

Article IV.—NOTES ON THE DEVONIAN "PLACODERM,"  
*DINICHTHYS INTERMEDIUS* NEWB.

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PLATE V.

Since the description of *Dinichthys* by Professor Newberry in 1873,<sup>1</sup> remains of this "Placoderm" have been collected, more or less abundantly, at various Devonian localities in Europe as well as in North America. Unfortunately, however, the fossils have usually proved fragmentary and even the better specimens in many cases are represented only by detached plates. It has been, therefore, through the association of parts of several individuals that our best understanding of the characters of the genus has been obtained. On the other hand, the fact must be sadly recorded that some of the best material from the classic Ohio localities has been lost through the vagaries of enthusiastic local collectors, who would detach from a concretion only the larger plates, casting out all other parts, and then shuffle together the detached elements so that it is well nigh impossible to bring together again the parts from the same concretion.

Little is known, therefore, of *Dinichthys* as restored from parts of unquestionably the same individual. For this reason, my attention has been directed to a conspicuous exception in the way of Dinichthyid material in the shape of a slab<sup>2</sup> containing associated plates which I have had the opportunity of examining in the American Museum of Natural History. This slab, it may be mentioned, exhibits the majority of the body plates belonging to a single individual of *D. intermedius*. The cranial shield is wanting, but data for its proportions may be deduced from the measurement of related parts, as well as from comparisons of the preserved plates with separate crania belonging to the same species. Dr. Eastman, who some years ago studied this slab for another purpose, declared it "valuable for furnishing comparative measurements of the different bones."<sup>3</sup>

As shown in Plate V, the slab presents for examination ten readily recognizable plates scattered over its surface, and three or four fragmentary elements of doubtful position. They do not retain their natural relations but are wrenched out of place, dorsal and ventral plates being commingled, some partly overlying and

<sup>1</sup> Report of the Geol. Survey of Ohio, Vol. I.

<sup>2</sup> Newberry Collection, No. 195. Locality, Cleveland Shales, Ohio.

<sup>3</sup> On the Relation of Certain Plates in the Dinichthyids, with Descriptions of New Species. Bull. Mus. Compar. Zool. Harvard, Vol. XXXI, 1897, No. 2, p. 21.

concealing others. They seem not to have settled into their present places naturally upon decomposition, but rather to have been tossed by violence; but as to the nature of a disturbance that could so destroy the calm of the Cleveland Sea we can draw no conclusion.<sup>1</sup> The various plates as they appear in the slab will first be described.

*Dorso-Median* (Plate V, D M). This is the largest and most conspicuous piece in the slab—the shovel-shaped plate lying on the right hand side. It here rests on its back, which is arched from side to side. On the right, it is broken off in nearly a straight line and the fragment appears to be lost (restored in the plate).

*Antero-Dorso-Lateral* (A D L). This plate, the right, appears beside the dorso-median and partly overlies it. The visceral aspect is uppermost.

*Postero-Dorso-Lateral* (P D L<sup>1</sup>). This is the somewhat triangular plate, lying immediately above and to the left of the antero-dorso-lateral, and exposing its visceral face. Its fellow is recognized in the remarkably well-preserved triangular plate near the bottom of the slab (P D L<sup>2</sup>).

*Antero-Ventro-Lateral* (A V L). This may be recognized in the plate lying to the left and partly beneath the postero-dorso-lateral. The one preserved is from the right side of the animal: it exposes the outer surface.

“*Mandibles*” (Mn). The antero-ventro-lateral partly overlaps one of the “mandibles”—that from the right side, exhibiting the visceral aspect. To the right is the counterpart of the anterior half of its fellow.

“*Premaxillary*” (Pxm). Near the “mandibles,” appears the right “premaxillary.” It lies on its side, the visceral aspect being turned outward.

*Antero-Ventro-Median* (A V M). Below the “premaxillary” lies an elongated triangular element, the antero-ventro-median. It is a small plate which in its natural position was wedged in anteriorly between the two antero-ventro-laterals of the plastron. This specimen differs, in this respect, therefore, from *D. terrelli*, in which the antero-ventro-median fuses with the postero-ventro-median,—the latter character, however, may be but a symptom of age.<sup>2</sup>

<sup>1</sup> For tranquility and general conditions of the seas in which the Cleveland Shale was deposited, *vide*, Bashford Dean: The Preservation of Muscle-Fibres in Sharks of the Cleveland Shale. *Amer. Geologist*, Vol. XXX, 1902, espec. pp. 277-278.

