THE

STRUCTURE AND RELATIONS

OF

DINICHTHYS,

WITH DESCRIPTIONS OF

SOME OTHER NEW FOSSIL FISHES.

BY J. S. NEWBERRY.

FROM THE REPORT OF THE GEOLOGICAL SURVEY OF OHIO, VOL. II.

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GEOLOGICAL SURVEY OF OHIO.

VOL. II. PART II.

PALÆONTOLOGY.

DESCRIPTIONS OF FOSSIL FISHES.

BY

J. S. NEWBERRY.

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FISHES OF THE DEVONIAN SYSTEM.

GANOIDEI.

PLACODERMI

GENUS DINICHTHYS, Newb.

SINCE the publication of the first volume of this Report, a large amount of interesting material, illustrating the structure of this genus, has been brought to light. In this material is to be found nearly the entire bony system of one large individual, which gives us a more complete representation of *Dinichthys* than has yet been obtained of any of the larger fossil fishes of the Old World. These specimens we owe to the enthusiasm and intelligence of Mr. Jay Terrell, who found them at his home in Sheffield, Lorain Co. Here the upper portion of the Huron shale forms, along the Lake Shore, cliffs, which are being constantly worn away by the waves. These cliffs have been Mr. Terrell's favorite hunting ground, and as the erosion of the surface revealed here and there the projecting point of a bone, each indication has been followed up with care, and the bone taken out, perhaps in many fragments, but yet complete in all its parts. Mr. Terrell has carefully preserved and united these fragments, and thus has been able to contribute to science some of the most interesting and valuable palæontological material ever discovered. Some months since, while scanning the cliffs near his house, his attention was attracted to a bone of which only a small portion was visible, the remainder being concealed in the rock. On taking this out, others immediately associated with it were revealed, which were, however, so deeply buried, as to be inaccessible by ordinary means. In these circumstances Mr. Terrell began operations on a shoulder of the cliff immediately above, and excavated a space about twelve feet square down to the locality of the bones. Here he found the ventral shield, before unknown, quite complete; one perfect mandible, a "premaxillary," and two "maxillaries;" a perfect dorsal shield, two feet in diameter; two scapulo-coracoids, with a large number of additional bones, including the ossified rays of a large fin. From the same locality Mr. Terrell had before obtained a cranium almost complete, and two Supra-

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scapulas, thus giving us, as has been said, nearly the entire bony structure.

Since this important discovery, Mr. Terrell has found a complete mandible and maxillary of larger size than any before met with; the mandible being twenty-two inches in length.

From this rich array of material we get not only much additional light in regard to the structure of *Dinichthys*, but are furnished with the means for accurately defining the two known species of the genus. It also shows that some errors were committed, from confounding the two species, in writing the descriptions contained in Vol. I.

When the main portion of that volume was written, neither maxillary nor mandible had been found on the Lake Shore, and all the bones of *Dinichthys* collected at Sheffield, Monroeville, and Delaware, had been grouped together under one specific name.

In a foot note appended to the description of *Dinichthys* on page 322 of Vol. I., Part II., is mentioned the discovery at Sheffield, by Prof. A. A. Wright, of a mandible quite different from those found at Delaware. This evidently belonged to a new species, to which the name *Dinichthys Terrelli* was then attached. The large number of specimens since obtained, and, indeed, all the remains of *Dinichthys* hitherto taken from the summit of the Huron shale at Sheffield, belong, as we now know, to this species, which is quite distinct from that found at the base of the formation at Delaware. Hence the Dorsal plate figured on Plate 32, the Cranium on Plate 33, and the Supra-scapulas on Plate 34, Vol. I., should be credited to *Dinichthys Terrelli* rather than to *D. Hertzeri*, with which they were formerly and erroneously connected. The details of structure in which the species differ, will be given further on.

The study of the specimens, the discovery of which has been described, has resulted not only in a better knowledge of the anatomy of *Dinichthys*, but has revealed some interesting things in regard to the relations of this genus to living and fossil fishes; all of which will be briefly referred to in the pages which follow.

The most striking feature of *Dinichthys*, apart from its great size, is its dentition, of which we have now all the parts. In this the most conspicuous elements are the massive mandibles, of which the posterior extremities are rounded and flattened, and were evidently connected with cartilaginous articular portions. The anterior end of each mandible is turned up to form a strong, acute, and prominent tooth. Behind this the jaw is thickened by a ridge on the inside, which usually terminates above in a triangular, tooth-like projection. The upper margin of the mandible, for five or six inches behind this projection, is compressed, and consists of remarkably dense, enamel-like bone. In *D. Hertzeri* this is produced

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into a row of conical teeth, about half an inch in length. In *D. Terrelli*, on the contrary, the margin of the mandible here forms a sharp cutting edge. At the posterior end of this edge it is sometimes obscurely crenulated by what are evidently rudimentary teeth, the dwarfed and abortive homologues of those which occupy the margins of the maxillaries and mandibles of *D. Hertzeri*.

The dentition of the upper jaw consists of what I have called, for convenience in my description, premaxillaries and maxillaries, without, however, intending to commit myself fully to this view of their homologies.* These have been partially described in the notice of *Dinicthys* contained in Vol. I., Part II., of this Report, but new material has made it possible to give a fuller description of them now.

Beginning at the anterior extremity of the head, the muzzle is terminated by two large, triangular "premaxillaries," of which the upper sides are flattened and concave, while the opposite angles project downward to form great, incisor-like teeth. These interlock with and shut over the projecting points of the turned up mandibles, which are received into their concavities.

Behind the premaxillaries, two oblong dental plates or *maxillæ* are set directly over the prominent, denticulated, or cutting edges of the mandible. In *D. Hertzeri* the *maxillæ* are somewhat irregular in outline, the lower margins being the longer and set with teeth similar to and interlocking with those of the mandible below. In *D. Terrelli* the maxillaries are oblong or quadrangular, with rounded angles, and the lower edges are sharp and knife-like, and overlap and play upon the sharp edges of the mandibles.

When we compare this peculiar dentition with that of other fishes, we find that *Coccosteus* among fossil, and *Lepidosiren* among living fishes, offer some remarkable and suggestive points of resemblance.

The dentition of *Coccosteus* will be referred to further on in connection with some other anatomical features which it has in common with *Dinich-*

* In describing these bones I have called them premaxillaries and maxillaries, because they hold the positions and perform the functions of these organs in other fishes. We have not yet found the anterior and upper portions of the head so well preserved that its structure can all be made out, and we can only be *certain* of the homologies of the bones in question when we shall have obtained more, and more perfect, material. One head of *D. Hertzeri*, found at Delaware by Mr. Hertzer, shows the "premaxillaries" and "maxillaries" in position, but the interior of the head is not visible. As will be shown further on, the dentition of *Dinichthys* corresponds very closely with that of *Lepidosiren*, but even with full proof of identity of structure in the dentition of these genera, the question before us would hardly be cleared of doubt, as what Professor Owen calls maxillaries in *Lepidosiren*, Professor Huxley calls, probably with good reason, palato-pterygoid dental plates.

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thys, but it may be said here, in passing, that it is on the same general plan with that of *Dinichthys,* and, in some respects, is strikingly similar to that of *D. Hertzeri.*

Comparing *Dinichthys* and *Lepidosiren,* a surprising similarity is at once apparent, and it may be said that the dentition of *Dinichthys Terrelli* is almost exactly like that of *Lepidosiren annectens,* except that it is more than a hundred times larger.

This similarity is well shown in the subjoined wood-cuts, which represent the dentition of both, one of the size of nature, and the other about one-tenth the natural size, linear.

DENTITION OF LEPIDOSIREN ANNECTENS, OWEN.

Front and side views of head, natural size, drawn from specimen.

From these figures it will be seen that the dentition of *Lepidosiren* consists of mandibles which have almost the exact form of those of *Dinichthys Terrelli,* and have the same structure and functions. In *Lepidosiren* the anterior extremity of each mandible rises into a prominent tooth, while, behind this, the upper margin presents, first, a ridge or fold, which produces a subordinate denticle, and then, for about one-third the length of the mandible, is a sharp edge of enamel. At its posterior end this is slightly denticulated, as though with rudimentary teeth, as in *Dinichthys.* In the upper jaw we find two dental plates, more or less perfectly joined at the symphysis, and forming, first, by a strong anterior fold on either side, prominences which are functional teeth, and which match the produced extremities of the mandibles. Behind these, on each side, is a second ridge or fold, and then a wing-like plate of enameled bone, which plays upon the corresponding edge of the mandible. The most cursory examination of the figures and descriptions of the dentition of *Dinichthys* will show that it corresponds closely to this pattern.

In *Lepidosiren* there are also two small, pointed teeth ("nasal," Owen; "vomerine," Huxley) which overhang and precede the dentition that has been described. No teeth corresponding to these have been discovered with the remains of *Dinichthys,* but this is not strange, for even if the

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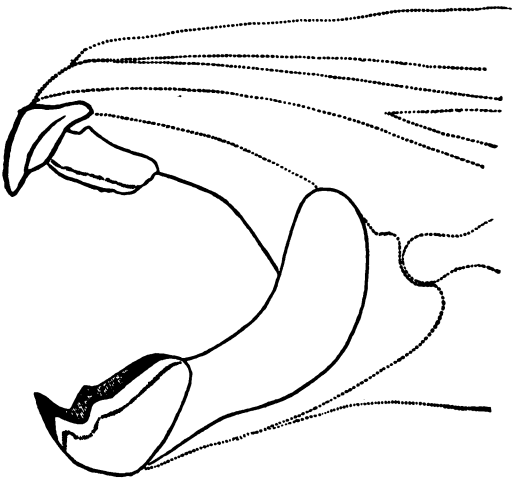
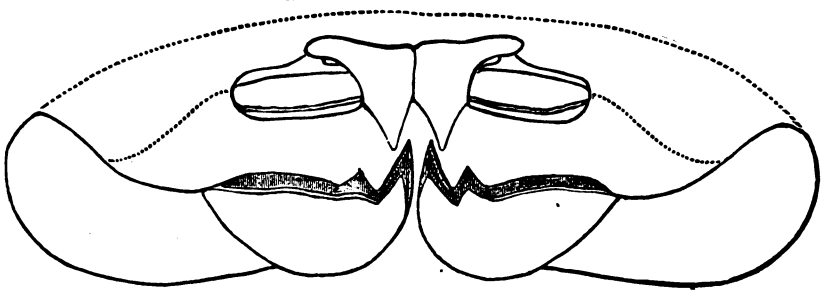
DENTITION OF DINICHTHYS TERRELLI, N.



Side view, one-tenth natural size, linear.

correspondence in dentition had been made exact by the existence in *Dinichthys* of parts homologous to these, they would probably have been easily separated from the cranium, as they are in *Lepidosiren*, and would be quite sure not to be found in position.

DENTITION OF DINICHTHYS TERRELLI.



Front view (diagram) one-tenth natural size, linear.

Professor Theodore Gill, the distinguished zoologist, who has examined my specimens of *Dinichthys*, while recognizing the great similarity existing between the dentition of this genus and that of *Lepidosiren*, and accepting my view of their close zoological relationship, is inclined to consider the great anterior "teeth" of *Dinichthys* as homologous with the small pair of nasal or vomerine teeth of *Lepidosiren*. The reason which he gives for this opinion, is the separation in *Dinichthys* of the parts which I have called premaxillaries and maxillaries, while in *Lepidosiren*, the dental apparatus of the upper jaw consists of a single, though folded

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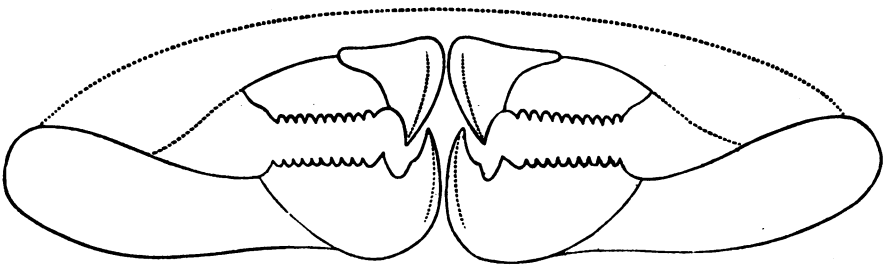
plate on either side. This seems to me, however, a less important feature than he regards it, and the argument used to sustain the view cited above, viz.: that "teeth never coalesce," is hardly supported by facts. Even if true, it could have no bearing on this question, as the organs under discussion cannot be accurately called teeth.

Among the bones of the head in fishes, we find a very wide range of variation, in number, size, position, and mode of union, and this where the homologies can be clearly made out. Now we must suppose each phase of variation to be the result of a special creation, or that the various modifications are derived one from the other. The teeth of fishes are far more variable than the bones proper, and many instances might be cited in which the diversity of size, number, and form of the teeth has apparently resulted from fission or union. A good illustration of this is seen in the genus *Cochliodus*, where some of the species differ mainly in this, that in one (e. g., *C. contortus*) the scroll-like teeth are composed of several rings, set side by side, while in others (as *C. nobilis*), they are united in a solid cylinder. Perhaps a still better example is afforded by the genera *Dipterus* and *Heliodus*. These are closely allied, and they are of special interest in this connection, as they are the ancient representatives of the group of Dipnoans to which the Australian Barramunda (*Ceratodus Forsteri*) belongs. In *Dipterus*, there are *two* triangular fanlike teeth set on the palato-pterygoid bones. These are in contact by the longer of the sides which inclose the right angle, but are not united. In *Heliodus*, these two teeth are completely fused into one (see Plate LVIII., Figs. 15–18).

Where the general plan of dentition is so distinctly preserved, as it is through phases of variations similar to those mentioned above, it is impossible to resist the conclusion that these phases have had a common origin.

DENTITION OF DINICHTHYS HERTZERI.



Front view (diagram) one-tenth natural size, linear.

The question of the homologies of the "premaxillaries" of *Dinichthys*—

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i. e., whether they are the homologues of the anterior, vomerine teeth of *Lepidosiren*, or whether they represent the anterior folds of the great "palato-pterygoid" dental plates, separated from their maxilla-like wings,—though one of interest, does not materially affect the greater question of the general relationship of *Dinichthys* to *Lepidosiren*. The minor question will doubtless be settled in due time by the discovery of some specimen in an unusual state of preservation. The broader and more important one, it seems to me, may be decided from the material now before us.

Whatever may be said in regard to the dentition of the upper jaw, the peculiar mandibles of *Lepidosiren* and *Dinichthys* are so alike in every essential particular that they would seem to afford evidence of relationship, even if all other proof was wanting. On the whole, the correspondence between the dentition of *Dinichthys* and *Lepidosiren* is so remarkably close that it seems to afford good ground for believing that we have in the latter the dwarfed and diminished representative of the great group of fishes which, in the Devonian age, populated and dominated the waters of the globe; and that the peculiar dentition of *Lepidosiren* is a remnant of an antique fashion once much in vogue but now obsolete, except as preserved in this little living Dipnoan. The proof of relationship between *Dinichthys* and *Lepidosiren* seems to be at least as satisfactory as that of *Ceratodus Forsteri* of Australia with *Ceratodus* of the Trias, *Ctenodus* of the Carboniferous, and *Dipterus* of the Devonian; and if the view here presented should be accepted, the facts cited will, perhaps, not be regarded as less important and suggestive than those connected with the discovery of a living species of *Ceratodus*.

The relations of *Dinichthys* to other fossil fishes, as revealed by the series of specimens found during the past year, are no less interesting than those which this great fish bears to the living *Lepidosiren*. The most striking specimens obtained by Mr. Terrell are the bones composing the ventro-pectoral and dorsal shields; both of which are almost entirely complete. These are so perfectly represented in the figures now published (Charts V. and VI.—natural size, from photographs) that no detailed description of them will be required. The large view given of the pectoral and ventral bones represents their inner surfaces, and they are somewhat separated in order that their outlines may be more clearly shown. In the subjoined wood-cut, however, they are represented (one-tenth natural size, linear) in their natural positions, as seen from the outside.

By comparing this plastron—if we may so call it—of *Dinichthys*, with that of *Coccosteus*, which is also given below in outline, it will be seen that they correspond in all essential particulars; so much so that the bones which compose them might be taken to be the homologous parts in different species of the same genus. It is true that the ventral shield of *Coccosteus*,

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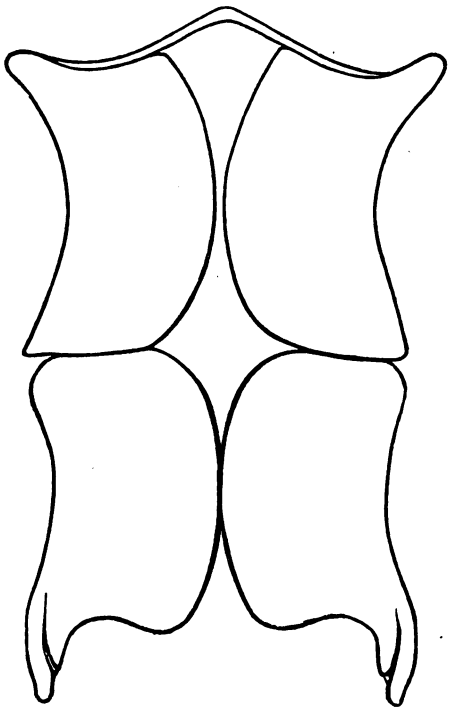
as described and figured by Pander and Owen, consists of six pieces; the central rhomboidal plate ("ventro-median") being detached from the

VENTRAL SHIELD OF DINICHTHYS TERRELLI, N.



One-tenth natural size.

triangular plate which forms the middle of the anterior margin ("pre-ventro-median"). In *Dinichthys*, these two bones, having almost exactly the same form, are united by a narrow bony band. It is almost certain also that they were connected in *Coccosteus*, though it is possible that the isthmus that united them was cartilaginous. The union of these bones is plainly seen in Pander's figures (*Ueber die Placodermen des Devonischen Systems.* Taf. 5, Fig. 1, No. 13.)

The anterior pair of lateral plates (*pre-ventro-laterals* of Owen) are relatively longer and narrower in *Dinichthys* than in *Coccosteus*, and their anterior angles are more prominent; but these differences are of trifling import. The anterior margin of these plates, as well as that of the *pre-ventro-median* is strongly reflexed. This character is indicated by a double line, and is common to the plastrons of both the genera under consideration.

The posterior lateral plates (*post-ventro-laterals* of Owen) are broader

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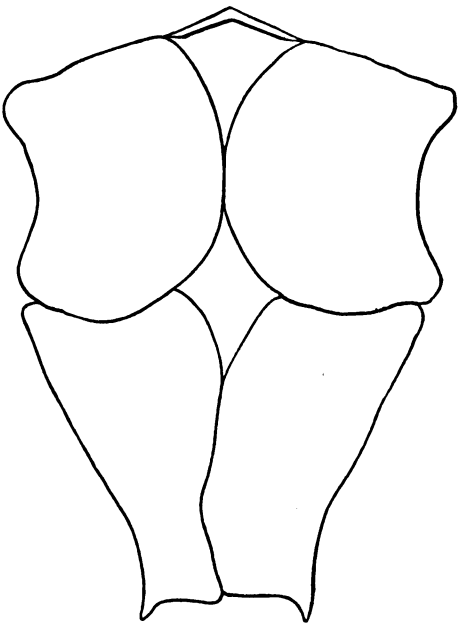
and somewhat more rounded in outline in *Dinichthys* that in *Coccosteus*, but less so than might be inferred from the figures; as in that of the plas-

VENTRAL SHIELD OF COCCOSTEUS DECIPIENS, AGASS.



