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TRANSACTIONS OF THE SOCIETY.

I.—*On the Structure and Affinities of the Genus Porosphæra, Steinmann.*

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(*Read December 16th, 1903.*)

PLATES I. AND II.

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I. INTRODUCTION.

THE genus *Porosphæra* was established in 1878 by Dr. G. Steinmann for certain small rounded fossils widely distributed in the Cretaceous rocks of this country and the Continent, which, in 1829, had been named and figured by Prof. John Phillips, *Millepora globularis*. Steinmann considered the fossils to be nearly allied structurally to *Parkeria*, and he placed the genus in the family Milleporidæ, Moseley, thus in approximately the same systematic position as that to which they had been assigned by Phillips fifty years previously. Very divergent views respecting the nature of these fossils have been held by older authors, and they have been referred in turn to Foraminifera, Sponges, and Cyclostomate Polyzoa. Latterly, Steinmann's determination of their hydrozoal characters has been accepted generally as correct, though some

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competent authorities have questioned his conclusions. The general resemblance of *Porosphæra* to sponges, which has led several authors to place the fossils in this group, induced me for many years past to collect and study all the forms I could meet with; for a long time I failed to discover any decisive evidence respecting the original characters of their calcareous skeletal fibres, but at last, about eight years ago, a small specimen, preserved in flint, which was sent to me by Mr. H. Muller of Eltham, clearly showed that the fibres were built up of spicules. On further investigation this spicular structure was recognised in microscopic sections of many other specimens, and it became apparent, as I have already mentioned elsewhere,* that *Porosphæra* belonged to the Lithonine division of Calcsponges, and possessed the same structural characters as the genus *Plectoninia*, Hinde,† from the Eocene Tertiary of Victoria, Australia, and the recent *Petrostroma*, Döderlein,‡ from the Japanese sea.

Other work has prevented me from giving till now a detailed description of the structure of *Porosphæra*, but the delay has been in one respect an advantage, for in the interval my friend, Dr. A. W. Rowe, F.G.S., has carried on a series of researches on the fossils from the different zones of the Chalk on the east and south coasts of England, during which he has met with many hundred examples of *Porosphæra*, all of which he has most generously forwarded to me for examination. The study of this large series of well-preserved specimens, together with those of my own collecting, has enabled me to gain a better knowledge of the real characters of these fossils than hitherto, and, further, to trace out their distribution in the various zones of the Chalk of this country.

II. HISTORY OF THE GENUS.

The following is a brief history of the fossils which are now included under *Porosphæra*.

In 1822, Dr. G. A. Mantell figured, in the *Geology of Sussex*, pl. xvi. figs. 17, 18, p. 162, 'Siliceous specimens of a Zoophyte of a pyriform shape, the nature of which is unknown,' from the Chalk near Brighton. These are examples of *Porosphæra nuciformis*, von Hag. sp. Figs. 22-24 of the same plate, referred to *Lunulites* (?), probably belong to *P. patelliformis*. In 1835, they were placed by this author under *Orbitolites lenticulata*, Lam., Trans. Geol. Soc. s. 2, vol. iii. p. 204.

In 1829, Prof. J. Phillips, in the *Geology of Yorkshire*, pt. i. p. 186, pl. i., fig. 12, gave a figure of *Millepora globularis*, and

* Quart. Journ. Geol. Soc., lvi. (1900) p. 57.

† Op. cit., p. 51.

‡ Zool. Jahrb., x. (1898) pp. 15-32, pls. ii.-vi.

another (fig. 11) is named *Lunulites urceolata*, Lam. Both specimens are partly imbedded in a slab of hard chalk from Dane's Dike, Flamborough, now preserved in the York Museum. Steinmann has taken the first of these as the type of the genus *Porosphaera*, whilst the *Lunulites urceolata* is now known as *Porosphaera pileolus*. No description accompanied either of the forms figured by Phillips. In the third edition of the *Geology of Yorkshire*, which appeared in 1875, both *Millepora globularis* and *Lunulites urceolata* are placed in the genus *Coscinopora*, Goldfuss, but here again no description is given; the specific name of the latter is, however, changed to *pileolus*.

In 1833, S. Woodward figured in the *Outline of the Geology of Norfolk*, pl. iv., figs. 10-12, several examples of *Millepora globularis* from the Chalk of Norwich and near Holt, which are placed with other fossil sponges under the heading Polypi. It is doubtful if the *Lunulites urceolata*, pl. iv., fig. 9, belongs to *Porosphaera*. I have not been able to trace the originals of the figures.

In 1839, F. von Hagenow described and figured in the 'Monographie der Rügenschon Kreide Versteinerungen' (*Neues Jahrbuch für Mineralogie*), as a new species of Polyzoa, *Ceripora nuciformis*, the same pear-shaped forms of *Porosphaera* which had been already figured by Mantell in 1822. He regarded them as a more complete development of the rounded forms, i.e. of *P. globularis*, Phill. sp., though he does not mention this species (p. 286, pl. v., fig. 9). In the same work (p. 260) a description is given of another rounded fossil from the Chalk of Rügen, named *Achilleum globosum*, which appears to have been partly based on specimens of *P. globularis*, and partly on small round siliceous sponges subsequently named by v. Zittel, *Plinthosella squamosa*.

In 1844, A. E. Reuss, in *Geognostische Skizzen aus Böhmen*, vol. ii., p. 140, quoted *Ceripora pisum* = *Millepora globularis*, Phill., from the Plänerkalk of Kutschlin and near Bilin; and shortly after (1845-6), in *Die Versteinerungen der böhmischen Kreideformation*, Abth. 2, p. 78, pl. xx., fig. 5, he described and figured the same form as a sponge under the name of *Tragos globularis*.

