52. *On the* STRUCTURE *and* AFFINITIES *of the* FAMILY *of the* RECEPTACULITIDÆ, *including therein the Genera* ISCHADITES, *Murchison* (=TETRAGONIS, *Eichwald*); SPHÆROSPONGIA, *Pengelly*; ACANTHOCHONIA, *gen. nov.*; *and* RECEPTACULITES, *Defrance*. By GEORGE JENNINGS HINDE, Ph.D., F.G.S. (Read June 25, 1884.)

[PLATES XXXVI., XXXVII.]

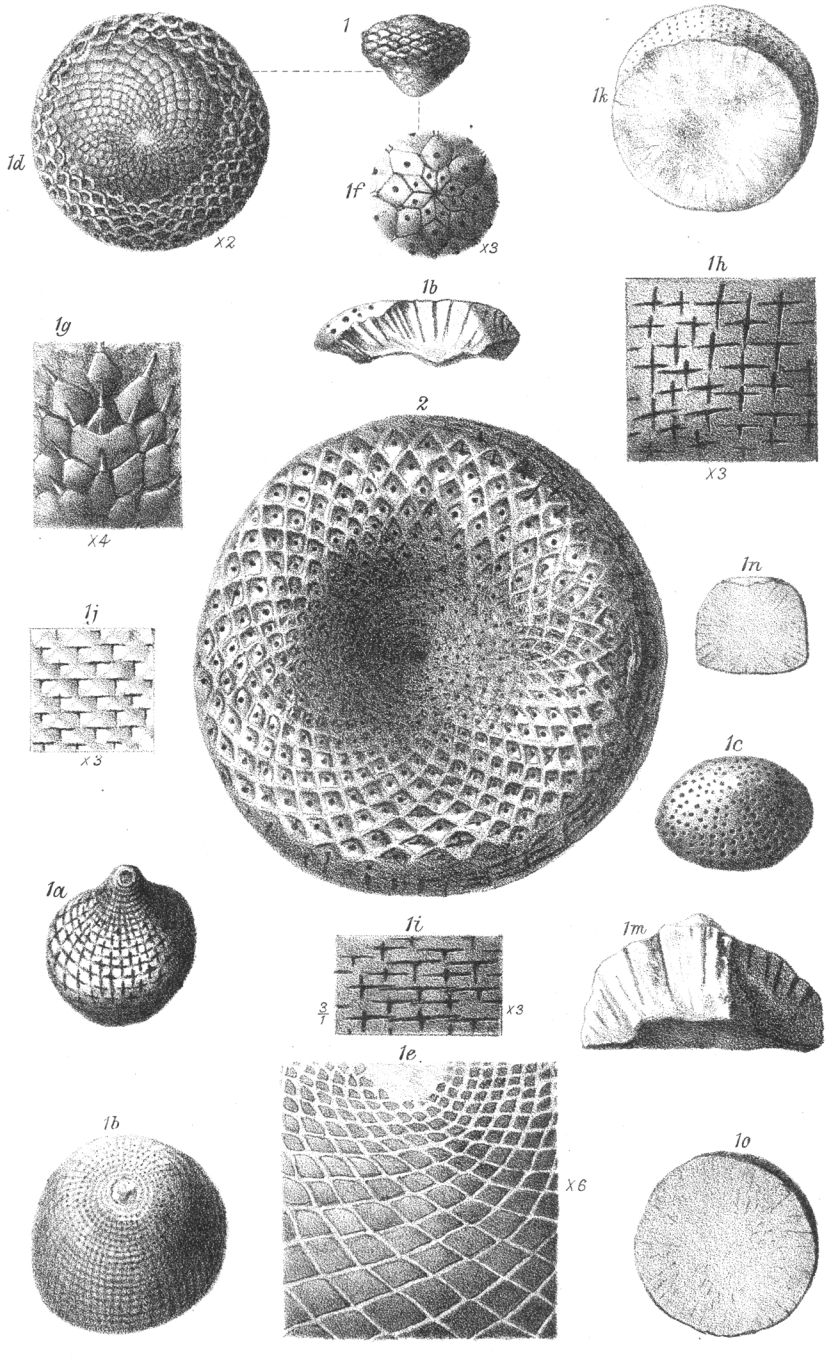
CONTENTS.

I. INTRODUCTION.

AMONGST the Palæozoic fossils whose characters differ to such an extent from those of existing organisms that great differences of opinion as to their affinities have been expressed by the various palæontologists who have studied them, the above-named genera occupy a prominent position. They have been assigned in turn to pine-cones, Foraminifera, Sponges, Corals, Cystideans, and Tunicate Mollusca; but after all that has been written on them, such competent authorities as Ferdinand Römer * and Zittel † agree in stating that they form an altogether uncertain group of organisms, which, though ranged provisionally amongst the Foraminifera, have hardly a single typical character in common with them. Under these circumstances a fresh attempt to interpret their structure will not be inappropriate; and though the new facts which I have to bring forward do not make any very important additions to those ascertained by previous students of the group, they at least furnish, in my opinion, striking evidence in favour of the affinity of these forms to Sponges. This relationship has already been strongly advocated by the late Mr. Billings ‡; and though the basis of comparison which he instituted between the structure of *Receptaculites* and the gemmulæ of freshwater sponges cannot now be maintained, yet in regarding the former as a sponge, Mr. Billings showed, in my opinion, a clearer insight into its systematic position and structure than later authorities, such as Prof. Gümbel and Dr. Dames, who have ranged it with Foraminifera.

The materials which have served as the foundation for the following observations have been derived from several sources. First, the collection in the British Museum of Natural History, of which a list will be found in the 'Catalogue of the fossil Forami-

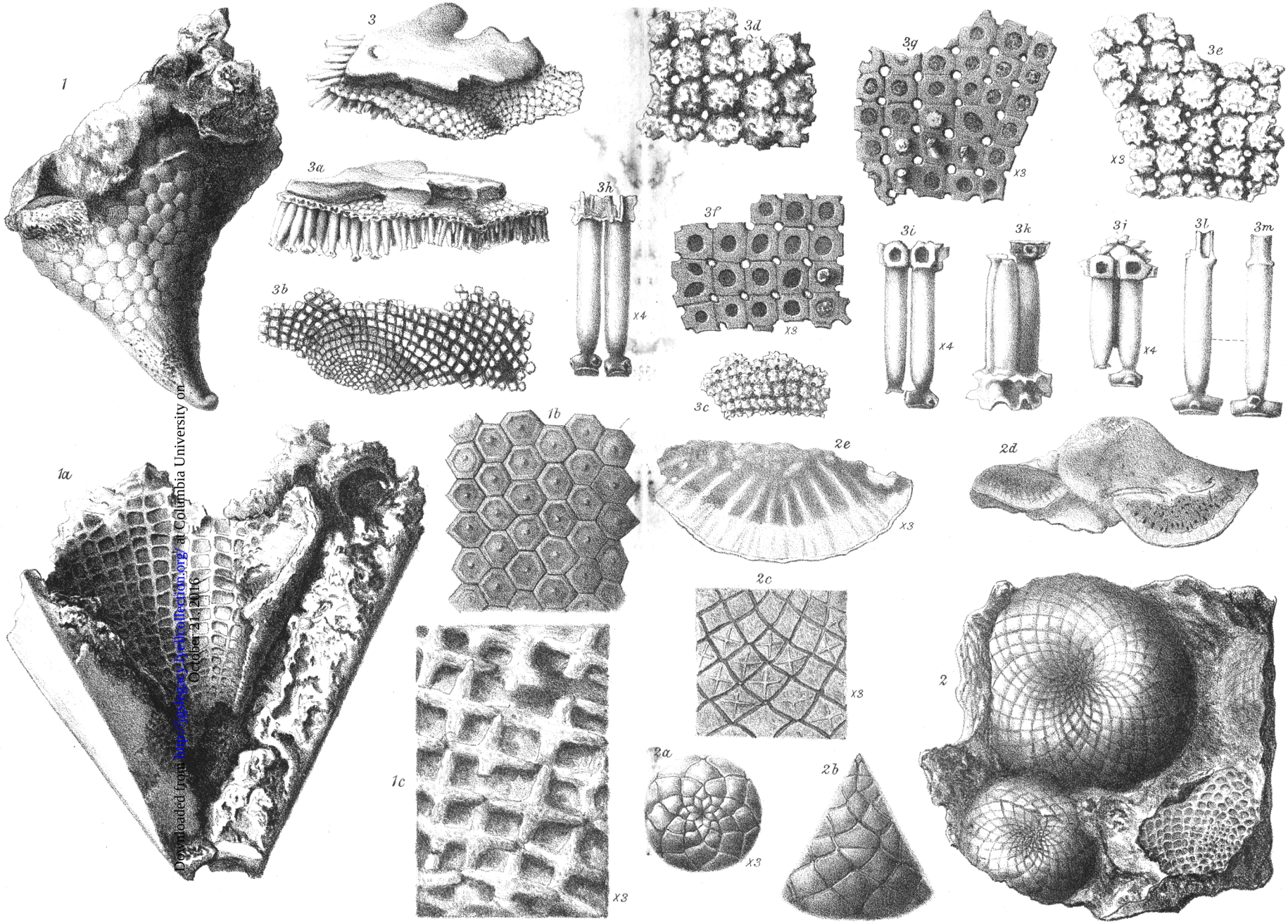
* Lethæa Pal. 1 Th. p. 285. † Handb. der Pal. 1 Bd. 1880, p. 727.
‡ Pal. Fossils of Canada, vol. i. 1865, p. 388.