Natural size: after Pander.

tron of *Coccosteus*—which is taken from Pander's restoration—the posterior lateral plates are represented as overlapped by the anterior laterals, and thus their anterior margins are concealed. One of these plates is also made by Pander in his restoration to overlap the other, and the posterior end of the plastron is thereby much narrowed. What evidence of such overlapping he had does not appear, as no indications of it are seen in his figures of the fossils themselves, either the individual plates, or the groups in which they are shown. The posterior lateral angles of the hinder pair of ventral plates are produced in both *Dinichthys* and *Coccosteus*, but much more so in the former than in the latter. In *Dinichthys* this portion of the plate is greatly thickened, and its interior face is excavated in a deep longitudinal furrow, which must have served to hold and protect the nerves and blood-vessels that passed out to the ventral fins. This furrow is shown in the figures of the post-ventro-lateral plates, which are given, of the natural size, on Chart VI.*

* I have elsewhere called attention to the fact that in position and form these bones correspond so closely with the pubic bones of *Plesiosaurus* as to suggest homology with them. It will also be noticed that the anterior pair of ventral plates offer us striking

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The remarkable correspondence between the ventral shields of *Dinichthys* and *Coccosteus* will probably be accepted without argument as evidence of consanguinity, even though the cephalic and dorsal shields should seem quite unlike. In fact, however, the differences in the armament of the upper part of the body of the two genera are those of degree rather than of kind, and are much less important than would appear at first sight. They will be referred to again on another page.

The relationship of *Dinichthys* and *Coccosteus* is also indicated by similarities of dentition. The jaws and teeth of *Coccosteus* are not yet perfectly known, but Pander has figured the mandibles, and has given some indication of the dentition of the upper jaw; or at least has given figures which show that the premaxillaries (?) were united in one piece, which was set with small, pointed teeth. In all the specimens figured and described by Pander, the anterior extremities of the mandibles seem to have been defective, and we have yet to learn precisely how they were united. In the middle portion of each mandible there is seen a row of teeth formed by the prolongation of the jaw-tissue, precisely as in *Dinichthys Hertzeri*. In the specimens represented in the figure cited above, in addition to the view given of the under side of the ventral plates, the posterior extremities of both mandibles are distinctly shown. These are flattened and spatulate, precisely as in *Dinichthys*. Unfortunately the anterior extremities are broken away; the mutilation of the specimen depriving us of information that would be peculiarly precious in this connection. Many other fragments of the mandibles of *Coccosteus* are figured by Pander, but none supply us the data necessary for a complete comparison with those of *Dinichthys*. We are, however, justified in saying that the dentition, as a whole, was very similar in the two genera.

When now we come to consider the bones of the cranium and the dorsal shields, we find some marked differences between those of *Coccosteus* and *Dinichthys*. In *Coccosteus* the cranial bones form a nearly circular, solidly cemented, and highly ornamented cephalic shield, to which the dorsal carapace is supposed to have been firmly united. In regard to this latter point there is some doubt, for the articulation of the "suprascapular bones" with the posterior lateral angles of the head is such as to indicate considerable freedom of motion; and I am led to believe that the body plates were disconnected with the head except by this articula-

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resemblance to the coracoids of *Plesiosaurus*. In the present state of our knowledge it would doubtless be safer to consider these resemblances those of anolagous rather than homologous bones, but for reasons which will be given further on, it seems to me not *impossible* that we have in the plastron of *Dinichthys* elements of both the pectoral and pelvic arches, here more highly developed than in any living fishes, and presenting Amphibian and even Reptilian characters.

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tion, as we know was the case in *Dinichthys*. The different plates of the body buckler in *Coccosteus* are usually supposed to have been somewhat firmly united. By Agassiz, Pander, Miller, and Owen, they are represented as being all soldered together, but as they were plainly united by splint joints—the margins in some instances greatly overlapping, and the component bones separating so easily that they are usually found disconnected—we are compelled to believe that they were less firmly joined than the head bones.

The Supra-Scapulas (Post-Temporals of Parker) of *Coccosteus* are very much like those of *Dinichthys;* being similar in form, and having a corresponding articulation with the angle of the head. The only noticeable difference in this articulation in the two genera is the thumb-like process thrown out from the epiotic (?) bone, to strengthen it, in *Dinichthys*. This is wanting in *Coccosteus*, but the linear furrows forming the large-figured ornamentation, described elsewhere, is visible on the "Post-Temporals" and Epiotics (?) of both genera.* The "Post-Temporals" of *Chelyophorus* are still more like those of *Dinichthys;* scarcely differing in any respect, except in size.

In the present volume are published figures of the dorsal shield of *Coccosteus*, from American and Scotch specimens; and the dorsal shield of *Dinichthys* is represented on one of the large plates (Chart V.) which accompany this report. From the figures on this chart, all of which are of the natural size, a comparison may be readily made, and it will be seen at a glance that the difference is considerable. That the bones under consideration are homologous, there can be no reasonable doubt; but we must turn to another group of Placoderms to find dorsal shields like that of *Dinichthys*. These we meet with in *Asterolepis* and *Heterostius*, especially the latter. The dorsal shield of *Asterolepis* is the bone described by Hugh Miller as a hyoid plate. Pander, however, places it in its true position, on the back, immediately behind the head. By reference to the figures given on Plate 8 of his work, cited above, it will be seen that in all essential points of structure the dorsal shields of *Heteros-*

* The bone of fishes, called the *Supra-Scapula* by Cuvier, and by most zoologists since his time, is asserted by Mr. W. K. Parker to be the *Post-Temporal*, and since the oblong quadrangular bone which is articulated by a very perfect and movable joint with the head in *Coccosteus* is named the Supra-Scapula by Prof. Huxley, Mr. Parker calls that also the Post-Temporal. While not prepared to deny the accuracy of this view of an anatomist so deservedly distinguished as Mr. Parker, I venture to ask for this case a rehearing, and the consideration of the suggestion that this bone, so entirely independent genetically from the cranium, belongs to a posterior vertebral arch; and that it is either what it has been called, the Supra-Scapula, or still better, the Supra-Clavicle. With this interpretation, the bone with which it articulates, and which forms the posterior lateral angle of the head would be the Post-Temporal.

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tius and *Dinichthys* are the same; the only difference being that in *Heterostius* this bone is much shorter than broad, while in *Dinichthys* the two diameters are nearly equal.

The cranium of *Dinichthys* seems also to approach more nearly in structure to those of *Asterolepis* and *Heterostius* than to that of *Coccosteus*. The resemblance would also seem to be somewhat closer with *Heterostius* than with *Asterolepis*. In the latter genus the occipital portion of the cranium forms nearly a straight, transverse line, while in *Heterostius* it is very much arched, as in *Dinichthys*. The posterior margin of the supra-occipital plate—which forms the center of the arch—has nearly the same character in *Dinichthys* and *Heterostius*, that is, it is impressed with two deep pits separated by a narrow ridge, and behind these is a peculiar pyramidal projection. All the bones of the hinder part of the head in *Dinichthys* are usually found soldered firmly together, the union between the Supra-occipital and the Epiotics being so firm that their points of junction cannot be discerned, and they seem to form one solid bone. This bone is, however, sometimes found disarticulated, and it is figured on Plate LIX.

The anterior portion of the head is generally dismembered, and seems to have consisted of strong bony plates lined with and more or less firmly united by cartilage, as in *Heterostius* and *Asterolepis*.

The outer surfaces of the external bones of *Dinichthys* are marked with a fine granular, almost imperceptible ornamentation. In addition to this, the cranial surface is inscribed with a series of excavated lines which form an ornamental pattern, of which the outlines have not yet been fully made out. Something of the sort is discernible on the crania of nearly all the Placoderms. It may also be seen on the Post-Temporals ("Supra-Scapulas"), and in *Dinichthys* and *Coccosteus* traces of it are visible on the bones of the plastron.

There is this marked difference, however, between *Dinichthys* and its congeners, *Asterolepis*, *Heterostius*, *Coccosteus*, *Pterichthys*, *Aspidichthys*, etc., that they all have the surfaces of their external plates ornamented with thickly-set and often prominent and stellate tubercles, while the surface bones of *Dinichthys* show only the granulation and linear furrows referred to above.

In one instance the anterior part of the head has been found entire, but this was in a concretion, and it was so much injured by the removal of its hard and tough matrix, that the outlines of the plates composing it cannot be discerned. This shows, however, that a sheet of bone covered the entire surface of the head. In all the crania found at Sheffield, the muzzle has disappeared; only the occipital and central portions remaining. The brain-box was apparently partly bone and part cartilage; as we find,

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anterior to the bony arches which strengthen the occipital portion, a depressed area (as seen from the inner side), where some flat radiately-striated bones are crushed up against the roof of the skull. Possibly the brain was completely encased in bone, but the obscure and confused appearance of the under side of the cranium has led me to infer that a considerable portion of the original structure was cartilage.

Two detached cranial bones found with the head, by Mr. Terrell, and referred to on another page, evidently correspond with those figured by Hugh Miller and Pander, as belonging to the anterior part of the head of *Asterolepis*, and partially inclosing the eye-orbits.

A pair of large bones, not before met with, formed part of the great skeleton of *Dinichthys*, quarried out at Sheffield last year, by Mr. Terrell. They are nearly two feet in length, at one end somewhat fan-shaped, flat, and about seven inches wide, at the other narrow and bifurcate. These would be called Coraco-scapular bones by Gill, Coracoids by Owen and Gunther, and Clavicles by Parker. They will be referred to again in the notes on *Dinichthys Terrelli*.

The fins of *Dinichthys* are only made known to us by a single fragment, six inches long by three or four wide. This is apparently a portion of a median fin, of which the rays are as thick as one's little finger, and well ossified. Several large flat plates have been found associated with the bones described above, but their places are not yet fully determined. They will be noticed more at length in the description of *D. Terrelli*.

From the foregoing remarks it will be seen that the discovery of *Dinichthys* is a matter of interest, not simply because it adds another and the most gigantic to a strange, extinct group of fishes, but also because it serves as a connecting link between several genera of Devonian Placoderms, of which the affinities have been somewhat obscure, viz.: *Coccosteus* and *Pterichthys* with *Asterolepis* and *Heterostius*; and more especially because it shows a relationship to exist between these peculiar fishes and the anomalous living *Lepidosiren*.

The finding of a living species of *Ceratodus* (*C. Forsteri*) and its careful study by Dr. Gunther, have apparently resulted in tracing a genetic line from *Dipterus* of the Devonian, through *Ctenodus* of the Carboniferous, and *Ceratodus* of the Trias, to one marked form of living Dipnoans. From what we have seen of the resemblance in structure between *Lepidosiren* and *Dinichthys*, we may conclude that a parallel line ran upward from the Devonian Placoderms to the other living branch of the Dipnoan family, now represented by *Lepidosiren* and *Protopterus*. The links in this chain have not yet been found, but there is little doubt that they will hereafter be discovered.

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It is an interesting fact that the living Dipnoans are inhabitants of the Southern Hemisphere, while the living Ganoids (as formerly defined) are found only in the rivers of the continents lying north of the Equator. This difference of geographical distribution, and the differences noticeable in their anatomical structure, have led zoologists to place the Dipnoans and Ganoids in distinct orders; but Dr. Gunther proposes to unite them in the order *Ganoidei*. The recent discoveries that have been alluded to, seem to confirm this classification, by tracing the living Dipnoans back to the Ganoids of the Palæozoic ages, which then occupied both hemispheres, and formed the most powerful and highly organized living beings.

The relationship which has been shown to exist between the Devonian Ganoids and the modern Dipnoans suggests the question of the relative grade of these ancient fishes; for it is well known that the living Dipnoans, from several points in their structure, and especially from the possession of a three-chambered heart, and both lungs and gills, have been regarded, first, as amphibians, and afterwards, as the highest order of fishes. The terms high and low in classification, have been somewhat vaguely employed, and have created much misapprehension. They are certainly not expressive of the true relationship between the synthetic or *generalized* types of ancient times, and the more *specialized* of the present. The modern Teleost is undoubtedly a more perfect *fish* than any of the so-called fishes of the Palæozoic ages, although the latter include in their structure certain points which link them more closely with the higher classes, the *Amphibia* and *Reptilia*. In one aspect, therefore, —their relationship to the higher groups—the earlier fishes were higher in the scale than the more modern, but in other respects they were more rudimentary in structure, for the vertebral column and brain-box were in them cartilaginous, while in modern fishes they are ossified. The fact seems to be simply this, that the great group of Ganoid fishes, which led and gave character to the fauna of the Devonian age, formed the parent stock from which, by differentiation, the fishes have branched off on one side, the amphibians and reptiles on another. In a tree the lower branches may bear only leaves, and in that respect are but one step in advance of the trunk, while the higher branches bear flowers and fruit; but both are outgrowths from the trunk, and fibres, reaching down from each, blend there; so that the trunk—low in position and function as it is—has more in common with the branches which bear respectively the vegetative and reproductive organs, than they have with each other.

The mingling of amphibian and ichthyic characters in the ancient fishes is readily explained—and we may say, can only be explained—by supposing them to have formed the common stem from which both fishes

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and salamanders have branched. In this original stock the characters of all the derived groups are to be found, though in an imperfectly developed state. Our modern fishes, for the most part, belong to the group called osseous fishes, because they have complete bony skeletons, but in the ancient fishes the quantity of dense bony tissue which formed their exo-skeletons exceeded many times the quantity of bone in the modern fishes, and it was apparently in structure more like the bones of amphibians and reptiles than like the bone-tissue of fishes. Joined to this extreme development of external bone was the cartilaginous vertebral column, which was a mark of embryonic and rudimentary development. It is evident, therefore, that the quantity and the perfection of bone tissue is no safe guide in the classification of fishes. The massive bones of *Dinichthys* are very impressive, not only from their magnitude, but from their density and perfect preservation. None of the bones of reptiles or mammals would have been, under the circumstances, more completely unaffected by the influences that have surrounded them. In this respect they are evidently superior to the soft and elastic bony tissue which forms the skeletons of most, and the highest, modern fishes. We are compelled, however, to regard the complete and impenetrable armor, and the massive and formidable jaws of the great Placoderms, as heavy and rude first models, rather than the light, elegant, and efficient machines which are the perfected results of a long process of improvement. The heavy armor worn by the knights of old has long since been laid aside, for the mail-clad warriors of the middle ages would be clumsy and powerless antagonists to our light-armed troops, carrying repeating rifles and revolvers, and moving with the celerity and precision of modern tactics. So in the progress of ichthyic life, increased intelligence, rapidity of movement and address, have proved in the struggle of life more than a match for the impenetrable but cumbrous defenses of the sluggish and over-loaded Placoderms.

Facts of like import may be found in the life-history of all classes of animals, and those not less real and suggestive in the history of man and the progress of civilization.

In a note appended to a preceding page, I have called attention to another point in the structure of *Dinichthys* which may possibly show a relationship between the Placoderms and the Teleost fishes, and it may even be with the higher classes of Vertebrates. This subject is one of such interest that I venture to again call attention to it. By reference to the figures now given of the ventro-pectoral shield of *Dinichthys*, it will be seen to be composed of two pairs of flattened bones, which apparently held some relations with the pectoral and abdominal fins. This is clearly shown with regard to the posterior pair by the deeply excavated furrows

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which mark their posterior lateral angles. Every anatomist will recognize the probability that these furrows served for the reception of nerves and blood vessels which passed to the posterior members. When, now, we compare this shield with corresponding or analogous parts in other animals, we find some remarkable and suggestive resemblances:

1st. The elements of the ventral shield of *Dinichthys* offer a striking parallel with the flattened bones which compose the lower parts of the pectoral and pelvic arches in *Plesiosaurus*, viz., the coracoids, the interclavicular (or sternal) cartilage, and the pubic bones. It is quite certain that the bones of each series held corresponding positions and performed, more or less perfectly, the same functions, and it has seemed to me not impossible that they are homologous. In this view the anterior lateral bones of the shield would be considered as coracoids, the posterior pair as pubic bones, and the median plate as the equivalent of a sternum, and, perhaps, an interclavicle.

The notion that the paired bones of the plastron of *Dinichthys* can be the representatives of the coracoids and pubic bones of reptiles will at first sight appear so heterodox as hardly to deserve a second thought, and the view that they are simply dermal ossifications, like the scutes of the sturgeon, the dorsal plates of the Siluroids, etc., will seem much more simple and satisfactory.

It would certainly be an easy way of explaining the origin of these plates, to suppose them to form one of the almost infinitely varied phases assumed by the exoskeleton of fishes, but it often happens that the easy and simple explanations of Nature's problems are not the true ones, and, as will be shown further on, reasons may be found for seriously doubting that these bones form any part of the exoskeleton.

2d. In the turtles the under side of the body is defended by a plastron which performs the same functions and resembles much in character the ventral shield of *Dinichthys*. Yet it will be noticed that there are important differences between them. The plastron of the Chelonians usually consists of four pairs of plates, with a wedge-shaped intermediate one in front. All of these are claimed, and are apparently shown, by Rathke, to be membrane bones developed in the integuments, and having no connection with the endoskeleton. The anterior three bones of the plastron of the turtle are thought by Huxley to correspond to the three gular plates of the Labyrinthodont Amphibians and to be the representatives of the clavicles and an interclavicle.

The two pairs of bones which compose the central and chief portion of the plastron of the turtle, hold the positions of the two pairs in the shield of *Dinichthys*, and some turtles possess those which are not greatly unlike them in form. It is, therefore, not impossible that they are their equiva-

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lents; but the Chelonian plastron consists of nine bones, while there are only five in that of *Dinichthys*. Of these five the anterior three correspond more closely in position with the anterior three of the turtle's ventral shield, and have better claims to be considered their equivalents than have the second pair to be regarded as the homologues of the second pair, in the shield of the turtle. The hinder pair of plates in the plastron of *Dinichthys* are much more free and independent than the second pair of the turtle's shield, and have much less the character of dermal scutes, and more that of internal bones. Still farther the posterior pair of the turtle's plates (Xiphoplastrons) are, so far as we know, entirely absent from the plastron of *Dinichthys*. It is perhaps possible that the as yet unlocated plates of the under side of the body of *Dinichthys*, described in the notes on *D. Terrelli*, may have been so associated with those of the plastron as to give the ventral armor more similarity to that of the turtles than it now seems to have, but in the present state of our knowledge the differences seem to be not only great but radical.

3d. The characteristic gular plates of some Amphibians (*Archægosaurus*, etc.) have been referred to as offering some similarity to the anterior three bones of the plastron of *Dinichthys*.

These Amphibian throat-plates consist of a rhomboidal median one, with a pair somewhat triangular in outline, converging forward and united with the median plate by its antero-lateral margins. Von Meyer considers these plates as homologous with the anterior plates of the plastron of the turtles, while Owen compares them with the jugular plates of *Megalichthys* and *Sudis*. By Prof. Huxley they are regarded as clavicles and an interclavicle. Taken by themselves, the anterior three bones of the plastron of *Dinichthys* are not very unlike, in form and position, the gular plates of Amphibians, but we must know more of the plates which protected the throat of *Dinichthys*, before we can make the comparison satisfactorily. Possibly the homologues of the Amphibian gular plates, if any existed in *Dinichthys*, were placed quite anterior to the plastron. However that may be, the posterior pair of plates of *Dinichthys* are without any representatives in the shield of *Archæyosaurus*; a difference so important as to throw doubt over any suggestion of homology.

