PALÆONTOGRAPHICAL SOCIETY.

VOL. LXXI.

THE WEALDEN AND PURBECK FISHES.

Part III.

Pages i—viii, 105—148; Plates XXI—XXVI.
Title-page and Index.

THE PLIOCENE MOLLUSCA.

Part IV.

Pages i—xii, 463—483. Title-page and Index to Vol. I.

THE PALÆOZOIC ASTEROZOA.

Part IV.

Pages 169—196.

THE CAMBRIAN TRILOBITES.

Part V.

Pages 89—120; Plates XI—XIV.

Issued for 1917.

PALÆONTOGRAPHICAL SOCIETY.

VOLUME LXXI.

CONTAINING

1. THE WEALDEN AND PURBECK FISHES. Part III. By Dr. A. S. WOODWARD. Six Plates.
2. THE PLIOCENE MOLLUSCA. Part IV. By Mr. F. W. HARMER. Title-page and Index to Vol. I.
3. THE PALÆOZOIC ASTEROZOA. Part IV. By Dr. W. K. SPENCER. Twenty-six Text-figures.
4. THE CAMBRIAN TRILOBITES. Part V. By Mr. P. LAKE. Four Plates.

ISSUED FOR 1917.

LONDON:
PRINTED FOR THE PALÆONTOGRAPHICAL SOCIETY.

AGENTS FOR THE SOCIETY
DULAU AND CO., LTD., 34-36, MARGARET STREET, W. 1.

APRIL, 1919.

THE PALÆONTOGRAPHICAL SOCIETY was established in the year 1847, for the purpose of figuring and describing British Fossils.

Each person subscribing ONE GUINEA *is considered a Member of the Society, and is entitled to the Volume issued for the Year to which the Subscription relates. The price of the Volume to Non-subscribers is* TWENTY-FIVE SHILLINGS NET.

Subscriptions are considered to be due on the 1st of January in each year.

The Annual Volumes are now issued in *two forms of Binding:* 1st, with all the Monographs stitched together and enclosed in one cover; 2nd, with each of the Monographs in a paper cover, and the whole of the separate parts enclosed in an envelope. Members wishing to obtain the Volume arranged in the LATTER FORM are requested to communicate with the Secretary.

Most of the *back volumes* are in stock. Monographs or parts of Monographs already published can be obtained, apart from the annual volumes, from Messrs. DULAU AND CO., LTD., 34–36, Margaret Street, London, W. 1, who will forward a complete price list on application.

Members desirous of forwarding the objects of the Society can be provided with plates and circulars for distribution on application to the Secretary, Dr. A. SMITH WOODWARD, British Museum (Nat. Hist.), South Kensington, London, S.W. 7.

The following Monographs are in course of preparation and publication:

The Cambrian Trilobites, by Mr. Philip Lake.

The Palæozoic Asterozoa, by Dr. W. K. Spencer.

The Ordovician and Silurian Mollusca, by Dr. Wheelton Hind.

The British Bellerophontacea, by Dr. F. R. Cowper Reed.

The Pliocene Mollusca, by Mr. F. W. Harmer.

The Pleistocene Mammalia, by Prof. S. H. Reynolds.

Owing to scarcity of paper, the Council has decided to omit from the present volume the usual lists of members and publications. Full particulars can be obtained from the Secretary.

Members deceased during 1917: Dr. C. T. Clough, Sir Charles Holcroft, E. J. Power, Esq., and Miss A. F. Yule.

New member: Dr. Wyatt Wingrave.

ANNUAL REPORT OF THE COUNCIL

FOR THE YEAR ENDING 31st DECEMBER, 1916.

READ AND ADOPTED AT THE

ANNUAL GENERAL MEETING,

HELD AT THE APARTMENTS OF THE GEOLOGICAL SOCIETY, BURLINGTON HOUSE
30th MARCH, 1917.

Dr. HENRY WOODWARD, F.R.S., President,

IN THE CHAIR.

The Council in presenting its Seventieth Annual Report, regrets that, owing to the various difficulties of existing circumstances, its publications still remain in arrear. Palæontological research continues to make progress, and there is no lack of offers of Monographs to the Society ; but authors are hindered by many drawbacks, and the increased cost of publication necessarily reduces the amount of the annual issue. The volume for 1915, which was ready for distribution in October, 1916, contains another instalment of Mr. W. K. Spencer's Monograph of "Palæozoic Asterozoa," with four plates, and the first part of a Monograph of "Wealden and Purbeck Fishes," by Dr. A. Smith Woodward, with ten plates. The volume for 1916 is planned to contain instalments of the Monographs of "Pliocene Mollusca," "Palæozoic Asterozoa," "Cambrian Trilobites," "British Graptolites," and "Wealden and Purbeck Fishes," altogether with twenty-six plates.

The delay in the publications again increased the balance at the bank, and the Council resolved, from patriotic motives, to invest £400 in Exchequer Bonds, 1920, bearing interest at 6 per cent.

Among members who have died during the year, the Council desires especially to refer to Mr. C. T. Clough, Mr. Bedford McNeill, Mr. Clement Reid, and

Miss A. F. Yule. These were all valued supporters of the Society, and Mr. Clement Reid had not only served on the Council but had also contributed an index to the Monograph of the "Devonian Fauna" by the Rev. G. F. Whidborne. To replace the losses sustained, the Council would welcome the help and personal influence of the members in making the work and needs of the Society more widely known among those who are interested in the study of fossils. It would also appreciate the more sympathetic co-operation of the various Field Clubs and Natural History Societies.

The thanks of the Society are due to the Council of the Geological Society for permission both to store the stock of back volumes, and to hold the Council Meetings and Annual General Meeting in their apartments.

In conclusion, it is proposed that the retiring members of the Council be Dr. Kitchin, Mr. Oke, and Dr. Strahan; that the new members be Mr. H. A. Allen, Mr. E. Heron-Allen, Rev. H. N. Hutchinson, and Dr. C. T. Trechmann; that the President be Dr. Henry Woodward; the Treasurer, Mr. Robert S. Herries; and the Secretary, Dr. A. Smith Woodward.

Annexed is the Balance-sheet.

The PALÆONTOGRAPHICAL SOCIETY in account with ROBERT S. HERRIES, Esq., M.A., F.G.S., Treasurer.

Cr. *From January 1st, 1916, to December 31st, 1916.* *Dr.*

Cr.		£	s.	d.	£	s.	d.
Balance from last Account					638	13	11
Members' Subscriptions—1914–1915	129	135	9	0			
,, ,, 1916	147	154	7	0			
,, ,, 1917	6	6	6	0			
	282				296	2	0
Carriage paid by Members					0	14	4
Sales of back stock to Members					13	17	0
Sales by Messrs. Dulau & Co., Ltd.					35	15	4
Repaid Income Tax (1 year)					2	5	0
Dividends on £500 Natal 3 per cent. Stock (less income tax) and £200 4½ per cent. War Loan					20	16	3
Interest on Deposit					20	11	10
					£1028	15	8

Dr.	£	s.	d.	£	s.	d.
Printing, paper, etc., Vol. LXIX				54	18	6
Binding, packing and distribution, Vol. LXIX				77	18	1
Drawing illustrations				78	0	8
Collotype printing and making blocks				41	10	2
Secretary's honorarium				52	10	0
Postage and stationery				4	1	4
Premium, Fire Insurance				0	15	0
Petty charges—Porter	0	15	0			
Bank	0	2	9			
				0	17	9
Returned subscription paid in error				1	1	0
Anti-aircraft insurance of Stock				1	0	0
Investment in 6 per cent. Exchequer Bonds				400	0	0
Balance at Bank—Current Account	166	3	2			
Deposit Account	150	0	0			
				316	3	2
				£1028	15	8

We have examined the above account, compared it with the vouchers, and find it to be correct; we have also seen the receipt for £500 Natal 3 per Cent. Consolidated Stock, and for the £200 4½ per cent. War Loan, and £400 6 per cent. Exchequer Bonds.

Robert S. Herries,
Treasurer.

March 28th, 1917.

H. A. Allen
W. Gibson
W. D. Lang
S. H. Warren
} Auditors.

Council and Officers elected March, 1917.

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Staffordshire—Dr. Wheelton Hind, F.G.S.

Palæontographical Society, 1917.

THE FOSSIL FISHES OF THE ENGLISH WEALDEN AND PURBECK FORMATIONS.

BY

ARTHUR SMITH WOODWARD, LL.D., F.R.S.,
KEEPER OF THE DEPARTMENT OF GEOLOGY IN THE BRITISH MUSEUM; SECRETARY OF THE PALÆONTOGRAPHICAL SOCIETY.

PART III.

Pages 105—148, i—viii, Plates XXI–XXVI (including Title-page and Index).

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THE

PALÆONTOGRAPHICAL SOCIETY.

INSTITUTED MDCCCXLVII.

VOLUME FOR 1917.

LONDON:

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THE FOSSIL FISHES OF THE ENGLISH WEALDEN AND PURBECK FORMATIONS.

ORDER OF BINDING AND DATES OF PUBLICATION.

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Title-page and Index	—	1917	April, 1919
1—48	I—X	1915	October, 1916
49—104	XI—XX	1916	February, 1918
105—148	XXI—XXVI	1917	April, 1919

THE FOSSIL FISHES OF THE ENGLISH WEALDEN AND PURBECK FORMATIONS.

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SYSTEMATIC INDEX.

LIST OF TEXT-FIGURES.

widely apart, are not much shorter than the pectorals; but each comprises only about 10 rays, the foremost fringed with fulcra which are larger than those of the pectoral and especially stout at the base. In the original of Pl. XX, fig. 6, the foremost pelvic fin-ray is ornamented with longitudinal flutings of enamel. The dorsal fin is best preserved in the same specimen, with about 16 smooth rays which rapidly decrease in length backwards. In a larger specimen (Mus. Pract. Geol. no. 28438) there are three or four slender basal fulcra besides conspicuous fringing fulcra above, and some of the fin-rays are marked by a longitudinal line of enamel. The anal fin, which is well behind the dorsal, is comparatively small with 9 or 10 rays, best seen, though crushed, in the type specimen (Pl. XX, fig. 5, *a.*). Its fulcra are very slender and deeply overlapping, and its broad articulated rays bear some smooth longitudinal strips of enamel. The caudal fin is also best seen in the type specimen, as already described (p. 102). All the fin-rays are much expanded laminæ, obliquely overlapping: their appearance of stoutness, therefore, in the fossils depends upon the direction in which they are exposed.

Nearly all the scales are conspicuously ornamented with coarse plications ending in sharp prominent serrations. As counted along the course of the lateral line they are regularly arranged in from 40 to 45 transverse series; and the series above the origin of the pelvic fin comprises 13 or 14 scales, of which the seventh or eighth is crossed by the lateral line. On the flank of the abdominal region about six scales in each series are deeper than broad, that crossed by the lateral line and the one immediately below being especially deepened. The two or three lowest ventro-lateral scales are not so deep as broad; and one of these seems to be bent along its long axis to form the edge of the ventral surface of the fish. All these scales are very conspicuously ornamented by the oblique pectinations throughout their depth; but the postero-superior angle is sometimes rounded or truncated, while on the less deepened scales of the caudal region the pectinations gradually become restricted to the lower part and sometimes on the caudal pedicle disappear. Among the rhombic scales of the ventral surface (Pl. XX, fig. 8) and the dorsal border, there is also sometimes a tendency to similar reduction of the ornament. On the scales of the abdominal region the lateral line is marked only by a posterior notch and an occasional perforation; but on the rhombic scales in the hinder half of the caudal region (Pl. XX, fig. 7), it forms a sharp smooth ridge, which is also occasionally perforated in the middle. There is slight irregularity in the arrangement of the scales at the insertion of the paired fins; and on the inner side of each pelvic fin (Pl. XXI, fig. 4, *plv.*) there is a peculiar row of two small scales and a posterior large elongate-oval scale, less ornamented than usual. As shown by the type specimen (Pl. XX, fig. 5) a large elongate-ovoid ridge-scale, finely rugose but not serrated, occurs on the upper border of the caudal pedicle at the origin of the caudal fin. There are no prominent ventral ridge-scales (Pl. XXI, fig. 4). All the principal scales are united by a peg-and-socket joint, which is strengthened by a low vertical ridge on their inner face (Pl. XX, fig. 7*a*).

Horizon and Localities.—Middle Purbeck Beds: Swanage; Upway, near Weymouth.

2. **Pholidophorus granulatus,** Egerton. Plate XXI, figs. 5, 6.

1854–55. *Pholidophorus granulatus*, P. M. G. Egerton, Ann. Mag. Nat. Hist. [2], vol. iii, p. 434; and Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. viii, no. 4, pl. iv, figs. 1, 2.
1895. *Pholidophorus granulatus*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 470.

Type.—Imperfect fish; Dorset County Museum, Dorchester.

Specific Characters.—A very robust species, attaining a length of about 30 cm.; maximum depth of trunk equalling about one-third of the total length of the fish. Head and opercular bones finely tuberculated or rugose, the tuberculations extending over the dorsal scales of the abdominal region. Fin-rays smooth and stout, and fulcra comparatively large. Pelvic fins arising far in advance of the middle point of the trunk, and the dorsal fin opposed to them. Scales large, ornamented with very fine oblique ridges, which radiate slightly and end at the hinder margin in delicate serrations; several series of flank-scales deeper than broad; lateral line inconspicuous.

Description of Specimens.—The type specimen displays well the squamation of the trunk and the paired fins; but it is deepened a little by crushing in the ventral region, and the head bones are broken and displaced. Of the median fins it exhibits only fragments. The other known specimens are still more imperfect, but they show several of the most important characters of the genus and species. One of these specimens (Pl. XXI, fig. 5) is interesting as proving that in the abdominal region there is a narrow flattened ventral face between the paired fins.

The roof of the skull, partly shown in Pl. XXI, fig. 6, is broad and not much arched from side to side. The parietals (*pa.*) and squamosals (*sq.*) are not more than one-third as long as the frontals, and their external face is closely ornamented with radiating rows of fine tubercles. They are crossed by a groove for the transverse slime-canal, and their hinder margin is deeply overlapped by the supratemporals. Each frontal (*fr.*) is nearly twice as wide behind as in front, slightly excavated for the large orbit at the outer border, and bifurcating at the front border, where the antero-external angle is less produced than the antero-internal angle, which must have rested on the mesethmoid. The median frontal suture is deeply jagged between the middle of the orbits, but otherwise only slightly wavy. A narrow supraorbital margin is nearly smooth, but the greater part of the frontal is closely ornamented by radiating rows of fine tubercles, which are fused into coarser ridges on the anterior bifurcating portion.

The longitudinal slime-canal is marked by a few pores. Remains of the supra-temporal and post-temporal plates behind are also closely and finely tuberculated.

The opercular apparatus is shown in inner view in Pl. XXI, fig. 5. The operculum (*op.*) is narrow above owing to the rounding of the postero-superior angle, and its depth to the middle of the lower border equals its maximum width. The large suboperculum (*sop.*) is half as deep as the operculum, and bears the usual antero-superior prominence. The preoperculum is much expanded at its angle, and the interoperculum is relatively small. The opercular bones and remains of branchiostegal rays in the type specimen are finely granulated.

Although the neural and hæmal arches in the vertebral axis are well ossified, the centra must have been extremely delicate, for there is scarcely a trace of them in the known specimens.

The scales are regularly arranged in about 45 transverse series; and there are 16 scales in the series above the origin of the pelvic fins, the ninth from below being traversed by the slime-canal of the lateral line. On the flattened ventral surface of the abdominal region they are rhombic and nearly equilateral, deeply overlapping, and ornamented in their exposed portion with fine radiating ridges, which end behind in serrations and pass forwards into tuberculations. On the lateral edge of this ventral area each scale is bent along its antero-posterior diagonal. On the flank of the abdominal region the dorsal and ventral scales are also rhombic and nearly equilateral; but in each series eight or nine scales are deeper than broad, the deepest being those of the lateral line and the three horizontal rows beneath it. In the anterior series (Pl. XXI, fig. 5*a*) these scales are very deeply overlapping, and all are conspicuously ornamented with the fine radiating ridges, which end at the hinder border in serrations. On the principal scales the ridges cover nearly the whole of the exposed surface, leaving only a small triangular rugose or tuberculated area near the lower border; but on most of the abdominal scales they pass forwards into tuberculations or rugæ. Further back and on the caudal region (fig. 5*b*) the fine radiating ridges gradually become shorter, leaving the rest of the scale smooth; until towards the end of the caudal pedicle both ridges and serrations disappear. In the anterior part of the abdominal region (Pl. XXI, fig. 5*a*) the lateral line is marked only by a slight ridge and posterior notch on the scale; but further back and in the caudal region (fig. 5*b*) it opens by a prominent perforation on most of the scales. In all the scales of the abdominal region the peg-and-socket articulation is large, while the inner rib is broad and prominent (Pl. XXI, fig. 6*a*); in the hinder half of the caudal region (fig. 6*b*) both the articulation and the inner rib disappear. There are enlarged scales round the anus near the origin of the anal fin.

The position of the fins is shown in the type specimen, but they are imperfect in all known specimens. The pectoral fins, which comprise about 18 rays, are not much more elevated than the pelvic fins, which comprise 10 or 12 rays and are fringed with stout fulcra. The pelvic pair is inserted nearer to the pectorals than to the anal, directly opposite the origin of the dorsal fin, which begins with 5 or 6 very stout but small basal fulcra, more or less enamelled, and comprises not less than 12 rays, perhaps 2 or 3 more. The anal fin must have been comparatively small; in the original of Pl. XXI, fig. 5, there are the bases of 9 rays, with traces of stout basal fulcra.

Horizon and Locality.—Middle Purbeck Beds: Swanage, Dorset.

3. **Pholidophorus purbeckensis,** Davies. Plate XXII, figs. 1—3.

1887. *Pholidophorus purbeckensis,* W. Davies, Geol. Mag. [3], vol. iv, p. 337, pl. x, figs. 2—4.
1888. *Pholidophorus purbeckensis,* W. Davies, in R. Damon, Geol. Weymouth, ed. 3, Suppl. pl. xix, fig. 1.
1895. *Pholidophorus purbeckensis,* A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 460.

Type.—Imperfect fish; British Museum.

Specific Characters.—Attaining a length of 8—10 cm. Length of head with opercular apparatus about equal to the maximum depth of the trunk and nearly one-quarter of the total length of the fish. Head and opercular bones smooth or feebly rugose; teeth stout and sometimes slightly recurved. Fulcra smooth, unusually large and stout on all the fins. Pelvic fins inserted about midway between the pectoral and anal fins; dorsal fin opposed to the space between the pelvic and anal fins, with about 10 rays, the length of the foremost and longest somewhat less than the depth of the trunk at its insertion; anal fin also with about 10 rays, as elevated as the dorsal; length from insertion of anal fin to that of caudal fin about equal to maximum depth of trunk. Scales large and smooth, the hinder margin not serrated; those of the lateral line much deepened, some four times as deep as broad; two scales above and below those of the lateral line also moderately deepened; lateral line forming only a feeble ridge.

Description of Specimens.—The type specimen (Pl. XXII, fig. 1), obtained by Mr. Robert Damon from the Lower Purbeck of the Isle of Portland, lacks the greater part of the head, but displays well the contour of the trunk in side-view, with fragments of all the fins. It also shows satisfactorily the squamation. Another specimen, much splintered by crushing, also figured by Davies (*loc. cit.* 1887, pl. x, fig. 2), gives the proportions of the head and caudal fin, and displays the characteristic large fulcra on the dorsal fin. A still finer specimen, with all the fins, is represented somewhat magnified in Pl. XXII, fig. 2, with a further enlargement of the fin-fulcra in fig. 2*a*. A dwarf example evidently of the same species from a corresponding horizon at Teffont, Wiltshire, is shown enlarged twice in Pl. XXII, fig. 3.

As shown in a specimen figured by Davies (1887, pl. x, fig. 2), and in another from Swanage (B.M. no. P. 12347), the postorbital part of the cranial roof is very feebly but coarsely rugose. So far as can be observed in other specimens, the cheek-plates, mandible, and opercular bones are for the most part smooth, but bear occasional prominent tubercles. The cheek-plates seem to be arranged as ordinarily in *Pholidophorus*, but they are often much broken by crushing (as in the original of Pl. XXII, fig. 3). The large orbit as usual is crossed by a very stout parasphenoid bone; and an inner bone of the mouth, perhaps the vomer, bears a few stout conical teeth. The mandibular suspensorium is inclined forwards below, so that the quadrate articulation is beneath the hinder half of the orbit. The maxilla is gently arched, with comparatively small teeth. About half the length of the mandibular ramus is occupied by its elevated coronoid portion.

As shown in the type specimen (Pl. XXII, fig. 1, *pop.*) the narrow preoperculum is gently curved forwards below and not much expanded at the angle, where it is grooved and pitted by the slime-canal but otherwise smooth. As shown from within in Pl. XXII, fig. 3, the suboperculum (*sop.*) is scarcely half as deep as the operculum (*op.*), while the interoperculum (*iop.*) is large, long, and narrow. The branchiostegal rays are short and broad; and there seems to be a long and narrow gular plate in the specimen figured by Davies (1887, pl. x, fig. 2), though this interpretation is not certain.

The axial skeleton of the trunk is always more or less obscured by the squamation, but a close series of vertebral centra in the form of delicate ossified cylinders is seen in side-view in B.M. no. P. 8379, and an isolated centrum occurs in end-view in the same specimen. Traces of similar centra and short delicate ribs are also seen in the original of Pl. XXII, fig. 2.

In the pectoral arch the supraclavicle (Pl. XXII, fig. 1, *scl.*) is about three times as deep as broad, with the outer face and hinder margin smooth. The narrow exposed portion of the clavicle is marked by longitudinal ridges or plications. Two postclavicular scales are clearly seen above the pectoral fin both in the original of Pl. XXII, fig. 3, and in B.M. no. 40635, the lower being about as broad as deep, the upper much deeper than broad, and tapering upwards. In the pectoral fin (Pl. XXII, fig. 2) the foremost ray is much stouter than the others, and seems to have borne large fulcra. The pelvic fins are not much smaller than the pectorals, and their foremost ray bears at least six large and deeply overlapping smooth fulcra, which extend nearly to its distal end. The dorsal and anal fins, the former just in advance of the latter, are similar in size and shape, each with about ten divided rays, which rapidly decrease in length backwards, and of which the foremost is fringed nearly to the end with eight or nine large and deeply overlapping smooth fulcra. The relatively large forked caudal fin, with nearly twenty rays, is similarly fulcrated, but the dozen fulcra above and below rapidly decrease in size distally and do not reach the extremity of the foremost ray. In all the fin-rays the segments between the articulations are somewhat longer than broad.

All the scales are smooth, with no posterior serrations. They are strengthened on their inner face with a stout vertical ridge, and those of the abdominal region are united by a large peg-and-socket articulation. They are arranged in nearly 40 regular transverse series; and above the origin of the pelvic fin the series comprises 11 or 12 scales, of which the lateral line traverses the seventh or eighth from the ventral border. In the abdominal region (Pl. XXII, fig. 1*a*), the scales of the lateral line are from four to three times as deep as broad; the next scales above and below these are about twice as deep as broad; the next above and below are still somewhat deeper than broad; those dorsally and ventrally are smaller and nearly equilateral, or even broader than deep. The very narrow flattened ventral face of the abdominal region is covered with small rhombic scales; and there seem to have been slightly enlarged and modified scales, with two or three posterior denticulations, round the anus. In the caudal region (Pl. XXII, fig. 1*b*) the scales of the lateral line still remain somewhat deeper than broad, and they are crossed very obliquely by the slime-canal. The other caudal scales are rhombic and nearly equilateral, with a tendency to the rounding of the hinder and upper margins. There is no conspicuously enlarged ridge-scale on the caudal pedicle above or below, but there seem to be two or three short and broad dorsal ridge-scales. The lateral line is marked only by a faint smooth ridge.

Horizons and Localities.—Lower Purbeck Beds: Portland, Dorset; Teffont, Wiltshire. Middle Purbeck Beds: Swanage, Dorset.

4. **Pholidophorus brevis,** Davies. Plate XXII, figs. 4, 5.

1887. *Pholidophorus brevis*, W. Davies, Geol. Mag. [3], vol. iv, p. 338, pl. x, fig. 1.

Type.—Imperfect fish; British Museum.

Specific Characters.—A stout mutation of *P. purbeckensis*, with a comparatively short and robust caudal region.

Description of Specimens.—The type specimen (Pl. XXII, fig. 4), from the Upper Purbeck Beds, is distorted, so that the head is accidentally shortened and the abdominal region deepened, but it evidently represents a shorter and stouter fish than the Lower Purbeckian *P. purbeckensis*. Part of a second specimen, in counterpart in the Egerton and Enniskillen Collections, indicates an equally stout form (Pl. XXII, fig. 5).

In the latter fossil the head appears to exhibit its true shape; and its length to the back of the opercular apparatus clearly equals the maximum depth of the trunk. Traces of a coarse rugosity are seen on the cranial roof. Stout conical teeth, some with a slightly curved apex, occur in both jaws of the type specimen. The suboperculum is less than half as deep as the operculum in both specimens. Crushed obscure remains of the very delicate ring-vertebræ are preserved especially in the counterpart of the specimen figured in Pl. XXII, fig. 5.

The pelvic, dorsal, and anal fins are rather well shown in the type specimen (Pl. XXII, fig. 4), which also retains fragments of the pectorals and caudal. The former appear to agree in all respects with the corresponding fins of *P. purbeckensis*, being only slightly smaller in proportion to the depth of the trunk. The scales are also evidently similar to those of the earlier species just mentioned. In both specimens they are much fractured, and nearly all are exposed from the inner face, displaying the strong vertical rib, with the peg-and-socket articulation in the abdominal region. They are, however, clearly smooth and without posterior serration.

Horizon and Locality.—Upper Purbeck Beds: Upway, near Weymouth, Dorset.

Genus **CERAMURUS**, Egerton.

Ceramurus, P. M. G. Egerton, in Brodie's Fossil Insects, 1845, p. 17.

Generic Characters.—Trunk slender fusiform, and head relatively large; notochord persistent, surrounded with spaced ring-vertebræ; ribs short and delicate. Fin-fulcra few, long and slender. Pectoral and pelvic fins long, but few-rayed; dorsal and anal fins not extended, the former in advance of the latter; caudal fin long, but probably somewhat forked. Squamation absent on flanks, except, perhaps, a rudiment anteriorly; a short series of robust ganoid ridge-scales on both borders of the hinder half of the caudal region.

Type Species.—*Ceramurus macrocephalus*, from the English Purbeck Beds.

1. **Ceramurus macrocephalus**, Egerton. Plate XXII, fig. 7.

1845. *Ceramurus macrocephalus*, P. M. G. Egerton, in Brodie's Fossil Insects, p. 17, pl. i, fig. 2.
1895. *Ceramurus macrocephalus*, A. S. Woodward, Geol. Mag. [4], vol. ii, p. 401; and Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 489.

Type.—Nearly complete fish; British Museum.

Specific Characters.—A slender species, at least 4·5 cm. in length. Length of head with opercular apparatus nearly twice as great as the maximum depth of the trunk, and contained about four-and-a-half times in the total length of the fish. Pectoral and pelvic fin-rays about equal in length; dorsal fin with about 10 rays, opposed to the pelvic pair; anal fin with 8 or 9 rays, completely behind the dorsal. Caudal ridge-scales smooth, those of the upper border especially acuminate, each being produced into a long point.

Description of Specimens.—This species is known only by three specimens: the type discovered in the Middle Purbeck of Dinton, Wiltshire, by the Rev. P. B. Brodie (shown enlarged in Pl. XXII, figs. 7, 7*a*); a more imperfect fish discovered in the Lower Purbeck of Teffont, Wiltshire, by the Rev. W. R. Andrews (B.M. no. P. 9850); and a nearly complete specimen from an unrecorded locality near Weymouth (B.M. no. P. 7506). The type specimen is preserved in counterpart, but the head and caudal fin are crushed and imperfect, while a vein of calcite crosses obliquely the hinder end of the abdominal region. Remains of the cranial roof show that the bones are smooth or only faintly rugose. The frontals (*fr.*) form a symmetrical pair separated by a straight median suture, and excavated laterally by a large orbit. The parietals (*pa.*), which are also a symmetrical pair divided by a straight median suture, are each longer than broad, and marked behind by a large groove for the transverse slime-canal. They are well seen again in inner view in B.M. no. P. 9850. The parasphenoid, which is displaced, is very stout. The mandibular suspensorium must have been inclined forwards, and the small fan-shaped quadrate (*qu.*), with its posterior cleft for the symplectic, is seen in the fossil below the front of the orbit. Remains of the opercular apparatus show that it is smooth.

The vertebral centra are delicate rings, which appear to have been arranged in a spaced series, so that in their crushed condition in the type specimen most of them are exposed in end-view. Some of those in the abdominal region of B.M. no. P. 7506 are in side-view, and shown to be slightly constricted. Towards the end of the caudal region the centra may have been incomplete, and in the upturned extremity they are apparently absent. In advance of the dorsal fin the neural arches are much shorter than their appended spines, which are loosely apposed and seem to have nearly reached the dorsal border. Beneath the dorsal fin the short neural arches bear extremely short spines. The ribs shown in the type, but best seen in B.M. no. P. 9850, are short and delicate throughout the abdominal region. The short neural and hæmal spines in the caudal region are fused with their respective arches, and these also probably with the vertebral rings. Where the axis is upturned within the caudal fin, the hæmal spines are enlarged and thickened as usual. There are no traces of intermuscular bones.

The fins consist of long, slender rays, with distant articulations, and apparently not forked more than once at the distal end. Each is fringed by a few very long and slender fulcra, which are conspicuous by their enamelled surface. The clavicle (*cl.*) is relatively large and much curved, widest below, and with a thin laminar expansion in its anterior concavity. Above the left clavicle, which is displaced backwards in the type specimen, there is a deep and narrow supraclavicle (*scl.*). There also seem to be remains of large, smooth postclavicular scales. Both the pectoral and pelvic fins are crushed close to the body, and display their characteristic fulcra. One of the pelvic fin-supports is seen, slightly expanded proximally, much constricted mesially, more widely expanded distally. The length of the longest rays of the short dorsal fin is greater than the depth of the trunk at their insertion, and the elongated fulcra are especially stout at the base. Nine supports, of which those anteriorly are stouter than the rest and somewhat winged, can be counted in front of the vein of calcite in the type fossil. The anal fin, which is slightly less elevated than the dorsal, comprises 8 or 9 rays, which, when adpressed, nearly reach the base of the caudal fin. Five fulcra are conspicuous on the anterior margin. The caudal fin, known only in the type specimen, is imperfect, and distorted upwards so that its precise shape is uncertain, but it seems to have been forked.

The only traces of scales on the trunk are immediately behind the pectoral arch, but these may represent merely postclaviculars. Robust, smooth, overlapping ganoid ridge-scales, however, are conspicuous on both borders of the caudal pedicle. The dorsal series begins above the middle of the anal fin, the scales all very sharply pointed (Pl. XXII, fig. 7*b*) and gradually increasing in size until they pass into the upper caudal fulcra. The ventral series comprises only three smaller and less acuminate scales, occupying the hinder half of the space between the anal and caudal fins.

Horizon and Locality.—Middle and Lower Purbeck Beds: Vale of Wardour, Wiltshire. Purbeck Beds: near Weymouth, Dorset.

Genus **PLEUROPHOLIS**, Egerton.

Pleuropholis, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. ix, 1858, no. 7.

Generic Characters.—Trunk elongate-fusiform, with rounded back and sharp ventral border; upper caudal lobe conspicuous. External bones smooth, or delicately ornamented with rugæ and tuberculations; sensory canal on cheek-plates with branches; mouth very small, with minute teeth; maxilla more or less arched, the oral margin convex. Vertebral centra annular; ribs short and delicate. Fulcra present on all the fins. Pelvic fins well developed, but smaller than the pectorals; dorsal and anal fins longer than deep, opposite; caudal fin forked. Squamation complete; scales thick and moderately overlapping; those of the middle of the flank excessively deepened, covering nearly the whole of it, each strengthened within by a broad rib and exhibiting a peg-and-socket articulation; dorsal and ventral scales few, relatively small and rhomboidal. Lateral line deflected, passing down the second or third deepened flank-scale and then traversing the uppermost row of small ventral scales.

Type Species.—*Pleuropholis attenuata*, from the English Middle Purbeck Beds.

Remarks.—The osteology of the head in *Pleuropholis* is still very imperfectly known, but its cheek-plates seem to resemble those of *Pholidophorus* in being only in a single series. The most remarkable feature of the genus is the deflection of the lateral line; but it must be added that in one species from the Lithographic Stone of Bavaria Miss Mary S. Johnston has also discovered slight traces of a slime-canal on the deepened flank-scales of the caudal region (Geol. Mag. [5], vol. vi, 1909, p. 311), and there are similar traces in *Pleuropholis serrata* described below (p. 121).

Pleuropholis occurs chiefly in the Lithographic Stone (Lower Kimmeridgian) of Bavaria and France, but is also known by fragments in the Wealden of Belgium (R. H. Traquair, "Les Poissons Wealdiens de Bernissart." Mém. Mus. Roy. Hist. Nat. Belg., vol. v, 1911, p. 45, pl. ix, figs. 1—3).

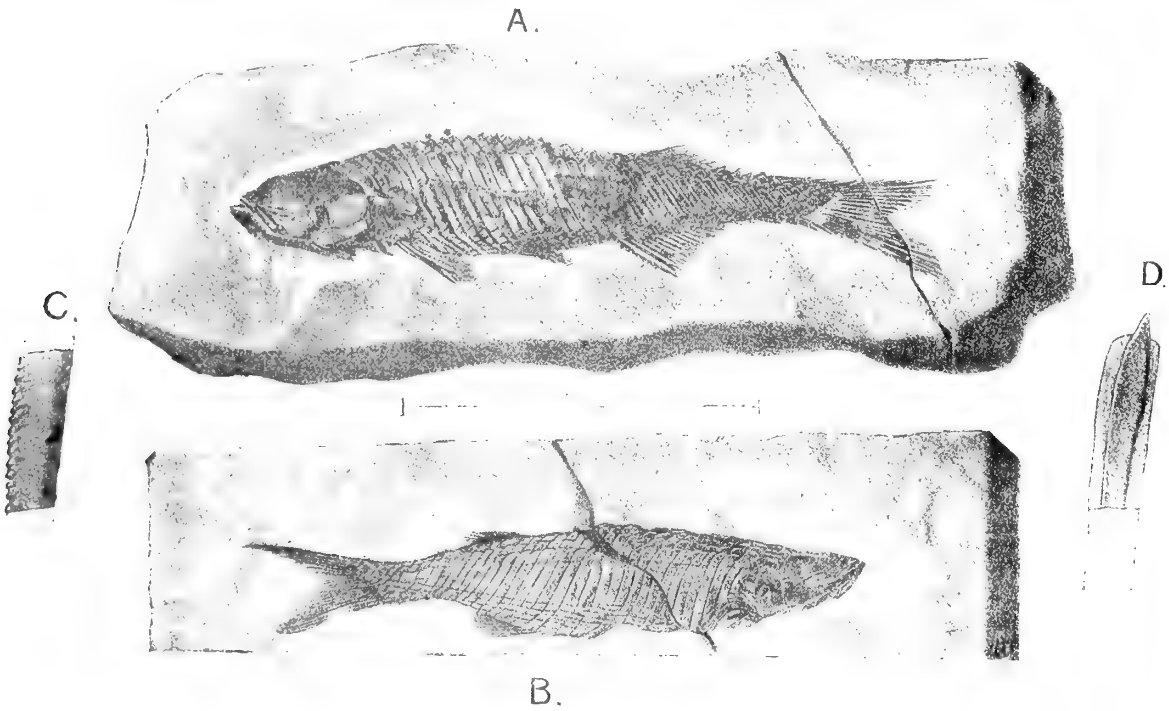

FIG. 35.—A. *Pleuropholis attenuata*, Egerton; type specimen, about twice nat. size.—Middle Purbeck Beds; Apsel Lane, Sutton Mandeville, Wiltshire. B. *Pleuropholis longicauda*, Egerton; type specimen, nat. size.—Middle Purbeck Beds; Swanage, Dorset. C, D. *Pleuropholis serrata*, Egerton; portions of flank-scales, outer (C) and inner (D) views, enlarged.—Purbeck Beds; Hartwell, near Aylesbury, Buckinghamshire. After Egerton.

1. **Pleuropholis attenuata,** Egerton. Text-figure 35A.

1854. *Pleuropholis attenuatus*, J. Morris (*ex* Egerton, MS.), Catal. Brit. Foss., ed. 2, p. 339 (name only).

1858. *Pleuropholis attenuatus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. ix, no. 7, p. 1, pl. vii, fig. 1.

1895. *Pleuropholis attenuata*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 483.

Type.—Imperfect fish; apparently lost.

Specific Characters.—The type species [known only by one specimen 5 cm. in length]. Length of head with opercular apparatus somewhat exceeding maximum depth of trunk and contained about five times in total length of fish; caudal pedicle slender, about half as deep as deepest flank-scale. Opercular bones smooth. Pelvic fins arising midway between the pectorals and the anal; dorsal fin, with 10 rays, arising opposite the origin of the anal fin, which comprises at least 12 rays, and arises nearly midway between the pectoral and caudal fins. Scales smooth, not serrated.

Remarks.—This species is still known only by the type specimen discovered by Mr. H. W. Bristow, which is now missing. The above definition is based on Egerton's description and figure (reproduced here in Text-fig. 35A).

Horizon and Locality.—Middle Purbeck Beds: Apsel Lane, Sutton Mandeville, Wiltshire.

2. **Pleuropholis formosa**, sp. nov. Plate XXII, fig. 8; Plate XXIII, figs. 8—11; Text-figure 36.

Type.—Nearly complete fish; British Museum.

Specific Characters.—A slender, regularly fusiform species, attaining a length of about 7 cm. Length of head with opercular apparatus about equalling maximum depth of trunk, and contained from five to six times in total length of fish; caudal pedicle about two-thirds as deep as deepest flank-scale. Opercular bones smooth. Pelvic fins arising slightly nearer to the anal than to the pectorals; dorsal fin, with 9 or 10 rays, arising just behind the origin of the anal, which is somewhat larger, with 11 or 12 rays, of which the length of the foremost is somewhat less than the depth of the trunk at its insertion. Scales smooth, not serrated.

Description of Specimens.—The type specimen, though fractured, seems to exhibit the general shape of the fish, with the complete caudal fin and enough remains of the other fins to indicate their position and proportions (Pl. XXIII, fig. 8). Parts of five smaller specimens on the same slab of limestone show various additional details; and several distorted examples obtained by the Rev. W. R. Andrews and others from the same horizon and locality confirm and extend our knowledge of the osteology of the species.

All the external bones of the head and opercular apparatus seem to have been smooth, covered with shining ganoine, and marked only by the occasional ridges and pores of the slime-canals. The cranial roof slopes gently downwards and forwards, without any marked bend in the frontal region; but in the basicranial axis the parasphenoid, as seen in side view crossing the orbit (Pl. XXIII, fig. 9, *pas.*), is much arched, inclining downwards and forwards as it leaves the pro-otic region, and then turning upwards to the short ethmoid region. The orbit is very large, and there is a delicate ossification in the sclerotic. The single series of cheek-plates round the orbit is narrow, and marked only by the large slime-canal, which traverses the orbital margin as usual. The mandibular suspensorium is much curved forwards, so that the quadrate articulation is beneath the anterior half of the orbit, and the gape of the mouth is very small. The entopterygoid (Pl. XXIII, fig. 9, *enpt.*) is a relatively large delicate lamina of bone, while the ectopterygoid (*ecpt.*) forms a stout bar at its lower border in front of the quadrate. The maxilla and premaxilla are unknown. The mandibular ramus (*md.*) is especially short and deep, and its dentary portion must have been comparatively small. There seem to be traces of minute conical teeth near the front of both jaws.

The operculum, displayed partly from within, partly as an impression in Pl. XXIII, fig. 9 (*op.*), is not less than two-thirds as wide as deep, and narrowed towards the upper end. Its outer face is somewhat convex, and quite smooth, though marked by a feeble waviness concentric with the lines of growth. The suboperculum and interoperculum are comparatively small: the former is much wider than deep, while the latter seems to taper upwards into a point between the operculum and preoperculum. The preoperculum, seen from within in Pl. XXIII, fig. 9 (*pop.*), is sharply bent at the expanded angle, the tapering upper and lower

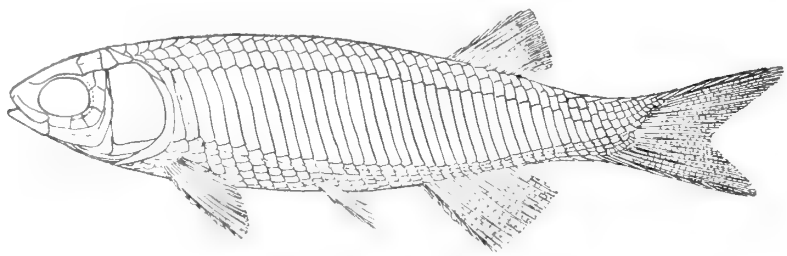

FIG. 36.—*Pleuropholis formosa*, sp. nov.; restoration, somewhat enlarged.—Lower Purbeck Beds; Teffont, Wiltshire.

limbs being nearly equal in size and at right-angles to each other. It is traversed by a conspicuous slime-canal, from which two or three straight branches radiate backwards at the angle. There are traces of large branchiostegal rays below the interoperculum.

The axial skeleton of the trunk is usually obscured by the thick squamation, but delicate cylindrical vertebral centra are observable in some broken specimens discovered by the Rev. W. R. Andrews (B.M. no. P. 9851).