M. Suft del. et lith.

Hanhart imp

ISCHADITES.



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SPHÆROSPONGIA ACANTHOCHONIA AND RECEPTACULITES.

nifera' by Prof. Rupert Jones. It includes several species of *Receptaculites* from the Silurian strata of the Baltic, Canada, the United States, and the Arctic regions, also from the Devonian of Belgium; *Ischadites Kœnigii*, from the West of England and Gotland; *Sphærospongia tessellata*, from Devonshire; and specimens of a new genus, *Acanthochonia*, from the Silurian of Bohemia. For the opportunity afforded me of studying this collection, I beg to express my thanks to the Keeper of the Geological Department, Dr. Henry Woodward, F.R.S. Next, a splendid collection of nearly 150 specimens of *Ischadites*, from the Silurian strata of Gotland, which have been freely placed at my disposal for examination by Prof. G. Lindström of Stockholm, to whom I feel under great obligations for thus enabling me to study specimens in excellent preservation. Further, Prof. F. Römer generously sent me from Breslau a small collection, including figured types of *Receptaculites* from Devonian strata at Ober-Kunzendorf in Silesia. My thanks are also due to Prof. M'Kenny Hughes for the opportunity of studying the collection in the Woodwardian Museum at Cambridge; to Mr. J. F. Whiteaves, F.G.S., for specimens of *Receptaculites* from Canada; and to Mr. A. Champernowne, F.G.S., for an example of the same genus from Devonshire. In the Museum of the Society I have studied the type specimen of *Ischadites Kœnigii*, Murch.; and in the Museum at Jermyn Street, I have, through the kind permission of the Director-General of the Geological Survey, examined numerous examples of *Ischadites* and the type specimen of *Sphærospongia tessellata*, Phill. Lastly, I have made use of specimens collected by myself from Silurian and Devonian strata of Canada.

A short historical sketch of the principal notices which have appeared respecting this group of fossils will be of interest, as showing the various opinions brought forward about their nature and affinities.

The first account of a member of this group is by Defrance, in the 'Dictionnaire des Sciences Naturelles,' 1827, tom. 45, p. 5, Atlas, pl. 68, who describes and figures two specimens from Devonian strata in the neighbourhood of Chimay, Belgium, to which he gave the name of *Receptaculites Neptuni*. These specimens, the types of the genus, show very imperfectly the real characters of the organism. The original structures have either been replaced by iron-peroxide, or the spaces which they occupied are now vacant. Defrance gives a very clear account of the characters exhibited, and compares the regular arrangement of the rhomboidal plates of the outer surface to the disposition of the scales on the cone of a pine-tree. The connecting pillars are, in these specimens, merely hollow cells. The author expresses doubts whether the fossils are marine organisms, but finally concludes that they may belong to the order of Polyps.

Goldfuss, in the 'Petrefacta Germaniæ' (1826–33) p. 31, t. 9, f. 18, 19, describes and figures under the names of *Coscinopora placenta* and *C. sulcata* two fragments of the same species already made known by Defrance. The first-named species is stated to be from the Uebergangs-Kalk (Devonian) of the Eifel, and the latter, evi-

dently erroneously, from the Jura-Kalk, probably from Switzerland. The condition of these specimens appears to have been similar to that of Defrance's types in having the places occupied by the connecting pillars vacant; and this fact apparently led Goldfuss to compare the tubes to the canals in the siliceous sponge *Coscinopora infundibuliformis*, Goldf.

Murchison, in the 'Silurian System' (1839), p. 697, pl. xxvi. f. 11, under the name of *Ischadites Kœnigii*, figures a group of fossils on the surface of a slab of shaly limestone from Lower Ludlow rocks at Ludlow. Though the specimens have all been compressed, and the original structure entirely removed, leaving merely impressions of its former presence, yet the originally ovate or subspherical form and the tessellation of the surface can be clearly recognized. Murchison, without expressing an opinion as to the affinities of these fossils, referred them to Mr. König, who thought that they might belong to the family of Ascidiæ. No suspicion of any relationship between these ovate bodies and the cup- and disk-shaped specimens of *Receptaculites* appears to have been entertained.

Professor Phillips, in the 'Palæozoic Fossils of Devon and Cornwall' (1841), p. 135, t. 59, f. 49, first named the type of another genus of this group, *Sphæronites tessellatus*. The type specimen had, indeed, been already figured nine years previously, in connexion with a paper by De la Beche "On the Geology of Tor and Babbicombe Bays, Devonshire"*, though it had not been named; but Mr. W. J. Broderip, to whom it had been referred, stated that the fossil may have belonged to the Tunicata. The specimen is pear-shaped, partially imbedded in a hard limestone, and showing a surface of hexagonal plates. Phillips regarded it as a Cystidean, allied to the genus *Echinosphærites*, Wahlenberg, and he placed it in the Cystidean genus *Sphæronites*, Hisinger.

In 1840, Eichwald, in 'Die Urwelt Russlands,' p. 81, t. 3, f. 18, proposed the genus *Tetragonis* for a fossil of uncertain origin, which he thought might probably belong to the same family as the problematical *Ischadites*, Murch. Curiously enough, Eichwald's type specimen was brought to London by Murchison to show to W. Lonsdale; but that palæontologist does not appear to have recognized any relationship between it and *Ischadites*, though, as we shall see later on, it is undoubtedly congeneric with this latter genus. The specimen is pear-shaped, and the outer surface is divided by vertical and transverse lines into oblong areas, with small perforations at the alternate angles. Oblique lines regularly winding round the fossil are also mentioned. I shall show further on that the appearances presented by the type of *Tetragonis* are similar to those of *Ischadites*, when the rhomboidal surface plates are removed and the horizontal spicular rays beneath are exposed. This being the case, Eichwald's name *Tetragonis* will have to give place to Murchison's name *Ischadites*, which has the priority. Eichwald ranks *Tetragonis* with corals, and in this order he also places another example of *Ischadites* which is named *Receptaculites Bronnii*.

* Trans. Geol. Soc. ser. 2, vol. iii. p. 164, t. 20. figs. 1, 2.

In the 'Palæontology of New York,' vol. i. (1847) p. 68, t. 24, f. 3, Prof. J. Hall refers, with a query, to *Receptaculites Neptuni*, Defr., some fragmentary specimens from the Trenton limestone of Carlisle, Pennsylvania.