4th. Prof. Huxley, in his admirable memoir, "On the Classification of Devonian Fishes," * compares the sternal shield of *Coccosteus* with those of some existing Siluroid fishes—*Clarias*, *Loricaria*, etc.—and finds such correspondence in these parts, as well as in the cranial plates and dorsal armor, that he suggests a genetic relationship between the ancient Placo-

* Memoir of the Geological Survey of the United Kingdom, Decade X.

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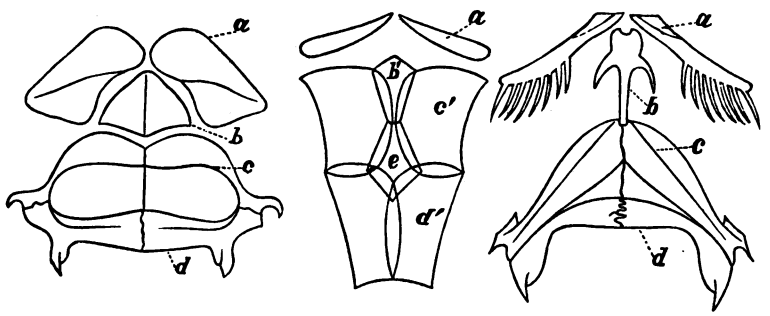
derms and the modern Siluroids. Prof. Owen had previously called attention to this resemblance,* though rather to explain the function of the plate armor of the Placoderms, than to prove a zoological affinity. In fact this resemblance is in many respects very striking; so much so that it is difficult to believe that it is simply "homoplastic," and not "homogenetic." Assuming the theory that our modern Fishes, as well as Amphibians and Reptiles, are derived from a common ichthyic stock, it is not illogical to suppose that the characters of that ancient stock have been divided among their descendants, one line taking one, and another, another of the most striking features, and handing them down as heirlooms through generation after generation. The plate armor of the ancient fishes doubtless served a very useful purpose, and there has probably never been, in the history of fishes, a "piping time of peace," when they could all "lay their armor down," but some tribes have constantly worn it, either in the old time-honored and well-tried patterns, or modified to suit changed circumstances.

Thus it may very well be that the plate armor of the old Placoderms has become the heritage of the Siluroids, and they have retained little beside; while the dentition and much of the internal structure have been preserved by the far more old-fashioned fishes, the *Dipnoi*.

In Professor Huxley's memoir "On the Classification of Devonian Fishes," outline figures are given of the pectoral shields of *Coccosteus*, *Clarias*, and *Loricaria*, which are reproduced below.



CLARIAS. COCCOSTEUS. LORICARIA.

a a a, Hyoid bones. *b b' b*, Urohyals. *c c' c*, "Coracoids." *d d' d*, "Radii."

From the text which accompanies these figures the following passages are quoted:

"On comparing this apparatus with the sternal shield of *Coccosteus*, one is tempted to compare the antero-median piece of the latter with the urohyal of the Siluroid, the antero-lateral piece with the 'coracoid,' and

* Palæontology, Second Edition, p. 148.

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the postero-lateral piece with the so-called 'radius,' the more especially as the antero-lateral piece corresponds with that part of the thoracic shield of *Pterichthys* which supports the plated appendage representing the pectoral fin in that genus.

"On the other hand, it must be confessed that the closer connection of the antero-median piece with the thoracic plates than with the hyoidean cornua, and the very backward position of the postero-lateral plates, apparently out of reach of any connection with the fins, militate against this view; which, in addition, leaves the median rhomboidal plate unaccounted for.

"In the Siluroids to which I have referred (*Clarias*, *Bagrus*, *Arius*, etc.) and in *Loricaria*, a vast latero-ventral shield is produced by the prodigious expansion and coalescence of the bony elements which are homologous with those termed 'coracoid' and 'radius' in other fishes.

"Viewed from the ventral surface, these bones form four great plates, those of each side being closely united, or even amalgamated together, while the opposite pairs are joined in the middle line by a strongly serrated suture.

"When the pectoral fin is provided with an anterior spine, this is articulated by a curiously complicated joint with the so-called coracoid. The cornua of the hyoid are large stout bones, and the urohyal, also a large and strong bone, which is particularly broad in *Loricaria*, connects the hyoidean with the pectoral apparatus."

Mr. W. Kitchen Parker, in his "Monograph on the Shoulder-Girdle" (p. 23, *et seq.*), discusses, with much learning and ability, the homologies of the pectoral shields of the Siluroids and that of *Coccosteus*, but does not fully adopt the suggestion of Prof. Huxley in regard to these. By him the bones of *Clarias* and *Loricaria*, marked *c* and *d* in the above woodcut, are considered to be, respectively, clavicles and interclavicles, while the anterior pair of plates of the ventral shield of *Coccosteus* (marked *c'* in the figures), he regards as interclavicles, and considers them as the counterparts of the lowest bone in the shoulder-girdle of the sturgeon. Of the posterior pair of plates in *Coccosteus*, he says: "The bones lettered *d'* may either belong to the post-clavicular cincture, or they may answer, in their sub-cutaneous portion, to the second pair of interclavicular bones of the *Lophobranchii* (*Hippocampus*, *Syngnathus*, etc.)." He says, further: "The keystone pieces (*b' e* of figures) are the exact counterparts of the first two abdominal line plates of the *Lophobranchii*."

From the almost complete identity of structure in the ventral shields of *Coccosteus* and *Dinichthys*, the questions here raised are of special interest in the study of the latter genus; and, whatever conclusion shall be reached in regard to one, will equally affect the other.

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As I have remarked on a preceding page, before the homologies of the anterior three plates of the ventral shield of *Dinichthys* can be accurately determined, we must know something more than we now do of the other elements of the shoulder-girdle in this genus. First of all, the homology and relations of the great bones, which I have called scapulo-coracoids, must be ascertained. These evidently correspond wholly, or in part, to the so-called coracoids of *Polypterus* (C of Prof. Huxley's diagram, "Classification of Devonian Ganoids," p. 22, Fig. 17), and many other fishes; and probably to the "Clavicles" in Parker's diagram of the shoulder-girdle of *Lepidosiren*.* How these bones terminate below, whether in an epicoracoid cartilage, or in interclavicular plates anterior to the ventro-pectoral shield, we have not yet learned, but must ascertain before we can fully reconstruct the shoulder-girdle. In the absence of proof to the contrary, we may accept, provisionally, the view of Parker that the antero-lateral plates of the shield of *Coccosteus* (and hence of *Dinichthys*) are the homologues of the broad, bony plates which form the basal supports of the pectoral fins in the sturgeon, and those which meet to complete the pectoral arch in *Gasterosteus*, the interclavicles of *Calamichthys*, etc. In all these cases, however, there are no median plates in the pectoral shield, and, to find this element, Parker sends us to the Lophobranchs, where, in the "abdominal line plates," he sees the exact counterparts of the median bones of the shield of *Coccosteus*. It seems to me, however, that this version of the homologies of the plates of the plastron of the great extinct Placoderms cannot be strongly insisted on, though it would be difficult to disprove it. The plastron of *Dinichthys*, for example, composed of but five, large and ponderous, bony plates, is so simple and symmetrical that the effort to find its homologues among the multitudinous scutes of the little Teleost pipe-fish, appears somewhat hopeless; little less difficult, indeed, of satisfactory accomplishment than to identify the homologues of these great plates among the rhomboid or circular scales of a scaled Ganoid.

Leaving the anterior series of the ventral plates of *Coccosteus* and *Dinichthys* with the provisional interpretation given above, and passing to the posterior pair, we have still greater difficulty in following the lead of the great anatomists who have written on the affinities of the Placoderms.

It will be remembered that Mr. Parker says they may either belong to the post-clavicular cincture, or may represent the second pair of interclavicular bones of *Syngnathus;* while Huxley considers them the equivalents of the posterior pair of bones of the ventral shield of *Loricaria*,

* Monograph on the Shoulder-Girdle, Plate 11, Fig. 1.

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etc., and these as corresponding to the so-called "radius." Commenting on this interpretation, Mr. Parker says:

"Professor Huxley, in his invaluable 'Memoir on the Ganoids,' pp. 34, 35, speaks of the interclavicle as 'the so-called radius' (p. 35, Fig. 21, *d*), but it has nothing to do with Professor Owen's 'radius,' which is, in reality, the coracoid."

Here there is evidently a little confusion, for Mr. Parker elsewhere (Monograph, p. 29, near bottom) says: "The large bones below are best seen in Fig. 21, p. 35 (Huxley's Memoir), where *c* is the huge interclavicle;" whereas Prof. Huxley, on the page quoted above, compares the *antero*-lateral piece (interclavicle of Parker) with the "coracoid," and the *postero*-lateral piece with the so-called "radius." With this "coracoid" and "radius" matter we have, however, nothing to do further than to ascertain accurately Professor Huxley's view on the comparison of the ventral shields of *Coccosteus* and *Loricaria*, and to discover in what points Mr. Parker dissents from that view. The facts seem to be as follows: Professor Huxley compares the median plate of the shield of *Coccosteus* with the urohyal of *Loricaria*, the anterior paired plates of the shield of one with those of the other, and the posterior with the posterior. Mr. Parker, however, regards the anterior pair of the ventral plates of *Coccosteus* as the equivalents of the posterior pair of *Loricaria*, and both these as interclavicles; the anterior pair in the Siluroids being supposed by him to be clavicles.

To these conclusions I hesitate to subscribe, because if there is any homology between the ventral shields of *Coccosteus* and *Dinichthys*, and those of our living *Siluroids*—and this is rendered highly probable, both by the resemblances which they present and by the very evident homologies pointed out by Professor Huxley in the dorsal and cranial plates—the posterior pair of plates are, anatomically, the same in both groups.

This is indicated by their like position and backward reach, and by the peculiar processes which form the posterior lateral angles in each.

The position of these plates, as remarked by Professor Huxley, seems to be so far backward as to render it improbable that they had any connection with the pectoral fins, and I venture to suggest that they were post-umbilical and held the same position as the third pair of plates in the plastron of Chelonians; and further that they represent the palmated "interspinous" bones of *Cœlacanthus*, and like them served as supports to the abdominal fins.

If this is true, they belong rather to the pelvic, than to the pectoral arches, and by their size, form, and solidity, were prophetic of the more complete condition of the pelvic arch which characterizes the higher classes of Vertebrates.

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I have frequently been asked by those examining the bones of *Dinichthys*, what was the probable size of this great fish? and what inference as to its habits could be drawn from its remarkable dentition?

To these questions, which will doubtless suggest themselves to the readers of the foregoing pages, I will attempt such answers as are deducible from the facts in my possession. The size of the two species of *Dinichthys* was apparently about the same. This we infer from the relative size of the corresponding bones; the mandibles, for example, having a maximum length of about two feet in both.

The length of the body cannot be accurately determined from any facts yet obtained, as the caudal extremity was provided with no external or internal bony parts, which have been found. In all probability, it was, as in *Coccosteus*, protected by a leathery skin, and the vertebral column was cartilaginous.

We shall, however, find some traces of the interspinous bones, and the rays of the caudal fin, by which the length of the body may be ascertained, as has been done in regard to *Coccosteus*. If we take the proportions of *Coccosteus* (the nearest known ally of *Dinichthys*) as our guide, we may estimate the length to have been fifteen to eighteen feet, and the diameter of body about three.

In regard to the habits of *Dinichthys*, I think we may say with confidence that it was carnivorous. This is plainly taught by the dentition of *D. Hertzeri*, in which the mandibles and "maxillaries" are set with sharp teeth, which must have served to hold other fishes, perhaps the smaller ones, brought within the embrace of the formidable jaws. The cutting edges of the mandibles and "maxillaries" of *D. Terrelli*, are not so plainly indicative of a carnivorous habit, for some of the turtles are vegetable-feeders, with a dental apparatus similar in form and function too, though homologically different from that of this species of *Dinichthys*. Still, the huge anterior teeth, interlocking to a distance of three or four inches, would hardly have been used for any other purpose than for seizing and holding living, struggling prey.

As the dentition of *Lepidosiren* is almost precisely that of *Dinichthys*, it is doubtless used for the same purposes and in the same way. And since this similarity of dentition indicates a general similarity of habit, it has seemed to me that we might perhaps learn something of the nature of the food of *Dinichthys*, and his mode of seizing and masticating it, by observing the habits of *Lepidosiren*.

The fullest exposition of the anatomical structure of *Lepidosiren* will be found in Owen's Memoir, cited above, but this contains almost nothing in regard to its habits. The most satisfactory description of the *life* of the animal is furnished by the Rev. J. G. Wood, in his "Natural History." A-

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the information which he gives will doubtless be new to most readers, and throws some light on the manner in which the formidable dentition of *Dinichthys* was used, I venture to repeat here a portion of his interesting notes. After describing the appearance of *Lepidosiren*, he says: "The habits of this creature are very remarkable. Living in localities where the sun attains a heat so terrific, during a long period of the year, that the waters are dried, and even their muddy beds baked into a hard and stony flooring, these animals would be soon extirpated unless they had some means of securing themselves against this periodical infliction, and of obtaining, throughout the year, some proportion of that moisture for lack of which they would soon die.

"When the hot season has fairly commenced and the waters have begun to lessen in volume, the *Lepidosiren* wriggles its way deeply into the mud, its eyes being so constructed that the wet soil cannot injure them, and the external nostrils being merely two shallow blind sacs. After it has arrived at a suitable depth, it curls itself round, with its tail wrapped partly over the head. A large amount of a slimy substance is then secreted from the body, which has the effect of making the walls of its cell very smooth, and probably aids in binding the muddy particles together. When the rains fall, the moisture penetrates rapidly through the fissures of the earth, cracked in all directions by the constant heat, reaches the cell of the *Lepidosiren*, dissolves its walls, and restores the inhabitant to life and energy.

"Several *Lepidosirens*, or Mud-fishes, as they are popularly called, were sent to the Crystal Palace, while still in their muddy nests, or 'cocoons,' according to the technical term, and in one instance, three specimens were inclosed in a single lump of hard mud, weighing, when dry, about twenty pounds.

"On being immersed in water, the earthy cocoons fell to pieces, as if they had been made of sugar, and the imprisoned creatures were thus released. At first they were exceedingly sluggish, and hardly stirred, but after the lapse of an hour or two they became tolerably alert. * * * Finding that the *Lepidosiren* would rise to the surface of the water when a splash was made, the attendants used to feed it by paddling about with the finger, and then holding a piece of raw beef in the spot where the disturbance had been made. The creature used to rise deliberately, snatch the meat away, and, with a peculiarly graceful turn of the body, descend to its former resting-place for the purpose of eating its food.

"This mode of eating was very remarkable. Taking the extreme tip of the meat between its sharp and strongly-formed teeth, it would bite very severely, the whole of the head seeming to participate in the movement. It then seemed to suck the meat a very little farther into its mouth, and

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gave another bite, proceeding in this fashion until it had subjected the entire morsel to the same treatment.

"It then suddenly shot out the meat, caught it as before by the tip, and repeated the same process. After a third such manœuvre, it swallowed the morsel with a quick jerk. The animal always went through this curious series of operations, never swallowing the meat until after the third time of masticating.

"After a while, it was thought that the water in which it lived was not sufficiently warm to represent the tepid streams of its native land, and its tank was consequently sunk in the north basin of the building, where the water is kept at a tepid heat for the purpose of nourishing the tropical plants which grow in it.

"It remained here for some time, and being deprived of its ordinary supply of raw beef, took to foraging for itself. The gold-fish, with which the basin was stocked, became its victims, and it was quite as destructive as an otter would have been. It had a fancy for attacking the largest fishes; and though apparently slow in its movements, could catch any fish on which it had set its wishes. As the fish was quietly swimming about, suspecting no evil, the Lepidosiren would rise very quietly beneath it until quite close to its victim, just as the terrible ground-shark rises to take its prey. It then made a quick dart with open mouth, seized the luckless fish just by the pectoral fin, and with a single effort bit entirely through the skin, flesh, and bones, taking out a piece exactly the shape of its mouth, and then sinking to the bed of the basin with its plunder. The poor fish was never chased, but was suffered to float about in a half-dead state, and numbers of mutilated gold-fish were taken out of the basin.

"Not choosing to supply a succession of gold-fish, out of each of which the fastidious creature would only take one bite, the superintendent bethought himself of frogs, and fed the animal regularly with these batrachians. But having been warned, by the effect on the gold-fish, not to trust his fingers within reach of the teeth that could inflict such very effective bites, he got a long stick, cleft one end of it, put one hind foot of the frog into the cleft, and held it on the surface of the water, so that the struggles of the intended victim should agitate the surface.

"No sooner did the frog begin to splash than the Lepidosiren rose rapidly beneath it, seized it in its mouth, dragged it off the stick like a pike striking at a roach, and sunk to the bottom with its prey. Not a vestige of the frog was ever seen afterwards.

As has been remarked elsewhere, no traces of scales have been found with the remains of *Dinichthys*, and it is almost certain that it was not provided with scales; in this respect, as in many others, resembling *Coccosteus*.

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The departure from this structure exhibited by the scaled body of the *Lepidosiren* will suggest itself at once as a marked point of difference between them, but we find great diversity in the dermal defenses of fishes even within the same family; for example, *Pterichthys* and *Coccosteus* seem to have been closely allied, yet the hinder portion of the body in one was scaled, in the other naked.

Again, in the living Siluroids most are without scales or plates, the body being protected, as in our cat-fishes, only by a leathery skin; yet, as we have seen, some genera of this family, as *Arius*, *Bagrus*, etc., have the region of the vital organs protected by large bony plates.

A similar difference seems to prevail between the ancient and modern representatives of the genus *Ceratodus*. No traces of scales have been found with the teeth of the Triassic species, while the living *Ceratodus* of Australia has the body covered with large scales, like those of *Lepidosiren*.

Dinichthys Terrelli, Newb.

Charts V. and VI.

Dinichthys Hertzeri, N., in part, Vol. I., Part II., p. 316, Pl. 32, 33, 34.
Dinichthys Terrelli, N., Vol. I., Part II., p. 332, note.

As indicated in the above references, this species was named in a note appended to the description of *Dinichthys Hertzeri* in our first volume on Palæontology. On the preceding pages some of the bones belonging to this fish were referred to as parts of *D. Hertzeri*, and some of the figures given to illustrate the text were ascribed to that species; whereas, in fact, they represent bones of *D. Terrelli*. This confusion of the two species was occasioned by the circumstance that the most complete specimens found by Mr. Hertzer, at Delaware, consisted of the jaws and teeth, and for a long time almost nothing was known of the plates of the head and body of the Delaware species. Singularly enough, it happened that all the specimens found on the Lake Shore by Prof. Allen and Mr. Terrell during two years subsequent to the discovery of the first bone there, were cranial and body plates. Hence, the material for the diagnosis of the species was not in my possession, and all the bones from both localities were ascribed to *D. Hertzeri*.

The most characteristic features of *Dinichthys Terrelli* have been incidentally mentioned on the preceding pages; no extended description of the species is therefore required here. A concise review of its structure is, however, desirable for its more accurate definition, and to bring out the characters in which it differs from *D. Hertzeri*. Such a review is given below.

