitulation to fill in my own account of the skull.

To examine the cranium we must take the head of a fresh specimen, remove the shoulder-girdle, all the ganoid plates, and other structures below and laterally that do not belong to it. Then, from a superior view, we have presented us for examination a large, central quadrilateral, cartilaginous track (Fig. 6). At the anterior extremity of this, we see the intermaxillary (*Sm.*); the premaxillary (*Pmx.*), and the prefrontal (*Prf.*). Occupying a lateral and at the same time a mid position we see the postfrontal (Fig. 6 *Psf.*), while it is bounded behind by the *opisthotic* at the outermost angle (Fig. 6 *Jc*, intercalare, Sagemehl, *op. o*, opisthotic of Bridge), just within which, and above it, we find the exoccipital (*Ex*)—this latter is marked *ep. o.* in Bridge's figure, he considering it the epiotic. Behind these two bones we observe in Fig. 6 a segment marked *Ol*, this is the *occipitale laterale* of Sagemehl, and the exoccipital of Bridge. To the rear of this again we find the occipital arches, so well described by the former author in Part I of this paper.

Now, turning the cranium over, we have presented us upon its inferior aspect, for examination (Fig. 2), first, the pair of *vomers* (*vo.*), situated anteriorly; then traversing the basis cranii longitudinally the parasphenoid *Ps.* (*pa.s* in Bridge's figure). An almond-shaped area in the middle of this latter bone is covered by fine teeth, while the anterior thirds of the vomers support others which are very much larger and arranged in a circular group. The vomers and parasphenoid must now be carefully removed; then we have before us the ossifications shown in Fig. 3—the base of the cranium. Proceeding from before backwards, there are the premaxillary (*Pmx.*); the septo-maxillary (*Smx.*); the prefrontal (*Prf.*); the orbito-sphenoid (*Os.*); the alisphenoid (*As.*); the postfrontal (*Prf.*); petrosal (*Pe.*) (the *proötic* of Bridge); the opisthotic (*Jc.*); and the *occipitale laterale* (*Ol.*) spoken of above. The inferior view of the co-ossified occipital vertebræ is also to be seen from this side.

Upon a direct lateral view (Fig. 5) may be seen the premaxillary (*Pmx.*); the septo-maxillary (*Smx.*); the prefontal (*Prf.*); the orbitosphenoid (*os.*); the post-frontal (*Psf.*); the alisphenoid (*As.*); the proötic (*Pe.*); the epiotic (*Ex.*); the opisthotic (*Jc.*); the exoccipital (*Ol.*), and the lateral view of the co-ossified "occipital arches" of Sagemehl.

Lastly, viewing the cranium directly from behind (Pl. III, Fig. 13), we may see the opisthotic (*Jc.*); the exoccipital (*Ol.*); the epiotic (*Ex.*), and the rear view of the vertebræ that have co-ossified with the occiput. Should the vomers and parasphenoid be allowed to remain on, these may also be seen upon lateral views.

As the preceding paragraphs give the differences in nomenclature as used by Sagemehl and Bridge, it will be unnecessary for me to remark upon it further in this connection. I will simply say here that from this point on, I propose to adopt the terms employed by the latter author in designating the various bones.

The *vomers* are cleft behind to admit the parasphenoid, while they are united for their anterior thirds by suture.

Near its middle, the *parasphenoid* throws off on either side a lateral wing, which in each case passes upwards in a curve to bound the proötic anteriorly, lying between the foramina of exit for the fifth and seventh nerves, and finally terminates against the postfrontal.

Viewed from below, the united *premaxillæ* form a crescent-shaped bone, that supports a complete single row of sharp, incurved teeth. These are second in point of size of the various teeth found upon this part of the skull; the largest being on the palatines, and the smallest on the posterior margins of the maxillaries, that is if we do not take into consideration those minute teeth found on certain areas of the bones of the mouth. The ascending portion of the *premaxillæ* is carried back between the nasals and the sub-nasal cartilage as far as the frontals, being covered in this situation by the nasals and ethmoid. Each ascending process is pierced near its center by an oval foramen for the passage of the olfactory nerve.

We now come to examine the chondro-cranium proper and the ossifications that take place in it. Removing the bones we have just described, the remaining part, pyramidal in form, has its broad end posteriorly, while it terminates in front in the prenasal process. The cartilaginous vault is unpierced by any foramina, and neither prominent otic or nasal projections exist, as seen in many of the Teleostei. Accommodating itself to the form of the cranium, the brain-box passes between the orbits to have its apical anterior end terminate between the prefrontals against the hinder margin of the lamina perpendicularis, which in turn terminates anteriorly in the prenasal process, referred to above.

The *supraoccipital* is absent and the *basioccipital* is much elongated, owing to the fact that it has appropriated two of the leading vertebræ of the column, the neural arches of which ride it above.

Exoccipitals are well developed, and contribute both to the peripheries of the foramen magnum and the opening for the vagus.

Independent epiotic, opisthotic, sphenotic (postfrontal), and proötic osseous elements are represented in the auditory capsule, but the proötic is the only one that passes through the cranial wall to be discerned upon the inner aspect of the brain-case. The pterotics are absent.

By the proper interchange of the nomenclature, minute descriptions of all these elements are contained in Part I. Bridge's descriptions are also terse and clear. For those who may by chance in their reading wish to compare the investigations and studies of Bridge upon the cranium of Amia, in his article in the Journal of Anatomy, with Part I of this paper, the following table will be found to be useful in the connection, presenting as it does in a concise form a few of the differences interminology employed by these two authors; where the number of the figure is given in parentheses it is reproduced in this memoir.

TABLE.

Shufeldt.	Figures and lettering.	Bridge.	Sagemehl.
Ethmoid	Fig. 1 + (*Eth.*)	Ethmoid	Ethmoideum. (*Eth.*)
Nasal	Fig. 1 + (*Na.*)	Nasal	Nasale. (*Na.*)
Septomaxillary	Fig. 3 + (*Smx.*)	Septemaxillary	Septomaxillare. (*Smx.*)
Premaxillary	Fig. 2 + (*Pmx.*)	Premaxilla	Praemaxillare. (*Pmx.*)
Preorbital	Fig. 1 (*An.*)	Preorbital	Antorbitale. (*An.*)
Prefrontal	Fig. 3 + (*Prf.*)	Prefrontal	Præfrontale. (*Prf.*)
Frontal	Fig. 16 + (*F.* or *Fr.*)	Frontal	Frontale. (*F.*)
Postfrontal	Fig. 3 + (*Psf.*)	Postfrontal (sphenotic)	Postfrontale. (*Psf.*)
Parietal	Fig. 1 + (*Pa.*)	Dermo-supraoccipital	Parietale. (*Pa.*)
Squamosal	Fig. 1 + (*Sq.*)	Parietal	Squamosum. (*Sq.*)
Supratemporal	Figs. 1, 16 + (S. *t. p.* and *Esc*)	Supratemporal	Extrascapula. (*Exc.*)
Posttemporal	Fig. 1, 16 + (*Sc.* or *Pst. T.*)	Posttemporal	Suprascapula. (*Sc.*)
Exoccipital	Fig. 1 + (*Ol*)	Exoccipital	Occipitale laterale. (*Ol.*)
Basioccipital	Fig. 5 + (*Ob.*)		Occipitale basilare. (*Ob.*)
Epiotic (*Ep. o*)	Fig. 5 + (*Ex.*)	Epiotic (*Ep. o*)	Occipitale externum. (*Ex.*)
Proötic (*Pr. o*)	Fig. 5 + (*Pe.*)	Proötic	Petrosum. (*Pe.*)
Pterotic (absent)		Absent	Absent.
Opisthotic (*Op. o*)	Fig. 3 + (*Jc.*)	Opisthotic	Intercalare. (*Jc.*)
Vomer	Fig. 2 + (*Vo.*)	Vomer	Vomer. (*Vo.*)
Parasphenoid	Fig. 2 + (*Ps.*)	Parasphenoid	Parasphenoid. (*Ps.*)
Orbitosphenoid	Fig. 2 + (*Os.*)	Orbitosphenoid	Orbitosphenoid. (*Os.*)
Alisphenoid	Fig. 2 + (*As.*)	Alisphenoid	Alisphenoid. (*As.*)

A + means other figures than the one quoted in the second column show the same bone similarly lettered.

The mucus canals have been so thoroughly treated in Part I that I will not revert to them again here. In the mandible the single ramal branch commences in the angular element to pass through the dentary for its entire length, to meet the fellow of the opposite side at the symphysis. This branch connects with the system of the rest of the skull, where the angular articulates with the preoperculum, through which latter bone the lateral mucus canal passes, after having traversed the supratemporal and squamosal.

Both the orbitosphenoids and alisphenoids are more or less circular bones. This is due to the fact that during their extension and development they have not proceeded sufficiently far as to impinge upon neighboring osseous elements for the major part of their peripheries. The position of these bones is well shown in Fig. 3, and others.

The alisphenoid develops two processes and is pierced by two foramina. Of the processes, the smaller one arches over the canal for the orbital muscles; the other is the "descending process of the alisphenoid." The larger foramen passes the first division of the fifth nerve; while the outer and smaller one transmits the second and third divisions.

In each orbitosphenoid we see a deep cleft to allow for the exit of the optic nerve from the brain-case. They are supported by the coalesced trabeculæ below, articulate with the alisphenoids laterally, and support the cover-bones above.

The eye-muscle canal; the shallow pituitary fossa; the trabecular groove; the anterior clinoid process or wall, with the ossifications in its substance; the "proötic bridge;" the openings of the carotid arteries; and other structures in this region have all been sufficiently dwelt upon in Part I.

The lamina perpendicularis being in cartilage, *Amia* in consequence lacks the true ethmoid found in *Polypterus*. In referring to the septomaxillaries Mr. Bridge says that "The two ossifications above referred to as forming the antero-lateral angles of the internasal area are peculiar to Amia amongst Ganoids. They lie, one on each side of the prenasal process, and appear to be ossifications in the cartilage of the floors of the nasal capsules; inferiorly they rest upon the upper surfaces of the vomers. There can, I think, be but little doubt that these ossicles (*sep. mx.*) [Fig. 3 and others of this paper *smx.*] are homologous with the paired endosteal ossifications, which are to be found at the distal end of the great prenasal rostrum in the Pike. In fact, if the prenasal region in Amia were produced anteriorly into a rostrum comparable to that of the Pike, these bones would exactly resemble in position and relations their homologues in the latter fish."

"These ossicles would also appear to be homologous with the septomaxillary bone described by Mr. Parker as existing in the flow of the nasal capsules in the Frog; and also with similar bones in the Ophidia. A section carried through these bones and adjacent cartilage in Amia would resemble in all essentials the various sections given in Mr. Parker's paper (Phil. Trans., 1871) on the development of the frog's skull (Pl. X)"

The next step in our dissection is to carefully remove the suborbital chain of bones; the maxillary and admaxillary; and the ganoid plates overlying the nasal and premaxillary regions, then we have exposed in the prepared skull the elements of the

PALATO-PTERYGOID ARCADE.

This is made up of the palatine, entopterygoid, ectopterygoid, with which are associated the metapterygoid, hyomandibular, symplectic, and quadrate. While intimately related to it is the preoperculum, and less so the operculum itself, which latter merely articulates with the hyomandibular. The entire arrangement of these bones in *Amia* is upon the Teleostean type, and all the elements found in the bony fishes are present.

Mr. Bridge, in his figure (Jour. Anat., 1877, Fig. 6) representing what I here have drawn in my figure 19, has inserted cartilage among the palatine and the several pterygoid bones. This material I have failed to find in this situation in any specimen *of the age* represented in either figure that I have thus far examined.

The *palatine* (Pl. VI, Fig. 19, *Pl.*) is thoroughly well developed and armed with two sets or kinds of teeth; the first of these, and the largest in this part of the skull, form a single row upon the lateral or exosteal portion of the bone in continuation with those on the premaxillæ. Others, very much smaller, are arranged internal to these on the endosteal lamina of the palatine and continue the vomerine series. Anteriorly at its apex the palatine is grooved to receive the inturned process of the maxillary, which is here wedged in between this bone and the premaxillary. The palatine is also in relation in this region with the septomaxillary, vomer, and prefrontal. It possesses the unique character among Ganoids in its relation with the latter bone in being carried in front of its articulation, a condition well known to us among the bony fishes.

The *entopterygoid* forms the major share of the floor of the orbit, articulating by overlapping sutures with the bones it comes in contact with, while its entire buccal surface seems to be overspread with very minute teeth. This latter condition applies also to the *ectopterygoid* (Pl. VI, Fig. 19, *Enpt. Ectp.*), this bone being additionally armed with a row of fine teeth upon its lower border containing the palatine series. It connects the palatine and quadrate but is separated from the metapterygoid by a thin strip of the entopterygoid.

The *metapterygoid* (Fig. 19, *M. Pt.*) is shaped like a fan with its handle, tipped on the end with cartilage, directed upwards toward the orbit. This is the ascending process of the metapterygoid. The fan part terminates in an angle at either extremity; the anterior angle nearly touches the alisphenoid, while the posterior one overlaps the hyomandibular.

So close is the union between the *quadrate* and *symplectic*, that these two elements appear to form one bone. Taken together they are shaped somewhat like a spherical triangle, the lower angle of each being distinct, the symplectic terminating above the quadrate, each to bear an articular facet for the mandible. In the case of the quadrate this is convex and hemispherical, while in the companion bone it is crescentic and concave, being in reality, one-third of the socket of which the preoperculum affords the remaining two-thirds.

It requires severe maceration in order to separate the symplectic from the quadrate, the union almost amounting to true anchylosis.

The *hyomandibular* (Fig. 19, *H. M.*) is obliquely pierced by an elliptical foramen, near its centre for the exit of the facial nerve. Above, its straight border articulates in an elongated facet in the cartilage over the otic region. Behind, it supports a large circular facet, borne upon a subsessile stem, for the operculum (*ro*).