In the 'Geological Survey of Wisconsin, Iowa, and Minnesota' (1852), p. 586, t. 2B, f. 13, D. Dale Owen refers another example of this group, from Lower Silurian limestones in Iowa, to a new genus of Foraminifera, under the name of *Selenoides iowensis*. Only the concave base of the specimen is figured; but as the upper portion is described as dome-shaped, it probably belongs to the genus *Ischadites*. According to Miller's 'Catalogue of American Fossils,' the same author, D. Dale Owen, had previously described, in 1840 and 1844, three other species of *Receptaculites*, which bear the names of *R. dactioloides*, *R. reticulatus*, and *R. sulcatus*; but the works containing the descriptions are not accessible to me.

In 1859, J. W. Salter gives descriptions and figures in 'Canadian Organic Remains,' Dec. i. p. 43, t. 10, of two disk-shaped specimens of *Receptaculites*; one, *R. occidentalis*, from Trenton limestone at Pauquette's Rapids, on the Ottawa, the other, *R. australis*, from Upper Silurian strata of New South Wales. Salter regarded these bodies as allied to the Foraminiferal genus *Orbitolites*, and stated that the rhomboidal plates and the columns, which in these specimens are of silex, represented the spaces formerly occupied by the animal sarcode. Salter figures and refers to four connecting processes or stolons given off from the columns, and also indicates the perforations in the plate of the inner or upper surface.

D'Eichwald in 'Lethæa Rossica' (1860), p. 427, brings under the family of the Receptaculitidæ the following genera, *Receptaculites*, *Tetragonis*, *Mastopora*, *Escharipora*, and *Ischadites*. The family is regarded as belonging to the Anthozoa, and its structure is stated to consist of very regularly arranged cells or tubes which appear to be covered by a corneous operculum. In addition to the species mentioned by the author in the 'Urwelt Russlands,' there are here further enumerated, *R. orbis* (=*Escharites forniculosus*, Schlot.), from the *Orthoceras*-Kalk of Baltischport; *Tetragonis sulcata* and *T. parvipora*, which, judging from the figures, do not belong to the family at all, and *Ischadites Eichwaldi*, O. Schmidt, and *I. altaicus*, Eichw. *Sphæronites tessellatus*, Phill., is stated to approach near to *Ischadites*. The genera *Mastopora*, Eichw., and *Escharipora*, Hall, do not appear to me to be in any way allied to the Receptaculitidæ.

Mr. W. Pengelly, in the 'Geologist' (1861), vol. iv. p. 340, t. 5, figures a specimen of *Sphæronites tessellatus*, Phill., showing the inner surface divided into a network of quadrilateral meshes by the interlacing of what may be termed vertical and horizontal ribs. Pengelly regards the form as a sponge, and applies to it the generic name *Sphærospongia*.

In the same year in which Pengelly employed the term *Sphærospongia* for the *Sphæronites tessellatus*, Phill., J. W. Salter, referring to the same form ('Memoirs of the Geological Survey of Great Britain; the Geology of the neighbourhood of Edinburgh,' 1861,

p. 136), states that it is a sponge, and that he proposed the term *Sphærospongia* for the Devonian species. At the same time he mentions a Caradoc fossil (without adding any further description) as of the same genus, in which, as will be shown, he was mistaken. Whether, however, we regard Pengelly or Salter as the author of the term, there is no doubt that it was first applied to the Devonian species *Sphæronites tessellatus*, Phill., and this form will thus remain as the type, and the genus will not be invalidated by the circumstance that Salter ranged under it, several years later, other forms which have no relationship whatever with the type species. Salter further states, in the same memoir, that *Ischadites* is a regularly formed sponge, with vertical and transverse bundles of fibres, and that he now regarded *Receptaculites* also as a very regular cup-shaped sponge, with a skeleton arranged precisely after the pattern of the soft parts in *Orbitolites*.

According to Miller's 'Catalogue of American Palæozoic Fossils' Prof. Hall has described in the 'Report of the Superintendent of the Geological Survey of Wisconsin, 1861,' five species of *Receptaculites* from strata of Trenton and Niagara age. I have in vain sought for a copy of the pamphlet containing this Report in the libraries of the scientific societies of London, and cannot therefore express an opinion as to the character of these species.

Mr. E. Billings, in the 'Palæozoic Fossils of Canada' (1865), vol. i. p. 378, gave an elaborate description of the structure of *Receptaculites*, based principally on the characters of *R. occidentalis*, Salt. He described the genus as consisting of discoid, cylindrical, ovate, or globular-shaped bodies, hollow within, and usually, if not always, with an aperture in the upper side. He supposed that even the large flattened examples of *R. occidentalis* were but the basal portions of conical hollow individuals, of which the upper portions had fallen to pieces after the death of the animal. The body-wall, according to Billings, consisted of three parts, an external integument, the ectorhin, and an internal, the endorhin, composed of rhomboidal plates, between which are cylindrical hollow tubes or spicules, which extend between plates of the outer and inner surface. The outer extremity of each spicule carries four small slender stolons extending to the four corners of the plate which covers them, and Billings states that they seem to form a connexion with the stolons of adjacent spicules. The plates of the endorhin are said to possess four small canals which radiate from the centre of each plate (where they communicate with the vertical spicule) to each of its sides; and further a circular orifice is present at the angles of the plates. Billings's description is supplemented by diagrammatic representations of a vertical section of a subconical species and of the structure of the body-wall. It ought not to be forgotten that these figures are merely diagrammatical, and I do not think any *conical* form has ever been discovered with an interior plate like that figured by Billings, though it fairly represents the structure of the open cup-shaped examples of *Receptaculites*. Billings recognized the affinity between *Receptaculites* and the genera *Tetra-*

gonis and *Ischadites*, and states that *Tetragonis* appears to be merely *Receptaculites* with the ectorhin removed. He institutes a comparison between the structure of the wall of *Receptaculites* and that of the gemmulæ or resting-spores of the fresh-water siliceous sponges of the genus *Spongilla*, and regards the small birotulate spicules, or amphidisks, and the enveloping coriaceous membrane of the gemmules of *Spongilla* as analogous to the spicules of *Receptaculites*.

In the same volume, Billings also describes as new species *Receptaculites calciferus* and *R. elegantulus* from the Calciferous formation, *R. canadensis* and *R.? insularis* from the Silurian of Anticosti, and *R. Jonesi* from Lower Helderberg strata at Gaspé.

Mr. J. W. Salter, in the 'Palæontology of Niti in the Northern Himalaya' (1865), p. 47, t. 5, gives a definition of *Sphærospongia* as a *new* genus, in which he includes a sponge from the Caradoc rocks of Britain (without giving either the name or the description of the form), and two species, *S. melliflua* and *S. inosculans*, from the Himalaya. The generic definition by no means corresponds with the characters of *Sphærospongia tessellata*, Phill., sp., the real type, and Salter seems to have included therein the characters of two or three heterogeneous fossils. Of the species enumerated from the Himalaya, only one, *S. inosculans*, probably belongs to the present group, and this, as Salter remarks, much resembles *Ischadites* and may provisionally be included in that genus.

Dr. W. Dames, in a memoir on the Devonian deposits in the vicinity of Freiburg, in Lower Silesia (Zeitschrift der deutschen geologischen Gesellschaft, Bd. xx. 1868, p. 483, t. 10. f. 1), gives a detailed account of the structure of *Receptaculites Neptuni*, Defr., as shown in examples of this species from Ober-Kunzendorf, which agrees in the main points with that of Billings, though Dames failed to perceive, in the so-called endorhinal plates of this species, the apertures and the interior canals described by Billings in the inner plate of *R. occidentalis*; but he states that there are certainly more than four canals in the ectorhinal plates. Dames denies that any real similarity exists between *Receptaculites* and the gemmulæ of *Spongilla*, on the grounds that there is no evidence of the originally coriaceous character which Billings attributes to some of the integumentary plates of *Receptaculites*, and that the spicules of the fossil genus are much larger at the periphery than near the nucleus; whereas the amphidisks of *Spongilla* are of uniform dimensions throughout. In conclusion, Dames places *Receptaculites* with the Foraminifera, in proximity to the family of the Orbitolitidæ, and proposes to form for it, with *Tetragonis* and *Ischadites*, the family of the Receptaculitidæ. This author further mentions the occurrence of *Receptaculites* in shales of Carboniferous age at Rothwaltersdorf.