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Cranium.—The form and dimensions of the cranium in *D. Terrelli* have not yet been fully made out, though several heads have been found, and one of these is figured, credited to *D. Hertzeri*, in Vol. I., Plate 33. This shows only the posterior half. The anterior portion seems to have consisted, originally, of several bones united by cartilage, for they are always found dismembered and displaced. This is also the case with the crania of the congeners of *Dinichthys*—*Asterolepis* and *Heterostius*—of the European Devonian. There was, however, a bony shell over the connecting cartilages, and, sooner or later, the head will, doubtless, be found so complete that its form and the homologies of its component plates can be fully made out. This I infer from the fact that a head of *Dinichthys Hertzeri* was found by Mr. Hertzer at Delaware, forming the nucleus of a large concretion, and retaining nearly the natural position of all its parts. The length of the head cannot be accurately determined, but it was, probably, about three feet. Its width, at the broadest part, was, perhaps, two feet. The largest cranium of *D. Terrelli*, found at Sheffield, measures thirty inches, from angle to angle, across the occiput.

The surface of the cranium was, as we know, gently arched, and, in its general aspect, smooth. The external surface everywhere shows a fine, almost microscopic figure, or grain, but nothing of the tuberculation common to all other known Placoderms. It is also marked, like *Coccosteus*, by a series of linear furrows which form a kind of Arabesque pattern. Whether the bones of the head of *D. Hertzeri* were similarly ornamented we have not yet learned, as the plates of the head, which has been referred to, and the only one found, are so much exfoliated that they show no markings.

The bones composing the cranium of *D. Terrelli* have rarely been found disarticulated. We are therefore unable to compare them in detail with those of *D. Hertzeri*, or those of other Ganoids. It is evident that in the living fish they were firmly soldered together, and formed a brain-case impenetrable to even the formidable dentition with which it was associated.

The occiput was symmetrically arched, the center, or keystone of the arch being formed by the Supra-occipital. This bone is triangular in outline, with a prominent point projecting from the middle of its longest and posterior side. In its central part it is sometimes three inches in thickness; below it is excavated on either side for articulation with the "*ossa articularia capitis*" (Epiotics?), and behind it slopes downward and shows a broad, deep, and partially double pit. In *D. Hertzeri*, the posterior margin of this bone is more nearly vertical, and bears at its central point a pyramidal projection, as does the corresponding bone in *Heterostius;* anterior to this and on the under surface of the thickest part,

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is a single or double depression, also like that in *Heterostius*. This is the bone called by Pander *os occipitale medium*.

The lateral angles of the head are formed by what Pander calls *ossa articularia capitis*, shown in Figs. 3a, 3b, and 4, of Plate 34, Vol. I. The posterior angle of this bone is excavated to form a deep, somewhat conical socket, into which fits a strong condyle projecting from the middle of the Supra-scapula (Post Temporal), making one of the most complete joints known in the animal kingdom. It is strengthened by a guard, or rest, which projects like a flattened thumb, from the margin of the socket, backward, beneath the Supra-scapula. In all the specimens yet found the "*os articulare capitis*" is so firmly united to the other bones of the cranium that its outlines cannot be accurately determined. I have supposed that it represented chiefly the Epiotic, but it may also represent this bone inseparably blended with the squamosal and parietal bones. Future discoveries will probably afford the means for deciding this question.

Dentition.—The "premaxillaries" in *D. Terelli* are triangular in outline, but are narrower than those of *D. Hertzeri*. They terminate below in a sharp but strong point. The upper margin, instead of being flattened and laminar, as in *D. Hertzeri*, is thickened, and the posterior lateral angle sometimes becomes a massive knob. The central position of the upper margin is excavated, forming a kind of socket. The exterior surface of the "premaxillaries" is smooth, and without the line of tubercles which ornament those of *D. Hertzeri*. The inner side is concave and frequently much worn and excavated by the prominent extremity of the mandible, over which it shuts. Front and lateral views of a complete "premaxillary" of medium size, are shown in Figs. 1 and 2, of Chart V.

The "maxillaries" are oblong with the angles somewhat rounded. The upper margin recedes, and near the anterior extremity bears a flattened process an inch or more in length. The external surface is slightly arched in both directions; it is nearly smooth, but along the lower margin, shows a band of low, flattened ridges (enamel folds). The interior face is concave, and on the lower margin, which is always sharp, it is more or less worn by contact with the knife-edge of the mandible upon which it plays. Figures representing the internal and external aspects of a "maxillary" of *D. Terrelli* are given in Chart V. (Figs. 3 and 4).

The "maxillaries" of *D. Hertzeri* are less quadrangular in form than in *D. Terrelli*, the lower margin being considerably the longer. They are also thinner and flatter, and are set with sharp, conical teeth.

The mandibles of the species under consideration have a maximum length of about two feet, the largest complete one in my possession being twenty-two inches in length. Two others which I have

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are smaller, being respectively eighteen and twenty inches long, but both these are much worn, as though belonging to mature individuals. In all these the form is essentially the same, the anterior extremity is turned up, and terminates in a strong, acute, tooth-like projection. This is much worn, and was maintained in a sharp state by friction with the "premaxillary," into the concavity of which it enters. Behind this great tooth is a triangular, flattened projection, formed by a ridge on the inside of the mandible. Back of this, the upper margin of the mandible, for about six inches, is sharp, and is composed of dense, enamel-like tissue. At the posterior end of this sharp edge tubercles may frequently be discovered, which seem to be the rudimentary representatives of the teeth that surmount the margin of the mandible in *D. Hertzeri.** Usually the edge of the mandible is worn and sharp, from contact with the maxillary. The outline of this portion of the mandible is not all shown in Fig. 6 of Chart V., as both the triangular denticle and the cutting edge are broken away.

From the posterior end of the knife-edge of the mandible, a distinct shoulder runs in a curved line downward and forward to the beginning of the anterior curve. Above and before this shoulder the mandible is thick and massive, and was, evidently, never covered. The surface is nearly smooth, but shows everywhere the fine, granular reticulation which characterizes all the external surfaces of the bones of *Dinichthys*. The great terminal "tooth" is smooth, and wants the line of tubercles found on this part of the mandible of *D. Hertzeri*. The posterior portion of the mandible is flattened and smooth; in outline it is more spatulate than the corresponding portion of this bone in the other species, and is more turned up. All this part, as far forward as the shoulder referred to above, was, evidently, once covered with integument, or spliced on to the cartilage which formed the articular extremity. The more prominent characters mentioned in the above description will be seen in the full-sized figure of a mandible of *D. Terrelli*, represented on Chart V. (Fig. 6).

Body Plates.—The dorsal shield of *D. Terrelli* is so well shown in Fig. 5, Chart V., that no lengthy description is required of it. In the mature individual it is about two feet in length and breadth, one side being evenly rounded, the opposite one irregularly emarginate. Transversely, it is strongly arched; in its antero-posterior diameter, nearly straight. The external surface is smooth or granulated. Below, it bears along the central line an elevated, compressed ridge, which, at the curved margin of the shield, rises four inches from the inner surface, and has a

* A precisely similar crenulation is visible on the corresponding portion of the lateral dental plates ("maxillaries") of *Lepidosiren*.

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maximum thickness of about one inch. It projects beyond the curved border from six to eight inches in a flattened neck.

As has been before stated, the dorsal shield of *D. Hertzeri* is, as yet, imperfectly known. Two incomplete specimens, which I have, indicate that it was of nearly the same general size and form as that of *D. Terrelli;* but the neck-like projection is relatively much shorter, as though cut off, obliquely, from above.

The *Supra-scapulas* (or Post Temporals) of *Dinichthys Terrelli* are somewhat imperfectly represented in Figs. 1, 1*a*, 2, 2*a*, of Plate 34, Vol. I. They are flattened, triangular, or trapezoidal bones, about one foot in length by eight inches in width at the broadest part. They are thickest in the middle, where the exposed portion is comparatively small, and thin off on either side, where they are overlapped by other plates. Near the center of the thickest border a strong, flattened condyle is obliquely set, which fits into a deep cavity in the *os articulare capitis.*

The exposed portion of the Supra-scapulas, like the cranial surface, is marked by simple, linear furrows, which form some large pattern of ornamentation, as yet not fully made out.

The Plastron or ventral shield of *Dinichthys Hertzeri* is represented nearly complete, and of the natural size on Chart VI. The inside of the bones composing it is there shown. In the smaller diagram on the same chart, these bones are represented in position and seen from the outside. This shield is composed of five flat bones; two pairs and an elongated central one, which is interposed between them. The central plate is somewhat overlapped by the lateral ones, and when all are in their normal positions, the shield is twenty inches wide, and about three feet in length. The exposed surfaces of these bones are granulated, like those of the head, and the hinder pair are marked with the peculiar linear furrows seen on the bones of the cranium and the Supra-scapulas. The homologies of the bones of the ventral shield, and their correspondence with those of the ventral shield of *Coccosteus* have been discussed in the general description. The exterior margins of the anterior pair of plates (pre-ventro laterals, of Owen) show contact with other plates, and it is almost certain that the sides of the body between the dorsal shield and Supra-scapulas, and the ventral shield, were defended by plates of some kind, but none have yet been found that can certainly be referred to this position. Among the specimens collected at Delaware by Mr. Hertzer, and appertaining to *D. Hertzeri*, is one imperfect triangular plate, nearly three feet in length, and one foot wide at its broadest end. This, I have thought, might have occupied the side of the body, as there seemed no other place for it, but its location is yet only conjectural. No such plate has been found entire in connection with the remains of *D. Terrelli*, but a large number of frag-

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ments of plates have been collected, some of which may have belonged to this region of the body.

Clavicles ?—Reference has been made, on a preceding page, to the discovery by Mr. Jay Terrell of most of the bones of one large individual of *Dinichthys Terrelli*, lying together, but not in apposition. The more important of them are figured on Charts V. and VI., but with these are found several bones which have not yet been described. Two of them, forming a pair, are apparently Scapulo-coracoids (Clavicles, Parker). These are nearly two feet in length, and very massive. They are considerably curved in outline, about six inches broad in the widest part, toward the other extremity narrow and forked. The external surface is granulated like the bones of the head.

There are also two other plates of which the places are not yet determined. Of these, one is eighteen inches in length, seven inches wide in the middle, where it is broadest, and narrowing to the extremities, which are subacute. One of the sides is nearly straight, the other arched.

Only the central portion of this bone was exposed, as all the margins, except the straight one, are deeply impressed by the associated plates which broadly overlapped it. Whether this formed part of the defenses of the body, or protected the side of the head cannot yet be certainly told. Another plate found with this, is elliptical in outline, fifteen inches long (and incomplete at both ends) by ten inches wide. It is thin, flat, and without ornamentation. We may infer, from its symmetry, that it was placed on the median line. It is probable, also, that it was located on the under side of the body, but whether before or behind the ventral shield, remains to be determined.

With one of the heads of *D. Terrelli*, found at Sheffield, were two bones, forming a pair, which apparently correspond to those figured by Hugh Miller and Prof. Pander in their illustrations of *Asterolepis*, and called by the latter, *ossa anteriora lateralia capitis*. They are rudely triangular in outline, the broader side very thick. They were probably set on either side of the head near the muzzle, and formed the supports of the maxillaries.

Genus COCCOSTEUS, Agass.

Coccosteus occidentalis (n. sp.).

Plate LIII., Figs. 2, 2 *a*.

Posterior dorsal plate somewhat urn-shaped in outline, four inches in length, one and a half inches in breadth, broadly emarginate above and terminating posteriorly in a long, acute, smooth, styliform point. The

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anterior half of the upper surface is mostly smooth. The posterior half and margins of the anterior portion are set with relatively fine crowded tubercles.

The specimen now described gives us the first intimation of the existence of the remains of *Coccosteus* on the North American continent. This was obtained by Mr. J. H. Klippart from the Corniferous limestone at Delaware, Ohio. It is plainly the post-dorsal shield of a Placoderm, and corresponds so closely in size, form, and markings with the terminal shield of the carapace worn by some species of *Coccosteus* that I have little hesitation in referring it to that genus. The resemblance to which I refer will be seen by comparing the figure of the fossil now described with that of the dorsal plate of *Coccosteus cuspidatus*, Agass., on the same plate and drawn from a specimen recently received from Scotland. A single rhomboidal plate shown on Plate LIV., Fig. 2*a*, may be the central plate of the ventral shield, but unfortunately only its inner surface is shown, and from this we should be unwarranted in pronouncing it a plate of *Coccosteus*. There is good reason, however, for believing this to be the case. It certainly does not belong to the bony structure of any of the more common fishes of the Corniferous limestone, and its symmetrical form indicates that it held a central position in the ventral shield of some Placoderm allied to *Pterichthys* and *Coccosteus*.

For comparison with this, representations of the external and internal surfaces of the ventro-median plate of *Coccosteus* are given in Figs. 4, 4 *a* of Plate LIV.

The discovery of the remains of *Coccosteus* in the Devonian rocks of America is a fact of interest as adding another to the forms of ancient life common to the old and new worlds; but it has been long expected, and, since this is one of the most characteristic fossil fishes of the Old Red Sandstone of Scotland, and has been met with in Russia and Bohemia, its absence from all collections of fish remains heretofore made in this country has been a matter of some surprise. I have offered an explanation of this absence, however, in the Palæontology of our first volume, by suggesting that the fish remains found in the Old Red Sandstone of Scotland were taken from a different member of the Devonian system, and from deposits of a different character from that—the Corniferous limestone—which has furnished most of our Devonian fishes. The Corniferous limestone is the central member of the system, and is an open sea deposit, while much of the Old Red Sandstone is of later date, and is a shore deposit, formed either in fresh water, as supposed by Prof. Ramsay, or in bays or gulfs. I have suggested, therefore, that the remains of *Coccosteus*, *Pterichthys*, and the scaled Ganoids, *Osteolepis*, *Dipterus*, etc., as well as the Acanthodeans, so common in Europe, and heretofore not found in this country, would probably be discovered in the Catskill and

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Chemung rocks, where they should be carefully searched for. This prediction has been verified, as far as regards *Dipterus*, by the recent discovery, by Mr. Andrew Sherwood, of a species of this genus in the Catskill of Pennsylvania.

The finding of *Coccosteus* in the Corniferous limestone of Ohio is a fact which will be regarded as discordant with the view that this was a fresh water, or shore-inhabiting fish; but the discordance is more apparent than real, for the specimen now figured is unique in all the great collections of fish remains made from the Corniferous limestone during the last twenty-five years.

This indicates the rarity of this fish in the *sea* of the Devonian age, and the presence of its bones, in this one instance, in the sediment of that sea, must be looked upon as an exceptional fact, like the finding of the floated trunks of tree ferns in the same formation and locality. The open sea was evidently not the *home* of *Coccosteus*, either in America or in Europe. The discovery of its remains here proves that it had a home in the Western Hemisphere, but we have not yet found it; and the probability is strengthened, that if sought in the shore and off-shore deposits of the Chemung, Catskill, and Vespertine of Pennsylvania and New York, the remains of *Coccosteus* will be met with in greater abundance than anywhere in the Corniferous limestone. We may also look there for the associates of *Coccosteus* in the old world—*Pterichthys*, *Cephalaspis*, *Acanthodes*, etc.,—as the unity of the Devonian fauna is such that we may expect to find in America representatives of all the more common genera of the European Devonian rocks.

In his interesting paper on *Ceratodus Forsteri*, Dr. Gunther proposes to group the Ganoids and Elasmobranchs together in one sub-class, to which he gives the name of *Palæichthyes;* thereby indicating their antiquity. He also makes the generalization that the Elasmobranchs were the marine, and the Ganoids the fresh-water fishes of ancient times. With this latter view, I cannot coincide, as I have elsewhere shown that in the Devonian age the Ganoids far surpassed the Elasmobranchs in number and size, and that they were the rulers of the seas as well as of the rivers and lakes. This is proved by the abundance of the remains of the great Ganoids, *Onychodus*, *Macropetalichthys*, etc., in the Corniferous limestone, which is unquestionably a marine formation; and by the few and small relics of Elasmobranchs associated with them. Among the many thousands of fish remains from the Corniferous limestone, which I have examined, I have seen very few that could be referred to the group of Elasmobranchs. In the Carboniferous sea a different state of things prevailed.

There the Elasmobranchs were numerous and powerful; while in this age the Ganoids were almost exclusively confined to the shores and inland waters.

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CHONDROSTEIDÆ (?).

GENUS ASTEROSTEUS (nov. gen.).

Of this fish the cranium only is known, and of this all the specimens yet obtained are incomplete. The head was apparently long and narrow, the sides nearly straight, broadening suddenly in the occipital region. The posterior margin of the cranium shows two broad arches—one on either side of the median line—in which the cranial bones are deeply excavated, as though for muscular attachment. The skull is terminated behind by two conspicuous rounded projections having the aspect of condyles, but which, so far as can be seen, show no articulating faces. The upper surface of the cranium is covered with relatively large, beautifully stellate tubercles, which vary considerably in size. Toward the nasal extremity are two linear furrows which diverge from the middle line of the cranium, and inclose two strongly-marked elliptical pits that closely resemble the nostrils of some reptiles. In none of the specimens of this peculiar fish yet obtained, have the outlines of the cranial plates been distinguishable; the surface being covered by a sheet of tuberculated enamel by which the sutures are entirely concealed. On the sides, the cranium is somewhat beveled off, as though for the attachment of some coriaceous or ligamentous appendage, or perhaps for co-adaptation to lateral head plates; none of which have, however, been found. The dentition of *Asterosteus* is quite unknown, as no jaws or teeth have been discovered with its remains.

The figure given on Plate LIV. will show better than a description the general aspect of this singular cranium, and there are certain features which it reveals, that will strike the most casual observer. These are the condyle-like posterior projections of the skull, and the strongly marked nasal pits. Until more material shall be accumulated for determining its structure and relations, it would be presumptuous to make any comparisons between this fish and other known living or fossil forms, but the reptilian aspect of the cranium will not fail to be noticed by all who shall see the figure now published. So far as yet known no reptiles existed in the Devonian age, and the reptilian features presented by *Asterosteus* are perhaps merely superficial resemblances, but there is little doubt that if found in rocks of a later date, this would be considered (until proof to the contrary were gathered) the cranium of a reptile or amphibian. Though a number of crania of *Asterosteus* have been obtained in the Corniferous limestone of Ohio, none of them show either jaws or teeth, and it is quite

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possible, therefore, that we have in this fish an ally of *Macropetalichthys*, and thus, perhaps, a Chondrostean in which, as in the sturgeon, the sides and lower portions of the head were protected simply by a leathery integument. Future discoveries will doubtless make more plain what is now so obscure in the structure of this fish.

ASTEROSTEUS STENOCEPHALUS (n. sp.).

Plate LIV., Fig. 1.

Head 8 inches or more in length, by 2½ inches in width, except at the occiput, where it suddenly widens and becomes 4 or 5 inches broad. It terminates posteriorly in two excavated arches, of which the surface is roughened, apparently for muscular attachment. Projecting behind and below these arches are two bony condyloid prominences an inch or more in length. The upper surface of the cranium is somewhat irregularly covered with stellate tubercles which vary in size from one-eighth to one-twentieth of an inch in diameter. The sides of the cranium are somewhat beveled and roughened, and are traversed by an irregular line of relatively large tubercles. Near the anterior end the head seems to be suddenly narrowed, and just at this point it bears two deeply impressed, elliptical, nasal (?) orifices, placed side by side, somewhat divergent forward, and having a length of 5 lines and a breadth of 2 lines. The dentition is entirely unknown, as also the covering of the body.

Formation and locality: Corniferous limestone, Sandusky and Delaware, Ohio.

CEPHALASPIDÆ (?)

GENUS ACANTHASPIS (nov. gen.).