In A. d'Orbigny's *Prodrome de Paléontologie*, vol. ii. (1850) p. 284, *Tragos globularis*, Reuss (= *P. globularis*, Phill.) is placed in the genus *Coscinopora*, Goldfuss.

John Morris, in the second edition of the *Catalogue of British Fossils* (1854) pp. 27, 28, follows d'Orbigny in placing *P. globularis* under *Coscinopora*, and to the same genus he refers *Lunulites*, Mant., *L. urceolatus*, Phill., and *Orbitolites lenticulata*, Mant. These forms are placed with a query as synonyms of Lamarek's species (*O.*) *pileolus*.

In the *Ann. and Mag. Nat. Hist.*, s. 3, vol. vi. (1860) p. 30, W. K. Parker and T. R. Jones described *P. globularis*, Phill. sp., as a Foraminifer, and placed it in the genus *Orbitolina*, d'Orbigny,

whilst the allied conical, hemispherical, and depressed forms are definitely assigned to *O. concava*, Lamk. sp.

F. A. Roemer, in 'Die Spongitarien des Norddeutschen Kreidegebirges' (*Palæontographica*, vol. xiii. (1864) p. 56), placed *Tragos globularis*, Reuss (= *P. globularis*, Phill.), as a synonym of *Achilleum globosum*, v. Hag.

In the 'Seeschwämme des mittleren und oberen Quaders' (*Palæontographica*, vol. xxii. (1872-5) p. 4), H. B. Geinitz pointed out that the resemblance in outer form between *Ceriopora nuciformis*, v. Hag. (= *P. nuciformis*) and *Achilleum globosum* (= *Plinthosella squamosa*, v. Zitt.) is so close that they may readily be mistaken for each other. Geinitz placed this latter sponge with the Lithistidæ, where it rightly belongs.

H. J. Carter, in the *Ann. and Mag. Nat. Hist.*, s. 4, vol. xix. (1877) p. 64, and s. 5, vol. i. (1878) p. 298, described under the names, first of (?) *Brudya tergestina*, and afterwards of *Millepora Woodwardi*, a new species of *Porosphæra*, characterised by branched canals which radiate from points on the surface. It is regarded as a Hydrozoön with a structure similar to that of *Parkeria*. The forms occur in the Grey Chalk near Dover, and the types are now in the British Museum (Natural History), South Kensington.

In his memoir 'Ueber fossile Hydrozoen aus der Familie der Coryniden' (*Palæontographica*, vol. xxv. (1878) p. 120, pl. xiii., figs. 8-12), Dr. G. Steinmann referred *Millepora globularis* to a distinct genus, *Porosphæra*, belonging to the Hydrocorallinæ. The skeleton is stated to consist of anastomosing calcareous fibres, like those of *Parkeria*, and their microstructure is distinctly radiate. The author recognises the close resemblance in outer form of *Porosphæra* to Sponges, but stated that the definite connected calcareous skeleton is quite unknown in existing sponges, though it occurs in numerous fossils. The various forms of *Porosphæra*, including *P. Woodwardi*, Carter, are regarded as belonging to a single species, *P. globularis*, Phillips.

In the *Elemente der Palæontologie* (1888) p. 77, fig. 73, by the same author and Dr. Döderlein, *Porosphæra* is retained in the same systematic position. The Gastroporen are stated to be radial and numerous, in other respects like *Millepora*.

Dr. F. A. Quenstedt, in the *Petrefaktenkunde Deutschlands*, vol. vi. (1879) p. 262; Atlas, pl. 153, figs. 1-12, referred a series of the usual forms of *P. globularis* to *Ceriopora nuciformis*; v. Hag., and considers them as Bryozoa. Quenstedt further mentioned that amongst a suite of specimens sent to him direct by v. Hagenow as examples of his *Achilleum globosum*, some were genuine forms of *Ceriopora nuciformis*, whilst others were definite sponges.

In the *Handbuch der Palæontologie*, vol. i. (1879) p. 288, Prof. v. Zittel accepted Steinmann's determination of *Porosphæra*, and placed the genus in the family Milleporidæ; in the same

author's *Grundzüge der Paläontologie* (1895) p. 102, it is placed next to *Parkeria* in the Order Tubulariæ; and in the English edition of the work (1900) p. 111, it is retained in the same position.

Treating of the affinities of the genus *Parkeria*, Carpenter, *Ann. and Mag. Nat. Hist.*, s. 6, vol. i. (1888) p. 11, the late Prof. H. A. Nicholson stated that microscopic sections of *Porosphaera globularis* show that its minute structure differs from that of any Hydrozoön, and that it has no special relationship with *Parkeria*. The author thinks that it will be found to belong to the group of the Lithistid sponges, and to be related to the genus *Hindia*, Duncan. The same opinion is also expressed in the *Manual of Palæontology*, 3rd ed. (1889) vol. i., p. 200.

Prof. A. Fritsch gives a description of *Amorphospongia globosa*, v. Hag. sp., in *Studien im Gebiete der böhmische Kreideformation*, iv. Die Teplitzer Schichten (1889) p. 108, fig. 52. It is stated that the inner skeleton appears to consist of a plait-work of calcareous spicules, and that there is a surface layer which likewise seems to be of spicules. Through the kindness of Dr. Fritsch, I have examined a microscopic section of the specimen which he has described, and can confirm his statement of the spicular character of the interior skeleton, which is similar to that of *Porosphaera globularis*; but I failed to recognise any spicular structure in the outer crust. The specimen seems to me to belong to *P. globularis*, Phill.