Its relation with the cartilaginous interhyal and the symplectic agrees very closely with typical Teleosteans.

Bridge seems to be inclined to believe that the angle formed anteriorly by the long axes of hyomandibular and symplectic, which give these bones their directions, may account for the movement forward of the metapterygoid in this Ganoid. In most Teleosteans this latter bone is directly over the quadrate, and not in front of it. In this I cannot agree with him, but attribute the position of the metapterygoid in *Amia*, entirely to its unusual size, as compared with the neighboring bones, rendering it a physical impossibility to assume any other position. This bone in a bass (*Micropterus salmoides*) before me is squarely over the quadrate and rather behind it, whereas the anterior angle formed by the hyomandibular and symplectic is quite as acute as it is in *Amia*, but the quadrate is relatively very much smaller.

Of the hyoidean and branchial arches (Fig. 19).—In this connection I will also describe the extraordinary series of branchiostegal rays in *Amia*.[62] There are twelve of these appendages, articulating through ligamentous attachment, well within the posterior borders of the epihyal and ceratohyal, upon their outer surfaces. They diminish gradually in size from above downward, slightly overlapping each other about half way down the series. The superior and largest has a somewhat different form from the others, being a long ellipse, with a well-marked longitudinal groove close to its upper border on its external aspect. This surface likewise is sculptured all over quite as thoroughly as one of the ganoid plates and in a similar manner. It articulates both with the epihyal and ceratohyal. The sculpturing gradually disappears as we near the middle of the series, through it can be faintly discerned to the very anterior ray. In life, these rays lap each other anteriorly, the set from one side over the set from the other, under the throat, where they constitute a striking feature and unique ornament.

The articulation of the hyoid with the hyomandibular and symplectic, through the intervention of the cartilaginous interhyal with this bone and the epihyal is very similar to the state of affairs as we find it among ordinary teleostean fishes. Holding a mid-position in the arch, the ceratohyal is a strong, well developed bone, bent at an elbow near its middle (Fig. 19 *c. hy*). The arch is completed by the lumpy little hypohyal, borne at its anterior extremity (*H. hy*). No evidences exist of an ossified glosso-hyal.

The basibranchial elements of the branchial apparatus are composed chiefly of cartilage with very little bone; one of the number seems to be

[62] Mr. Bridge seems to have unfortunately secured an imperfect specimen of the mudfish in this particular, as he affirms that there are but eleven of these rays, that is hardly a good reason, however, for figuring but *ten*.—(Jour. of Anat., July, 1877, p. 609, and Fig. 6, Plate IV.)

better ossified than the others. There are altogether four of them, and they are much compressed from side to side. The arches proper are five in number, the first four being complete, with the usual elements present. They are completely beset with groups of minute teeth, which ride them above, and come off like scales during maceration. The gill-rakers are very small and thick-set.

Mr. Bridge completes his article in the Journal of Anatomy by a very valuable and concise summary. As this occupies but little more than a page, and contains so much, and in such a convenient form, of use in the present connection, I feel quite sure the reader will think me warranted in reproducing it here, and no doubt be thankful for it.

This author says that "In summarizing the result of the foregoing description of the skull of Amia, I would lay stress on the following facts, as having a special bearing on the affinities of Amia to the more highly specialized osseous fishes and to the amphibia.

"I. The possession of a complete chondrocranium, *i. e.* the absence of fenestræ in the cranial roof, as in Lepidasteus and the Pike (Esox).

"II. The existence of a nearly complete series of otic bones, comprising a large pro-otic, with internal plates forming a characteristic "pro-otic bridge" in the floor of the cranium, opisthotic, epiotic, and sphenotic elements.

"III. The presence of two ossific centers, partly exosteal and in part endosteal, forming rudimentary basisphenoid.

"IV. Septo-maxillary ossifications in the subnasal lamina, as in Clarias, Esox, Rana, and Ophidia.

"V. The interorbital prolongation of the cranial cavity, separating distinct, paired ali- and orbitosphenoids.

"VI. The prolongation of the palatine in front of its prefrontal articulation, and the connection of its anterior end with the inwardly curved process of the maxilla.

"VII. The possession of a T-shaped dermal ethmoid overlying the *premaxillæ*, and the close analogy in number and relations between the investing ganoid plates of Amia and those of the Siluroidei, and especially with those of Clarias, as has been previously described.

"VIII. A complete series of opercular bones, a preoperculum anchylosed to the hyomandibular and symplectic bones, an operculum, an interoperculum, and a suboperculum.

"IX. The presence of a jugal bone [admaxillary (*a*)] attached as in Teleostei to the upper edge of the posterior part of the maxilla.

"X. The existence of a mento-meckelian ossicle, as in Spatularia, and of several additional centers of ossification in the proximal extremity of Meckel's cartilage.

"XI. The presence of five accessory dentigerous splenial elements in addition to the normal mandibular splints, as in the young Polypterus and Ceratodus among Ganoids, and in Siren and larval Salamanders among Amphibia.

"In continuing in its cranial structure the anatomical facts expressed in paragraphs I–IX inclusive, Amia differs from all other living Ganoidei, and exhibits distinct and decided affinities to such generalized types of *physostomus Teleostei* as the Siluroidei, Cyprinoidei, &c. On the other hand, in common with all other Ganoids, Amia possesses several points of resemblance with larval and adult forms of Amphibia, especially as regards the structure to which attention has been directed in paragraphs IV, X, and XI."

"Moreover, in the angulation of the mandibular arch, caused by the forward growth of its metapterygoid element, we have a repetition of an arrangement characteristic of the adult frog, and of certain Selachians, Notidanus. But notwithstanding these evidences of widespread affinity it is evident that if, in addition to the above-mentioned facts, we credit Amia with the possession of cycloid scales, non-lobate fins, a nearly homocercal tail, and note the absence of spiracles, the Teleostean affinities predominate; and it may be asked whether, despite certain peculiarities in structure of its generative organs and bulbous arteriosus, the gap between the ganoid Amia and the physostomus Teleostei is not less than need be expressed by ordinal distinction. It may be that just as Polypterus and its near ally of the same family are the sole surviving examples of the otherwise long extinct order of Crossopterygian Ganoids, so the Amiidæ are the sole survivors of those widely-generalized Ganoidei out of which more specialized Teleostei were directly evolved."

Now, if it were my intention to carry the comparative studies of the skeleton of Amia further than Dr. Sagemehl has in Part I, I would enter the tempting fields offered by the minute examinations that could be made of other American Ganoids and compare them in every particular with our subject. Then comparisons made with the complete skeletons of *Elops* and *Megalops* would be particularly interesting, and on some future occasions these may be treated as I have endeavored to treat *Amia* in this paper. But to undertake such comparisons here would lead me far beyond the intention and scope of my original plan.

It does, however, fall within the limits of this plan to present here a concise review of the skull and other parts of the skeleton of a well-specialized Teleostean, more particularly the skull. Such a review, it is hoped, with its illustrations and figures, will be valuable, from a comparative point of view, taken in the present connection, as well as forming a groundwork for future studies or the observations of others entering upon the study of the anatomy of fishes for the first time.

Of a Teleostean skull.—For my review of this part of the skeleton of a Teleost and for references to such other parts of the osseous system as I propose to enter upon, I have chosen a specimen of *Micropterus salmoides*. This was done because the large-mouthed black bass is a fish of pretty general distribution in the United States, and consequently will be more easily available for those who wish to compare my statements with the specimen of the fish before them.

In the adult *Micropterus* we find the entire skull very thoroughly ossified, with the vast majority of the bony elements pertaining to this part of the Telesotean skeleton present. Viewing the *cranium* from above, we have presented us for examination, on its hinder calf, five prominent crests; two on either side and a median one. This latter appears to be developed entirely by the supraoccipital (Plate XI, Fig. 27, *S. O*). If the free margins of the lateral crests were produced anteriorly they would all meet at a point just beyond the supraethmoid. The inner pair of these crests are developed by the parietals (Fig. 27, *Pa.*), and they terminate posteriorly in horizontally flattened processes formed by the *epiotics* (*Ep. O*). On the outer side the crests are formed by the squamosals, which in their turn are completed behind by the *pterotics*, which here are vertically compressed plates (Fig. 27, *Sq. Pt. O*). The crest part of the squamosal is formed of two lamina, between which passes the squamosal mucus canal. A deep sulcus is found between the hinder ends of the parietal and squamosal crests, at the base of which we find a large triangular foramen, covered over in the recent state by membrane, just beyond the squamosal, on either side the crescent-shaped and upper part of the *postfrontal* (*Pt. f*). The mid-region of this aspect of the cranium, and constituting the vault of the orbits, is formed by the broad *frontals* (*Fr.*) with a tolerably distinct suture still visible between them. Here an interesting condition of the mucus canals presents itself. This consists in a large V-shaped covered canal with its convex arc just beyond the crest of the supraoccipital, where it has in the median line a common opening. The limbs of this covered V pass through each frontal, to open on the surface, in elliptical apertures, a little behind the prefrontals. They then tunnel again to open once more directly forward on either side of the supraethmoid and over the surface of the nasals. From our superior aspect we also have a good view of the upper surface of the sculptured prefrontals (Fig. 27, *Prf.*), forming the anterior walls of the orbits. Beyond this the region is occupied by the supraethmoid and upper part of the vomer. It is pierced on either side of the promontory formed by the supraethmoid, by the nasal foramen, and the opening for the olfactory nerve.

Upon a lateral view of the cranium we are to note the deep articular facet for the hyomandibular extending from the postfrontal along below the squamosal crest, and occupying the lateral portion of this bone.

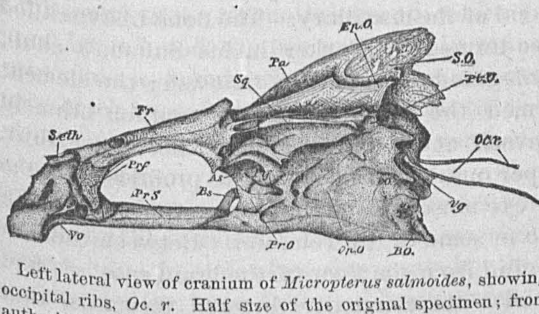
Here we see, also, that the *postfrontals* dip pretty well down on the lateral wall, wedging in between the alisphenoid and proötic (Fig. 27, *As. Pr. O. and Ptf.*). The *opisthotics* occupy their most usual site in front of the exoccipital on either side. Beyond the alisphenoid I find an ossification I take to be the *orbitosphenoid*, it is in contact with the alisphenoid behind, runs down the lateral wall of the cranial cavity, while it forms a prominent ridge traversing forwards on the under side of the frontal. Above each one we observe a canal for the passage of the olfactory nerve from the brain-case to the nasal capsule. The exit for the trigeminal nerve is bridged across by a thin lamina of bone, apparently afforded by the proötic. Another and smaller osseous bridge is found immediately to the rear of this first one. Upon this view the suture between the ex- and basioccipital is plainly visible, while a deep concavity exists in the region through which it is directed.

The *parasphenoid* (Fig. 27, *Pr. S.*), prefrontal, and vomer may also be studied from a lateral view, and the *basisphenoid* is likewise brought into sight. (*B. S.*)

A rear view of the cranium presents most conspicuously among its points for examination the circular and conically concave facet for articulation with the centrum of the atlas. It is developed by the basioccipital and somewhat lower in position than the horizontal plane of the parasphenoid. Above it are two elliptical facets, directed downwards, backwards, and inwards, for articulation with similar surfaces on the first verterbra. Between these exoccipital facets and yet well above them is the foramen magnum, a heart-shaped opening looking downward and backward. The suture dividing the exoccipitals is plainly visible in the median plane of its inferior circumference.

Just above the exoccipital facet, on either side, we find the vagus foramen for the exit of that nerve. Anterior, and at the same time internal to these openings, is to be found a shallow facet, one on each side. These are for the heads of a pair of *occipital ribs* that articulate at these points, and which I have elsewhere described.[63]

The exoccipitals meet just above the foramen magnum, at which point they receive between them the thin lamelliform crest of the supraocci-



Left lateral view of cranium of *Micropterus salmoides*, showing occipital ribs, *Oc. r.* Half size of the original specimen; from author's drawing published in Science (No. 65.) *S. eth*, supraethmoid: *vg.* vagus foramen; and the other lettering the same as figures in this paper.

[63] Shufeldt, R. W. "Osteology of the large-mouthed Black Bass." *Science*, No. 65. Cambridge, May 2, 1884, p. 532. These ribs are of so much interest and at the same time so much importance from a morphological point of view, that I feel warranted in reproducing my original figure of them in this foot-note, illustrating what I have said above in the text. As already announced in *Science*, I have since detected them in the Tunny (*O. Thynnus*) and suspect their occurrence in some of the Scombridæ. It will be interesting for those now engaged in dissecting fishes, or others investigating the anatomy of the class, to be on the lookout for these structures. The family Centrarchidæ should receive particular attention in this regard, and of these the genus *Lepomis* stands among the first to be suspected. Their exact location and constancy should be noted.

pital. The body of this latter bone makes up the major portion of the quadrate surface, upon this aspect of the cranium, contained between the spur-like epiotics and the facets of the exoccipitals. Beyond this surface the pterotics project on either side, in about the same horizontal plane with the superior circumference of the foramen magnum.

An inferior view of the cranium presents principally for our inspection the two bones, *parasphenoid* and *vomer* (Fig. 27, *Pr. S.* vomer not in sight). These, as we well know, are in the adult bass, azygos bones lying in the median plane. The *parasphenoid*, by the assistance of the basioccipital, forms a large oval-shaped surface beneath the canal for the eye muscles; it then contracts again, at which contraction it throws up on either side a plate-like process that has been nearly entirely absorbed by the proötic. The bone beyond this shows another dilation, but not as large as the rear one. It then contracts to form the solid bar that lies between and beneath the orbits (Fig. 27, *Pr. S.*), which anteriorly runs above the vomer and under the prefrontals.