This name is used to designate certain cranial bones of what seems to have been a Cephalaspid, found in the Corniferous limestone of Ohio. Considerable variety is noticeable in the shape of these plates, and it is apparent that they formed parts of a tessellated cranium. They are generally somewhat oblong in form, the greater part of the plate being quadrangular, while one of the margins is oblique and prolonged into an acute point, and to this margin is spliced a carinated, toothed spine, sometimes four or five inches in length. These spines bear considerable resemblance to the dorsal spines of some extinct sharks. They might, indeed, under some circumstances, be accepted as the spines of *Ctenacanthus*,

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since they are marked with pectinated ribs much in the same way, but their attachment to bony plates and the denticulation of *both* sides of the pointed extremity shows distinctly that they have only a superficial resemblance to the defensive spines of Elasmobranch fishes. When complete and seen in position they reveal their affinities with the lateral cornua of the cephalic buckler of *Cephalaspis*. The external surface of the plates to which these spines are attached is marked with a conspicuous and peculiar ornamentation, much like that of *Bothriolepis*, a series of convoluted, locally parallel, raised and beaded lines. As the cranial plates of *Acanthaspis* have never been found in connection, it is impossible to give at present the form of the cranium, but they are seen to be in pairs, and it is highly probable that when united they formed a rounded head-buckler which differed from that of *Cephalaspis* mainly in being composed of a series of separable plates, instead of forming a solid box.

Acanthaspis armatus (n. sp.).

Plate LV., Figs. 1–6.

Cranium consisting of a number of bony plates, forming several pairs, and differing considerably in outline. To at least one of these pairs are attached, on the outer margin, strong, slightly curved, carinated, tuberculated and toothed spines. The external surface of the plates is covered with convoluted or radiated raised lines, which are more or less tuberculated.

Several cranial plates of this species are represented in the figures now published, and these will give a better idea of their form and marking than any verbal description can do. These plates, and the spines which are connected with some of them, are frequently met with in the Corniferous limestone of Sandusky and Delaware, but, like the cranial plates of *Onychodus*, they seem to have had no bony attachment to each other, and, in the dissolution of the body of the fish which bore them, they have been widely separated. There is little doubt that, sooner or later, some cranium will be found in which the bones hold their normal positions, and, from such a specimen, a more complete description of the fish can be drawn than can now be given. Waiting the discovery of such complete material, the plates now figured will, doubtless, be looked upon with interest, and will stimulate the search for more remains of what has hitherto been an entirely unknown Devonian fish.

Figures 1 and 2 of Plate LV. represent a pair of plates which occupied corresponding positions on opposite sides of the head (?) of, perhaps, the

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same individual. In these plates the external markings are nearly obliterated, slight traces, only, of the tuberculation remaining.

Fig. 3 shows a similar plate, in which the surface-markings are somewhat more distinct, and the suture between the plate and the attached spine is plainly visible.

Fig. 4 gives an inside view of a plate which, like the preceding ones, carries a spine, but its form is quite different. A number of such plates have been found with those having the shape of Figures 1, 2, and 3, so that I have supposed them all to belong to the same species. The spines attached to the smaller plates were, apparently, without denticles.

The plate represented by Fig. 5 has a different outline from either of those before mentioned, but they are often found together, and the tuberculation, though stronger in Fig. 5, is essentially the same as in Fig. 3. Fig 5 *a* represents a portion of the surface of Fig. 5, slightly magnified.

Fig. 6 shows the inner face of a plate like Fig. 3, without its spine.

Formation and Locality: Corniferous limestone, Sandusky and Delaware, Ohio.

Genus ACANTHOLEPIS (nov. gen.).

Among the many fish remains found in the Corniferous limestone, there are none more puzzling than those to which the above name has been given. They consist of tuberculated cranial or dermal plates, which have a prevailing spatulate outline, but which differ very much among themselves in form and consistence. Some are thin and have somewhat the appearance of large, elongated, unsymmetrical scales. Others are stronger, and are produced into points that sometimes become spines. The surface of all these plates is more or less tuberculated; the tubercules in some of them being strong and closely crowded, in others sparse and fine. Whether these are body scutes or cranial plates remains to be shown by farther discoveries. That they form parts of a somewhat extended series is shown by the fact, that, in some instances, two or more are found occupying nearly their true position as regards each other.

Acantholepis pustulosus (n. sp.).

Plate LVI., Figs. 1–6.

Cranial or body scutes, having a somewhat spatulate form, and attaining, in some cases, a length of seven or eight inches, with a width of two inches. These scutes were set contiguous to each other to form a defense

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to the body or head; the more elongated ones becoming real curved spines, similar in general character to those of *Acanthaspis*, but differing in this, that they are not united by sutures with flat bones or plates, but are the extremities of such plates drawn out into spines that must have projected from the general surface. The broader plates are quite thin and seem to have been applied to flat or arched surfaces, while those which form spines have their remote extremities narrowed and thickened till they become prominent and effective defensive organs. In some instances the plates are triangular in outline and seem to have been thin cones of bone or enamel, supported by cartilaginous centres. As the latter are decomposed, the sides, which were once widely separated, are brought together, or crushed in like broken shells.

The external surface of these plates is tuberculated in a variety of ways. In some instances the tubercles are large, scattered, smooth and round, and resemble pustules. In other cases they are irregular and crowded; while occasionally they are in regular rows; the interstices between them being beautifully chased and ornamented. Along the margins of the spinous extremities of the plates, the tubercles are elongated until they become conical denticles. In a paper published by the writer some years since in the "Bulletin of the National Institute" at Washington, descriptions were given of a number of fish remains obtained at Delaware, Ohio, by the late Dr. Mann. Among these, three species of "*Oracanthus*" were described, viz.: *O. fragilis*, *O. granulatus* and *O. abbreviatus;* all of which I now believe to be simply phases of the varied scutes of *Acantholepis*. Some of the triangular ones seem to have resembled, in form and function, the dermal spines of *Climatius*, *Parexus*, etc., and it is quite possible that they were set in greater or less number on the body. In the reduced outlines, shown in Fig. 1 *b*, the relative positions of two pairs of the larger scutes were given, and we may infer from these that they were set along certain lines, more likely on the body than head (since, except laterally, they show no signs of contact), just as the dermal scutes are placed in *Accipenser*.

Much more material will be required before we can reconstruct *Acantholepis*, but its remarkable scutes are so frequently met with in the Corniferous limestone, that it is evident it was numerously represented in the Devonian sea. Future discoveries will, unquestionably, give us the full information about it which we crave, but which is as yet beyond our reach.

On Plate LVI., Figs. 1, 1 *a*, represent a large pair of plates in their relative positions. A number of pairs of this kind have been found, though the individual plates are oftener met with entirely separated from their connections. The extremity of Fig. 1 is not quite complete. Other speci-

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mens show that it was produced to a moderately acute, flattened point. This narrow end was beautifully denticulated, was tuberculated on both sides, and evidently projected from the body or head as a defensive spine.

Fig. 2. represents the inside of a scale-like scute, which was probably attached by its entire under surface. At the narrow end the bone is removed, revealing the impressions of the tuberculation of the outer surface.

The original of Fig. 3 is a small scute corresponding to 1 *a*; though drawn out to an acute point it was not a spine.

Figs. 4, 5, 6 represent broader and narrower spine-like scutes, which I have reason to believe belonged to the same species with the scutes from which Figs. 1, 2, and 3 are drawn. Specimens of intermediate character seem to unite them all together.

Formation and locality: Corniferous limestone, Sandusky, Kelly Island, Marble Head and Delaware, Ohio.

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FISHES OF THE CARBONIFEROUS SYSTEM.

MARSIPOBRANCHII (?)

"*CONODONTS.*"

Plate LVII.

In the first volume of this Report reference was made in several places to certain minute, comb-like or tooth-like organs, found in great numbers in the Cleveland shale of the Waverly group at Bedford, Cuyahoga county. They are from one-twentieth to one-fourth of an inch in length, and usually consist of a narrow, compressed, slightly arched base, from which spring numerous flattened denticles. These are generally long lance-shaped, and very acute at the margins and summits (see Figs. 1, 2, 12, 14, 16, 18, 19, 20).

Occasionally they are in part rounded and obtuse (Figs. 3, 9, 10, 15), but much oftener are acute and somewhat subulate. A not uncommon form is represented by Figs. 4 and 8. In this variety the base is elongated and narrow, in a few cases rod-like, and but slightly curved. From this base rises a series of denticles of nearly uniform size, connected by coalescing intermediate ones of two-thirds their height; the whole forming a fin-like margin or wing. Still another variety is seen in Fig. 1. In this the teeth are fine and closely approximated, and the organ has a wonderful likeness to an elongated comb.

The material of which the Conodonts are composed is slightly translucent, horn-like in color, and closely resembles the enamel of many teeth.

The number of these objects is immense, and the variety of form which they exhibit, is but imperfectly shown in the figures now given. In regard to their zoological relations it is as yet quite impossible to speak with certainty. The Conodonts found by Prof. Pander in the Lower Silurian marls of St. Petersburg, Russia, were considered by him to be the teeth of small sharks. This conclusion has not been generally accepted by other palæontologists, though no perfectly satisfactory explanation of their zoological relations has been offered. Prof. Owen (Palæontology, p. 116), discusses their structure and affinities at considerable length, and concludes that "they have most analogy with the spines, hooklets, or denticles of naked mollusks, or annelids."

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When Conodonts were first found in Ohio, I submitted them to Prof. Agassiz, who pronounced them the teeth of Selachians.

Prof. E. S. Morse, one of the best living authorities on the structure of invertebrate animals, to whom they were referred as possibly the teeth of naked mollusks, such as *Doris*, *Æolis*, etc., said that they bore a strong resemblance to the teeth of mollusks, and might have belonged to the progenitors of some of our living forms.

The late Prof. Wm. Stimpson, one of our most learned and accurate zoologists, and one who had given special attention to the *Crustacea*, after examining a large number of Conodonts, gave the opinion that they might very well be the lingual teeth of mollusks, but they could not have formed the dentition or spinous armament of any Crustacean.

The Conodonts found by Prof. Pander were submitted by him to chemical analysis, and he found them to be composed of carbonate of lime. English chemists have found in them traces of phosphate of lime. Under the microscope they are shown to be composed throughout of concentric layers of fine, structureless, but punctate tissue, not exactly like that of the teeth of any living fishes; though their peculiarities of structure are not such as necessarily to exclude them from that class.

It has also been suggested by some zoologists that these singular bodies are the teeth of Cyclostomous fishes, and by others that they are dermal ossicles. These different theories will be briefly noticed in order.

1. That the Conodonts were not the teeth of Selachians seems to me almost certain, from their small size, their peculiar forms, and the homogeneity of their composition. In all known sharks the teeth are composed of two distinct portions, the crown and the base. Of these the first is the only part exposed, and it is formed of very dense tissue (dentine), traversed by radiating and ramifying canals, and is covered with enamel. In the center is a pulp cavity, or less dense cancellated tissue.

The base is usually composed of rough, more or less porous, bone. This is sunk in the integument and adheres to the cartilaginous jaw by strong ligamentous attachment. The line of demarcation between the crown and base is generally well marked, and when the teeth are fossilized, the soft base has often perished, while the hard crown remains unchanged. In the Conodonts, on the contrary, the crown and base are similar in composition, or, rather, they have no base such as sharks' teeth exhibit. From the form of their inferior margins we may infer that they were implanted in soft tissue, like the teeth of mollusks, the hooks of annelids, etc., and were not set on jaws.

2. Excluding the theory that they were the teeth of sharks, the range of possibility in their affinities is still great. They may, as suggested

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by Owen and Morse, be the teeth of mollusks, for they strongly resemble them in their peculiar and varied forms and their chitonous composition, but if the teeth of mollusks, these must have been shelless, for no molluscous shells have been found in the formation which contains them, and it would be somewhat singular if the *Mollusca* were represented in the sea from which the Huron shale was deposited, only by naked species.

3. In the first volume of this Report I ventured to suggest that the Conodonts might be the dermal ossicles of ancient fishes. Among the Elasmobranchs there are some of which the external surface is protected by a shagreen composed of divergent, acute ossicles, not very unlike some of the Conodonts in form and composition. We know of no shagreen, however, composed of such neat, regular bodies as the Conodonts are, and the conjecture that they may be the shagreen of sharks is as yet supported by little evidence.

I also called attention to the fact that the scutes of the Sturgeon, about and within the branchial apertures, have almost exactly the outline of the simpler Conodonts, but further observation has led me to consider this resemblance as accidental, and without zoological significance.

4. Waiting further evidence of the nature of these interesting organs, I take the liberty of offering, as a possible and plausible explanation of the enigma, the theory that they are the teeth of Cyclostomous fishes. If any one will take the trouble to compare the Conodonts with the teeth of *Myxine* and *Bdellostoma*, he will find a very close and remarkable similarity between them. Indeed, except that they are very much larger, the teeth of *Bdellostoma polytrema* are almost exactly like the Conodonts represented in Figs. 12, 14, and 16. The teeth of *Myxine glutinosa* are even more like these in size and delicacy of structure, and scarcely less so in form, than those of *Bdellostoma*. In composition and internal structure, the teeth of the modern Marsipobranchs seems to be almost identical with the Conodonts, and the resemblances which they present are throughout so strong that few will make a comparison between them without being convinced that they are nearly related zoologically. From the low place held by the *Marsipobranchii* in the zoological scale we might naturally suppose that they existed in considerable numbers in the Palæozoic seas, and it has been a matter of some surprise that no traces of them have been heretofore recognized in any ancient strata. This fact has been explained by the suggestion that none of the Cyclostomes have organs composed of tissues that would resist decay.

This explanation is, however, not altogether satisfactory. It is true that nothing but the teeth would be likely to be preserved, but even if composed of horn-like tissue, as in *Petromyzon*, they should have left some traces when buried in the finer sediments; when harder, like those of

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the Myxinoids, they would certainly be preserved. Possibly some other relics of Cyclostomous fishes will yet be found, but with the facts now before us we seem justified in concluding that if the Conodonts are not the remains of Marsipobranchs, these vertebrate animals, though very low in the scale of beings, are, like Fungi, Lichens and Mosses among plants, of modern date. If, however, the view now proposed be proven true, in the Conodonts of the St. Petersburg Silurian marls, described by Pander, those of the Mountain limestone of England, collected in such numbers by Moore, and in those of the Waverly of Ohio, we have a very respectable representation of this group of fishes in the Palæozoic faunas; for they exhibit so great a variety of form that if they are the teeth of fishes they are the relics of many genera and species. This hypothesis encounters a difficulty in the fact that while the Conodonts are calcareous, the teeth of the living Cyclostomous fishes are horny or chitonous. It is quite possible, however, that the ancient species had calcareous teeth, and in that respect differed from the modern ones; just as the calcareous sponges, so common in the Palæozoic seas, have, for the most part, been superseded by those having horny tissues containing siliceous spicules.

A similar objection may be urged against the theory that the Conodonts are the teeth of Mollusks, as the modern *Mollusca* have siliceous teeth.

More proof must be gathered before it can be positively asserted that the Conodonts are teeth of Marsipobranchs, but they resemble them so closely that it seems at least possible that we have in these delicate organs the teeth of small Lampreys, or Hags, which inhabited the Palæozoic seas in large numbers. If this is their true nature, they represent the first fishes that existed on the globe; unless, indeed, they were preceded by the progenitors of *Amphioxus*, and they, like the living Lancelet, were without hard parts, and could leave no trace of their existence.

ELASMOBRANCHII.

Genus DIPLODUS, Agass.

In the notes on *Diplodus* published in the first volume of this Report (Part I., p. 334), three species found in Ohio are described, but no figures of them are given. These are all now figured on Plate LVIII. Figs. 1, 1 *a*, 1 *b*, represent *Diplodus latus;* fine specimens of which have been obtained from Linton during the past year. As will be seen from the figures, this species may be readily recognized by its large size, its broad,

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lance-shaped and serrated cornua, by its tuberculated base and by the absence of a median denticle.

Diplodus compressus (Fig. 2) is never more than half as large as *D. latus*, and has relatively broad, serrated, flattened and divergent cornua. These are often nearly straight, and sometimes have the sharpness of the edges increased by a concavity of the slope from the median line. It might be supposed that this was only the immature state of *D. latus*, which it somewhat resembles in form, but in that species the cornua are more lance-shaped and the surfaces more uniformly arched. The tuberculated base and the absence of a median denticle are also characters wanting in *D. compressus*. It may be said also that some thousands of the teeth of the latter species have been found at Linton, so like in size and shape that they evidently exhibit its normal features. From this average character the teeth of *D. latus* depart very widely.

As has been elsewhere remarked the differences between *D. compressus* and *D. gracilis* (Figs. 3, 3 *a*) are not strongly marked nor very constant, and they may be but varieties of the same species. The figures now published will show that the teeth named *D. gracilis* are narrower, with less spreading, more curved, and less flattened cornua, than those to which the name *D. compressus* has been given. There are, however, among the specimens from Linton, some teeth which seem to share the characters of the two species, and it may be found that they run into each other. Several jaws have been obtained at Linton to which the teeth of *Diplodus* are still attached. These have been carefully examined in order to ascertain what diversity of form could be observed in the dental series of one individual, but they are too imperfect to fully settle this question. The upper and lower jaws have not yet been found together, and although there seems to be less variation of size and form than was expected in the teeth of a single jaw, the teeth of the upper and lower jaws may have been somewhat different. It will be necessary to have the entire dentition under view before the limits of variation in the teeth can be accurately defined.

Cladodus acuminatus, Newb.

Plate LVIII., Fig. 4.

Cladodus acuminatus N.; **Proc. Phila. Acad. Nat. Sciences, 1856, p 99.**

Teeth of medium size, average specimens being about one inch in height, and three-fourths of an inch in breadth of base; central denticle robust, conical and very acute, with a nearly circular section throughout, both

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anterior and posterior faces strongly striated. Lateral denticles four, the outer pair largest, all conical, acute and striated. Base elliptical in outline, thin and sharp-edged.

The most distinctive character of this species is the extreme sharpness of the strong central and lateral denticles. They all have a nearly circular section, and are distinctly striated; at their summits they are drawn out into fine points more elongated and acute than in any other equally large species with which I am acquainted.

Formation and Locality: Bituminous shale over Coal No. 5, Mineral Point, Tuscarawas Co., Ohio.

Cladodus Hertzeri (n. sp.).

Plate LVIII., Figs. 5, 5 *a*.

Teeth broader than high, massive and strong; base semi-elliptical in outline, 7 lines long by 3½ lines wide; central cone 6 lines high, robust, conical, subacute, with a circular section, considerably inclined backward; lateral denticles, two pairs, the interior pair more than half as large as the central cone, outer pair much smaller; both central and lateral cones rather finely striated, striæ strongest on posterior face and sides.

The most striking peculiarities of this remarkable species, are the breadth of the base, which exceeds the height of the central cone, and the reversed and abnormal inequality in the size of the lateral denticles. In most species of *Cladodus*, the external pair are longer than the intermediate ones, and Agassiz, in his description of the genus (*Poissons Fossiles, Tome III., p.* 196) makes this a diagnostic character, and that by which he distinguishes *Cladodus* from *Hybodus*. There is little doubt, however, that *Cladodus* of the Devonian and Carboniferous, is represented by *Hybodus* in the Mesozoic rocks. The two genera shade into each other in such a way that it is impossible to draw any sharply-defined line between them, and it is difficult to resist the conclusion that the relationship which they hold to each other is a genetic one; in other words, that *Hybodus* is descended from *Cladodus*.*

The rule given by Agassiz for distinguishing these genera is, however, of such general application, that it seems hardly necessary to modify it, further than to report some exceptions to it.