<sup>2</sup> For a discussion of this subject, *vide*: Bashford Dean: On the Vertebral Column, Fins and Ventral Armoring of Dinichthys. *Trans. N. Y. Acad. Sc.*, Vol. XV, 1895, pp. 157-163, plate vii. Chas. R. Eastman: On the Relations of Certain Plates in the Dinichthyids, etc., *Bull. Mus. Compar. Zool. Harvard*, Vol. XXXI, 1897, No. 2. A. A. Wright: New Evidence upon the Structure of Dinichthys (Abstract). 5th Ann. Rept. Ohio Acad. Sc., 1897.

## EXPLANATION OF PLATE V.

*Dinichthys intermedius* Newb. Plates in the matrix.  $\times \frac{1}{2}$ . Cleveland Shales, Ohio. *A D L*, antero-dorso-lateral; *A V L*, antero-ventro-lateral; *A V M*, antero-ventro-median; *D M*, dorso-median; *Mn*, "mandible"; *Pmx*, "premaxillary"; *P D L*<sup>1</sup>, *P D L*<sup>2</sup>, postero-dorso-laterals; *S O*, sub-orbital.





DINICHTHYS INTERMEDIUS *Newb.*



*Sub-Orbital* (S O). One other plate may be identified—the one occupying the center of the slab,—the right sub-orbital. It is, however, so completely covered over by the postero- and the antero-dorso-laterals, that only a small corner projects on either side of them.

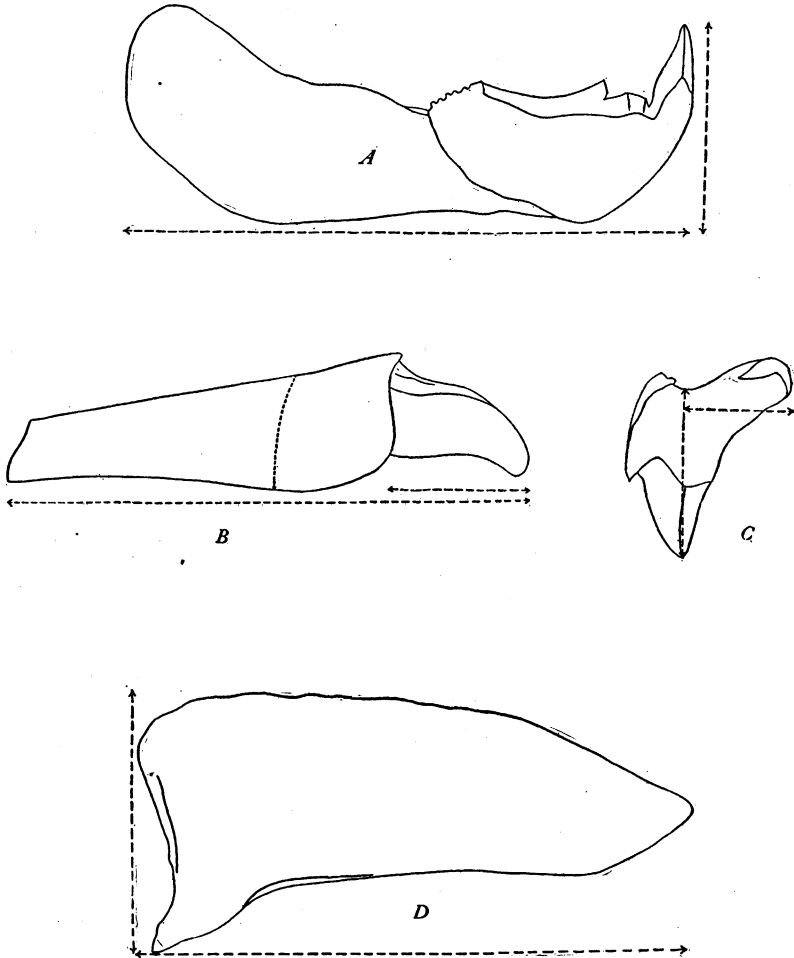


Fig. 1. Diagrams illustrating the mode of measurement of Dinichthyid plates. All *D. intermedius*. Somewhat less than one fourth natural size.