Each of the pectoral fins comprises a dozen rays, of which the length of the longest about equals that of the head without operculum. Near its base the fringing fulcra are normal, but in its distal half they are more widely spaced and each bears an ovate expansion at its apex (Pl. XXIII, fig. 10). The pelvic fins are only about two-thirds as large as the pectorals, with not less than 6 rays and normal slender fulcra. The dorsal and anal fins are about equally elevated, with 9 and 11 rays respectively, of which the length of the foremost is less than the depth of the trunk at its insertion. As shown when the squamation is removed (Pl. XXIII, fig. 11), each ray is separated from its corresponding support by a short intercalated rod, as in the existing *Amia*. All the rays bifurcate once or twice distally, with wide articulations. As in the type specimen, the fulcra are usually slender and normal, becoming very small before disappearing distally; but in one specimen (B.M. no. P. 6304) the fulcra of the anal fin bear expansions like those already described on the pectoral fulcra. The caudal fin is nearly complete in the type specimen, displaying its 16 rays, of which 4 in the middle are well spaced. Its deeply overlapping fulcra are very slender, and become minute distally before they disappear. The upper caudal lobe of the body is prominent.

As shown by the type specimen, all the scales are smooth, without posterior serrations, and they are arranged in about 40 regular transverse series. All, except those near the end of the tail, are strengthened within by a broad vertical ridge, and united by a peg-and-socket articulation. The deepened flank-scale occurs in more than 30 of these series before it begins to subdivide on the caudal pedicle, being from four to five times as deep as its complete width in the front part of the abdominal region, and gradually becoming not much more than twice as deep as wide before subdivision on the caudal region. Each scale exhibits a slightly sigmoidal bend, and its lower end is truncated, while its upper end tapers a little as it curves forwards. Above each large flank-scale there are two other scales, of which the lower at least is deeper than wide; and there seem to be indications of the large flattened dorsal ridge-scales, such as are well seen in an example of another species of *Pleuropholis* from the Lithographic Stone of Cirin, Ain, France, in the British Museum (no. P. 4691*a*). The foremost upper scale is traversed by the slime-canal of the lateral line, which then passes down the second deepened flank-scale, and continues its course along a row of nearly square scales adjacent to the lower ends of the deepened flank-scales. Usually in the fossils the tubular excavation of the lateral line is exposed, but when a scale is perfect its only mark is a faint ridge. In the abdominal region there are four scales, wider than deep, beneath that of the lateral line, the lowest apparently forming the ventral ridge. At the base of the anal fin one row occurs beneath the lateral line, while in the caudal region beyond there seem to be three rows. On the caudal pedicle the deepened flank-scale is divided by a transverse suture into two, then into three scales, and the terminal scales are very small and rhombic. The lateral line ends abruptly at the insertion of the lowest of the four spaced caudal fin-rays. The acutely pointed and deeply overlapping caudal ridge-scales which pass into the fulcra of the caudal fin above and below are only moderately enlarged.

Immature Fish (Pl. XXII, fig. 8).—The immature *Pleuropholis*, only about 3 cm. in length, shown enlarged in Pl. XXII, fig. 8, has a relatively large head; but it may well be the fry of the species now described. It still lacks all the scales except the middle portion of those of the flank, and thus displays the internal skeleton. The remains of the head are much broken by crushing, but the curved parasphenoid is distinct in side view, and the relatively small mandible is observable. The course of the persistent notochord is indicated by a vacant space, but the neural and hæmal arches are well calcified. In the abdominal region, the right and left halves of each neural arch are separate both from each other and from the neural spine, which is comparatively short; the ribs, which do not reach the ventral border, are very slender, but attached to rather stout triangular ossifications abutting on the notochord. In the caudal region both the neural and hæmal arches are fused with their recurved spines, which are also small. Beneath the upturned end of the notochord the hæmal arches supporting the caudal fin are much enlarged and thickened; and in the upper caudal lobe there are traces of a separate series of short rods below the fulcral ridge-scales. Fulcra are not clear on any of the fins except the caudal, but the rays and their supports are well calcified. Six divided rays and one short simple anterior ray are seen in one of the pelvic fins. Nine and eleven divided rays respectively can be counted in the dorsal (fig. 8*a*) and anal fins, besides a few short simple rays in front, each ray (except perhaps anteriorly) being separated from its corresponding support by a short intercalated rod, as in *Amia*. It may be added that there are traces of ganoine on some of the rudimentary flank-scales. White granular material, probably phosphatic, in the body-cavity may represent food.

Horizon and Locality.—Lower Purbeck Beds: Teffont, Vale of Wardour, Wiltshire.

3. **Pleuropholis crassicauda**, Egerton. Plate XXIII, figs. 12, 13.

1858. *Pleuropholis crassicaudus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. ix, no. 7, p. 3, pl. vii, fig. 2.

1895. *Pleuropholis crassicaudata*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 484, pl. xiv, fig. 5.

Type.—Portion of fish; British Museum.

Specific Characters.—As *P. formosa*, so far as known, but the trunk relatively deeper, its maximum depth a little exceeding the length of the head with opercular apparatus.

Description of Specimens.—The type specimen in the P. B. Brodie Collection (Pl. XXIII, fig. 12) is too imperfect for specific determination, but it evidently represents the same species as a more nearly complete specimen from the same horizon and locality shown enlarged in Pl. XXIII, fig. 13. The latter may therefore be used for the specific diagnosis, as above.

The type specimen (Pl. XXIII, fig. 12) seems to show the complete length of the head, with indications of the very large orbit, stained black, the short ethmoid region, and the narrow postorbitals traversed by a large slime-canal. The upper limb of the preoperculum, also with a conspicuous slime-canal, is distinct; and the nearly complete operculum, about two-thirds as wide as deep, is seen to be smooth, but marked with a slight waviness concentric with the lines of growth.

The second specimen (fig. 13), of which the jaws, shown mainly in impression, are somewhat displaced forwards, exhibits also traces of an ossified sclerotic.

Only fragments of the fins are preserved, but the places of origin of all except the dorsal are seen in the second specimen, where the extent of the forked caudal is also traceable. Stout deeply overlapping fulcra fringe the pelvic, anal, and caudal fins, those at the origin of the lower lobe of the caudal fin in the type specimen being displaced and especially conspicuous. The distantly articulated rays in the lower caudal lobe are especially well enamelled.

The scales must have been in about 40 transverse series. Some of the deepened flank-scales in the type specimen exhibit an irregular waviness of the outer face, doubtless following lines of growth, while those of the second specimen are exposed from within, showing the broad vertical ridge on their inner face, and the peg-and-socket articulation. The caudal scales preserved in the type specimen are clearly not serrated, while those in the second specimen, though bearing the internal ridge, lack the peg-and-socket articulation. As shown in Pl. XXIII, fig. 13, the lateral line curves down the second deepened flank-scale to traverse the usual ventral row of nearly equilateral scales; as shown on the tail of the type specimen, its course is marked by a slight smooth ridge on the outer face.

Horizon and Locality.—Middle Purbeck Beds: Durdlestone Bay, Swanage, Dorset.

4. **Pleuropholis longicauda,** Egerton. Plate XXIV, figs. 1, 2; Text-figure 35B.

1858. *Pleuropholis longicaudus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. ix, no. 7, p. 3, pl. vii, fig. 4.

1895. *Pleuropholis longicaudata*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 483.

Type.—Imperfect fish; apparently lost.

Specific Characters.—Imperfectly known, but attaining a length of about 9 cm., and the head with opercular apparatus occupying somewhat more than one-sixth of this length. Probably distinguished from all other known species by the depression of the head, which seems to have been scarcely more than half as deep as the middle part of the trunk. Scales smooth, not serrated; the rhombic dorsal and ventral scales often produced to a sharp point at their postero-inferior angle.

Description of Specimens.—The type specimen (Text-fig. 35B, p. 114), which was in Mr. W. R. Brodie's Collection, cannot now be traced, and the description and figure given by Egerton are insufficient to diagnose the species. One specimen in the British Museum, however, from the Middle Purbeck Beds of Swanage, is labelled "*Pleuropholis longicaudus*" by Egerton, and two other specimens from the same formation and locality also seem to belong to this species. It may, therefore, probably be defined as above.

The head seems to be crushed upwards in the type specimen. Its comparatively small size is best shown in the original of Pl. XXIV, fig. 1, but the bones are so much broken by crushing that their outlines are rather obscured. The relatively large orbit is bounded behind, below, and in front by the single series of smooth cheek-plates, which are traversed by the usual circumorbital slime-canal. The gape of the mouth is evidently small. The opercular bones, partly seen also in Pl. XXIV, fig. 2, are smooth. The large angularly-bent preoperculum is marked only by the groove of the slime-canal. The operculum is about two-thirds as wide as deep, and the suboperculum is relatively small. The interoperculum seems to be triangular in shape and deeper than wide, its apex rising between the lower end of the operculum and the preoperculum.

Delicate ring-vertebræ and short slender ribs are exposed by the removal of the scales in the specimen labelled by Egerton (B.M. no. P. 1101).

The bases of about nine very stout rays are seen spread out in the pectoral fin of Pl. XXIV, fig. 1; and the foremost pectoral ray in fig. 2 bears a regular series of very slender fulcra. The pelvic fins, which are shown in two specimens to arise midway between the pectorals and the anal, also consist of unusually stout rays. The dorsal and anal fins arise directly opposite each other, but are incompletely known.

The scales are clearly all smooth without any posterior serrations. The depth of the deepest flank-scale, above the pelvic fins, slightly exceeds four times its complete width (fig. 2*a*). The rhombic dorsal and ventral scales are often produced into a sharp point at their postero-inferior angle, and both the dorsal and ventral ridge-scales are sharply pointed behind (figs. 1*a*, 2*a*). Two rows of scales intervene as usual between the principal flank-scales and the dorsal ridge-series, the lower being slightly the deeper; while five small scales occur below each principal flank-scale as far back as the pelvic fins, the uppermost being traversed by the lateral line. The ventral scales become fewer behind, as already described in *P. formosa* (p. 117), and the stout ventral ridge-scales are comparatively small.

Horizon and Locality.—Middle Purbeck Beds: Swanage, Dorset.

5. **Pleuropholis serrata,** Egerton. Text-figure 35c, d.

1858. *Pleuropholis serratus*, P. M. G. Egerton, Figs. and Descripts. Brit. Organic Remains (Mem. Geol. Surv.), dec. ix, no. 7, p. 5, pl. vii, figs. 5—9.

1895. *Pleuropholis serrata*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, p. 487.

Type.—Imperfect fish; collection of late Dr. John Lee, Hartwell.

Specific Characters.—Imperfectly known, but a comparatively stout fish attaining a length of about 10 cm. Head and opercular bones smooth. Scales also smooth, but those of the deepened flank-series with fine oblique serrations on the hinder border.

Description of Specimens.—All the known examples of this species are much crushed and broken, but it is easily distinguished from the other Purbeckian species by its less elegant proportions and by the serration of the principal flank-scales. Both the head and opercular bones are shown to have been smooth. The vertebral centra are preserved as delicate cylinders, with very little constriction. The fulcra on the anal fin are very slender. The fine oblique serration of the principal flank-scales has already been described and figured by Egerton, who also notes the broad thickened band on the inner face connected with the peg-and-socket articulation (Text-fig. 35C, D, p. 114). There is an occasional opening for slime-apparatus in these scales, but the lateral line as usual clearly passes along the row of small scales immediately below. The dorsal and ventral scales do not appear to be serrated.

Horizon and Localities.—Purbeck Beds: Hartwell and Bishopstone, Buckinghamshire.

Family OLIGOPLEURIDÆ.

These are the latest primitive teleosteans which retain fulcra on all the fins. They occur chiefly in the Lower Kimmeridgian (Lithographic Stone) of France and Germany, though they also range through Cretaceous formations. Some Wealden and Purbeck fossils have been wrongly referred to *Oligopleurus* itself on imperfect evidence (see p. 129), but a maxilla (Pl. XVII, fig. 8), from the Middle Purbeck of Swanage, may perhaps belong to the allied genus *Œonoscopus*, Costa. This bone much resembles the maxilla of *Megalurus* and *Amiopsis*, but it agrees still more closely with the same bone in two specimens of *Œonoscopus cyprinoides*, from the Lithographic Stone of Bavaria, in the British Museum (as already mentioned in Geol. Mag. [4], vol. ii, 1895, p. 151, pl. vii, fig. 9). It is much laterally compressed, and more than twice as deep behind as in front; its hinder margin is slightly excavated, while its anterior end is produced into a stout incurved portion for articulation with the palatine. Its outer face is almost smooth, being very faintly rugose, and the oral margin is only slightly sinuous. The teeth do not vary much in size, and are small, but stout and conical, with the blunt enamelled apex turned somewhat inwards. They are hollow and smooth, and closely though irregularly arranged. Some teeth are broken away from the gaps observed in the series.

Family LEPTOLEPIDÆ.

Genus **LEPTOLEPIS**, Agassiz.

Leptolepis, L. Agassiz, Neues Jahrb. für Min., etc., 1832, p. 146.
Oxygonius, L. Agassiz, in Brodie's Fossil Insects, 1845, p. 16.
Tharsis, C. G. Giebel, Fauna der Vorwelt, Fische, 1848, p. 145.
Sarginites, O. G. Costa, Atti Accad. Pontan., vol. v, 1850, p. 285.
Megastoma, O. G. Costa, *loc. cit.*, 1850, p. 287.

Generic Characters.—Head large and teeth minute; sclerotic ossified. Maxilla arched, with a slightly convex tooth-bearing border; mandible prominent, and dentary rising sharply into a thickened, obtuse elevation near its anterior end; preoperculum broad mesially, with a large inferior limb, marked with radiating ridges; suboperculum large, but smaller than the trapezoidal operculum, from which it is divided by an oblique suture. Vertebral centra in the form of much-constricted cylinders, with little or no secondary ossification. Pelvic fins relatively large; dorsal fin about as long as deep, opposed to the pelvic pair or to the space between the latter and the anal; anal fin small, not much extended; caudal fin deeply forked. Scales completely covering the trunk; no enlarged or thickened ridge-scales.

Type Species.—*Leptolepis bronni* (L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1833,

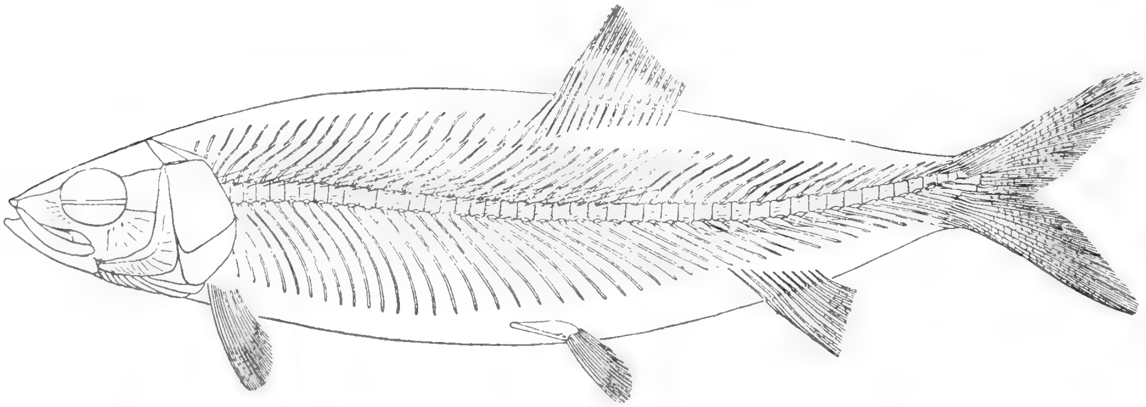

Fig. 37.—*Leptolepis dubius* (Blainville); restoration of skeleton, scales omitted, reduced in size.—Lower Kimmeridgian (Lithographic Stone); Bavaria. From British Museum Catalogue of Fossil Fishes.

p. 13; pt. ii, 1844, pp. 133, 294), from the Upper Lias of Würtemberg, Bavaria, France, and England.

Remarks.—The most characteristic bone of *Leptolepis* is the dentary of the mandible (Pl. XXIII, fig. 7). The genus has a very wide distribution both in time and space, ranging from the Upper Lias to the Lower Cretaceous in Europe, and from Spitzbergen in the north to Australia in the south. The later species as a rule (*e. g. Leptolepis dubius*, Text-fig. 37) exhibit more secondary ossification in the vertebræ than the earlier species; but a Kimmeridgian form from King Charles Land (*L. nathorsti*, A. S. Woodward, Bihang K. Svensk. Vet.-Akad. Handl., vol. xxv, sect. iv, no. 5, 1900, p. 4, figs. 2—11) and the Purbeckian species described below seem to have primitive vertebral centra like those of *L. bronni*.

1. **Leptolepis brodiei**, Agassiz. Plate XXIII, figs. 1—6.

1845. *Leptolepis brodiei*, L. Agassiz, in P. B. Brodie, Foss. Insects, p. 15, pl. i, figs. 1, 3.
1845. *Leptolepis nanus*, P. M. G. Egerton, in P. B. Brodie, *op. cit.*, p. 15, pl. i, fig. 5.

1845. *Oxygonius tenuis*, L. Agassiz, in P. B. Brodie, *op. cit.*, p. 16, pl. i, fig. 4.
1850. *Sarginites pygmæus*, O. G. Costa, Atti Accad. Pontan., vol. v, p. 285, pl. vi, figs. 6—8.
1850. *Megastoma apenninum*, O. G. Costa, *loc. cit.*, vol. v, p. 287, pl. vi, figs. 9, 10.
1853. *Sarginites pygmæus*, O. G. Costa, *loc. cit.*, vol. vii, p. 7, pl. i, fig. 4.
1853. *Megastoma apenninum*, O. G. Costa, *loc. cit.*, vol. vii, p. 8, pl. i, fig. 3.
1879. *Leptolepis neocomiensis*, F. Bassani, Verhandl. k. k. geol. Reichsanst., p. 164.
1882. *Leptolepis neocomiensis*, F. Bassani, Denkschr. k. Akad. Wiss. Wien, math.-naturw. Cl., vol. xlv, p. 204, pl. ii, figs. 1—5.
1895. *Leptolepis brodiei*, A. S. Woodward, Geol. Mag. [4], vol. ii, p. 150, pl. vii, figs. 5, 6; also Catal. Foss. Fishes Brit. Mus., pt. iii, p. 515.
1912. *Leptolepis brodiei*, F. Bassani and G. D'Erasmo, Mem. Soc. Ital. Sci., XL [3], vol. xvii, p. 229, pl. iv, fig. 6.
1915. *Leptolepis brodiei*, F. Bassani and G. D'Erasmo, Palæont. Italica, vol. xxi, p. 12, pl. i, figs. 4—6.

Type.—Imperfect fish; British Museum.

Specific Characters.—A small species, attaining a length of about 5 cm., but usually smaller. Length of head with opercular apparatus exceeding the maximum depth of the trunk, and contained about four times in the total length of the fish; width of caudal pedicle at least half the maximum depth of the abdominal region. Vertebræ from 40 to 45 in number, about half being caudal; the centra smooth; the neural and hæmal spines in the caudal region nearly straight. Pelvic fins arising about midway between the pectoral and anal fins, opposite to the anterior half of the dorsal, which has 10 or 11 bifurcated rays besides 2 or 3 shorter simple rays in front; anal fin with about 7 rays, arising nearer to the caudal than to the pelvic fins.

Description of Specimens.—The type specimen, which is shown enlarged in Pl. XXIII, fig. 3, is a little distorted by the crushing upwards of the ventral border of the hinder abdominal region, while its caudal region is imperfect and lacks the caudal fin. The clavicles of the fish may also be slightly crushed backwards. It shows, however, most of the characteristic features of the species. The second specimen figured by Brodie is similarly crushed, and is important as displaying the distinctive shape of the dentary bone (Pl. XXIII, fig. 4). Other specimens in the Brodie Collection, and still finer examples discovered by the Rev. W. R. Andrews, nearly complete our knowledge of the species. Two of these seem to show the true shape of the trunk and the proportions of the caudal fin (Pl. XXIII, figs. 5, 6).

All these fishes have the appearance of immaturity, with a relatively large orbit, which is often marked by a black stain. The head and opercular bones are smooth, and the slime-canals are relatively large, as shown especially by the frontals when exposed from below (B.M. no. P. 7635). The slender parasphenoid is nearly straight, but curves upwards a little both in front and behind. The mandibular suspensorium is inclined much forwards, so that the articulation is beneath the middle of the orbit. In one specimen discovered by Rev. W. R. Andrews (B.M. no. P. 6305) minute teeth seem to occur on the slender arched maxilla, which has a thickened upper border. In three specimens the ceratohyal is shown as a simple hour-glass-shaped bone, without any ossified filament connecting its ends. The preoperculum, as usual, is sharply bent at its angle, with a relatively large lower limb; and there seem to be two or three ridges radiating backwards from the slime-canal on the slight expansion at the angle. There are not less than 10 branchiostegal rays, of which the foremost are relatively small, slender, and spaced.

The exact number of the vertebræ is uncertain, but there are about 22 in the abdominal region and at least 20 in the tail. About four are comprised within the branchial region, and there are five or six in the upturned end which supports the caudal fin. As shown both by the type specimen and by others, the centra are delicate constricted cylinders pierced by a considerable remnant of the notochord, and their outer surface is smooth, not strengthened by longitudinal ridges. The neural arches are longest in the anterior half of the abdominal region, where they support loosely-apposed stout neural spines as far back as the origin of the dorsal fin (Pl. XXIII, fig. 3). Beneath the dorsal fin the neural arches are much shortened, without separate neural spines, and in the caudal region they are also short, sharply inclined backwards, and symmetrical with the hæmal arches. The slender arched ribs extend nearly to the ventral border, and the expanded hæmal arches supporting the caudal fin are all separate (Pl. XXIII, fig. 5). Intermuscular bones, very delicate, are seen only lying across the neural spines in the abdominal region.

As shown in both the specimens figured by Brodie (re-figured in Pl. XXIII, figs. 3, 4), the pelvic fins are not much less elevated than the pectorals. They comprise 7 or 8 rays, and seem to be inserted opposite the front half or the middle of the dorsal, their position varying in the fossils according to the manner in which they are crushed. The dorsal fin is especially well seen in the type specimen, where its maximum depth somewhat exceeds that of the trunk (fig. 3). Its foremost three rays are short and simple, gradually increasing in length; next there are 10 or 11 rays which bifurcate, and are distantly articulated in their distal half and slightly diminish in size backwards. Of the fin-supports the foremost two or three are fused together at an acute angle, while above the others there are distinct traces of the short intercalary pieces which are well known in *Amia* and several fossil Amioids. The remote anal fin, best seen in Pl. XXIII, fig. 6, is small, and comprises only about 7 rays, rapidly shortening backwards. Its rays also bifurcate and are distantly articulated in their distal half. The forked caudal fin is especially powerful (Pl. XXIII, figs. 5, 6), with distantly-articulated bifurcating rays, of which the five or six shortest in the middle of the fork are spaced. Stout sigmoidally-bent fulcral rays are seen at its base both above and below (fig. 6).

The thin cycloidal scales are often seen in the fossils, marked only by the concentric lines of growth; but no enlarged or thickened ridge-scales have been observed.

It may be added that in one of the specimens figured (Pl. XXIII, fig. 5, *c.*) the intestine is conspicuous, filled with white fæcal matter.

Immature Fishes.—The type specimen of the so-called *Leptolepis nanus*, which is re-drawn enlarged in Pl. XXIII, fig. 2, is obviously an immature example of *Leptolepis* much shortened by distortion, and there is nothing to distinguish it from *L. brodiei.* Below and in front of the large orbit, which is stained black, the characteristic dentary bone is conspicuous. The telescoped vertebræ irregularly overlap, but the crushed dorsal and pelvic fins remain almost in their natural relative positions. The base of the caudal fin is widened by the distortion.

There can also be no doubt that the immature fishes named *Oxygonius tenuis* by Agassiz are very young individuals of *Leptolepis*, almost certainly of *L. brodiei.* Their relatively large and delicately ossified vertebral column is a well-known mark of immaturity.[1] The type specimen, which is re-drawn enlarged in Pl. XXIII, fig. 1, is made a little slender by crushing, but not otherwise distorted. Its skull is missing, but the orbit is marked by a black stain, and the characteristic jaws are seen. The relative width of the opercular apparatus is also clear. The feebly ossified vertebral centra, in close series, are much deeper than long, not constricted, and apparently about 40 in number. Slight traces of the pectoral fins and the small remote anal fin are preserved, while the dorsal and pelvic fins are nearly complete, though depressed by crushing. The large forked caudal fin is also well displayed. Among other specimens labelled by Brodie, one in a group in the British Museum (no. P. 7634) exhibits very clearly the ascending process of the dentary bone, and others show that the fins must have been as in *L. brodiei.*

Horizon and Locality.—Lower Purbeck Beds: Vale of Wardour, Wiltshire.

Specifically indeterminable fragments of *Leptolepis* have also been found in the Wealden. Among them may be specially noted the dentary bone of the mandible shown enlarged in Pl. XXIII, fig. 7.

Genus **ÆTHALION**, Münster.

Æthalion, G. von Münster, Neues Jahrb. f. Min., etc., 1842, p. 41.

Generic Characters.—As *Leptolepis*, but dentary bone of mandible gradually deepening from the symphysis backwards without any marked thickening, and vertebral centra much strengthened by secondary ossification in fine longitudinal ridges.

Type Species.—*Æthalion knorri* (*Clupea knorri*, H. D. de Blainville, Nouv. Dict. d'Hist. Nat., vol. xxvii, 1818, p. 331), from the Lower Kimmeridgian (Lithographic Stone) of Bavaria.

[1] W. C. McIntosh and A. T. Masterman, The Life-Histories of the British Marine Food-Fishes (1897), p. 415.

Remarks.—This genus occurs chiefly in the Lithographic Stone of Bavaria, France, and Northern Spain (*A. vidali*, H. E. Sauvage, Mem. R. Acad. Cienc. Barcelona [3], vol. iv, no. 35, 1903, p. 13, pl. ii, fig. 2). One species has been identified from the Wealden of Belgium (*A. robustus*, R. H. Traquair, Poiss. Weald. Bernissart, Mém. Mus. Roy. Hist. Nat. Belg., vol. v, 1911, p. 50, pl. xi), and the same or a closely allied form is recorded from the Lower Cretaceous of Castellamare, Naples (F. Bassani and G. D'Erasmo, Mem. Soc. Ital. Sci. XL [3], vol. xvii, 1912, p. 234, pl. iii, fig. 3, pl. vi, figs. 1, 2, text-figs. 13—15; also G. D'Erasmo, Palæont. Italica, vol. xxi, 1915, p. 15, pl. i, fig. 8, text-fig. 22). Dr. Traquair's

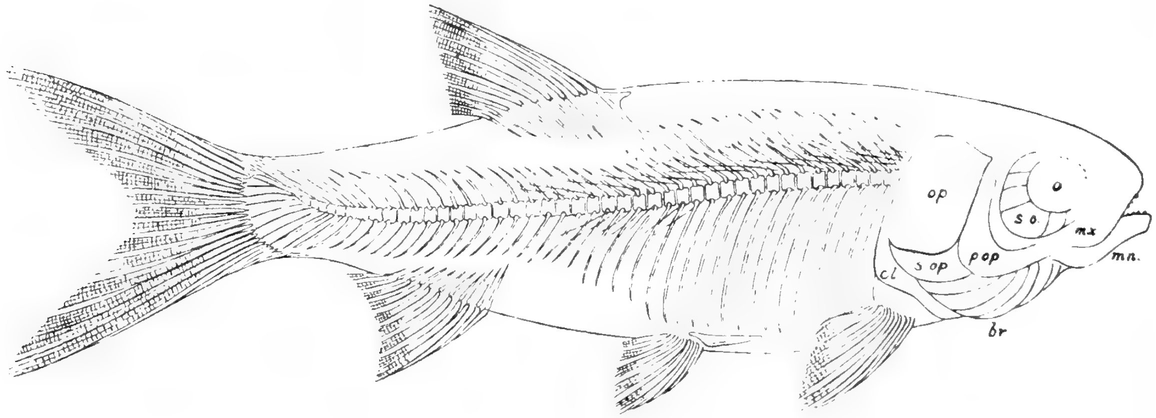

Fig. 38.—*Æthalion robustus*, Traquair; restoration of skeleton, scales omitted, reduced in size.—Wealden; Bernissart, Belgium. After R. H. Traquair. *br.*, branchiostegal rays; *cl.*, clavicle; *mn.*, mandible; *mx.*, maxilla; *o.*, orbit; *op.*, operculum; *pop.*, preoperculum; *s.o.*, cheek-plates; *s.op.*, suboperculum.

sketch of the restored skeleton of the Wealden *A. robustus* is reproduced in Text-fig. 38.

1. **Æthalion valdensis**, A. S. Woodward. Text-figure 39.

1907. *Leptolepis valdensis*, A. S. Woodward, Ann. Mag. Nat. Hist. [7], vol. xx, p. 93, pl. i.

Type.—Imperfect fish; British Museum.

Specific Characters.—A stout species attaining a length of about 40 cm. Length of head with opercular apparatus exceeding the maximum depth of the trunk, which equals about one-third the length from the pectoral arch to the base of the caudal fin, and would probably equal about one-fifth of the total length of the fish. Vertebræ 60. Pelvic fins arising midway between the pectoral and anal fins, opposite the front half of the dorsal, which arises much nearer to the occiput than to the caudal fin and comprises 18 to 20 rays; anal fin with about 14 rays, arising slightly nearer to the caudal than to the pelvic pair. Scales rather large and very deeply overlapping, some feebly crimped.

Description of Specimen.—The type specimen (Text-fig. 39) is still unique, but exhibits most of the characters of the species in the counterpart halves of a slab of clay. The mandibular suspensorium is clearly inclined forwards, so that the articulation of the lower jaw must have been directly beneath the hinder part of the orbit. The hyomandibular bone (*hm.*) bears a rather long process for the suspension of the operculum (*op.*), which is too imperfect to show its shape completely. The angle of the preoperculum (*pop.*) is much expanded, and its tapering ascending limb is upright. The suboperculum (*sop.*) must have been about four times as broad as deep. Fifteen branchiostegal rays (*br.*) can be counted, the upper seven being expanded and in close series, the lower eight being

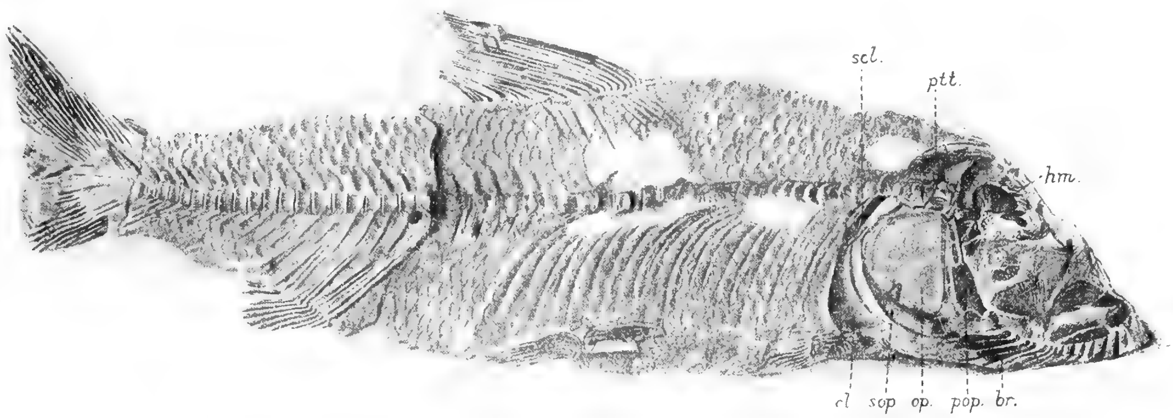

FIG. 39.—*Æthalion valdensis*, A. S. Woodward; type specimen, nearly one-half nat. size.—Weald Clay; Southwater, Sussex. British Museum, no. P. 10440. *br.*, branchiostegal rays; *cl.*, clavicle; *hm.*, hyomandibular; *op.*, operculum; *pop.*, preoperculum; *ptt.*, post-temporal; *scl.*, supraclavicle; *sop.*, suboperculum.

narrower bars and more widely spaced. All the opercular apparatus is smooth, not ornamented. The total number of vertebræ is about 60, half being in the abdominal region. The centra are about as long as deep in the anterior part of the caudal region, but are somewhat shorter than deep both in the abdominal and in the hinder part of the caudal region. They are well ossified, and their primitive double cone is strengthened by secondary bone arranged in fine, close, longitudinal ridges. The ribs are stout, apparently borne on very short transverse processes, and extending to the ventral border of the fish. The fixed neural and hæmal arches in the caudal region are also stout and gently arched. The hinder end of the vertebral column turns only slightly upwards, and its hæmal arches are expanded without fusion. The intermuscular bones are much obscured by the scales in the fossil, but there are traces of them above the vertebral column in the abdominal region, and both above and below this column in the caudal region.

The post-temporal bone (*ptt.*) is a thick plate, almost triangular in shape, and the supraclavicle (*scl.*) is a deep and narrow bone. The clavicle (*cl.*), as shown in impression, is expanded into a large smooth plate above the pectoral fin, which is inserted close to the ventral border. When adpressed to the trunk this fin extends at least half-way to the insertion of the pelvic fins. The latter are smaller than the pectorals, and their supports are a pair of elongated thin laminæ, which meet in the middle line and are thickened along their outer borders. The dorsal fin arises well in front of the middle point between the occiput and the caudal fin, comprising 18 to 20 rays, of which the three foremost are short, undivided, closely pressed together, and gradually increase in length. The length of the fourth or longest dorsal fin-ray somewhat exceeds two-thirds of the depth of the trunk at its insertion. The anal fin resembles the dorsal, but is much smaller, and comprises only 13 or 14 rays. The remains of the caudal fin-rays show that they are comparatively stout and closely articulated. The fulcral scales at the base of the upper caudal lobe are especially stout, and are continued up the foremost ray as a short fringe.

The scales are relatively large, cycloid, and smooth, occasionally with feeble traces of a radiating pectination at the hinder border, but usually exhibiting structural lines, including wavy concentric markings. They are scarcely displaced in the fossil, and are seen to be deeply overlapping, with the exposed area narrow and deep. The lateral line is scarcely traceable, but seems to produce a slight depression along some scales in a series above the vertebral column.

Remarks.—The fossil thus described evidently belongs either to *Leptolepis* or to *Æthalion*, but the absence of the mandible leaves its reference to one or other of these two genera uncertain. It was originally assigned to *Leptolepis*, but the extent of the intermuscular bones and the close articulation of the caudal fin-rays are suggestive rather of *Æthalion*; its general resemblance to the species of *Æthalion* described by Traquair from the Wealden of Bernissart, Belgium, is indeed noteworthy. It may, therefore, best be placed provisionally in the latter genus. Its number of vertebræ exceeds that of all the known species of both *Leptolepis* and *Æthalion*, except *A. vidali* from the Upper Jurassic of Spain.

Horizon and Locality.—Weald Clay: Southwater, Sussex.

Genus **PACHYTHRISSOPS**, novum.

Parathrissops, C. R. Eastman (*non* Sauvage, 1875), Mem. Carnegie Mus. Pittsburgh, vol. vi (1914), p. 423.

Generic Characters.—Head as in *Leptolepis*, but the elevation of the dentary relatively broad and less thickened. Vertebral centra much strengthened by secondary ossification in fine longitudinal ridges, short and deep in the abdominal region, sometimes longer in the tail. Pelvic fins relatively large; dorsal and anal fins acuminate, the dorsal about as long as deep, arising opposite or just in advance of the origin of the anal fin, which is equally deep and usually more extended; caudal fin deeply forked. Scales very delicate, often not preserved in the fossils.

Type Species.—*Pachythrissops lævis*, from the English Purbeck Beds.

Remarks.—The two species defined below were originally referred in error to *Oligopleurus*, and are proved by the new specimens now described to belong to the Leptolepidæ. They seem to be generically identical with a fish from the Lithographic Stone of Bavaria named *Parathrissops furcatus* by Eastman (Mem. Carnegie Mus. Pittsburgh, vol. vi, 1914, p. 423, pl. lix, fig. 2), which is distinguished by the characters of its dorsal and anal fins. The generic name *Parathrissops*, however, is preoccupied by Sauvage (Bull. Soc. Sci. Yonne, vol. xlv, pt. ii, 1891, p. 37). The species also bear some resemblance to *Eurystethus brongniarti* (H. E. Sauvage, Bull. Soc. Géol. France [3], vol. vi, 1878, p. 629, pl. xiii, fig. 2), from the Kimmeridgian of Morestel, Ain, France, but this fish is too imperfectly known for precise comparison.

1. **Pachythrissops lævis,** sp. nov. Plate XXIV, figs. 3—5; Plate XXV, figs. 1—3.

1890. *Oligopleurus (?) vectensis*, A. S. Woodward, Proc. Zool. Soc., p. 346, pl. xxviii, figs. 2—4, pl. xxix, figs. 1—3.

Type.—Immature fish; British Museum.

Specific Characters.—The type species, probably attaining a length of 50 cm., but usually smaller. Length of head with opercular apparatus much exceeding maximum depth, also much exceeding distance between paired fins, and occupying nearly one-quarter of total length of fish. Operculum smooth, but with slime-pit defined by two ridges on outer face at point of suspension; preoperculum with few radiating ridges near the angle. Vertebræ 35 in abdominal, nearly 30 in caudal region; the centra of the latter longer than the former, and marked by a sharp lateral ridge. Dorsal and anal fins arising directly opposite, the former with about 18, the latter with slightly more than 20 rays.

Description of Specimens.—The type specimen (Pl. XXV, fig. 1) is a small fish, which must probably be regarded as immature. It is shown in direct side view, apparently not distorted, but its vertebral axis is not well preserved, and the ribs are scarcely seen. All the known larger specimens are fragmentary, and one of these (Pl. XXIV, fig. 4) was wrongly referred to *Lepidotus minor* by L. Agassiz, Poiss. Foss., vol. ii, pt. i (1844), p. 269, pl. xxix *c*, fig. 12.

The head is much crushed and broken in the type specimen, but enough is clear both in this and other specimens to identify with the same species the roof of a skull shown in Pl. XXIV, fig. 3. Here the specimen is somewhat flattened by vertical crushing, but the bones are complete as far forwards as the front of the orbit. The occiput is well ossified, and its upper portion is formed by a supra-occipital in the middle with a pair of epiotics at the sides. The supraoccipital (*socc.*) occupies the middle third, and bears a vertical median crest on its hinder hollowed face. The epiotic (*epo.*) is very prominent on each side, triangular in shape when viewed from above, nearly as long as broad, and united in a finely-toothed suture with the next otic element in front. Its upper face, like that of the supraoccipital, is smooth, and must have been overlapped by the supratemporal. Each parietal (*pa.*) is slightly more than twice as long as broad, meeting its fellow in an almost straight median suture, and deeply interdigitating with the frontal anteriorly. The middle of its hinder half is raised into a coarsely rugose boss, in which the partly reticulating ridges tend to radiate from the transverse groove of the slime-canal. Its anterior half is nearly smooth. Each squamosal (*sq.*) is about as wide as the pair of parietals, and equally long. It unites in a slightly wavy suture with the corresponding parietal, and in small digitations with the frontal, while its outer border is somewhat concave. Its outer face is nearly smooth, with some irregular pitting and longitudinal grooving. The relatively large frontals (*fr.*), which also meet in a nearly straight median suture, are much narrowed between the relatively large orbits, and resemble the squamosals in the irregular grooving and pitting of the nearly smooth outer face. The postfrontals or sphenotics (*ptf.*) form a conspicuous pair of smooth, truncated prominences about as long as wide. There is a well-marked median depression in the cranial roof, beginning behind between the parietal bosses, and widening and deepening to the greatest extent between the hinder part of the orbits. The whole appearance of the bones suggests a considerable development of the slime-apparatus. The otic region and the basioccipital are well ossified, and the parasphenoid is comparatively stout, bearing an elongated patch of minute teeth where it underlies the hinder part of the orbit (seen in B.M. no. 21974). In some specimens there are broken traces of very thin cheek-plates. As shown in the type specimen, the mandibular suspensorium is arched forwards, so that the articulation for the mandible is beneath the middle of the orbit. The hyomandibular is a deep and much expanded thin lamina of bone, but is known only in a crushed specimen (B.M. no. P. 4535). It is strengthened by a vertical ridge, from which a short ridge proceeds at right-angles to an elongated articular process for the operculum. The triangular quadrate is cleft behind to accommodate a rod-shaped symplectic, and articulates above with a large triangular metapterygoid. The ectopterygoid (best seen in Pl. XXIV, fig. 4, *ecpt.*) is an arched, thin lamina of bone tapering forwards, and the entopterygoid seems to be still thinner. It is uncertain whether these elements bore teeth. As shown in the type specimen, the premaxilla is more extended backwards than usual in Amioids; and, as seen in another specimen (B.M. no. P. 4535), it bears a single series of small but stout, hollow, conical teeth. The maxilla, of which the middle portion is broken away in the type specimen, is relatively large and arched, with a flattened and nearly smooth outer face, and the convex oral border bearing minute teeth. Its posterior half is overlapped by two supramaxillæ, of which the posterior is the larger, and excavated in front for the anterior, which is elongate-triangular in shape. In the mandible, the dentary bone is relatively large, and its posterior end extends along the lower border almost as far as the position of the mandibular articulation. Though well shown in the type specimen, its complete shape is better seen in the original of Pl. XXV, fig. 2. The bone is truncated at the symphysis, and gradually rises in its middle portion into a high and stout coronoid process, which inclines a little backwards and ends abruptly behind. Beyond this process the tapering posterior end of the bone is much shorter than in the corresponding part of *Leptolepis*. The lower half of the bone is bent inwards along an obtuse-angled longitudinal ridge beginning below the middle of the symphysis, and this face is marked by large pits and a groove, which indicate a considerable development of slime-apparatus. The outer face is for the most part smooth, but there is a little rugosity near the oral border, which (as shown in Pl. XXIV, fig. 4 *a*) bears small, hollow, smooth, and bluntly-conical teeth.

The hyoid arch, seen in Pl. XXIV, fig. 4, is relatively large, the ceratohyal (*ch.*) being laterally compressed, mesially constricted, and deepest behind at its articulation with the epihyal (*eph.*). Its upper angles seem to be united by a rod of bone as in *Leptolepis*. The basihyal (*bh.*) is very short.