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*Mr. W. J. Barkas, in a paper published in the Geological Magazine of April, 1874, claims to have discovered true *Hybodus* in the Coal Measures of Northumberland and Staffordshire, England.

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Among all the species of *Cladodus* known to me, there is only one other than that now described, in which the exterior pair of lateral cusps are larger than the inner ones. This is a beautiful new species sent me by Dr. C. Rominger, the State Geologist of Michigan, and by him obtained from the Waverly group of that State. A brief description of that species is appended, but the specimen came to me too late to be figured for this volume. In *C. Romingeri* the interior pair of secondary cones is very little larger than the outer ones, while in *C. Hertzeri* they are more than twice as long.

Formation and Locality: Obtained by Rev. H. Hertzer from the beds of impure limestone in the red shale, under the Berea Grit at Berea, Ohio.

Cladodus Pattersoni (n. sp.).

Plate LVIII., Figs. 6, 6 *a*.

Teeth small, not exceeding 6 lines in height; base small, rounded, bearing no lateral denticles. Median cone robust, much reflexed and sigmoidally curved at point, smooth and polished throughout. Near the base the section is circular, toward the apex flattened with a winged margin that makes it strongly ancipital. The small, rounded base apparently supported only one cone. The plain and polished surface, strong curvature and ancipital apex of the central cone, will serve to distinguish this species at once from any other.

A specimen collected by Prof. Andrews is of special interest, as it consists of a lower jaw bearing nearly its entire dentition, the teeth in position. These are placed apparently in quincunx order, alternating instead of forming antero-posterior rows as in most of our sharks. So far as can be seen all the teeth have precisely the same form; those situated at the lateral extremities of the dental area being much smaller than the others, but not otherwise different. The number of teeth borne by both jaws must have been three hundred to four hundred.

Formation and Locality: "Waverly Black Shale," Waverly, Ohio.

Cladodus subulatus (n. sp.).

Plate LVIII., Fig. 7.

Teeth small, 6 lines in height and breadth; base elliptical, equal in breadth to height of tooth, bearing a central cone with two nearly equal

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lateral denticles on either side, all striated. Central cone slightly recurved, section above nearly circular, below, posterior face flattened, giving lateral angles.

This species is about equal in size to *Cladodus Pattersoni*, but may be readily distinguished from that by its lateral denticles, less curvature and striated surfaces.

Formation and Locality. Cuyahoga Shale over Berea Grit, Berea, Ohio.

Cladodus concinnus (n. sp.).

Plate LVIII., Fig. 8.

Teeth small, about 6 lines in height and breadth; base very narrow, boat-shaped, with pointed extremities; central cone much compressed with sharp edges, posterior face flat, anterior rounded, both strongly striated; lateral denticles two pairs, both striated, external pair the larger, and divergent.

This small species is noticeable for its compressed, double-edged, and strongly-striated cone, its divergent lateral denticles, and narrow pointed base. These characters will serve to distinguish it from any others with which it may be compared. It is not unlike in general appearance *C. zygopus*, described in the Illinois Geological Report, Vol. II., p. 25, Plate I., Figs. 9, 9 *a*, 10, but in that species the base is distinctly yoke-shaped—*i. e.*, arched on one side, excavated on the other—and the posterior face of the cone has a deep furrow at the base.

This is the most elegant in form and most highly ornamented of all the species of *Cladodus* yet found in Ohio, and the specific name given it was chosen to indicate this.

Formation and Locality: Huron Shale; valley of Black River, Lorain County.

Cladodus parvulus (n. sp.).

Plate LVIII., Figs. 9, 9 *a*.

Teeth very small, and exhibiting two forms; the larger 4 lines high and broad; crown compressed and ancipital; summit very tapering and acute; anterior face rounded; posterior flattened, often slightly keeled above, deeply excavated below; both faces toward the base having fine, somewhat interrupted and irregular striæ; lateral denticles two, flattened, triangular, divergent; base yoke-shaped, posterior margin deeply sinused, under surface concave.

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Smaller form without lateral denticles, from 2 to 3 lines high, central cone and base as in larger form. These small teeth occur in large numbers in the fish bed discovered by Mr. Jay Terrell in the valley of Black River. As will be seen from the description given above, they differ much among themselves in form and size, but between the extremes are all possible shades of variation. The peculiar yoke-shaped and cupped base is the same in all, but some have no lateral denticles, others have tubercles at the sides of the central cone, while others still have two well-developed lateral cones. This diversity is not greater than we find in the dentition of modern sharks, and it is highly probable that in all of the species of *Cladodus*, the teeth were more or less variable in size and form according to the places they held in the mouth. This introduces an element of uncertainty in the diagnosis of species from a few teeth, which should be kept in mind in describing or discussing species of this and other genera of extinct sharks. It is not probable, however, that the species of *Cladodus* have been very much multiplied from this cause, for the reasons that: (1) the number of species yet described is small, (2) they are distributed through a great vertical and geographical range—from the base of the Devonian to the Permian, and from Russia to Kansas—very few having been taken from the same stratum and locality, and (3) the dentition of each species, however much varied, has generally something in common, of form or ornamentation, by which the different members of the series may, with due care, be identified.

The danger of multiplying species from this cause is at least not sufficient to make it necessary or wise to neglect all material of this kind until such time as the complete dentition of each species shall be discovered. This cannot be hoped for in regard to many fossil sharks, as their skeletons were cartilaginous, and the connection between the teeth and jaws was ligamentous and was dissolved in decay. In the only cases that have come under my observation where any considerable portion of the dental series has been found with the teeth in position (*Cladodus Pattersoni* and *Diplodus compressus*), the only difference visible among some hundreds of teeth shown is in size. Had the entire dentition of both jaws been visible in these cases, their testimony would have been more conclusive, but it has much weight as it is.

Cladodus Romingeri (n. sp.).

Teeth small, breadth of base 7 lines, height of median cone 5 lines; central cone flattened behind, anterior face rounded; basal portion of posterior face deeply sinused; lateral cones two pairs (sometimes with a

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rudimentary one at the base of the central cone), of which the inner pair are slightly higher than the outer ones; surface of both central and lateral cones very strongly striated.

This beautiful species strongly resembles in general appearance *C. acutus* and *C. mirabilis*, of Agassiz (described in the *Poissons Fossiles*, *Tome III.*, *pp.* 197, 199, *Plate* 22, *Figs.* 9, 13–21), but differs from both in having the internal pair of secondary cones as large as, or larger than, the outer pair. In this respect it is unlike any other species known to me, except *C. Hertzeri*, described on another page.

This remarkable tooth was found by Dr. C. Rominger, in a calcareous sandstone of Waverly age, at Battle Creek, Michigan. To his kindness I am indebted for an opportunity of examining it; a courtesy which I take pleasure in acknowledging by attaching his name to it.

It has not been possible to have drawings made of it in time for publication in this volume.

Polyrhizodus modestus (n. sp.).

Plate LVIII., Figs. 10, 10 *a*.

Teeth small, largest half an inch in breadth and height. Crown surface 2 lines wide, much depressed, terminating posteriorly in an acute edge; root broad, and divided below into five or six flattened radicles.

Of this little tooth only one complete specimen has yet been found. This, with fragments of others, give fairly well the character of the species and show it to be distinct from any other yet described.

In the Report of the Geological Survey of Illinois, Vol. II., several species of *Polyrhizodus* are figured and described, all indeed, with one exception, that have been heretofore met with in this country. By comparing the figure now given with those in the Report referred to, it will be seen at a glance that the tooth before us is so different that no detailed comparisons are required.

Formation and Locality: Cleveland shale, Bedford, Cuyahoga County, Ohio.

Orodus variabilis (n. sp.).

Plate LVIII., Figs. 11, 11 *h*.

Teeth of various forms and dimensions, the largest 15 lines in breadth, 5 lines in height and 2½ lines in thickness; the crown on the posterior face forming half the height of the tooth, rising in the

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center into a conspicuous boss, from which the surface falls off with several gentle undulations to either end. The enameled surface is highly polished but finely punctate throughout; on the posterior face of the central tubercle are a few fine radiating carinations. The enamel folds at the base of the crown form, on the posterior face, a relatively broad but irregular band; on the opposite face a more sharply-defined, single raised line. The root is flattened, pitted, and beveled on its lower edge. This variety is represented in Figs. 11–11 *b*. A second variety is indicated by Figs. 11 *c*–11 *f*. This is 12 lines long and very much flattened, the crown showing several rudimentary tubercles, of which the most conspicuous is nearer one end of the tooth than the other. Still another form is half the size of those already mentioned and more symmetrical, the central cone more prominent, the surface smoother, etc. (Figs. 11 *g*, 11 *h*).

All these, with many other specimens, were found so associated together that it cannot be doubted that they formed the dentition of a single individual. Their diversity of form and size shows very plainly the liability to multiply species when describing detached teeth.

With these teeth are quantities of dermal tubercles, which doubtless belonged to the same fish that bore the teeth. These tubercles are generally elongated and have the enameled surface strongly marked with revolving ridges and furrows. In the same stratum and in immediate proximity to these teeth, were found spines of two species of *Ctenacanthus* (*Ct. formosus and Ct. furcicarinatus*), and teeth of *Cladodus Pattersoni*. With one of these spines the teeth under consideration undoubtedly belong; and as the *Cladodus* is a very small species, we may conclude that *Orodus* and *Ctenacanthus* are only parts of the same genus.

Formation and Locality: Black shale of Waverly Group, Sciotoville, Ohio, and Vanceburg, Ky.

Orodus elegantulus. N. and W.

Plate LVIII. Figs. 12, 12 *a*.

A small and very neat species of *Orodus* which occurs rarely in the Cleveland shale at Bedford, Cuyahoga County, is so much like that described by Mr. Worthen and myself in the Illinois Report, under the above name, that I have regarded it as probably the same. Some of the specimens found, like that now figured, have all the essential characteristics of those from Illinois, except that they are less arched; while other and smaller teeth have sometimes the median cone somewhat pyramidal, and

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obtuse *points* occur between that and the ends. These may belong to another species, but the material at hand does not justify us in separating them from the forms which have been found at the West.

Orodus elegantulus occurs in Illinois, in the Burlington limestone.

Ctenoptychius semicircularis. N. and W.

Plate LVIII., Fig. 14.

A single tooth of this species was found in a Coal Measure limestone, Adams Township, Muskingum County, O., by Professor J. J. Stevenson. It is rather less arched than most specimens of the species, but, in other respects, is undistinguishable from many which I have from the Coal Measures of Indiana and Illinois.

Teeth generically identical with these, and with difficulty distinguishable specifically, are common in the Carboniferous limestone of Armagh, Ireland. These have not yet been described, but were named by Agassiz *Ctenoptychius dentatus*. He subsequently referred them, in his MS. catalogues, to the genus *Harpacodus*, created to receive them; still later to a new genus, *Peripristis*. The latter name has been adopted by Mr. O. St. John, who gives a definition of the genus in Dr. Hayden's "Final Report on the Geology of Nebraska," p. 242. I find it impossible, however, to recognize more than specific differences between these teeth and those which form Prof. Agassiz's type species of *Ctenoptychius* (*Ct. serratus*).

From the Crinoidal limestone of the Lower Barren Measures, in the city of Pittsburgh, I have a single tooth which is closely allied to, but distinct from, those under consideration. In this specimen only a part of the crown is shown. This is much flatter than that of *Ct. semicircularis*, the denticles larger and symmetrically lance-shaped, and the whole surface covered with a fine, crape-like wrinkling, instead of being highly polished, as it is in the other specimens from America and Ireland.

Petalodus Alleghaniensis, Leidy.

Plate LVIII., Figs. 13, 13 *a*.

The Crinoidal limestone, which is a very constant member of the Lower Barren Coal Measures of Ohio, has furnished so many fish teeth that it deserves to be specified as one of the "fish beds" of the State. Most of the fish remains of this horizon are small and usually imperfect shark's

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teeth, among which are species of *Petalodus*, *Cladodus*, and *Ctenoptychius*.

Of these the largest and most abundant belong to a species of *Petalodus*, which seems to agree in all respects with *P. Alleghaniensis*, described by Dr. Leidy, and first obtained from the Coal Measure limestones of Pennsylvania. Two of these teeth are now figured, and they represent fairly well the size and forms of the specimens found. It will be noticed that in one of these the crown is higher, and the root larger than in the other. These differences are not constant, however, and can hardly have specific value. They are probably due to the positions held by the different teeth in the extended series which formed the dentition of the fish to which they belonged.

In the Report of the Geological Survey of Illinois, several species of *Petalodus* are described, one of which, *P. destructor*, is from the Coal Measures. From its large size and peculiar root, this tooth was considered distinct from *P. Alleghaniensis*, but Mr. O. St. John, who has given much study to the fish teeth found in Illinois and Iowa, regards them as identical. This seems to me probable, but it is not yet proved by any facts which have come under my observation. None of the specimens of *P. Alleghaniensis* yet found in Ohio are more than half as large as some of those from Sangamon County, or from Cassville, Illinois. They differ too, in the form of the root; the specimens from Ohio having more elongated and narrower roots than the great teeth, with spatulate, pointed roots, which are found in the Coal Measures of Illinois. These differences may be only local, however, and it is quite possible that intermediate forms will hereafter be found which shall connect the robust and powerful teeth of the West, with the smaller and more delicate forms which occur in the Crinoidal limestone of Ohio.

Ctenacanthus formosus, Newb.

Plate LIX., Figs. 1–1*e*.

This fine species of *Ctenacanthus* is described in Vol. I., Part II., p. 328, of this Report. The figure now given is taken from a very perfect specimen obtained by M. C. Read, Esq., from the Cuyahoga shale at Warren, Trumbull County. It illustrates the size, form, and markings better than the figure before given, and much better than any verbal description could do. During the progress of the Survey, more or less perfect specimens of this species were met with in various parts of the State, where the Waverly rocks were exposed, and it is evident that the shark which bore them was the most common, and probably the most formidable of those

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which here inhabited the shallows of the incoming sea of the Carboniferous age. In the limestones which form the open sea deposits of this age, no traces of this fossil have yet been discovered. In the specimen from which the drawing was made for the figure now given, the denticulation is remarkably regular and exact. The lithographer has, however, failed to represent this with accuracy.

Ctenacanthus furcicarinatus (n. sp.).

Plate LIX., Figs. 2–2 *c*.

Spine of medium size, robust; 8 to 10 inches long, 1¼ inches wide. Section near summit compressed, with flattened and nearly parallel sides, near base oval. Basal portion smooth or longitudinally striated, rounded below and thin from the expansion of the medullary cavity. Line separating the plain from the ornamented surfaces very oblique and sigmoidally curved. Exposed portion of spine covered with numerous strong, more or less flattened and pectinated longitudinal costæ, many of which are dichotomously forked near the base.

Toward the summit of the spine, there are about 15 of these costæ. Near the base they are much more numerous from bifurcation. Those near the anterior and posterior margins are fine, those occupying the middle of each side more than twice as broad. The posterior face is flattened so as to form a distinct angle with the sides, but is raised along the median line in a strongly-marked but rounded ridge.

The most striking features in this spine are the obliquity of the line of contact between the exposed and buried portions, the bifurcation of the rounded longitudinal ribs, and the general, but inconspicuous pectination. This is well shown in the enlarged view of three of the costæ given in Plate LIX., Fig. 2 *c*.

These spines are found so associated with the teeth of *Orodus variabilis* as to make it extremely probable that they belonged to the same fish. There are also found with them quantities of dermal tubercles which are undoubtedly those of this species of *Ctenacanthus*. Some of these are represented, somewhat enlarged, in Fig. 4. They are obscurely rhomboidal in outline and marked with a few coarse furrows and ridges. From the association of these fossils we are justified in concluding that we have in them the teeth, spines, and dermal tubercles of one of the sharks that inhabited the Lower Carboniferous seas. These are all the really bony portions of most Selachians and all that are generally fossilized; but with these, in the present instance, are numerous traces of

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organs which, under all ordinary circumstances, have disappeared, viz., the tail and fins. In some cases almost the perfect outlines of sharks six or more feet in length are said have been found by the quarrymen traced upon the surfaces of shale. One of these specimens represents the heterocercal tail of a large shark in which the vertebræ have entirely disappeared, leaving a smooth band representing the vertebral column. On either side of this, however, the outlines of the interspinous bones are distinctly traced; but the most remarkable thing about this fossil is that the lower lobe of the tail consists of rays that were distinctly ossified and now retain their original positions and forms. This indicates that these old, Carboniferous sharks were as highly organized as any of those inhabiting the present seas.

No similar instance of the preservation of the soft parts of cartilaginous fishes is known to me except that of *Chondrosteus* in the marls of the Lias of England. In both these cases the unusual preservation of the remains is probably due to the comparatively rapid deposition of an earthy carbonaceous sediment over them. In the formation of limestones, derived exclusively from organic structures, the accumulation of material on the sea bottom must necessarily have been exceedingly slow, and the soft parts of aquatic animals deposited with it have been so exposed to decay, and to the depredations of the various forms of marine life that subsist upon such food, that they have been totally destroyed.

Formation and Locality : Black shale of Waverly Group, Vanceburg, Ky.

Ctenacanthus parvulus (n. sp.).

Plate LIX., Fig. 3.

Spine very small, 1 to 2 inches in length by 2 to 3 lines wide; basal portion relatively broad and long, flattened, irregularly striated; exposed portion slightly curved, acute, compressed, but arched transversely; surface covered with relatively broad, but somewhat irregular longitudinal ridges. Posterior face set with large and much depressed hooks.

This little spine is referred to *Ctenacanthus* with some doubt, as the longitudinal ribs show no tubercles or scales such as are usually found in the species of this genus. It agrees with them, however, in the generalities of its form and markings, and scarcely affords material for the creation of a new genus.

In the figure now given the longitudinal ribs are too strong and continuous.

Formation and Locality : Cleveland shale, Bedford, Ohio.

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Listracanthus hystrix, N. and W.

Plate LIX., Fig. 5.

The species represented in the figure cited above, is very common in the Coal Measures of Indiana and Illinois, though but rarely seen in Ohio. It will be found described in the Geological Report of Illinois, Vol. IV., p. 372, Plate XI., Figs. 3, 3*a*. In Indiana these spines occur so frequently with the dermal tubercles of *Petrodus* that they are generally supposed to belong to the same fish. While this may be possible, it should be said that we have never yet found the tubercles of *Petrodus* in Ohio, while *Listracanthus* is not unknown here.

Formation and Locality : Black shale over Coal No. 6, Perry County, Ohio.

Listracanthus Hildrethii (n. sp.).

Plate LIX., Fig. 6.

Spine of relatively large size; nearly 6 lines broad, 2 inches from the summit; curved and sharply carinated, carinæ slightly granular; convex side strongly squamose.

Only a single specimen of this spine is known, and that lacks the basal portion. It is sufficient, however, to show that it was much broader, more curved, and more strongly and sharply marked than even the largest specimens of the common species, *L. hystrix*.

Formation and Locality : This specimen was found near Marietta, by the late Dr. S. P. Hildreth, and is now in the Cabinet of Marietta College.

Orthacanthus gracilis (n. sp.).

Plate LIX., Fig. 7.

Spine small and straight, about three inches long, very slender and acute; section circular at base, posterior face and sides flattened above; the angle inclosed by them set with acute, recurved, compressed denticles throughout the upper two-thirds of the entire length; surface smooth or very finely striated longitudinally.