The *vomer* of Micropterus is a very prominent bone. It is carried back well on the under surface of the parasphenoid in a pointed process, the suture between the two bones being easily distinguishable, although this part of the vomer in other respects appears like an extension of the parasphenoid. Anteriorly it forms a beak which is rounded in front, carried well below the general surface beneath, the inferior aspect of this latter part being semicircular in outline and thickly studded with fine teeth.

Of a few of the general points to be noticed about the cranium of *Micropterus*, we have the raised pedicle on the line extending from the prefrontal to the vomer. This pedicle supports an articular facet, directed downwards and forwards, for articulation with a rounded and elevated facet on the anterior end of the maxillary. The bone I have called *supraethmoid* in Fig. 27 is so termed by Parker in his Salmon's skull, because it overlies the cartilaginous ethmoid in that fish; the element is, however, generally termed the ethmoid, or the medium ethmoid (Gegenbaur), and I feel myself at liberty to apply either name to it. The ethmoid is a very proper one. In this bass the proötics form the antero-lateral walls of the eye-muscle canal, but do not meet below in the median line, as they do in some of the Teleostei. Between them in the median line, and springing from the floor of the brain-case, we find a delicate arch of bone, with its convexity directed forwards, that comes down to meet the parasphenoid. This arch belongs to the basisphenoid (Fig. 27, *B. S.*) and is found in many of the bony fishes.

As the relations of many of these bones, described above, on the inner cranial wall, show very well in a vertical, longitudinal section of the cranium of our common American perch (*Perca americana*), I figure such a section here in preference to Micropterus, where the bounding lines or sutures among the elements are not so evident or easily studied.

Some of these cranial bones may be considered to form certain groups, of which *four* enter into the *occipital region*. These are the basioccipital, the two exoccipitals, and the supraoccipital. In *Micropterus*, as in all fishes, the basioccipital is the direct continuation of the spinal column, and possesses many of the characters pertaining to the vertebræ. The *exoccipitals* inclose the aperture of the foramen magnum entirely in this fish, only partly in many others. The supraoccipital, or the upper segment, supports a median crest that corresponds to the neural spine of the vertebra. Its form varies exceedingly, as well as its size. Another group of bones inclose the ear capsule, and have had names bestowed upon them that denote the relative position they bear to it. First and most constant among these is the *proötic;* it is either pierced by or limits the foramen for the trigeminal nerve. Second in order come the *epiotic*, which overlies the superior vertical semicircular canal. It, in the vast majority of fishes, always forms a projecting process. Next we have the *opisthotic*, a segment lying in front and to the side of the exoccipital, but does not appear on the internal aspect of the brain-case nor bear any direct relation with the labyrinth. To these three bones Mr. Parker added a fourth, the *pterotic*, which in fishes forms the postero-external angle of the cranium. In most bony fishes it articulates with the outer limit of the posttemporal. I may add here, in passing, that these bones form the "periotic mass," and are the same found in the petro-mastoid portion of the temporal in man and the other higher vertebrates. It is unnecessary to say more than I already have above about the *squamosal* and *postfrontal*. The latter is sometimes termed the sphenotic, and assists often the former in the formation of the articular facet for the hyomandibular. This is the case in *Micropterus*.

Beyond these, in another group, we have the alisphenoid at the sides and behind and the orbitosphenoids anterior to them, while the basisphenoid is found below. This latter bone, we have already shown in the black bass, forms an osseous partition between the two sets of orbital muscles; it may be absent in some of the Teleostei and very small in others.

On the cranial vault the parietals are not always separated from each other by the intervention of the supraoccipital as they are in *Micropterus*, nor are the frontals always separate bones, they sometimes forming only a single piece, as in *Gadus*. The segments of the ethmoidal region have been sufficiently described above. They all, the prefrontals, ethmoid, and vomer, vary greatly in size, form, and relationship throughout the class.

To still further illustrate the relations that may exist among the bones in crania of osseous fishes, as well as some of the remarkable forms they may assume, I am indebted to Professor Gill for the loan from his private cabinet of the cranium and portion of the palato-quadrate arch of a specimen of *Albula vulpes* and an imperfect cranium of *Megalops*, the latter being the only one he had in his possession. I chose these two crania, from which I made the drawings that illustrate this essay, because we find in the organization of both *Albula* and *Megalops* at least one feature that they possess in common with *Amia*. In *Albula* it is the peculiar structure of the *bulbus arteriosus* and in *Megalops* the presence of the gular plate. But in describing the crania of these two forms I will confine myself strictly to the two specimens in question, and only describe what is to be seen in them. The sequel will prove that there is much of interest and importance. Judging from the cranium alone, the complete dissection of *Albula* will well repay the anatomist some day, for this part of its skeleton presents many points of the greatest interest and diversity in development.

There is but this one species of *Albula* known to science, and its principal habitat are the warm tropical seas, where it is abundant. With us, however, it has been taken from Cape Cod clear around to Southern California (Jordan and Gilbert.) This fish, we are told by the authors just quoted, possesses "no gular plate."

Viewing the cranium of *Albula* from above, and proceeding with our examination from before, backwards, the first object that strikes us is the extraordinary ethmoid it possesses. (Plate XII, Fig. 30, *Eth.*)

This bone is fashioned off in front so as to remind one very much of the snout of a pig. From this part it extends backwards in a median crest, deeply grooved above. This runs in between two prolongations developed by the frontals, and can be seen opposite the letters Na^2 in Fig. 29. Anteriorly the ethmoid projects over the parasphenoid, which bone abuts against it. From the base of its median crest it sends downwards and outwards on either side a plate-like portion, the margins of which curl up for their posterior moiety. A vacuity of an elliptical outline exists in the crest anteriorly as it reaches the snout-like protuberence, and only the grooved part is carried over to meet this portion of the bone. This foramen can only be seen upon a lateral view as shown in this figure.

The frontals (Plate XIII, Fig. 30, *Fr.*) are very extensive bones and cover nearly the entire superior aspect of the cranium. Their union with the ethmoid is of such a nature as at first to give one the impression that the two are but one bone, and indeed the suture between them is not always discovered at once. Just above the prefrontals, bones which they overshadow all to their outstanding wings, they present on either side of the extension of the ethmoidal crest the openings of two very large mucus canals. These open behind in slit-like foramina, just beyond the letters *Fr.* (Fig. 30), as well as in more minute openings behind and to the outer side of them. The frontals completely overarch the orbits, lap down upon the postfrontals and squamosals, while posteriorly in this specimen the left-hand bone appears to overlie the fellow of the opposite side as well as both the parietals. These latter bones are comparatively small plates of a quadrilateral outline, with the supraoccipital wedged in between them from behind. The squamosals present quite an extensive surface on superior aspect, and they too have running through them longitudinally, with anterior and posterior apertures, capacious mucus canals. These apertures can be well seen in Fig. 30, the hinder elliptical one just below the letters *Sq.*, and the anterior one opening out over the surface of the prefrontal. (*Ptf.*)

A certain amount of sculpturing is seen upon the surface of the frontals, parietals, and squamosals, in the form of a decided radiation from a central point. This is most perfectly marked in the frontals, where fine radiating lines are carried clear to the peripheries of these bones. A longitudinal depression is found between these latter segments in *Albula*, of a triangular form, being narrow and deep anteriorly, shallow and broad behind. The epiotic and supraoccipital we will reserve for description until we come to deal with the posterior aspect of the cranium of this fish. Fig. 30 shows very well indeed the extent to which these bones may be seen from a superior view of this part of the skull.

The inferior view (Plate XIII, Fig. 31) of the cranium of *Albula* is even more interesting than the superior, owing to the numerous points presented for our examination. This view shows us how far the ethmoid overhangs the parasphenoid, for the narrow, little transverse suture between these two bones is distinctly visible. Just beyond it, on the former bone, we observe a globular protuberance, deeply cleft by a transverse facet, which I take to be the articulation for the upper jaw. Behind this ethmo-parasphenoidal suture the vomer is seen. This bone is shaped like a little fan, the handle being directed backwards in the median line, while the expanded portion lies in the horizontal plane with a rounded margin anteriorly. Within this we find a double row of sockets in the specimen evidently intended for a series of minute teeth. Posterior to the vomerine region the parasphenoid presents a considerable excavation mesially, while opposite this the bone develops, on either side, a horizontal wing-like lamina. Each wing is raised above the general inferior surface of the parasphenoid, being between that bone and the prefrontal behind, while anteriorly it merges into it again. Outside they are bounded by a sharp margin, gently convex throughout.

This aspect also reveals to us again a partial view of the prefrontals (Fig. 31, *Prf.*) with their postero-alar projections. The central point of interest, however, centers about the paraspheroid in this region. It is here broad and elliptical, concave from before, backwards, and slightly so from side to side. An area of teeth occupy this space, conforming to its shape, though separated from its limiting margins all about by some two or three millimeters. These teeth are of various sizes, the smaller ones being arranged all the way round, externally, while they become larger and larger as we approach the mid parts of the space. They are beautifully enameled and rounded. Where the large ones, however, are crowded together centrally, they assume hexagonal or perhaps pentagonal forms. When they drop out and are lost, they leave quite a deep, conical pit or socket behind them. Posterior to this dental area, the parasphenoid lies horizontally, being convex from side to side, in order to conform with the lower surface of the cranium. Behind, it is forked, the limbs being carried backward to within a millimeter or so of the posterior margin of the basioccipital. Between them we find a triangular depression with its apex directed forward. Viewing the cranium from this aspect, its posterior third is broad and of a quadrilateral outline, the figure being bounded in front by the postfrontals (Fig. 31, *Ptf.*); laterally by the squamosals, and behind by the ex- and basioccipital, opisthotics, and squamosals. Rising in the center of this space, mesially, is the portion formed principally by the proötics and basioccipital, being overlapped by the parasphenoid. This contains the eye-muscle canal, with the braincase above it. Its form is well shown in the figures I present of the lateral and inferior views of the cranium of this fish. On either side of it occurs a deep conical indentation, about which the various foramina pierce the bone to enter the brain-case. These openings, and this great, blind, conical pit are bounded externally by the facet, on either side, for the hyomandibular.

The rear view of the cranium of *Abula* is an exceedingly interesting study, presenting conditions that I have never observed in any other fish. On the superior aspect of the cranium (Fig. 30 *S. O.*) we saw how the supraoccipital was wedged in between the parietals. From this portion in the middle line, it throws backwards and downwards a stumpy, triangular crest, composed for its greater part of two parallel and vertical laminæ, separated from each other by about a millimeter. On either side of this the bone extends horizontally for a little distance to meet the epiotics. These last elements may also be seen upon superior view (Fig. 30 *Ep. O.*). They there articulate with the squamosals and parietals, and with the supraoccipital as just described. Each epiotic from this position, is extended backwards as a stout horizontal and triangular process, a peculiar tubercle being developed on its superior surface. Beneath, and anteriorly, the under surface of this process sends down a vertical plate, lying parallel to the median plane. These two plates inclose a general concavity on the posterior aspect of the cranium, which is partially divided in two by a vertical crest on the supraoccipital which again is directly continued by the crest formed through the uniting suture of the exoccipitals. The upper part of the base of this concavity is composed of the vertical portion of the supra occipital, while all the lower part is composed of the broad exoccipitals, the cranium being held and viewed with the frontals upwards and in the horizontal plane. Now, wedged in, in this concavity, on each side, and outwards, we observe what first appears to be a separate and nearly circular piece of bone, it being pierced by three foraminæ. Towards the median line it articulates with the supraoccipital and exoccipital.

while externally it meets the epiotic. Careful examination shows that this plate belongs to the *squamosal*. At the base of each vertical epiotic plate is to be seen a stumpy process, formed by a separate segment of bone, which I take to be the *opisthotic*. It articulates with the epiotic, exoccipital, and squamosal. On the outer side of each vertical epiotic plate there is another very deep concavity formed entirely by the squamosal, except such inner part of its entrance which is entered into by the vertical epiotic plate just mentioned. It is near the opening of this deep pit (1.25 cm) on the inner hand that we have the opportunity to study the manner in which the squamosal furnishes the little circular plate that appears superficially in the larger concavity, as described above.

The *foramen magnum* is of a cordate outline, with its base below. It is directed, that is the plane tangent to its margins, somewhat downwards as well as backwards. Its boundary below is formed by the upper surface of the basioccipital condyle, while its lateral margins and apex are furnished by a bone shaped like a little saddle, which straddles the exoccipitals (Fig. 29, *c. v*). This bone, but loosely united along its median line above, articulates with these last-mentioned segments throughout its entire anterior margin, and in the specimen in my hand is slightly movable. At its lower and outer angles are seen a minute pair, one on either side, of postzygapophyses. This bone fails to come in contact with the basioccipital, and were it removed the foramen magnum would then be formed entirely by the basioccipital and exoccipitals, though these latter would be without articular zygapophysial facets for the first vertebra of the trunk. Dr. Gill expresses the opinion, in which I concur, that this double bonelet is the neural arch of the first vertebra of the column. This being the case, it is important to compare it with the co-ossified vertebræ found in this situation in Amia. I would not care to do this, however, until in possession of a recent specimen of *Albula* as well as its young. The outline of the basioccipital condyle is pentagonal, and it is deeply and conically concave. A large elliptical foramen pierces the supraoccipital on either side beneath, at the angle of its horizontal and vertical portion. Two small foramina are also found on either side in the exoccipitals just before we arrive at the suture, where they join the aforesaid free neural arch just mentioned.