The preoperculum (Pl. XXV, fig. 1, *pop.*) is sharply angulated, with the lower limb nearly as long as the upper limb, and the anterior border much thickened. This thickening is smooth and widest at the bend, from which a few coarse ridges, more or less fused into a reticulation, radiate backwards over the thin triangular expansion. The traversing slime-canal is very large. The operculum (*op.*) seems to have been two-thirds as wide as deep, and is also thickened along its anterior border, from which at the point of suspension a short ridge diverges at an acute angle downwards and backwards, as if to bound a slime-pit (Pl. XXV, fig. 1 *a*). The outer face is entirely smooth. The suboperculum (*sop.*) and interoperculum are comparatively small, and both these and the broad upper branchiostegal rays are smooth. The lower branchiostegal rays, of which some are seen below the ceratohyal in Pl. XXIV, fig. 4 (*br.*), are slender, rod-shaped, and spaced.

As shown in several specimens, but especially well in the original of Pl. XXIV, fig. 4, the gill-arches bear a close series of large bony gill-rakers (*g.r.*) which are smooth, laterally-compressed elongated cones, each with a notch just above its base of attachment. Similar gill-rakers appear to occur in *Leptolepis* (B.M. no. P. 3674), *Æthalion* (B.M. no. 37042), and *Thrissops* (B.M. no. P. 917).

The vertebræ in the type specimen (Pl. XXV, fig. 1) are in undisturbed series, but they are somewhat broken, and not so well seen as in some of the portions of larger individuals. About 35 can be counted in the abdominal, 26 in the caudal region. The centra are all well ossified, the primitive double cone being thick and forming two wide rims, between which the secondary ossification is in fine longitudinal ridges, producing a striated appearance on superficial view. When a centrum is isolated and exposed on the articular face (Pl. XXV, fig. 3), a median perforation is seen for a persistent strand of the notochord. All the abdominal vertebral centra are deeper than long, with gently rounded sides, and their appended arches are loosely articulated. The foremost centrum is not united with the basioccipital, but (as shown in Pl. XXIV, fig. 4) it is peculiar in consisting of two fused discs, which are limited by a sharp line, the front disc bearing a slight prominence above for the support of the first neural arch, the second bearing a similar pair of slight prominences below to carry the first pair of ribs. The second centrum (sometimes also the third centrum) again exhibits prominences, but all the other abdominal centra are pitted for the reception of both the neural arches and ribs. The caudal vertebral centra are more elongated, about as long as deep, and their secondary ossification is disposed so as to form a sharp median longitudinal ridge on each side. Their appended arches are more firmly fixed in the sockets than those in the abdominal region, even if they are not fused. The arches are almost destroyed in the type specimen, but they are seen in others, as in the fragment represented in Pl. XXIV, fig. 5 The neural arches are comparatively small and delicate, and unite by large anterior zygapophyses, but they are obscured in the abdominal region by the numerous well-developed intermuscular bones which overlie them. In the caudal region the neural and hæmal arches are nearly symmetrical, and sharply curved backwards, and a few intermuscular bones occur both above and below the vertebral centra. The stout gently-curved ribs extend to the ventral border of the fish, each with a slightly expanded articular head and a wide groove along its anterior or outer face.

The stout clavicle, of which the upper half is shown in Pl. XXV, fig. 1 (*cl.*), bears a large lateral expansion which is nearly smooth, only marked by a few vertical ridges and grooves or wrinkles at the upper end. The long and narrow supraclavicle (*scl.*) is similarly ridged, and traversed by a large slime-canal. The pectoral fin must have been relatively large, its rays when adpressed to the trunk (as in the type specimen) reaching two-thirds of the distance to the insertion of the pelvic fins. The pelvic fin-supports (Pl. XXIV, fig. 5, *plv.*) are long and narrow laminæ, widest at the articular end, tapering forwards, strengthened by a rib-like thickening along the outer edge, and apparently fixed together along the thin inner edge. The pelvic fin-rays, about 10 in number, are deeply imbricating and closely articulated distally. The dorsal and anal fins are shown in the type specimen to be acuminate in front and directly opposed, but their details are better seen in other specimens. In the dorsal fin there are about 18 rays, of which the anterior four are simple and gradually increase in length, while the fifth is the longest, and this and the following are divided and articulated distally (B.M. no. P. 4536). The foremost support is fan-shaped, bearing the first three rays (Pl. XXIV, fig. 5, *d.*), and the other supports are winged at the articular end.

The anal fin is as deep as the dorsal and closely similar, but more extended, probably with not less than 23 rays. The long foremost support is rod-shaped, and the wings at the articular ends of the other supports are short. The forked caudal fin is well shown in the type specimen, with the step-shaped articulations of its thicker rays. All the hæmal spines within the base of the caudal fin are stout, and two bearing the middle rays are slightly expanded. There are no traces of fulcra on any of the fins.

Remains of rather large cycloidal scales are seen in the original of Pl. XXIV, fig. 5, but they must have been very thin, and are usually absent in the fossils.

Remarks.—When examples of *Pachythrissops lævis* were first described, they were provisionally ascribed to the Wealden species treated below; but the form is readily distinguished by the characters of the opercular apparatus and the sharpness of the lateral ridge on the caudal vertebræ, besides by the proportions of the head.

Horizon and Locality.—Middle Purbeck Beds: Swanage, Dorset.

2. **Pachythrissops vectensis,** A. S. Woodward. Plate XXIV, figs. 6, 7; Plate XXV, figs. 4, 5; Text-figure 40.

1890. *Oligopleurus vectensis*, A. S. Woodward, Proc. Zool. Soc., p. 346, pl. xxviii, fig. 1.

1911. *Oligopleurus vectensis,* R. H. Traquair, Poiss. Wealdiens de Bernissart (Mém. Mus. Roy. Hist. Nat. Belg., vol. v), p. 47, pl. x.

1913. *Oligopleurus vectensis,* E. S. Goodrich, Proc. Zool. Soc., p. 84.

Type.—Head; British Museum.

Specific Characters.—Attaining a length of a little more than a metre. Length of head with opercular apparatus about equal to the distance between the paired fins. Operculum apparently without slime-pit, smooth, or faintly rugose, but fimbriated at the postero-superior border; preoperculum with a few strong radiating ridges spaced over the lower limb. Vertebræ 35 in abdominal region; centra in caudal region not longer than those in abdominal region, without any sharp lateral ridge, but slightly indented above and below to produce a broad rounded lateral ridge. [Fins imperfectly known.] Scales ornamented with sparse pustulations, and more or less fimbriated at the hinder border.

Description of Specimens.—The type specimen is an imperfectly preserved skull and mandible shown of one-half nat. size from the right side in Text-fig. 40. The greater part of a fish (Pl. XXV, fig. 4) discovered by Mr. Reginald W. Hooley, F.G.S., exhibits the head and most of the vertebral axis, besides some remains of fins. Other more fragmentary specimens make known a few additional details.

The skull is always more or less crushed and broken, but many of its principal features are shown in the fossils. As seen in the type specimen, there is a well-ossified supraoccipital, bearing a vertical median crest on its posterior face; and on either side of this there are remains of an equally well-ossified epiotic. These bones are exposed as a narrow rim at the posterior border of the cranial roof. As in *P. lævis*, each parietal bone is longer than wide, and the squamosal is relatively wide, though not much longer than the parietal. The large frontal bones, as shown in the type specimen and in Mr. Hooley's fish (Pl. XXV, fig. 4), are narrowed between the orbits; but, as also shown in Mr. Hooley's specimens, they are much expanded in the postorbital region and overlap the well-ossified postfrontals to an undetermined extent. The parietals, squamosals and frontals are marked only by fine radiating ridges and an occasional trace of the slime-canal,

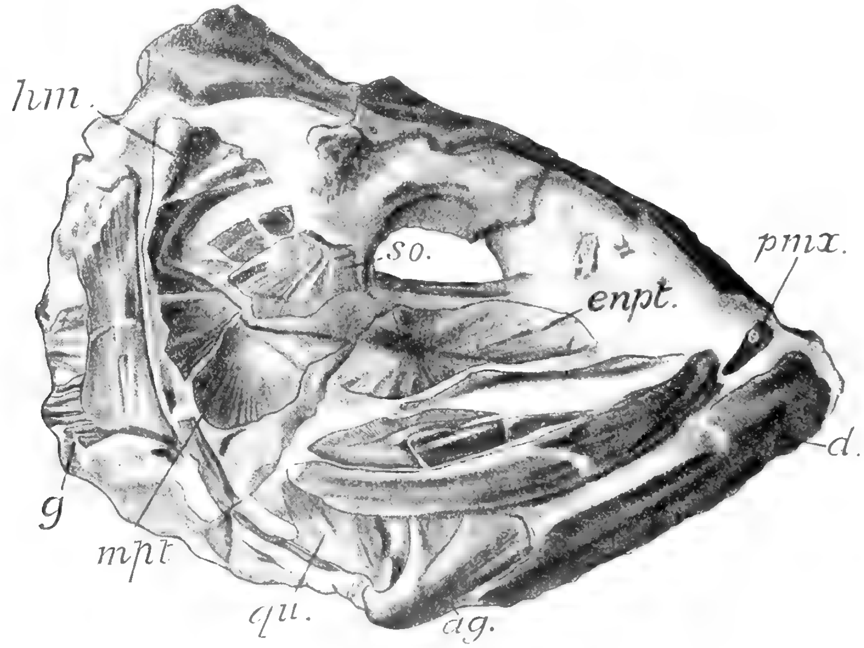

FIG. 40.—*Pachythrissops vectensis*, A. S. Woodward; type skull, right lateral view, one-half nat. size.—Wealden; Isle of Wight. British Museum, no 42013. *ag.*, articulo-angular; *d.*, dentary; *enpt.*, entopterygoid; *g.*, gill-rakers; *hm.*, hyomandibular; *mpt.*, metapterygoid; *pmx.*, premaxilla; *qu.*, quadrate; *so.*, portion of hinder cheek-plate.

but along the middle of the cranial roof there is a well-marked depression, which is widest and deepest between the hinder part of the orbits. The type specimen proves that the ethmoid region is comparatively small. Fragments of very thin cheek-plates occur in the type specimen (Text-fig. 40, *so.*) and in the original of Pl. XXV, fig. 4; and a single broad series is seen to cover the postorbital region of the cheek in Pl. XXIV, fig. 6, *so.* These plates are nearly smooth, but are marked with slight radiating ridges or fimbriations. They are also traversed by the slime-canal near the orbital border. The mandibular suspensorium curves forwards so that the articulation for the mandible is beneath the hinder part of the orbit. The hyomandibular (Pl. XXV, fig. 5) is much expanded at the upper end, with an apparently double-headed articulation; and, as in other fishes in which the preoperculum is relatively large, the process (*p.*) for the suspension of the operculum is much elongated. Just below the latter process the bone is antero-posteriorly compressed and rises to a sharp vertical crest along its outer face. The triangular quadrate (Text-fig. 40, *qu.*) is cleft postero-superiorly for the rod-shaped symplectic (Pl. XXV, fig. 4, *sy.*), and articulates above with a large triangular metapterygoid (*mpt.*). Its articular condyle for the mandible is somewhat constricted from the main part of the bone, and has a robust inwardly-directed process arising from its base. The entopterygoid (*enpt.*) is an elongated thin lamina of bone, bluntly pointed in front, truncated behind, slightly convex on the oral face, and inclined inwards towards the parasphenoid. The ectopterygoid (Pl. XXV, fig. 4, *ecpt.*) is a narrower elongated lamina, more rapidly tapering in front. It is toothless along the lower border, but its oral face, like that of the other pterygoid plates, has not been seen. The premaxilla, imperfectly shown in the type specimen (Text-fig. 40, *pmx.*), is comparatively small, but longer than deep. The large maxilla (Text-fig. 40 and Pl. XXV, fig. 4, *mx.*) is arched, and its outer face is nearly smooth, marked only in places with a faint rugosity; its convex oral border exhibits the points of attachment of clustered minute teeth. Its posterior two-thirds are overlapped by two supramaxillæ, of which the posterior is the larger and excavated in front for the anterior, which is very long and narrow and tapers forwards. The outer face of the posterior supramaxilla is slightly rugose, and bears a ridge along the lower margin of its antero-superior extension. The articulo-angular bone of the mandible (Text-fig. 40, *ag.*) is short and deep, and its lower portion is ornamented with fine longitudinal rugæ. The very large dentary (*d.*), which is imperfectly known, is evidently truncated at the symphysis, and its lower half is sharply bent inwards, separated from the upper half by an obtuse longitudinal ridge.

The hyoid arch, partly seen in the original of Pl. XXV, fig. 4, is relatively large, and the upper branchiostegal rays, attached to the epihyal, are especially large smooth laminæ of bone (*br.*).

The preoperculum, incomplete and abraded in the type specimen, is best seen in Pl. XXIV, figs. 6 (*pop.*), 6 *a*. It is sharply angulated, with a relatively large lower limb, and a great smooth expansion behind. The anterior border is much thickened and smooth, and from this thickening six or seven coarse ridges radiate over the outer face of the lower limb. The operculum (*op.*) is imperfect in all the specimens, and the proportions of the suboperculum and interoperculum are uncertain. The operculum seems to have been smooth or only faintly rugose, except at its postero-superior border, where it is finely fimbriated.

A single vertebral centrum attached to the occipital region of the type specimen is completely ossified, deeper than wide, and very short, marked on the sides by fine striations which extend between a thickened rim anteriorly and posteriorly. The neural and hæmal arches are inserted in pits. As shown by the large fish (Pl. XXV, fig. 4), all the vertebral centra are of this type, except that they are generally longer in proportion to their depth. There seem to be 34 or 35 in the abdominal region, but the number of caudals is uncertain. The centra in the caudal region are scarcely longer than those in the abdominal region, but they differ in exhibiting a slight lateral indentation above and below a rounded median lateral ridge. The neural arches in the abdominal region are long and slender, but most of them are broken and displaced, and obscured by the overlapping intermuscular bones. The stout, gently-arched ribs are well shown, reaching the ventral border, each impressed by a longitudinal groove. The neural and hæmal arches in the caudal region are firmly fixed in their sockets in the centra.

The remains of the clavicle (Pl. XXV, fig. 4, *cl.*) and supraclavicle (*scl.*) include a wide, nearly smooth, exposed portion; and a large smooth plate of bone (*x.*) shown behind the skull is probably the post-temporal, much expanded, as in *Thrissops.* The long pectoral fin-rays (*pct.*) are very closely articulated distally. The pelvic fins (*plv.*), with slender supports, are much smaller than the pectorals, and are evidently inserted nearer to the anal than to the latter. Of the anal fin (*a.*), only a fragment remains with at least 17 rays. As the anterior supports are relatively long and stout, this fin must have been acuminate. The dorsal and caudal fins are unknown.

Scales are seen in some of Mr. Hooley's specimens, all large, thin, and cycloidal, and deeply overlapping. They are most conspicuously marked by the concentric lines of growth; but some exhibit sparse pustulations, usually in rows, on the smooth exposed face, besides fine fimbriations at the hinder margin (Pl. XXIV, fig. 7).

Horizon and Localities.—Weald Clay: Atherfield, Isle of Wight; Berwick, Sussex.

Genus **THRISSOPS**, Agassiz.

Thrissops, L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1833, p. 12.

Generic Characters.—Head as in *Leptolepis*, but smaller, and the dentary bone with a broader, less thickened elevation. Vertebral centra much strengthened by secondary ossification in longitudinal ridges, of which the median lateral is usually very prominent; no centra much deeper than long. Ribs especially stout. Pelvic fins relatively small; dorsal and anal fins acuminate and opposite, the former small and short-based, the latter much extended; caudal fin forked. Scales thin, completely covering the trunk; no enlarged or thickened ridge-scales.

Type Species.—*Thrissops formosus* (L. Agassiz, Poiss. Foss., vol. ii, pt. i, 1833,

p. 12; vol. ii, pt. ii, 1844, p. 124, pl. lxv *a*), from the Lithographic Stone (Lower Kimmeridgian) of Bavaria.

Remarks.—*Thrissops* seems to range in Europe from the Middle Jurassic (Oxfordian) to the Lower Cretaceous; but without a knowledge of their cranial osteology, the systematic position of the later species usually ascribed to this genus must remain uncertain. They closely approach the Ichthyodectidæ or Chirocentridæ.

1. **Thrissops curtus,** sp. nov. Plate XXVI, fig. 1.

Type.—Imperfect fish; British Museum

Specific Characters.—At least 16 cm. in length. Length of head with opercular apparatus nearly equalling maximum depth of trunk, and contained from four to five times in total length of fish; maximum depth of trunk contained about two-and-a-half times in length from pectoral arch to base of caudal fin. Pelvic fins half as large as pectorals, inserted nearer to the anal fin than to the latter; dorsal fin, with 13 rays, arising behind the origin of the anal fin, which is slightly more elevated in front and comprises 30 rays; caudal fin very deeply forked and lobes slender.

Description of Specimen.—The type and only known specimen (Pl. XXVI, fig. 1) lacks the jaws, but is otherwise nearly complete. In the skull the ethmoidal region is very short and small, and the parasphenoid is seen crossing the relatively large orbit. A short ridge inclined upwards at the back of the occiput may perhaps be the thickened upper border of a triangular supraoccipital crest such as seems to occur in *Thrissops formosus* (Brit. Mus. no. P. 917). The preoperculum is vaguely shown to be much expanded at the angle and marked with several fine radiating ridges. The operculum, which is smooth, is widest below, and its maximum width is at least three-quarters of its depth. It seems to show a peculiar slime-pit near its point of suspension like that already described in *Pachythrissops lævis* (p. 131, Pl. XXV, fig. 1*a*). The suboperculum, which is also smooth, is slightly more than one-third as deep as the operculum. The vertebral centra are evidently well ossified, but are not clearly seen except at the end of the tail, where they bear the usual sharp median lateral ridge. Over twenty vertebræ can be counted in the caudal region. The neural arches in the abdominal region are separated from the neural spines, which reach the dorsal border. Some of the anterior spines of this series have a small laminar expansion at their lower end. The stout grooved ribs, of which there are over twenty pairs, reach the ventral border. The neural and hæmal arches in the caudal region are fused both with their spines and with the corresponding centra; they are slender, short, and much inclined backwards. At least nine hæmals are included in the base of the caudal fin. Intermuscular bones occur only in the dorsal part of the abdominal region. Behind the skull, the post-temporal is a large, smooth, rhomboid plate, nearly as wide as deep, strengthened by a ridge extending diagonally from its antero-superior angle. The supraclavicle is relatively deep and narrow, and the clavicle is much arched. The anal fin comprises 27 rays, with three gradually lengthening fulcral rays in front, and its anterior acumination is about three-quarters as deep as the trunk at its insertion. The dorsal fin is slightly less elevated, with only 10 ordinary rays preceded by three fulcrals. Traces of the usual thin scales are seen, none with ornament.

Remarks.—Although the abdominal part of the vertebral column in the type specimen is somewhat displaced by crushing, the arrangement of the neural arches and ribs suggests that it has not been much shortened. The species is therefore peculiar in the shortness of the trunk, and it differs from the only known species from Portland (*T. portlandicus*, A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. iii, 1895, p. 525, pl. xviii, fig. 4) not only in this feature, but also in the more remote insertion of the dorsal fin.

Horizon and Locality.—Lower Purbeck Beds: Isle of Portland. The stratigraphical position was determined by the collector of the type specimen, Mr. J. R. Short. The exact horizon of *T. portlandicus* was not recorded by the collector.

2. **Thrissops molossus**, sp. nov. Plate XXVI, fig. 2.

Type.—Imperfect fish; British Museum.

Specific Characters.—At least 35 cm. in length. Head remarkably short and deep. Length of head with opercular apparatus nearly equalling maximum depth of trunk, and about one-fifth of total length of fish; maximum depth of trunk contained about three-and-a-half times in length from pectoral arch to base of caudal fin. Caudal fin very deeply forked and lobes slender.

Description of Specimen.—There is no doubt that the fragmentary fish shown of one-half the natural size in Pl. XXVI, fig. 2, represents a hitherto unrecognised species, but it is too imperfect for precise determination. The cranium is lacking, but the adjacent remains are sufficiently undisturbed to show that the head is unusually short and deep. The ossified border of the sclerotic of the very large eye is well preserved, and the mandibular suspensorium and jaws are also seen. The stout rod-shaped symplectic occurs below the hyomandibular, evidently fitting into a cleft of the large fan-shaped quadrate. The pterygoid bones form an extensive laminar expansion above the maxilla, which is gently arched and bears a regular close series of small conical teeth. Of the premaxilla only a fragment remains. The mandible is very imperfect, but its articulation is clearly below the hinder border of the orbit, and its oral border bears conical teeth which are larger than those of the maxilla. The remains of the operculum are bordered behind by part of the clavicle, and its width is thus shown to equal half the length of the head. The lower branchiostegal rays are very slender. The parts of the trunk preserved seem to be almost in their natural position, but some of the abdominal vertebræ are displaced above the fossil, while the upper lobe of the caudal fin is torn away and displaced below. The axial skeleton is typically that of *Thrissops*, and the middle hæmal spine at the base of the caudal fin is much-expanded. The stoutness and length of the anterior supports of the anal fin show that this must have been very deep and acuminate in front.

Horizon and Locality.—Middle Purbeck Beds: Swanage, Dorsetshire.

SUPPLEMENT.

Hybodus basanus, Egerton (p. 5). Plate XXVI, fig. 3.

Mr. Reginald W. Hooley, F.G.S., has obtained from the top of the Weald Clay in the typical locality, Atherfield, Isle of Wight, the well-preserved small head partly shown in Pl. XXVI, fig. 3. In the front part of the jaws it displays some of the characteristic teeth; and at the limits of the gape of the mouth there are remains of the labial cartilages, as already described (p. 7, Pl. II, figs. 1 *a*, 1 *b*). Even allowing for some vertical crushing, however, the skull clearly differs from the well-preserved specimen from Pevensey (Pl. II, fig. 1) in being relatively shorter and broader, with less widened postorbital processes. As seen from above (Pl. XXVI, fig. 3), the supraorbital flanges are well developed, and the interorbital width exceeds half the total length of the cranial roof. The posterior depression (*p.f.*) is less elongated than in the best-preserved Pevensey specimen. The small rostral prominence is evidently broken away by accident. The occiput (Pl. XXVI, fig. 3 *a*) is especially well shown, only abraded at its median vertical crest, which is still best seen in the skull already mentioned on p. 6. The occipital face is more than half as deep as wide, and its most conspicuous feature is the large excavation for the notochord (*n.*) in the basioccipital region, resembling that in *Notidanus* (*Hexanchus*).[1] The foramen magnum (*f.m.*), seen above this excavation, is comparatively small. A pair of deep pits (*v.*) in the cartilage flanking the foramen magnum would probably be pierced by the foramina of the vagus nerves.

Hybodus sulcatus, Agassiz.

The two fragments of a dorsal fin-spine named *Hybodus sulcatus* by Agassiz (Poiss. Foss., vol. iii, 1837, p. 44, pl. x *b*, figs. 15, 16), though originally stated by

[1] C. Gegenbaur, Untersuchungen zur vergleichenden Anatomie der Wirbelthiere.—III. Das Kopfskelet der Selachier (1872), p. 120, pl. iv, fig. 2, pl. xv, fig. 2.

Mantell to have been obtained from the Chalk of Lewes, are generally regarded as Wealden fossils (S. J. Mackie, The Geologist, vol. vi, 1863, p. 242, and A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. i, 1889, p. 275). A renewed examination of these fragments, however, suggests that they are from a ferruginous concretion in the Chalk, and not from any Wealden deposit. As already suspected by M. Leriche (Mém. Soc. Géol. Nord, vol. v, 1906, p. 91), they are parts of the dorsal fin-spine of a Chimæroid fish; but they still remain unique. The anterior border of the spine is less compressed to an edge than usual, and it is ornamented with a few large and irregularly arranged tubercles (not shown in Agassiz' figures). The longitudinal ribbing of the lateral faces is coarser and more marked than in any other known Chimæroid spine. The specimen may perhaps belong to a species of *Ischyodus*.

Hybodus subcarinatus, Agassiz (p. 10).

Lepidotus mantelli, Agassiz (p. 36).

According to Mr. J. Wilfrid Jackson, the type specimens of *Hybodus subcarinatus* and the so-called *Tetragonolepis mastodonteus* (= small dentary of *Lepidotus*) are in the Cumberland Collection in the Manchester Museum.

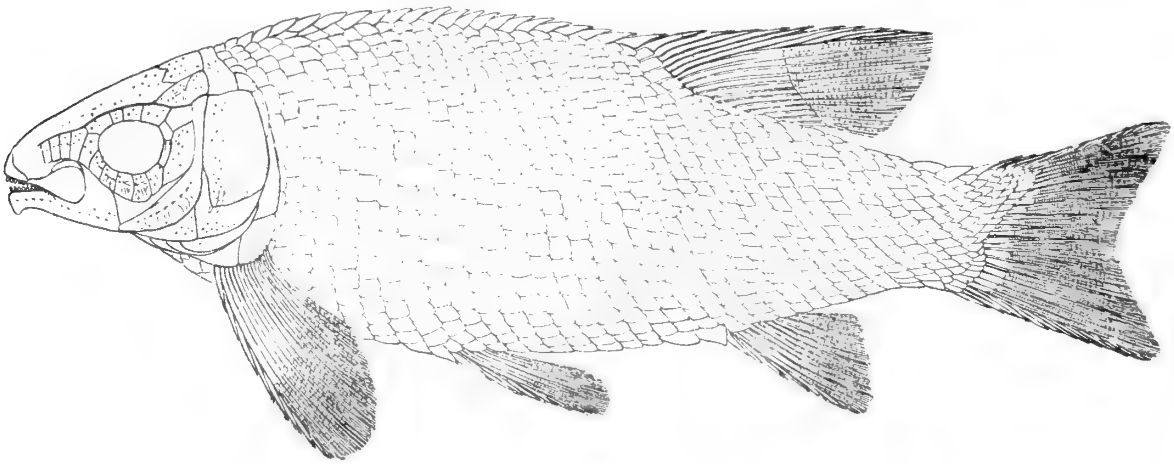

FIG. 41.—*Lepidotus minor,* Agassiz; restoration with amended dorsal and anal fins, to replace the restoration given in Text-fig. 14, p. 28.

Lepidotus minor, Agassiz (p. 27). Plate XXVI, fig. 4.

Dr. F. Du Cane Godman, F.R.S., has lately given to the British Museum the large specimen of the stout variety of *Lepidotus minor*, from the Middle Purbeck Beds of Swanage, shown of one-third the natural size in Pl. XXVI, fig. 4. It is important as displaying the complete dorsal fin, which is proved to have been wrongly drawn in the restoration of the species in Text-fig. 14, p. 28. A new restoration with the dorsal and anal fins amended is accordingly given in Text-fig. 41. The specimen is much laterally compressed by crushing, so that the left half of the cranial roof is bent downwards and has slipped partly beneath the right half. The mouth is also opened, and the ventral part of the abdominal region is displaced downwards. The large characteristic smooth maxilla (*mx.*) is well seen, with part of the supramaxilla, and the ectopterygoid (*ecpt.*) and quadrate (*qu.*) are exposed. The small upper postorbital cheek-plate seems to be subdivided by a vertical suture; the large postorbital is also divided transversely in its lower half, but this may be merely an accidental crack. The tubercular ornament of the opercular bones is unusually extensive and dense. Remains of the paired fins show their relative proportions. The enamelled fulcra in the dorsal fin are slightly curved, forming a convexly arched border; the closely divided and articulated fin-rays seem to be complete, and resemble those of *L. mantelli* (see Pl. VII, fig. 7). Some of the anterior scales of the flank are coarsely serrated in their lower half, but further back the corresponding scales do not exhibit more than one denticulation above the produced postero-inferior angle, and this soon disappears at the beginning of the tail. From the produced angle, and sometimes from the denticulation above, a faint oblique ridge extends forwards over the scale. The upper slime-canal, which begins as usual on the third row of scales below the dorsal ridge, descends and becomes a little irregular near the dorsal fin.

SUMMARY AND CONCLUSION.

Little is added to our knowledge of the Wealden and Purbeck fish-fauna by the fossils discovered in the corresponding formations on the European continent. Even in the great collection described by Traquair,[1] from the Wealden of Bernissart, Belgium, there is only one genus, the Macrosemiid *Notagogus*, additional to those represented among the English fossils. At Bernissart no Selachian remains are known, but in north Germany[2] there are teeth and spines of *Hybodus* much resembling those now described. In north Germany several fine specimens of *Lepidotus* have also been discovered,[3] but of other ganoids there are only teeth and fragmentary jaws, chiefly referable to Pycnodonts.

So far as known, therefore, the fishes of the Wealden and Purbeck formations are essentially Jurassic, and not mingled with any typically Cretaceous forms. Most of them are, indeed, the specialised and evidently final representatives of the Jurassic families to which they belong, and very few can be regarded as possible ancestors of fishes which followed in Cretaceous and later times.

[1] R. H. Traquair, "Les Poissons Wealdiens de Bernissart," Mém. Mus. Roy. Hist. Nat. Belgique, vol. vi (1911), pp. 1—65, pls. i—xii.

[2] W. Dunker, Monographie der Norddeutschen Wealdenbildung. Brunswick, 1846.

[3] W. Branco, "Beiträge zur Kenntniss der Gattung *Lepidotus*," Abhandl. geol. Specialk. Preussen u. Thüring. Staaten, vol. vii (1887), pt. 4, pp. 1—84, pls. i—viii.

Among the Selachians, the well-preserved skulls of *Hybodus basanus* are especially interesting, because they exhibit much more resemblance to those of the Notidanidæ than to the skull of the modern *Cestracion*, to which *Hybodus* is commonly regarded as nearly allied. The teeth of some of the Lower Jurassic species of *Hybodus*, indeed, seem to pass into those of the earliest known species of *Notidanus*[1]; just as the high-cusped teeth of the Wealden *H. basanus* are closely similar to some of the Middle and Upper Jurassic teeth of *Orthacodus*,[2] which seem to pass into those of the primitive though typical Lamnidæ of the Cretaceous period. Some of the more generalised Hybodonts, when better known, may therefore prove to be ancestral to several later types of sharks.

Hybodus basanus is also noteworthy in having only one pair of hooked cephalic spines instead of the two pairs, of nearly equal size, which characterise the early Liassic species.[3] In one species of the allied genus *Asteracanthus*, from the Oxford Clay of Peterborough, the late Mr. Alfred N. Leeds observed that of the two pairs of cephalic spines one was much smaller than the other. There was thus probably a similar reduction of one pair in some species of *Hybodus*, which eventually resulted in its complete loss.

The occurrence of a dwarf species of *Acrodus* in the Wealden is paralleled by that of a similar dwarf species in an estuarine deposit of nearly the same age in Bahia, Brazil.[4] This is almost the last appearance of the genus, the latest known species being *Acrodus levis* from the Gault.

No remains of Crossopterygians have hitherto been found in the Wealden, and the only specimen from the Purbeck Beds is that of the typically Jurassic *Undina* now described. The ornament of the scales clearly distinguishes it from the Cretaceous *Macropoma*.

Among Chondrosteans the Palæoniscidæ are represented for the last time by the genus *Coccolepis*, which is too specialised to be ancestral to the later sturgeons.

The representatives of *Lepidotus* are interesting as including a comparatively generalised species, *L. minor*, which might even be Lower Jurassic, besides a large and highly specialised species, *L. mantelli*, which could not be earlier than Upper Jurassic, and might be Lower Cretaceous. The vertebral ossifications in the latter species are particularly remarkable.

The Pycnodonts also comprise both generalised and moderately specialised

[1] Compare *Hybodus polyprion*, Ag., with *Notidanus muensteri*, Ag. (A. S. Woodward, Geol. Mag., [3] vol. iii (1886), p. 257, pl. vi, figs. 1—5).

[2] O. Jaekel, Sitzungsb. Gesell. naturf. Freunde, Berlin, 1898, p. 139, text-fig. 2; F. Priem, Bull. Soc. Géol. France, [4] vol. xii (1912), p. 254, with figs. A large tooth apparently of *Orthacodus*, from the Danian of Scandinavia, has been described as *Oxyrhina lundgreni*, J. W. Davis, Trans. Roy. Dublin Soc., [2] vol. iv (1890), p. 393, pl. xxxix, figs. 8—13.

[3] See *Hybodus delabechei* (Charlesworth), A. S. Woodward, Catal. Foss. Fishes, Brit. Mus., pt. i (1889), p. 259, pl. viii, fig. 1.

[4] *Acrodus nitidus*, A. S. Woodward, *op. cit.* (1889), p. 297, pl. xiv, fig. 8.

forms, but no exclusively Cretaceous genera. The specimens of *Microdon radiatus* and *Mesodon parvus* from the Purbeck Beds are especially well preserved to show the osteology, and a study of them has led to several new observations.[1] There can no longer be any doubt as to the close relationship of these fishes to the *Lepidotus*-like ganoids.

The Purbeckian specimens of *Ophiopsis* and *Histionotus* make some additions to our knowledge of the osteology of the more generalised Macrosemiidæ, which emphasise their affinity to the Eugnathidæ. The curious development of large slime-pits in the preoperculum and supratemporal bones of *Histionotus* still awaits explanation. If the new genus *Enchelyolepis* be rightly placed in the same family, its very thin cycloidal scales are particularly interesting and novel.

Besides the remains of typical Eugnathidæ of Jurassic facies, one example of the later Cretaceous genus *Neorhombolepis* is described from the Wealden. Either this, however, or a nearly similar genus also occurs in the apparently Lower Cretaceous estuarine deposit in Bahia, Brazil,[2] already mentioned, while the closely-related *Otomitla* is found in the Neocomian of Mexico.[3]

Amiopsis, though so closely similar to *Amia*, still retains the short dorsal fin which distinguishes the Jurassic members of the family. It is a Cretaceous genus.

The Purbeckian *Aspidorhynchus fisheri* seems to be the latest species of the genus hitherto discovered. The specimens now described show much of the osteology, and suggest that the supposed close relationships of the Aspidorhynchidæ to the Lepidosteidæ need further examination. The Wealden remains of *Belonostomus* are unfortunately too fragmentary for discussion.

The Pholidophoridæ occur for the last time, and the Purbeckian species of *Pholidophorus* are interesting for the strength of their fins. *P. ornatus* and *P. granulatus* are especially similar to species from the Upper Jurassic Lithographic Stone of Germany and France. The almost scaleless *Ceramurus* may be regarded as a highly specialised member of the family. Some of the Purbeckian specimens of *Pleuropholis* are in an unusually good state of preservation, and add to our knowledge of the osteology of the genus.

Among the Leptolepidæ, which are also essentially Jurassic fishes, may perhaps be recognised some of the ancestors of the typical physostomous teleosteans of the later Cretaceous seas. They evidently connect the more typical "ganoids" with the primitive Elopidæ which are so abundant in marine Cretaceous formations. By a relative enlargement of the supraoccipital and otic bones in the skull, a

[1] A. S. Woodward, "Notes on the Pycnodont Fishes," Geol. Mag., [6] vol. iv (1917), pp. 385—389, pl. xxiv.

[2] A. S. Woodward, "The Fossil Fishes of the English Chalk" (Palæont. Soc., 1911), p. 256.

[3] *Otomitla speciosa*, J. Felix, Palæontographica, vol. xxxvii (1891), p. 189, pl. xxix, fig. 3, pl. xxx, figs. 3—5.

partial fusion of the hæmal spines at the base of the caudal fin, and an increased development of the intermuscular bones, some of them may have become Clupeidæ. By nearly the same changes, such genera as *Pachythrissops* and *Thrissops* may also have passed into the *Chirocentrus*-like fishes, which were as numerous in the Cretaceous fauna as the Elopines and Clupeoids, and are represented at the present day by a genus (*Chirocentrus*) which retains a remnant of the primitive spiral valve in the intestine.[1]

It is therefore interesting to compare the fishes of the Wealden and Purbeck estuary with those of the contemporaneous seas in the European area. It is only unfortunate that the latter are thus far very imperfectly known. Fish-remains are not uncommon in some of the marine Neocomian formations of France which seem to be contemporary with at least the later Wealden deposits, but they are all very fragmentary.[2] So far as determinable, nearly all of them are typically Jurassic; though it should be remembered that these are durable fossils such as the teeth and fin-spines of sharks, and the teeth and jaws of Pycnodonts and *Lepidotus*. More delicate skeletons may have been destroyed beyond recognition, as suggested by the discovery of an otolith which may be Clupeoid.[3] Among these fossils, however, both in France and in Switzerland there are a few Selachian teeth[4] so closely similar to those of the Lamnidæ that they evidently indicate the appearance of the modern type of shark which became so abundant and widely spread in the later Cretaceous seas. Well-preserved fishes in another Neocomian formation in the Voirons, Switzerland,[5] include recognisable forerunners of the Chirocentrids (*Spathodactylus neocomiensis*) and Clupeoids (*Crossognathus sabaudianus*, *Clupea antiqua*, and *Clupea voironensis*), those referred to *Clupea* itself showing distinctly the characteristic ventral ridge-scutes. The Clupeoid *Crossognathus* also occurs in the Hilsthon of Hanover, which seems to correspond with the uppermost part of the Weald Clay. The marine fish-fauna of Europe before the end of Wealden times was thus distinctly in advance of the estuarine fauna so far as known, and approached the later Cretaceous fauna in its Lamnid sharks, Chirocentrids, and Clupeoids.

The nearly contemporaneous estuarine deposit on the coast of Bahia, Brazil, to which reference has already been made, shows that the Lower Cretaceous fish-

[1] Cuvier and Valenciennes, Histoire Naturelle des Poissons, vol. xix (1846), p. 160, pl. 565.

[2] M. Leriche, "Sur quelques Poissons du Crétacé du Bassin de Paris," Bull. Soc. Géol. France, [4] vol. x (1910), pp. 455—469, pl. vi.

[3] *Otolithus* (*Clupeidarum?*) *neocomiensis*, F. Priem, "Poissons Fossiles du Bassin Parisien" (Publ. Ann. Paléont., 1908), p. 37, text-figs. 11—14.

[4] *Lamna* (*Odontaspis*) *gracilis*, L. Agassiz, Poiss. Foss., vol. iii (1843), p. 295, pl. xxxvii*a*, figs. 2—4. *Odontaspis macrorhiza* mut. *infracretacea*, M. Leriche, Bull. Soc. Géol. France, [4] vol. x (1910), p. 459.

[5] F. J. Pictet, "Description des Fossiles du Terrain Néocomien des Voirons" (Matér. Paléont. Suisse, ser. 2, 1858), pp. 1—54, pls. i—vii.

fauna of that region was essentially the same as in Europe. According to the discoveries of Mr. Joseph Mawson,[1] it includes such typical survivors of the Jurassic fauna as *Acrodus*, *Lepidotus*, *Megalurus*, and probably *Belonostomus*, besides a few more advanced forms, among which a Chirocentrid (*Chiromystus mawsoni*) and a Clupeoid (*Diplomystus longicostatus*) are clearly recognisable. The only unique fish found here is a gigantic Cœlacanth, *Mawsonia*, as highly specialised as the Upper Cretaceous *Macropoma*. The fish-remains hitherto recorded from the supposed Neocomian of Mexico,[2] the United States,[3] and East Africa[4] are also of an essentially Jurassic facies. It is therefore evident that a specially rapid evolution of sharks, skates, and teleosteans occurred in Middle Cretaceous times.

In conclusion, the author desires to express his thanks to the many friends who have facilitated this work. He is especially indebted to the Director of the Geological Survey, Dr. F. L. Kitchin, and Mr. H. A. Allen; to the President and Committee of the Dorset Field Club, and Captain John E. Acland of the Dorset County Museum; to the late and present Woodwardian Professors at Cambridge, and Mr. Henry Woods of the Sedgwick Museum; to the Curators of the Museums of Devizes, Hastings, Manchester, Sherborne School, Warwick, and York; to the late Mr. Charles Dawson; and to Mr. Reginald W. Hooley. He also owes both the drawings on the plates and the new text-figures to Miss Gertrude M. Woodward.

[1] J. Mawson and A. S. Woodward, "On the Cretaceous Formation of Bahia (Brazil) and on Vertebrate Fossils collected therein," Quart. Journ. Geol. Soc., vol. lxiii (1907), pp. 128—139, pls. vi—viii. See also A. S. Woodward, Quart. Journ. Geol. Soc., vol. lxiv (1908), pp. 358—362, pls. xlii, xliii; and D. S. Jordan, Ann. Carnegie Mus. Pittsburgh, vol. vii (1910), pp. 23—34, pls. v—xiii.

[2] J. Felix, Palæontographica, vol. xxxvii (1891), pp. 189—194, pls. xxviii—xxx.

[3] E. D. Cope, Journ. Acad. Nat. Sci. Philad., [2] vol. ix (1894), pp. 441—447, pls. xix, xx; J. W. Gidley, Proc. U.S. Nat. Mus., vol. xlvi (1913), pp. 445—448, text-figs. 1—4.

[4] E. Hennig, Sitzungsb. Gesell. naturf. Freunde, Berlin, 1913, pp. 309, 315.