- A.—Right "mandible"; from without.
- B.—Dorso-median; side view.
- C.—Right "premaxillary", inner view.
- D.—Right antero-ventro-lateral; from without.

Thus it is seen that most of the body plates of a single individual of *Dinichthys* are here preserved. By the careful measurement of these, and by inferences based upon their apposing surfaces to give

approximate estimates of the sizes of the plates missing, we may arrive at tolerably accurate data for the proportions of most of the exoskeletal elements. But before recording the measurements, some explanation is necessary as to the manner in which they were made.

It has been the custom of American palæontologists to record the measurements of elements in the Arthrodira without indicating clearly the manner in which they were taken. It thus happens that disagreement upon the size of a bone in a certain species may be due altogether to a difference in the mode of measurement. To obviate this source of error, a uniform method of measurement is desirable. The following is the plan adopted in the present paper and one which makes possible accurate definition. Whenever a flattened plate is under consideration, *e.g.*, an antero-ventro-lateral, its length is measured on a straight line parallel to its longest axis, a process when present being included—the length of the process is, however, also recorded separately. The width of the plate is taken at right angles to the base line, and one or more measurements are recorded according to the particular variation in form. In dealing with such a plate as the dorso-median, it is desirable to measure the width by a tape applied to the external surface between the two points farthest apart. A straight line measuring the span between the edges on the ventral side will lead to error, since all dorso-medians in any species, even when of the same age, are not equally arched from side to side, some having suffered more flattening than others. A reference to the diagrams (Fig. 1) will best bring out how the measurements in a few instances were made. The proportions of the plates preserved in the slab are given in the table on the opposite page. In two cases, indicated by an \*, the restoration of contours was attempted after carefully comparing the plates in the slab with similar isolated, but well-preserved elements of the same size. Thus errors due to weathering are as far as possible eliminated.

An examination of this table shows that we have here the length of the plates forming the shoulder armor. If we supplied the length of the cranium, we would possess a complete measurement of the dorsal armor and so be enabled to calculate with some degree of accuracy the total length of the creature when alive. Fortunately data for supplying this deficiency are not lacking.

In the Newberry Collection there is another slab exposing a cranium in ventral aspect, with the antero-dorso-laterals *in situ*. This belongs to *Dinichthys intermedius* as is evidenced by the angular prominences of the posterior rims of the orbits—in *D. terrelli* these



being rounded off—as well as by the proportions of the individual skull elements. The measurements of this cranium are as follows:

Length (including median-occipital process), 27 cm.

Width, at anterior margin, 20.6 cm.

MEASUREMENT OF THE BODY PLATES IN A SINGLE INDIVIDUAL OF  
*D. intermedius*.<sup>1</sup>

Name of Plate.	Length.	Width.	Remarks.
*Dorso-median	33.75 cm.	30.0 cm.	Length, excluding process, 24.4.
Antero-dorso-lateral	14.5	25.5	
*Postero-dorso-lateral	37.5	17.5	Width, omitting overlapping area, 10.0. <sup>2</sup>
"Premaxillary"	8.8	7.0	Length is from tip of tooth to upper inner surface; width, at process.
"Mandible"	31.0	10.0	
Sub-orbital	25.6	11.9	Length includes process; process alone 10.0.
Antero-ventro-median	14.4	7.5	Width at anterior end.
Antero-ventro-lateral			Imperfect.
Postero-ventro-lateral			Wanting.