G. J. Hinde stated in the *Quart. Journ. Geol. Soc.*, vol. lvi., Feb. 1900, p. 57, that *Porosphaera*, Steinmann was a Calcsponge in which the spicules of the skeletal mesh were fused together as in *Plectroninia* and *Petrostroma*, and that it belonged to the Lithonina.

Dr. G. Steinmann, in the *Einführung in die Paläontologie* (1903) p. 95, places *Porosphaera globularis* in the Lithonina as a group of the Pharetrones.

The varied opinions respecting the nature of *Porosphaera* indicated in the references given above may to some extent be accounted for by the minute and delicate structure of the fibrous skeletal mesh of the organism, which appears in the majority of microscopic sections, even of well-preserved specimens, as a continuous network in which scarcely any traces of the constituent spicular elements can be recognised. Another source of error arises from the fact that certain zones of the Chalk in which *Porosphaera* is plentiful likewise contain specimens of the siliceous sponge, *Plinthosella squamosa*, v. Zitt., which closely resemble *Porosphaera globularis* in form and size, and the two kinds of sponges appear to have been confused together by von Hagenow and other authorities.

III. MODE OF OCCURRENCE AND ZONAL DISTRIBUTION.

In this country *Porosphaera* is met with most commonly in the Chalk cliffs of the coasts of Yorkshire, Kent, Sussex, Isle of Wight, Dorset, and South Devon. It is by no means uniformly distributed in the Chalk, for whilst in some beds and horizons specimens are very plentiful, in others they are rare or apparently absent altogether. They are usually seen slightly projecting from the weathered face of the cliff, from which they can readily be picked out with a blunt knife or chisel. When naturally weathered out of the cliff and fallen to the beach, they are soon worn smooth and their surface characters are partly obliterated. As a rule, they are seldom found in inland areas, either in Chalk pits or on downs and other places where the Chalk outcrops at or close to the surface; but their apparent scarcity in these positions may be due to their generally small size and to their close resemblance to rolled fragments of Chalk. As an instance of their occurrence in such places when carefully searched for, I may mention that within the limits of a moderately-sized garden situated on the slope of a Chalk down at Croydon, Surrey, I have during the last sixteen years picked from the surface soil 632 specimens of different forms of *Porosphaera* which have all been derived by slow weathering from the underlying Chalk.

With the object of tracing the development of *Porosphaera* at various horizons in the Chalk, the collections made by Dr. Rowe and by myself from each zone and locality have carefully been kept separate, and in the list below details are given of the number and range of size of each species from the respective zones, which will show approximately the relative proportions of the different forms which occur together. About two-thirds of the total number of specimens in this list have been obtained by Dr. Rowe.

It will be seen from this list that the earliest appearance of *Porosphaera* in the Chalk of this country is in the zone of *Holaster subglobosus* at Dover and at Durdle Cove, Dorset. There are only very few specimens present on this horizon, and they all belong to one species, *P. Woodwardi*, Carter, which, so far, has not been found in any higher zone.

In the next higher zone of *Rhynchonella Cuvieri*, the predominant species, *P. globularis*, Phillips, occurs for the first time—it is represented by only a few small specimens; with it are some diminutive forms of *P. arrecta*. *P. globularis* is more abundant in the succeeding zone of *Terebratulina gracilis*, but the specimens are still small generally; in this zone the limpet-shaped *P. patelliformis* is first met with.

At the base of the Upper Chalk, in the zone of *Holaster planus*, the thimble or inverted cup-shaped *P. pileolus* makes its first appearance.

In the succeeding zones of *Micraster cor-testudinarium* and *M. cor-anguinum*, we find *P. globularis* more numerous and of larger size; in the latter zone, the ribbed, pear-shaped *P. nuciformis* has been first noted. *P. pileolus* and *P. patelliformis* are more common than in the Middle Chalk; but they form only a small percentage in comparison with the numbers of *P. globularis*.

It will be noticed that the forms from South Croydon, which I have placed in the zone of *Micraster cor-anguinum*, differ considerably in their maximum size from those of the same zone on the Thanet coast, and approach more nearly in this respect to those obtained by Dr. Rowe from the *Marsupites* zone of Margate. This fact has led me to question whether the Chalk at South Croydon has been correctly referred to the *M. cor-anguinum* zone; but I have hitherto failed to find in it any remains of *Marsupites*. I have, however, found a single specimen of *Offaster pillula*, Lam., associated in the same area with the large specimens of *P. globularis*; and as this echinoderm, according to Dr. Rowe, also occurs, though rarely, in the *Marsupites* zone of Thanet, there is some probability that the Chalk at South Croydon may be correlated to this zone.

From the zone of *Marsupites*, at Margate more particularly, and also at Flamborough, *Porosphaera* is very common, and Dr. Rowe has obtained a large series of the different species. The greater number were found in the lower part of this zone, the *Uintacrinus* Band of Dr. Rowe. At this horizon, in Kent, the specimens generally are notably larger than those from the lower zones of the Chalk, some of *P. globularis* reaching a maximum diameter of 34 mm.; the larger forms also are in part loaf- or cushion-shaped, a feature still more strongly pronounced in specimens from the higher zone of *Belemnitella mucronata*.

At various places on the Sussex coast, and at Sewerby on the Yorkshire coast, *Porosphaera* is very abundant in the next higher zone of *Actinocamax quadratus*. *P. nuciformis* is numerous in the Sussex cliffs. The specimens are generally smaller than those from the *Marsupites* zone, and approximate in size to those from the *Micraster cor-anguinum* zone on the Thanet coast.