This completes my description of the posterior view of the cranium of *Albula*, as far as I mean to carry it. I am well aware that these bones may be differently construed, but the moment we do so it becomes necessary to have the various segments articulate among each other in a manner differing from the general rule they adhere to in the vast majority of cases among teleosts. To satisfy himself of this fact the reader has but to call the bone I have described as a neural arch of the first vertebra, the united exoccipitals, and the result will soon be evident. We must remember, in this connection, that the facet for the atlas, supplied by the occiput in *Amia*, is upon a co-ossified vertebra. (See Part I.)

Nearly all objects in nature are best seen, studied, and appreciated in direct lateral view, and to this aphorism the cranium of a fish offers no exception. This will at once be recognized in the case of our present subject the "Lady fish," a side view of the parts already examined, which I have endeavored to execute with great care, being presented in Fig. 29, along with the greater portion of the palato-quadrate arch. The shape of the curiously formed *ethmoid* (*Eth.*) is now easily seen, and its relations with its neighboring bones better understood; while beneath it the *vomer* shows but slightly, though enough of it can be observed in order to expose the position of the series of minute teeth spoken of above. The *prefrontal* is seen to be enormously developed. It meets its fellow in the median plane, each one being pierced near this region by a large elliptical foramen. Between the anterior convex border of this bone and the ethmoid we find a vertical lamina of bone articulating as shown in Fig. 29 at *Na*[2]. This element I take to be merely a plate of semi-ossified cartilage, though an examination of *Albula* in the flesh, on some future occasion, may force me to a change of opinion. The true *nasals* in the specimen must have been lost. The orbits are seen to be almost completely separated from each other by a thoroughly ossified inter-orbital septum, an extension forward of the co-ossified *orbitosphenoids*. (Fig. 29 *Os.*) This septum is very materially added to by the broad, vertical plate, afforded by the *basisphenoid* (*ib. B. S.*)

This bone also sends upwards and outwards an osseous limb to articulate with the *alisphenoid* (*As.*). The three sphenoidal bones mentioned surround the optic foramen, as shown in the figure. While the prefrontal completely forms the anterior wall of the orbital cavity, the frontal the vault, the parasphenoid the floor, we find, in addition to the bones we have mentioned, that the posterior wall is largely formed by the *postfrontal* and *proötic*. Altogether this cavity is a very thoroughly circumscribed one, so far as its osseous boundaries are concerned.

The posterior aspect of the postfrontal (sphenotic) assists the squamosal in forming an extraordinarily deep pit in the region to the rear of the upper and posterior angle of the orbit. This pit is bounded above by the squamosal and frontal, anteriorly by the alisphenoid and postfrontal, internally by the squamosal, which bone with the postfrontal forms its floor; behind, it opens along a longitudinal concavity of the squamosal. Immediately below this concavity we find the facet for articulation with the hyomandibular, also formed by the squamosal in part, its anterior moiety being constituted by the postfrontal—not an uncommon condition among the Teleostei.

The regions occupied by the basi- and exoccipital, the proötic and other bones, are so well shown in the figure as not to need any special description here.

We are still further impressed with the marked departures from the ordinary fishes made by *Albula* in its skull when we come to examine such of the bones of the palatoquadrate arch as I have before me, for which I am also indebted to Professor Gill. One view of this arch I have drawn in connection with the lateral view of the cranium (Fig. 29); the other is an inner view of the same specimen, and awarded a separate figure (Fig. 28). When this arch is snugly articulated with the cranium, the *hyomandibular* (*H. M.*) is nearly in contact with the postfrontal and proötic for its entire length, or rather as much of it as is opposite these bones; the same may be said for the remaining elements, the metapterygoidal and entopterygoidal margins meeting the opposed margin of the parasphenoid. Upon an inner aspect this brings the area of teeth found upon the entopterygoid (Fig. 28) opposite and at right angles with the similarly constituted teeth upon the parasphenoid. That teeth should occur exclusively upon the first-mentioned segment is a remarkable fact of itself and worthy of special note. Particular attention is invited to the *symplectic* (*Sym.*) of *Albula*, shown in these drawings, holding as it does a most unique position. Indeed, this may be said of all the bones in this arch; the *metapterygoid* is thrown clear to the rear of the *quadrate*, while in *Amia* it reaches well beyond that bone. Both the *entopterygoid* and *ectopterygoid* are enormously developed. Wedged in between them posteriorly and above is a large mass of bone that appears to be developed on the part of the first mentioned element. Where they meet at the apex anteriorly I find another irregular piece of bone, with a little process on its outer side. This element appears to be separately ossified, but without a complete skull I could not say positively whether it be the *palatine* or not. It occupies about the proper position for that bone, and, everything considered, it would not surprise me to find it assuming any remarkable shape. A highly developed and prominent semiglobular facet is found on the upper third of the posterior margin of the hyomandibular, for articulation with the operculum.

Of the cranium of Megalops.—The specimen of the cranium of this fish is also from the cabinet of Professor Gill, and from it I have made two drawings (Plate XIV, Figs. 33 and 34)—a direct lateral view and a posterior one. The specimen is evidently not a perfect one, though it is the best I could secure for the purpose, and my reasons for choosing it have already been stated above. In this particular specimen the basisphenoid is apparently missing, its median plate having been broken off, leaving the points of fracture distinctly visible. Again, either a single parietal plate or a pair of parietals have undoubtedly been lost, and when perfect individuals come to be examined I believe the space existing in Fig. 34 between the supraoccipital and frontals will be properly filled in by such a plate or plates. The rear view of this cranium is unaffected by these losses, as none of the bones mentioned would come in sight in this aspect.

In *Megalops* the *vomer* is the most anterior bone of the cranium. Viewed from above, it presents a median crest with sloping sides, and is overlapped by a triangular process of the ethmoid. Below it is a broad semicircular plate, with a sharp spine directed backwards, which is mortised into the parasphenoid. Anteriorly this plate supports a raised elliptical disk, armed over its entire surface with exceedingly minute teeth (Fig. 34, *Vo.*). The *ethmoid* throws out on either side a curved and flattened process, directed outwards, downwards, and backwards; against the extremity of each rests an irregular prefrontal (Fig. 34, *Prf. Eth.*). This region is completed by the anterior extremities of the frontal and parasphenoid as far as its bony walls are concerned, while its remaining parts are fashioned in cartilage. The rostrum of the *parasphenoid* makes an angle of 45° with the plane of its body. Its anterior extremity is dilated from side to side, and articulates with the vomer, as already described. The under surface of the rostrum is longitudinally concave, deepest near its middle third. Its upper surface is composed of two sides, each directed upwards and outwards; they meet for the entire length in the median line. The lower part, or body, of the parasphenoid is scooped out above to assist in the formation of the eye-muscle canal; its outer margins articulating with the proötics (Fig. 34, *Pro.*). Posteriorly the parasphenoid is sharply forked, but is not carried backwards quite as far as the basioccipital goes.

The frontals (*Fr.*) are separated bones, divided by a median, and in the specimen rather an open, suture. Behind they overlap the squamosals on either side, while in turn they are beneath the hinder margin of the ethmoid in front. Their posterior margins are scalloped and the superficies of the bones above strongly sculptured. Either *postfrontal* develops a prominent lateral process; the extensive base supporting it so expands as to articulate with the squamosal and frontal above the alisphenoid internally and the proötic below. It also assists the squamosal in forming the anterior end of the hyomandibular facet (Fig. 34, *Ptf.*). A median tubular foramen passes longitudinally through the *orbitosphenoid*, below which it sends forward a peculiar little process as shown in the figure. This is carried backwards as a bony division, separating the alisphenoid, and forming the apex of the margin of the optic foramen. The body of the orbitosphenoid articulates with a cartilaginous plate anteriorly, while its sides, which are tipped upwards, inclose a space which we will devote our attention to further on. The *alisphenoids* are large circular bones, separated from each other by the orbitosphenoid in the median line. They bound the optic foramen laterally and form the posterior wall for the orbits. There seems to be every indication that in life they are separated above from the frontals by cartilage, though they articulate by suture with the postfrontals and proötics (Fig. 34, *As.*).

The *squamosal* is a very large and prominent bone in the cranium of this fish. Above, it forms a considerable share of the vault of the skull, articulating with the epiotic behind, and the frontal and sphenotic in front. (*Sq.*) Laterally it forms the hyomandibular facet, and enters with the opisthotic and proötic into the formation of a deep conical indentation, immediately below the facet in question. It has a strongly marked and raised ridge, extending from its outer and posterior angle obliquely to the corresponding angle of the frontal (Fig. 34).

The *basioccipital* occupying its usual position, is much compressed from side to side, notwithstanding its centrum behind is very large, with raised periphery. Most of the antero-lateral region of the cranium of *Megalops* is made up of the *proötic* (*Pr. O.*). This bone is pierced by its usual foramina, and meets its fellow of the opposite side in the floor of the cranium. Upon the lateral view of this part of the skull, the most striking feature is a thin lamina of bone, with its plane nearly parallel with the basioccipital, and formed not altogether unlike a diminutive hand. This appendage seems to be developed on the part of the *opisthotic*, but of its function I can say nothing until I am permitted to make a dissection of a fresh specimen of *Megalops*. A *posterior view* of the cranium of this fish reveals to us its most extraordinary structure, and one that would not be suspected hardly from a direct lateral aspect; indeed, not at all, if the vacuity were filled in, where I believe the parietals really belong.

To arrive at a good description of the condition of affairs, as I find them here, it will be necessary for me to describe one or two of the bones seen on posterior view, and first among these the *supraoccipital*. Viewed from above, this bone presents somewhat of an extensive surface, being greatly convex from side to side, while it is carried forward in the median line as a sharp process (Fig. 34, *S. O.*), and behind we see developed a stunted, lamelliform "supraoccipital crest," extending directly backwards, with a small foramen on either side of it. Behind, this bone is represented by a vertical plate wedged in between the epiotics, a vacuity existing at its apex below. The *epiotics* are well shown in Fig. 33 (*Ep. O.*), and the manner in which they articulate with the exoccipitals and squamosals (*E. O.* and *Sq.*). Now upon the anterior aspect the supraoccipital and the epiotic on either side, chiefly the former bone, go to form a plowshare-shaped projection, that forms the hinder and upper part of the vault of the cranium. Beyond it lies a convex surface, in the specimen formed of dried membrane; this constitutes the next section of the *cranial vault*. Upon the outer side of either epiotic we observe a large elliptical opening; these lead into a capacious cavity that exists between the frontals, squamosals, and other bones of the roof above, and the true outer cranial vault, composed of the alisphenoids, prefrontals, squamosals, and other bones below. This cavity is irregularly wedge-shaped, its base being behind and its thin edge situated anteriorly. This latter part lies between the orbitosphenoids below and the frontals above. As we proceed backwards the interspace becomes greater, and it is here bounded by the frontals above and the alisphenoid and postfrontals below. In this region, too, in the median line, we find that the alisphenoids and orbitosphenoids contribute to form a bony stanchion, that is directed forwards and upwards for the support of the frontal plates which rest upon its apex. The alisphenoids are produced clear backwards to form a dome-like surface, convex outwards, that is the anterior roof of the cranial vault. In this the alisphenoids are assisted by the postfrontals on either side, and both of these bones can be seen through the apertures of this cavity behind (Fig. 33, *As.* and *Ptf.*). The sides of the roof of the cranium are formed by an incurved surface on the part of each squamosal, while a somewhat similar surface, afforded by either exoccipital, completes the parietes of the brain case in the rear.

The form of the *exoccipitals*, the method in which they articulate with the surrounding bones, and how they contribute to the formation of the foramen magnum, is all well shown in Fig. 33, where these bones are marked *E. O.* A vagus foramen pierces each one on either side of the foramen magnum, while, owing to the fact that the exit for the optic nerves being so large, the parasphenoid can easily be discerned through the latter opening (Fig. 33). The basioccipital forms the lower arc of the periphery of the foramen magnum, as shown in the figure. Its large articular facet is completely covered, through the very interesting fact that it is so far anchylosed with the first vertebra of the column that it is impossible to remove the latter in the specimen without doing it injury (see Plate XIX, Figs. 33 and 34, *c. v.*). This is particularly interesting when we recall what has been said above, in regard to the co-ossified vertebra of *Amia*, found in this locality, as well as the suspicious condition of affairs in these parts in *Albula vulpes*. The suture between this vertebra in *Megalops* and the exoccipital is distinctly retained, and may be traced completely around the bone. Upon the upper side of this co-ossified or rather co-anchylosed vertebra are seen two circular pits, of some little depth and size. Dr. Gill states that these are intended to lodge the extremities of the neural arch. They are placed side by side transversely and about a millimeter apart. Two similar pits and similarly situated occur on the under side of the vertebra. I am unable to pronounce upon these without first examining a recent specimen of this fish.

Far as *Megalops* is removed from *Amia calva*, I still find in this old imperfect cranium from Professor Gill's cabinet plenty of food for thought—with its suspicious-looking basioccipital vertebra, with its appropriation of at least one trunk vertebra, with its *sculptured* frontals and other bones raised above the cranium proper, with its more or less *circular* ali- and orbito-sphenoids, and with the knowledge that a *gular plate* is found between the rami of its mandible.

We now return to our more typical Teleostean, *Micropterus salmoides*, and discuss other bones of its skull that I have as yet not touched upon in this memoir.