Messrs. Meek and Worthen, in the 'Geology of Illinois,' vol. iii. (1878), described, and figured for the first time, two species of *Receptaculites*, *R. globularis* and *R. Oweni*, from the Galena strata of Illinois. They also figure, as a doubtfully new species, a specimen which, from the figure, appears to be identical with the form placed under *R. globularis*, which, it may be stated, really belongs to the

genus *Ischadites*. The authors express no opinion on the characters of these fossils, and refer to the hollow casts of the spicules as cells.

J. W. Salter, in the 'Catalogue of the Cambrian and Silurian fossils in the Geological Museum of the University of Cambridge' (1873), gives a figure of *Ischadites Kœnigii*, Murch., from Dudley, representing it with a short cylindrical stem and diverging rootlets, and states that it is one of the regular sponges, like *Sphærospongia*, and that it possesses a root and a foramen at the top, after the manner of *Grantia*. I may here remark that the stem and root represented as belonging to this specimen are probably imaginary, since neither in the Museum at Cambridge nor in the Jermyn Street or British Museum is there a single example showing traces of any basal stem, nor is such an appendage presented in the numerous and perfectly preserved examples of this species which occur in the isle of Gotland.

In 1875 an important treatise on the organization and systematic position of *Receptaculites* *, by Dr. C. W. Gümbel, appeared in the 'Abhandlungen der k. bayer. Akademie der Wissenschaften.' The author's observations were based on examples of *R. Neptuni*, Defr., from Devonian strata in Belgium and Silesia, and he considers the original form of these bodies to have been open cup-shaped as they are now found, and not conical with a small central aperture, as supposed by Billings. By making sections through specimens, Gümbel was enabled to ascertain more thoroughly their interior characters, and to add further particulars of their structure to those made known by Billings. Both the outer and inner surfaces of the organism are stated to possess a very thin layer, now of a carbonaceous material, but originally probably of a leathery or horny consistency. The contact margins of the plates of the outer surface are stated to be uneven, and provided with minute sinuosities, which probably indicate the presence of small canals, thus allowing communication between the interior of the organism and the outer medium. The surface-plates are said to consist of three distinct layers—(1) a thin coaly surface-layer; (2) an upper layer of calcite; and (3) an under-layer of the same substance. This under-layer, if I understand correctly Gümbel's explanations, consists of the four radiating arms at the ends of the pillars, with canals in the centres of each, which are termed the epistyle. The radiating arms of the epistyle are stated not to connect directly with those of adjoining epistyles, but to rest side by side. The inner termination of the pillars, according to Gümbel, is not furnished, like the outer, with an epistyle of four arms, but they possess a greater number of thick irregular branches with subdivisions. These are never intergrown with the main plates of the inner integument, which are said to be strongly folded in the interior. Further, the plates of the inner surface of this species are said not to possess the circular canals described by Billings in *R. occidentalis*, but are covered with small warty elevations indicating the presence of cells. Gümbel agrees with Billings that the interspaces between the

* Beiträge zur Kenntniss der Organisation und systematischen Stellung von *Receptaculites*; Abhandl. k. bayer. Akad. Wiss. Band xii. Abth. i. pp. 170-215, Pl. A.

columns of the interior of the organism, now uniformly filled with matrix, were, in the lifetime of the animal, occupied by sarcode. He further believes that the original material of the skeleton was a finely fibrous crystalline aragonite, and that this structure was entirely opposed to the probability of its alliance to sponges. On the other hand, the inner organization agrees very well with that of the Foraminifera, with which order *Receptaculites* may unquestionably be placed, though its relationships are not with the Orbitolitidæ, as Salter first, and Dames afterwards, supposed, but with the family of the Dactyloporidæ. As the result of an examination of specimens of *Ischadites Kœnigii* from the Silurian of the isle of Gotland, Gümbel concludes that its organization does not in the least differ from that of *Receptaculites*, so that there is no ground for constituting it a distinct species; and *Tetragonis* only differs in the accidental absence, through weathering, of the plates of the outer surface. Still further, Gümbel finds a relationship between *Protospongia fenestrata*, Salt., and *Receptaculites*.

In 1878, Mr. R. Etheridge, F.R.S., described, in the Quart. Journ. Geol. Soc. vol. xxxiv. p. 575, from Silurian strata in the Arctic Regions, two species of *Receptaculites*, one of which is referred to *R. occidentalis*, and the other, which is the largest species yet known, is named *R. arcticus*.

Quenstedt, in the 'Petrefactenkunde Deutschlands,' Bd. 5 (1878), p. 586, states that though the characters of *Receptaculites* are not yet well understood, it may nevertheless belong to the corals. The author figures, as a new species, *R. scyphioides*, a cup-shaped specimen from Devonian strata at Ober-Kunzendorf in Silesia, without, however, indicating any characters which could distinguish it from *R. Neptuni*. Other species of *Receptaculites* are figured, and the characters of *Ischadites* and *Tetragonis* are referred to, without, however, adding anything of importance respecting these genera.

Ferd. Römer, in the 'Lethæa Palæozoica,' 1 Th. (1880), p. 285, proposes to include in the family of the Receptaculitidæ the genera *Receptaculites*, *Cyclocrinus*, *Pasceolus*, *Tetragonis*, *Polygonosphærites*, and *Archæocyathus*, and places the family provisionally with the Foraminifera, although there is no satisfactory ground for a comparison with that group. He adopts the description of the structure of *Receptaculites* given by Gümbel, and agrees with this author that there are no apertures in the plates of the inner surface as described by Billings; but he does not think that there is any communication between the margins of the plates as surmised by Gümbel. Römer further adds a description and figure of a new species, *Receptaculites carbonarius*, from the Carboniferous Limestone of Silesia. With respect to *Ischadites*, Römer thinks that this genus, if not identical with *Receptaculites*, stands very near to it. Bohemian specimens usually referred to *I. Kœnigii*, are, according to Römer, distinct from this species, probably belonging to a different genus. The term *Polygonosphærites* is employed instead of *Sphærospongia*, Pengelly, as the author thinks that this latter term should be rejected, since it implies a connexion with sponges. Römer regards the relationship between *Sphærospongia tessellata*, Phill., sp., and *Receptaculites* as

hardly doubtful. As regards *Tetragonis*, the author remarks that our knowledge of it is as incomplete as its position is uncertain, and that the presence of surface-plates has not been decisively determined any more than the existence of perforations at the angles of the squares into which the surface of the fossil is divided as described by Eichwald. In addition to the type species *T. Murchisonii*, Eichw., the author includes in *Tetragonis*, *T. Danbyi*, McCoy, and *T. eifeliensis*, Röm., which, however, do not properly belong to the genus. As the essential characters of the other genera placed by Römer in the Receptaculitidæ, namely *Cyclocrinus*, Eichw., *Pasceolus*, Bill., and *Archæocyathus*, Bill., do not in my opinion agree in the least with those of *Receptaculites* and its allied genera, it is not worth while to notice his statements respecting them.

In the first part of the first volume of the 'Handbuch der Paläontologie' (1876), p. 83, Prof. Zittel places *Receptaculites* in the family of the Dactyloporidæ; but in a supplement at the end of the volume (p. 727) *Receptaculites* and its allied genera are stated to form an altogether doubtful group; and as they have hardly a single typical feature in common with Foraminifera, and as the Dactyloporidæ, with which they were placed by Gümbel, are now known to be calcareous Algæ, and not Foraminifera, they should be removed from this Order. In addition to the various genera included in this family by Römer, Zittel further adds *Goniolina*, D'Orb., *Archæocyathellus*, Ford, and *Protocyathus*, Ford.

Lastly, in the 'Catalogue of the Fossil Foraminifera in the British Museum' (1882), Prof. T. Rupert Jones gives a list of the species of *Receptaculites* and its allies under the heading of "Rhizopoda of uncertain alliance." In a note on the Receptaculitidæ (p. 83) the author adopts Gümbel's reference of the leading genus to Foraminifera on the ground of the similarity of its structure to *Dactylopora*.