These delicate spines might be supposed to represent the immature state of *O. arcuatus*, but it is hardly supposable that they should have

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become so decidedly arched in subsequent stages of growth, as the latter spines are. As it is now generally believed that the spines of *Orthacanthus* were worn by the sharks of which the teeth are called *Diplodus*; and as at least two species of *Diplodus* are found at Linton, it is highly probable that the curved and straight spines were associated respectively with these different teeth. When found in connection with the teeth so as to fix the relationship between them, the names now given to these spines may be suppressed. Until such relationship shall be determined, however, it will serve a useful purpose to describe them under distinct names.

Formation and Locality: Coal Measures, Linton, Ohio.

Genus GYRACANTHUS, Agass.

Since the publication of the descriptions of the species of *Gyracanthus* found in Ohio (Vol. I., Part II., p. 330), I have received a letter from Mr. D. Honeyman, of Halifax, in which it is stated that the great spine figured by Prof. Dawson (Acadian Geology, 2d Edition, p. 210), and named by him *Gyracanthus magnificus*, was taken by Mr. Honeyman from the *Lower Carboniferous limestone* of Baddeck, Cape Breton, and not from the Coal Measures, as I inferred from Prof. Dawson's notes. This case, therefore, instead of forming an exception to the rule to which I have referred, viz., that the spines of *Gyracanthus*, while common in the Coal Measures of Europe, in America have only yet been found in Lower Carboniferous rocks, affords another illustration of it. We should not be justified in saying that *Gyracanthus* did not exist in America during the Coal Measure Epoch, for it may be any day found in the coal strata; but it is an interesting fact that, up to the present time, no traces of it have been seen in this country in other than Lower Carboniferous rocks.

In letters received from Sir Philip Egerton since the publication of my notes on *Gyracanthus*, it is stated that it has been demonstrated that many of the spines of *Gyracanthus* found in Europe were attached to the pectoral fins, and that some of these are much worn, as though by contact with the bottom of the sea in which this shark lived.

These facts are cited by Sir Philip Egerton as confirmatory of the view presented in my notes, that the spines of *Machæracanthus* belonged to the pectoral fins.

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Genus PLATYODUS (nov. gen.).

Teeth elliptical in outline, crown slightly arched in both directions, surface punctate in undulate lines, but without folds or ridges.

Nothing is known of this genus except what is taught by a single specimen, which forms the basis of the specific description given below.

It is evident that it was once worn by an ancient Elasmobranch fish allied to *Deltodus*, *Sandalodus*, etc., but distinctly separated from them by its rounded outline, simple margin, low, evenly-arched crown, and linear punctation. How many teeth were borne on the jaws, and how much varied in form they were, if more than two, will doubtless be determined by future discoveries.

Platyodus lineatus (n. sp.).

Plate LIX., Fig. 12.

Teeth broad and low, ovoid or elliptical in outline, 3 inches long by 1½ inches wide; crown surface gently arched in both directions, punctate throughout, punctations arranged in broadly undulate lines which cross the crown transversely.

The only tooth of this fish yet known was found by the writer in the Waverly shales, on the farm of Mr. Dunn, eight miles south of Liberty, Casey County, Ky. It is somewhat worn by use, and corroded by exposure, but still exhibits characters by which it may be distinguished, at a glance, from any other heretofore described. Of these characters the most conspicuous are its great size, low, doubly-arched crown, without ridges or furrows, and the undulate lines of punctæ which occupy all the surface.

HOLOCEPHALI.

CHIMÆROIDI.

Genus RHYNCHODUS, Newb.

The announcement made in our first volume that the remains of Chimæroid fishes had been discovered in the Devonian rocks of Ohio, and the reference of the genus *Rhynchodus* to this family, may have excited some surprise and perhaps incredulity, as Chimæroids had not before been

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found in rocks older than the Jurassic. I am happy to be able to say, however, that the views there expressed in regard to the zoological relations of this genus are fully confirmed by Sir Philip Egerton, who has made a special study of the Chimæroids, living and fossil, and is confessedly the highest living authority in all that relates to their structure and classification. He writes me that the teeth described in Vol. I., Part II., pp. 307–313, under the name of *Rhynchodus*, are unquestionably those of Chimæroid fishes.

Ptyctodus calceolus, N. and W.

Plate LIX., Figs. 13, 13 *a*.

A tooth which probably belongs to the same species with that now figured, was described in the Illinois Geological Report, Vol. II., p. 106, Plate X., Fig. 10, under the name of *Rinodus calceolus*. This name was subsequently (Vol. IV., p. 374) changed to that given above, as it was discovered that the tooth designated by it came within Pander's genus *Ptyctodus*.

During the past year I have received from Mr. A. S. Tiffany, of Davenport, Iowa, the specimen of which a figure is now given. This is longer and narrower than that described in the Illinois Report, and the triturating surface instead of being depressed or sunken into the crown of the tooth, as in the Illinois specimen, is distinctly raised above the general surface. This difference is, I suspect, due to the fact that one is an upper and the other an under tooth; the elevated portions of one fitting into the depressions of the other.

As stated in the description contained in the Illinois Report, I suppose these to be the teeth of Chimæroid fishes.

Formation and Locality: Hamilton Group, Davenport, Iowa.

GANOIDEI.

DIPTERINI.

Genus CTENODUS, Agass.

Ctenodus serratus (n. sp.).

Teeth of lower (?) jaw of medium size, 16 lines long by 9 lines wide, somewhat triangular in outline; crown marked with eight prominent and

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sharp radiating ridges, which terminate above in numerous compressed, acute denticles; the furrows between the ridges being pitted to receive corresponding denticles of the opposite teeth. These ridges and furrows vary much in length, so that one end of the tooth forms a long pointed triangle, and at the opposite extremity the crown is rounded and the base projects in a depressed and flattened point.

In general form and marking this tooth bears considerable resemblance to that of *Ct. obliquus* of the Northumberland coal-fields, England, but the ridges are more numerous and much narrower. From the larger species of *Ctenodus* found in England, *Ct. tuberculatus*, etc., it will be at once distinguished by the fan-like radiation of its ridges, which all centre at the most prominent point of the crown. When in its perfect condition this is the most elegant species of the genus yet discovered. It is characterized by a remarkable exactness of form and sculpture. The internal margin forms a graceful arch from which the prominent point of the base projects at the end of the tooth where the ridges are shortest. The denticles which crown the ridges are much compressed, very sharp, and somewhat curved outward.

Fig. 15 represents a tooth of the lower jaw seen from above; 15*a*, one of the ridges in profile; 16, a small, triangular tooth probably from the upper jaw of a smaller individual of the same species.

In the Report of Prof. E. D. Cope, contained in this volume, will be found a figure and description of a portion of a large cranium of what is supposed to be a species of *Ctenodus*, found at Linton. A more complete cranium of the same kind, which I have, is about 8 inches in diameter, and the teeth which were once connected with it must have been considerably larger than any yet found at Linton. Prof. Cope calls his species *Ct. Ohioensis*. Whether it is identical with either of the species I have named from the teeth is not yet known.

Formation and Locality: Coal Measures, Linton, Ohio.

Ctenodus reticulatus (n. sp.).

Teeth of medium size (15 lines long, by 10 lines wide); general outline triangular, the inner margin arched. Crown marked with 7 low, radiating ridges, of which the summits form zigzag salient lines. The whole crown of the tooth exhibits a fine reticulated ornamentation, which on the ridges is more or less radiate, and has the appearance of *hachures*.

The only specimen of this species yet found is too imperfect for figuring or full description. The characters given above will, however, serve

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to distinguish it at a glance. The ridges are also broader and fewer in number than in *Ct. serratus*, while the zigzag lines of the summit and the vermicular ornamentation of the surface, present features that are not found in any other known species. In most of the teeth of *Ctenodus* the crown surface is smooth, and the acute denticles which crown the ridges are highly polished.

Formation and Locality: Coal Measures of Linton, Ohio.

Dipterus Sherwoodi (n. sp.).

Plate LVIII., Figs. 17, 17 *a*, 17 *b*.

Teeth one inch in length, triangular in outline; crown marked with three prominent tuberculated ridges, separated by deep furrows somewhat wider than the ridges. The strongest of these ridges forms one side of the triangular tooth. On the angle opposite this side are a few irregular tubercles but no traces of distinct ridges. The denticles which crown the ridges are somewhat compressed laterally, are rounded, smooth, and blunt at the summit.

This is apparently one of the upper palate teeth of a species of *Dipterus*, and is specially interesting, as being the first relic of that genus found on this continent. It can be readily distinguished from all the species described abroad, by the small number of its radiating ridges. This specimen is from the Catskill group of Tioga County, Pa., and was discovered by my former assistant, Mr. Andrew Sherwood, now of the Geological Corps of Pennsylvania, to whom I am indebted for an opportunity of examining it.

In the same rock with this tooth are a number of imperfectly preserved rhomboidal, or rounded scales, which are thick and strong, and have the upper surface punctate precisely as in the scales of the foreign species of *Dipterus*. The surface of these scales was, probably, once highly polished, but like all the fish remains of the Catskill, the organic tissue seems somewhat corroded.

It is a singular fact, that while previous to last year, no teeth of Dipterians had been found in this country, both *Ctenodus* and *Dipterus* were almost simultaneously discovered; one in the Coal Measures of Ohio, the other in the Catskill of Pennsylvania. More material is wanted for comparing the fishes which now bear the names of *Ctenodus* and *Dipterus*, but, judging from the teeth alone, they might, with propriety, be included in one genus. It is true that no scales have been found in the Coal Measures which could be referred to *Ctenodus*, and it is quite possible that the

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Carboniferous species yet known, were without scales; but the same difference probably existed between the *Ceratodus* of the Trias, and the "Barramunda" of Australia; both of which have been included by Dr. Gunther in the same genus. No scales have been found in connection with the Triassic teeth, while the Australian *Ceratodus* has the body covered with large imbricated scales.

Fig. 17 represents the tooth of the natural size, seen from above. Fig. 17 *a*, a side view of the same, and Fig. 17 *b*, a profile view of the marginal row of denticles.

Genus Heliodus (nov. gen.).

A Ganoid fish, closely allied to *Dipterus*, from which it differs in having the upper palate teeth united together to form a single large rounded, or semi-circular triturating plate, bearing several tuberculated ridges which radiate symmetrically on either side of the central line. These ridges are highest on the margin of the tooth and gradually diminish to the centre, which is smooth. The dental plates of the lower jaw have not yet been found. Whether they were consolidated in one, or separated like those of *Dipterus* is not yet known. Since, however, they were in *Dipterus* and *Ctenodus* more widely separated than the upper teeth it is possible that they were not joined together in *Heliodus*. In microscopic structure this tooth is similar to those of *Dipterus*. The tuberculation of the ridges is precisely the same, and if divided through the middle, each half would be accepted as one of the upper dental plates of that fish.

There is little doubt that we have in *Heliodus* a new member of the family of Dipterine Ganoids to which *Dipterus*, *Ctenodus* and *Ceratodus* belong, and its dental plates present a simple but hitherto unknown modification of the characteristic dentition of the group. In the other genera of the family the palate teeth vary much in form and in the number and character of their radiating ridges. In *Dipterus* the upper teeth have the form of right-angled triangles, or half opened fans, the ridges being set with rounded and generally obtuse tubercles. The lower teeth are longer, like a fan two thirds opened. In *Ctenodus* the number and form of the teeth is the same as in *Dipterus*, but the radiating ridges are generally more compressed, and the tubercles are more acute. In *Ceratodus* the teeth are smooth, the ridges few and large, and without tubercles. Finally in *Heliodus* we have the upper pair of palate teeth firmly joined in one plate, taking the form of a fully opened fan, and bearing radiating tuberculated ridges like those of *Dipterus*.

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In the "Bulletin of the Royal Academy of Belgium" (2e *Serie*, t. XXVII. p. 385), P. J. Van Beneden describes the palate tooth of a fish, which is without much doubt, generically identical with that on which the above description is founded. It differs, however, from that here described in having five tuberculated ridges, instead of four, on either side of the median line, in the number of tubercles on the ridges, and most of all in size; for the Belgian tooth is eight inches in diameter. M. Van Beneden considers his specimen as generically identical with a fish described by M. De Koninck and himself, in a preceding volume of the "Bulletin of the Royal Academy of Belgium" (2e *Serie*, t. XVII., p. 143), and which was made the type of a new genus (*Palaedaphus*). This remarkable fossil was found in the Carboniferous limestone of Belgium, and was considered by the distinguished authors of the paper referred to, as a portion of the head and upper jaw of a Plagiostomous fish, having some resemblance to *Squatina*.

Excellent figures of both fossils were published by Van Beneden and De Koninck; and judging from these and the minute descriptions which they give, I am compelled to dissent from their view of the generic identity of their two species of *Palaedaphus* (*P. Insignis* and *P. Devoniensis*).

The first seems to me, as to them, a portion of the head of a large Plagiostome, but the second exhibits characters which lead me to conclude that it is the palate tooth of a Dipterian Ganoid, and that it belongs to a genus that required a new name and description. These I have ventured to supply in describing the American specimen recently found; uniting it with the Belgian species ("*Palaedaphus Devoniensis*"), in the genus *Heliodus*.

My reasons for considering these the teeth of Ganoids and not of Selachians are that they have essentially the structure of those of *Dipterus*, —i. e., are composed throughout of true bone, and bear radiating ridges crowned with tubercles, of which the summits are coated with enamel— and no such structure is known to exist in any Elasmobranch fish. In all the members of this order the jaws are cartilaginous, and the teeth are united to them by mere ligamentous attachments.

If I am correct in separating generically the two species of *Palaedaphus*, that described by Van Beneden under the name of *Palaedaphus Devoniensis* becomes *Heliodus Devoniensis;* and if the view now advanced in regard to the zoological relations of *Heliodus* is the true one, we have in *H. Devoniensis* by far the most gigantic member of the Dipterian family yet known, and one that must have rivalled in dimension *Dinichthys*, the largest of the other great branch of the Ganoid order, the Placoderms.

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Heliodus Lesleyi (n. sp.).

Plate LVIII., Fig. 18.

Upper dental plate rounded or hippocrepiform, 1½ inches in length and breadth; triturating surface more than a half circle, highest in the centre, where it forms a broad smooth boss; from this radiate eight tuberculated ridges, four on either side of the median line, which is marked by a deep and smooth furrow. The ridges on each side differ among themselves, but are symmetrical with those on the other side, the lateral ridges being shortest, and bearing several tubercles, while the pair which borders the central furrow have but a single tubercle at the extremity of each. On both sides of the central boss the crown of the tooth is worn in a shallow, rounded depression by the opposing teeth of the lower jaw. The posterior margin of the crown is nearly straight, and is slightly crenulated at the centre. This is bordered by a sloping surface which extends downward and backward about four lines, and expands laterally to form low, winglike projections. This portion of the tooth was doubtless covered with integument.

The more important features of this tooth and its relations to allied forms, are given in the generic description. It was obtained by Mr. Andrew Sherwood, in the Upper Chemung rocks of Northern Pennsylvania, and is named in honor of Prof. J. P. Lesley, the Director of the Geological Survey of that State.

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PLATE LIV.

PAGE.

Fig. 1. ASTEROSTEUS STENOCEPHALUS, Newb. 36

Upper surface of cranium. Natural size.

Fig. 2. COCCOSTEUS OCCIDENTALUS, Newb 32

Dorsal shield. Natural size.

2a. Ventro-median plate, inner surface.

Fig. 3. COCCOSTEUS CUSPIDATUS, Agass 33

Dorsal shield. Two-thirds natural size.

Fig. 4. COCCOSTEUS DECIPIENS, Agass 11

Ventro-median plate, external surface.

4a. Ventro-median plate, inner face.
Natural size.

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4

3

1

2 a

4 a

J. S. Newberry del.

Strobridge & Co. Lith. Cincinnati

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Geological Survey of Ohio.

DEVONIAN. (Corniferous Limestone) PLATE LV.

1

4

5

5a

6

3

2

J.S.Newberry del.

Strobridge & Co Lith Cincinnati

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PLATE LVI.

Fig. 1, 1*a*. Two cranial? plates in their relative positions. Natural size.
1*b*. Reduced outlines of four plates probably in their relative positions.
2. Interior surface of plate probably homologous with 1*a*.
3. Exterior surface of small, strongly tuberculated plate corresponding to 1*a*.
4. Triangular plate, probably one side of a flattened spine.
5. Slender spine, prabably from body.
6. Robust spine, with strongly squamose margin, from body?
All the figures, except 1*b*, are of the size of nature; the originals from the Corniferous limestone at Delaware and Sandusky, Ohio.

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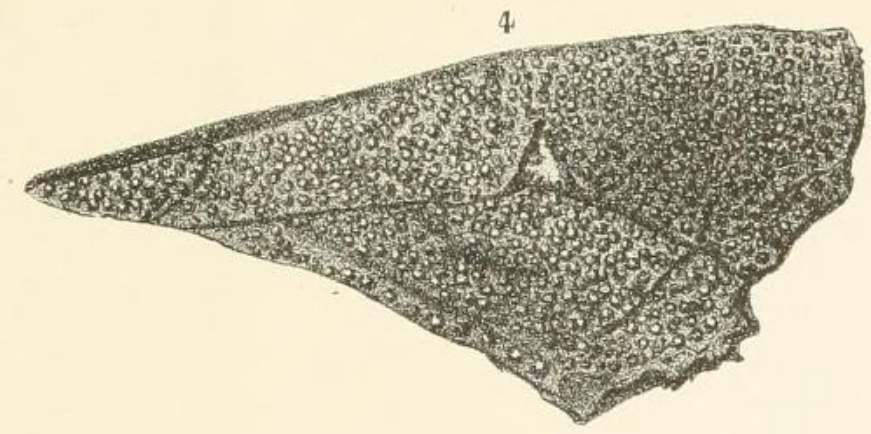
Geological Survey of Ohio.