As in so many other bony fishes, we find in this Bass a series of irregularly-shaped bonelets, circumscribing the lower boundary of the orbit. These are the *suborbitals* (Fig. 27, *Sb. o.*). They are seven or eight in number, the hinder one resting on the postfrontal, while the large anterior one, which, in common with other osteologists, I have termed the *lacrymal*, overlaps, when in position, the maxillary and prefrontal (*La.*). On either side of the ethmoid, and what at first appears to be almost a continuation of this chain of bones, we observe another slender osseous element. This is the *nasal*. A mucus canal perforates its substance for its entire length (Fig. 27, *Na.*). In designating these bones as the nasals, I am aware it disagrees with what Sir Richard Owen has stated in his Anatomy of Vertebrates in the matter (Vol. I, pages 113 and 114), and must believe with Parker that "the proper nasal (*na.*) is a small ossification on each nasal roof, external to the supraethmoid in its middle region" (The Salmon, Morph. of the Skull, page 74). I must also believe, until some better observer corrects me, that the bone I have described as the ethmoid in *Megalops* and *Albula* is a single ossification in the adult, and the nasals of these forms I take to be missing in the specimens in hand. Resting on the forward end of the cranium in *Micropterus* we find a handsomely developed pair of *premaxillaries* (Fig. 27, *Pmx.*). Each bone has an ascending process in this region of its support, and when the two are properly articulated they form a graceful and nearly semicircular arch, the lower surface of which is thickly studded with very fine teeth. A rounded, lamelliform process is also developed on the upper side of the limb of each premaxillary, about one-third the distance above its pointed extremity (Plate VIII, Fig. 22).

The *maxillary* is a large bone, with expanded hinder extremity, on the upper border of which it supports an *admaxillary* (Figs. 27 and 22*a*). It is completely edentulous as in most other osseous fishes. Anteriorly it does not meet its fellow of the opposite side, but develops at this end, internally a circular and vertical disk, with a raised facet to articulate with the cranium. Another elliptical disk is found at this extremity, directed outwards. It is for the maxillary process of the palatine to play on. The form of the *palatine* in *Micropterus* is well shown in Fig. 22, *Pl.* This bone being firmly articulated with the palato-quadrate arch, and the maxillaries and premaxillaries being freely movable, the mechanism of these latter bones offers an interesting study. The manner in which they may move upon each other is easily seen in Fig. 22. This is still more engaging a subject in those fishes with protractile snouts, of which there are many genera.

In *Micropterus* the opercular group of bones is very well developed (Fig. 27, and Plate XIII, Fig. 32, *Op.*, *S. Op.*, *Pr. O.*, and *I. Op.*). The *operculum* is a beautiful scale-like plate of bone, the largest of the four. In outline it is an irregular quadrilateral, with a reinforced border on its anterior margin, which is so fashioned and strengthened at its upper and anterior angle as to form a proper enlargement to support the articular facet for the hyomandibular. Viewed from without, its lower border overlaps for a couple of millimeters the *suboperculum*. This latter bone is shaped as shown in Figs. 27 and 32. Anteriorly it develops a pointed and upturned process, that lies between the lower angle of the operculum and the upper angle of the interoperculum.

The *interoperculum* has a quadrilateral outline, with the angles rounded off. Externally it is well overlapped by the preoperculum, and is attached to the mandible by ligament, while internally the epihyal and interhyal of the hyoid arch rest against it. In texture these three bones of the group are semitransparent and exquisitely marked with radiating and wavy concentric lines.

The *preoperculum* overlies all the other opercular bones, while it itself is overlaid by the hyomandibular above and the quadrate below. It is roughly crescentric in form, being carried to a gradually tapering point above, and strengthened throughout its entire length by a raised ridge of bone. On its inner aspect the lower limit of the hyomandibular, the interhyal, and the symplectic rest against it (Fig. 32).

It has been said that the opercular bones are but modified, or rather transformed, branchiostegal rays.

Situated beyond the opercula we discover another arcade of bones; this consists, from above downwards, of the *hyomandibular*, *symplectic*, and *quadrate*, the chain constituting the *suspensorium*. They connect, in *Micropterus* as in the osseous fishes generally, the cranium with the lower jaw (Figs. 27 and 32, *H. M.*, *Sym.* and *Qu.*). By the intervention of the *interhyal*, the hyomandibular has also suspended from its lower extremity the hyoid arch, and its upper and posterior angle, as we saw above, also articulates with the operculum. The hyomandibular is compressed from side to side, expanded above, to be gradually drawn down to a blunt point below, where it is united through a common cartilaginous bridge with the apices of the interhyal and symplectic. This latter element is wedged in between the quadrate and preoperculum, with the metapterygoid resting against its anterior border, it being merely a small bone that has been segmented off from the hyomandibular.

The *quadrate* is here, as is usually the case among fishes, a triangular bone of some size, articulating with the mandible at its lower angle (Fig. 27, *Qu.*). Against the upper half of its anterior border, by a very close suture, the ectopterygoid is placed, forming a part of the connection of the next arch beyond with the suspensorium. Upon the cranium the hyomandibular articulates with the postfrontal and squamosal in a long, narrow, longitudinal facet.

The arch next beyond the suspensorium is the *pterygo-palatine arch*. It is made up of the *metapterygoid*, the *ento-* and *ectoptergoid* and the *palatine*. This last element I have figured and sufficiently described above. In a great many fishes the palatine is movably connected at the anterior extremity of the arch to which it belongs. The *metapterygoid* (Fig. 32, *M. Pt.*), a flattened and irregularly shaped bone is wedged in between the hyomandibular and quadrate, and firmly establishes the connection of the two arches at this extremity. It overlies also a thin scale-like process thrown out on the part of the *ectopterygoid*, just opposite the angle this bone makes above its articulation with the quadrate. The *ectopterygoid* is a bent and narrow strip of bone that directly connects the quadrate with the palatine. It forms the outer margin of the floor of the orbit, which is chiefly made up of the entopterygoid. Both the palatine and ectopterygoid support a dense area of very fine teeth upon their lower surfaces. The *entopterygoid* is a beautiful shell-like bone which is overlapped by the palatine anteriorly and the metapterygoid behind. It is bent upon itself at about its lower third towards the median plane, and thus forms the greater part of the floor of the orbit by its upper surface, and by its lower the roof of the mouth. The entopterygoid is quite transparent, and for some little distance from its outer margin marked by wavy and delicate concentric lines.

Although the bones just described are so intimately connected with the quadrate, I prefer to call this arch, as I have done above, the pterygo-palatine, considering the quadrate as the property of the suspensorium. It is often termed, however, the palato-quadrate arch, and I took occasion to use this term in the first part of this paper.

Of the Hyoid and Branchial Arches of Micropterus.—Our large-mouthed black bass offers us very little that differs from the more typical Teleosteans in the skeletal parts of its respiratory apparatus. From the lower end of each hyomandibular there is, as we saw above, suspended a small rod of bone, the interhyal (the stylohyal of many authors). To these is articulated, on either side, a broad triangular piece, the *epihyal* (Fig. 32, *E. hy.*), which in its turn connects with the larger and longer piece, the *ceratohyal*. The connection between these two latter elements is very much strengthened by a longitudinal lashing of bony fibers on the inner aspects over the joint, the bones themselves being quite compressed and flattened plates of a form shown in the figure. The ceratohyals, the anterior pair, meet in front in a ligamentous symphysis, over which ride, side by side, two other separate elements, the *hypohyals* (*H. hy.*). These are broadly conical in form, with their apices drawn out into blunt processes, which are directed upwards and backwards. Resting upon the hypohyals above is an azygos bone about a centimeter long (in a bass that would weigh three pounds), which is the *glossohyal* (Fig. 27, *G. hy.*). It is a flattened bone, shaped somewhat like the vertical section of an hour-glass, it being the part of the skeleton which supports the soft parts of the tongue. This bone has also been called the *os linguale*. It may be absent in some of the true bony fishes.

In the specimen I have in my hand we see on the outer aspect of the epihyal, just above its lower and near its anterior border, two large and curved branchiostegal rays, which in life are held in this position by ligament. The hinder and larger one is possessed of quite a blade-like extension, and the bone, like the rest of the series, is gently curved upwards. Two more branchiostegal rays are attached in a similar manner to the ceratohyal, the four bones being placed at about equal distances apart. The series of branchiostegal rays progressively increase in size from before backwards, the anterior ones being the most abruptly curved. The next two rays in order are attached to the lower margin of the ceratohyal, and I am under the impression that I have dissected specimens where a seventh ray has existed that was attached in order, beyond these, just within this border. As we know, the branchiostegal rays support a membrane of the same name, which forms sort of an auxiliary gill-flap.

Lying in the median plane, posterior to, but attached by ligament to the symphysis of the cerato-hyals, we find a plate of bone, that in the living fish separates the sternohyoid muscles. This bone is of a triangular outline, with its apex forward, a part of which bears a dilatation and *superior osseous loop* for a greater ligamentous attachment. Its lower margin is transversely expanded, and the plate is further strengthened by the development of an osseous rod that runs longitudinally through its center. This azygos plate is the *urohyal*, and is peculiar to fishes. In life it lies between the sternohyoid muscles, and is not always present where a glossohyal exists.

Aside from this *urohyal* and the branchiostegal rays, the bones we have been thus far examining constitute the *hyoid arch*, and this Bass presents it in what may be said a typical form for fishes, if anything can be adopted as a standard in form in a class where all the structures vary so in shape.

The relation of the various bones of the piscine skull and their functions, when we come to compare them with the homologous elements in the higher animals—man, for instance—has always presented to my mind one of the most interesting subjects in anatomy. Here in our specimen we have the hyoid arch, supporting, on either side, a series of branchiostegal rays. *These rays constitute the skeleton of an organ of defense to the respiratory apparatus.* It is believed by some that the opercular bones are modified branchiostegal rays, and these in their turn form the *lateral osseous wall of defense to the gill chamber, also the respiratory apparatus.* The *operculum articulates* with the hyomandibular of the suspensorium, which bone is said to be the representative of the *incus* of the human *ear*, while the lower bone, the *quadrate*, of the suspensorium, is a segmented portion of the *malleus*, another of the auditory ossicles in man. Now, in its turn the quadrate articulates with the *mandible* or lower jaw, a bone in one way subservient to the *digestive* apparatus.

Lying in the angle formed by the limbs of the hyoid, we find the branchial arches. The arrangement of these in *Micropterus* is so like it is found in *Perca*, and the arches in this latter fish have become so well known both to layman and ichthyotomist, through the many reproductions made of Cuvier's old figure, that I have not thought it necessary to present a figure of this part of the skeleton to illustrate our subject. In the specimen of the bass in my hand, I find but *two* of the copulæ or basibranchials ossified. We remember that three of them ossify in the perch. Then follow on either side the five pair of segmented branchial arches common to the vast majority of the class; these bear the dentigerous patches on their upper surfaces—the gill-rakers being found farther back and on the outer pair only—while below they support the gills proper.

My collection contains specimens, however, where all three of the basibranchials are well ossified, and teeth appear on the upper surface of the rear one in two circular patches. The ultimate gill-raker is T-shaped, the horizontal bar being applied to the outer side of the arch.

The outer pair of branchial arches are each in two segments—a long, posterior, and inferiorly grooved pair, and an anterior or shorter pair that articulate with the middle of the indented sides of the mid-basibranchial. These latter are bent at a right angle, the long limb being continuous with the hinder segment; the short one, which is quite broad, is the part that meets the basibranchial. This description answers very well for the second branchial arch. The anterior segments of the third arch are much broader, and lie on either side of the ultimate basibranchial, while the fourth arch has no anterior segments; the posterior ones, or those that correspond to them in the other arches, touch each other in the median line.

The *infrapharyngeal bones* are broad, thickly studded with teeth on their superior surfaces, and drawn out into sharp extremities behind. Supported in the usual manner through the means of ligaments by the upturned portions of the arches, and lying beneath the cranium—the *suprapharyngeal* bones—are also thickly beset with teeth.

OF THE MANDIBLE OF MICROPTERUS.

We saw that the lower jaw of *Amia* ossified on either side from quite a number of centers; that it developed a large splenial and other separate elements. This is not the case, however, with the large-mouthed black bass. In this fish, as in many other Teleosteans, each ramus is composed in the adult of but three distinct pieces. These are the *dentary*, the *articular*, and the *angular* (Plate III, Fig. 15, *D. Art.* and *Ang.*). Owen tells us that "in both Sudis and Lepidosteus there is superadded a small bony piece, answering to the surangular of Reptiles." (Anat. Verts, vol. i, page 123.)

The *articular* of Micropterus (*Art.*) consists of a vertical and a horizontal portion, the latter being attached to its posterior half, and is extended backwards to bear the concave lunar facet to articulate with the quadrate. The articular surface of this facet, although on the horizontal portion, of course, looks almost directly upwards. The upper aspect of this plate is marked by wavy lines, five or six in depth, that run round the bone parallel to its outer margin. Passing obliquely through the center of the bone is a mucus canal, the posterior opening of which is a circular foramen placed at the back of the articular process. The anterior opening is flattened and is opposite a similar canal that passes through the body of the dentary. The vertical portion of the articular is of a triangular form, and contains, in a canal in its substance, open on the inner aspect, running longitudinally at its base, the Mecklian cartilage (Fig. 15 *M.c.*). This cartilage passes into the dentary which ensheaths it nearly to the symphysis. The posterior border of the vertical plate of the articular is re-enforced by a thickened and raised rim, the laminated portion being beautifully marked by white lines running parallel to its superior margin. Radiating lines are also carried out to this border from the angle formed by its thickened posterior border and its line of union with the horizontal portion.

The inner posterior angle of the horizontal portion of the articular is completed by a separate piece of bone. This is the *angular*. It is triangular in form and unites with the articular in a roughened suture. This union is not so firm but that the piece comes away during ordinary maceration.

The two *dentary* pieces join each other anteriorly in the median plane in quite a firm symphysis. Thus formed, the entire bone constitutes the major part of the mandible, its superior border being thickly studded with rows of teeth. These rows become fewer in number, and the teeth progressively smaller as we proceed backwards, and they cease to appear within short distance of the posterior projections behind. Each dentary element, posteriorly in the vertical plane, is deeply notched by a triangular indentation (Fig. 15). At the anterior apex of this triangle enters the Mecklian cartilage. The limb below, of this fork, lies in the horizontal plane, constituting the hinder half of an elliptical plate of the dentary, similarly situated. It is through this part that the mucus canal is ensheathed, and into it on the inferior surface open three foramina placed a short distance apart. Other foramina pierce each dentary element on the outer aspect, half way between the symphysis and the apex of the postero-superior process. They are for the passage of vessels and nerves.