Terminology employed.

In conformity with the opinion which I shall endeavour to establish, that the systematic position of the Receptaculitidæ is with Sponges, it seems desirable to employ other terms for the component parts of the organism than those which have been used by Gümbel, Dames, and other writers, who have regarded these organisms as Foraminifera. I propose therefore to adopt the term "spicules" for the component parts of these fossils. The different parts of each separate spicule may be designated as follows:—(1) "Head- or summit-plate" of the spicule, for the rhomboidal or hexagonal-plates of the outer surface, which are the equivalents of the rhomboidal-plates of the ectorhin, Billings; rhomboidische Tafeln, Dames; rhombische Plättchen, Gümbel. (2) For the four horizontally extended arms or rays immediately beneath the head-plate (the Stolons, Bill.; Kanäle, Dames; Epistyle, Stützarme, Gümb.), I propose the term "horizontal rays" of the spicule. (3) For the tapering or subcylindrical arm or ray extending at right angles to the horizontal rays towards the interior of the organism, and in *Receptaculites* reaching to the inner plate (the cylindrical tubes or hollow spicula, Bill.;

cylindrische Röhre, Dames; Säulchen, Gümbel; cells, Hall, Meek, and other American palæontologists; trous ronds, Defrance), the name "vertical ray" may be used. As regards the relative position in the organism of the spicular plates and rays, that angle of the summit-plate and the horizontal ray beneath it which point towards the basal nucleus or commencement of growth of the organism (one of the radial stolons, Bill.; radial-centripetaler Ast, Gümb.) may be termed the "proximal angle and ray;" whilst the angle and ray pointing in the opposite direction, that is, towards the periphery of the organism in the flattened examples, or towards the summit in the conical forms (radial-centrifugaler Ast, Gümb.), will be the "distal angle and ray." The other two angles of the summit-plate and the corresponding rays (=cyclical stolons, Bill.; concentrische Aestchen, Gümb.) may be named "lateral angles and rays." Thus in those specimens in which the head-plates of the spicules have been removed, and the surface below them appears as if divided into small rectangular spaces, the lines radiating from the nucleus to the periphery, or to the summit in conical examples, are formed by the distal and proximal rays of the spicules, whilst the lines crossing the former at right angles, and producing concentric circles, are formed by the lateral rays.

For the inner or upper integument in the genus *Receptaculites* (=Endorhin, Bill.; innere Hülle, Gümb.) I propose merely to use the term "inner layer."

II. Mineral Structure and Aspect under different Conditions of Preservation.

One of the first considerations in relation to the true nature of these fossils, and one to which little attention appears to have been directed by those who have hitherto studied them, is that of their original mineral constitution. The generally accepted conclusion of the Foraminiferal nature of *Receptaculites* appears to have lulled any suspicion that might have been entertained as to the originally calcareous constitution of its skeleton; and even in the solitary instance in which a serious attempt has been made by Mr. Billings to compare its structure with that of spicules of siliceous sponges, there is no evidence brought forward to show the probability that its skeleton may have been also originally siliceous. Though, in the majority of examples, the skeleton is now of carbonate of lime, yet, so far as I am aware, not a single specimen has been found in which this mineral is otherwise than in a crystalline condition, and cannot therefore be regarded as the original structure of the organism. This circumstance alone is sufficient to show that there is a *prima facie* ground for questioning whether some other mineral than calcite may have formed the hard parts of the organism. The extraordinary diversity of appearance which *Receptaculites* and its allies exhibit, according to the different conditions in which the skeleton is preserved, stands also in intimate connexion with the question of its original nature, and renders it of importance to ascertain this point by a comparison of the different condition of these fossils from strata

of different lithological constitution, and also of the present nature of other fossils which are associated with them, and whose normal mineral structure is known.

The different states in which the fossils now occur may be enumerated as follows:—

(1) That in which the skeleton has been entirely removed, leaving only impressions and hollow casts to indicate its former presence.

(2) That in which the skeleton is now in the condition of crystalline calcite.

(3) That in which the skeleton consists of iron peroxide and iron pyrites.

(4) That in which the skeleton is of silica.

Though, as a rule, individual specimens are exclusively in one or another of these mineral conditions, it not unfrequently happens that the same specimen may be composed of two or more different minerals, thus, for example, part may be of crystalline calcite and part of iron peroxide, and these two substances may even be intermingled in different proportions; in another specimen the skeleton may be partly of calcite and partly of silica; whilst, again, the structure of another may partly consist of iron peroxide and partly of empty moulds.

(1) Considering the condition in which the solid parts of the skeleton have disappeared, leaving empty moulds, we find that this principally occurs in specimens preserved in calcareous shales and mudstones and in dolomites. Instances are met with in the Devonian mudstones of Belgium; and the typical forms of *Receptaculites*, described by Defrance, were partly in this condition, since he mentions 'trous ronds' which appear to have been partly empty and partly filled with iron peroxide and calcite. In the calcareous shales and mudstones of the Wenlock and Ludlow strata of the West of England, the specimens of *Ischadites Kœnigii* occur, with rare exceptions, as compressed casts, which rarely show more than the impressions of the summit-plates of the spicules and of the horizontal rays beneath. The other calcareous fossils in these beds with *Ischadites*, such as corals, brachiopods, lamellibranchs, trilobites, &c., have well-preserved calcareous skeletons. In the Galena beds or dolomites of Trenton age, in the States of Illinois, Iowa, and Wisconsin, the large flattened examples of *Receptaculites occidentalis*, Salt., generally known as the "sunflower coral" or "lead fossil," are entirely in the condition of casts. In these beds, also, even the shells of the brachiopods (with the exception of *Lingula*) and gastropods have disappeared, leaving only casts. It is a significant fact, however, particularly when we recollect the association of flint nodules and casts of siliceous sponges in the Upper Chalk of this country, that in the Galena beds of Illinois, where the casts of *Receptaculites* are so abundant, certain portions of the limestone are marked by an abundance of flints arranged in parallel layers*.

* Geol. of Illinois, vol. i. p. 171.

The aspect of the casts of *Receptaculites* and *Ischadites* differs so much from that of the same fossils when the structures themselves are present that one can readily understand the origin of the erroneous opinion held by several palæontologists that these fossils consisted of series of hollow cylindrical cells. In the examples from the Galena limestones of Illinois, the surface of the fossil is divided into shallow lozenge-shaped areas by the crossing of comparatively thick curved ridges of yellowish coarsely-granular dolomite. At the bottom of these areas are the hollow cylindrical tubes, the casts of the vertical spicular rays, which extend quite through to the horizontal plate above. The tube-walls, or rather the interspaces between the tubes, for there are no definite walls, consist of the same dolomitic material as the matrix. When the under surface is worn down or broken away only the cylindrical tubes are exposed. The only indications in these specimens of the horizontal rays of the spicules are four small horizontal projections, which extend from the cell-walls immediately beneath the cast of the summit-plate. These projecting processes fill the interspaces originally existing between the horizontal rays. The coarse-grained character of the dolomitic matrix of these fossils is ill-adapted for retaining their finer structural markings.

The casts of *Ischadites* from the finer calcareous mud of the Wenlock and Ludlow strata vary considerably in appearance from those of the fossils just referred to. In the best-preserved specimens, which, however, are more or less distorted and flattened by compression, the surface is marked by distinct ridges which cross each other diagonally, leaving between them small lozenge-shaped or rhomboidal depressions. The ridges are usually even, though sometimes they exhibit minute sinuosities. Occasionally the depressions are crossed by two other series of lines, less distinctly marked than the diagonal ridges, which divide each rhomboidal area into four triangles. At the intersection of these lines, in the centre of each area, are small circular apertures, not always shown however, which are the casts of the vertical spicular rays. The diagonal ridges represent the minute linear interspaces between the margins of the head-plates of the spicules; and the vertical and concentric lines, which are more clearly shown when the diagonal ridges are worn down, indicate the horizontal rays.