In the zone of *Belemnitella mucronata*, the highest in the English Chalk, an interesting series of forms was collected by Dr. Rowe at Ballard's Cliff and at Studland Bay, Dorset, and also from the Norfolk coast. The Dorset specimens are characterised by their fairly large size, the abundance of loaf- and cushion-shaped forms of *P. globularis*, and the relatively large proportion of *P. nuciformis*.

Summing up the zonal distribution of *Porosphaera* in the Chalk: the genus is first noted in the Lower or Grey Chalk, of the zone of *Holaster subglobosus*, by a few specimens of the rare *P. Woodwardi*; the principal species, *P. globularis*, appears for the first time in the zone of *R. Cuvieri*, the lowest horizon of the Middle Chalk, accompanied by *P. arrecta*. In the zone of *T. gracilis*, we first meet

LIST SHOWING THE NUMBER AND RANGE OF SIZE OF THE DIFFERENT FORMS

		<i>Porosphaera globularis.</i>	<i>Porosphaera nuciformis.</i>
Middle Chalk. Lower Chalk. Cenomanian. Turonian.	Zone of <i>Holaster subglobosus</i> .		
	Dover	..	..
	Durdle Cove, Dorset Coast	..	..
	Zone of <i>Rhynchonella Cuvieri</i> .		
	Dover	8 (2-4 mm.)	..
	Branscombe and Berry Cliff, S. Devon Coast	12 (1-5-5 mm)	..
	Zone of <i>Terebratulina gracilis</i> .		
	Dover, East Cliffs	..	..
	Dover, West Cliffs	34 (2-4 mm.)	..
	Seaton, S. Devon Coast	43 (2-7 mm.)	..
Upper Chalk. Senonian.	Flamborough, Yorkshire Coast	2 (2 mm.)	..
	Zone of <i>Holaster planus</i> .		
	Dover, East Cliffs	29 (3-7 mm.)	..
	S. Devon Coast	6 (3-4 mm.)	..
	Zone of <i>Micraster cor-testudinarium</i> .		
	Chatham	18 (2-4 mm.)	..
	Dover, East Cliffs	50 (2-9 mm.)	..
	Seaford Head and Newhaven	266 (1-15 mm.)	..
	S. Devon Coast	..	..
	Zone of <i>Micraster cor-anguinum</i> .		
	Gravesend	..	..
	Chatham	3 (6-9 mm.)	..
	Thanet Coast	51 (2-14 mm.)	5 (7-9 mm.)
	Dover, St. Margaret's	..	..
	Dorset Coast	..	3 (9-13 mm.)
	S. Devon Coast	..	..
	South Croydon, Avondale Road	579 (4-27 mm.)	28 (6-20 mm.)
	Croydon, near	33 (1-5-25 mm.)	..
	Flamborough, Yorkshire Coast	77 (3-13 mm.)	2 (7-9 mm.)
	Zone of <i>Marsupites testudinarius</i> .		
	<i>Uintacrinus Band</i> .		
	Thanet Coast	35 (7-23 mm.)	36 (4-15 mm.)
	Margate	429 (2-5-34 mm.)	25 (5-20 mm.)
	Flamborough	35 (2-13 mm.)	4 (5-13 mm.)
	<i>Marsupites Band</i> .		
	Sussex Coast	7 (13-31 mm.)	1 (12 mm.)
	Dorset Coast	1 (2 mm.)	1 (13 mm.)
	Sewerby, Yorkshire Coast	53 (2-5-12 mm.)	3 (5-10 mm.)
	Zone of <i>Actinocamax quadratus</i> .		
	Seaford Head and Newhaven	72 (3-17 mm.)	69 (5-14 mm.)
	Sussex Coast	12 (9-23 mm.)	14 (7-14 mm.)
	Brighton, East of pumping station	181 (2-5-13 mm.)	20 (4-9 mm.)
	Isle of Wight, Scratchells Bay	56 (2-5-9 mm.)	8 (4-14 mm.)
	Dorset Coast	..	..
	Winchester	..	5 (7-12 mm.)
	Sewerby	166 (2-5-15 mm.)	8 (6-10 mm.)
	Zone of <i>Belemnitella mucronata</i> .		
	Ballard Cliff and Studland Bay, Dorset Coast	62 (6-24 mm.)	23 (5-12 mm.)
	Sheringham, Weybourne, Overstrand, Norfolk	6 (7-24 mm.)	..
	Trimingham, Norfolk Coast	16 (2-12 mm.)	2 (6, 7 mm.)
	Norwich, near, Catton Pit	1 (14 mm.)	..
	Zones unknown.		
	Surrey and Kent	8 (1-12 mm.)	..
	Hampshire and Wiltshire	6 (1-15 mm.)	..

OF POROSPHERA OBTAINED FROM THE ZONES OF THE ENGLISH CHALK.