Huxley, in speaking of the mode of development that takes place in this region, tells us that "two ossifications commonly appear near the proximal end of Meckel's cartilage, and become bones movably articulated together. The proximal of these is the *quadrate* bone found in most vertebrates, the *malleus* of mammals; the distal is the *os articulare* of the lower jaw in most vertebrates, but does not seem to be represented in mammals. The remainder of Meckel's cartilage usually persists for a longer or shorter time, but does not ossify. It becomes surrounded by bone, arising from one or several centers, in the adjacent membrane, and the *ramus of the mandible* thus formed articulates with the squamosal bone in mammals, but in other *vertebrata* is immovably united with the *os articulare.* Hence the complete ramus of the mandible articulates directly with the skull in mammals, but only indirectly, or through the intermediation of the quadrate, in other *Vertebrata*" (Anat. of vertebrated animals, p. 28, 29). Many of the Teleostei have various muco-dermal bones attached to, or connected with the skull, such as the chain of "supertemporals" that overarch the temporal fossa in some fishes. The most important of these in *Micropterus*, a pair on either side, I propose to call the *supralinear* ossicles (*sl*), as they overlie the anterior end of the lateral line. The largest and most external of these is shaped like a T, the ends of the horizontal portion resting on the squamosal on one hand, and the posttemporal on the other. The vertical limb is directed inwards and a little forwards, having attached to it by ligament the second piece, directed still a little more anteriorly. In the living bass these bones are easily detected, lying just beneath the skin in the lateral line as it arches over the temporal region.

OF THE SHOULDER GIRDLE OF AMIA CALVA.

My description of the girdle of *Amia* will be presented *pari passu* with that of *Micropterus salmoides*, the Teleost we have chosen for comparison in the skull as given above. The nomenclature of the various segments of this part of the skeleton is a matter of great importance, and without entering into any discussion upon this point, I propose here to adopt that of Professor Gill, as set forth in his Arrangement of the Families of Fishes, published by the Smithsonian Institution (November, 1872). Dr. Gill very tersely gives his reasons for departing from the older authors on this subject in the introduction of this valuable and classical paper. It is not necessary for me to repeat his remarks here, as they are now well known to ichthyotomists generally, having been in the hands of scientists for many years.

As the two tables Dr. Gill presents, however, are of great value, and will add so much to my remarks in the present connection, it gives me much pleasure to introduce these here. This eminent ichthyologist first treats of the girdle in Dipnoans, and says in review that "the homologies of the elements of the shoulder girdle of the Dipnoi appear then to be as follows":

Nomenclature adopted.	Owen.	Parker.	Günther.
HUMERUS.	Humerus.	Humerus.	Forearm.
CORACOID (or PARAGLENIAL).	}	Scapula.	Humeral cartilage.
SCAPULA.	} Coracoid.	Supraclavicle.	} Coracoid.
ECTOCORACOID (or CORACOID).	}	Clavicle.	}
STERNUM.		Epicoracoid.	Median cartilage.
POSTTEMPORAL.	Scapula.	Posttemporal.	Suprascapula.

In this table I have omitted certain foot notes and quotations connected with it. As to "The Girdle in other Fishes" Dr. Gill remarks that "the homologies of the elements of the girdle of Dipnoans with those of other fishes, and the added elements in the latter will be as follows":

	Cuvier.	Owen.	Gegenbaur.	Parker.
ACTINOSTS.	Os du carpe.	Carpal.	Basalstücke der Brustflosse.	Brachial.
CORACOID or PARAGLENIAL.		Simple in Dipnoi and Ganoidei.		
HYPERCORACOID.	Radial.	Ulna.	Oberes Stück (Scapulare).	Scapula.
MESOCORACOID.	Troisième os de l'avant bras qui porte le nageoire pectorale.	Humerus	Spangenstück.	Precoracoid.
HYPOCORACOID.	Cubital.	Radius.	Vorderes Stück (Procoracoid.)	Coracoid.
PROSCAPULA.	Huméral.	Coracoid.	Clavicula.	Clavicle.
SCAPULA. ECTOCORACOID.	}	Differentiated only in Dipnoi.		
STERNUM.		Differentiated in Dipnoi.		

POSTTEMPORAL ELEMENTS.

POSTTEMPORAL.	Suprascapulaire.	Suprascapula	Sapraclaviculare (*a*).	Posttemporal.
POSTTEROTEMPORAL.	Scapulaire.	Scapula.	Supraclaviculare (*b*).	Supraclavicle.
TELEOTEMPORALS.	Os coracoidien.	Clavicle.	Accessorisches Stück.	Postclavicles.

Among Teleosteans, as a rule, the *posttemporal*, a forked bone (Plate VIII, Figs. 23, 24 *Pst. T.*), has its inner limb resting on the epiotic, and its outer one resting against or articulating with the pterotic. In some fishes, as the Cats, this limb comes lower down on the side of the cranium.

The *posttemporal* of *Amia*, although it has on side view (Fig. 24) very much the appearance of this bone in *Micropterus*, this is by no means the case on superior view. In the Ganoid the bone is much spread out horizontally and sculptured for a narrow strip just within its external border, like the "cover-bones" of the skull. Moreover, its inner limb, in *Amia*, articulates with the epiotic, while its outer and lower one, a rounded prong, meets the opisthotic.

The *posttemporal* in *Micropterus* is placed much more in the vertical plane; the anterior extremity of its somewhat compressed and longer upper limb rests on the epiotic, while its lower and shorter limb abuts against the pterotic. A process in both these fishes projects backwards from this fork of the posttemporal, against the inner aspect of which the *posterotemporal* articulates. This latter is a scale-like element, with rather a rounded superior head. Its posterior border is deeply notched in *Amia*, and in both cases its flat surface is nearly parallel with the median plane (Figs. 23 and 24, *Psto. T*). Resting on the inner surface of the lower fifth of the *posterotemporal* in *Amia*, we see the upper *teleotemporal* and the superior part of the vertical portion of the *proscapula*. This arrangement is far different in *Micropterus*, where the *teleotemporals* do not come in contact with the *posterotemporals* at all. The *teleotemporal* of the Mudfish is of a quadrilateral outline, and this Ganoid is without any lower *teleotemporal* (Fig. 23 *T.*).

In *Micropterus* there are two of these bones, an upper and a lower one, attached to the other elements of the girdle by ligaments. The upper piece is a scale-like bone parallel to the median plane, while the lower segment is a straight spine resting upon the inner aspect of the entire length of its anterior border (Fig. 23 *T.*). This lower *teleotemporal* was regarded by Carus as a displaced iliac bone. These *teleotemporals* of the bass rest against the coracoids, and above the *proscapula* (Fig. 23). This latter element in *Amia* presents for examination a vertical portion, which has a strong process developed, directed upwards, at its antero-superior angle, a feature it holds in common with *Micropterus*. Now, the outer aspect of this vertical portion is sculptured in *Amia* like the opercular bones, while in the bass it is marked like its own opercular bones, with white, wavy lines and radiations.

The proscapula of *Amia* next sends off anteriorly from its vertical plate, nearly at right angles, a longer and broader portion. This part is pointed at its further end where it articulates with the fellow of the opposite side by ligament. Its upper surface is gently convex, and its inner margin is fortified by a raised rim, directed downwards. This rim, similarly situated, becomes a prominent feature in *Micropterus* (Fig. 23), and the coracoids articulate at its lower edge. They occupy nearly the same position in *Amia*, but here they have become completely amalgamated and are represented only in cartilage (*Yn.*). *Micropterus* lacks a mesocoracoid, but both the *hyper-* and *hypocoracoid* are thoroughly developed. The hypercoracoid is perforated about its middle by an elliptical foramen (Fig. 23, *Hyp. c.*), which is met in many other Teleosteans. Above, this bone articulates with the proscapula, as described above; anteriorly it articulates with the hypocoracoid (*Hyo. c.*), lying in the same plane, while below it articulates with three of the actinosts; the fourth and largest of these bones articulating with the hypocoracoid. This latter bone throws forwards a long, lamelliform spur that reaches far forwards on the under side of the proscapula. It shows a rounded notch behind, just anterior of the facet for the lower actinost. There are *four actinosts* in *Micropterus*, shaped like little dice-boxes, and forming a graded series as regards their size. From their hinder ends spring the sixteen rays that go to form the *pectoral fin* (Plate XIV, Fig. 35, *Ast. Pf.*). I find nine actinosts in the carpus of *Amia*, composed of very elementary bone, with dilated posterior ends, to which are attached the twenty-two rays of the pectoral fin. We cannot see all of these in Fig. 24, because the view does not admit of it, but they are correct in Fig. 35. Delicate markings encircle these rays for their entire length, commencing a short distance beyond their anterior ends.

These members, after passing backwards for about half their distance, divide in two, the forks keeping close side by side and one above the other. This phenomenon is repeated once more before arriving at the posterior margin of the fin. A similar splitting of the fin rays obtains also in the Mudfish. Here, too, the rays, if maceration is carried to excess, cleave in twain longitudinally, but as this can be studied to better advantage in the caudal rays of this Ganoid, I defer saying anything more about it until that part comes to be described.

In *Micropterus* the apex of the united pelvic bones are inserted posteriorly into the angle formed by the articulation of the proscapulæ. The pelvic bones are situated, as we shall see further on, far back in *Amia*, and differ very much in their general character.

Upon the outer side of each proscapula in *Amia* are found a pair of very curious-appearing scales, composed apparently of a toughened membrane, marked in an irregular manner by lines of semi-osseous material, that require the aid of a lens to properly study. These peculiar affairs are attached loosely to the sides of the proscapulæ, but up to the present writing I am not aware that any physiologist has advanced a theory as to the original function of these appendages. They have no evident use now. In referring to these interesting structures, Dr. Wilder says that[64] "upon each side of the *copula*, or isthmus, which connects the shoulder-girdle of *Amia*[65] with the hyoid arch, there are two appendages which are rarely mentioned by authors, and whose nature appears to be undetermined."[66]

"*Historical sketch.*—According to Duméril,[67] these appendages are what Linnæus referred to in the following phrase, to which zoologists who have spoken of *Amia* do not appear to have attached a definite significance: *Gula ossiculis, scutiformibus, e centro striatus.* Valenciennes supposed that he was impressed by the appearance of the branchiostegal rays, which form on each side a sort of striated plate; but in the phrase cited reference is evidently made to the two small dentated pieces of which I am speaking, and which is easy to see. I have also found them mentioned by Stannius." With further quotation from Duméril, the doctor says, "The appendages are not mentioned in Franque's description of *Amia*, nor in the monographs or systematic

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[64] Wilder, Burt G., on the Serrated Appendages of the Throat of Amia, Proc. Amer. Assn. of Science, 1876, page 259.

[65] *Amia* is a fish found living in the Mississippi River and its tributaries, and in the great lakes. It attains a length of two feet, and is called by fishermen "mudfish," "dogfish," and "lake-lawyer." Under the tip of the lower jaw is a movable plate, which does not exist in any other fresh-water fish of America. The adult male has a circular dark spot at the base of the tail (Jordan, 23, 306). *Amia* is now usually regarded as a ganoid, and its brain closely resembles that of Lepidosteus (the garpike); but it seems to be, as remarked by Gill (10), the "most teleosteoid" of that group. [This foot-note is from Dr. Wilder's article.]

[66] I regret to say that it proved to be impracticable to reproduce Dr. Wilder's figures in his very instructive plate.

[67] I have omitted, in this long but important quotation from Wilder's paper, the figures which this author gives that refer to the bibliographical table at the end of his article. Those who wish to refer to the authorities quoted will have to turn to the Proceedings containing this list. So short is Dr. Wilder's paper, and yet his observations are so valuable in the present connection, that I have incorporated them quite extensively, a fact that the reader no doubt will appreciate.

works of Agassiz, Cuvier, Cope, DeKay, Gill, Günther, Huxley, Jordan, Müller, Owen, Rolleston, or Vogt."

With regard to their location and general appearance, this author states that "in the adult *Amia* there are two appendages on each side. They are usually concealed from view by the operculum; but the tip of the hinder one sometimes projects beyond the operculum at a point a little above the base of the pectoral fin. The anterior appendage is about 2 centimeters long, and its anterior extremity is a little more than half its length from the union of the isthmus with the hyoid arch. Its hinder end is nearly opposite the medium tip of the shoulder-girdle. It is wholly superficial, and its hinder border projects but slightly beyond its attachment. The posterior appendage is about twice the length of the anterior, and consists of three portions: a short triangular *root* just beneath the skin; a short but broad *base*, the deep surface of which is continuous with the skin; a long *free* portion, which gradually tapers backward to the tip, which is less than 1^{mm} wide. The root lies to the mesial side of the posterior extremity of the anterior appendage, but there is a distance of nearly 2^{mm} between them. The posterior appendage inclines dorsad, and rests quite closely against the adjacent surface of the shoulder-girdle.

"Neither has any direct connection with bone. The attached surfaces rest upon the muscles which constitute the isthmus, but do not appear to be attached to them. While observing living *Amias* with reference to their respiratory function I never saw any movement of these appendages. The thickness of the posterior one is about $\frac{1}{2}$^{mm}. It is quite flexible during life and while moist, but becomes more rigid when dried.

"The free surfaces of both appendages are corrugated in the adult. The general direction of the ridges and furrows is across the length of the surfaces obliquely forward from the dorsal toward the ventral border. The ridges are more or less wavy in outline, and present irregularities of direction and arrangement, especially toward the tip and ventral border of the posterior appendage. But the distance between any two ridges is quite uniform; the number of ridges being about 18 to the centimeter upon the anterior appendage, and about 12 upon the posterior. The transverse ridges do not always reach the ventral border upon the anterior two-thirds of the posterior appendage; the ventral third of the surfaces is in some cases nearly free, but may present one or more ridges running nearly parallel with the border, or more often, especially on the inner surface, there may be a series of short ridges trending dorsad and *forward* from the lower border to meet the dorsal series at open angles.