(2) In which the skeleton consists of crystalline calcite. This is the common condition in which these fossils occur, and it is found in specimens from different formations and localities. Thus calcite is present in *Ischadites* from Gotland and in some forms of the same genus from Dudley and Malvern; it forms the skeleton of *Sphærospongia* from Devonian strata in Devonshire, also of *Acanthochonia* from the Silurian rocks of Bohemia, and of *Receptaculites* from the Trenton limestone in Canada, from the Silurian strata of the Baltic and the Arctic regions, and from the Devonian of Silesia and Belgium. The matrix enclosing these crystalline calcite specimens is usually an organic limestone in which the remains of other kinds of fossils are abundant, and these, for the most part, retain the calcite in an amorphous condition; in other cases the matrix is a calcareous

shale or mudstone. In no instance, so far as I am aware, has any member of this group been discovered in arenaceous strata.

In examples of *Ischadites* from Djupvik in Gotland, as also in some forms of *Sphærospongia* and *Acanthochonia*, the head-plates of the spicules are exceptionally well preserved, and exhibit a smooth shining horny lustre so as to give an impression that they are formed of amorphous calcite. This smooth appearance is, however, merely confined to the outer surface of the plates, for in transverse sections the material immediately beneath the surface is decidedly crystalline. As a general rule the outer surface of the spicules, when laid bare by weathering, is slightly rough and uneven, and the internal aspect in polished sections or fractured surfaces is more or less coarsely crystalline. The interspace between the outer and inner surface is usually filled with a matrix of a similar character to that of the enveloping limestone rock, and in this the vertical spicular rays, as seen in sections, show well-defined outlines, but no special wall-substance is apparent between the matrix and the crystalline substance of the rays. In some instances the summit-plates and the horizontal rays are amalgamated into a continuous mass of crystalline calcite in which neither canals nor the separate horizontal rays can be distinguished. In these cases it would seem as if the original material had been first completely removed by solution and the moulds afterwards filled with the crystalline calcite. In none of the Silesian specimens of *Receptaculites* which I have seen is there any indication of the finely fibrous crystalline structure which Gümbel regards as the original character of the skeleton, though in some of the weathered examples of *Acanthochonia* from Bohemia, the crystalline calcite is fibrous and the crystals radiate from centres in a somewhat similar manner to that figured by Gümbel. The calcite in weathered-out specimens of *Sphærospongia* from Devonshire is mostly of a granular crystalline character, and the surface of the spicular plates and rays is peculiarly rough and uneven.

(3) In which the skeleton consists of iron peroxide and iron pyrites. The former material is of very common occurrence in specimens of *Receptaculites* from Belgium, Silesia, and Canada, and of *Ischadites* from Gotland. The matrix of these fossils is either limestone or calcareous shale. The instances in which the skeleton consists of iron pyrites are rare. Not unfrequently the iron peroxide is partly intermingled with calcite. It is sometimes of a dark brown, but more usually of a rusty tint. As a rule the head-plates are not clearly shown in specimens of this material, and when the outer surface is preserved, it appears as a thin continuous dark or rusty crust. When this is slightly weathered, the outlines of the plates are indicated by delicate lines of the fine-grained matrix; further weathering exposes the horizontal rays of the spicules, forming, in the examples of *Ischadites*, clearly marked dark lines running from the base to the summit crossed by other lines tracing concentric circles. When more closely examined, the lines are seen not to be in all cases continuous, as the spicular rays sometimes do not meet,

though very frequently they overlap each other. In specimens still further worn, by weathering or other causes, the horizontal rays disappear, and the surface is covered with circular apertures, infilled with the iron peroxide, disposed in straight lines running from the nucleus to the summit or the periphery of the fossil. The rusty infilling is frequently removed by the weather, and the holes themselves become considerably enlarged. Though the horizontal and vertical spicular rays are very clearly shown in these iron-peroxide specimens, yet I have not detected in them any traces of the interior canals, nor, in fact, could these structures be expected to be preserved in such soft incoherent material.

(4) In which the skeleton is of silica. The only examples in which, to my knowledge, this mineral constitutes the skeleton are specimens of *Receptaculites* from Trenton limestone at Pauquettes rapids, on the Ottawa River. The matrix enclosing these specimens is a compact blue limestone filled with the remains of corals and mollusca, some of which at least are replaced by silica in the form of Beekite. The silica in *Receptaculites* is evidently in a secondary condition, as it appears, after the matrix has been removed by dilute acid, in a minutely granular state on the exterior surface of the plates and rays, giving them a rough aspect under the lens, and in the form of delicate plates and radiating crystalline fibres in their interior. It happens even here that the specimens are not invariably of silica, but part of an individual may be of crystalline calcite and part of silica; and it is a notable circumstance, as tending to throw some light on the original material of these bodies, that whilst in the siliceous portion of the specimens the interior canals are clearly shown in the spicular rays, no traces of them appear in those parts which have been replaced by crystalline calcite.

From the above it is evident that the question of the original mineral nature of *Receptaculites* and its allies is a complex one, and that it is doubtful if a single specimen has yet been discovered in which the original structure has been preserved. It will I think be generally conceded that crystalline calcite, of which the skeleton is now most frequently composed, does not constitute its primary structure, which must either have been another form of carbonate of lime, such as aragonite, or silica. Gümbel * maintains that in certain specimens from Silesia the original structure of *Receptaculites* exists in the form of a finely fibrous crystalline material which may be taken to be aragonite, but he does not mention the characters by which it may be distinguished from calcite. The proof brought forward by Gümbel that this material forms the original structural element of the skeleton is that the constant oblique direction in which the crystalline fibres radiate from the central axis of the vertical spicular rays never appears in purely crystalline structures, and also that there are numerous parallel lines within the fibrous material which cannot be attributed either to aragonite or to fibrous calcite, but to organic structure; this material, in thin microscopic sections, has a great resemblance to the prismatic layer (Kalkstäbchenschicht) in the

* Beitr. p. 26 (sep. copy).

shells of certain mollusca. The facts brought forward by Gümbel do not, however, appear to me to be sufficient to prove the organic nature of this fibrous crystalline structure. The constant direction of the radiation of the fibres may be attributed to the fact that the vertical axis of the spicular ray is the centre from which the rays diverge to the surface of the spicule. That the faint concentric and parallel lines, noted by Gümbel in vertical and transverse sections of the spicules, may indicate their mode of growth by the addition of concentric layers seems extremely probable, but such markings might yet be shown even on the supposition that calcite had replaced silica, and so far from being directly opposed to the supposed relationship to Sponges, as Gümbel asserts, they are, in fact, strong evidences in favour thereof, since the spicules alike of calcareous and siliceous sponges are built up of concentric layers deposited round a central axial canal.

If we now take into consideration the supposition that silica has been the original mineral constituent of the Receptaculitidæ, we are confronted by the fact that the instances are comparatively few in which this mineral now forms the skeleton, and even then it is, like the crystalline calcite, in a secondary condition. But from the experiences obtained of the changes which the organic silica of sponges undergoes in the fossil condition, there are reasonable grounds for believing that the skeleton of *Receptaculites* may have been of a siliceous and not of a calcareous character. Nothing is more common than to find the spicular mesh-work of undoubted siliceous sponges in the Jurassic limestones of Germany and elsewhere wholly replaced by crystalline calcite, but so that the perfect form is retained, and in some instances even the central axial canal can be detected. Equally familiar too is the fact that in the Upper Chalk of this country the siliceous skeleton of the sponges has been wholly removed by solution, and the cavities are now either empty or replaced by iron peroxide. And this solution and replacement are so general that in the sponge-beds of certain Jurassic areas it is very rare to find a single individual sponge in which the original siliceous skeleton is intact; whilst in the Upper Chalk of this country we must resort to the sponges enclosed in flint nodules to find a specimen in which the spicules are of silica, and even then the silica is in a secondary condition. The examples of undoubted siliceous sponges from Palæozoic rocks are not very numerous, but in many of them the skeletons have been either removed, leaving empty casts, or replaced by crystalline calcite, iron peroxide, and iron pyrites. The siliceous sponges of the genera *Aulocopium* and *Astylospongia*, from Silurian strata of the Baltic basin and in West Tennessee, are, indeed, often in a siliceous matrix; but it happens that the minute structure of the sponges themselves, when it is preserved at all, is generally a compound of iron or merely represented by empty moulds, and these sponges may be considered somewhat in the light of siliceous nodules in which the silica liberated from their own skeletons and those of other sponges has been aggregated. Other siliceous sponges of the genus *Astræospongia*, from the Silurian of Tennessee