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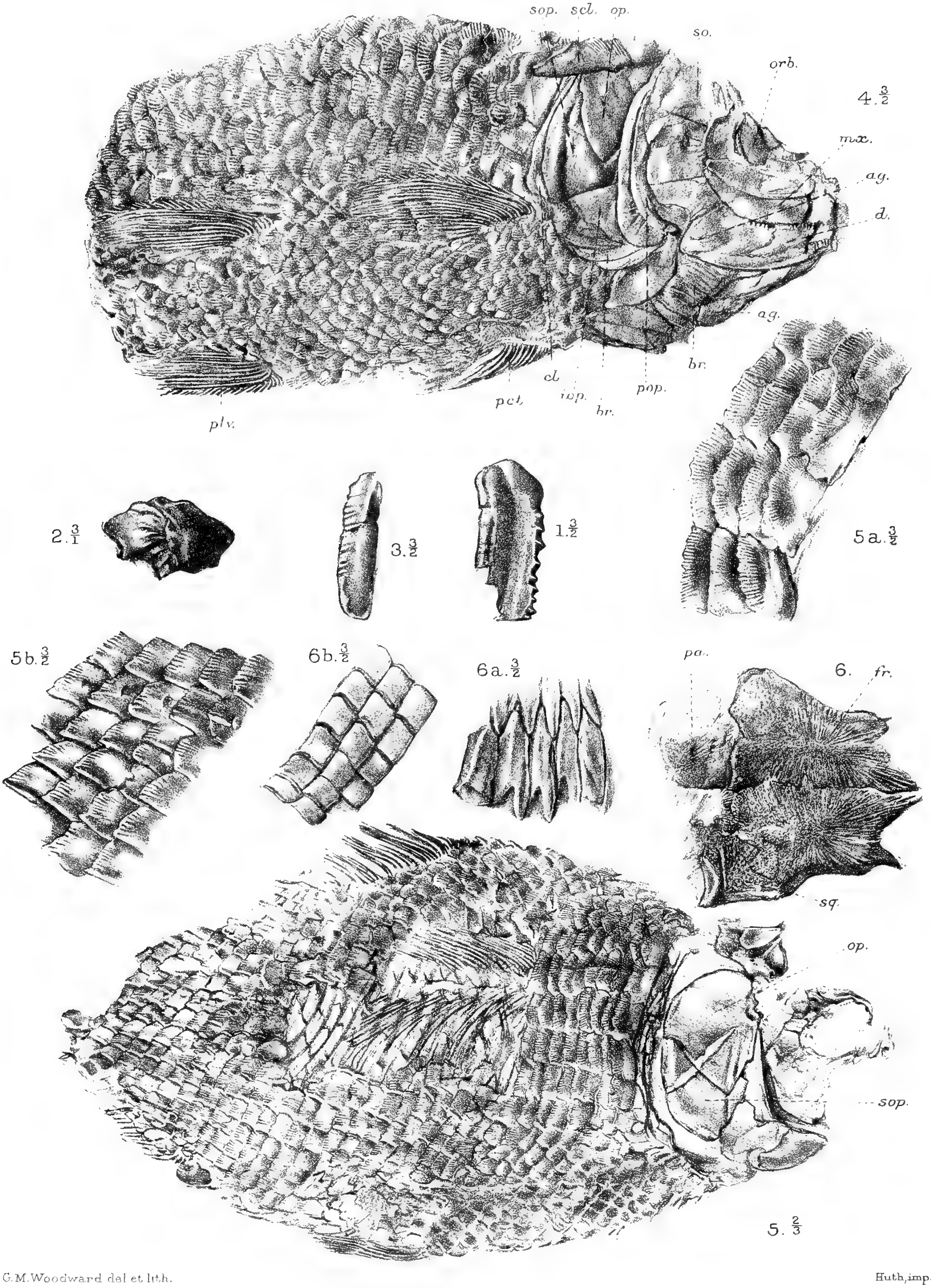
PLATE XXI.

FIG.		PAGE
1.	*Belonostomus hooleyi*, sp. nov.; left flank-scale, outer view, lacking lower end and part of outer face, one-and-a-half times nat. size.—Wealden; Atherfield, Isle of Wight. The type specimen. Collection of Reginald W. Hooley, Esq., F.G.S.	100.
2.	Ditto; dorsal scale, outer view, three times nat. size.—Wealden; Isle of Wight. Mantell Collection (B. M. no. 28419).	100.
3.	Ditto (?); right flank-scale, outer view, one-and-a-half times nat. size.—Wealden; Sevenoaks, Kent. Sedgwick Museum, Cambridge.	101.
4.	*Pholidophorus ornatus*, Agassiz; imperfect head and abdominal region, right lateral and ventral view, one-and-a-half times nat. size.—Middle Purbeck Beds; Swanage, Dorset. Museum of Practical Geology, London, no. 28439. *ag.*, angular; *br.*, branchiostegal rays; *cl.*, clavicle; *d.*, dentary; *iop.*, interoperculum; *mx.*, maxilla; *op.*, operculum; *orb.*, orbit; *pct.*, pectoral fin; *plv.*, pelvic fin; *pop.*, preoperculum; *scl.*, supraclavicle; *so.*, postorbitals; *sop.*, suboperculum.	103.
5.	*Pholidophorus granulatus*, Egerton; greater part of fish, right lateral and ventral view, two-thirds nat. size, with some anterior flank-scales (5 *a*) and some caudal flank-scales (5 *b*), outer view, enlarged one-and-a-half times.—Ibid. Beckles Collection (B. M. no. P. 6379). *op.*, left operculum, inner view; *sop.*, left suboperculum, inner view.	106.
6.	Ditto; portion of roof of skull, upper view, showing frontals (*fr.*), left parietal (*pa.*), and right squamosal (*sq.*), nat. size, with some anterior flank-scales (6 *a*) and caudal scales (6 *b*), inner view, enlarged one-and-a-half times.—Ibid. Enniskillen Collection (B. M. no. P. 3605).	106.

A. S. Woodward, Wealden & Purbeck Fishes. Plate XXI.



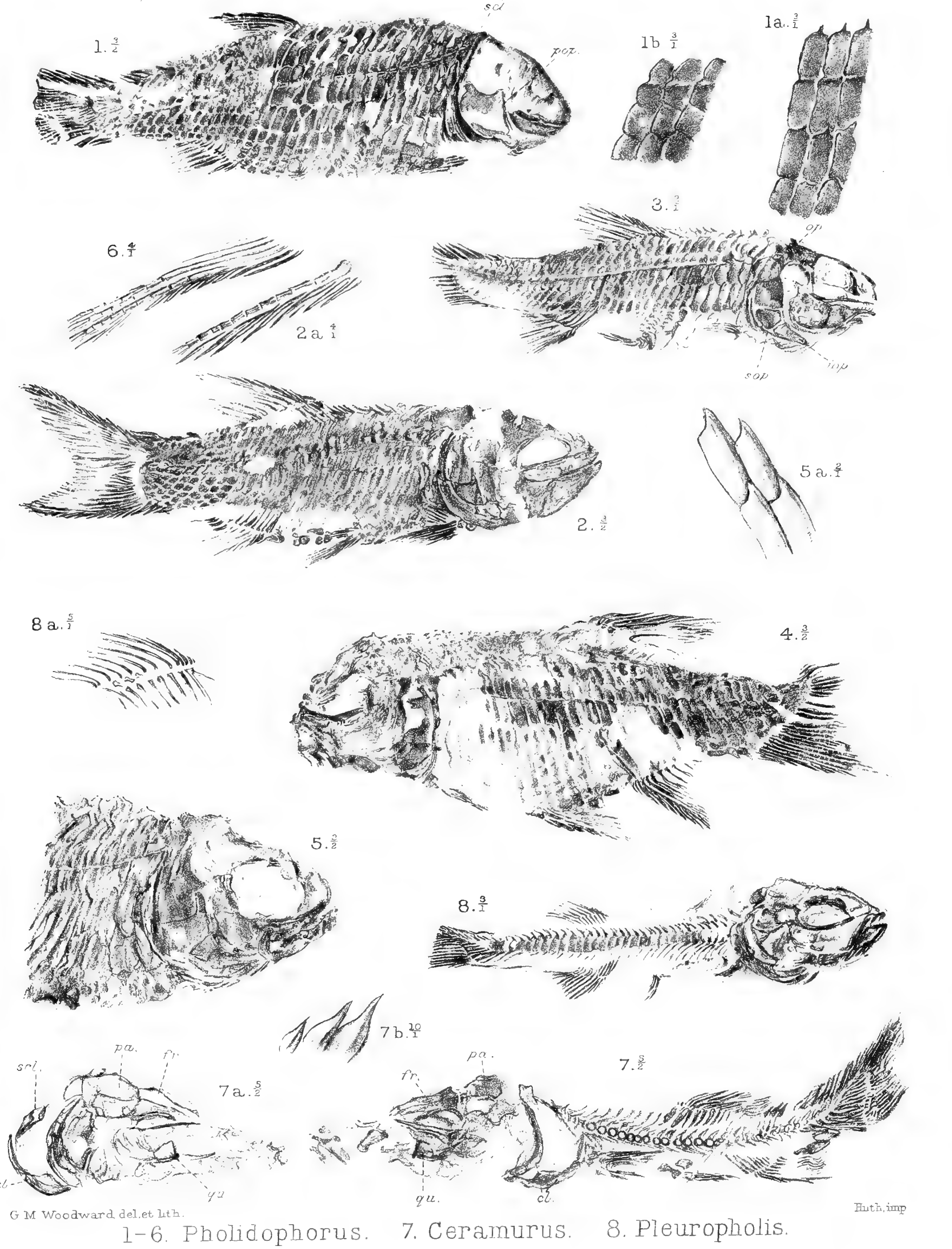
G. M. Woodward del et lith. Huth, imp.

1–3. Belonostomus. 4–6. Pholidophorus.

PLATE XXII.

Fig. | Page.

1. *Pholidophorus purbeckensis*, Davies; imperfect fish, right lateral view, one-and-a-half times nat. size, with some anterior flank-scales (1 *a*) and caudal scales (1 *b*), outer view, enlarged three times.—Lower Purbeck Beds; Isle of Portland. The type specimen. Damon Collection (B. M. no. P. 6171). *pop.*, preoperculum; *scl.*, supraclavicle. 108.
2. Ditto; nearly complete fish, right lateral view, one-and-a-half times nat. size, with foremost anal fin-ray and fulcra (2 *a*) enlarged four times.—Ibid. British Museum, no. P. 8378. 108.
3. Ditto; small fish, right lateral view, twice nat. size.—Lower Purbeck Beds; Teffont, Vale of Wardour, Wiltshire. *iop.*, interoperculum; *op.*, upper part of operculum; *sop.*, suboperculum. P. B. Brodie Collection (B. M. no. P. 7640). 108.
4. *Pholidophorus brevis*, Davies; imperfect fish, left lateral view, one-and-a-half times nat. size.—Upper Purbeck Beds; Upway, near Weymouth. The type specimen. Egerton Collection (B. M. no. P. 1074). 110.
5. Ditto; head and anterior abdominal region, much broken by crushing, one-and-a-half times nat. size, with some flank-scales (5 *a*), inner view, enlarged twice.—Ibid. Enniskillen Collection (B. M. no. P. 3607). 110.
6. *Pholidophorus limbatus*, Agassiz; front of anal fin with fulcra, four times nat. size, for comparison with fig. 2 *a*.—Lower Lias; Lyme Regis, Dorset. Egerton Collection (B. M. no. P. 1047 *b*).
7. *Ceramurus macrocephalus*, Egerton; distorted fish, left lateral view, with counterpart of head (7 *a*), two-and-a-half times nat. size, and three caudal ridge-scales (7 *b*), enlarged ten times.—Middle Purbeck Beds; Dinton, Vale of Wardour, Wiltshire. The type specimen. Brodie Collection. (B. M. no. P. 7639). *cl.*, clavicle; *fr.*, frontal; *pa.*, parietal; *qu.*, quadrate; *scl.*, supraclavicle. 111.
8. *Pleuropholis*, sp.; immature fish, right lateral view, three times nat. size, with dorsal fin (8 *a*) enlarged five times.—Lower Purbeck Beds; Teffont, Vale of Wardour, Wiltshire. Rev. W. R. Andrews' Collection (B. M. no. P. 9846). 117.



G M Woodward del.et lith. Huth, imp

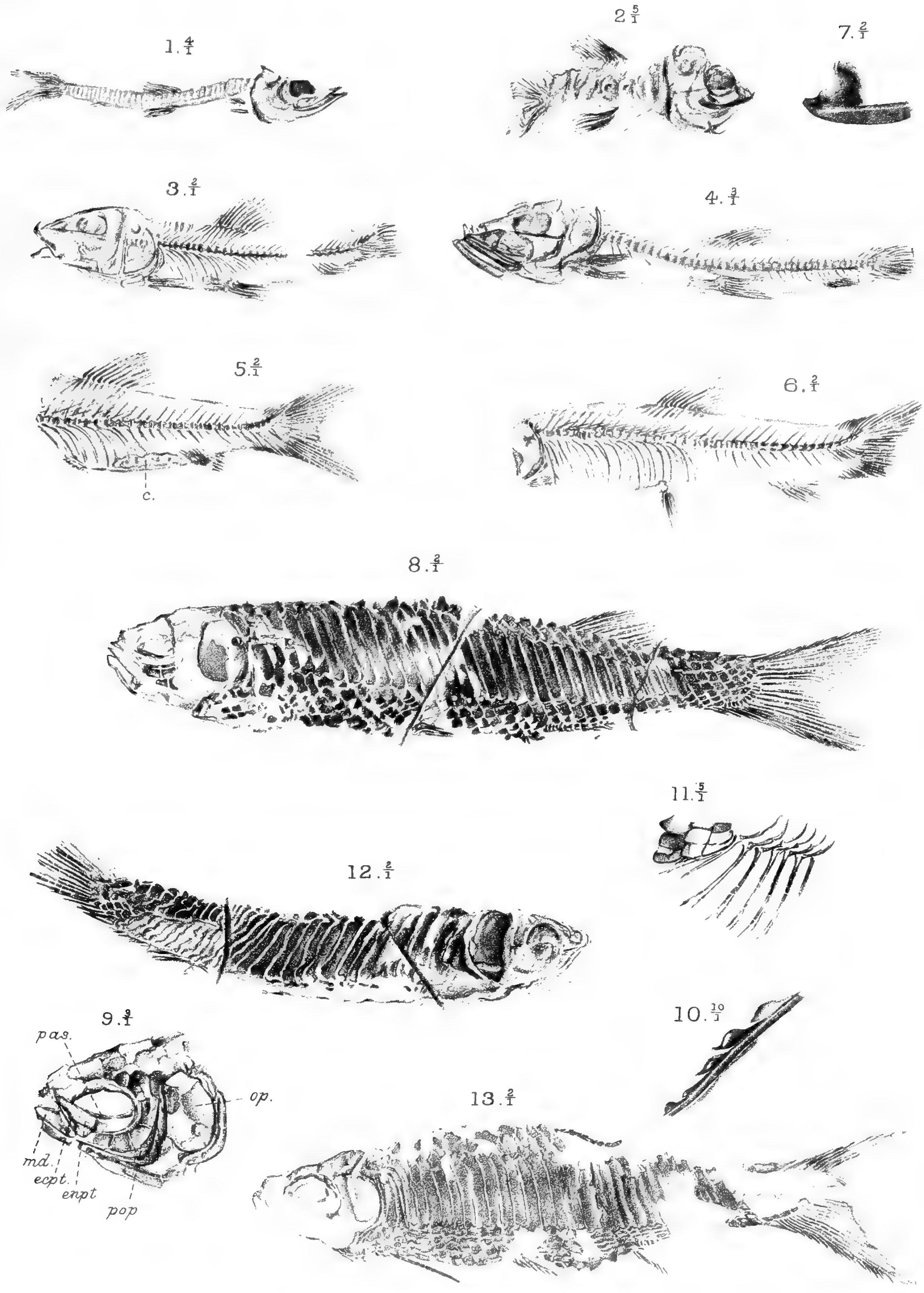
1–6. Pholidophorus. 7. Ceramurus. 8. Pleuropholis.

PLATE XXIII.

Fig.		Page.
1.	*Leptolepis brodiei*, Agassiz; very small immature fish, right lateral view, four times nat. size.—Lower Purbeck Beds; Vale of Wardour, Wiltshire. The type specimen of *Oxygonius tenuis*, Agassiz. P. B. Brodie Collection (B. M. no. P. 4730).	125.
2.	Ditto; immature fish shortened by distortion, right lateral view, five times nat. size.—Ibid. The type specimen of *Leptolepis nanus*, Egerton. P. B. Brodie Collection (B. M. no. P. 7637).	125.
3.	Ditto; fish lacking most of caudal fin, left lateral view, twice nat. size.—Ibid. The type specimen. P. B. Brodie Collection (B. M. no. P. 7635).	123.
4.	Ditto; distorted fish, three times nat size.—Ibid. P. B. Brodie Collection (B. M. no. P. 7635 *a*).	123.
5, 6.	Ditto; two well-preserved specimens of trunk, left lateral view, twice nat. size.—Lower Purbeck Beds; Lime Kiln Quarry, Teffont, Vale of Wardour, Wiltshire. Rev. W. R. Andrews' Collection (B. M. nos. P. 9847, 48). *c.*, coprolitic matter in intestine.	123.
7.	*Leptolepis*, sp.; right dentary bone, inner view, twice nat. size.—Wealden (Wadhurst Clay); Broad Oaks, Brede, near Hastings. Teilhard and Pelletier Collection (B. M. no. P. 11904).	125.
8.	*Pleuropholis formosa*, sp. nov.; nearly complete fish, left lateral view, twice nat. size.—Lower Purbeck Beds; Teffont, Wiltshire. The type specimen. British Museum, no. P. 10986.	115.
9.	Ditto; head, left lateral view, three times nat. size.—Ibid. British Museum, no. P. 10955. *ecpt.*, ectopterygoid; *enpt.*, entopterygoid; *md.*, mandible; *op.*, operculum; *pas.*, parasphenoid; *pop.*, pre-operculum.	116.
10.	Ditto; foremost pectoral fin-ray bearing expanded fulcra, enlarged ten times.—Ibid. British Museum, no. P. 9851.	116.
11.	Ditto; part of anal fin, showing supports, five times nat. size.—Ibid. British Museum, no. P. 10986.	116.
12.	*Pleuropholis crassicauda*, Egerton; imperfect fish, right lateral view, twice nat. size.—Middle Purbeck Beds; Durdlestone Bay, Swanage, Dorset. The type specimen. P. B. Brodie Collection (B. M. no. P. 7647).	118.
13.	Ditto; fish with incomplete fins, left lateral view, twice nat. size.—Ibid. British Museum, no. 43615.	118.

A.S.Woodward, Wealden & Purbeck Fishes.

Plate XXIII.



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Huth imp.

1–7. Leptolepis. 8–13. Pleuropholis.

PLATE XXIV.

Fig.		Page.
1.	*Pleuropholis longicauda*, Egerton; head and abdominal region, left lateral view, nat. size, with some dorsal scales (1 *a*) and some ventral scales (1 *b*) enlarged four times.—Middle Purbeck Beds; Swanage, Dorset. British Museum, no. 40724.	120.
2.	Ditto; imperfect fish, left lateral view, nat. size, with some scales (2 *a*) enlarged twice.—Ibid. British Museum, no. P. 7664.	120.
3.	*Pachythrissops lævis*, sp. nov.; roof of skull, lacking end of snout, nat. size.—Ibid. British Museum, no. P. 12212. *epo.*, epiotic; *fr.*, frontal; *pa.*, parietal; *ptf.*, postfrontal (sphenotic); *socc.*, supra-occipital; *sq.*, squamosal.	129.
4.	Ditto; remains of head and three anterior vertebræ, right lateral view, two-thirds nat. size, with some lower teeth (4 *a*) enlarged twice.—Ibid. Portion of specimen figured as *Lepidotus minor* by L. Agassiz, Poiss. Foss., vol. ii, pt. i (1844), pl. xxix *c*, fig. 12. Enniskillen Collection (B. M. no. P. 4219). *bh.*, basihyal; *br.*, branchiostegal rays; *ch.*, ceratohyal; *d.*, dentary; *ecpt.*, ectopterygoid; *eph.*, front of epihyal; *g.r.*, gill-rakers on gill-arch.	129.
5.	Ditto; middle portion of trunk, right lateral view, nat. size.—Ibid. British Museum, no. 44845. *d.*, dorsal fin-supports and fin; *plv.*, pelvic fin-supports with fins.	132.
6.	*Pachythrissops vectensis*, A. S. Woodward; portion of head, left lateral view, with lower expansion of right preoperculum (6 *a*), one-quarter nat. size.—Weald Clay; Atherfield, Isle of Wight. Collection of Reginald W. Hooley, Esq., F.G.S. *op.*, operculum; *pop.*, pre-operculum; *so.*, postorbital cheek-plates.	134.
7.	Ditto; scale, nat. size.—Ibid. Collection of Reginald W. Hooley, Esq., F.G.S.	136.

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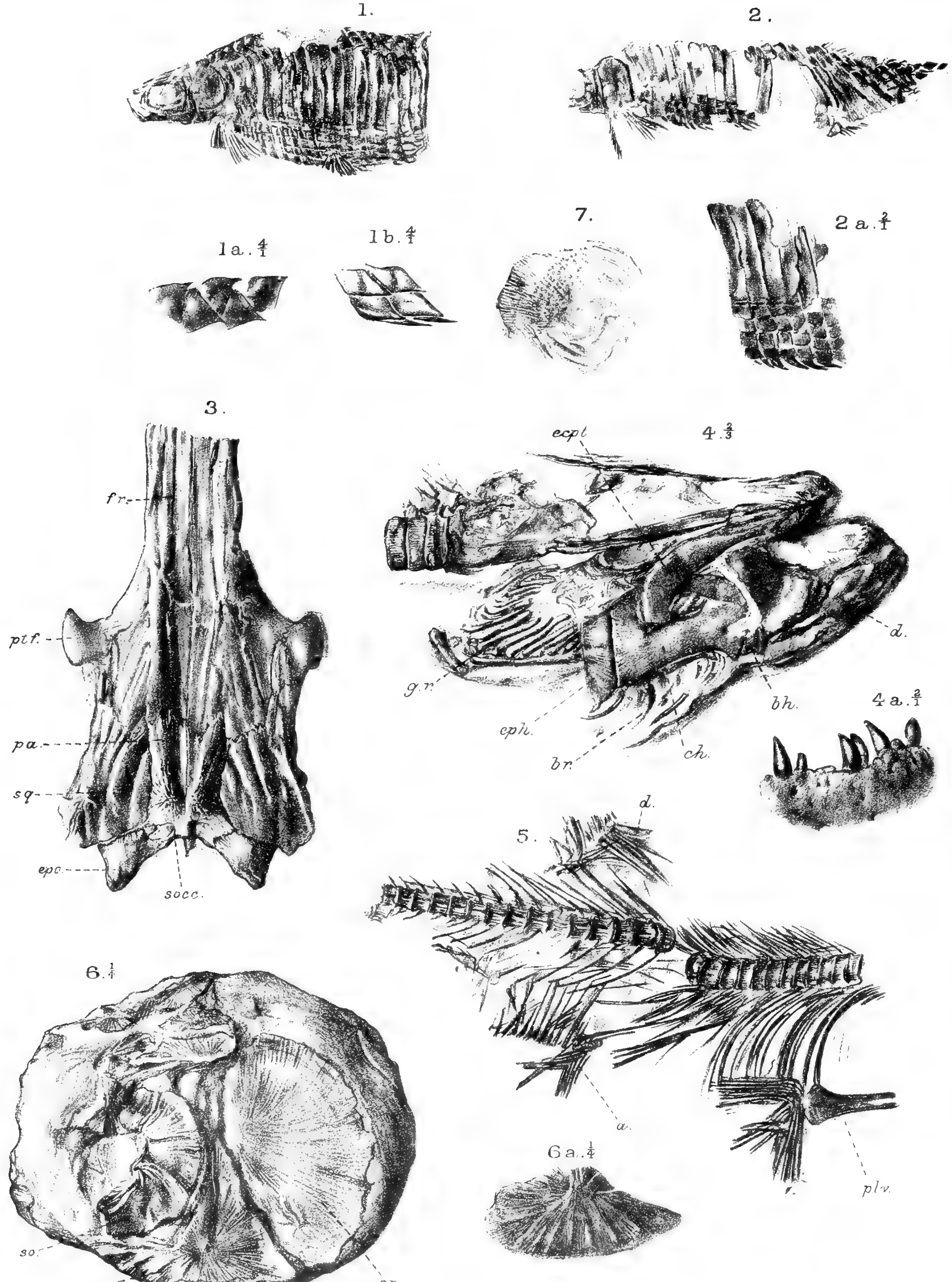
A.S. Woodward, Wealden & Purbeck Fishes. Plate XXIV.



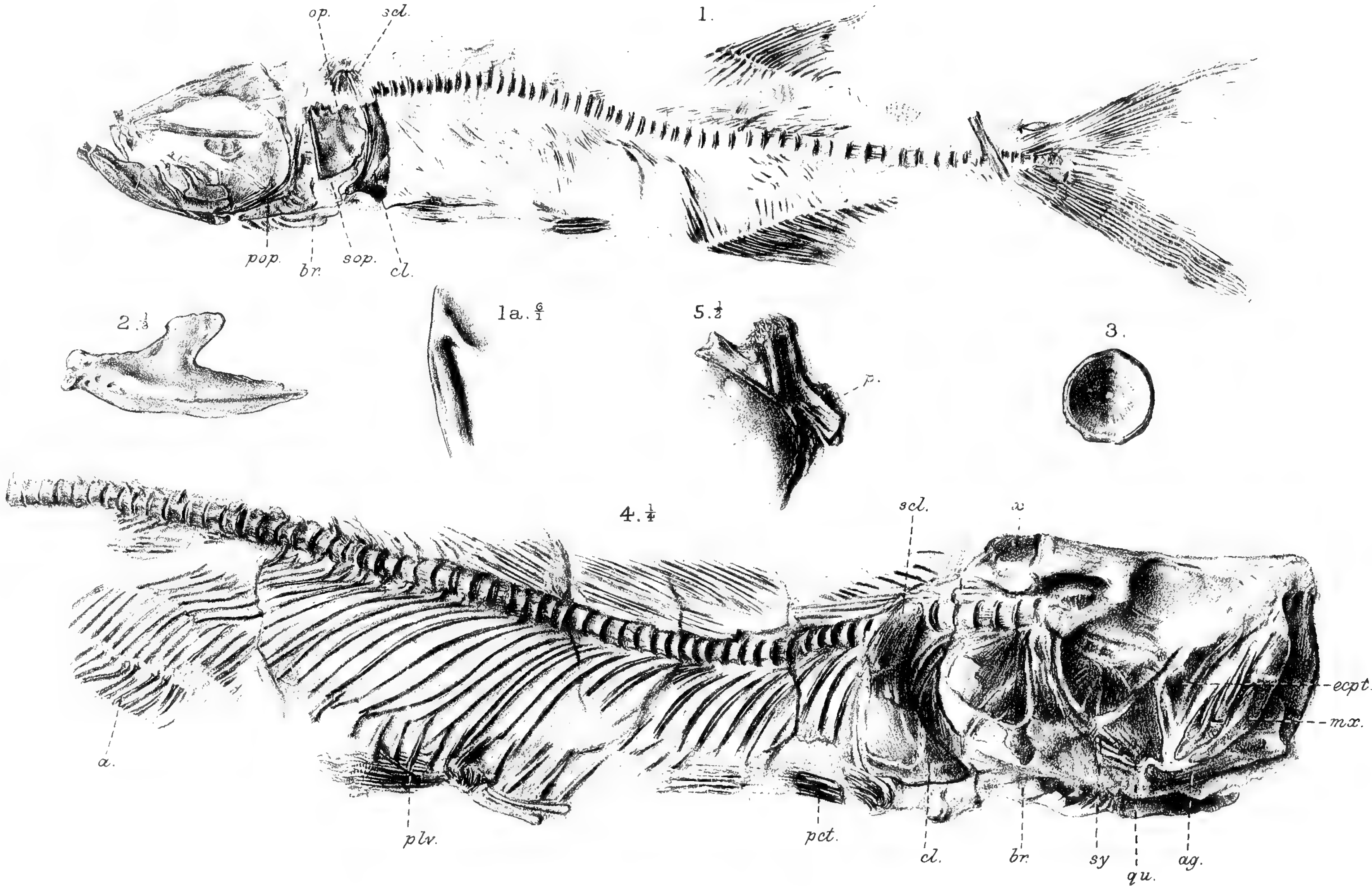
G.M.Woodward del et lith. Huth imp.

1, 2. Pleuropholis. 3–7. Pachythrissops.

PLATE XXV.

Fig.		Page.
1.	*Pachythrissops lævis*, sp. nov.; nearly complete fish, left lateral view, nat. size, with part of operculum (1 *a*) enlarged six times to show slime-pit.—Middle Purbeck Beds; Swanage, Dorset. The type specimen. British Museum, no. 40433. *br.*, branchiostegal rays; *cl.*, clavicle; *op.*, operculum; *pop.*, preoperculum; *scl.*, supraclavicle; *sop.*, suboperculum.	129.
2.	Ditto; left dentary, outer view, one-third nat. size.—Ibid. British Museum, no. 36083.	131.
3.	Ditto; vertebral centrum, end view to show perforation by notochord, nat. size.—Ibid. British Museum, no. 21974.	132.
4.	*Pachythrissops vectensis*, A. S. Woodward; imperfect fish, right lateral view, one-quarter nat. size.—Weald Clay; Atherfield, Isle of Wight. Collection of Reginald W. Hooley, Esq., F.G.S. *a.*, portion of anal fin; *ag.*, angular; *br.*, branchiostegal rays; *cl.*, clavicle; *ecpt.*, ectopterygoid; *mx.*, maxilla; *pct.*, pectoral fins; *plv.*, pelvic fins; *qu.*, quadrate; *scl.*, supraclavicle; *sy.*, symplectic; *x.*, probably post-temporal.	133.
5.	Ditto; upper part of left hyomandibular, outer view, one-half nat. size.—Wealden; Isle of Wight. British Museum, no. 42013. *p.*, process for support of operculum.	134.

 Plate XXV.



G.M.Woodward del. et lith.

Huth imp

Pachythrissops.

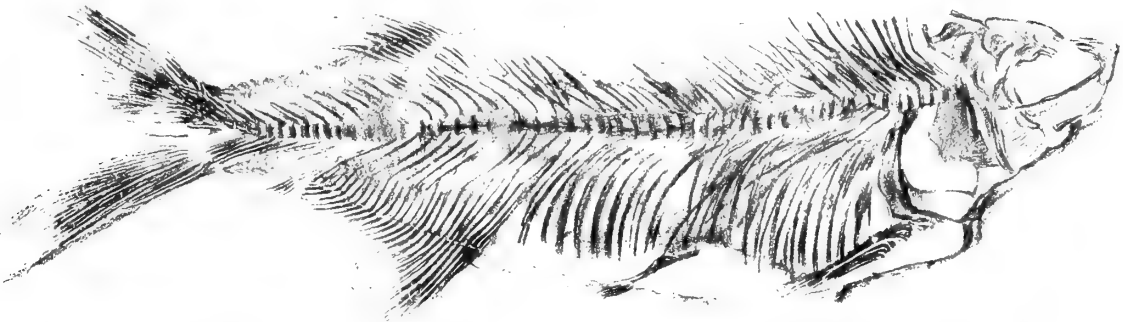
PLATE XXVI.

Fig.		Page.
1.	*Thrissops curtus*, sp. nov.; right lateral view of fish, nat. size.—Lower Purbeck Beds; Isle of Portland. The type specimen. British Museum, no. P. 10612.	137.
2.	*Thrissops molossus*, sp. nov.; left lateral view of fish, two-fifths nat. size. —Middle Purbeck Beds; Swanage. British Museum, no. P. 417 *a*.	138.
3.	*Hybodus basanus*, Egerton; cranium, upper and (3 *a*) posterior views, one-half nat. size.—Weald Clay; Atherfield, Isle of Wight. Collection of Reginald W. Hooley, Esq., F.G.S. *f.m.*, foramen magnum; *n.*, pit for notochord; *p.f.*, posterior fossa or fontanelle; *v.*, pair of pits into which the vagus nerves probably opened.	139.
4.	*Lepidotus minor*, Agassiz; imperfect fish, left lateral view, showing dorsal fin, one-third nat. size.—Middle Purbeck Beds; Swanage. British Museum, no. P. 12211.	140.

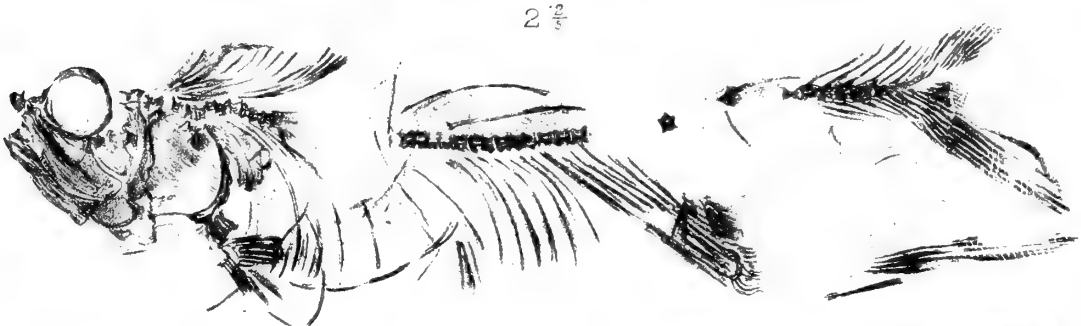
A. S. Woodward, Wealden & Purbeck Fishes.

Plate XXVI

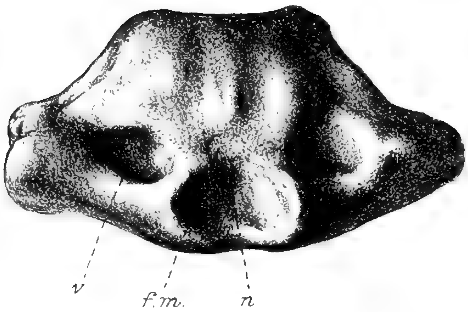
1.



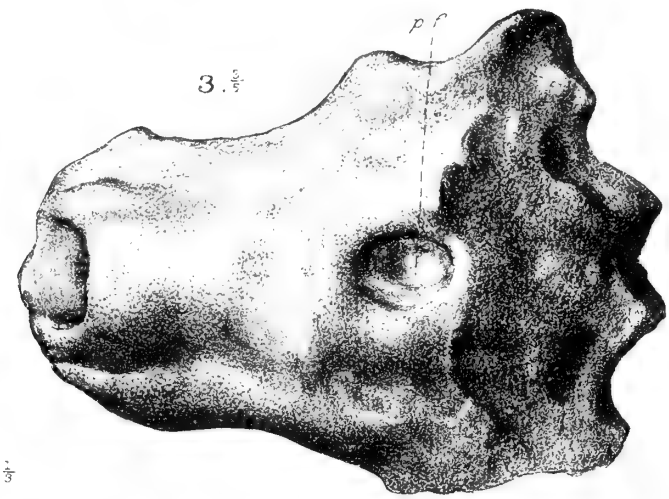
2 $\frac{2}{5}$



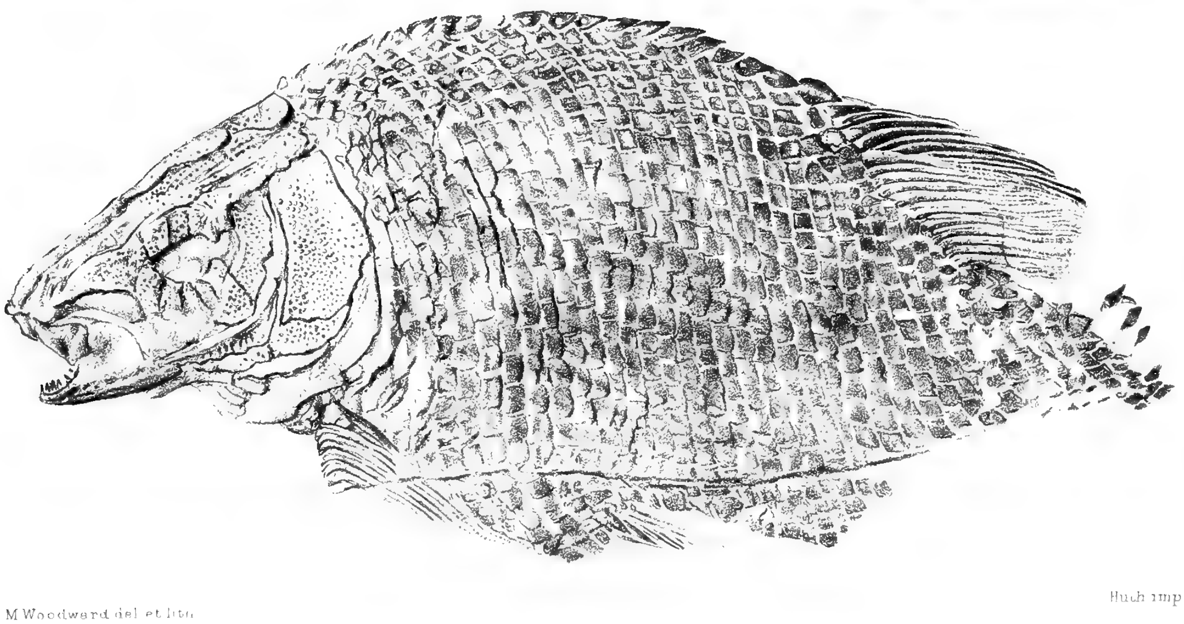
3 a. $\frac{3}{5}$



3. $\frac{3}{5}$



4. $\frac{1}{3}$



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1, 2. Th[illegible] 3 Hybodus. 4 Lepidotus

Palæontographical Society, 1917.

THE PLIOCENE MOLLUSCA OF GREAT BRITAIN,

BEING SUPPLEMENTARY TO

S. V. WOOD'S MONOGRAPH OF THE CRAG MOLLUSCA.

BY

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INDEX.

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Palæontographical Society, 1917.

A MONOGRAPH

OF THE

BRITISH PALÆOZOIC

ASTEROZOA

BY

W. K. SPENCER, M.A., D.Sc. (Oxon.), F.G.S.

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characters of the adambulacralia. These ossicles are extremely broad, with an oral surface scarcely above the level of the cross-ridge of the ambulacralia, and with a characteristic ornament (Text-figs. 118, 119, p. 174). The alignment of the ambulacralia with the adambulacralia makes the groove very shallow, and the oral surface of the arm flat. This, with the petaloid shape of the arm, produces a leaf-like appearance suggesting the generic name *Platanaster* for the Ordovician form (πλάτἄνος, a plane tree, so called from its broad, flat leaf).

Although both *Platanaster ordovicus* and *Palasteriscus devonicus* have the same peculiar adambulacralia, which, with other characters, show that they belong to one and the same small branch of the Asterozoa, they differ in other ways so considerably that one is loth to follow one's first inclination and put them in the same genus, regarding one species as the ancestor of the other. The earlier form has well-defined infero-marginalia which are lacking in the later species. This in itself would not be an insuperable objection to placing the forms on the same exact line of descent, for it is possible that infero-marginalia may be lost during lineage evolution. A far greater difficulty is the position of the madreporite. In the Ordovician species this plate is apical and marginal, while in the Devonian species it is oral and quite near the mouth. Following the line of argument developed later (pp. 178–182), one would place the first form, with its fused arm-bases (Text-fig. 114, p. 172) and its apical madreporite, with the Asteroidea. It is difficult to explain the position of the madreporite in the later form except by the supposition that its arms never fused at their bases, and so allowed a secondary growth of the apical interradii to carry the madreporite on to the oral surface. This would place *Palasteriscus devonicus* among the Ophiuroidea, and we should have the paradox of two nearly related forms belonging apparently to distinct branches of the Asterozoa.

Fortunately, we have other series of related forms which show similar phenomena. The arms of *Stenaster* often approximate at their bases because their adambulacralia are so very broad. This character causes fusion of the arm-bases of *Monaster*, which, according to Schuchert, is allied to *Stenaster*. The madreporite remains in consequence apical and marginal in this latter form. On the other hand, *Aspidosoma*, a near ally of *Stenaster*, has unfused arm-bases, and a downgrowth of the apical interradii, which carries the madreporite to an oral position.

We can only suppose that among the earliest Asterozoa the impulse to become definitely either Asteroidea or Ophiuroidea was not fixed. I have suggested below (p. 195) that the "Asteroid" character of fusion of the arm-bases and the "Ophiuroid" character of downward growth of the apical interradii are both brought about by feeding habits. According to my interpretation, *Platanaster ordovicus* is a form which has specialised in ciliary feeding, and has developed a large ciliary area by increasing the surface of the infero-marginalia, which in consequence meet along the interradii, while *Palasteriscus devonicus* is descended from a nearly related form with infero-marginalia small or absent, which has taken to mud-eating; its stomach has become enlarged, and the apical interradii have had to grow outwards to accommodate it.

There can be no doubt that the Platanasteridæ branched off from the Asterozoan stem at a very early date, and had reached a high stage of development in the Ordovician. That the family is far advanced in its lineage history is shown by:

(1) The large size of the species. The type is the largest English species of its time, and only the American Ordovician species of *Promopalæaster* approach it in size.

(2) The petaloid nature of the arms. Ruedemann (97, p. 35) has shown that this is a gerontic character in *Devonaster*.

(3) The enlarged mouth-angle plates comparable with those of *Promopalæaster* (compare Text-fig. 55, p. 96).

On the other hand the proximal ambulacralia are in a primitive condition. Usually among the Asterozoa the first ambulacralia are thickened and help to form a continuous ring-shaped mouth-frame. Here they are not thickened, and diverge very considerably from the radial line, forming a deep V in each radius. Similar divergent proximal ambulacralia are found in many other primitive Asterozoa, and Bather (89, p. 165, fig. 3) has figured divergent ambulacralia as a character of *Edrioaster*.

The diagnostic characters of the two genera are as follows:

Platanaster.—Arms fused at the base. Stout infero-marginalia present. Madreporite apical.

Palasteriscus.—No infero-marginalia. Madreporite oral.