"The anterior slopes of the ridges form an angle of about 45° with the surface; but the posterior slopes are nearly perpendicular. The crests are projected backward as numerous fine teeth which are barely visible to the naked eye."

This author then proceeds to give an interesting account of the development of these appendages, and in the matter of structure says they "consist mainly of fibers running longitudinally. I have not yet examined them under the microscope." The doctor is under the impression he has detected homologous structures in *Lepidosteus*, but as to their function he remarks that "I am not aware that any use has been assigned to these appendages, and I have no suggestion to offer. The anterior is evidently passive. The posterior, even if voluntarily movable by the fish, is too flexible for offense, and is, moreover, covered by the operculum," and with regard to morphological significance "unless some function can be assigned to these appendages the conclusion that must naturally suggests itself is that they are remnants of organs which had greater size and performed some function in more or less remote ancestors of *Amia*. The position and general appearance of the posterior pair are not wholly contradictory of the idea that they may have been accessory branchiæ; but this could hardly be surmised respecting the anterior pair, or the supposed homologous parts of *Lepidosteus*. The appendages should be examined in fossil *Amia* and *Lepidosteus*, and in other extinct Ganoids; likewise should careful search for them be made in all living Ganoids, and in the Teleostean genera *Elops* and *Megalops*, which possess some points of resemblance to *Amia*."

The opportunity has never been offered me to examine either of these latter forms with the view of searching for these structures, and at the present writing I am aware of no one who has thrown any further light upon this subject since Dr. Wilder made the above observations.

OF THE PELVIC BONES AND VENTRAL FINS OF AMIA.

In speaking in a general way of these structures, Professor Huxley remarks, that "In all Elasmobranchs and Ganoids, and in a large proportion of the Teleosteans, the pelvic fins are situated far back on the under side of the body, and are said to be "ventral" in position; but, in other Teleosteans, the ventral fins may work forward, so as to be placed immediately behind, or even in front of the pectoral fins. In the former case they are said to be "thoracic," in the latter "jugular." (Anat. Vert. Animals, p. 39.) These pelvic bones in our subject are quite well ossified, and hold a typical "ventral" position. (Plate X., Fig. 26.) They are in two distinct pieces, each piece being shaped like a paddle, with the blade directed forwards. In life they lie side by side just beneath the skin, with the expanded blades in the horizontal plane. Their anterior extremities are cut square across, while posteriorly they are enlarged so these aspects present an elliptical face in each case. In a specimen of *Amia* with a vertebral column 30 centimeters long, I find the pelvic bones each to measure 2½ centimeters in length. So far as this description goes it agrees very well with these parts, as they are figured and described by Franque, but I find other structures here that apparently are not referred to, in either way, by this anatomist. Now, we discover behind each pelvic bone in *Amia* and articulating with the posterior elliptical facet described above, another bone of a conical form, and about one-half a centimeter long. This element seems to take the place of the combined actinosts of the pectoral limb. Again, the rays of the ventral fins are arranged in a peculiar manner; these, which seem to number from seven to eight in an adult specimen, are split as they are in the pectoral rays. The ends thus divided are held well apart in order to allow the separate conical piece of bone to be inserted between them. As in the pectorals, too, these ventral fins are "branched" as they approach their posterior terminations. In form each fin is quite acute and the outer ray is the longest.

Among the Teleosts the pelvic bones not only vary in position, but, as we might readily imagine, vary almost infinitely in regard to their relative size and shape. Indeed, it would be a difficult thing to convey any adequate conception in such an essay as this, of these various forms. They are as numerous, nearly, as the species themselves. These bones are never attached to the vertebral column as we find them in vertebrates above fishes. (Owen.)

In *Micropterus salmoides* they are represented by two separate and symmetrical bones, that articulate with each other mesially, by their inner edges. When thus united they form an elongated isosceles triangle, with its apex held by ligament in the entering angle behind the proscapulæ. The outer borders develop a raised rim, and the planes of the surfaces contributed by the two bones superiorly, on either side, look upwards and outwards, the reverse being the case, of course, beneath. The postero-external angles, as well as the hinder border, is 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 which each pelvic bone takes an equal share. Above, it is bifid, being directed upwards and backwards, and compressed anteroposteriorly; below, it is peg-shaped and directed in the same degree forwards and downwards.

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.

OF THE VERTEBRAL COLUMN, AND SKELETON OF THE REMAINING PARTS.

FIGS. 14, 25, and 26.

Among the general characters of this part of the skeleton we know that "the vertebral column of fishes can only be divided into two regions, the body and the tail. They are distinguished from each other by the characters of the inferior processes of the vertebræ, while the upper arches are connected with the vertebræ in the same manner throughout; and are generally distinguished by the possession of median (spinous) processes. In the region of the trunk, the lower arches are divided into ribs, and supporting transverse processes (parapophyses). In the tail of the Selachii and Ganoïdei they are continuously connected with the centrum, and run out into spinous processes, just like the upper arches." (GEGENBAUR, Elem. Comp. Anat., p 430.) Again, among fishes, generally the vertebræ of the tail develop inferior arches through which the caudal vessels pass. The segments of the column beyond these support ribs which arch over the viscera, but never meet with any sternum mesially, on the ventral parietes. The fins have a skeleton of osseous rays which are supported upon the interhæmal spines.

So well known are they that it is not my intention in the present connection to enter upon the study of the scales of *Amia*. It is sufficient to say that they are of the cycloid type of structure and constitute the exoskeleton of this fish, being arranged much as we find them in the typical Teleosteans.

Anatomists have long understood the morphology of the skeletal parts of the tails of fishes. Professor Huxley tersely presents the conditions for us in these words, when he says that "In all Teleostean fishes the extremity of the spinal column bends up, and a far greater number of the caudal fin-rays lie below than above it. These fishes are, therefore, strictly speaking, heterocercal. Nevertheless, in the great majority of them (as has been already mentioned, page 19), the tail seems, upon a superficial view, to be symmetrical, the spinal column appearing to terminate in the center of a wedge-shaped hypural bone, to the free edges of which the caudal fin-rays are attached, so as to form an upper and a lower lobe, which are equal, or subequal. This characteristically Teleostean structure of the tail-fin has been termed homocercal—a name which may be retained, though it originated in a misconception of the relation of this structure to the heterocercal condition."

"In no Teleostean fish is the bent-up termination of the notochord replaced by vertebræ. Sometimes, as in the salmon, it becomes ensheathed in cartilage, and persists throughout life. But, more usually, its sheath becomes calcified, and the urostyle thus formed coalesces with the dorsal edge of the upper part of the wedge-shaped hypural bone, formed by the anchylosis of a series of ossicles, which are developed in connection with the ventral face of the sheath of the notochord." (Anat. of Vert. Animals, page 131.)

There are ninety vertebræ in the spinal column of *Amia calva;* they are of the amphicœlous type, and devoid of zygapophysial processes (Fig. 14). The centra of these vertebræ are thoroughly ossified, but their neural and hæmal arches remain free throughout life, articulating with them upon certain facets that are overlaid by their cartilage.

I fail to find a pair of ribs attached to the first free vertebra or what now corresponds to the "atlas." Its neural arch has an independent spine, articulating with it, and directed backwards. A similar spine, only longer, is found in a like position on the neural arch of the second and third vertebræ. Three or four others follow in sequence behind these, but they have no apparent connection with the neural arch of the vertebræ. The second vertebra supports a delicate pair of ribs, which articulate *directly* with the sides of its centrum. In the third segment a small pair of parapophyses have made their appearance, and the ribs of this vertebra articulate with their outer extremities. These parapophyses are characteristic of the vertebræ to the thirty-seventh inclusive. They are always directed downwards and outwards; are longest in mid series, but as they proceed backwards are situated lower down on the centrum of the vertebra. The ribs are long and slender and become more so as we proceed towards the tail; in every case they articulate with the extremity of the parapophyses.

The extremity of the neural spine of the sixth vertebra in *Amia* is bifurcated, and this feature is present for about two-thirds the way down the column; these spines being directed upward and backward, with the ones over the middle of the abdominal cavity more decidedly backwards, though the rear spines are the most deeply bifurcated. Twenty of the ultimate ones are simple in their structure. Not very well marked parapophyses are found upon the thirty-eighth vertebra, and this segment is without a pair of ribs. The neural arches inclose quite a capacious neural canal, and their bases articulate between each consecutive pair of vertebræ, these latter having a form to accommodate themselves to this unique condition (Fig. 26). No neural arch is found upon the forty-fifth vertebra, and from that onwards they only occur upon the alternate segments. In the thirty-ninth vertebra, what would at first appear to be the parapophyses in the anterior part of the column, are here much larger, freely articulated, and inclose a canal by the union of their extremities beneath, in the medium plane. These also skip *the same* vertebra as the neural arches do above them on the column; fourteen of them also support a free spine from their mid points below. After this they are united and pass round the bent-up vertebral column, becoming broader and gradually shorter, where they support the caudal fin rays (Fig. 25). The last six or seven of these *hæmal spines* appear to be anchylosed with the vertebræ.

I count in my specimen before me, fifty-three bony rays in the long dorsal fin; these branch above, and the ultimate ones branch a second time. These rays are supported by an equal number of *interspinous bones*, through the intervention of little ossicles that pass obliquely from one to the other (Fig. 25). All this part has been quite correctly figured by Franque, but this author overlooked a series of delicate little bones that continue the interspinous bones of the dorsal fin as far as the caudal fin. These are five in number and are seen at *jf* in Fig. 25. The rays of the dorsal and anal fin split longitudinally, as I described them for the pectoral and ventral fins. The anal fin possesses twelve rays in its membrane, and likewise twelve interspinous bones support it, of which the majority in the mid-series have intermediate ossicles as in the dorsal fin. These little bones are each shaped like a dice-box, and not as Franque has represented them in his drawing.

My representation of the skeleton of the tail of *Amia* I have taken so much pains with to secure its accuracy that I believe any verbal description of the parts hardly necessary. (Fig. 25.) More time than usual was devoted to this figure, because the illustrations of this part of *Amia's* anatomy that it has been my pleasure to examine are far from being correct; they are carelessly drawn or simply diagrammatic in character (Kolliker's).

There are twenty-five rays in the caudal fin of this Ganoid. Of these, the two superior ones are very delicately fashioned, the next two are long and slender, while the stoutest ones are found in the middle, from which series they gradually become smaller again as we proceed downwards. In the prepared specimen all of these rays are found to be split longitudinally in the vertical plane, and those chosen from near the middle of the member are found to be branched to the third or fourth division. They are also marked at irregular intervals by raised and transverse divisions. The splitting spoken of allows these rays to seize by their anterior ends the hypural bones coming from the vertebral column, which they do in the manner shown in the figure. In this, the best living example of a masked heterocercal tail, the notochord, being insheathed only in cartilage, has, of course, disappeared in the figure. It is in *Polypterus* that we find nearly the type of what has been termed the "diphycercal" tail, in which the notochord is scarcely bent up at all. Our example of *Micropterus* shows in a marked degree the remaining style of the skeletal parts of the tail in osseous fishes. This is well known to us under the term of the *homocercal* type, and in this fish shows a very completely ossified urostyle, directed upwards and backwards at an angle of about 45°, with a markedly straight vertebral column. The hypural plates are also very broad and perfect in this bass, and the fin rays, very similar in construction with those described for *Amia*, are attached to them in the same manner. As in so many osseous fishes, *Micropterus* has on either side, close to and between the column on the third hypural plate, a sharp, upturned process. This I believe is intended to afford additional surface and leverage for the origin of the muscle that controls the movements of the tail.

In speaking of this part of *Amia's* anatomy Wilder says [68] that "the

[68] Wilder, Burt G., On the tail of *Amia*. Proc. Amer. Association for the Adv. of Science, 1876, pages 264–266.

tail of *Amia* has been figured and described by Franque, Kölliker, and Huxley."[69]

Kölliker's paper is known to me only through the quotations by Duméril. Franque represents only the osseous portions of the skeleton. Huxley gives both form and structure, but not, as it seems to me, quite accurately. Neither of these authors mentions the young *Amia*, or intimates that the form or structure of the tail may vary with age. In discussing the external form this author further remarks that "Dumeril says that the tail of *Amia*, as to its external appearance, differs in no way from that of the ordinary osseous fishes. Its heterocercy, however decided, is well manifested only by the skeleton." Huxley does not allude to the form, but his figure does *not* very distinctly indicate any difference between the tail of *Amia* and that, for instance, of some Siluroids, where the whole is rounded, and the greatest length is midway between the dorsal and ventral borders."

And, continuing, in the same article he sums up the results of his valuable observations, and says: "I have examined many examples of *Amia*, young and adult, and all manifested the following features:

"1. The greatest length of the tail is considerably above the middle of its height.

"2. The change from the nearly horizontal dorsal and ventral borders to the curved posterior border occurs farther forward upon the ventral side. These features render the ventral slope both longer and more gradual than the dorsal.

"3. When the tail is fully expanded, as while the fish is swimming, the dorsal and ventral slopes meet, so as to form a gentle curve, and not an obtuse point, as in Huxley's figure. This is well shown in (Fig. 3 representing) the tail of a young example in the condition assumed at death.

"The tail of *Lepidosteus* presents the same general features, with some specific variation. Hence, with both these ganoid genera the external form of the tail is decidedly, though not very obviously, unequal."