are now partly of calcite and partly of silica, and spicules of this genus even occur detached in the condition of calcite in the same strata in Gotland from which the calcite specimens of *Ischadites* have been procured. Evidence in favour of the siliceous constitution of the Receptaculitidæ is also furnished by the circumstance, already alluded to, that the interior canals in the spicules of the siliceous examples of *Receptaculites* from the Trenton limestone are distinctly shown, whilst these structures have been entirely obliterated in portions of the same specimens which have been replaced by calcite. That some of the molluscan shells in the same rock have suffered a change from calcite to silica can be explained on the supposition that this silica has been derived from the solution of the portions of *Receptaculites* which have been replaced by calcite. The silica of the layers of flints in the Galena limestone of Illinois may also have originated from a similar source, as the numerous specimens of *Receptaculites* in these rocks are invariably in the form of hollow casts.

In conclusion it may be stated that on comparing the present condition of the skeleton of the Receptaculitidæ with that of undoubted siliceous sponges from both Palæozoic * and Mesozoic strata, we find that there is a great similarity in their mineral structure and that it is now very frequently in the form of crystalline calcite, iron peroxide, iron pyrites, silica in a secondary condition as well as empty cavities, and there are therefore good grounds for believing that if the Receptaculitidæ are allied to Sponges, the proof for which must be sought from other considerations, their spicular skeleton was originally composed of silica.

III. Characters of the different Genera.

Though the genera which I have included in the family of the Receptaculitidæ all possess similar essential structural features, yet in some forms these are of a simpler character and are better preserved than in others, and as these simpler forms furnish a key towards understanding the structure and character of the more complex, it seems desirable to consider them first. I therefore propose to commence with the genus *Ischadites* or *Tetragonis*, leaving *Receptaculites* to the last, since this genus possesses in certain respects a more complicated and variable structure than any of the others.

Genus Ischadites, Murchison, 1839, Siluria, p. 697.

Tetragonis, Eichwald †, *Receptaculites*, pars auct.

The type forms of this genus consist of a group of flattened bodies, with circular or ovate outlines, from 25 to 40 millim. in diameter, preserved on the surface of a slab of hard bluish calcareous shale.

* Since this paper was in type, specimens of *Ischadites Kœnigii* have been discovered in the Silurian of the Pentland Hills, which closely resemble in their condition of preservation the examples of *Amphispongia* from the same locality.

† Urwelt Russlands, Heft 2, 1842, p. 81.

The specimens are now only in the condition of casts, that is, of impressions in the shale of the structures of the organisms, which have entirely disappeared; and it is evident that they have been greatly compressed, and that they were originally subspherical or ovate in form. The details of the form in these specimens can only partially be ascertained; the basal extremity appears to have been obtusely conical without either stem or roots; the body gradually increased in diameter for about half the distance between the base and summit, and then gradually contracted to the summit, at which there was a small circular aperture, which originally opened into the inner cavity. The surface of these bodies is covered with delicate oblique ridges, crossing each other with the greatest regularity, and dividing the surface into small rhomboidal depressed areas, disposed in quincunx. These areas are small near the base, widest in the central zone, and again minute towards the summit. Within the rhomboidal areas, and only occasionally shown, are two sets of lines, one set running straight from the base to the summit, and the other crossing the first at right angles, so that each rhomboidal area is divided into four parts by the lines which intersect in the centres of the areas and extend to each of their angles. These lines in the type specimen are only faintly and rarely seen, though in Murchison's figures, which are partially restorations and not accurate representations of the originals, they are clearly delineated.

The above is all that can be learned from an examination of Murchison's type specimen of *Ischadites Kœnigii*, which is now in the Museum of the Society. It seemed desirable to refer to the type form before passing to a description of the structural details of the genus, as shown in examples of the same species from Silurian strata of the isle of Gotland, in which the component parts of the organism are beautifully preserved in calcite or iron peroxide.

Outer form.—This is to a certain extent variable even in the same species from the same locality. The prevalent forms are ovate or biconvex, or more or less depressed conical; some are subspherical, and others pyriform. The central zone in some specimens is bulged out conspicuously (Pl. XXXVI. fig. 1), but generally there is an evenly rounded contour from the base to the summit. The base may be either obtusely conical, flattened, or very frequently concave. The summit is usually obtusely conical; rarely there is a small central elevation (Pl. XXXVI. fig. 1 *a*). A small circular perforation is present in the centre of the summit which opens into the originally hollow cavity of the body; this is now invariably filled with the matrix of shale or mudstone.

Structure.—This entirely consists of spicules of various dimensions, regularly arranged in vertical and oblique rows, and held in position by the interlocking of their summit-plates and horizontal rays. We will first consider the plates which form the summits or heads of the spicules. These are apparently delicate structures with smooth flattened upper or outer surfaces, thickest in the central portion where they connect with the horizontal rays, and gradually diminishing towards the margins, which are very thin. They have a

generally rhomboidal outline, but in some parts of the specimen two of the sides of the rhomboids are not uniformly straight, but have a slight curve, which gives the plates the form of a sector of a circle. Another modification is frequently, if not invariably, present in the spicular plates of the basal portion, which have their distal angles, or those directed away from the basal nucleus, either truncate or with a slight notch, from which one of the horizontal rays projects and extends, as will be shown, nearly to the centre of the plate immediately in front (Pl. XXXVI. fig. 1*g*). The plates forming the basal nucleus are also more elongated than any others (Pl. XXXVI. fig. 1*f*). At the intercalation of fresh rows of spicules, there is a modified summit-plate of a pentagonal form and larger size; in front of this is a triangular plate, which is succeeded by plates of normal shape. The plates near the nucleus, as well as those of the nucleus itself, are relatively small, but they quickly increase in size towards the zonal area, where they attain their greatest dimensions (2 to 4 millim.); they then gradually diminish in size towards the summit, and the smallest plates surrounding the summit-aperture are scarcely distinguishable without a lens, measuring from ·25 to ·4 millim. in width, or about one-tenth the diameter of the zonal plates. In none of the examples of this genus have I detected any minute structure in the head-plates of the spicules; they are now throughout of crystalline calcite, and in some cases sufficiently thin and translucent to allow the horizontal rays to be seen through them.

The manner in which the spicular plates are arranged on the surface of the organism forms its most conspicuous feature. They are disposed in regular spiral curves which, starting in opposite directions from the basal nucleus and extending to the summit, give to the surface the exact appearance of the engine-turned case of a watch. This arrangement has been compared to that of the plates of a ganoid fish, and the scales of the cone of a pine tree. Each rhomboidal plate is so arranged that one of its angles points to the basal nucleus, and its opposite angle to the summit of the specimen, whilst the other angles are lateral, so that the distal angle of one plate is in contact with the proximal angle of the plate immediately in front of it. Thus vertical lines extending from the base to the summit would pass through the proximal and distal angles of the plates, whilst concentric lines would pass through the lateral angles. At the nucleus, or centre of the base, there is a series of 8 minute spicules with diamond-shaped head-plates, which are so arranged as to form a star-shaped figure, the distal angles of each plate representing one of the rays of the star, and a line connecting the lateral angles would trace a small circle, with the proximal angles of the plates for its centre (Pl. XXXVI. fig. 1*f*).