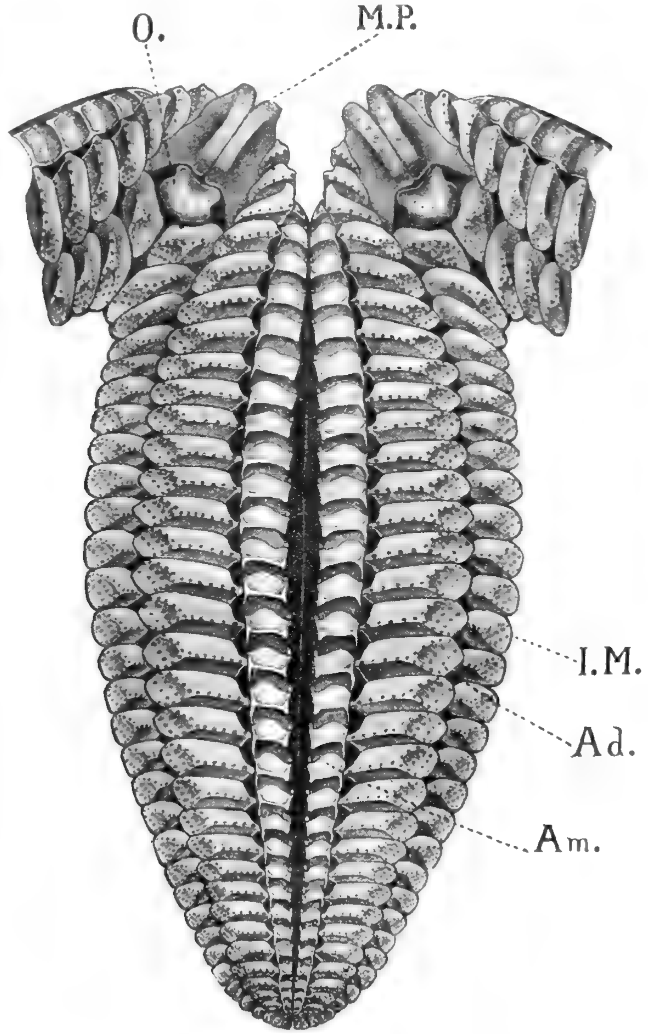
Genus **PLATANASTER**, novum.

Generic Characters.—As above.

1. **Platanaster ordovicus,** n. sp. Plate XIV, figs. 1—3; Text-figs. 114–118, 120, 121.

Material.—One well-preserved impression with counterpart in the collection of the Museum of Practical Geology, Jermyn Street, no. 8238 (mould of apical surface) and no. 25347 (mould of oral surface).

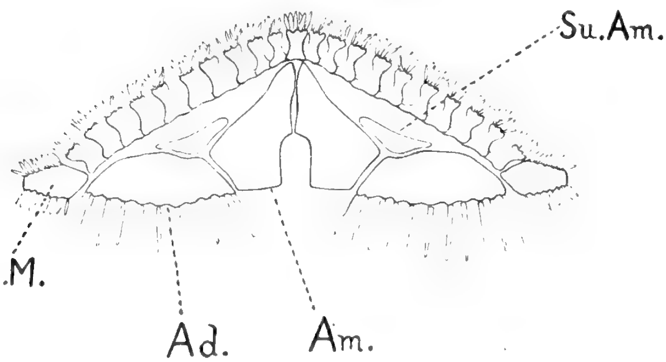
General Appearance (Text-fig. 114).—Text-fig. 114 is a reconstruction of one arm and the neighbouring interradii. The form is so well preserved that the figure is almost an exact drawing from a cast of the specimen. The broad petaloid shape of the arm is brought about by three factors—the great breadth of the adambulacralia, the spindle shape of the deep ambulacral channel, the decrease in size of both the ambulacralia and adambulacralia from about the middle length of the arm in both a proximal and distal direction. The first two infero-marginalia are incorporated in the disc. In front of these is a prominent breast-plate-shaped odontophor. The mouth-angle plates are very large and extend backwards as far as the third adambulacral. The cross-section of the arm, given as Text-fig. 115,



Text-fig. 114.—Slightly reconstructed drawing of the oral view of an arm and a portion of the disc of *Platanaster ordovicus*. *Ad.*, adambulacral; *Am.*, ambulacral; *I.M.*, infero-marginal; *M.P.*, mouth-angle plate; *O.*, odontophor. × 3.

shows the shallowness of the groove, the great depth of the ambulacral channel, and the apical covering of uniformly sized paxillæ.

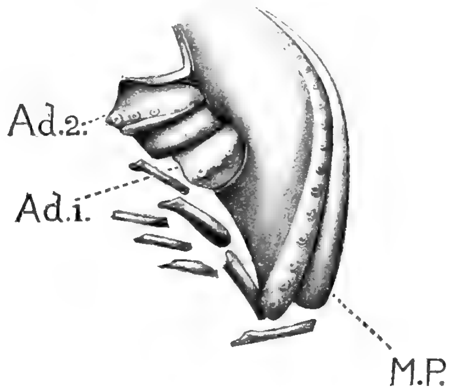
Oral Surface (Text-figs. 116—119).—The mouth-angle plates are high, narrow wedges which project well beyond the proximal limits of the groove into the mouth-cavity. The proximal extremity of each plate rises steeply and carries a row of spine-pits along its adoral edge. Stout spines, which once fitted on these, still remain scattered between the plates. The slightly swollen inner surface is excavated for the attachment of the first three adambulacralia. The third adambulacral has fallen away in the mouth-angle drawn (Text-fig. 116), but can be seen in Text-fig. 117, which is an aboral view of another mouth-angle. The clearest views of the distal extremities of the mouth-angle plates are given in Text-fig. 114. Here they are deeply hollowed, and the odontophor fits across the wide triangular space thus formed. The upward tilt of the adoral surface of the mouth-



TEXT-FIG. 115. - Cross-section through the arm of *Platanaster ordovicus*. *Ad.*, adambulacral; *Am.*, ambulacral; *I.M.*, infero-marginal; *Su. Am.*, super-ambulacral. × 5.

angle plates, as shown in the figures, suggests that the form was preserved while the external interdental muscles were in a state of contraction (Text-fig. 134, *D. musc.*$_2$, p. 193).

The ambulacral groove is wide and petaloid. The broad, short adambulacralia are very slightly higher than the ridges of the ambulacralia. A view of the ossicles



TEXT-FIG. 116.—Adoral view of an angle of the mouth-frame of *Platanaster ordovicus*. *Ad.*$_1$ and *Ad.*$_2$, the first two adambulacralia; *M.P.*, mouth-angle plate. × 10.

of the groove showing full details is given (Text-fig. 118). The ambulacral channel is deep and has precipitous sides. The concavities for the transverse muscles are well marked, suggesting that they were strong. There is a marked overlap of the ambulacralia, which takes the form of a wide curved peg much as in *Stenaster* (compare with Pl. I, fig. 6). The ridges across the ambulacralia are as described for *Schuchertia* (p. 183). Slight pustular elevations are seen on some of the outer extremities of the ridges of the ambulacralia. Bather has noted (91, IV, p. 123) that the ridge on the flooring plates of *Edrioaster bigsbyi* may be broken up into a row of tubercles. These are the only two instances of this character I have met with among the Echinodermata. There are no pores for the passage of ampullæ.

The noses of the adambulacralia fit on large triangular faces at the outer edges

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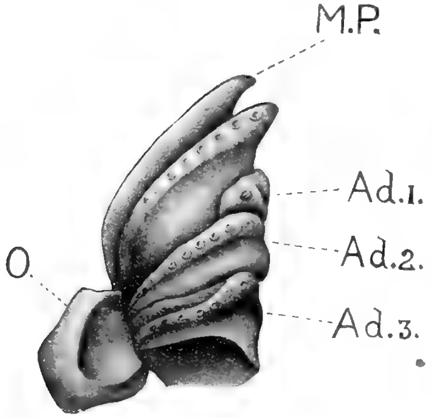

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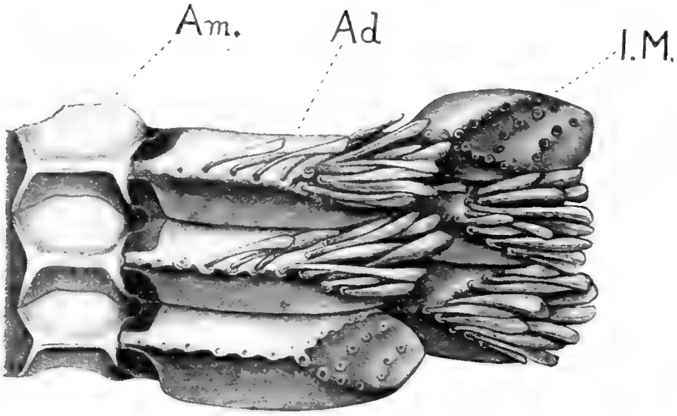
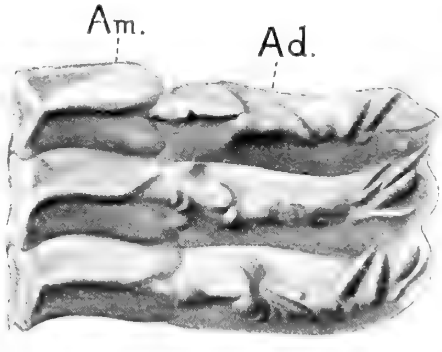


TEXT-FIG. 117.—Enlarged view of a mouth-angle of *Platanaster ordovicus*. *Ad.*$_1$, *Ad.*$_2$, *Ad.*$_3$, first, second and third adambulacrals; *M.P.*, mouth-angle plate; *O.*, odontophor. × 8.

TEXT-FIG. 118.—Enlarged view of a portion of the groove and neighbouring ossicles of *Platanaster ordovicus*. *Ad.*, adambulacral; *Am.*, ambulacral; *I.M.*, infero-marginal. × 10.

of the ambulacralia. Between the noses are shallow depressions for the tube-feet. Each nose is continued as a sharp ridge across the adambulacral for about two-thirds of the breadth of the ossicle, after which the ridge broadens and dies gradually away, forming an outer triangular area which carries oblique transverse rows of

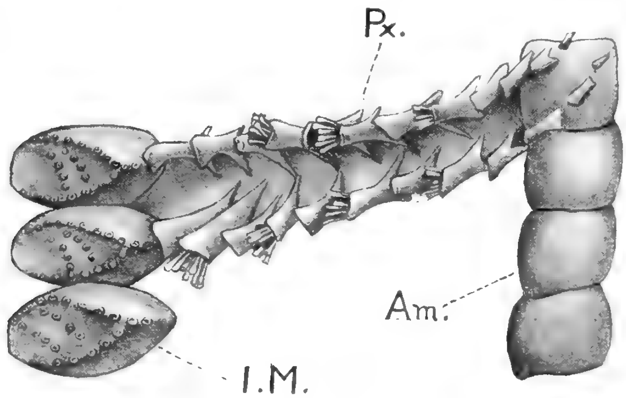


TEXT-FIG. 119.—Enlarged view of a portion of the groove and neighbouring ossicles of *Palasteriscus devonicus*. *Ad.*, adambulacral; *Am.*, ambulacral. × 4.

spines. Single spines are carried by the ridge right up to the point where the nose fits on to the ambulacral. The occurrence of these inner spines is interesting, because it shows that the linear arrangement of the ambulacralia and adambulacralia is a natural one, and not due to the collapse outwards of the adambulacralia after death. If during life the adambulacralia had stood, as is usual, at more or less a right angle to the ambulacralia, the walls of the groove would have been very steep and the spines unnecessary. A widely open groove would necessitate, on the contrary, the protection of the tube-feet by spines carried in the fashion described.

The adambulacralia are closely touching and slightly ridged at their points of contact. It is difficult to imagine that the arms had much power of flexion. At one point the ambulacralia and adambulacralia have been pushed away by post-mortem disturbance, and the base of a super-ambulacral plate is seen.

The infero-marginalia throughout the greater part of the length of the arms are closely-fitting plates alternating with the adambulacralia. They possess a large outer flat area ornamented with pustules, and a small inner sunk unornamented area. At the extreme tip of the arm they become globular. The two infero-marginalia which meet at the base of the arm are the largest and are sickle-shaped (Text-fig. 114). Just within the disc are two large plates

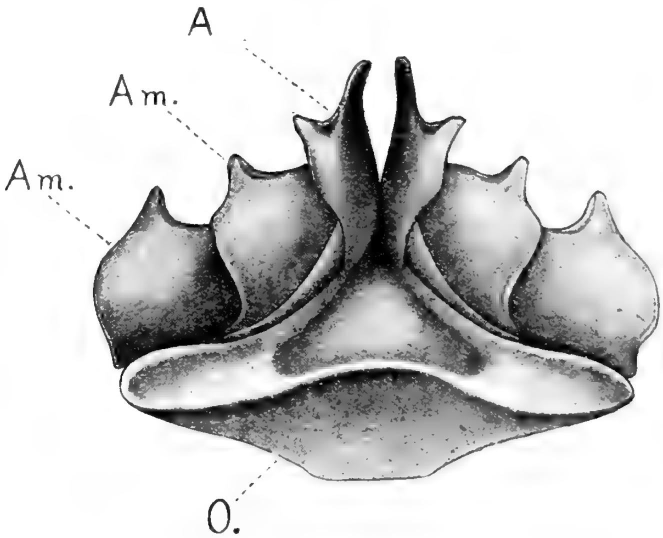


TEXT-FIG. 120.—Drawing of a portion of the apical surface of *Platanaster ordovicus*. *Am.*, ambulacral; *I.M.*, infero-marginal; *Px.*, paxilla. × 12.

which suggest, both by general appearance and ornament, that they are infero-marginalia incorporated into the disc by fusion of the arms at the base. The main axis of these plates is also sickle-shaped.

Apical Surface (Pl. XIV, fig. 1; Text-figs. 120, 121).—A side view of the original impression of the form shows that the broad bordering plates are the infero-marginalia. The apical surfaces of these are very similar to the oral faces described already. The remaining portion of the apical surface was originally covered with long slender paxillæ in rows alternating with the infero-marginalia. The paxillæ have fallen away from the central portions of the disc and exposed the mouth-frame. The proximal ambulacralia distinctly diverge, forming descending V's along the radii (Pl. XIV, fig. 1) and ascending Λ's along the interradii. Text-fig. 121 shows one of these ascending Λ's. The tip is occupied by the highest portions of the mouth-angle plates; the greater part of these plates lies too low to be in view. The groove pointed to by the dotted line reaching to the letter *A* is the groove for the water-vascular ring-canal. The canal was plainly carried along the top of the ambulacralia constituting the V. The course of this channel was not recognised, however, until the figure had been drawn, and it is not shown. The Λ is kept in position by the odontophor, which has wide flanges fitting against outer flanges of the ambulacralia. The intimate connection and close fitting of these components suggest that the odontophor played a very important part in holding the mouth-frame together.

Here and there accessory stiffening plates (Text-fig. 115) are exposed. I have termed these "superambulacralia," after the plates of similar function in the recent *Astropecten*. The madreporite is a long, roughly elliptical plate, situate near the margin (Plate XIV, fig. 1). The madreporiform markings are faint.



TEXT-FIG. 121.—Wash drawing of the apical view of the interradial mouth-region of *Platanaster ordovicus*. *A.*, ascending limit of the mouth-angle plate ; *Am.*, ambulacral ; *O.*, odontophor. × 10.

Measurements.—R : r : : 43 mm. : 15 mm. Width of arm at the base is 17 mm.

Horizon and Locality.—Upper Ordovician (Caradocian) of Cound, Madeley, Shropshire.

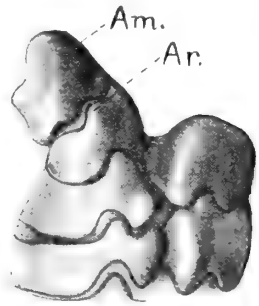
Genus **PALASTERISCUS**, Stürtz.

1886. *Palasteriscus*, Stürtz, Palæontographica, vol. xxxii, p. 95.
1890. „ Stürtz, Palæontographica, vol. xxxvi, pp. 223–225.
1893. „ Stürtz, Verhandl. Naturh. Ver. preuss. Rheinl., Jahrg. 50, pp. 44, 61.
1900. „ Gregory, Lankester's Treat. Zool., vol. iii, Echinoderma, p. 257.
1914. „ Schuchert, Fossilium Catalogus, Animalia, pt. 3, pp. 5, 8, 32.
1915. „ Schuchert, Bull. 88, U.S. Nat. Mus., pp. 44, 199, 200, 252.

Generic Characters.—No infero-marginalia. Madreporite oral.

Stürtz, as was his custom, tried to establish relationships of his genus with recent Asteroidea. At first (1886) he thought that these were with *Asterina* and *Palmipes* (=*Asteriscus*, Müller and Troschel), but later (1890) he decided that its real kinship was with *Solaster* and *Valvaster*, and as these were put in the recent family, the Echinasteridæ, he founded for it a new family, the Palæchinasteridæ. Gregory (1900) founded the family Palasteriscidæ for *Palasteriscus* and *Echinasterella*. Schuchert (1914) enlarged Gregory's family by the addition of *Cheiropteraster* and *Loriolaster*. The structure of these latter three genera will be dealt with later. They have a very different structure from that of *Palasteriscus*.

The only species is *Palasteriscus devonicus*, Stürtz, from the Lower Devonian slates of Bundenbach, Germany.[1] Three specimens, including Stürtz's type, are preserved in the British Museum (Nat. Hist.) nos. E. 3466 (the type), E. 3407, and E. 5026. A drawing of the ambulacralia and adambulacralia of E. 3407 is given here (Text-fig. 119, p. 174) to show the exact correspondence of these ossicles with those of *Platanaster ordovicus*. There are no infero-marginalia in



TEXT-FIG. 122.—Apical view of the ambulacralia of *Palasteriscus devonicus*. *Am.*, ambulacral; *Ar.*, forwardly projecting peg. × 10.

this species as there are in the earlier form. The photograph of the apical side of E. 5026 (Pl. XIV, fig. 4) shows transverse rows of paxillæ and broad petaloid arms—characters not shown in Stürtz's figures drawn from the type. It is possible that the form of the arm, as seen in the photograph, is somewhat over-emphasised by dorso-lateral compression, and that originally the arm was more rounded.

The apical surfaces of the ambulacralia show that the dorsal longitudinal muscles had increased their power beyond that observable in the Ordovician species. The closely fitting plates of *Platanaster ordovicus* (Text-fig. 120, p. 175) are replaced by ossicles which have a distinct peg-and-socket fitting. The development is comparable to that observed in *Schuchertia* (compare with Text-fig. 126, p. 186, and Text-fig. 127, p. 187). Measurements give R as approximately 140 mm. The large madreporite is 22 mm. long.

[1] *Loc. cit.*, vol. xxxii (1886), p. 95, pl. xiv, fig. 1; vol. xxxvi (1890), pp. 223–225, pl. xxviii, fig. 23, pl. xxix, fig. 24.

Section E.—Family Eoactinidæ, nova.

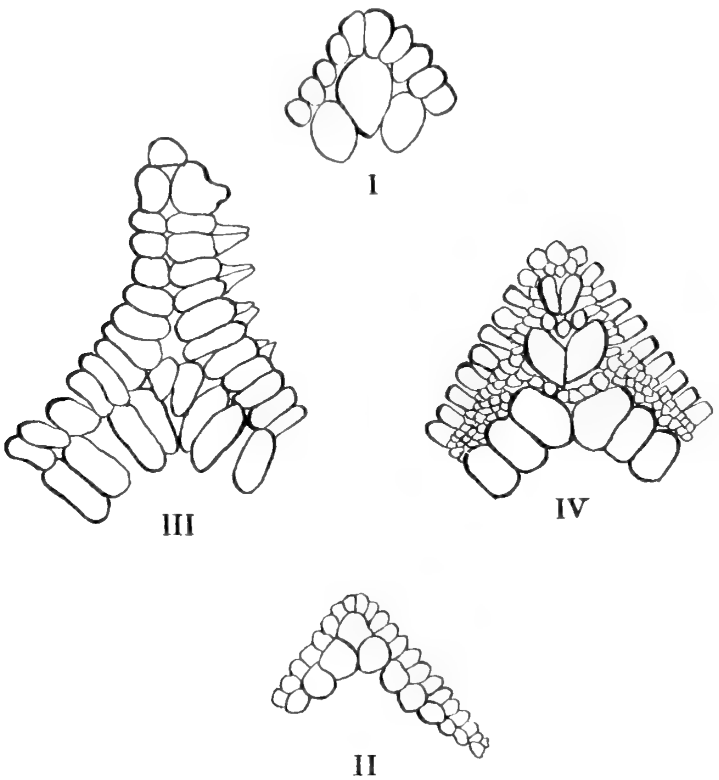
1890. *Palæasterinidæ,* Stürtz, Palæontographica, vol. xxxvi, p. 246 (contains *Palasterina*).
1899. „ (pars), Gregory, Geol. Mag., dec. iv, vol. vi, p. 348 (contains *Palasterina, Schœnaster, Schuchertia*).
1899. *Lindstromasterinæ* (pars), Gregory, Geol. Mag., dec. iv, vol. vi, p. 346 (contains *Lindstromaster* and *Uranaster*).
1910. *Palasterinidæ,* Schöndorf, Jahrb. nassauisch. Ver. Naturk., Wiesbaden, vol. lxiii, p. 220.
1914. „ (pars) Schuchert, Fossilium Catalogus, Animalia, pt. 3, p. 7 (contains *Petraster, Lindstromaster, Palasterina, Uranaster, Palæostella, Pseudopalasterina*).
1914. *Schuchertiidæ,* Schuchert, Fossilium Catalogus, Animalia, pt. 3, p. 8 (contains *Schuchertia*).
1915. *Palasterinidæ* (pars), Schuchert, Bull. 88, U.S. Nat. Mus., p. 138.
1915. *Schuchertiidæ,* Schuchert, Bull. 88, U.S. Nat. Mus., p. 194.

Diagnosis.—Interbrachial areas occupied by downgrowths of the apical interradii separating the bases of the arms. Madreporite oral. (*These characters are those distinctive of the Ophiuroidea, see below.*) Ambulacral channel open to exterior, ambulacralia not modified into vertebræ. (*These characters distinguish the Eoactinidæ from the recent Ophiuroidea and from the Palæozoic Ophiuroidea which have been termed Auluroidea.*) Adambulacralia usually broad and possessing broad surfaces of contact with their neighbours. When they form the oral margin of the arms they never occupy the whole of the lateral surface—that is, never are side plates. (*These characters distinguish the Eoactinidæ from other Palæozoic Ophiuroidea which possess an open ambulacral channel and ambulacralia not modified into vertebræ.*)

This section contains a number of forms of distinct Asteroid shape which up to the present have been regarded as Asteroidea, *e.g. Eoactis, Schuchertia* and *Palasterina.* They seem to be rather "Asteroid" forms which lie at the base of the Ophiuroidea.

In order to make this clear it is necessary to examine closely the exact differences between the Asteroidea and the Ophiuroidea. It is usual and natural for authors well acquainted with the living forms, when stating the differences between the two groups, to lay great emphasis upon the adaptations which the Ophiuroidea show for the wriggling habit. Thus MacBride states (43, p. 477) in respect to the Ophiuroidea that "like the Asteroidea, they are 'starfish,' that is to say, they consist of a disc and of arms radiating from it; but the scientific name Ophiuroidea really represents the great dominating feature of their organisation. Literally it signifies 'Snake-tail' (ὄφις snake; οὐρά tail), and thus vividly describes the wriggling, writhing movements of the long thin arms, by means of which the Ophiuroid climbs in and out of the crevices between the stones and gravel in which it lives. This feature, viz. the effecting of movement by means of muscular jerks of the arms instead of by the slow protrusion and retraction of the tube-feet, is the key to the understanding of most of the points wherein the Brittle Stars differ from the true starfish."

We should expect to find, when we study the fossil Asterozoa, primitive forms which would be near the stage at which the Ophiuroidea and the Asteroidea took their different paths of evolution. These forms would not, as yet, have pronounced distinctive habits; that is, the Ophiuroidea would not have acquired the long thin arms peculiarly adapted for wriggling. We must find, therefore, some more delicate test when dealing with the primitive forms. It seems to me that the manner of growth of the disc is such a test, although it must be noted that even this breaks down when applied to the most primitive forms (see above, p. 170). Nevertheless, until some better means be devised this test must be followed, and,



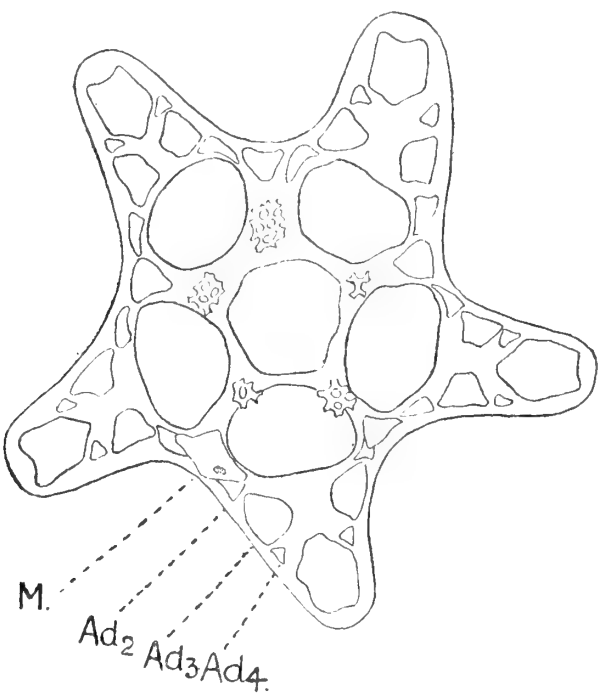
TEXT-FIG. 122*a*.—Diagrams illustrating the increase of growth of the disc in the Asteroidea. *I.* An angle of the disc of one of the Hudsonasteridæ. The bases of the arms are unfused, as shown by the entire separation of the proximal infero-marginalia by the median egg-shaped odontophor. *II.* In the Mesopalæasteridæ the first infero-marginalia of neighbouring arms have been brought together by the beginnings of arm-fusion, and have enclosed the odontophor. *III.* In *Promopalæaster bellulus* the fusion of the base of the arms is shown by the approximation of several of the adambulacralia. *IV.* In *Xenaster margaritatus* the arms have fused as far as the third infero-marginal. The incorporated infero-marginalia are still clearly distinguishable. (This figure is reproduced from Text-fig. 32, p. 62, of this monograph.)

as I hope to show, it serves adequately to separate and illuminate the great mass of the Asterozoa. Let us consider first the growth of the disc in the Asteroidea.

The most primitive Asteroidea have a very small disc with few plates (Section A, Text-figs. 34, 38, and Pls. II, III). In the Hudsonasteridæ (Text-fig. 122*a*) this disc is so small that the oral surface has only one interradial plate, the odontophor, within the axils of the arms. The series of drawings given in the text-figure shows that the enlargement of the disc took place by the approximation of the adambulacralia and infero-marginalia from neighbouring arms. It was only lately, when reading some observations of MacBride, that I grasped what this approximation signified. MacBride points out (43, p. 453) that the disc in the great majority of the recent Asteroidea is really composed of adherent arms, and that this is at once made clear when the body-cavity is cut open. "This space is found to be divided up by inwardly projecting folds called interradial septa, which are stiffened by calcareous deposits and represent the conjoined adjacent walls of two arms." He also states (*op. cit.*, p. 475) that in the recent Brisingoidea "the arms have what we must consider to have been the primitive arrangement, since there is no lateral adhesion between them, and interbrachial septa are consequently absent." The Palæozoic Hudsonasteridæ and the Asterozoa of Section C are like the Brisingoidea, and have no lateral adhesion of the arms; the Mesopalæasteridæ show the beginnings of adhesion by the approximation of the first pair of infero-marginalia which enclose the odontophor, a process which, as we can see by reference to the above-mentioned text-figure, is carried further still in the Promopalæasteridæ and the Xenasteridæ. In later evolution the odontophor is carried below the surface of the disc and its external origin disguised. In some recent forms, *e.g. Brisinga*, it still retains its primitive position (compare Perrier, 99, p. 55). The young form of the recent *Echinaster sepositus* shows an odontophor exactly in the *Mesopalæaster* position (see Ludwig 101, Pl. X, fig. 8). The infero-marginalia incorporated within the disc by arm-fusion can be traced in the development of *Echinaster sepositus* (Ludwig, *op. cit.*, Pl. X, fig. 11), but they are difficult to recognise in the adult. We can state that as a general rule arm-fusion can be recognised by a study of the external appearance far more readily in the Palæozoic Asteroidea than in recent forms, where it is only revealed by dissection and exposure of the interradial septa. If we now turn to the recent Ophiuroidea the bases of the arms do not fuse; in fact they cannot, because they are separated by a secondary growth of the apical parts of the interradii, which grow round on the oral surface to form pouches for the reception of the stomach and for space for the genital bursæ (Text-fig. 12, p. 16, and Text-fig. 134, p. 193).

Embryological evidence alone shows that this character must have had its inception at a very early stage in the racial history of the Ophiuroidea. We can see this most clearly from the observations on the position of the opening of the water-vascular system to the exterior. Both Ludwig and MacBride have shown that the very young Ophiuroid looks like an Asteroid, and MacBride has also shown that at this stage "the madreporite is on the edge of the disc, and the stone-canal extends horizontally outwards; and in some Asteroidea there is a similar outward direction in its course" (43, p. 487). The figures and descriptions of Ludwig show the exact point at which the "Ophiuroid impulse" is given. It is while the madreporite is still in association with the second adambulacral—that is, while the disc is still small (Text-fig. 123). At this very young stage growth takes place so that the madreporite (one of the mouth-shields perforated for the purpose) is forced round on to the oral side, the plate still retaining its association with the second adambulacral. As Sollas has pointed out, this is the position of the madreporite in the Silurian Ophiuroid *Lapworthura*, and I hope to show that the position is so universal in the Ophiuroidea that we can suppose the impulse to have arisen at the same developmental period and in the same way in almost all, if not all, Ophiuroidea.

Palæontological evidence supports the view deduced from embryology. There can be no doubt that the Ophiuroidea separated from the parent Asterozoan stock in very early times. We find readily recognisable Ophiuroidea with well-



TEXT-FIG. 123.—A stage in the development of the young *Amphiura squamata* (after Ludwig). *Ad.*$_2$, *Ad.*$_3$, *Ad.*$_4$, the second, third, and fourth adambulacralia; *M.*, the mouth-shield, which functions as a madreporite. × 140.

developed vertebræ and large discs in the Ordovician rocks—that is, more or less contemporaneously with the oldest known fossil Asteroidea. We also find in these rocks one or more series of forms which have not undergone such rapid evolution and show the early fossil stages of the evolution of the Ophiuroid disc. Such a form is *Schuchertia*, which is known from the Middle Ordovician to the Middle Silurian. If we look at the oral surface of this (see below) we see that the infero-marginalia and odontophor are arranged on the same common ground-plan as in *Hudsonaster* and *Urasterella*. The arms, however, could never fuse at the bases because they were separated by a number of interradial plates. Further, the oral position of the madreporite and its association with the proximal adambulacralia suggest most strongly that these interradial plates have arisen, as in the recent Ophiuroidea, by a portion of the apical surface being thrust round into the oral inter-radii. In fact, we may say that *Schuchertia* is a fossil representative of the "Asteroid" stage of the developing Ophiuroid. I am the more confirmed in this view as I have evidence to be brought forward later that there are Palæozoic genera allied to *Schuchertia* which even more approximate to undoubted Ophiuroidea.

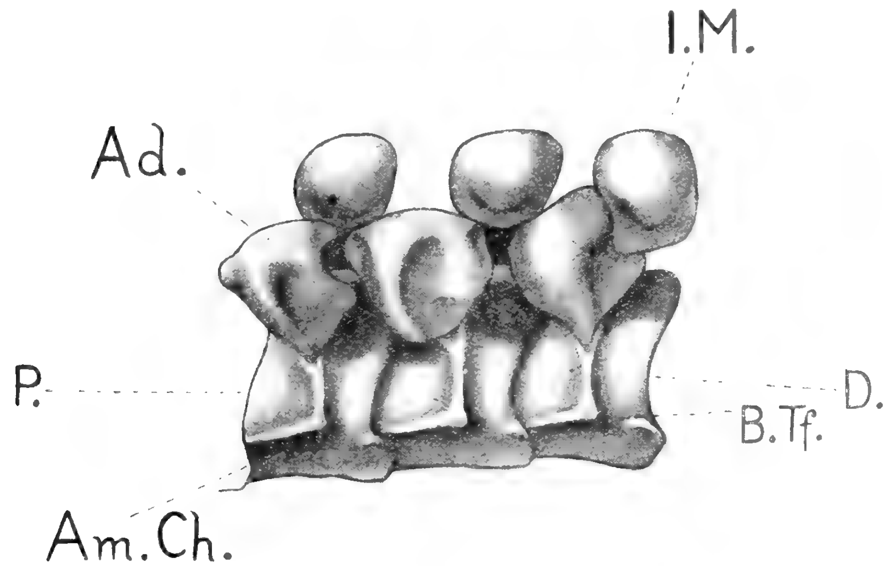
Although the ground-plan of the oral surface of *Schuchertia* can be compared with that of *Hudsonaster*, it must not be assumed, as Schuchert does (1915, p. 194), that it is descended from that genus. In my opinion the apical surface of the most primitive Asteroidea and that of *Schuchertia* differ so fundamentally that one can only assume that the Ophiuroidea must have been differentiated from the parent Asterozoan before the "*Hudsonaster*" structure was typically developed. If this be true many features which are common to the recent Asteroidea and the recent Ophiuroidea may not be due to the descent of the Ophiuroidea from the Asteroidea as commonly assumed, but because of the inheritance of these characters from a common ancestor.

Schuchertia and its allies enable us to study these common ancestral characters as well as the beginnings of typical characters of the Ophiuroidea.

In dealing with these in the following pages, I have taken opportunity to refer to the structure of recent forms, as many ambiguities in literature and observation require clearing up. One point that emerges is, that there is not such a fundamental difference between the Asteroid ambulacral and the Ophiuroid "vertebra" as was at one time imagined. Parallel evolution, probably due to the action of similar muscles, leads to the independent production of similar characters in several series.

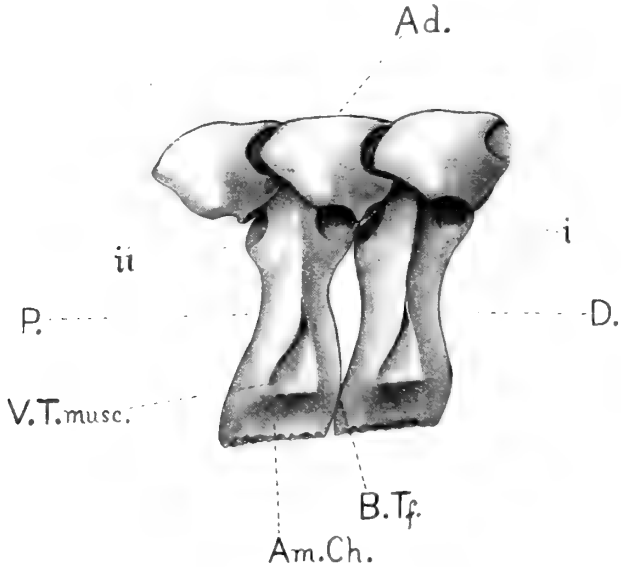
The Ambulacral Groove.—The ossicles of the ambulacral groove were undoubtedly laid down with all their essential peculiarities before the divergence of the various Asterozoan stocks, for in all these stocks we can trace a common primitive plan, based mainly on the support and protection of the tube-feet.

I have already touched upon this in the Introductory Section of this Monograph, but further points have emerged. Let us take, for example, the ambulacral groove of *Sch. wenlocki* (Text-fig. 124). The ossicles are shown in such a position that one is looking straight across the groove on to the wall formed by the inner surface of the adambulacralia. The nearest point to the observer is the exact radial line of the arm. The ambulacralia are of the flooring-plate type already described for many primitive Asterozoa (Text-fig. 54 *A*, p. 95; Pl. VIII, figs. 1, 2). Support is given to the floor by a distinct overlap of successive plates. The floor is hollowed in the middle (*Am. Ch.*) for the radial water-vascular vessel and accompanying soft structures. Each plate has two ridges placed in the form of a ⊣. The cross-ridge rises sharply from the body of the plate and provides one of the walls of the cup for the reception of the retracted tube-feet; the longitudinal ridge is parallel to the ambulacral channel, and afforded points of attachment for the ventral cross-muscle which closed the groove. We can see that this muscle must have been much less powerful than in the recent Asteroidea if we compare the slight concavity shown in the text-figure with the deep pit (*V.T. musc.*) of Text-figure 125. The place for the position of the passage of the branch from the radial water-vascular vessel to the tube-foot is indicated by the cut-away portion of the posterior branch of the longitudinal ridge. This position differs from that in recent Asteroidea (Text-fig. 125), where the branch is exactly between the ambulacralia —a condition which Ludwig (39, p. 355) regarded as primitive. The point will be returned to later.



TEXT-FIG. 124.—Floor and inner wall of the ambulacral groove of *Schuchertia wenlocki*. *Ad.*, adambulacral; *Am. Ch.*, ambulacral channel; *B. Tf.*, branch of radial water-vascular vessel to tube-foot; *D.*, distal direction; *I.M.*, infero-marginal; *P.*, proximal direction. This figure should be compared with Text-fig. 119. × 18.

Bather (90, pp. 317, 318) has shown that there is considerable resemblance between ambulacralia of this type and the flooring-plates of the groove of *Edrioaster*. His comparison is as follows: "In the older Asterozoa, from which the true Asteroidea and Ophiuroidea were derived, the plates which in a modern starfish are known as 'ambulacralia' were 'little more than mere flooring-plates to the ambulacral groove' (Spencer, p. 21). They formed a double series, either opposed as in recent Asteroidea, or alternating as in *Edrioaster*. Spencer, following Gregory and Jaekel, regards the latter arrangement as the more primitive. These ambulacrals were approximately rectangular in plan, and excavated along the perradial sutures by a shallow 'ambulacral channel' for the radial water-vessel. Along the sutures at right-angles to this the plates were deeply excavate, leaving a well-marked median transverse ridge along each. The longitudinal ridge, parallel to the ambulacral channel, was but slight, indicating the feeble development of the transverse ventral muscles. Thus far the description is equally applicable to *Edrioaster*." Bather then goes on to point out that *Edrioaster* has podial pores, while, in the primitive Asterozoa, I alleged them to be absent. I have already dealt with his statements (see above, p. 67). *Schuchertia*, n. sp., quoted there is *S. wenlocki* of this section. Podial pores are undoubtedly absent in certain primitive Asterozoa, *e. g.* in *Platanaster ordovicus* (p. 174), but they are present in more of these early forms than at one time I supposed. It still seems to me, however, that they arose independently in *Edrioaster* and in the Asterozoa. Bather would, I think, regard the impulse towards endothecal ampullæ as common to the Asterozoa and *Edrioaster*, and make their existence merely dependent on the existence in the rays of a thecal cavity large enough to contain ampullæ (*op. cit.*,



Text-fig. 125.—Floor and inner wall of the ambulacral groove of *Archaster typicus*. *Ad.*, adambulacral; *Am.Ch.*, ambulacral channel; *B.Tf.*, passage for branch water-vascular vessel to tube-foot; *D.*, distal direction; *i.*, articulation of the adambulacral with its own ambulacra; *ii.*, articulation of the adambulacral with the following ambulacral; *P.*, proximal direction; *V.T.musc.*, ventral transverse muscle. × 10. This figure may be compared with Text-fig. 5, p. 12.

p. 318). *P. ordovicus* has a large thecal cavity but no passages for endothecal ampullæ. I might also add that I cannot see that the question of presence or absence of endothecal ampullæ is of great importance in studying genetic affinity.

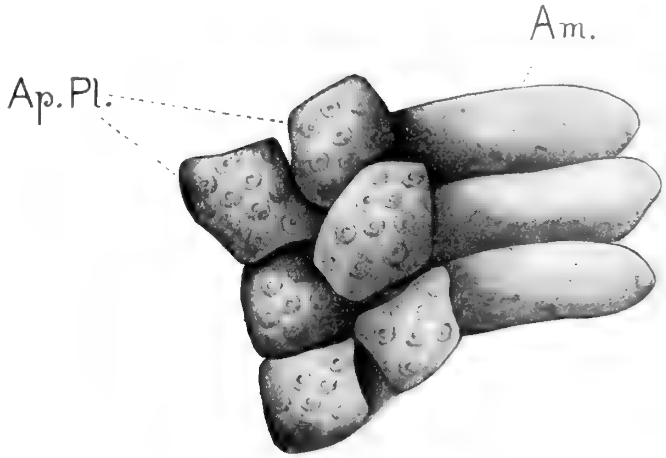
Bather also shows (*op. cit.*, pp. 318, 319) a resemblance between the adambulacralia and the covering-plates. He states that the main point of distinction is that "the adambulacrals of starfish do not close over the groove in the same way as did the cover-plates of *Edrioaster*, and the contents of the groove are generally protected by groove-spines borne on the adradial margin of the adambulacral plates. None the less, by the approximation of the two sides of the groove, effected by the ventral cross-muscles, the adambulacrals may be brought quite close together, and in some species they may when thus closed be observed to alternate just like the cover-plates of an Asteroid. See, for example, Ludwig, 1905, ‘Asteroidea of the Albatross,’ ‘Mem. Mus. Comp. Zool. Harvard,’ vol. xxxiii, fig. 51, *Pentagonaster ernesti*, fig. 135, *Paulia horrida*; Koehler, 1910, ‘Shallow-water Asteroidea in the Indian Museum,’ pl. xi, fig. 3, *Pentaceros indicus*, pl. xii, fig. 2, *P. reinhardti*, and others; Gregory, *op. cit.*, fig. 1*b*, *Lindstromaster*, the ray in the north-west position.”

I am inclined to think that originally the adambulacralia of the Asterozoa were even more like covering-plates than in the examples quoted by Bather. We have seen that in several genera, *Urasterella* and its allies, *Lepidaster* and *Lepidactis*, the adambulacralia are large and could completely cover the groove. The specimen of *Palasterina primæva* figured in Pl. XV, fig. 7, shows a similar condition. In the Middle Ordovician species *Schuchertia stellata* and the Upper Ordovician *S. laxata* (figured below) the adambulacralia completely cover the groove, while in the Middle Silurian form *S. wenlocki* the adambulacralia are comparatively small and the groove is widely open. A similar reduction in the size of the adambulacralia can be followed in the Asteroidea of Section A (compare, *e. g.*, *Belaster ordovicus*, Pl. III, fig. 3, and *Promopalæaster elizæ*, Pl. IV, fig. 2). This evidence goes to show that there is in some groups a progressive loss in size of the adambulacralia which disguises their original cover-plate form. This evidence might lead one to agree with Bather that *Edrioaster* and the Asterozoa descended from a common ancestor.