<i>Porosphæra</i> <i>Woodwardi</i> .	<i>Porosphæra</i> <i>puleolus</i> .	<i>Porosphæra</i> <i>patelliformis</i> .	<i>Porosphæra</i> <i>arrecta</i> .	<i>Porosphæra</i> . Irregular forms.	Totals.
2 (12, 14 mm.)	..	..	..	..	2
1 (9 mm.)	..	..	..	..	1
					— 3
..	..	..	..	..	8
..	..	..	7 (3-6 mm.)	..	19
					— 27
..	..	3 (2-8 mm.)	..	..	3
..	..	..	..	..	34
..	..	..	..	..	43
..	..	..	..	..	2
					— 82
..	1 (7 mm.)	1 (10 mm.)	..	..	31
..	..	..	..	..	6
					— 37
..	2 (3 mm.)	3 (4-6 mm.)	..	..	23
..	..	..	..	..	50
..	10 (2-9 mm.)	23 (2-11 mm.)	..	5 (1-5 mm.)	304
..	2 (4 mm.)	..	..	..	2
					— 379
..	..	2 (16 mm.)	..	..	2
..	..	..	..	..	3
..	..	2 (8-10 mm.)	..	..	58
..	..	1 (8 mm.)	..	..	1
..	..	..	..	..	3
..	2 (7-14 mm.)	..	..	..	2
..	23 (7-17 mm.)	2 (14-17 mm.)	..	..	632
..	1 (10 mm.)	..	..	..	34
..	9 (2-11 mm.)	9 (3-15 mm.)	1 (3 mm.)	..	98
					— 833
..	22 (4-17 mm.)	22 (4-23 mm.)	3 (6 mm.)	..	118
..	10 (5-18 mm.)	3 (11-13 mm.)	2 (3-6 mm.)	..	469
..	2 (7-13 mm.)	10 (7-11 mm.)	..	..	51
					— 638
..	4 (12-16 mm.)	1 (21 mm.)	..	..	13
..	2 (7-9 mm.)	..	..	..	4
..	8 (3-8 mm.)	..	..	..	64
					— 81
..	25 (7-18 mm.)	2 (10 mm.)	1 (7 mm.)	3 (8-10 mm.)	172
..	8 (7-13 mm.)	6 (11-22 mm.)	..	..	40
..	11 (5-13 mm.)	..	..	2 (7-9 mm.)	214
..	2 (2-5 mm.)	1 (7 mm.)	..	5 (5-12 mm.)	72
..	1 (7 mm.)	..	..	..	1
..	..	..	..	..	5
..	4 (5-13 mm.)	3 (2-5-13 mm.)	..	..	181
					— 685
..	..	3 (6-11 mm.)	..	..	88
..	..	..	..	..	6
..	..	..	..	4 (7-12 mm.)	22
..	..	..	..	..	1
					— 117
..	..	4 (8-12 mm.)	..	1 (14 mm.)	13
..	1 (13 mm.)	..	..	..	7
					— 20
					2902

with *P. patelliformis*, whilst *P. pileolus* first comes in at the base of the Upper Chalk in the zone of *Holaster planus*. The well-marked *P. nuciformis* has not been found until reaching the zone of *Micraster cor-anguinum*.

In the lower zones of the Chalk the examples of *Porosphaera* are comparatively rare and generally small, the large majority not exceeding 6 mm. in diameter, but in the higher zones in the South of England the various species are more numerous, and there is a gradual increase in size, which reaches its maximum in the zone of *Marsupites*, where some forms of *P. globularis* are 34 mm. in diameter. In the next higher zone of *Actin. quadratus* the specimens are smaller, but there is a reversion to larger forms in the *Bel. mucronata* zone.

In the Chalk of the vicinity of Flamborough, Yorkshire, the various species of *Porosphaera* are uniformly of small dimensions in all the zones, in marked contrast to those from the higher zones on the South coast.

IV. MINERAL CHARACTER AND CONDITION OF PRESERVATION.

The large majority of the specimens of *Porosphaera* from the Upper Chalk of this country consist of calcite, and their radial canals and the smaller interspaces of the skeletal mesh are usually filled up solid with the same mineral. In thin sections seen under the Microscope, the mesh appears as light grey bands by reflected light; whilst in transmitted light the bands or fibres are marked off from the calcitic matrix by numerous minute granules of a darkish tint, which, unless the sections are very thin, render them nearly opaque. This appearance of the mesh is very similar to that in many of the Pharetron Calcisponges from the Inferior Oolite, the Great Oolite, and the Coral Rag, and also in some of the Tertiary Calcisponges from Australia. In no instance have I seen a finely radiate fibrous micro-structure in the mesh, like that which characterises *Millepora* and Madreporarian corals generally.

In many specimens of *Porosphaera* the outer portions are of calcite, whilst in the interior, both the skeletal mesh and the matrix consist to a varying extent of silica. This has given rise to an impression that the fossils were originally of silica which has, in part, been replaced by calcite. That a reverse process has taken place, and that the silica is of secondary origin, is shown by the fact that in the silicified portion of these specimens the mesh is usually very indistinct or altogether obliterated, whilst its characters are retained in the outer or calcitic portion. We find, moreover, that *Porosphaera* is frequently associated in the same beds of Chalk with undoubted siliceous hexactinellid and lithistid sponges, in which the skeletal mesh has been either removed,

leaving an empty mould of silica, or it has been replaced by reddish ferric oxide, thus presenting a marked contrast to the usual state of preservation of *Porosphaera*. Under exceptional conditions, as in the Chalk at Flamborough, the matrix of the interior of many of the specimens of *Porosphaera*, also consists of powdery ferric oxide, but the exterior of these forms shows the calcitic mesh which readily distinguishes them from the siliceous sponges in the same beds.

Porosphaera likewise occurs either partially or entirely imbedded within the flint nodules of the Chalk, and in this condition the skeletal mesh is, in part, siliceous, as well as the matrix. In some of these flint-enclosed specimens the structural details are more distinctly shown than in the usual forms from the Chalk, but in others, and even in parts of the same specimen, they are only faintly visible.