DEVONIAN. (Corniferous Limestone) PLATE LVI.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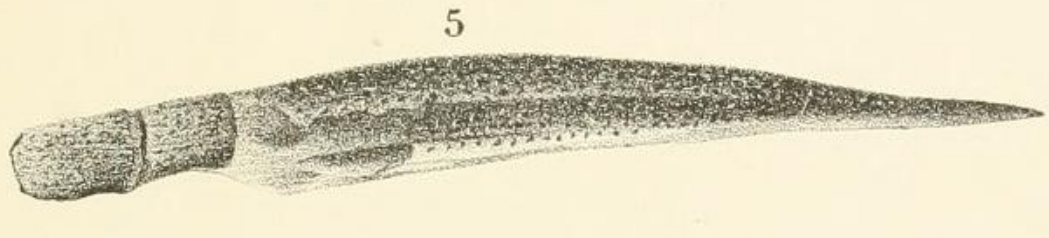
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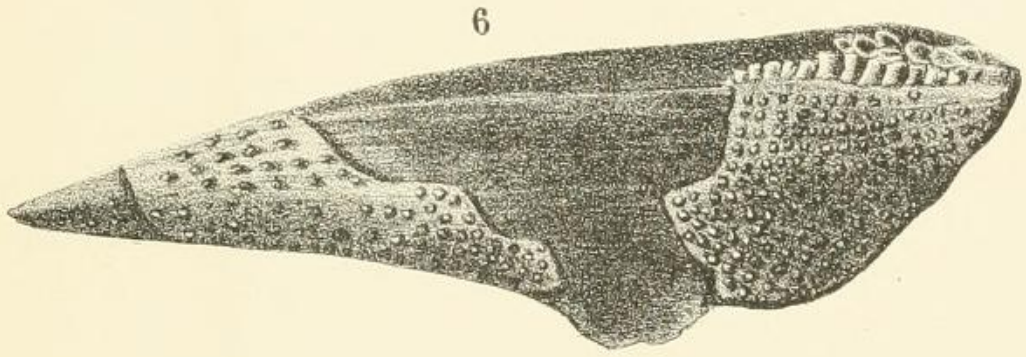
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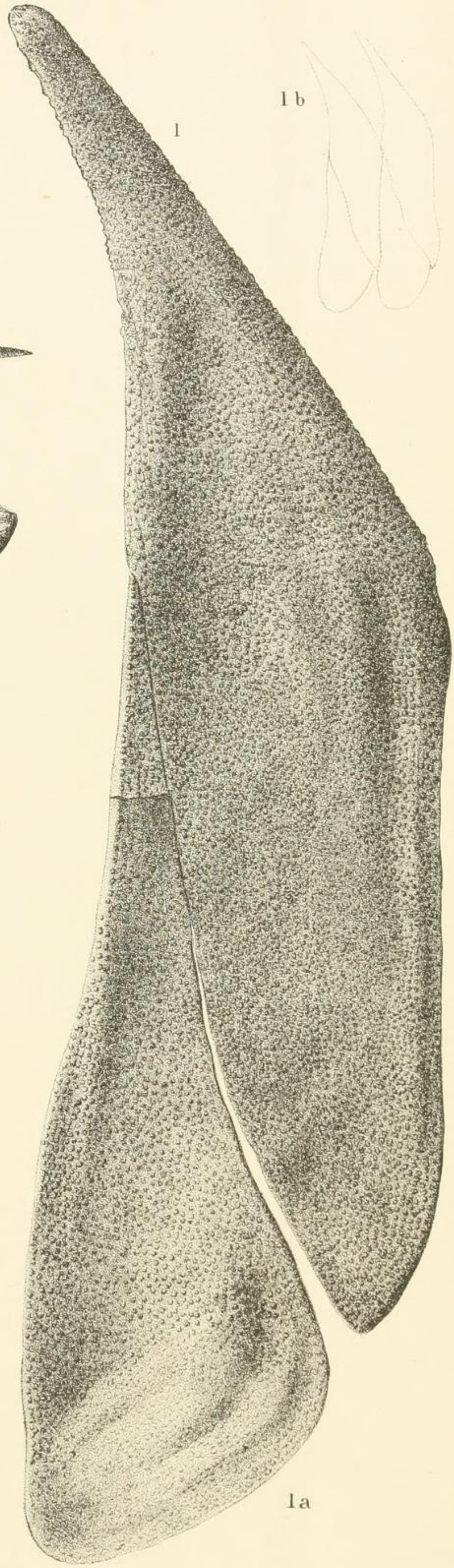
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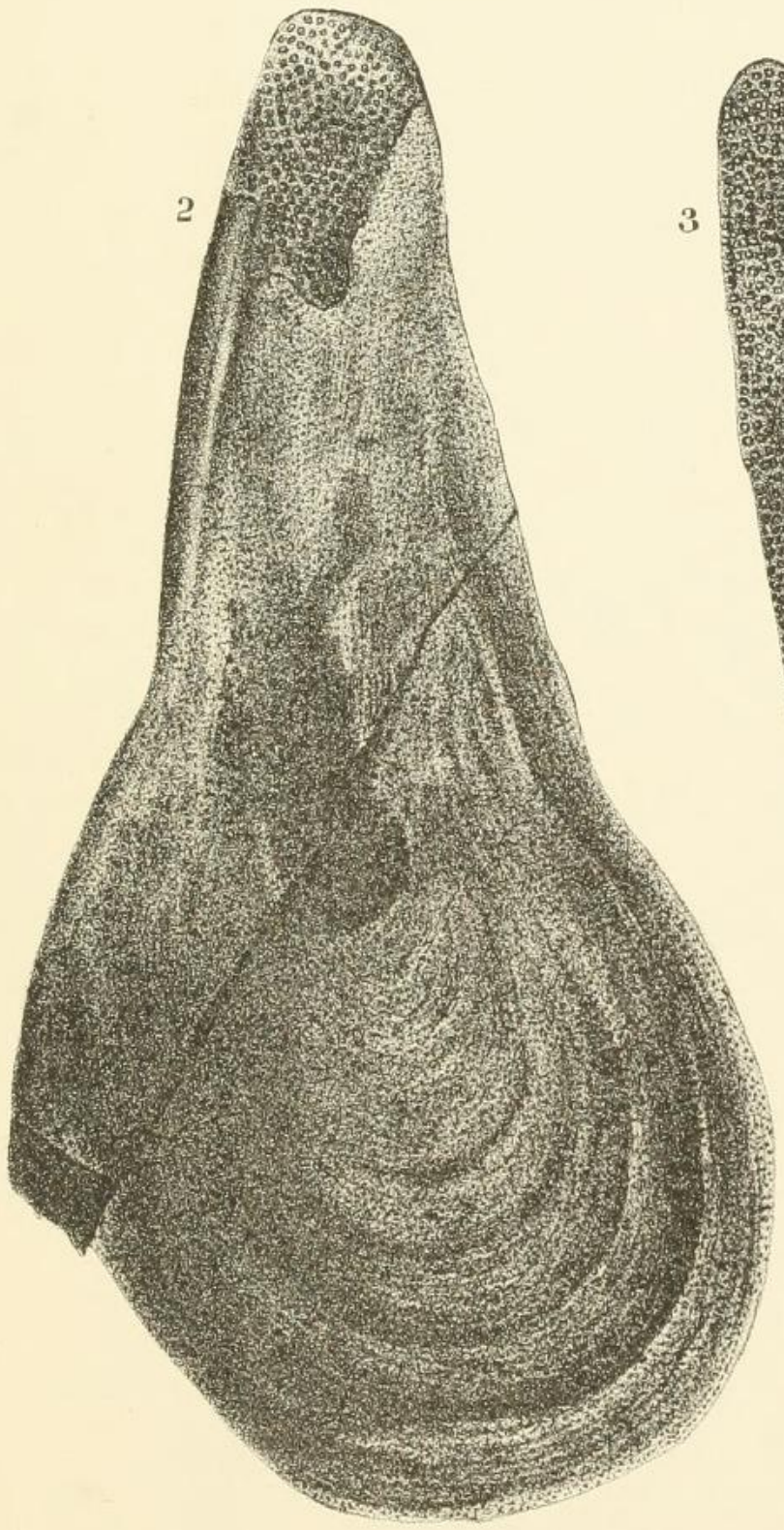
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J.S.Newberry del.

Strobridge & Co. Lith. Cincinnati.

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PLATE LVII.

PAGE.

Figs. 1–4. CONODONTS of various forms 41
5 and 7. Conical teeth of fishes associated with the *Conodonts* 41
6, 8–20. Various forms of *Conodonts* 41
Cleveland shale, Bedford, Ohio.

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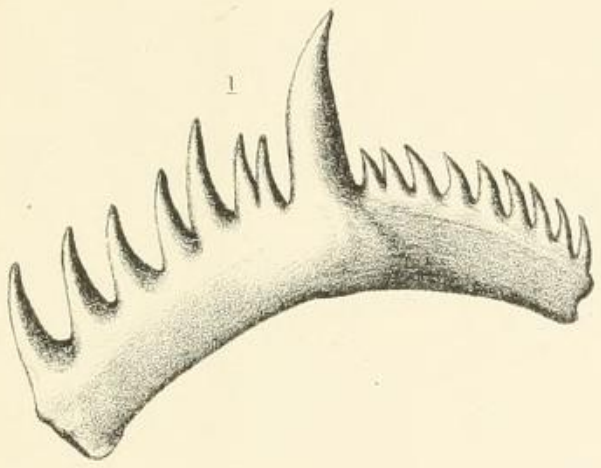

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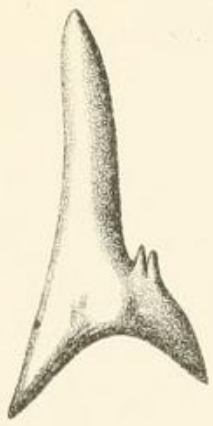

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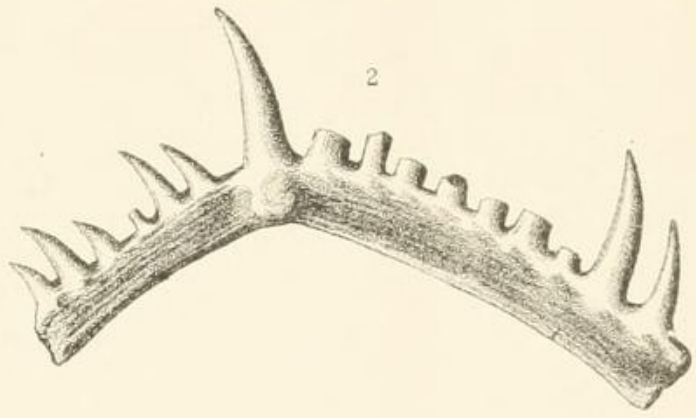

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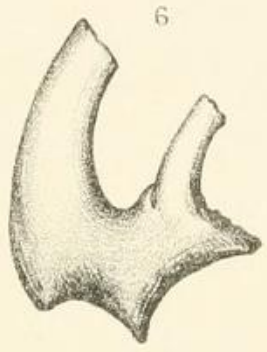

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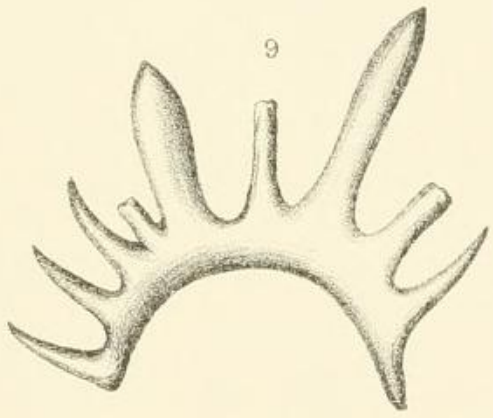

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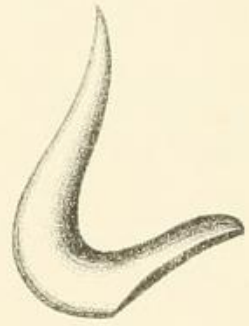

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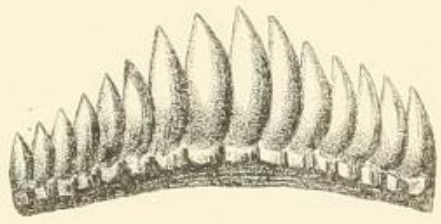

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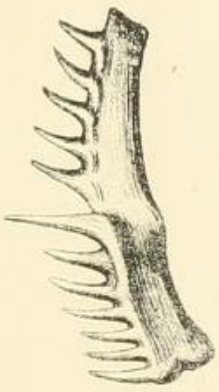

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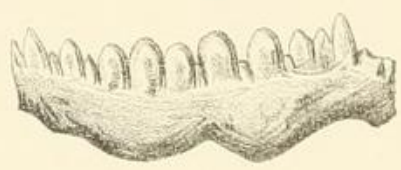

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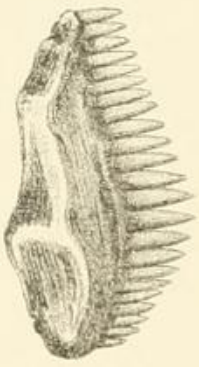

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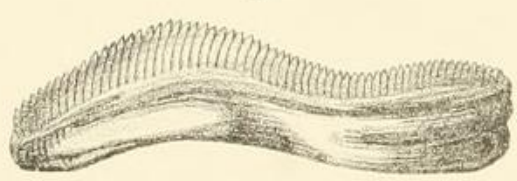

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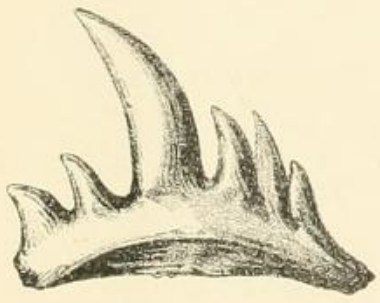

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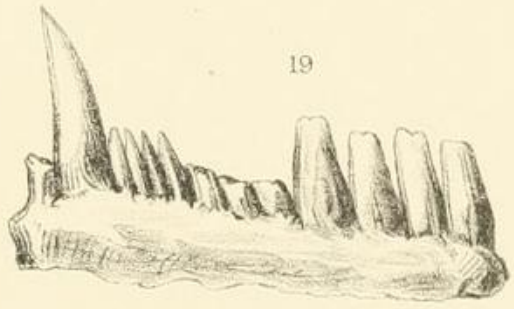

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PLATE LVIII.

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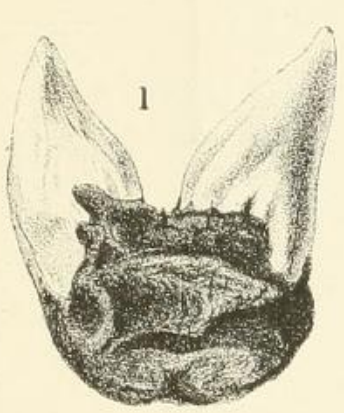
PLATE LVIII.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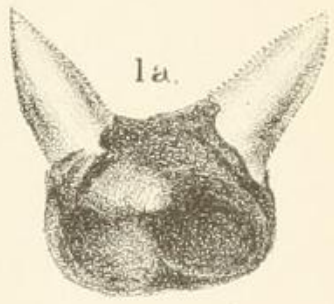
1b


3a


3


2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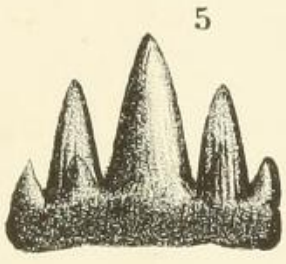
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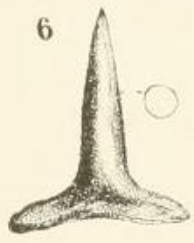
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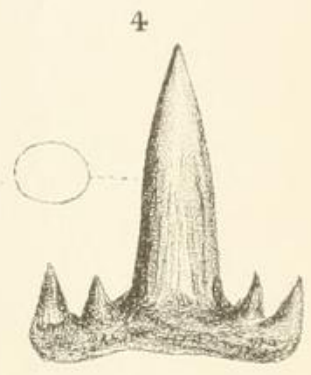
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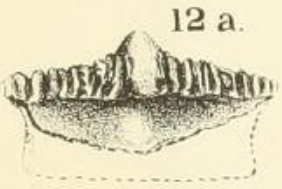
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10a


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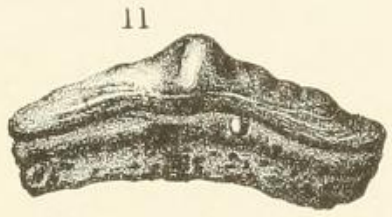
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9


9a


7


11a


11c


11e


11g

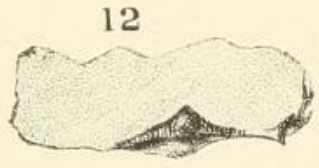

11b


11d


11f


11h

12a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13


14


13a

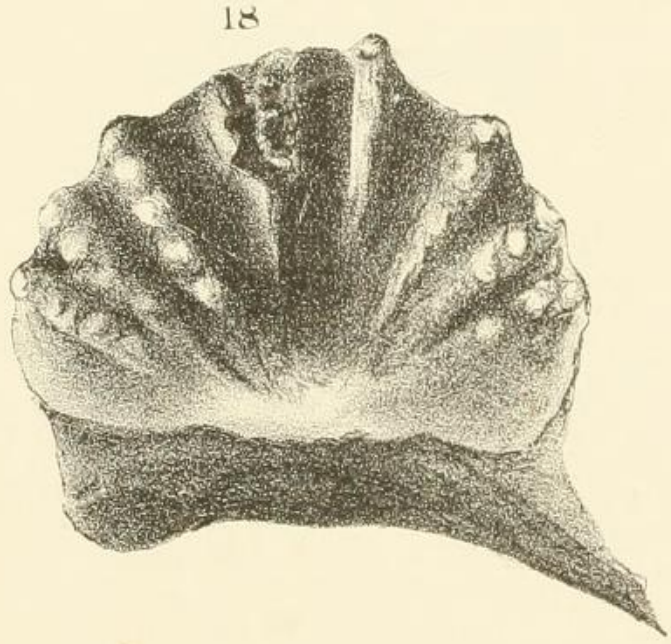

17a


17b


16


15a


17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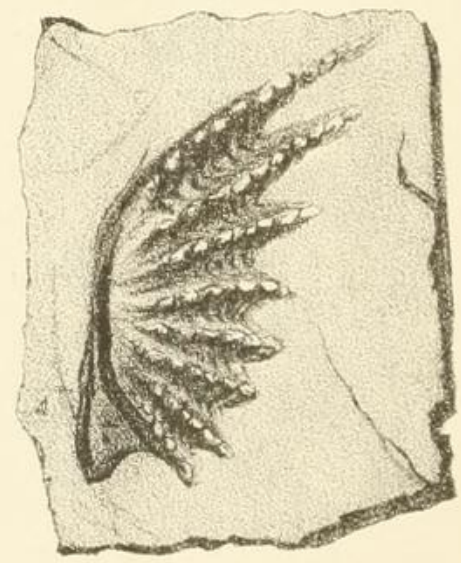
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PLATE LIX.

PAGE.

Fig. 1. CTENACANTHUS FORMOSUS, Newb. 53

Natural size.
1*a*, 1*b*, 1*c*. Transverse sections of spine.
1*d*, 1*e*. Surface markings. Enlarged.

Fig. 2. CTENACANTHUS FURCICARINATUS, Newb. 54

Base of spine. Natural size.
2*a*, 2*b*. Transverse sections.
2*c*. Surface markings. Enlarged.

Fig. 3. CTENACANTHUS PARVULUS, Newb. 55

Entire spine. Natural size.

Fig. 4. DERMAL TUBERCLES OF CTENACANTHUS? 54

Found with fig. 2.

Fig. 5. LISTRACANTHUS HYSTRIX, N. and W. 56

A small specimen. Natural size.

Fig. 6. LISTRACANTHUS HILDRETHI, Newb. 56

Summit of spine. Natural size.

Fig. 7. ORTHOCANTHUS GRACILIS, Newb. 56

A rather large specimen. Natural size.

Fig. 8. DINICHTHYS TERRELLI, Newb. 28

Supra-occipital plate, inside. Natural size.

Fig. 9. DINICHTHYS HERTZERI, Newb. 18

Supra-occipital plate, inside. Half natural size.

Fig. 10. SUPRA-OCCIPITAL AND DORSAL PLATES OF HETEROSTIUS. 14

Inside, much reduced. After Pander.

Fig. 11. SUPRA-OCCIPITAL AND DORSAL PLATES OF ASTEROLEPIS. 14

Inside, much reduced. After Pander.

Fig. 12. PLATYODUS LINEATUS, Newb. 58

Crown surface of tooth. Natural size.

Fig. 13. PTYCTODUS CALCEOLUS, N. and W. 59

Side view. Natural size.
13*a*. Upper surface. Natural size.
13*b*. Profile section. Natural size.

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1

1a

1b

1c

1d

1e

2

2a

2b

2c

3

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11

12

13

13a

13b