There is, however, a feature of the adambulacralia of the Asterozoa, namely, the adoral tip, which requires further investigation, as it may have a distinctive value. It has been noticed for *Hudsonaster* and *Urasterella* by Hudson (93, 98). In my account of the Urasterellidæ (see p. 133) I assumed that the tip arose because of the extra muscular power given to the adambulacral muscles. I find that the tip is exceedingly common in the Asterozoa. It may be seen in the recent *Archaster* (Text-fig. 125), in *Schuchertia* (Text-fig. 124), and in many other species. I have looked through Bather's descriptions to see if there is a similar appearance in the Edrioasteroidea, and find that in the description of *Edrioaster bigsbyi* (89, p. 162) he states that “the cover-plates abut closely, in tesselate fashion, when closed in the normal position over the radial groove. When pressed inwards, however, as in B, they have sometimes been made to imbricate with adoral overlap. This suggests a possibility of the converse action, namely, that in life they may have assumed a similar imbricate arrangement when they opened outwards, thus forming a slight gap between adjacent plates.” The point is an interesting one, and would repay further investigation.

So far we have dealt with the ambulacralia and adambulacralia as flooring- and covering-plates of the groove. It now remains to consider them as “bones” to which are attached the muscles concerned in arm-movement.

The arm-movements are of two kinds—(1) flexion downwards or upwards in a vertical plane; (2) lateral flexion. In the recent Asteroidea these movements are relatively slow and deliberate, while in the Ophiuroidea they are rapid and jerky. Distinct methods of moving the "bones" are used in each case. Ventral flexion, in the Asteroidea, is brought about by simultaneous contraction on both sides of the arm of the longitudinal muscles between the adambulacralia. Muscles which act counter to these are (*a*) a band running along the dorsal wall of the cœlom to the point of the arm (MacBride, 43, p. 435); (*b*) dorsal longitudinal muscles attached to the apical faces of the ambulacralia (Text-fig. 128, p. 188). Lateral flexion is brought about by the simultaneous contraction, on one side of the arm only, of the adambulacral and "b" muscles mentioned above. In the recent Ophiuroidea the adambulacralia (side plates) have no muscles between them, and there is no cœlomic band. The whole of the movements are brought about by the "b" muscles and a new set of muscles (the longitudinal ventral muscles,



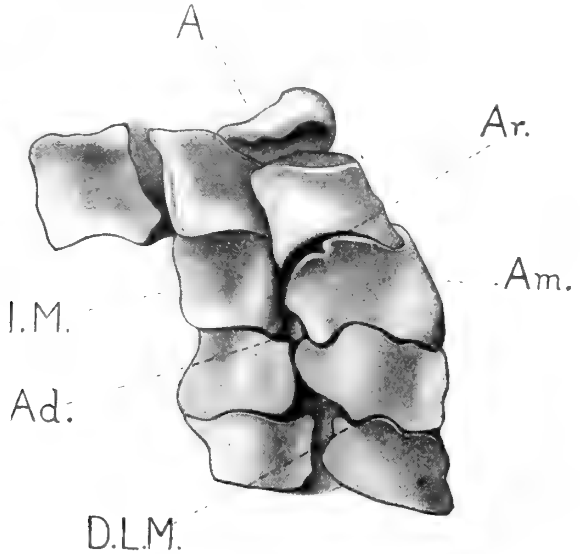
TEXT-FIG. 126.—Wash drawing of a portion of the apical surface of *Schuchertia laxata* (?), showing exposed ambulacralia. *Am.*, ambulacral; *Ap. Pl.*, apical plates. × 20.

Text-fig. 13, p. 16). The arrangement allows of independent movement of each "vertebral" sector, and as every sector has its own ganglionic swelling (MacBride, 43, p. 488) quick active movement is to be expected.

There are two points of interest in the evolutionary moulding of the vertebræ —(1) the development of the efficiency of the muscular action; (2) the parallel changes due to the fact that both the Asteroid ambulacral and the Ophiuroid vertebra have one set of muscles in common, namely, the "b" muscles. The fossil material allows us to follow these changes.

In the most primitive forms known, *e. g. S. laxata* (Text-fig. 126) or *Hudsonaster* (*Protopalæaster*) *narrawayi* (Text-fig. 19, p. 21), the ambulacralia are closely touching bars of calcite—that is, mere flooring-plates. The longitudinal adambulacral muscles were present, but the only muscle which could have been counter to this must have been that running in the body-wall, of which we can have now no trace.

S. wenlocki (Text-fig. 127) shows the beginnings of the development of the "b" muscles. The excavations for these are at the outer ends of the calcite bars, that is at the points of greatest power for lateral flexion. Between the excavations and the radial line the bars are in contact, and any lateral flexions will naturally cause the surfaces of contact to rub against each other. The greatest rub will be just at the angle on the inner side of the muscle-excavations, for this will be the fulcrum of the lever movements. Here we get a forwardly projecting peg (*Ar.* in figure). It is at this point that the dorsal ball and socket of the Ophiuroid vertebra develop just as the ventral ball and socket develop in relation to the overlap of the oral surface of this same bar (see p. 182). We find a similar development of the apical surfaces of the ambulacralia in the Platanasteridæ. In



TEXT-FIG. 127.—Wash drawing of the apical surface of the proximal ambulacralia and neighbouring plates of *Schuchertia wenlocki*. *A.*, ascending process of the mouth-angle plate; *Ad.*, adambulacral; *Am.*, ambulacral; *Ar.*, forwardly projecting peg; *D.L.M.*, position of dorsal longitudinal muscle; *I.M.*, inferomarginal. × 12.

the Ordovician representative the bars are closely touching (Text-fig. 120, p. 175); in the later Devonian species excavations and pegs arise (Text-fig. 122, p. 177).

Stellaster equestris may be taken as a recent Asteroid to show similar phenomena. Text-fig. 128 gives an appearance which we shall see in many Ophiuroidea. The "b" muscles are well developed. The proximal excavation for these muscles is situate upon a raised tongue, which projects forwards and overhangs the backwardly sloping distal excavation. The raising of the surface of the calcite into a tongue causes the formation of a median groove running across the ossicle. The slant causes the ossicles to overlap, as Viguier has remarked (100, p. 53), "just as tiles on a roof." The surfaces of contact are shaped much as in *Schuchertia*, with a forwardly projecting point (*Ar.*). A profile view (Text-fig. 129) shows that at the outer side of the surfaces of contact there are *wearing surfaces* (analogues of the ball and socket of the Ophiuroidea) not hitherto noticed.

As a result of these and similar observations I think that it will be possible to show that the shapes of the ambulacral ossicles are moulded by the stresses set up by muscular action.

The Mouth-Frame.—I think that it is also clear that the differences in the mouth-frames in the various Asterozoa are expressions of different habits. In order to show this it is necessary to supplement the accounts already given in the Introductory Section of this monograph. Viguier's description of the mouth-

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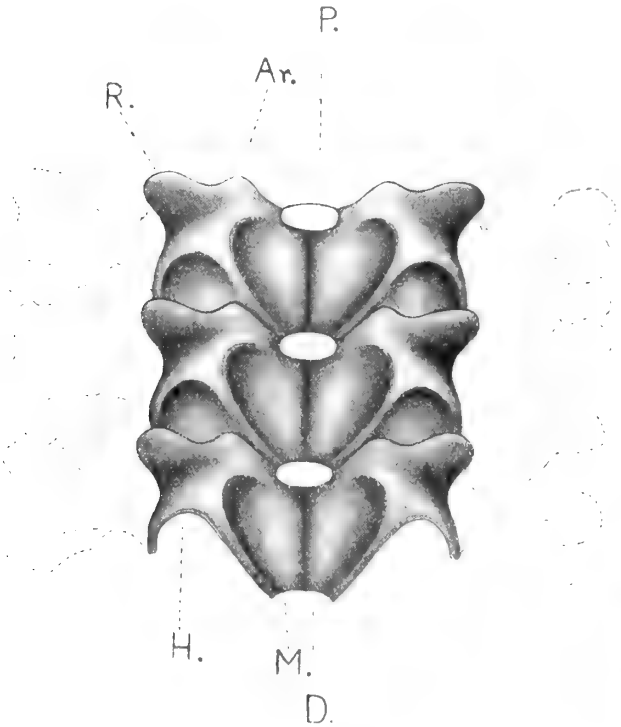

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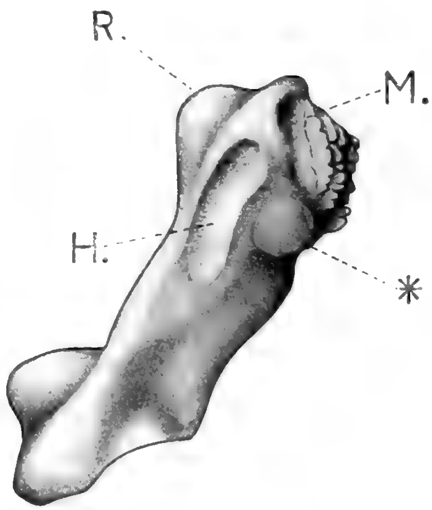


Text-fig. 128.—Apical view of the central region of the ambulacralia of *Stellaster equestris*. (The outer portions of the ossicles are shown by dotted lines—compare Text-fig. 6, p. 13.) *Ar.*, angle at line of contact of two ambulacralia; *D.*, distal direction; *H.*, hollow in which is inserted proximal end of a dorsal longitudinal muscle; *M.*, hollow for dorsal transverse muscle; *P.*, proximal direction; *R.*, ridge below which is inserted distal end of a dorsal longitudinal muscle. × 12.

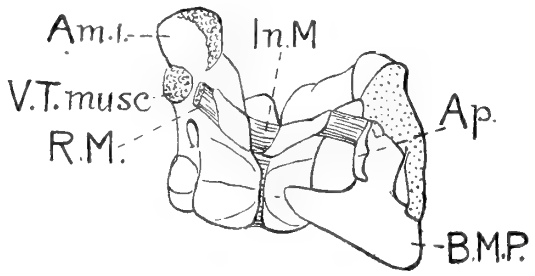
Text-fig. 129.—Aboral profile view of an ambulacral of *Stellaster equestris*. Lettering as in Text-fig. 121. *, wearing surface. × 20.

frame in the recent Asteroidea is classical (100). The following revision is in accordance with somewhat fuller knowledge.

We can conveniently divide the description into two parts: (*a*) The morphological constitution; (*b*) the disposition of the soft parts and the functional activities of the structures.

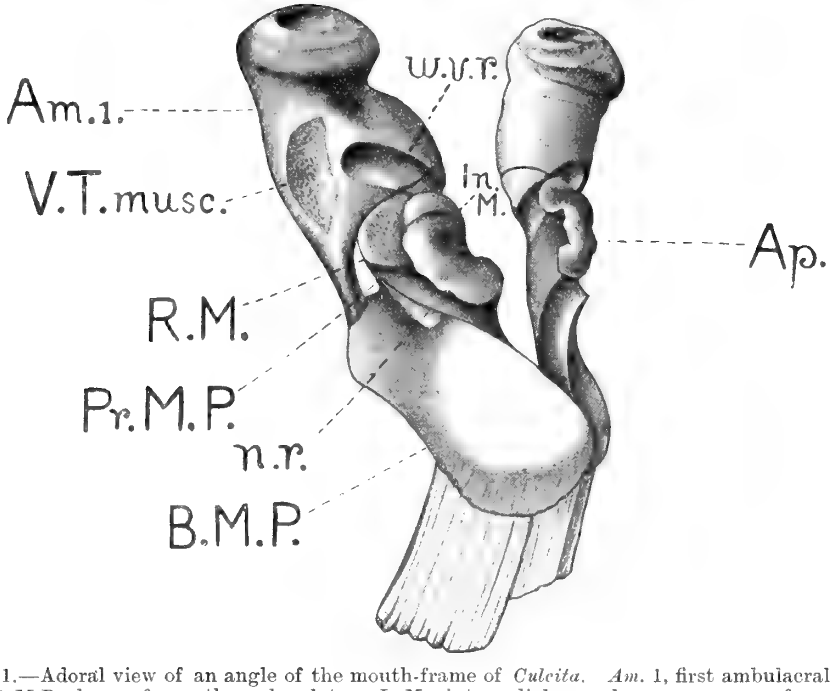
(a) *The Morphological Constituton.*

The mouth-frame is composed of twenty elements, ten of which are radial (the first ambulacralia) and ten are interradial (the mouth-angle plates). All these are intimately connected to make a firm skeleton. Viguier in his description lays emphasis on the fusion of a radial element with its interradial neighbour. The two together he names a "mâchoire." The right-hand portion of Scheme D of Viguier, reproduced here as Text-fig. 130, gives a side view of the "mâchoire." The shading which I have added to the original figure makes the double origin of



TEXT-FIG. 130.—Scheme D of Viguier. Lettering as in Text-fig. 131. The "*mâchoires*" are seen both in front (adoral) and side view.

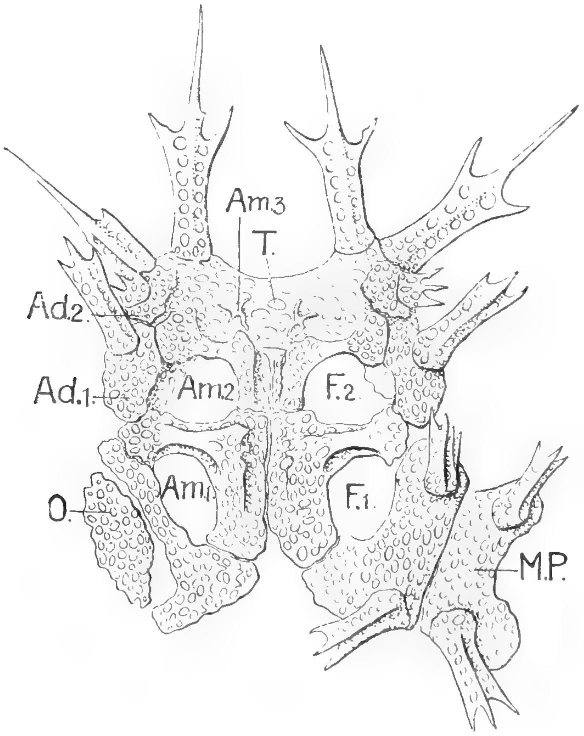
the structure more distinct. The lower unshaded portion is the mouth-angle plate; the upper shaded portion is the first ambulacral. Usually the division between these two ossicles cannot be distinguished without maceration in potash,



TEXT-FIG. 131.—Adoral view of an angle of the mouth-frame of *Culcita*. *Am.* 1, first ambulacral; *Ap.*, apophysis; *B.M.P.*, base of mouth-angle plate; *In.M.*, interradial muscle; *n.r.*, groove for nerve-ring; *Pr.M.P.*, ascending branch of mouth-angle plate; *R.M.*, radial muscle (muscle abducteur des dents); *V.T.musc.*, ventral transverse muscle of first ambulacral; *w.v.r.*, groove for water-vascular ring. × 3½.

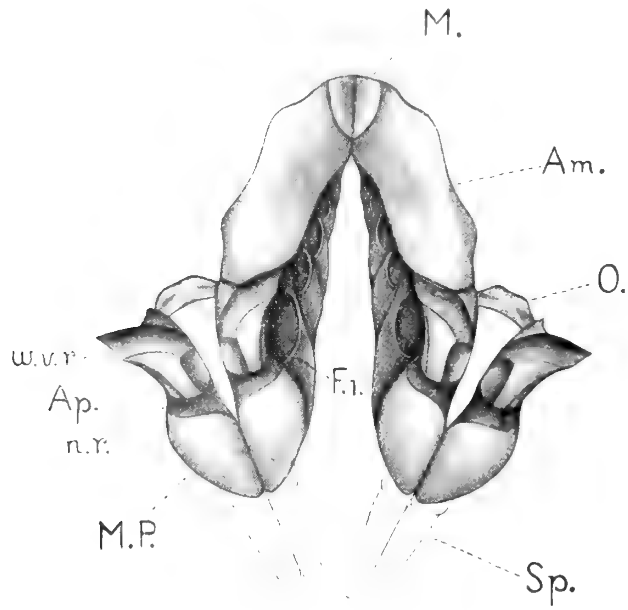
although occasionally the shrinkage in a dried specimen may make this unnecessary. Viguier's diagram is based on a study of *Pentaceros*. In order to show the details more clearly I am adding a wash drawing, similarly oriented, of *Culcita*.

Viguier, for descriptive purposes, recognised two regions of the mouth-angle plate ("la dent"); the one, a wedge, which projects into the interior of the mouth ("la dent proprement dite"); the other ("la branche montante"), a limb which projects upwards to unite with the first ambulacral. On this ascending limb is a wing-shaped apophysis which has two faces separated by a swollen ridge carrying important muscles, which will be described later. The first ambulacral is thickened on its proximal surface, and the thickened portion meets the ascending limb. The distal half of the ambulacral sends down a slender pillar on to the body of the mouth-angle plate. Between the pillar and the ascending limb is a long slit for the passage of the ampulla of the first tube-foot. Ludwig, contemporaneously



TEXT-FIG. 132.—Arrangement of the ossicles of the groove and mouth-region of a very young Asteroid (after Ludwig). *Ad.*$_1$, first adambulacral; *Ad.*$_2$, second adambulacral; *Am.*$_1$, first ambulacral; *Am.*$_2$, second ambulacral; *Am.*$_3$, third ambulacral; *F.*$_1$, opening for ampulla of first tube-foot; *F.*$_2$, opening for ampulla of second tube-foot; *M.P.*, mouth-angle plate; *O.*, odontophor; *T.*, terminal. × 170.

with Viguier, published a description of the mouth-frame which, on account of the reputation of the author, has achieved wide publicity. He regarded the ascending limb with the thickened portion of the first ambulacral—that is, the calcite bar in front of the first ampullal pore—as a separate ossicle, "the real first ambulacral." This allowed him to consider the mouth-angle plates as being the adambulacralia corresponding to his real first ambulacral, otherwise it was necessary to regard the mouth-angle plates as plates distinct from any other in the ambulacral groove. Thus, according to Ludwig, the mouth-frame was merely the modified proximal portion of the ossicles of the grooves. All later workers have omitted to notice that Ludwig himself withdrew this interpretation. So long ago as 1897 Ludwig published the figure reproduced here as Text-fig. 132, stated that he had been mistaken in his opposition to Viguier, and that he would write further upon the point (101, p. 469). The figure shows clearly that there is no first ambulacral proximal to the first ampullal pore. Unfortunately even now the morphological constitution of the mouth-frame of all fossil Asterozoa is not certain. *Urasterella* and its allies (Text-fig. 87, p. 134) have a mouth-angle plate which may well be a modified first adambulacral. Further research is necessary before all points can be cleared up. The position is, however, quite clear in the forms leading to the

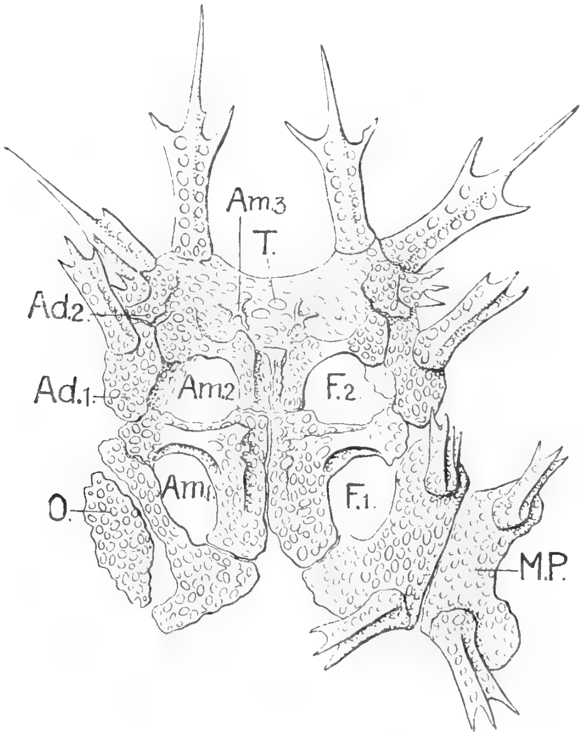


TEXT-FIG. 133.—Adoral view of mouth-frame of *Stellaster equestris*. *Am.*, first ambulacral; *Ap.*, apophysis; $F._1$, passage for ampulla of first tube-foot; *M.*, hollow for dorsal transverse muscle; *M.P.*, mouth-angle plate; *O.*, odontophor; *Sp.*, mouth-spine; *n.r.* and *w.v.r.*, as in Text-fig. 131.

Ophiuroidea. Here the mouth-frame has essentially the same structure as that described by Viguier.

(b) *The Disposition of the Soft Parts and the Functional Activities of the Structures.*

We can follow this evolution the more clearly if we learn to recognise the various grooves and excavations which show the disposition of the soft parts. The mouth-frame always carries the water-vascular ring-canal and the nerve-ring. The first-named is carried in a groove above the apophysis partially situate upon the ascending limb and partially upon the inner (adradial) side of the thickened portion of the first ambulacral. The groove for the nerve-ring, as Dr. Gemmill has pointed out to me, is that below (on the adoral side of) the same apophysis. It follows from this that the area between the two grooves is one which we can mark down whether the apophysis is prominent or not, and we shall see that the presence or absence of prominent apophyses will throw considerable plate ("la dent"); the one, a wedge, which projects into the interior of the mouth ("la dent proprement dite"); the other ("la branche montante"), a limb which projects upwards to unite with the first ambulacral. On this ascending limb is a wing-shaped apophysis which has two faces separated by a swollen ridge carrying important muscles, which will be described later. The first ambulacral is thickened on its proximal surface, and the thickened portion meets the ascending limb. The distal half of the ambulacral sends down a slender pillar on to the body of the mouth-angle plate. Between the pillar and the ascending limb is a long slit for the passage of the ampulla of the first tube-foot. Ludwig, contemporaneously



TEXT-FIG. 132.—Arrangement of the ossicles of the groove and mouth-region of a very young Asteroid (after Ludwig). *Ad.*$_1$, first adambulacral; *Ad.*$_2$. second adambulacral; *Am.*$_1$, first ambulacral; *Am.*$_2$, second ambulacral; *Am.*$_3$, third ambulacral; *F.*$_1$, opening for ampulla of first tube-foot; *F.*$_2$, opening for ampulla of second tube-foot; *M.P.*, mouth-angle plate; *O.*, odontophor; *T.*, terminal. × 170.

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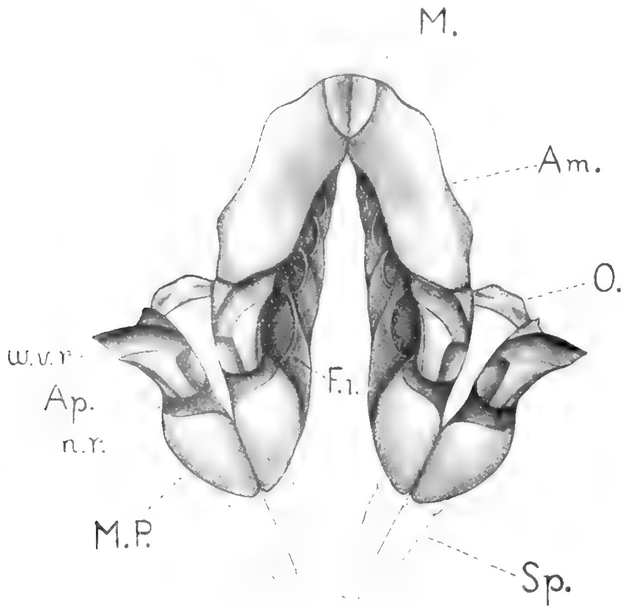


TEXT-FIG. 133.—Adoral view of mouth-frame of *Stellaster equestris*. *Am.*, first ambulacral; *Ap.*, apophysis; $F._1$, passage for ampulla of first tube-foot; *M.*, hollow for dorsal transverse muscle; *M.P.*, mouth-angle plate; *O.*, odontophor; *Sp.*, mouth-spine; *n.r.* and *w.v.r.*, as in Text-fig. 131.

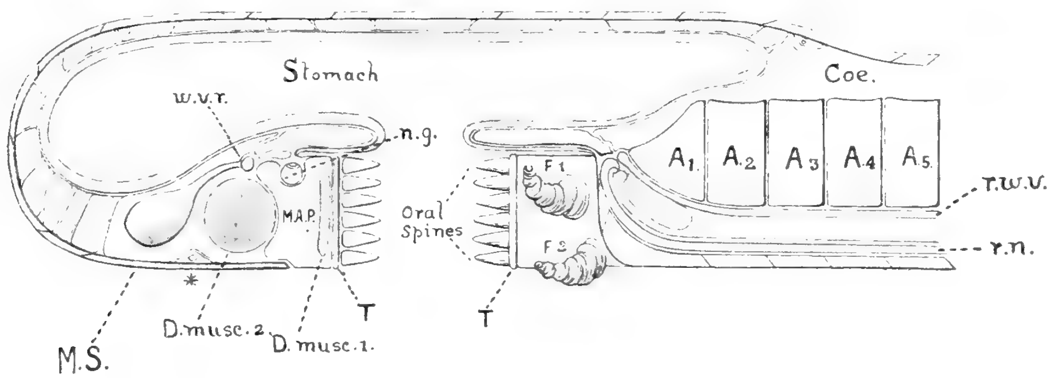
Ophiuroidea. Here the mouth-frame has essentially the same structure as that described by Viguier.

(b) *The Disposition of the Soft Parts and the Functional Activities of the Structures.*

We can follow this evolution the more clearly if we learn to recognise the various grooves and excavations which show the disposition of the soft parts. The mouth-frame always carries the water-vascular ring-canal and the nerve-ring. The first-named is carried in a groove above the apophysis partially situate upon the ascending limb and partially upon the inner (adradial) side of the thickened portion of the first ambulacral. The groove for the nerve-ring, as Dr. Gemmill has pointed out to me, is that below (on the adoral side of) the same apophysis. It follows from this that the area between the two grooves is one which we can mark down whether the apophysis is prominent or not, and we shall see that the presence or absence of prominent apophyses will throw considerable light on the habits of the various forms. In the starfish with adambulacral mouth-frames—that is, with the mouth-angle plates as prominent wedges—the apophyses are well developed. Their adradial faces carry the so-called "abductor muscles" which pull the teeth of the same pair apart; their abradial faces carry the adductor muscles which pull the teeth of the same pair together. Viguier points out that, in reality, the function of these muscles is the same, and that their simultaneous contraction, as a ring of ten muscles round the mouth, tends to close that opening. The same author shows that counter-action to these muscles is afforded by the odontophor. When the abductor and adductor muscles contract and so pull forward the mouth-angle plates, they must also pull forward the first ambulacralia, for these are all rigidly united (see above, p. 189). The forward oscillatory movement is communicated to the odontophor, which has wings fitting within and firmly united to the walls of the first ampullal pore. The distal end of the odontophor is attached to the firm wall of the oral interbrachial region. Thus the forward pull of the mouth-muscles is opposed by the strain upon the attachments of the odontophor to the interbrachial wall, and any relaxation of the mouth-musculature will cause the mouth-frame to spring back into place. The position and shape of the odontophor are shown in Pl. I, fig. 1, and in Text-fig. 133. It follows from this that we should expect a relationship between the strength of the mouth-musculature (conveniently judged from the size of the apophysis) and the odontophor. This is also dealt with by Viguier (*op. cit.*, pp. 76—80), who shows that in the recent *Asterias* and its allies, where the apophyses are barely noticeable, the odontophor is without its wings and has become of less functional importance.

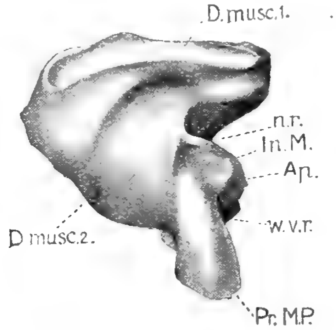
Now to apply these observations to habit. Unfortunately not nearly so much is known of the habits of recent Asteroidea as one would wish, but we must presume that the prominent wedges of the mouth-angles of the recent Asteroidea have function. MacBride (43, p. 469) points out that the recent Astropectens swallow their prey whole, and "the unfortunate victims, once inside the stomach, are compelled by suffocation to open sooner or later, when they are digested." The opening and closing of the wedges is therefore an opening and closing of a trap-door. *Asterias*, on the other hand, pulls open the bivalves (MacBride, *op. cit.*, p. 440) and then everts its stomach. The food is digested while it is still outside the mouth. The reduced wedges and permanently open mouth obviously allow ready extrusion of the stomach.

The apophyses are barely noticeable in the Ophiuroid jaw. This is because the mouth can be opened in another way. The development of the ambulacralia into vertebræ allows the jaws "to be rotated downwards so as greatly to enlarge the mouth, and again rotated upwards and inwards, when they form an excellent strainer to prevent the entrance of coarse particles. To permit this extensive movement the articulatory facets on the proximal surface of the first vertebra have been much modified; the median knob and pit have disappeared, and the dorso-lateral pits are raised on to the surfaces of processes, so that there are in all four processes, two of which articulate with one half of the jaw" (MacBride, *op. cit.*, p. 484). These movements are brought about by the intervertebral muscles connecting the basal parts of the jaws (the part behind *w.v.r.* of Pl. I,



TEXT-FIG. 134.—Longitudinal section through the disc of an Ophiuroid passing along one arm and the middle of the opposite interradius (slightly modified from Ludwig). A_{1-5}, ambulacrals; *Coe.*, cœlom; *D.musc.*$_1$, "binding" interdental muscle; *D.musc.*$_2$, "thrusting" interdental muscle; *F.*$_1$, first tube-foot; *F.*$_2$, second tube-foot; *M.A.P.*, mouth-angle plate; *M.S.*, mouth-shield; *n.g.*, groove for nerve-ring; *r.n.*, radial nerve; *r.w.v.*, radial water-vessel; *T.*, torus; *w.v.r.*, water-vascular ring; *, approximate position of madreporic pore.

fig. 2) with the succeeding vertebræ. We can connect these movements with the absence of the odontophor in the Ophiuroidea, for it is obvious that any plate connected with the proximal vertebræ and the floor of the disc would impede the free up-and-down movement of the jaws. Another series of movements of the jaws of the Ophiuroidea is brought about by the simultaneous

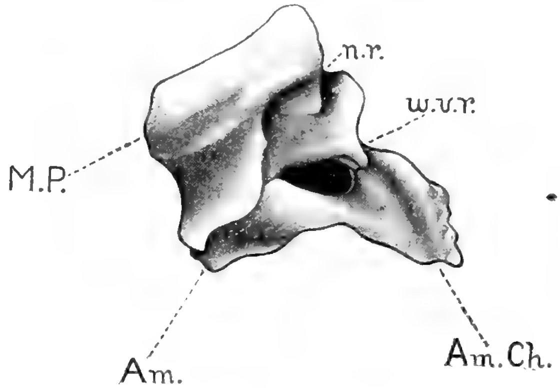


TEXT-FIG. 135.—Wash drawing of interradial surface of mouth-angle plate (that turned towards its opposing pair) of *Solaster papposus*. *Ap.*, apophysis; *D.musc.*$_1$, "binding" interdental muscle; *D.musc.*$_2$, "thrusting" interdental muscle; *In.M.*, interradial muscle (muscle "adducteur des dents"); *n.r.*, groove for nerve-ring; *Pr.M.P.*, ascending limb of mouth-angle plate; *w.v.r.*, groove for water-vascular ring. × 6.

contraction of five muscles, each of which unites the two halves of a jaw (MacBride, *op. cit.*). By this means the mouth can be narrowed and the jaws forced inwards. Pl. I, fig. 2, shows that the two forwardly projecting portions of the jaws of the same interradius are not adjoining, as are the mouth-angle plates of the Asteroidea, but form two sides of an acute-angled triangle. The muscles in question form the base of this triangle and are the external interradial muscles of Ludwig (*D. musc.*$_2$ of Text-fig. 134, p. 193). Contraction of these muscles elongates the triangle, and as movement backwards is prevented by the stiff mouth-frame, the jaws must move forward. There is a muscle at the apex of each triangle. This is the interradial muscle of Ludwig, and obviously serves to bind the jaws so that they do not split apart when the "thrusting" muscle is at work. In searching for the origin of these muscles I have been led to the discovery of a similar apparatus in, at any rate, some Asteroidea. It has been supposed that in the Asteroidea there is but one binding muscle between the basal processes of the mouth-angle plates of the same interradius. Text-fig. 135 shows that in *Solaster* there are two such muscles separated by a ridge. The upper muscle of the figure corresponds to the internal interradial muscle of the Ophiuroidea and is a "binding" muscle. The lower muscle is the external interradial muscle of the Ophiuroidea and obviously has a "thrusting" function. In *Solaster*, however, the muscles are almost at right-angles to the position in the Ophiuroidea—and the "jaw" triangle is not thrust so much forwards as upwards away from the mouth-cavity.

Certain of the Palæozoic Asterozoa show a considerable enlargement of the internal muscle, suggesting that in some forms this muscle could contract and move the mouth-parts by its own efforts. The wide gape between the mouth-angle plates of *Schuchertia* and *Palästerina* (see below) must have been occupied by such a muscle. In these forms the position of the external and internal muscles is intermediate between that occupied in *Solaster* and that in recent Ophiuroidea. The internal muscles would obviously act in the contrary way to the external muscles—that is, they would separate the bases of contiguous mouth-angle plates, shorten the "mouth-angle plate" triangle, and so tend to make the mouth-aperture wider.

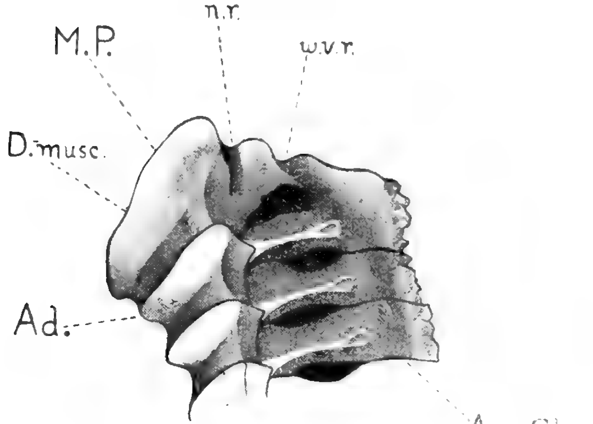
If we try, therefore, to follow the evolution of the movements of the mouth-parts, we obtain a result somewhat as follows: The earliest mouth-frame is somewhat loosely built, *e.g.* that of *Platanaster*. The chief movements are brought about by the external and internal interradial muscles, which thrust the angle-plates backwards or forwards. The movements are limited by the odontophor. Later, both in the Asteroidea and the Ophiuroidea, the mouth-frame became stiffened to help to sustain the backward thrust. The stiffening was brought about by the enlargement of the apical portion of the first ambulacral, or by the fusion of the proximal portions of the first few ambulacralia. The adductor, muscles between the apophyses of the mouth-angle plates assisted the mouth-closure, but it is probable that abductor muscles were absent. The earliest Ophiuroidea opened and closed their mouth in this manner; when later their ambulacralia became modified into vertebræ, freer movements were allowed by the rotation of the jaws on the vertebral faces. The Asteroidea probably developed along two lines. In one of these, that including *Brisinga*, the original movements persist; the backward thrust is taken, however, by the mouth-frame rather than by the odontophor, which seems to be of little importance. In the other line, which includes *Astropecten* and *Pentaceros*, the main movements are brought about by the abductor and adductor muscles working in combination with a winged odontophor as described above. I hope in the near future to work out these points in greater detail.



TEXT-FIG. 136.—Wash drawing of a mouth-angle plate and first ambulacral of a recent *Astropecten* after the form had been soaked in potash and the plates isolated. Lettering as in Text-fig. 137.

The question arises whether feeding habits do not give us a clue to the divergent methods of development. The earliest Asterozoa probably lived by a combination of ciliary feeding and podial feeding (see p. 12). Adaptations arose later in order that advantage might be taken of the variety of food on the sea bottom.

137



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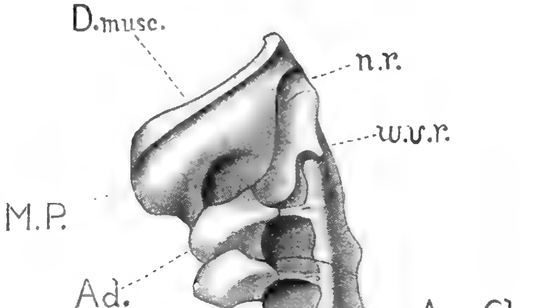

TEXT-FIG. 137.—View of inside of the ambulacral groove in the mouth-region of a recent *Astropecten*. *Ad.*, adambulacral; *Am.Ch.*, ambulacral channel; *D.musc.*, interdental muscle; *M.P.*, mouth-angle plate; *n.r.*, groove for nerve-ring; *w.v.r.*, groove for water-vascular ring.
TEXT-FIG. 138.—View of inside of the ambulacral groove in the region of the mouth of *Palasterina primæva*. Lettering as in Text-fig 137. × 18.

The Ophiuroidea probably arose in relation to a mud environment, for a mud-eating habit would necessitate a large stomach to deal with the mass of material required to give adequate nourishment. Professor MacBride tells me that the downgrowth of the apical interradii is simply a provision to allow space for the enlarged stomach. The Asteroidea have a relatively small stomach. They require little bulk of food, but large digestive glands. It is possible that as these glands are situate at the bases of the arms, the enlargement of the glands, due to a perfection of the digestive apparatus, may have been a primary cause of the approximation and final fusion of these arm bases. We know, *e.g.*, that the power of the digestive juices of *Asterias* is such that the lips of the everted stomach can digest a lamellibranch on touch, and that it is not necessary for the prey to be taken within the mouth-cavity (see p. 11). A further contributory cause of the enlargement of the arms at the base is suggested by the following remarks of Verrill (103, p. 32), who states in respect to the recent Asteriidæ: "Moreover, in most species, the rapid increase of the dorsal skeleton alone apparently does not give sufficient space for the rapidly growing internal organs, especially the reproductive organs, within the bases of the rays, and therefore new rows of plates (figs. i, iii, iv) must be interpolated between the infero-marginals and the adambulacrals, and sometimes between the upper and lower marginals, to increase the diameter of the rays." In other words, mere increase in size of the reproductive organs causes a widening, approximation, and possible final fusion of the arm bases in the Asteroidea. Space for the reproductive organs is found, in the Ophiuroidea, within the already enlarged interradial disc areas, as may be seen by reference to Text-fig. 134, p. 193 (compare Text-fig. 214, p. 490, MacBride, 43).

It is clear from these considerations that a study of the mouth-frame of the fossil Asterozoa may give one important clues as to habits, and I am giving therefore a series of oral views (Text-figs. 136—138) as standards for comparison.

The apical views figured on the previous pages are often difficult to obtain, but the corresponding oral region usually can be exposed readily, even when it lies at the bottom of a deep, narrow groove. Nearly all the fossil material is preserved as moulds, and the gutta-percha casts can be bent whilst still warm and the groove opened out. Maceration in potash will give corresponding views for recent forms.

Text-figs. 136 and 137 were drawn from species of *Astropecten* after maceration in potash. These figures show the junction of the ascending limb and the first ambulacral very clearly. The important points to notice in the figures are the position of the groove for the water-vascular ring (just at the junction of the ascending limb and the first ambulacral) and the nerve-ring (just below the oral surface of the mouth-angle plate). The area between the two grooves is that occupied by the wing-shaped apophysis. A similar oriented view (Text-fig. 138) of the Silurian form *Palasterina primæva* is given. The correspondence between the recent and fossil forms in all essential details is very exact. The only important difference is that no ambulacral pores are visible in *Palasterina* and the ascending limb of the mouth-angle plate has not as yet become firmly ossified with the first ambulacral.

Palæontographical Society, 1917.

A MONOGRAPH

OF THE

BRITISH CAMBRIAN TRILOBITES.

BY

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PART V.

PAGES 89—120; PLATES XI—XIV.

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but neither of these differences appears to be of much importance, and the absence of the tubercle is probably due to the imperfect state of preservation.

The species is characterised especially by the width of the fixed cheek at the eye and the very strong emargination of the anterior border. In *Ct. directa* the fixed cheek is also wide, but not quite so wide as in this form, and moreover, the front margin appears to be nearly straight.

Horizon and Localities.—Upper Lingula Flags: Moel Gron; Malvern.

7. **Ctenopyge directa,** sp. nov. Plate X, fig. 11.; Plate XI, fig. 1.

Only the cranidium is known; almost straight in front. Glabella slightly tapering forwards, rounded in front, reaching the margin; anterior glabellar furrows absent, posterior pair strongly marked, oblique, meeting across the middle line; neck-furrow well defined, somewhat shallower in the middle; neck-segment with a large median tubercle, probably the base of a spine. Eyes placed about half-way between the anterior and posterior margins, distant from the glabella considerably more than the width of the latter; ocular ridge curved, almost at right angles to the axis. Facial suture beginning a little to one side of the glabella, curving backwards and outwards to the eye, and behind the eye obliquely backwards and outwards to the posterior margin. Fixed cheeks at the eye about one and a quarter times the width of the glabella, behind the eye about one and a half times the width of the neck-ring; posterior margin fairly straight.

Dimensions.—Cranidium (Plate X, fig. 11) 4 mm. long, 9·4 mm. wide at posterior margin.

The special features which distinguish this form from most of the other species of the genus, are the greater width of the fixed cheek at the eye, and the curved ocular ridge, which is more nearly at right angles to the axis than in any other British *Ctenopyge* except *Ct. teretifrons*. The width of the fixed cheek at the posterior margin remains about the same as in *Ct. bisulcata*, *Ct. falcifera* and *Ct. pecten*, and thus the posterior branch of the facial suture runs more directly backwards than in those species.