V. FORM AND MANNER OF GROWTH.

A large proportion of the specimens of *P. globularis* are approximately spherical without any indication of a point of attachment. Small individuals of about 1 mm. in diameter show that the rounded form prevailed in the early stages of the growth of the organism, and there is but little variation in the shape of the specimens up to 6 mm. in diameter. In larger specimens the growth is less symmetrical, they become oval, loaf-shaped, cushion-shaped, rounded or subangular at the bases, which are flattened or even slightly concave (pl. I., figs. 1-4, 9, 10). In some instances growth does not take place uniformly over all the surface, but in layers which only extend over parts of the surface and overlap each other (pl. I., fig. 2). Usually the entire outer surface is dotted over closely with the minute apertures of the radial canals bounded by the skeletal mesh, but in a very few rare examples these are covered by small patches of a spicular dermal layer (pl. I., figs. 7, 8).

The specimens of *P. nuciformis* vary in form from nearly round to melon- and pear-shaped; they appear in all cases to have been free. Their surfaces are covered with simple, slightly raised ridges or swellings with correspondingly open, shallow, intermediate furrows, which extend longitudinally from the rounded to the obtusely pointed summit of the specimens (pl. I., figs. 11-17). In a few rare examples there are two or more areas from which the ridges extend (pl. I., fig. 18).

Numerous specimens of *P. globularis*, both of the spherical and of the oval or cushion-shaped forms, and also of *P. nuciformis*, are penetrated by cylindrical tubes, some of which extend quite through, so that the specimen becomes a natural bead, whilst others reach only to the central portion of the fossil or beyond to

near the opposite side, but without passing through it completely (pl. I., fig. 1). The tubes generally pass straight through the centres of the rounded forms, but they are not definitely oriented in the cushion- or pear-shaped fossils, through which they extend either longitudinally, transversely or obliquely. In the collections examined from the zone of *Micraster cor-testudinarium* upwards to the *Bel. mucronata* zone, out of 1799 specimens of *P. globularis* from different localities, there were 321 or about 18 p.c. perforated; of this number 147 were completely perforated or natural beads, whilst 174 were partially perforated. In 184 specimens of *P. nuciformis* from the same beds, there were tubes in 32, or about 17 p.c.; in only 6 instances the tubes extended through; whilst in 26 they only reached to varying depths in the fossils.

EXPLANATION OF PLATE I.

The figures are of natural size except where otherwise indicated.

- Fig. 1. *Porosphæra globularis*, Phillips, sp. Large oval specimen, with tubular perforation. Zone of *Micraster cor-anguinum*; South Croydon, Surrey. Collection of G. J. Hinde.
- „ 2. Ditto; showing overlapping layers of growth. Zone of *Marsupites*; Margate, Kent. Collection of Dr. A. W. Rowe, F.G.S.
- „ 3. Ditto; loaf-shaped. Zone of *Belemnitella mucronata*; Ballard Cliff, Dorset coast. Collection of Dr. Rowe.
- „ 4. Ditto; cushion-shaped specimen. Zone of *Bel. mucronata*; Ballard Cliff. Collection of Dr. Rowe.
- „ 5. Ditto; of average size. Zone of *Actinocamax quadratus*; Cliff, east of Brighton. Collection of G. J. Hinde.
- „ 6. Ditto; median section, showing the arrangement of the radial canals. Upper Chalk. Collection of G. J. Hinde.
- „ 7. Ditto; completely enveloped with a spicular dermal layer. Zone of *B. mucronata*; Ballard Cliff. Collection of Dr. Rowe.
- „ 8. Ditto; partially covered with an uneven dermal layer. Same zone and locality as the preceding. Collection of Dr. Rowe.
- „ 9, 10. Ditto; loaf-shaped specimens, showing faint indications of surface grooves. Zone of *Marsupites (Uintacrinus Band)*; Thanet coast. Collection of Dr. Rowe.
- „ 11. *Porosphæra nuciformis*, v. Hagenow, sp. Viewed from above, showing the convergence of the grooves at the summit. Zone of *Marsupites (Uintacrinus Band)*; Margate. Collection of Dr. Rowe.
- „ 12. Ditto; side view. Zone of *A. quadratus*; near Newhaven. Collection of Dr. Rowe.
- „ 13. Ditto; showing closely-arranged grooves. Zone of *A. quadratus*; Winchester. Collection of Dr. Rowe.
- „ 14. Ditto; with prominent apex. Zone of *A. quadratus*; Sussex coast. Collection of Dr. Rowe.
- „ 15. Ditto; with fragments of the dermal layer. Zone of *A. quadratus*; near Newhaven. Collection of Dr. Rowe.
- „ 16, 16a. Ditto; viewed from above and in profile. Zone of *Marsupites (Uintacrinus Band)*; Thanet coast, Kent. Collection of Dr. Rowe.
- „ 17. Ditto; viewed from above. Same zone and locality as the preceding. Collection of Dr. Rowe.
- „ 18. Ditto; with surface grooves and ridges radiating from several centres. $\times 2$ diam. From same zone as the preceding; Sussex coast. Collection of Dr. Rowe.

These tubes are generally considered to have been occupied originally by some organic body, such as the stem of a sea-weed, not capable of preservation as fossil, round which the *Porosphaera* lived and grew. They are now found solidly infilled with the soft chalky matrix which can readily be extracted.

A further interest is attached to these naturally perforated examples of *Porosphaera* from the fact that similar forms have been found in association with the remains of the "River-Drift" folk, and it has been surmised* with much probability that they may have been used by them for personal adornment, such as necklaces, etc.