If we now compare the antero-dorso-laterals belonging to this cranium with the ones given in the table, we may conclude from their agreement or disagreement, as to the size of the skull to accompany the measurements in the table. Unfortunately, the antero-dorso-laterals sink into the matrix at an angle, being partly hidden within and making measurement impossible. We may, however, compare the articular processes in the two, although a comparison based upon the relative sizes of processes is generally misleading as I shall endeavor to show farther on. A comparison of the processes in this specimen with those of the antero-dorso-lateral in the slab, shows that those in the former are a trifle smaller. Hence, this much is certain, that the cranium accompanying the measurements in the table is somewhat larger than 27 cm. This conclusion we are enabled to check by the study of another specimen at our disposal. There is preserved in the Newberry Collection the cranium,<sup>3</sup> dorso-median, and a few other plates which went together. These are in excellent preservation and allow of accurate measurement. The

<sup>1</sup> The measurement of various plates of this species given by Dr. Eastman are evidently of plates belonging to individuals of different ages. (*l. c.*, p. 32).

<sup>2</sup> Agrees with Nos. 84 and 5143 in Newberry Collection.

<sup>3</sup> Figured by Newberry: Palaeozoic Fishes N. Amer., plate li.

cranium, from the tip of the rostral to the end of the median-occipital process, is 30.6 cm. The dorso-median that accompanies it is 33 cm. long, or about 0.75 cm. shorter than the dorso-median of the slab. Hence the length of the cranium accompanying the latter must have been about 31 cm.

We now have the lengths of the cranium and of the shoulder armor. The two together, plus an allowance of some 4 cm. for the forward projection of the "premaxillaries" as well as for the space between the cranium and the antero-dorso-laterals at the articulating processes, gives us a total length of armor in the individual in the slab, of about 70 cm. This includes the dorso-median process.

From these figures we may attempt to calculate the total length of *D. intermedius* as it must have appeared in life in the Devonian seas. That it was a creature well adapted to an aquatic life there can be little doubt.<sup>1</sup> This may be inferred from the vast period during which it prevailed in the waters. It had a fish-like body gradually tapering forward and backward, and somewhat flattened ventrally. These facts have been established beyond doubt by the study of a specimen<sup>2</sup> in which are preserved the notochord and neural arches; as well as by comparisons with the structure of the allied form *Coccosteus* as interpreted in the careful restorations of Dr. Traquair and Dr. A. Smith Woodward. *Dinichthys* very probably followed the law clearly exhibited by perfectly adapted aquatic forms: namely, the entering angle must have been in the neighborhood of 36% of the total length of the animal.<sup>3</sup> We therefore are justified in assuming that in *Dinichthys* the dorsal surface from the tip of the snout to a point 36% of the length gradually sloped upward; and that back of this point, to the tail, it sloped downward.

Hence the figure, 70 cm., which we obtained above as the length of the dorsal armor, will enable us to calculate the total length of the creature. We must first, however, deduct some 10 cm. for the length of the dorso-median process, which did not contribute to the upward slope, but which lay buried in muscle beneath the surface. This leaves 60 cm. as 36% of the length. Hence the entire individual whose proportions are given in the table was 167 cm. or about 5½ feet long. That this was not the maximum size attained by the species is quite certain, for Dr. Eastman mentions a dorso-

<sup>1</sup> H. Simroth in his 'Entstehung der Landthiere' has suggested that the primitive armored forms to which *Dinichthys* belongs were land animals. However, this view, as far as the writer is aware, has received no acceptance among morphologists.

<sup>2</sup> Prof. Dean's type specimen in his paper On the Vertebral Column, Fins and Ventral Armoring of *Dinichthys*. Trans. N. Y. Acad. Sc., Vol. XV, 1895, pp. 157-163; plate vii.

<sup>3</sup> Vide, Bashford Dean: Fishes Living and Fossil, 1895, pp. 5-7.

median 41.91 cm. or 8 cm. longer than the one in the slab, and a cranium of *D. intermedius* in the Newberry Collection measures 33.4