From *Ct. teretifrons* it is distinguished by the straight front margin and the more tapering glabella; moreover, the fixed cheek is not quite so wide as in that species and the posterior margin is straighter.

Horizon and Locality.—Upper Lingula Flags: Malvern; Dolgelly.

Genus **LEPTOPLASTUS,** Angelin.

In *Leptoplastus* and *Eurycare*, as in *Sphærophthalmus* and *Ctenopyge*, the genal spines spring from the middle of the external margin of the cheeks. In the first two, however, the pleuræ end in short points; in the last two, at least in the hinder part of the thorax, they are produced into long spines. In *Leptoplastus* the number of thoracic segments is 12 (according to Angelin 11 or 12), in *Eurycare* it is 12—17; while in *Sphærophthalmus* and *Ctenopyge* there are apparently only 9 or 10.

Frequently the head alone is available, and in such cases it is sometimes very difficult to determine to which of the two groups the specimen should be referred. As a rule, however, in *Leptoplastus* and *Eurycare* the glabella is shorter and more nearly square in outline, while in *Sphærophthalmus* and *Ctenopyge* it is somewhat more elongated and more rounded in front.

Leptoplastus differs from *Eurycare* chiefly in its proportions. In both genera the head is wide in comparison with its length, but in *Eurycare* the width is greatly exaggerated. The extra width lies mainly in the fixed cheeks, and consequently in *Eurycare* the eyes are more remote from the glabella than in *Leptoplastus*. In *Eurycare*, moreover, the genal spines are longer and the thoracic axis is narrower relatively to the pleuræ.

Accordingly the following are the principal distinguishing features of the genus *Leptoplastus*:

As in the other members of the group the genal spines spring abruptly from the middle of the external margin of the cheeks. The head is wide, but not so wide as in *Ctenopyge* and *Eurycare*. The glabella is nearly square. The eyes are set approximately in the middle of the cheeks. The fixed cheeks at the eye are narrower than the glabella. The genal spines are short. The thorax consists of twelve segments, the pleuræ ending in short points. The tail is small, and its margin is either entire or is furnished with rudimentary points.

1. **Leptoplastus salteri** (Callaway). Plate XI, figs. 2—5.

1874. *Conocoryphe Salteri*, Callaway, Quart. Journ. Geol. Soc., vol. xxx, p. 196.
1877. *Olenus Salteri*, Callaway, *ibid.*, vol. xxxiii, p. 666, pl. xxiv, fig. 5.
1900. *Olenus Mitchinsoni*, H. H. Thomas, *ibid.*, vol. lvi, p. 619, pl. xxxv, figs. 5 and 6.
1907. *Leptoplastides Salteri*, Raw, Rep. Brit. Assoc., 1907, p 513.

Head transverse, width more than twice the length, straight in front, with a marginal rim and furrow. Glabella about four-fifths as wide as it is long, narrowing slightly forwards, rounded in front; three pairs of oblique glabellar furrows, of which the first is very short and often indistinct; neck-furrow well-defined, neck-segment with a median tubercle or spine. Eyes distant from the glabella, less than half the width of the latter, nearer to the anterior than to the posterior margin; a faint ocular ridge, nearly at right angles to the axial line, running towards the anterior angles of the glabella. Facial suture probably inframarginal in front, crossing the margin a little outside the glabella, in front of the eye forming a curve convex outwards, behind the eye running obliquely outwards to the posterior margin. Fixed cheeks less than the width of the glabella posteriorly, less than half the width at the eye. Free cheeks marginate, with the genal spine springing from the middle of the lateral margin; in front of the spine the external margin forms a smooth curve, behind it an oblique straight line meeting the posterior margin at an obtuse angle; genal spines short, directed outwards and backwards.

Thorax of twelve segments. Axis wider than the pleuræ in the first few segments, about the same width behind, with a row of median spines, commonly represented by tubercles on the internal cast. Pleuræ bent downwards about half-way between the axial furrow and their terminations, deeply grooved, ending in short curved points.

Tail small, broad, with a narrow raised margin. Axis wider than the lateral lobes, ending bluntly at the posterior margin, divided into three distinct rings and a terminal portion. Lateral lobes with two furrows on each side. Margin either entire, or sometimes with a minute point at the antero-lateral angles.

Dimensions.—The most nearly perfect specimens that I have seen are only 6 or 7 mm. long; but more fragmentary specimens indicate a length of 15 mm. Raw says that "the adult reaches a length apparently of $1\frac{1}{2}$ or $2\frac{1}{2}$ in., but only two specimens indicate such sizes."

Callaway observed the presence of median tubercles upon the thoracic segments; but even these are not usually distinct except upon external moulds, and internal casts often appear to be perfectly smooth. It is only in exceptional circumstances, when the matrix has split along the median plane, that the spines are clearly shown. They were first noticed by Thomas, who looked upon the spiny form as a distinct species, which he called *Olenus mitchinsoni*. It is evident, however, from the specimen figured in Plate XI, fig. 5, and from other similar specimens, that when the test was filled with sediment the spines usually remained empty except at their bases. Either the spines were actually solid or the hollow was too fine for the sediment to enter. Consequently, on internal casts there is no indication of the spine except a small tubercle, while in external moulds the impressions of the spines are generally conspicuous, though it is seldom clear that they were anything more than tubercles.

Since the form described by Thomas cannot be considered distinct, *Leptoplastus salteri* is the only species of the genus known in Great Britain, and accordingly the generic characters are sufficient to distinguish it from other British trilobites. It presents, however, a close general resemblance to several of the Scandinavian species of *Leptoplastus*. In *L. stenotus*, Ang., the axis of the thorax is somewhat narrower proportionately, and it bears neither spines nor tubercles; according to Angelin the number of segments is eleven, but Persson[1] describes and figures twelve; the tail is similar in shape to that of *L. salteri*, and

[1] Geol. Fören. Stockh. Förh., vol. xxvi (1904), p. 523, pl. ix, figs. 14—16.

the margin generally appears to be entire (as described by Angelin), but Persson states that in well-preserved specimens the constituent segments project slightly at their terminations, forming small points;[1] the axis of the tail shows two distinct rings besides the terminal portion.

In the width of the axis *L. ovatus*, Ang.,[2] approaches the present species more closely, and, moreover, its thorax bears a row of median tubercles; but the marginal teeth on the tail are more conspicuous. It may be remarked that in the specimens figured by Holtedahl[3] as *L. ovatus*, both the glabella and the thoracic axis appear too narrow for Angelin's species. Holtedahl thinks that this may be due to the fact that the axis is really highly convex, as in his specimens, but that in the Swedish specimens, which are preserved in shale, it has been flattened, and consequently widened, by pressure.

In *L. raphidophorus*, Ang., the axis bears a row of median tubercles, and in one of the posterior segments the tubercle becomes a spine. This species, however, has not yet been fully described or figured.

L. bröggeri, Holtedahl,[4] is distinguished from *L. salteri* mainly by the narrower axis and the absence of median spines. The tail has a narrow marginal fold with no trace of spines, and resembles that of *L. salteri* more closely than the tail of any of the other species.

L. longispinus, Holtedahl,[5] is too imperfectly known to permit of any useful comparison.

None of the Scandinavian species appear to possess the row of median spines characteristic of *L. salteri*. In *L. raphidophorus* a long spine springs from one of the posterior thoracic segments—according to Angelin from the last but one—but the remaining segments bear simple tubercles. In *L. ovatus* there are median tubercles but no spines, while in *L. stenotus* the axial rings are without even tubercles. Nevertheless, considering how many specimens of *L. salteri* might be examined without discovering any indication of spines, it would be unsafe to assume that the Scandinavian forms bore none.

Raw has suggested that *L. salteri* should be taken as the type of a new subgenus, which he calls *Leptoplastides* and in which he includes the *Acerocare claudicans*, *A. norvegicum*[6] and *A. paradoxum* of Moberg and Möller. The head

[1] In most of the specimens that I have myself examined the margin seems to be entire, but one or two showed small points.

[2] See Persson, *loc. cit.*, p. 520, pl. ix, figs. 17—23.

[3] See Norsk. geol. Tidsskr., vol. ii, no. 2 (1910), pl. i, figs. 4, 6, 7.

[4] *Ibid.*, p. 18, pl. iii, figs. 1—10.

[5] *Ibid.*, p. 11, pl. iii, figs. 12, 13, ? 14.

[6] This is the name applied by Moberg and Möller to the specimen described by Brögger as *Cyclognathus micropygus*, Lnrsn., which they consider to be distinct from that species. I cannot for my own part see any reason for placing it either in *Leptoplastus* or in *Leptoplastides*. The eye is set far forwards and close to the glabella, there are no genal spines, and the form of the free cheeks is similar to that of *Peltura* and not to that of *Leptoplastus*.

and thorax of *L. salteri*, he says, are very similar to those of Angelin's *Leptoplastus*, "the tail, however, is quite different from that genus, being broader than long, emarginate behind, and entire, as against triangular and toothed." It seems doubtful, however, whether these differences can be considered of subgeneric rank. In *L. ovatus* and *L. raphidophorus* the tail is triangular and toothed, but in the type-species of the genus, which is *L. stenotus*, the tail is broader than long and is not triangular, and the teeth are so minute that they are usually indistinguishable.

Raw's observations, however, certainly suggest that the triangular toothed tail, like that of *L. ovatus*, represents an early stage in the evolution of the genus. According to him, young specimens of *L. salteri* show this character, while in later stages the tail becomes broader and loses its teeth.

Horizon and Locality.—Shineton Shales: Shineton.

Genus **EURYCARE**, Angelin.

As a rule *Eurycare* is easily distinguished from *Sphærophthalmus* and *Leptoplastus* by the great width of the head, the length of the genal spines, the remote position of the eyes, and the narrowness of the thoracic axis. Moreover, the number of thoracic segments is 12—17, while in *Sphærophthalmus* it is 7—9, and in *Leptoplastus* 11—12. It is not always easy, however, to separate *Eurycare* from *Ctenopyge*. In *Eurycare* the pleuræ end in short points; in *Ctenopyge* the pleuræ of the posterior segments terminate in long geniculate spines, but those of the anterior segments often end in points. The tail of *Ctenopyge pecten* is certainly very different from that of *Eurycare*, but, as already noted (p. 79), it is by no means clear that all the species referred to *Ctenopyge* possess tails of this type. It is, however, when only the head is found that the greatest difficulty arises. In both genera the head is very wide in proportion to its length, and the eyes are more or less remote from the glabella. On the whole, these characters are most strongly marked in *Eurycare*, but in some species, such as *E. angustatum*, Ang., this is not the case. In *Eurycare* the glabella is usually shorter in proportion to its length than in *Ctenopyge*, and perhaps rather less rounded in front. In *Eurycare*, in fact, the glabella approximates more nearly to a square, while in *Ctenopyge* it is more cylindrical, tapering slightly forwards; but the difference is not very strongly marked in all species, and when only the cranidium is available it is not always possible to decide the genus with certainty.

The more important characters of the genus may be summarised as follows:

Head short, broad, with long genal spines springing abruptly from the external margin; glabella short and more or less square in outline; eyes small, about half-way between the anterior and posterior margins, remote from the glabella, with a long ocular ridge running towards the anterior angles of the glabella.

Thorax of 12—17 segments, with a narrow axis, pleuræ ending in short points. Tail triangular, with a toothed margin.

1. **? Eurycare,** sp. Plate XI, figs. 6—8.

1864. *Olenus (Sphærophthalmus) flagellifer ?*, Salter, Mem. Geol. Surv., Brit. Org. Rem., dec. xi, p. 3, pl. viii, figs. 7, 8.

1866. *Olenus (Sphærophthalmus) flagellifer ?*, Salter, Mem. Geol. Surv., vol. iii, p. 301, pl. v, figs. 8, 9.

From Carreg-wen, near Borth, a number of distorted specimens have been obtained which appear to differ from any of the species above described, but which are too imperfect to admit of satisfactory description. I refer them, with doubt, to *Eurycare*, chiefly on account of the width of the cheeks and the squareness of the glabella.

They are, for the most part, cranidia of rather large size. In shape they are wide and short, straight or slightly emarginate in front. The glabella is almost square, but with the front somewhat rounded; two pairs of glabellar furrows appear to have been present, though usually only the posterior pair is distinct; in most of the specimens the posterior furrows meet across the glabella, but this seems to be the result of compression, for in one which is less flattened than the rest they do not actually meet, but there is a shallow depression connecting their interior extremities. Neck-furrow well-defined, and on the neck-segment there are indications of a median tubercle. Eye rather large, placed at a distance from the glabella about equal to the width of the latter, and about half-way between the anterior and posterior margins; ocular ridge long and slightly inclined backwards. Facial suture obscure, but appears to run backwards and outwards from the anterior margin to the eye and then backwards and more strongly outwards to the posterior margin. Fixed cheeks at the eye about equal to the glabella in width, expanded behind. Free cheeks small.

Thorax with the axis considerably less than the pleuræ in width.

Dimensions.—Before distortion, the width of the cranidium at the base was probably about 8 mm., and its length about 3 mm.

Of the British forms the one which resembles this most closely is *Ctenopyge bisulcata*, but both the whole cranidium and the glabella are considerably wider in proportion to their length than in that species, and this does not seem to be due entirely to distortion; the fixed cheek is also wider and the ocular ridge is less oblique.

Owing to the imperfect state of preservation, it is scarcely possible to compare this form with the species of *Eurycare* which have already been described; but on the whole it seems to approach most nearly to *E. angustatum*, Ang.[1] In the latter

[1] Angelin, Pal. Scand., p. 48, pl. xxvi, fig. 5; Brögger, Die Silur. Etagen 2 und 3, p. 119, pl. xii, figs. 3, 3a; Persson, Geol. Fören. Stockh. Förh., vol. xxvi (1904), p. 517, pl. ix, figs. 9—13.

the glabella is very similar and the fixed cheek is about the same width, or perhaps a little narrower, compared with the glabella.

Horizon and Localities.—Upper Lingula Flags: Carreg-wen, Borth, Portmadoc.

Genus **PELTURA**, Milne-Edwards.

The genus *Peltura* was separated by Milne-Edwards[1] from the *Paradoxides* of Brongniart mainly on account of the character of the tail, which he describes as "scutiform and well developed." The type-species is the *Entomostracites scarabæoides* of Wahlenberg.[2] Milne-Edwards' description, like Wahlenberg's figure, was apparently based on specimens in which the free cheeks were missing, and accordingly he states that eyes are absent, and in well-preserved specimens the latero-posterior angles of the cephalic shield are prolonged into horns. He also appears to exaggerate the size of the tail; but otherwise his description is accurate.

The genus was subsequently more fully defined and more strictly limited by Angelin. In his diagnosis the more prominent distinguishing characters are as follows: Genal angles rounded, without spines; glabella broad, reaching nearly to the anterior margin, glabellar furrows faint; eyes small, set far forwards and close to the glabella; thorax of twelve segments, axis wider than the pleuræ, pleuræ pointed; tail small, with a toothed margin.

There are, however, certain forms which do not completely agree with Angelin's description, and which are yet very closely allied to *Peltura scarabæoides*. Thus Brögger's *Cyclognathus costatus* in general resembles *Peltura*, but the glabellar furrows are obsolete and the tail is entire. In *Protopeltura acanthura*, Brögger,[3] the cheeks bear short spines. Brögger[4] accordingly was led to modify Angelin's definition so as to include these forms, and he divides *Peltura* into *Protopeltura* (with genal spines), *Peltura* proper (equivalent to Angelin's *Peltura*), and *Cyclognathus* (with tail margin entire).

Angelin's genus *Acerocare* also resembles *Peltura* in many respects. The genal angles are rounded, the eyes set near to the glabella, and in the type-species, *A. ecorne*, the number of thoracic segments is twelve. But in *A. ecorne*, at least, the eyes are not so far forwards as in *Peltura*, the thoracic axis is narrower, the pleuræ are not pointed, the tail is larger and has an entire margin.

[1] Hist. nat. des Crustacés, vol. iii, p. 344.

[2] Under the name *Peltura bucklandi*, Milne-Edwards also included in the same genus the "trilobite de Dudley" of Brongniart. This, however, is a *Lichas* which has since been fully described and figured by Fletcher as *Lichas bucklandi*, Quart. Journ. Geol. Soc., vol. vi (1850), p. 235, pl. xxvii, figs. 1—5, and pl. xxvii *bis*. fig. 1.

[3] According to Moberg and Möller (Geol. Fören. Stockh. Förh., vol. xx (1898), p. 265) this is not, as Brögger supposed, the *Olenus*? *acanthurus* of Angelin. The latter, they state, is a *Parabolina*.

[4] Die Silur. Etagen 2 und 3, p. 105.

Moberg and Möller[1] have described a number of species which they refer to *Acerocare*. They recognise the affinities of the genus to *Peltura* and group the two together under the name of *Peltura* sensu lato, but divide this into *Peltura* sensu stricto, with spines to the tail, and *Acerocare*, without spines or with only rudimentary spines. According to them, the only practical difference between Linnarsson's *Cyclognathus* and *Acerocare* lies in the size of the tail, and amongst the new species which they describe there are intermediate forms. They, therefore, include *Cyclognathus* in *Acerocare*.

There can be no doubt that all these forms are very nearly allied. In all of them the eyes are set far forwards and near to the glabella, and in all the genal angles are rounded and either without spines or with only short and slender points. The whole series might very well be included under the name *Peltura* sensu lato, but to subdivide it according to the presence or absence of spines to the tail does not lead to a satisfactory grouping. According to the classification of Moberg and Möller, Brögger's *Cyclognathus costatus* would fall under *Acerocare*; but in the width of the axis, the shape and length of the glabella, the forward position of the eyes, the pointed ends of the pleuræ, and even in the form of the tail, it is much closer to *Peltura scarabæoides* than to *Acerocare ecorne*. In fact, the only respect in which it resembles the latter more closely is in the absence of spines to the tail. I therefore place this, and the other forms referred by Brögger to *Cyclognathus*, in *Peltura* rather than in *Acerocare*. And I should prefer to distinguish between *Peltura* and *Acerocare* as follows:

In *Peltura* the glabella is broad and reaches very nearly to the anterior margin, in *Acerocare* it is somewhat narrower, and is separated from the anterior margin by a distinct space. In *Peltura* the eyes are set farther forwards than in *Acerocare*. In *Peltura* the thoracic axis is wider than the pleuræ, and the pleuræ are obliquely truncate, but end in short points; in *Acerocare* the axis is narrower than the pleuræ, and the ends of the pleuræ are usually blunt, but may end in short points. In *Peltura* the tail is small, wider than long, with a broad axis terminating bluntly, and the margin may be either entire or spinose; in *Acerocare* the tail is larger, and longer in proportion to its width, and the axis is narrower and more pointed.

To judge from the descriptions and figures given by Linnarsson and by Moberg and Möller, the tail of *Cyclognathus micropygus*, Lnrsn., is distinctly different from that of either *Peltura* or *Acerocare*. The axis is deeply divided, so that in Moberg and Möller's figures it appears as a series of isolated rings, and it dies away posteriorly without any definite termination. The lateral lobes are strongly bent down, without spines or marginal fold, and are marked by a series of fine striations. *Acerocare granulatum*, Moberg and Möller,[2] has a similar tail. In both these forms

[1] Om Acerocarezonen: Geol. Fören. Stockh. Förh., vol. xx (1898), p. 197.

[2] *Loc. cit.*, p. 244, pl. xi, figs. 1–9, pl. xiv, figs. 1–5. See also Supplement till 'Om Acerocarezonen,' *loc. cit.*, p. 315, pl. xvi, fig. 6. It should be observed that the specimens figured on pl. xiv as

the eyes seem to be as far forward as in a typical *Peltura*, and in both the pleuræ are described as truncate. It might, perhaps, be well to retain the name *Cyclognathus* for these and similar species; but the forms referred to *Cyclognathus* by Brögger seem to be very distinctly different.

Practically, therefore, I adopt Brögger's definition of the genus *Peltura*, and include in it the forms which he refers to the "subgenus *Cyclognathus*." But I doubt whether these are really congeneric with Linnarsson's *Cyclognathus micropygus*, and, provisionally, I look upon the latter as the type of a distinct genus.

The following are the more important characters of *Peltura* :

Head short, subreniform, convex, marginate; exterior angles rounded (or sometimes with short spines). Glabella broad, subrectangular, convex, reaching very nearly to the front margin; glabellar furrows rather weak, or obsolete. Eyes small, set very close to the anterior angles of the glabella, with a short ocular ridge. Facial sutures with the anterior branches short and converging forwards in front of the eyes; the posterior branches long and leading from the eyes backwards and outwards to the posterior margin, which they cut near the rounded posterior angles. Free cheeks crescentic. Thorax generally of twelve segments; axis as broad as the pleuræ, or broader; pleuræ grooved, obliquely truncate, but produced into short points. Tail small, wide in proportion to its length, margin armed with short spines or entire; axis short, thick, ending bluntly, and usually not quite reaching the posterior margin.

Triarthrus, Green, resembles *Peltura* in some respects. The genal angles in most of the species are rounded, and the glabella and thoracic axis are both very broad. But it appears to be sufficiently distinguished by the eyes, which are larger and placed considerably farther back and farther from the glabella than in *Peltura*.

1. **Peltura scarabæoides** (Wahlenberg). Plate XI, figs. 9—12.

1821. *Entomostracites scarabæoides*, Wahlenberg, Petrif. Tell. Suec., p. 41, pl. i, fig. 2.
1822. *Paradoxides scarabæoides*, Brongniart, Crust. Foss., p. 34, pl. iii, fig. 5.
1827. *Olenus scarabæoides*, Dalman, Om Palæad., p. 257.
1827. *Trilobites scarabæoides*, Boeck, Laeren om Trilob., p. 36, pl., fig. 24 (*teste* Brögger).
1837. *Olenus scarabæoides*, Hisinger, Leth. Suec., p. 19, pl. iv, fig. 4.
1838. *Trilobites scarabæoides*, Boeck, Keilhau's Gaea Norv., p. 144.
1840. *Peltoura scaraboides*, H. Milne-Edwards, Hist. nat. d. crust., vol. iii, p. 344.
1847. *Peltura scarabæoides*, Corda, Prodrom., p. 127, pl. vi, fig. 68.
1848. *Olenus spinulosus ?*, Phillips, Mem. Geol. Surv., vol. ii, pt. i, p. 55, fig. 3, and p. 347.
1854. *Peltura scarabæoides*, Angelin, Pal. Scand., p. 45, pl. xxv, fig. 8.
— *Anopocare pusillum* (pars), Angelin, Pal. Scand., p. 50, pl. xxvii, fig. 1a (*teste* Linnarsson).

A. granulatum, var., can scarcely belong to this genus. Westergård in his Dictyograptusskiffern (Meddel. Lunds Geol. Fältklubb, ser. B, no. 4, p. 49) has doubtfully referred them to *Bœckia*, but figs. 1 and 2 at least seem to belong to *Sphærophthalmus* or *Ctenopyge*.

1857. *Peltura scarabæoides*, Kjerulf, Geol. d. südl. Norw., p. 284.
1864. *Olenus scarabæoides*, var. *obesus*, Salter, Brit. Organ. Rem., dec. xi, p. 5, pl. viii, figs. 1—4.
1865. *Peltura scarabæoides*, Kjerulf, Veiviser ved geol. excurs., p. 2.
1866. *Olenus scarabæoides*, Salter, Mem. Geol. Surv., vol. iii, p. 301, pl. v, figs. 2—5.
1871. *Conocephalus Malvernius*, Phillips, Geol. of Oxford, p. 68, fig. 5.
— *Olenus scarabæoides*, Phillips, Geol. of Oxford, p. 68, fig. 6.
1880. *Peltura scarabæoides*, Linnarsson, Geol. Fören. Stock. Förh., vol. v, p. 134, pl. v, figs. 1—5.
1882. *Peltura scarabæoides*, Brögger, Die Silur. Etagen 2 und 3, p. 107, pl. i, figs. 7—9; var. *acutidens*, p. 108, pl. ii, fig. 9; form. *typica*, p. 108, pl. ii, fig. 12.
1892. *Peltura scarabæoides*, Matthew, Trans. Roy. Soc. Canada, vol. ix (1891), Sect. iv, p. 53, pl. xiii, figs. 9a, b.

Head about twice as broad as it is long, with a narrow raised border and rounded genal angles. Glabella straight-sided, narrowing slightly forwards, somewhat rounded in front, reaching the anterior raised border; two pairs of oblique glabellar furrows; neck-furrow well defined; neck-segment obscurely divided into three parts by oblique furrows running from the middle of the neck-furrow to the posterior lateral angles of the segment, with indications of a median tubercle. Eyes small, placed far forwards and close to the anterior end of the glabella. Facial suture apparently marginal in front, running outwards from the anterior margin to the eye and thence outwards to the posterior lateral angle. Fixed cheeks, triangular, narrow, at their posterior margin about half the width of the neck-segment. Free cheeks crescentic, with a raised margin which is prolonged into a horn in front of the glabella.

Thorax of twelve segments. Axis wide, nearly twice the width of the pleuræ in front, tapering rapidly behind, where its width is but little more than that of the pleuræ; with a row of median tubercles. Pleuræ of the anterior segments very short, longer towards the middle of the body, decreasing again posteriorly; fulcrum placed very near the axis; all the pleuræ bent slightly downwards, and in the posterior segments backwards, at the fulcrum, with a deep oblique groove; obliquely truncate, but terminating in short points, which, except in the first two or three segments, are directed backwards.

Tail small, roughly semicircular in general outline, but provided on the margin with three short points on each side. Axis forming about a third of the total width, ending bluntly a little before the margin, divided into two distinct rings and a terminal portion. Lateral lobes with one well-marked furrow on each side, and probably a second shorter one.

Dimensions.—Fifteen to 20 mm. appears to be an average length, but much smaller and much larger specimens occur. A glabella in the Belt Collection is about 14 mm. long, indicating a total length of more than 40 mm.

Owing to the pressure to which they have been subjected our British specimens are usually flattened and do not show the marked convexity which is characteristic of the species. This is particularly the case with those from the Malvern Hills, which are, moreover, usually smaller than the Scandinavian specimens. Salter, indeed, supposed at one time that the British specimens constituted at least a distinct variety, which he called var. *obesus;* but in the Survey Memoir on North Wales he appears to have given up this distinction. Our British specimens, indeed, are not sufficiently well preserved to admit of minute differentiation.

As a rule, there is very little difficulty in recognising the genus, even when the remains are very fragmentary. The width of the glabella and the forward position of the eyes are usually sufficient to distinguish the head, while the thorax is characterised by the breadth of the axis and the form of the pleuræ. The present species is distinguished from *P. punctata* by the rounded anterior angles of the glabella, the absence of punctations in the marginal furrow, the wider free cheeks, and the presence of well-marked teeth on the margin of the tail. Of these characters the most reliable in the case of imperfectly-preserved specimens is the shape of the glabella.

Horizon and Localities.—Upper Lingula Flags: Malvern; Portmadoc; Moel Gron; Rhiwfelyn; Yr Orsedd; Arenig; Aran.

2. **Peltura punctata,** Crosfield and Skeat. Plate XI, fig. 13; Plate XII, figs. 1—3.

1896. *Peltura punctata,* Crosfield and Skeat, Quart. Journ. Geol. Soc., vol. lii, p. 535, pl. xxvi, figs. 1—10.

Head rather more than a semicircle, with rounded genal angles, width about four-thirds the length, surrounded by a narrow raised rim and furrow, with a row of small punctations in the furrow in front of the glabella. Glabella large, forming nearly one-half the total width, quadrate, nearly parallel-sided but with the anterior angles somewhat expanded, truncate in front, reaching the marginal furrow; two pairs of oblique glabellar furrows; neck-furrow well defined. Eye small, placed far forward and very near the anterior angle of the glabella; ocular ridge faintly indicated. Facial suture apparently marginal in front, running backwards from the anterior margin to the eye, and thence in a gentle curve to the genal angle. Cheeks gently convex, sloping downwards from the axial furrow; fixed cheeks triangular, at the base rather less than half the width of the glabella; free cheeks very narrow, crescentic, with the margin prolonged as a horn in front of the glabella.

Thorax of twelve segments. Axis considerably wider than the pleuræ, occasionally with traces of median tubercles on some of the segments. Pleuræ bent downwards at the fulcrum, which is placed about a quarter of the way out, deeply grooved, with a large articular facet; terminations with their front border obliquely rounded off, but ending in short points.

Tail small, semicircular, with an entire margin. Axis forming more than one-third the total width, ending bluntly, divided into three rings and a terminal portion. Lateral lobes with three fairly strong furrows, with a fine interlineation between the first and second.

Dimensions.—The specimen shown in Plate XII, fig. 1, which may be considered of normal size, is 24 mm. long. The large glabella in Plate XII, fig 2, indicates a total length of 37 mm.

None of the specimens that I have seen show the tail perfectly, and I do not feel sure that the margin is entire. The possibility of the presence of small points is not altogether excluded. A feature that is worthy of note is, that the pleuræ of the first segment of the tail show a tendency to become more or less detached from the rest.

The principal characters by which the authors of this species distinguish it from *Peltura scarabæoides* are the parallel-sided glabella, the very narrow free cheeks, the punctations in the marginal furrow in front of the glabella, the entire tail, and the form of the pleuræ. As remarked above, it is not quite clear that the tail is entire, and, in any case, it is usually very difficult to be certain on this point. The punctations, too, are by no means always distinct. But the shape of the glabella is usually clearly shown. The anterior angles are, as it were, somewhat pulled out like the corners of a sack or cushion. In *P. scarabæoides*, on the other hand, the glabella narrows slightly forwards and the anterior angles are rounded off.

The body as a whole and the axis (including the glabella) in particular, are less convex than in Swedish specimens of *P. scarabæoides;* but this may be due to pressure. The Malvern specimens of *P. scarabæoides* are quite as flat as *P. punctata.*

Raw [1] considers this species to be very closely allied to *Triarthrus shinetonensis*, and is inclined to regard the two as forming a special section of the genus *Triarthrus.* But in the number of thoracic segments and in the small size and very forward position of the eyes, *P. punctata* is a typical *Peltura* and differs altogether from *Triarthrus.*

Horizon and Localities.—Tremadoc: Nant-y-caws, Nant-y-glasdwr, Nant-cwm-ffrwd, and other localities near Carmarthen; Cwm-du, Llanarthney.

3. **Peltura olenoides** (Salter). Plate XII, figs. 4, 5.

1866. *Conocoryphe ? olenoides*, Salter, Mem. Geol. Surv., vol. iii, p. 308, pl. viii, fig. 6.

Head subreniform. Glabella convex, forming about half the total width of the head, nearly parallel-sided, rounded in front, reaching the anterior margin; neck-furrow rather broad and shallow, arched forwards in the middle line; no indications of lateral glabellar furrows. Eye small, placed very far forwards and

[1] Rep. Brit. Assoc., 1907, p. 512.

close to the anterior end of the glabella. Facial suture running backwards and slightly outwards from the anterior margin to the eye and thence in a gently sigmoidal curve to the posterior lateral angle. Fixed cheeks triangular, about half the width of the glabella at the base, sloping gently downwards from the axial furrows. Free cheeks crescentic, narrow, with a narrow raised marginal rim separated by a marginal furrow.

Thorax consisting of 11 (?) segments, widest about the sixth segment. Axis nearly twice as wide as the pleuræ in front, tapering rapidly in the hinder part of the thorax, where its width is but little greater than that of the pleuræ. Pleuræ very short in front, attaining their greatest length about the middle of the body; fulcrum placed very near the axis, deeply grooved, obliquely truncate but terminating in short points.

Tail obscure, but appears to form a small arc of a circle, with a wide axis, and a distinct marginal limb defined by a marginal furrow.

Dimensions.—Mr. Williams' specimen, allowing for the missing part of the tail, must have been about 16 mm. long. The type-specimen belongs to an individual about twice as long.

This species was founded by Salter on an imperfectly preserved head. It clearly belongs to *Peltura*, but is at once distinguished from the other British forms of the genus by the absence of any trace of glabellar furrows. The shallow neck-furrow arching forwards in the middle also appears to be characteristic. It should be remarked that this furrow may not be homologous with the true neck-furrow, but more probably represents the curving groove which in many trilobites, including *Peltura* itself, divides the neck-segment into a central posterior portion and an anterior lateral lobe on each side.

Mr. Williams' more nearly complete specimen (Plate XII, fig. 5) comes from the same horizon and locality as Salter's, and there can be little doubt that it belongs to this species. It shows the same shallow neck-furrow arching forwards in the middle line. Unfortunately it is much distorted, and it is not certain where the thorax ends and the tail begins. But the presence at the hinder end of the specimen of what seems to be clearly the marginal limb of the tail, indicates that there are not more than eleven segments in the thorax. It is even possible that the eleventh segment may belong to the tail.

Probably the nearest ally is Brögger's "*Cyclognathus*" *costatus*,[1] in which the glabellar furrows are obsolete and the tail is entire with a well-defined marginal limb. So far as it is possible to judge, the proportions are approximately the same, and it is impossible to point to any definite difference between the two forms. But the very imperfect condition of our specimens prevents detailed comparison.

[1] Die Silur. Etagen 2 und 3, p. 110, pl. i, figs. 5 a—d; pl. ii, figs. 10, 11.

The figure accompanying Salter's description is a restoration, and is evidently based upon a misapprehension of the specimen. It does not even correspond with the description. Apparently the artist thought that the whole of the glabella was exposed; and consequently he represents it as clavate in form, narrow at the neck-segment and expanded in front. In the actual specimen the neck-furrow arches forwards from the left axial furrow, and at the right-hand edge of the specimen it has only just begun to curve back to the right axial furrow. It is clear in fact that not much more than half of the basal portion of the glabella is visible; and if the remaining part is restored, as shown in outline in Plate XII, fig. 4, there is little, if any, increase in width towards the front.

The figure is also inaccurate in other respects. It leaves a wide space between the end of the glabella and the front margin, while Salter states that the glabella all but reaches the front margin. The eye is represented as in the middle of the cheek, whereas, in fact, it is very close to the anterior end of the glabella. Salter himself says that it is near the glabella.

Owing to the evident imperfection of the figure and description, neither Brögger[1] nor Reed[2] expresses any decided view as to the generic position of the species. Brögger suggests that it may be allied to *Cyclognathus*, and Reed says that it must be removed from *Conocoryphe* and placed in the Olenidæ.

Horizon and Locality.—Upper Tremadoc: Garth, Minffordd, near Portmadoc.

Genus **BELTELLA**, novum.

The three species next described are very closely allied to one another. There are, indeed, considerable differences in the form of the glabella, but for the reasons explained in the account of *Beltella verisimilis* I believe that some of these differences are sexual and not specific.

They were ascribed by Belt and Salter, with more or less hesitation, to *Conocoryphe*; but Belt clearly recognised that these Lingula Flag and Tremadoc forms are distinct from the true *Conocoryphe* of the lower part of the Cambrian, and he looked upon them as definitely belonging to the Olenidæ.

In their general characters they approximate most closely to *Olenus*, in the wider sense of the name, but they do not fall under any of the recognised genera or sub-genera into which *Olenus* sensu lato has been divided; and in some characters they approach the Conocephalidæ. I have accordingly, with some reluctance, placed them together under the new generic name *Beltella*.

Most of the specimens are flattened, but it is probable that originally the whole animal was decidedly convex. The head is more or less semicircular in form, with

[1] Verb. d. *Euloma-Niobe*-Fauna, Nyt Mag. f. Naturv., vol. xxxvi (1897), p. 203; separate copies (1896), p. 40.

[2] Geol. Mag. [4], vol. vii (1900), p. 255.

a rather broad margin, produced into genal spines. The glabella is quadrate or conical, truncate or rounded in front, separated from the marginal furrow by a frontal limb as wide as, or wider than, the margin. It is probable that the outer surface of the test of the glabella was almost devoid of furrows; but internal casts usually show two pairs, the posterior pair being very oblique and nearly reaching the neck-furrow. The facial suture starts at the outer edge of the anterior margin, close to the middle line, and runs very obliquely outwards across the margin; from the inner edge of the margin it turns inwards to the eye and thence outwards to the posterior margin, which it cuts well within the genal angle. The thorax, so far as is known, consists of twelve segments; all the pleuræ, even those of the hinder end of the body, have the outer part bent down and faceted; in the anterior segments the terminations appear to be rounded or bluntly pointed, in the later segments they are falcate or spined. In front the axis is as wide as, or wider than, the pleuræ; but posteriorly it becomes narrower than the pleuræ. The tail is small and entire.

Many of these characters are to be found in Devine's *Olenus? logani*[1] (for which he suggested the generic name *Loganellus*) and also in *Crepicephalus* (*Loganellus*) *haguei*, Hall and Whitfield.[2] The general shape is similar, the number of thoracic segments is the same and the pleuræ are of the same type, and the facial suture runs outwards in front of the eye as well as behind it. Both these species have since been ascribed by American palæontologists to *Ptychoparia*, and by Brögger[3] to *Liostracus*, and the use of the name *Loganellus* has long been discontinued.

In *Beltella*, however, the eye is placed farther forwards than in either of these forms, and the ocular ridge is much less distinct; but probably the most important difference is in the facial suture. In *Ptychoparia* and *Liostracus*, and apparently in *Loganellus logani* and *Crepicephalus haguei*, the facial suture crosses the anterior margin almost at right angles, and if the sutures of the two sides meet, it must be on the under surface; in *Beltella* the anterior branches of the facial sutures diverge forwards from the eye, but when they reach the margin they again curve inwards, cross the margin very obliquely and meet in the middle line on the upper surface of the body—as in *Dikelocephalus*. Behind the eye the facial sutures in *Beltella* are less divergent and make a smaller angle with the axial line than in the forms referred to.

The species described by Whitfield[4] as *Angelina hitchcocki*, and afterwards made

[1] Description of a new trilobite from the Quebec group, Can. Nat. and Geol., vol. viii (1863), p. 95; reprinted Geol. Surv. of Canada (1863), p. 21; see also Billings, Pal. Foss., vol. i, p. 200.

[2] U.S. Geol. Explor. 40th Parallel, vol. iv (1877), p. 210, pl. ii, figs. 14, 15. Walcott's observations on *Crepicephalus* show clearly that Hall and Whitfield's species do not belong to that genus; see Bull. U.S. Geol. Surv., no. 30 (1886), p. 206; Mon. U.S. Geol. Surv., vol. xxxii, pt. 2 (1899), p. 459; Smithsonian Misc. Coll., vol. lxiv, no. 3 (1916), p. 199.

[3] Geol. Fören. Stockh. Förh., vol. viii (1886), p. 202.

[4] Bull. Amer. Mus. Nat. Hist., vol. i, no. 5 (1884), p. 148, pl. xiv, fig. 13.

by Walcott[1] the type of a new genus, *Protypus*, shows many points of resemblance to *B. depressa*. The general shape is similar, the glabellar furrows are obsolete, the number of thoracic segments is the same, the pleural grooves are of the same character, and the tail is small and entire. But the ocular ridge is much more strongly marked, and the facial suture is described as cutting the margin at right angles. In his first notice Walcott ascribes the species to the Middle Cambrian, but in his later work he includes it in the *Olenellus* fauna.

The divergent course of the anterior branches of the facial suture distinguishes *Beltella* from all the other genera of *Olenus* sensu lato except *Parabolinella*. In the latter genus the general form is flatter and the number of thoracic segments greater, the glabella is usually more truncate and the glabellar furrows much more sharply defined, and the frontal limb is wider.

1. **Beltella depressa** (Salter). Plate XII, figs. 6—10.

1859. *Ellipsocephalus depressus*, Salter, Murchison's Siluria, 2nd edn.,[2] p. 47, Foss. 7, fig. 2.
1866. *Conocoryphe* (*Solenopleura*) *depressa*, Salter, Mem Geol. Surv., vol. iii p. 307, pl. vi, figs. 1, 2, 3.
? 1866. *Conocoryphe vexata*, Salter, *ibid.*, p. 307, pl. viii, fig. 7.

Head semicircular, with the genal angles produced into spines. Glabella quadrate, broadly rounded anteriorly, narrowing slightly towards the front, separated from the marginal furrow by a space about equal to the marginal rim in width; with two pairs of glabellar furrows, of which the first is almost obsolete and the second distinct, very oblique, reaching nearly to the neck-furrow; neck-furrow strong. Eyes small, placed a little nearer to the anterior than to the posterior margin, at a distance from the glabella less than half the width of the latter, with a very indistinct oblique ocular ridge running towards the anterior angles of the glabella. Facial suture apparently running very obliquely outwards across the margin, thence inwards to the eye and thence outwards to the posterior margin, which it cuts at a distance from the glabella about equal to two-thirds the width of the neck-segment. Fixed cheeks narrow at the eyes, widening both in front and behind; free cheeks fairly wide, with a broad margin which is prolonged at the angles to form the backwardly directed genal spines.

Thorax consisting of twelve segments, varying but little in width as far as the seventh segment, tapering rapidly behind. Axis forming rather less than one-third of the total width except in front. Pleuræ with the fulcrum placed more than half-way out, straight and horizontal up to the fulcrum, and then bent slightly

[1] Bull. U.S. Geol. Surv., no. 30 (1886), p. 211, pl. xxxi, fig. 4; Tenth Ann. Rep. U.S. Geol. Surv. (1890), p. 655, pl. xcviii, fig. 6.

[2] Called on the title-page—Third Edition (including "The Silurian System").

downwards and backwards; pleural grooves broad and deep; the anterior pleuræ ending in short points, the later pleuræ produced into backwardly directed spines.

Tail small, semicircular. Axis forming about a third of the total width, almost reaching the posterior border, and ending bluntly; with one ring clearly marked off and two others indistinctly indicated. Lateral lobes with two furrows on each side. No defined margin.

Dimensions.—Specimens of ordinary size are about 35 mm. long; but the thorax and tail figured in Plate XII, fig. 6, belong to an individual which must have been about 70 mm. in length.