P. Woodwardi, Carter, is generally of a rounded form with one or more slightly projecting peaks; the base is small, concave, and

* Rigollot, Mém. sur des Instruments en Silex, etc., Amiens, 1854, p. 16; Parker and Jones, Ann. and Mag. Nat. Hist., ser. 3, vi. (1860) p. 30; James Wyatt, Geologist, v. (1862) p. 233; T. Rupert Jones, tom. cit., p. 236; Sir C. Lyell, Antiquity of Man, 1863, p. 119, fig. 15; 4th ed., 1873, p. 165; Worthington Smith, The Primitive Savage, 1894, p. 272; Sir John Evans, Ancient Stone Implements of Great Britain, 2nd ed. 1897, p. 657.

EXPLANATION OF PLATE I.—continued.;

- Fig. 19. *Porosphaera Woodwardi*, Carter, sp. Showing the branching surface canals. $\times 2$ diam. Zone of *Holaster subglobosus*; Dover. Collection of Dr. Rowe.
- „ 20, 20a. *Porosphaera pileolus*. Thimble-shaped specimen, with a fragment of dermal layer on the exterior; the base (20a) showing concentric bands of growth. Zone of *A. quadratus*; near Newhaven. Collection of Dr. Rowe.
- „ 21, 21a. Ditto. Zone of *Marsupites (Uintacrinus Band)*; Thanet coast. Collection of Dr. Rowe.
- „ 22, 22a. *Porosphaera patelliformis*, sp. n. Viewed in profile (22); the deeply concave base (22a) showing concentric lines of growth and faint radial lines. Zone of *A. quadratus*; Sussex coast. Collection of Dr. Rowe.
- „ 23, 23a. Ditto; a conical specimen, viewed in profile (23); the base with faint concentric lines of growth (23a). Zone of *Marsupites (Uintacrinus Band)*; Thanet coast. Collection of Dr. Rowe.
- „ 24, 24a. Ditto; a depressed specimen, viewed in profile (24); the base with concentric and radial lines (24a). Same zone and locality as the preceding. Collection of Dr. Rowe.
- „ 25. Ditto; viewed from above, showing some fragments of the spicular dermal crust. Same zone and locality as the preceding. Collection of Dr. Rowe.
- „ 26, 26a. Ditto; a small specimen, viewed in profile, natural size (26); and the concave base, with rod-like spicules radiating from the centre to the margins, enlarged 4 diam. (26a). Zone of *Terebratulina gracilis*; East Cliff, Dover. Collection of Dr. Rowe.
- „ 27, 27a. *Porosphaera arrecta*, sp. n. Viewed in profile (27), and showing the base (27a), enlarged 3 diam. Zone of *Rhynchonella Cuvieri*; Branscombe Cliff, South Devon coast. Collection of Dr. Rowe.
- „ 28, 28a. Ditto; showing the exterior and the basal aspect, enlarged 3 diam. Zone of *Marsupites (Uintacrinus Band)*; Thanet coast. Collection of Dr. Rowe.

wrinkled (pl. I., fig. 19.). The specimens are now free, but the wrinkled character of their bases seems to indicate that they may have been attached to some foreign body during life. From the surface elevations deeply impressed branching canals radiate down their sides.

Typical examples of *Porosphaera pileolus* are thimble- or inverted cup-shaped, with thick walls and deeply concave bases; the basal hollow is lined with a spicular dermal layer and shows successive growth-rings or bands. The upper surface of this species resembles that of *P. globularis* (pl. I., figs. 20, 21). In *P. patelliformis*, the outer form resembles that of a limpet, the basal cavity is wide, the walls are comparatively thin, and it is furnished with a distinct basal dermal layer (pl. I., figs. 22-26a). In yet another form which I have named *arrecta*, the sponge is like a small, upright tapering pillar with a concave base (pl. I., figs. 27-28a). In some specimens the base may probably have been attached originally to some other body.

VI. SKELETAL MESH.

The skeleton of *Porosphaera* is of a stony character; in thin sections under the Microscope it appears to be made up of a finely porous mesh-work of continuous anastomosing fibres, in which, however, little structure can now be distinguished. The nature of the mesh-fibres is better shown on the surface of specimens obtained directly from the Chalk. These, when carefully cleaned from the matrix, exhibit under a strong lens or a Microscope a multitude of minute, projecting spines or rays, which also can be recognised by a rasping sensation when the finger is rubbed over the surface. On close examination, each of these projecting rays can be seen to spring from the central junction of three other short, generally recurved rays, and they are, in fact, the apical rays of four-rayed spicules similar to those in *Plectoninia* and *Petrostroma*. The three sub-equal, short facial rays of these spicules have truncate ends, which are fused or welded to the surfaces of the adjoining spicules, in such a manner as to form the mesh-fibres which delimit the radial canals (pl. II., figs. 6, 9).

The nature of the skeleton of *Porosphaera* in the early stages of growth is admirably shown in a small specimen of *P. globularis*, about 1.25 mm. in diameter, which has been preserved in a flint from the Upper Chalk of Kent (pl. II., fig. 1). The specimen was discovered by Mr. H. Muller, of Eltham, to whom I am indebted for the opportunity of studying it. The apical rays are very prominent, and the facial rays are already firmly fused to those of adjacent spicules. By further surface growth these prominent apical rays would be partially surrounded by and welded to the facial rays of the succeeding layer of spicules above them, and would thus be

incorporated with the mesh-fibres, so that they would be hardly, if at all, recognisable in microscopic sections of the interior of the organism. In older specimens of *Porosphaera* the mesh-spicules are frequently considerably larger and thicker than in the young individual just referred to (pl. II., fig. 9).