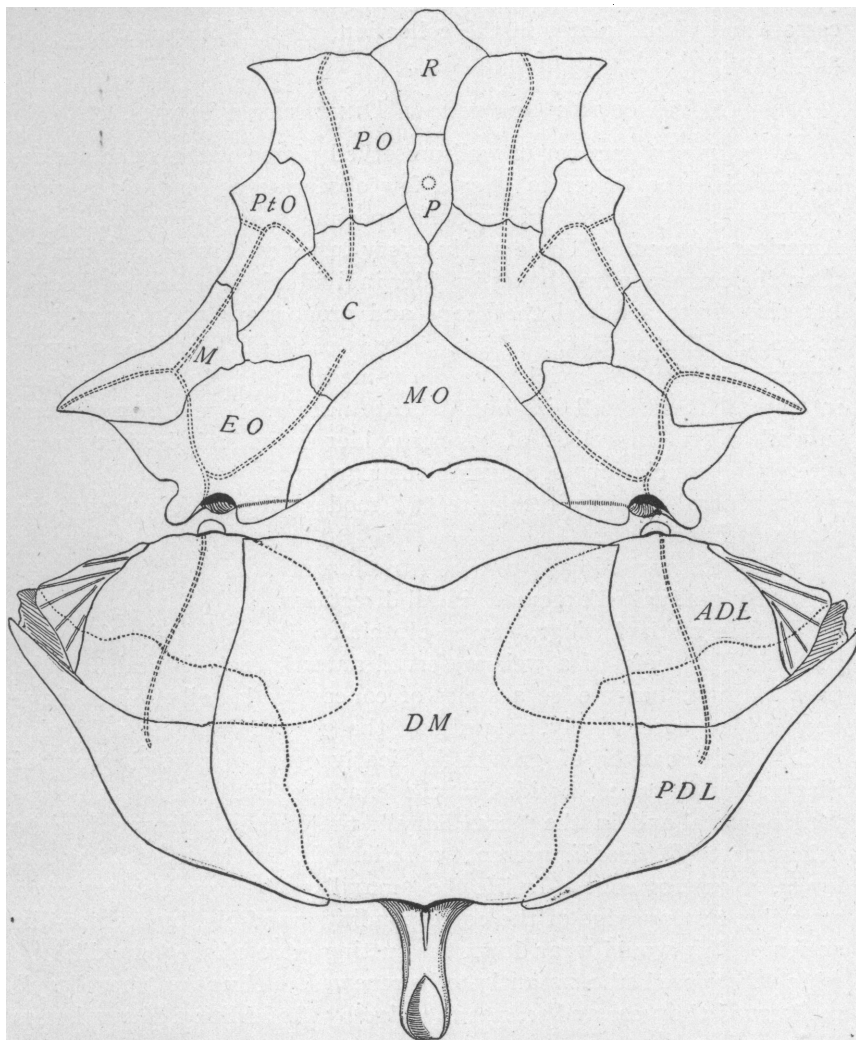


Fig. 2. *Dinichthys intermedius* Newb. Restoration of dorsal armor.  $\times \frac{1}{4}$ . ADL, antero-dorso-lateral; C, Central; DM, dorso-medial; EO, external occipital; M, marginal; MO, median occipital; P, pineal; PDL, postero-dorso-lateral; PO, preorbital; PtO, postorbital; R, rostral.

This restoration differs from the best hitherto published (Chas. R. Eastman, in Amer. Natur., Vol. XXXVII, 1898, p. 756) in a number of details, and in the following important points:

The relative sizes of the plates of the shoulder armor as compared with the cranium and amongst themselves.

The length of the Rostral and Pineal elements as compared with the length of the cranium.

The configuration of the Centrals and Marginals.

The size of the orbits.

cm. or 2.4 cm. larger than that of the individual here described. Upon a proportional estimate, the possessor of this last cranium must have been over  $6\frac{1}{2}$  feet in length. It may be said from the examination of certain individual plates in the collection, that *D. intermedius* probably attained a length of eight feet.

#### NOTE ON THE GROWTH OF DINICHTHYID PLATES.

A study of a number of well-preserved plates of the same species has enabled the writer to offer a few observations on their manner of growth. A number of juvenile specimens are preserved in the American Museum. These are in every instance thinner and smaller than the corresponding bones in older individuals of the same species, but they have attained the shape and proportions which enable us to readily identify them. Thus, there is no doubt of the identity of "premaxillaries," "clavicles," a dorso-median, etc., in the collection, in spite of their small size and delicate nature. The study of these juvenile plates as well as of bones in older individuals leads to some interesting conclusions concerning their growth.