My interest was first awakened in the structure of *Amia* more than ten years ago, at which time I was permitted to attend Dr. Wilder's lectures at Cornell University, where dissections upon *Amia calva* always held a prominent place. In those days, however, if I remember correctly, Dr. Wilder had made but few, if any, dissections of the young of *Amia*, so it affords me additional pleasure and a peculiar satisfaction to further quote from his paper in the Proceedings his remarks upon the structure of this part of the mudfish's anatomy, supplemented, as it now has been, by studies in that direction. Of it he says that "the terminal caudal vertebræ form an upward curve,

[69] I have, for obvious reasons, referred to elsewhere in this article, omitted Dr. Wilder's number references to his bibliographical table at the end of the above paper in the Proceedings; as well as the references in his text to the figures of his instructive plate.

as shown by Franque. Huxley's figure and description show that the notochord, enveloped by cartilage, extends upward toward the dorsal border of the tail. In all the adults examined by me the termination of this compound rod is considerably nearer the dorsal border than is indicated by Huxley's figure, and presents a rather broad and but slightly rounded tip, with a central depression corresponding to the neural or spinal canal. Here ends the distinct cartilage. Posterior to it, and between the two laminæ of the twenty-first or twenty-second fin-ray (counting from below), is a tract of gelatinous matter, which Kölliker, as quoted by Duméril, seems to have regarded as the prolongation of the notochord. I have been unable to detect any difference between this and the tracts of gelatinous matter between the laminæ of the other caudal fin-rays.

"But that it may fairly be regarded as the prolongation of the notochord, degenerated, and not enveloped by a cartilaginous sheath, is rendered at least probable by the following considerations:

"1. The condition of things in the adult *Lepidosteus*, as described and figured by Kölliker and myself; the notochord with its cartilaginous sheath forming a slender tapering rod, extending between the halves of fin-rays to the junction of the middle and hinder thirds of the tail.

"2. The existence of an undulation of the dorsal border of the tail of *Amia* corresponding with the termination of the supposed notochord.

"3. The greater distinctness of this undulation in young individuals."

This interesting paper concludes with remarks upon "transformation" and "variations in the shape of the tail."

Counting the one from which the urostyle springs, *Micropterus* reckons thirty-two vertebræ in its spinal column, fifteen of which are abdominal. These latter all support each a pair of ribs, which in their turn, all save the last four pair, have epipleural appendages. The atlantal pair articulate with the vertebra at the very base of the neural arch, but as we proceed backwards 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 hemal arches of this form are completely anchylosed with the vertebral elements, and in the best developed segments, both superior and inferior, post- and prezygapophyses are present.

The arrangement of the osseous fin-rays and interspinous bones in *Micropterus* differs somewhat, to be sure, from the arrangement of these parts in *Amia*, but not at all from what we have known to exist so long in Teleostean fishes, as in *Perca* for example.

Thus we see it is, that although the Ganoid *Amia calva* has in its skeleton many of the characters in common with the highly specialized forms as the Teleosteans, it is, on the other hand, still stamped with characters, more particularly in its vertebral column, of a veritable paleoichthyic type.

LIST OF THE PRINCIPAL WORKS, COMPRISING OTHERS THAN THOSE CITED IN THE FOOT-NOTES, THAT HAVE BEEN EITHER REFERRED TO OR EXAMINED DURING THE PREPARATION OF THIS MEMOIR.

1. **Agassiz, L.** Young garpikes from Lake Ontario. Proc. Boston Soc. of Nat. Hist. 1856. VI, 48.
2. **Agassiz, L.** Lake Superior; its Physical Character, Vegetation, and Animals. pp. 428. 8 pls. Boston. 1850.
3. **Agassiz, L.** Observations sur les métamorphoses des poissons. Ann. des sci. nat. 1865. III, 55–58.
4. **Agassiz, L.** Observations sur les poissons fossiles. 1833–45. 4 vols. 4to.
5. **Agassiz, L.** Notice of a collection of fishes from the southern bend of the Tennessee River. Am. Jour. of Sci. N. s. No. 21. 353–365.
6. **Agassiz, L.** A Journey in Brazil. 8vo. Ills. 1868.
7. **Agassiz, L.** An essay on classification. Lond. 1850.
8. **Agassiz, L.** The classification of the Siluroid fishes. Proc. Boston Soc. Nat. Hist. 1868. p. 354.
9. **Agassiz, L.** Contributions to the natural history of the United States. 4to. 4 vols.
10. **Balfour, F. M.** Development of the urogenital organs of vertebrates. Journal of Anat. and Phys. Vol. X. Pt. 1. 1875.
11. **Bloch, M. E.** Systema Ichthyologiae. 1801.
12. **Boake.** On the fishes inhabiting the Ceylon marshes. Jour. of the Ceylon branch of the Royal Asiatic Soc. 1865.
13. **Bridge, T. W.** The cranial osteology of Amia calva. Journ. of Anatomy and Physiology, Vol. XI, 1877, pages 605–622.
14. **Busch, W.** De Selachiorum et Ganoideorum encephalo. 4to. 1848.
15. **Cope, E. D.** Observations on the systematic relations of fishes. Proc. Am. Asso. Adv. Sci. 1871.
16. **Cuvier, G., and Valenciennes., A.** Histoire naturelle des poissons. Vol. XIX. 1846.
17. **Cuvier, G,** Le Règne animal. 1829.
18. **Day, F.** Observations on some of the fresh-water fishes of India. Proc. Zool. Soc. of Lond. 1868. 274–288.
19. **Dobson, G. E.** Notes on the respiration of some species of Indian fresh-water fishes. Proc. Zool. Soc. Lond. 1874. 312–321.
20. **Duméril, Aug.** Histoire naturelle des poissons ou ichthyologie générale. Tome I. Elasmobranches (sharks, skates, and chimeræ), pp. 720; 14 plates. 1865. Tome II. (Ganoïdes, Dipnés, Lophobranches), pp. 625; 12 plates. 1870. Paris. 8vo.
21. **Foster, M., and Balfour, F. M.** The elements of embryology. 16mo. Lond. 1874.
22. **Franque, Henricus.** Amiæ calvæ anatomium descripsit tabulaque illustravit. folio. pp. 12, 1 plate. Berlin. 1847.
23. **Gegenbaur, C.** Ueber die Kopfnerven von *Hexanchus*. Jenaische Zeitschrift. VI. Taf. XIII. 1871.
24. **Gill, T. N.** Arrangement of the Families of Fishes. Smith. Inst. Miss. Coll. 1872.
25. **Goodsir, John.** Anatomical memoirs. 8vo. 2 vols. pp. 993. Edin. 1868.
26. **Gottsche, C. M.** Vergl. Anat. des Gehirns der Gratenfische. Arch. für Anat. 1835, 244–294; 483–486. Taf. IV and VI.
27. **Günther, A.** *Ceratodus* and its place in the system. pp. 5. 2 figs. Ann. and Mag. of Nat. Hist. 1871. VII, 222–227.
28. **Günther, A.** Description of *Ceratodus*, a genus of Ganoid fishes recently discovered in the rivers of Queensland, Australia. Phil. Trans. Royal Soc. Lond. 1872. pl. 30–42.

29. **Günther, A.** Article Ichthyology. Encycl. Brit. Vol. XII. 9th ed. 1881.
30. **Hollard, H.** Recherches sur la structure de l'encéphale des poissons et sur la signification homologique de ses différentes parties. Robin's Jour. de l'anat. 1866. 286-335. pl. v-viii.
31. **Humphrey, G. M.** On the homological relations to one another of the mesial and lateral fins in osseous fishes. Jour. Anat. & Phys. November, 1870. 59-66.
32. **Huxley, T. H.** Preliminary essay upon the systematic arrangement of the fishes of the Devonian epoch. Mem. Geo. Surv. of the U. King. Decade X. 1861.
33. **Huxley, T. H.** Manual of the comparative anatomy of the vertebrated animals. N. Y. 1872.
34. **Huxley, T. H.** Observations on the development of the tail in Teleostean fishes. Quart. Jour. Micro. Sci. VII. 33-44. Plate III. 1859.
35. **Huxley, T. H.** On Ceratodus Forsteri. Proc. Zool. Soc. Lond. January 4, 1876.
36. **Jordan, D. S.**, and **Gilbert, C. H.** Synopsis of the fishes of North America. Bull. U. S. Nat. Mus., No. 16. 1882.
37. **Jordan, D. S.** Manual of the vertebrates of the Northern United States, exclusive of marine species. pp. 342. 12mo. Chicago. 1876.
38. **Kölliker.** Ueber das Ende wirbelsaüle Ganoiden und einigen Teleostien. 1860.
39. **Lacépède.** Histoire des poissons.
40. **Langerhaus, Paul.** Zur Anatomie des *Amphioxus lanceolatus*. Archiv für Kroskopische Anat. Band XII. Zweites Heft. 1875. Taf. XII-XV.
41. **Le Conte, Joseph.** Elements of geology. New York. 1883.
42. **Linnæus, Carl von.** Systema naturæ. 12th ed. 1766.
43. **Lütken, C.** On the limits and classification of the Ganoids. Trans. Ann. & Mag. of Nat. Hist. 1871. 329-339.
44. **Mayer, F. J. C.** Ueber den Bau der Gehirns Fische in Beziehung auf eine darauf gegründete Eintheilung dieser Thierklasse. Mit sieben Steintafeln. pp. 40. Novorum Actorum * * * Naturæ Curiosorum. Tom. Vicesimus Secundus. 1864.
45. **Miklucho-Maclay.** Beitrag zur vergleichenden Anatomie des Gehirns. pp. 19. 3 figs. Jenaischen Zeitschrift für Medicin und Naturwissenschaft. 1868.
46. **Miklucho-Maclay.** Beiträge zur vergl. Neurologie der Wirbelthiere. Leipzig. 1870.
47. **Milne-Edwards, A.** Leçons sur la physiologie et l'anatomie comparée de l'homme et des animaux. Tome deuxième. 1857.
48. **Mivart, St. George.** Lessons in elementary anatomy. Lond. 1877.
49. **Moreau, A.** Recherches expérimentales sur les fonctions de la vessie natatoire. Ann. des sciences nat. Tome IV. 1876. pp. 85. 2 plates.
50. **Müller, Johannes.** Vergleichende Neurologie der Myxinoiden. Abh. der königl. Akad. zu Berlin. 1838.
51. **Müller, Johannes.** Ueber den Bau und die Grenzen der Ganoiden und über das natürliche System der Fische. Abhandlung der königlichen Akademie der Wissenschaften zu Berlin. 1844. Quarto. 117-216; 16 plates.
52. **Müller, Johannes.** Bericht über die Fortschritte der vergleichenden Anatomie der Wirbelthiere im Jahre 1842. Archiv für Anat. 1843. ccxxxviii-cclxi.
53. **Müller, Johannes.** Ueber den eigenthümlicen Bau des Gehörorganes bei den Cyclostomen, mit Bemerkungen über die ungleiche Ausbildung der Sinnesorgane bei den Myxinoiden. pp 34. Taf. 1-3. Abhandlungen der königlichen Akademie der Wissenschaften zu Berlin. 1837.
54. **Müller, Johannes.** Mémoire sur les Ganoïdes et sur la classification naturelle des poissons. 1845. Ann. des sciences nat. 3me série, Tom. IV. 1845. 5-53.
55. **Newberry, J. S.** Description of fossil fishes of Ohio. pp. 110. 17 plates. Geol. Surv. of Ohio. Vol. 1. 1873.

56. **Ord, Wm. M.** Notes on comparative anatomy. Lond. 1871.
57. **Owen, R.** Description of *Lepidosiren annectens.* Linn. Trans. xviii. 5 plates.
58. **Owen, R.** Comparative anatomy and physiology of vertebrates. 3 vols. 8vo. Lond. 1861–68.
59. **Parker, W. K.** On the development of the salmon's skull. Trans. Royal Soc. Vol. 163.
60. **Parker, W. K.,** and **Bettany, G. T.** The morphology of the skull. Lond. 1877.
61. **Poey, F.** Observations on different points in the natural history of Cuba. Ann. of the Lyceum of Nat. Hist. N. Y. 1858. VI, 136.
62. **Shufeldt, R. W.** Osteology of the large-mouthed black bass (*Micropterus salmoides*). Science, Vol. III, No. 65. May 2, 1884. Cambridge.
63. **Stannius, H.** Ueber den Bau des Gehirns des Störs. Archiv für Anatomie. 1843. 36–44. Taf. III–IV.
64. **Stannius, H.** Handbuch der Zootomie. 2. Theil. 2d ed. 1854.
65. **Tiedemann, F.** The anatomy of the fœtal brain; with a comparative exposition of its structure in animals. (Eng. Trans.) 14 pls. Edinburgh. 1826.
66. **Valentin.** Ueber das centrale Nervensystem und die Nebenherzen der *Chimæra monstrosa.* Arch. für Anat. 1845. 25–45. Taf II.
67. **Vogt, C.** Quelques observations sur les caractères qui servent à la classification des poissons ganoïdes. Ann. des Sci. nat. 3^{me} série. Tom. XIV. 1845.
68. **Vulpian, A.** Leçons sur la physiologie générale et comparative du système nerveux. 1861. 8vo. pp. 20.
69. **Wilder, B. G.** Notes on the N. A. Ganoids. I. On the respiratory actions of *Amia* and *Lepidosteus.* Proc. Am. Asso. Adv. Sci. 1875. 151–153.
70. **Wilder, B. G.** On the serrated appendages of the throat of *Amia.* Proc. Am. Asso. Adv. Sci. 1876. 259–263.
71. **Wilder, B. G.** On the tail of *Amia.* Proc. Am. Asso. Adv. Sci. 1876. 264–266.
72. **Wilder, B. G.** Notes on the development and homologies of the anterior brain-mass with sharks and skates. Am. Jour. Sci. August, 1876. 105. 1 fig.
73. **Wyman, Jeffries.** Anatomy of the nervous system of *Rana pipiens.* Smith. Contri. to Knowledge. V, Art. 4. 1855. 4to. pp. 51, 2 pls.
74. **Wyman, Jeffries.** Observations on the development of *Raia batis.* Memoirs of Amer. Acad. of Arts and Sci. 1874. 4to. 1 pl.