In sections of specimens of *P. globularis* and of *P. pileolus* from South Croydon, the free apical spicular rays near the surface are seen to be furnished with stout lateral prickles, closely resembling those in *Plectronia Halli* (pl. II., figs. 5, 6).

VII. BASAL LAYER.

The hollow inverted cup- or thimble-shaped bases of *P. pileolus*, and the more open saucer-like bases of *P. patelliformis*, show concentric lines or bands, which mark intervals of growth (pl. I., figs. 20a-24a); and these are lined by very slender thread-like and occasionally wavy spicules, disposed generally parallel with each other, in the direction of the margin of the cup. These spicules are so fine and closely set that it is difficult to determine whether they are simple rods or rays of three-rayed spicules; but in some few specimens there is a thin exterior layer of straight, slender spicular rods, extending downwards and outwards like thatch on a roof (pl. I., fig. 26a).

In *P. Woodwardi* the base is small, concave and rugose, and its spicular characters are obscured.

VIII. SPICULAR DERMAL LAYER.

With a few rare exceptions, the outer surface of *Porosphaera*, even of well-preserved specimens which have had the chalky matrix carefully removed, only shows the skeletal fibres and the projecting apical rays of the spicules described above. But in the exceptional examples, the usual skeletal mesh is covered in places with a layer or crust of so different a character and appearance that at first sight it might have been taken for an encrusting sponge which had settled and grown on the outside of the *Porosphaera*. This dermal layer appears as a whitish crust, in some instances thin and smooth, in others of measurable thickness, uneven, and with occasional small projections (pl. I., figs. 7, 8). Examined directly under the Microscope, it is seen to consist, in the majority of cases, of an agglomeration of minute three- and four-rayed spicules, with an admixture of simple rods so intimately and irregularly mingled together that it is difficult to distinguish the individual forms. These spicules seem to have been originally quite free and not connected together organically in any way (pl. II., fig. 7). In one or two specimens the outer surface of the dermal

layer consists of very slender rod-like spicules, regularly disposed side by side or arranged concentrically round a small opening (? pore). (Pl. II., fig. 10.)

Out of a total number of about 3000 specimens of *Porosphaera* examined, I have only met with a dermal layer in eighteen individuals. In but two of these does it extend over the whole surface; in the others only small patches of the skeletal mesh are now covered by it. Where thin, the apical spicular rays can be seen to penetrate through it. It occurs in specimens of *P. globularis*, *P. nuciformis*, *P. pileolus* and *P. patelliformis*, from different localities and horizons, from the zone of *Micraster cor-testudinarium* upwards, with the exception of the zone of *M. cor-anguinum*. Proportionately, a larger number of specimens with the dermal layer partially preserved are found in the zone of *Bel. mucronata* than in the lower horizons of the English Chalk.

In its structure and general characters, the dermal layer of *Porosphaera* is very similar to that of the Tertiary *Plectroninia* and the recent *Petrostroma* from the Japanese Sea. In both of these

EXPLANATION OF PLATE II.

- Fig. 1. *Porosphaera globularis*, Phill., sp. A small specimen, preserved in flint, showing the spicular structure of the exterior. $\times 50$ diam. Upper Chalk; near Sidcup, Kent. Collection of Mr. H. Muller.
- .. 2. Ditto; portion of the outer surface, showing the arrangement of the skeletal spicules bounding the apertures of the radial canals. $\times 40$ diam. Zone of *Belemnitella mucronata*; Ballard Cliff, Dorset coast. Collection of Dr. Rowe.
- .. 3. Ditto; three-rayed spicules of the dermal layer. $\times 100$ diam. Zone of *Actinocamax quadratus*; Scratchell's Bay, Isle of Wight. Collection of G. J. Hinde.
- .. 4. *Porosphaera nuciformis*, v. Hag., sp. Portion of the surface, showing the skeletal spicules and the radial canal apertures. $\times 40$ diam. Zone of *A. quadratus*; Cliff, east of Brighton.
- .. 5. *Porosphaera pileolus*. A four-rayed mesh spicule, the apical ray armed with lateral prickles. From a microscopic section near the margin of the specimen. $\times 200$ diam. Zone of *Micraster cor-anguinum*; South Croydon. Collection of G. J. Hinde.
- .. 6. *P. globularis*. A portion of the skeletal mesh, showing its structure of four-rayed spicules, the basal rays of which are now fused together. $\times 100$ diam. Zone of *M. cor-anguinum*; South Croydon. Collection of G. J. Hinde.
- .. 7. Ditto; a fragment of the dermal layer, showing three- and four-rayed spicules irregularly intermingled. $\times 50$ diam. Zone of *B. mucronata*; Ballard Cliff, Dorset coast. Collection of Dr. Rowe.
- .. 8. Ditto; a small specimen preserved in chalk, showing blunted apical rays of spicules projecting from the surface. $\times 40$ diam. Upper Chalk, Gravesend, Kent. Collection of Mr. T. H. Powell.
- .. 9. Ditto; the skeletal mesh near the margin of a specimen preserved in flint, showing the curved facial and the projecting apical rays of four-rayed spicules. $\times 40$ diam. Upper Chalk; Chatham. Jermyn Street Museum.
- .. 10. Ditto; portion of the outer surface of the dermal layer, showing rod-like spicules arranged concentrically round a central pore (?). $\times 50$ diam. Zone of *Belemnitella mucronata*; Ballard Cliff, Dorset coast. Collection of Dr. Rowe.