In Salter's original specimens the earlier thoracic pleuræ seem to have rounded terminations, and the later pleuræ to be truncate; but the appearance is fallacious and is due to the fact that the actual ends of the pleuræ are buried in the matrix. That this is the correct interpretation is, I think, clearly shown by the specimen figured in Plate XII, fig. 9. On the right-hand side of this specimen the apparent terminations of the pleuræ are similar to the apparent terminations in the type-specimen, and seem to be rounded or truncate. But the left-hand side shows that the anterior pleuræ end in short points, and the later pleuræ are produced into spines.

B. depressa is distinguished from *B. verisimilis* and *B. bucephala* by its square and somewhat truncate glabella. From *B. verisimilis* it is further separated by the more backward and rather more distant position of the eyes, and by the greater width of the head and thorax in proportion to their length. *B. bucephala* approaches it more closely in its proportions; but in that species the glabella is narrower, more conical, and well rounded in front, and the eyes are set a little more forwards.

Salter's *Conocoryphe vexata* is probably an imperfectly preserved *Beltella depressa*. In their general form and proportions the head and glabella show no recognisable differences, and the characters on which Salter relies to distinguish the species are the absence of glabellar furrows and the nearness of the eyes to the glabella. But the state of preservation is such that the glabellar furrows may well have been lost,[1] and with regard to the eyes I do not find any decided difference. The specimen is slightly distorted, and on the right-hand side the eye is nearer to the axial furrow than in *B. depressa*, but on the left-hand side it is at about the same distance.

Brögger[2] has suggested that this species may belong to *Cyclognathus*, but he

[1] It is worthy of note that Belt (Geol. Mag., vol. v, 1868, p. 10) says that in his *Conocoryphe bucephala* and Salter's *C. depressa* the glabellar furrows are only seen in specimens which have been compressed or have been deprived of their test.

[2] Die Silur. Etagen, 2 u. 3, p. 111; see also Verb. d. *Euloma-Niobe*-Fauna, Nyt Mag. f. Naturvid., vol. xxxvi (1897), p. 198—separate copies (1896), p. 35. It would appear from his remarks in the latter paper that the author had seen the specimens in the Jermyn Street Museum, but he does not profess to have examined them closely.

evidently allows a very large margin for inaccuracy in the original description and figures. As Reed[1] has pointed out, the presence of genal spines, the more remote and backward position of the eyes, the glabellar furrows, the relative shortness of the glabella, the rather wide frontal limb, and the shape of the head-shield are opposed to this view. To these characters may be added the course of the anterior branch of the facial suture, which runs inwards from the anterior margin to the eye, instead of outwards as in *Cyclognathus*.

Reed himself considers the generic position of the species as still uncertain, but refers it provisionally to *Solenopleura*.

Horizon and Localities.—Tremadoc: Tyn-y-llan; Penmorfa. The specimens referred by Salter to this species come from the Lower Tremadoc, and the specimens which he refers to *Conocoryphe vexata* from the passage-beds between Lower and Upper Tremadoc.

2. **Beltella bucephala** (Belt). Plate XII, figs. 11—15.

1868. *Conocoryphe ? bucephala*, Belt, Geol. Mag., vol. v, p. 10, pl. ii, figs. 1—6.
1873. *Conocoryphe Williamsoni*, Salter, Cat. Camb. and Sil. Foss. Mus. Cambridge, p. 12.

Head semicircular, with genal spines projecting backwards and outwards. Glabella prominent, conical, rounded in front, separated from the anterior margin by a space about equal to the width of the latter, with two pairs of somewhat faint glabellar furrows, the anterior pair short, the posterior pair very oblique and reaching nearly to the neck-furrow; neck-furrow strong. Eyes small, placed nearer to the anterior than to the posterior margin, distant from the glabella about half the width of the latter; ocular ridge indistinct. Facial suture apparently running very obliquely outwards across the margin, then inwards and backwards to the eye, and thence outwards and backwards to the posterior margin, which it cuts at a distance from the glabella a little less than the width of the neck-segment. Cheeks prominent, with the neck-furrow strongly marked. Free cheeks rather wide. Margin broad, somewhat thickened in front of the glabella; produced at the genal angles into rather slender spines, which are directed slightly outwards, and reach backwards to the sixth thoracic segment.

Thorax probably of twelve segments, almost uniform in width up to the sixth or seventh segment, tapering rapidly posteriorly. Axis in front about as wide as the pleuræ; posteriorly rather narrower. Pleuræ strongly bent downwards, and in the earlier segments backwards, at the fulcrum, which is placed less than half-way out in the first segment, more than half-way in the middle segments, and about half-way in the later segments; deeply grooved; extremities falcate.

Tail unknown, but must have been small.

Dimensions.—Length when complete must have been about 30 mm.

[1] Geol. Mag. [4], vol. vii (1900), p. 253.

I have not found any really good specimens of this species in the Belt Collection at the British Museum. I. 7592 bore the specific name, but it is clear that the label had at some time been misplaced, for this specimen (see Plate VI, fig. 6) corresponds with Belt's description of "*Conocoryphe ? longispina*." Moreover, it shows the tail, while Belt states that the tail of his "*Conocoryphe ? bucephala*" is unknown.

Mr. G. J. Williams has, however, obtained a number of fragmentary specimens which agree with Belt's description of the species and come from the same horizon; and there can be very little doubt that they belong to *B. bucephala.*

But the best specimen that I have seen is that figured in Plate XII, fig. 11, which Salter in 1873 called *Conocoryphe williamsoni*, n. sp. It is somewhat remarkable that he should have used the same name that Belt had previously given to an entirely distinct species; but possibly he had come to the conclusion that Belt's *Conocoryphe ? williamsoni* was not a *Conocoryphe.* In any case, Salter's *Conocoryphe williamsoni* differs from Belt's species of the same name, but, on the other hand, agrees with Belt's *Conocoryphe ? bucephala.*

Belt describes the glabella as subconical, truncated, very prominent; but in his figures it is rounded in front rather than truncate. According to him, it is "without furrows when perfect; but when crushed, or divested of outer crust, showing two pairs of internal ones." Some of the specimens that I have seen support this view, but they are hardly conclusive. In his description Belt gives the number of thoracic segments doubtfully as fourteen, but his figure shows only twelve.

In its general form and proportions *B. bucephala* is very like *B. depressa*, and in distorted specimens it is not always easy to distinguish between the two. In *B. bucephala*, however, the glabella is conical and rounded in front, while in *B. depressa* it is more quadrate and truncate in front. In the former, moreover, the eye is a little farther forwards than in the latter. These appear to be the only differences that survive compression and distortion.

In *B. verisimilis* both the head and thorax are longer in proportion to their width. The glabella also is more elongated and the eye is set considerably farther forwards and closer to the glabella.

Horizons and Localities.—Upper part of the Middle Lingula Flags: Nant Cistfaen, Arenig. Upper Lingula Flags: Rhiwfelyn, Mawddach.

3. **Beltella verisimilis** (Salter). Plate XIII, figs. 1—5.

1866. *Conocoryphe ? verisimilis*, Salter, Mem. Geol. Surv., vol. iii, p. 308, pl. vi, fig. 13.

Head approximating to a semicircle, but somewhat elongated, with the length more than half the width. Glabella long, tapering slightly forwards, rounded in front, separated from the anterior margin by a frontal limb of considerable width;

with two pairs of oblique glabellar furrows, often indistinct; neck-furrow almost obsolete and neck-segment consequently ill-defined. Eyes small, set very near to the glabella, much nearer to the anterior than to the posterior margin, but nevertheless some distance behind the anterior end of the glabella. Facial suture curving inwards and backwards from the anterior margin to the eye, and thence running outwards and backwards, nearly in a straight line, to the posterior margin, which it cuts at a distance from the glabella about equal to half the width of the latter. Fixed cheeks narrow, even at their base. Free cheeks somewhat crescentic, with a broad, down-turned margin, which is produced posteriorly into a genal spine running directly backwards.

Thorax consisting of twelve segments. Axis in the earlier segments wider than the pleuræ, in the later segments not quite so wide. The pleuræ of the first segment extremely short, only about half the width of the axis; in the later segments longer, bent downwards and backwards about half-way out from the axis, apparently with falcate terminations; pleural grooves rather sharp.

Tail small, semicircular, slightly emarginate behind. Axis forming about a third of the total width, with one ring clearly defined and a second indistinctly indicated. Lateral lobes flat, with two oblique furrows on each side.

Dimensions.— The type-specimen, when complete, must have been about 38 mm. in length.

According to Salter the glabella is entirely destitute of lobes. But his description seems to be based on the specimen shown in Plate XIII, fig. 1, and its condition is too imperfect to allow of any safe conclusion on this point. The specimen represented in Plate XIII, fig. 3, is amongst those referred by Salter to *B. depressa*; but the glabella is too elongated and too much rounded in front, the eyes are too far forwards, and the pleuræ of the first thoracic segment are too short for that species.

B. verisimilis is in general easily distinguished from *B. depressa* and *B. bucephala* by its elongated glabella and the more forward and approximate position of the eyes. The vagueness of the neck-furrow also seems to be a feature of some value, but in crushed and distorted specimens the apparent presence or absence of furrows of any kind is not a reliable character. In the thorax the greater length, in proportion to the width, and the extreme shortness of the first thoracic pleuræ, are the most important distinguishing features.

It is no doubt probable that the specimens from the Middle Lingula Flags are not specifically identical with the Tremadoc form, though they are hardly perfect enough to admit of definite separation at present. Moreover, the fact that a narrow form of *Beltella* with long glabella, forwardly-placed eye, obscure neck-furrow, and very short first thoracic segment occurs both in the Middle Lingula Flags along with *B. bucephala* and in the Tremadoc along with *B. depressa*, strongly suggests that these characters are not specific but sexual. It seems probable, accordingly, that *B. verisimilis* is not a distinct species but is the other sex of *B. bucephala* and *B. depressa*, or, to be more precise, *B. verisimilis* (Salter) is the other sex of *B. depressa*, and the Middle Lingula forms that I have provisionally included in *B. verisimilis* belong to the other sex of *B. bucephala*.

Imperfect specimens sometimes bear a striking general resemblance to specimens of *Angelina sedgwicki*, or even of *Olenus cataractes*, which have been strongly compressed from side to side. It is difficult in such cases to judge the true relative widths of the axis and the side-lobes, and glabellar furrows may easily be obliterated. Perhaps the most reliable characters to depend upon are the number of thoracic segments and the position of the eyes, which is more forward in *B. verisimilis* than in either of the other species.

Brögger[1] has suggested that this species, as well as *B. depressa*, may belong to *Cyclognathus*. But although the type specimen is decidedly obscure in many respects, the presence of genal spines, the comparative narrowness of the glabella and thoracic axis, the position of the eyes distinctly behind the anterior end of the glabella, and the course of the facial suture, are sufficient to distinguish it from that genus.

Reed[2] refers it to *Angelina*, and to that genus it offers several points of resemblance. The width of the frontal limb, the vagueness of the neck-furrow, and the apparent absence, in the type specimen, of glabellar furrows, are features which it has in common with *Angelina*. But, as Reed remarks, the number of thoracic segments is twelve instead of fifteen, and the eyes are too far forwards. Reed thinks that these characters may be due to immaturity, but they are not present in undoubted specimens of *Angelina* of considerably smaller size. If I am right in referring the specimen figured in Plate XIII, fig. 3, to the same species, the presence of glabellar furrows at once removes it from *Angelina*. In any case, even in the type specimen, the side-lobes are much narrower, as compared with the axis, than in *Angelina*, and the very short pleuræ of the first thoracic segment are also a distinguishing feature.

Belt[3] considers *B. depressa* and *B. verisimilis* to be the same species in different states of preservation. He thinks that the outer surface of the test was smooth, and that glabellar furrows are shown only on the internal cast or when the specimen has been crushed.

Horizons and Localities.—Middle Lingula Flags: Trinant and Nant Cistfaen, Arenig (these are the specimens figured in Plate XIII, figs. 4 and 5, which may be distinct from the Tremadoc form). Lower Tremadoc: Penmorfa.

[1] Die Silur. Etagen 2 u. 3, p. 111; Verb d. *Euloma-Niobe*-Fauna, Nyt Mag. f. Naturvid., vol. xxxvi (1897), p. 199—separate copies (1896), p. 36.

[2] Geol. Mag. [4], vol. vii (1900), p. 256.

[3] *Loc. cit.*, vol. v (1868), p. 10.

Genus **PARABOLINELLA,** Brögger. (*Addendum* to p. 70.)

To complete the account of the British forms referable to *Olenus* sensu lato I add here a description of the very poor specimen which Salter called *Conocoryphe? simplex*. I have no doubt that it belongs to the genus *Parabolinella*, but, owing to its very imperfect condition, it has no claim to be considered as the type of a distinct species. It may very possibly belong to one of the species already described.

1. **Parabolinella simplex** (Salter). Plate XIII, fig. 6.

1866. ***Conocoryphe? simplex***, Salter, Mem. Geol. Surv., vol. iii, p. 306, pl. v, fig. 17.
1878. ***Ellipsocephalus*** sp., Cat. Camb. and Sil. Foss. Mus. Pract. Geol., p. 12.

The very imperfect specimen described by Salter as *Conocoryphe? simplex* shows only the middle of the head.

The glabella is prominent, short, and square, but somewhat expanded near the base, and it is separated from the margin by a space which is three or four times as wide as the margin. According to Salter the glabella is without lobes; but, although they are very imperfectly shown, there are, on the left-hand side of the specimen, indications of at least two glabellar furrows. The eye is about half-way between the anterior and posterior margins, and distant from the glabella about half the width of the latter. The facial suture runs inwards from the anterior margin to the eye and thence outwards to the posterior margin, which it cuts at a distance from the axial furrow rather less than the width of the glabella. The margin is narrow, flat, and, so far as it is shown, very uniform in width.

Dimensions.—Length of the head 10·5 mm., of the glabella 7·5 mm. (measured on the counterpart, which is rather more complete posteriorly than the figured specimen).

The short, square glabella, the narrow, uniform margin, the width of the frontal limb, and the course of the facial suture are the characters which lead me to place the specimen in *Parabolinella*. The faintness of the glabellar furrows seems to be due simply to the state of preservation.

Both Reed[1] and Brögger[2] have referred it to *Cyclognathus;* but they appear to have been misled by Salter's figure, which is not very accurate. It is to some extent a restoration, but the original specimens, an internal cast and its counterpart, are in the Geological Survey Museum. From them it is clear that the facial suture runs inwards from the anterior margin to the eye, instead of outwards as

[1] Geol. Mag. [4], vol. vii (1900), p. 255.

[2] Verb. d. *Euloma-Niobe*-Fauna, Nyt Mag. f. Naturvid., vol. xxxvi (1897), p. 200—separate copies (1896), p. 37.

in both Linnarsson's and Brögger's *Cyclognathus.* Moreover, the glabella is much too short and the eye too far back for that genus.

Horizon and Locality.—Upper Lingula Flags: Penmorfa Church, Portmadoc.

Genus **ANGELINA**, Salter.

Salter's description of the genus *Angelina*,[1] is as follows: Depressed, head smooth, and with long posterior spines; eyes small, sub-median, without ocular ridge; glabella lobeless. Body segments fourteen to fifteen, with an angular fulcrum, faceted for rolling up. Tail of a few (four or five) segments. Labrum emarginate.

The most important addition to be made to this description is with regard to the course of the facial suture, which is not quite correctly represented in Salter's figures. The two sutures meet in front in the median line. From there they run obliquely outwards across the margin, curve backwards and very slightly inwards to the eye, from which they run outwards and backwards to the posterior margin.

In spite of the abundance of *Angelina sedgwicki* in the Tremadoc of North Wales, hardly any representative of the genus has been found elsewhere.

Whitfield,[2] in 1884, described a form from the Cambian of Vermont, U.S.A., to which he gave the name *Angelina hitchcocki;* but, as he himself pointed out, it does not altogether agree with Salter's definition of the genus. In particular it possesses strongly marked ocular ridges, and the number of thoracic segments is only twelve. Walcott[3] subsequently made it the type of a new genus, which he called *Protypus.* As has already been remarked in the account of *Beltella*, Whitfield's species bears a close resemblance to *Beltella depressa.*

Matthew[4] has described and figured a head from the Tremadoc of Cape Breton, which he thinks may belong to a young *Angelina.* It differs from the adult chiefly in the greater size of the eyes and in the presence of strong ocular ridges.

Reed[5] has suggested that Salter's *Conocoryphe ? verisimilis*, described above as *Beltella verisimilis*, should be referred to *Angelina*, and thinks that the differences from the type may be due to immaturity. The difficulties in the way of accepting this view have already been dealt with; but it may be observed that *Beltella* and *Angelina* appear to be closely related to each other.

In the collections of the Vetenskaps Akademi in Stockholm I saw, more than twenty years ago, a specimen from Yerrestad in Skåne labelled *Angelina salteri*, Holm, but I have been unable to find any published figure or description. According

[1] Brit. Organ. Rem., dec. xi, pt. vii.

[2] Bull. Amer. Mus. Nat. Hist., vol. i, no. 5, p. 148, pl. xiv, fig. 13.

[3] Bull. U.S. Geol. Surv., no. 30 (1886), p. 211, pl. xxxi, fig. 4; Tenth Ann. Rep. U.S. Geol. Surv. (1890), p. 655, pl. xcviii, fig. 6.

[4] Bull. Nat. Hist. Soc. New Brunswick, vol. iv, p. 413, pl. xviii, fig. 9; Report on the Cambrian Rocks of Cape Breton (1903), p. 232, pl. xviii, fig. 9.

[5] Geol. Mag. [4], vol. vii (1900), p. 256.

to my notes made at the time, the head was semicircular but broken, and the thoracic segments were as in *Angelina sedgwicki* except that posteriorly the spines seemed to be somewhat larger. The principal difference from that species lay in the tail, which was entire instead of spinose. This is the only specimen from abroad known to me which can be referred with any confidence to *Angelina*.

Salter looked upon the genus as intermediate between *Olenus* and *Conocoryphe* (a name which he used as equivalent to Barrande's *Conocephalites*), and the characters to which he seems to have attached most importance are the absence of glabellar furrows and of ocular ridges and the grooved and faceted pleuræ, which are bent down at the fulcrum, though not so strongly as in *Conocephalites*. The pleuræ are not unlike those of *Beltella*, and in that genus glabellar furrows seem to be absent on the surface of the test, though they sometimes appear on the cast. In *Beltella* the ocular ridges are ill-defined, but they are not entirely absent. On the whole, *Beltella* seems to be the genus most closely allied to *Angelina*, but it has only twelve thoracic segments instead of fifteen, and the anterior branches of the facial sutures are much more divergent. According to Brögger,[1] *Angelina sedgwicki* stands so close to *Parabolinella limitis*, Brögger, that the two cannot belong to different genera. But with this view I am unable to concur. In *Parabolinella*, including *P. limitis*, the glabella is short, nearly parallel-sided, and truncate in front, and has deeply impressed glabellar furrows; in *Angelina* it is longer and narrower, tapers slightly forwards, and is well rounded in front, glabellar furrows are absent and even the neck-furrow is weak. The eye, moreover, lies farther back than in *Parabolinella*.

1. **Angelina sedgwicki,** Salter. Plate XIII, figs. 7—12; Plate XIV, fig. 1.

1859. *Angelina Sedgwickii*, Salter, Murchison's Siluria, 2nd edition, p. 53, Foss. 9, fig. 2.
1859. *Angelina subarmata*, Salter, *ibid.*, fig. 3.
1864. *Angelina sedgwicki*, Salter, Mem. Geol. Surv., Brit. Organ. Rem., dec. xi, pt. vii, p. 1, pl. vii, figs. 1–5.
1866. *Angelina Sedgwickii*, Salter, Mem. Geol. Surv., vol. iii, p. 308, pl. vii, figs. 1—5.

General form ovate, depressed.

Head semicircular, with the genal angles produced into long spines. Glabella occupying about three-quarters of the total length of the head, sub-parabolic in outline, moderately convex, neck-furrow shallow and ill-defined, glabellar furrows absent or very obscurely indicated by vaguely marked depressions. Eyes small, placed near to the glabella and about half-way between the anterior and posterior margins. Facial sutures meeting in front at an obtuse angle in the median line, crossing the margin very obliquely, then running in a gentle curve almost directly backwards to the eye, and from the eye obliquely

[1] *Euloma-Niobe*-Fauna, Nyt Mag. f. Naturvid., vol. xxxvi, p. 198.

outwards and backwards to the posterior margin, which they cut about half-way between the axial furrow and the outer margin. Fixed cheeks nearly flat, with a broad frontal limb in front of the glabella; free cheeks wide, gently arched downwards. Head surrounded by a narrow raised rim separated by a marginal furrow, which in front of the glabella bends slightly backwards, and is there marked by a number of small close-set punctations; marginal furrow continuous posteriorly with the shallow occipital furrow. Genal angles produced into long and strong spines continuing the curve formed by the outer margin and running almost straight backwards to about the tenth thoracic segment. Hypostome subquadrate, consisting of a central convex portion surrounded by a rather broad margin, which appears to be toothed at the posterior angles.

Thorax consisting of fifteen segments. Axis moderately convex, tapering very regularly backwards, forming less than one-third the total width in front and less than one-quarter posteriorly; extremities of the axial rings somewhat nodular. Pleuræ flat near the axis, bent downwards, and a little backwards, at the fulcrum, which is placed more than one-third of the way out in the anterior segments, less than one-quarter in the posterior segments; obliquely grooved; faceted; extremities falcate, and in the later segments produced into short spines.

Tail small, approximately semicircular, spinose. Axis convex, occupying less than one-third the total width, ending bluntly some distance in front of the posterior margin, showing three rings besides the articular surface and the rounded terminal portion. Lateral lobes gently arched downwards, consisting of two segments similar to the posterior thoracic segments fixed to a rounded terminal plate, the points of the fixed pleuræ projecting as two short, but well-defined, spines upon each side.

Dimensions.—As in most common species, the size varies considerably, but 8 cm. may be considered a medium length. The specimen figured on Plate XIII, fig. 7, must have been at least 11 cm. long before distortion.

Perhaps the most useful diagnostic character of the species is the total absence of any definite glabellar furrows and the faintness of the neck-furrow. Some specimens, indeed, with the light in certain directions, show very shallow ill-defined depressions, which may represent glabellar furrows, but they are always vague and indefinite; and this is true both when the actual test is preserved and in the much more common case of internal casts. In *Beltella* the outer surface of the test is, apparently, devoid of definite glabellar furrows, but on the internal cast the furrows are often quite distinct. *B. verisimilis* is the species which most nearly approaches *Angelina* in this respect; but it may be distinguished by the more forward position of the eye, the smaller number of thoracic segments, and the greater relative width of the axis.

Internal casts of *Angelina sedgwicki*, when well preserved, show the anterior branch of the facial suture as a double line. The suture forks at the marginal furrow, and the two lines into which it splits reach their maximum separation at the eye. Some specimens also seem to show a similar doubling of the suture behind the eye, but this is always less distinct. Such a duplication of the suture may be observed in other trilobites, but it seems to be particularly conspicuous in *A. sedgwicki.*

All the best specimens of *Angelina sedgwicki* that I have seen are preserved in slate, and are internal casts devoid of the test and more or less flattened and distorted. In the Sedgwick Museum, however, there are several specimens (Plate XIII, figs. 9, 10, 12) from more gritty beds at Garth, Portmadoc, which seem to have suffered less from pressure. Unfortunately they are somewhat fragmentary, but they serve to indicate that the general form was rather more convex than it appears in the specimens from slaty beds.

Horizon and Localities.—Upper Tremadoc: Garth Hill, Ynys Towyn, Ty-hwnt-yr-bwlch, and other places near Portmadoc.

Genus **DIKELOCEPHALUS,** Owen.

The type of *Dikelocephalus* is *D. minnesotensis*, Owen, but the name has been somewhat loosely applied to many forms which differ too greatly from that species to be properly included in the same genus. Recently, however, in a memoir[1] on "*Dikelocephalus* and other genera of the Dikelocephalinæ," Walcott has subjected the whole group to a careful revision, and it is accordingly unnecessary for me to discuss the true limits of the genus.

The head is transverse, with the genal angles produced into spines. The glabella is subquadrate, narrowing slightly towards the front, which is broadly rounded; the posterior pair of glabellar furrows is strong and continuous across, though somewhat shallower towards the middle; the middle pair is short, and the anterior pair shorter still or absent altogether; the neck-furrow is strong. The eye is rather large, crescentic, placed near to the glabella and to the occipital furrow. The facial sutures meet on the upper surface a little behind the extreme front of the head, forming either an obtuse angle or else a continuous curve; from there they run outwards and slightly backwards, then bend inwards to the anterior extremity of the eye, pass round the palpebral lobe, turn almost directly outwards and finally curve backwards to the posterior margin, which they cut at a considerable distance from the genal angle. The tail is large; in outline the anterior border forms a curve which is convex forwards, and the antero-lateral angles are rounded off; the posterior border may or may not have two postero-lateral spines; the axis is much narrower than the lateral lobes and ends bluntly before the

[1] Smithsonian Misc. Coll., vol. lvii, no. 13 (1914).

margin; near the axis the lateral lobes are almost level, but farther out and posteriorly they bend down to the broad, flat margin; the furrows on the lateral lobes curve backwards, the anterior furrows following the curve of the anterior border, and the later ones being bent still more strongly backwards.

Dikelocephalus is characteristically an American genus, and, indeed, in his revision Walcott does not allow a single species outside America; but he leaves some doubtful, and he refers the Scandinavian form *Dikelocephalus ? leptænarum*, Wiman, to the closely allied genus *Saukia*, Walcott. *Dikelocephalus celticus*, Salter, however, shows all the characters of a true *Dikelocephalus* tail, the only special feature being the slight emargination posteriorly; and in *D. discoidalis*, Salter, the facial suture takes the characteristic course for *Dikelocephalus*, the eye has the proper position and the glabella the right shape, but the specimens are too imperfect to show clearly whether the posterior glabellar furrows were continuous across.

1. **Dikelocephalus discoidalis,** Salter. Plate XIV, figs. 2—7.

1866. *Dikelocephalus (Centropleura) ? discoidalis*, Salter, Mem. Geol. Surv., vol. iii, p. 304, pl. v, figs. 18, 19.

Head forming an arc of a circle, with the genal angles produced into spines. Glabella less than two-thirds the length of the head, quadrate, narrowing slightly forwards, truncate or even slightly emarginate in front, with three pairs of glabellar furrows and a strongly marked neck-furrow. Eyes rather large, crescentic, placed far back, very near to the occipital furrow and to the glabella. Facial sutures meeting at an obtuse angle in the median line a considerable distance in front of the glabella, thence running obliquely outwards and backwards, and then curving strongly inwards and backwards to the eye, behind which they turn outwards almost at right angles to the axis and cut the posterior margin at a distance from the axial furrow about equal to the width of the glabella at its base. Fixed cheeks forming in front of the glabella a broad, flat expansion, which on the internal cast shows a fine lineation; very narrow at the eye, and behind the eye extending outwards as a narrow wing marked by a strong occipital furrow. Free cheeks wide, gently arched, bordered by a rather narrow margin of very uniform width, which projects in front of the cranidium; genal angles produced into rather slender spines of no great length.

Dimensions.—The head, before distortion, was probably 15—20 mm. long, and more than twice that breadth.

D. discoidalis is probably the head of *D. celticus*. It occurs at the same horizon and in the same locality, and the sizes are not discordant. It should be noted that the specimens of the free cheek figured on Plate XIV, figs. 6, 7, do not come much depends upon the state of preservation. Indeed, Salter, whose figures show only four, says that there are six, which is the number represented by Angelin. The principal difference lies in the outline, the lateral borders in *D. furca* being straighter and making a more definite angle with the anterior border than in *D. dicræura:* but it should be remembered that our specimens are distorted and the Scandinavian ones are incomplete.

The head shown in Plate XIV, fig. 11, is similar in character to that doubtfully ascribed by Salter to this species. It corresponds very well with the tails in size, and it comes from the same locality and horizon as that represented in fig. 13, about which there can be no question; but the chief reason for referring it to this species is the resemblance of the glabellar furrows to those of *D. dicræura*, as figured by Moberg and Segerberg. It differs from this form in the presence of a distinct ridge defining the inner edge of the wide margin. There can, however, be little doubt that this ridge has been greatly accentuated by compression, and in the original condition it was probably much less conspicuous. In *D. villebruni*, Bergeron,[1] which seems to be closely allied, the outer half of the broad margin is concave and the inner half convex; and if such a margin were crushed against the cheeks and glabella, the convex portion would naturally be compressed into a ridge.

All of Salter's figures are from specimens belonging to Mr. Ash and coming from Moel-y-gest. Mr. Ash's collection seems to have been dispersed; but in the Sedgwick Museum there is a specimen of *D. furca* lettered a. 30 (see Plate XIV, fig. 12), and in Salter's Catalogue[2] Mr. Ash is stated to be the donor and the locality is given as Moel-y-gest. Probably this is the original of Salter's plate viii, fig. 10, or else its counterpart.

Horizon and Localities.—Upper Tremadoc: Moel-y-gest and Garth Hill, Portmadoc.

Genus **APATOKEPHALUS**, Brögger.

The name *Apatokephalus* was proposed by Brögger, who looked upon it as denoting a subgenus of *Dikelocephalus.* The type species is the *Trilobites serratus* of Boeck, which was originally founded upon the tail alone; but Holm has shown that the cranidium subsequently described by Linnarsson as *Remopleurides dubius* belongs to the same species. Since this cranidium is so very different from that of *Dikelocephalus* it seems better to look upon *Apatokephalus* as a distinct genus.

The glabella is urceolate, the posterior portion, exclusive of the neck-segment, being greatly expanded, the anterior portion narrower, tongue-like. The eyes are long, crescentic, and almost touch the glabella at their extremities. The

[1] Bull. Soc. Géol. France, [3] vol. xxiii (1895), pl. v, figs. 1, 2.

[2] Cat. Camb. Sil. Foss. Mus. Cambridge, p. 17.

PLATE XIII.

FIGS. PAGE

Beltella verisimilis (Salter). 107

1. The type specimen, nearly complete but for the tail. Lower Tremadoc, Penmorfa Village. Sedgwick Museum. Presented by Mr. D. Homfray. (Figured by Salter, Mem. Geol. Surv., vol. iii, pl. vi, fig. 13.) Nat. size.
2. Thorax and tail with part of head. Lower Tremadoc, near Penmorfa, Portmadoc. Museum of Practical Geology, 10841. Nat. size.

2a. Tail of the same specimen enlarged. × 2.

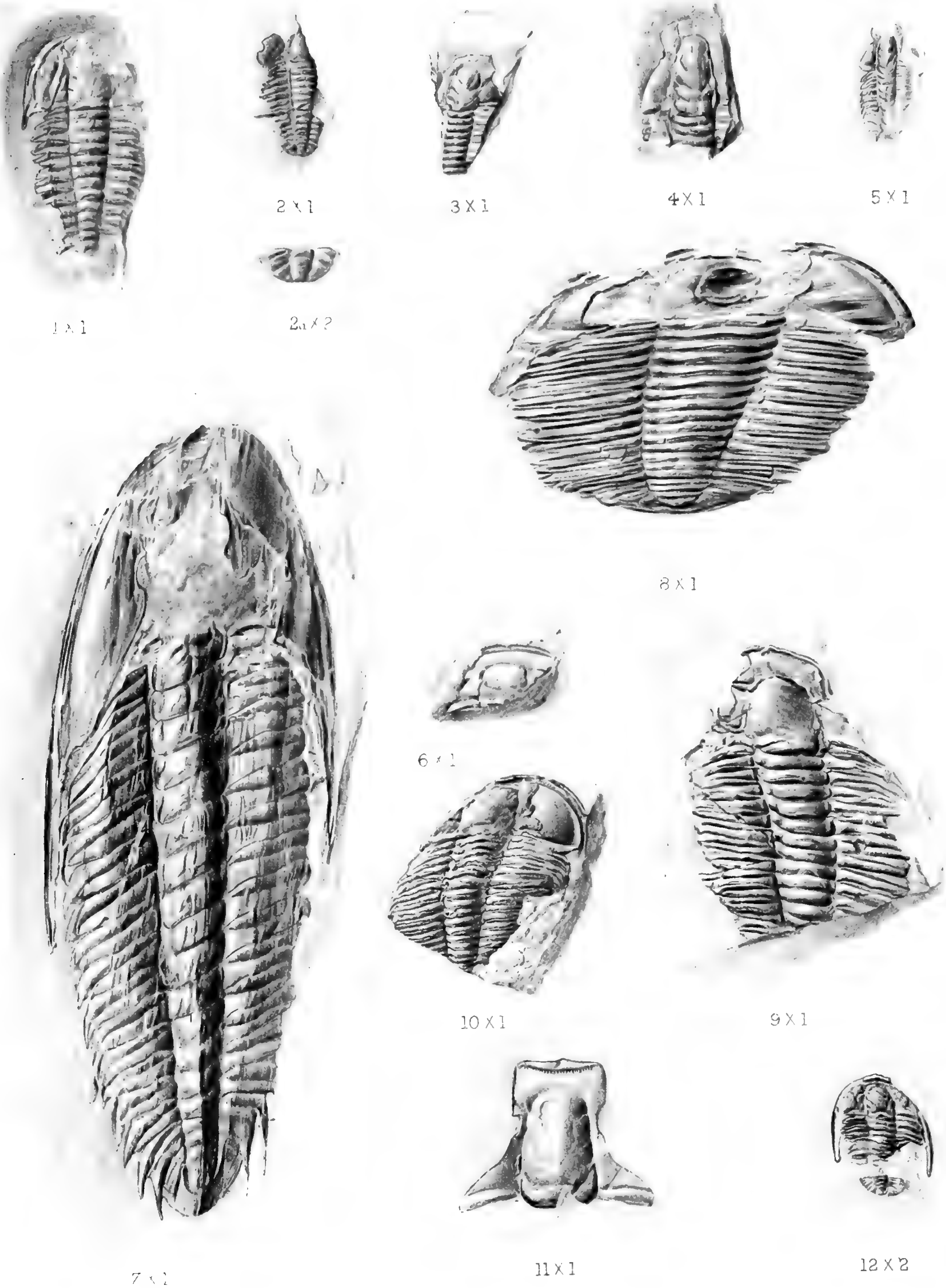
3. Cranidium and part of thorax, showing glabellar furrows. Lower Tremadoc, near Penmorfa, Portmadoc. Museum of Practical Geology, 10839. Nat. size.
4. Cranidium with long glabella, three thoracic segments attached. Upper portion of Middle Lingula Flags, Nant Cistfaen, Arenig, just above pool. Mr. G. J. Williams' Collection. Nat. size.
5. Cranidium with shorter glabella, part of thorax attached. Middle Lingula Flags, Trinant, above pool. Mr. G. J. Williams' Collection. Nat. size.

Parabolinella simplex (Salter). 110

6. Cranidium. Upper Lingula Flags, Penmorfa Church, Portmadoc. Museum of Practical Geology, 10217. (Figured by Salter, Mem. Geol. Surv., vol. iii, pl. v, fig. 17.) Nat. size.

Angelina sedgwicki, Salter. 112

7. Nearly complete specimen of large size. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. Nat. size.
8. Specimen showing hypostome. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. (Counterpart of 10248 in the Museum of Practical Geology figured by Salter, Brit. Organ. Rem., dec. xi, pl. vii, fig. 5.) Nat. size.
9. Uncompressed specimen from a hard bed. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. Presented by Mrs. Hughes. Nat. size.
10. Uncompressed specimen from a gritty bed. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. Presented by Prof. Seward. Nat. size.
11. Cranidium showing course of facial suture, punctations in marginal groove, and faint depressions indicating the positions of the obsolete glabellar furrows. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. Nat. size.
12. Young specimen from a gritty bed. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. Presented by Mrs. Hughes. × 2.



BELTELLA, PARABOLINELLA, ANGELINA.

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PLATE XIV.

FIGS. PAGE

Angelina sedgwicki, Salter. 112

1. Head, showing duplication of the sutures. Upper Tremadoc, near Tremadoc. Museum of Practical Geology, 10191. Nat. size.

Dikelocephalus discoidalis, Salter. 115

2. Glabella and frontal limb. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10214. (Figured by Salter, Mem. Geol. Surv., vol. iii, pl. v, fig. 18.) × 1½.
3. Glabella and eye. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10209. × 1½.
4. Glabella and fixed cheek. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10210. × 1½.
5. Free cheek and part of frontal limb. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10213. (Figured by Salter, Mem. Geol. Surv., vol. iii, pl. v, fig. 18a.) × 1½.
6. Free cheek. Upper Lingula Flags, Carreg-wen, Borth. Sedgwick Museum. × 1½.
7. Free cheek. Upper Lingula Flags, Carreg-wen, Borth. Sedgwick Museum. × 1½.

Dikelocephalus celticus, Salter. 116

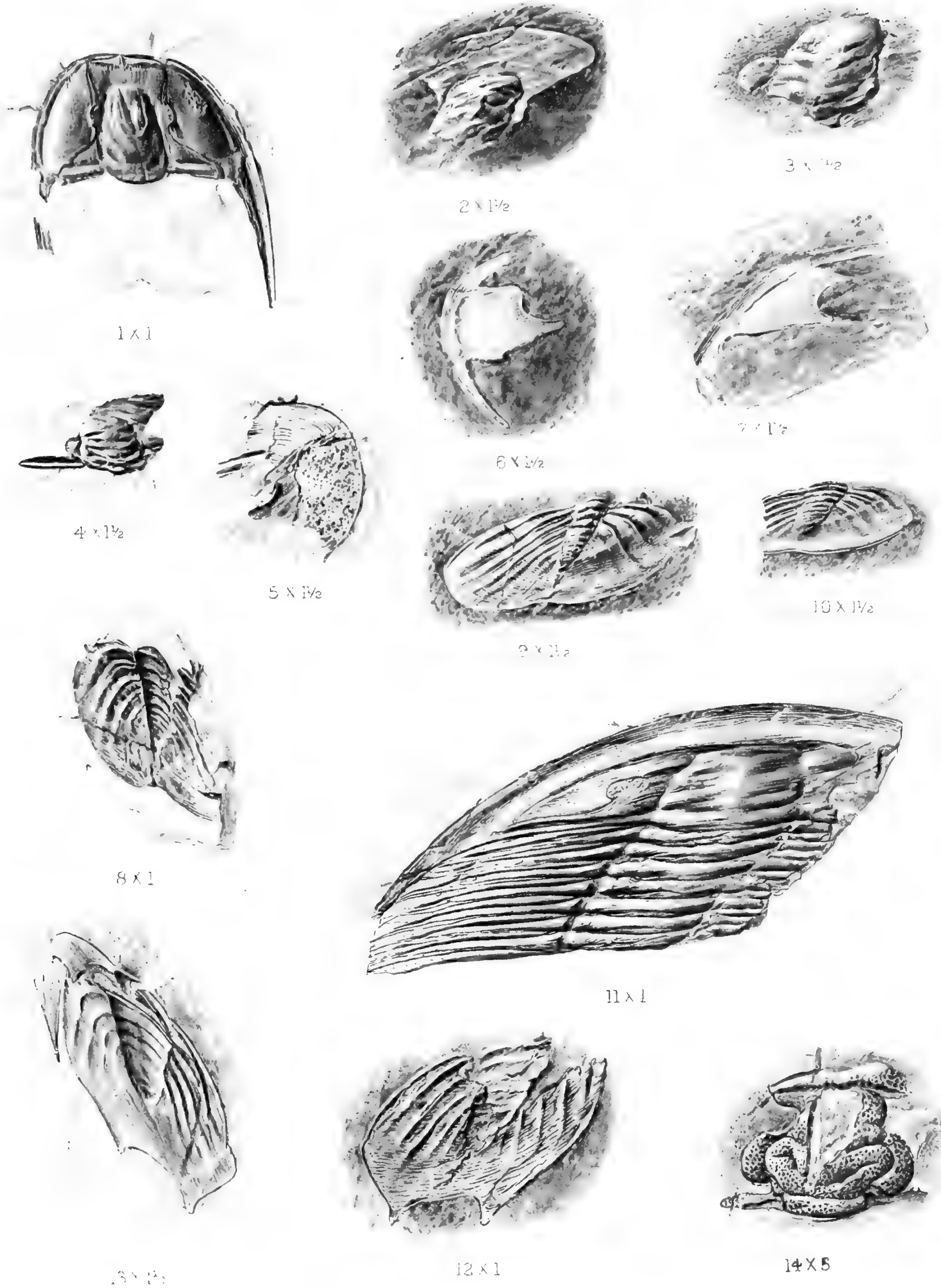
8. Interior of tail. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10208. (Probably used by Salter in Mem. Geol. Surv., vol. iii, pl. v, fig. 21.) Nat. size.
9. Tail, internal cast. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10206a; completed from its counterpart, 10206. (Probably used by Salter in Mem. Geol. Surv., vol. iii, pl. v, fig. 22.) × 1½.
10. Tail, with part of test preserved. Upper Lingula Flags, Ogof-ddu, Criccieth. Museum of Practical Geology, 10211. (Figured by Salter as *Dikelocephalus ?* sp., Mem. Geol. Surv., vol. iii, pl. v, fig. 20.) × 1½.

Dikelocephalina furca (Salter). 118

11. Head and part of thorax. Upper Tremadoc, Garth Hill, Portmadoc. Mr. G. J. Williams' Collection. Nat. size.
12. Interior of tail. Bottom beds of the Upper Tremadoc, Moel-y-Gest, Portmadoc. Sedgwick Museum. Presented by Mr. Ash (a 30 of Salter's Catalogue). (Probably the original, or its counterpart, of Mem. Geol. Surv., vol. iii, pl. viii, fig. 10.) Nat. size.
13. Interior of tail and last thoracic segment. Upper Tremadoc, Garth, Portmadoc. Sedgwick Museum. Presented by Mr. D. Homfray (a 30* of Salter's Catalogue). × 1½.

Apatokephalus serratus (Boeck). 122

14. Cranidium. Upper Tremadoc, Anmodd Wen, Arenig. Mr. G. J. Williams' Collection. × 5.



ANGELINA, DIKELOCEPHALUS, DIKELOCEPHALINA, APATOKEPHALUS.

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