In general we may recognize two modes of growth amongst the plates of *Dinichthys*:

1. By the periodic addition of growth zones.
2. By gradual enlargement in all directions.

I. This method of growth is especially perceptible in thin flat plates. The study of a well-preserved antero-ventro-lateral exhibits parallel to its outer edge a series of concentric lamellæ which have been added successively, resembling the growth zones in a bivalve shell. This manner of growth is clearly seen in several types of plates; for instance, besides in the example cited, in the postero-ventro-lateral and in the "maxillary"; the last, in a detached plate belonging to *D. terrelli*, presents a series of growth zones along the lower, or cutting edge. In life the "maxillary" on each side worked over the cutting edge of the corresponding mandible, by a shear-like action. This would wear down the cutting edge of the "maxillary," which therefore had constantly to be renewed. Thus the "maxillary" made good the wear and tear at the edge by the addition of new layers of dense bone.

II. The slow, uniform growth of a bone. The laws underlying this manner of growth are difficult to detect as for this purpose an extensive series of comparisons must be made in some one species, of a particular bone at different ages. Such a study of at least five stages of a dorso-median of *D. intermedius* has been made, the results of

which will first be tabulated and then discussed. If authors had adopted a uniform mode of measurement a far larger series might be available for consideration.

TABLE SHOWING GROWTH OF DORSO-MEDIAN.

Specimen.	Length including process.	Length without process.	Width.	Length of process.
No. 50 a	26.3 cm.	20.0 cm.	24.4 cm.	6.3 cm.
50	29.9	20.9	27.2	9.0
27	33.0	24.0	28.0	9.0
slab	33.75	24.35	30.0 $\pm$	9.4
<sup>1</sup> Eastman's	41.91	29.21	[26.67] <sup>2</sup>	12.7

This table offers several points for consideration. If we compare the proportional increase of length to width, we find a gradual but certain tendency for the bone to grow more rapidly in length than in width. Thus in the smallest specimen, No. 50a, the ratio of width to length is 0.93. In specimen No. 50, which is the next larger in size, this ratio is 0.91; while in specimen No. 27, the ratio has become reduced to 0.86. We are not able to present the figures for Dr. Eastman's specimen as his manner of measuring the width was evidently different from that used here; but even this limited series justifies the conclusion that the dorso-median grew more rapidly in a longitudinal (antero-posteriorly) than in a transverse (lateral) direction. What is true of the unequal growth of the dorso-median may likewise be true of other plates, but material for the further study of this point is not available.

If this conclusion be granted, an important corollary may be drawn from it, as to the classification of the species of *Dinichthys* by individual plates. Investigators have sometimes based a species on a single dorso-median; e.g., *D. precursor* Newberry; *D. newberryi* Clark. That this method may be misleading is evident from the amount of difference in shape and proportions due to age and individual variation. The youthful dorso-median when placed side by side with the full-grown element of the same species, may easily be mistaken for that belonging to an entirely different type.

Another inference which follows from this table bears on the growth of the dorso-median process, which is seen to have proceeded very slowly. While the dorso-median increases in length (see third

<sup>1</sup> Bull. Mus. Compar. Zool. Harvard, Vol. XXXI, No. 2, p. 32.

<sup>2</sup> Manner of measurement different from that here employed.

column of table) from 20.0 to 29.21 cm., a length of 9.21 cm., the process grows only from 6.3 cm. to 12.7 or 6.4 cm. In other words, the plate itself grows about  $1\frac{1}{2}$  times as fast as the process. The individual increments of the "peg" are very small; in one instance, for an increase in dorso-median length of 3.1 cm., there is no appreciable increase in the length of the process. Quite a minute difference in size of process, therefore, may be correlated with several centimetres of difference in the plates themselves. Consequently great care should be exercised in drawing conclusions concerning the size of plates from an examination of their processes. In our present study of the cranium of *Dinichthys intermedius*, it was seen that a minute difference in the articular processes of the antero-dorso-laterals was correlated with a difference of several centimetres in length of cranial shield.

In conclusion, I desire to take this opportunity to thank Professor Bashford Dean for his kindness in placing in my hands the "Placoderm" material for the present paper, as well as for many helpful suggestions.