As a rule, the margins of the plates appear to fit closely and evenly to each other, so as not to leave any interspace between their edges, but in some cases the upper or front margins seem to be slightly elevated as if they imbricated over the lower or hind margins of the spicular plates immediately in front, and left a small

intermediate space, now filled with the matrix. That the plates, or at least those of the lower portion of the organism, did not fit so closely as to exclude the passage of water from the exterior to the interior cavity of the organism, is shown by the fact that one of the horizontal spicular rays projects from underneath the distal angle of each of the plates and extends over the outer surface of the plate in front, thus clearly preventing a close-fitting union at the margins, and, further, the ridges, which characterize the outer surface of the casts of specimens, are produced by the infilling of the matrix in the interspaces between the margins of the plates. Though the spicular plates in some of the Gotland examples appear as if cemented together at their margins, yet a very slight degree of weathering is sufficient to show that there was originally a distinct, though minute, linear interval between them; and their apparent union is probably caused by the calcitic replacement of the originally separate structures which gives the appearance of their having been fused together into one mass.

These summit- or head-plates appear to have been connected by a somewhat narrow neck to the horizontal rays of the spicules at the central point of junction with these and the vertical rays, as the horizontal rays appear to be independent except at their central junction. As a rule, the head-plates are seldom preserved *in situ*. Thus in the large majority of the specimens from Gotland, they have quite disappeared, but in a few from a single locality, Djupvik, they are still retained. That they were present in all originally is made clear by faint traces of their marginal outlines which can generally be detected, and their absence is to be attributed to the facilities which their extended surfaces offer to weathering influences.

It has been already mentioned that the surface of the fossil immediately beneath the rhomboidal spicular plates is divided into minute oblong rectangular areas by vertical and concentric lines. These lines are formed by the apposition of the horizontal spicular arms or rays. The spicules, in addition to the head-plate, consist of five rays; four extended in a horizontal direction, at right angles to each other, whilst the fifth extends from the junction of the four with the summit-plate towards the interior of the organism and thus at right angles to the horizontal rays. The spicular rays are circular in transverse section, thickest at their central point of junction with each other and the head-plate, and they gradually taper to bluntly-pointed extremities. Only in one specimen have I been able to detect the presence of canals in the interior of the rays. The vertical or entering ray appears to be the longest, the lateral rays are subequal, whilst the distal ray, or that pointing to the summit of the specimen, seems to be longer than the opposite or proximal ray.

The four horizontal rays are so arranged that each ray extends towards one of the angles of the head-plate of the spicule. Thus one ray, the proximal, points to the basal nucleus, and its opposite, the distal, to the summit. This distal ray in the basal portion of the

organism frequently projects beyond the margin of the spicular head, and overlies the head-plate of the spicule immediately in front or above it (Pl. XXXVI. fig. 1 *g*). There is, of course, a correspondence in size between the head-plates and the horizontal and vertical rays of the spicules of which they form parts, that is, the largest plates are attached to the longest and stoutest rays, but the horizontal rays are not limited in length to the areas of the summit-plates, as they most frequently extend beyond and overlap the rays from adjoining spicules. As a general rule the horizontal rays vary in length from one half the diameter to the entire diameter of the summit-plate. Very frequently in specimens in which the spicular plates have been weathered away, either the proximal or distal ray of the horizontal rays is absent, and this probably arises from the missing ray having been in close contact with the under or inner surface of the head-plate, and thus becoming destroyed with the plate; the lateral rays on the other hand are usually intact (Pl. XXXVI. fig. 1 *i*). The rays of the eight spicules of the nucleus appear to be of the same character, though smaller than those succeeding them.

The effect of the arrangement of the horizontal rays of the spicules above described is to produce vertical and transverse lines which form by their intersection oblong areas, the angles of which correspond to the angles and the centres of the head-plates. It will be seen that every alternate angle corresponds with the centre of one of the head-plates, and with the vertical ray of each spicule.

The vertical rays of the spicules, which extend at right angles to the summit-plates and the horizontal rays, are only seen when the interior of the specimens is exposed by fracture or by section. They are never so clearly shown as the horizontal rays, many have apparently disappeared, and their characters can only be known by comparing different specimens in which a few are yet preserved. They appear as delicate, gradually tapering shafts, the extremities of which are pointed, and reach about half way to the centre of the interior cavity, where they terminate freely (Pl. XXXVI. figs. 1 *k–o*). In numerous specimens which I have examined, whether fractured irregularly or cut so as to show even vertical and transverse sections, I have been unable to discover any traces of an interior plate or integument corresponding to that in *Receptaculites*, though the pointed ends of the rays were readily discernible; and the fact of the gradual tapering of the spicules, and the distance to which they extend in the interior cavity, appear to me strongly presumptive that in this genus an inner layer is not developed. This distinctive feature of the genus as contrasted with *Receptaculites*, is not only apparent in specimens from Gotland, but also in one example at least from Wenlock strata at Dudley. Billings has also shown a similarly free termination of the vertical spicular rays in an example of the genus from the Lower Helderberg group at Gaspé, Quebec, which he has named *Receptaculites Jonesi* *. He makes no mention however, of the absence of an inner layer, and the dark shaded space in the figure is inserted to show where it is supposed to exist.

* Pal. Fossils of Can. vol. i. p. 385, fig. 363.

In a similar manner, Gümbel has figured a vertical section of an *Ischadites* * from Gotland, in which a dark shading is intended to indicate the outline of an inner layer, but, from the form and extension of the spicular rays, the figure is evidently diagrammatical, and I have no doubt that, as in the Gotland specimens which I have examined, the spicular rays terminate freely.

Not unfrequently examples of *Ischadites* occur, in which, through weathering, both the spicular head-plates and the horizontal rays have disappeared, and only the basal ends of the vertical rays are shown on the surface as small rounded nodes, disposed in vertical lines (Pl. XXXVI. fig. 1 *c*). I have also noticed, in some specimens in which the walls have been crushed in, spicules completely detached and removed from their original positions, thus showing clearly their independence.

From the characters of *Ischadites* as given above, there can be no doubt that the genus *Tetragonis*, Eichwald †, is congeneric therewith. From the descriptions and figures of the type species, *T. Murchisoni*, Eichw., it is evident that it is a specimen in which the spicular head-plates have entirely disappeared, and the surface exhibits the small oblong areas formed by the horizontal rays, together with the apertures of the vertical rays at their angles. Eichwald himself recognized a relationship to *Ischadites*, and entrusted his type specimen to Murchison for comparison with this latter genus; but in the 'Lethæa Rossica' ‡, he makes no further mention of this, although he therein describes some forms of *Ischadites*, and also includes under *Tetragonis* two new species, *T. sulcata* and *T. parvipora*, which, however, belong to an entirely different group than the type species. By most later writers the generic identity of *Tetragonis* and *Ischadites* has been freely acknowledged; Ferd. Römer §, however, expresses doubts as to the former existence of plates and of the apertures at the angles in the type specimen, but this mistake has probably arisen from regarding as examples of the genus, other forms which have no close relation to it.

As the term *Ischadites*, Murch., has the priority of publication the name *Tetragonis*, Eichw., becomes obsolete.

The genus *Ischadites* itself has, by several writers, been regarded as identical with *Receptaculites*, but though similar in its main structural features to this latter genus, it is sufficiently characterized by its conical or ovate form, inclosing a central cavity, with a small summit-aperture, and by the absence of an inner layer. From *Sphærospongia*, Pengelly, it is distinguished by the rhomboidal form of the spicular plates, and the development of vertical spicular rays; and from *Acanthochonia*, gen. nov., by its conical ovate form and central cavity.

* Beitr. Taf. A. f. 29.
† Urwelt Russlands, Heft 2 (1842), p. 81, t. 3. f. 18.
‡ Vol. i. pt. 1, p. 430. § Lethæa Pal. Th. i. p. 303.

Genus SPHÆROSPONGIA, Pengelly, 1861, Geologist, vol. iv. p. 340.

1841. *Sphæronites*, Phillips (non Hisinger), Pal. Fossils of Devon and Cornwall, p. 135.

1861. *Sphærospongia*, Salter, pars, Memoirs of the Geological Survey of Great Britain. The Geology of the Neighbourhood of Edinburgh, p. 136.

1875. *Pasceolus*, Kayser (non Billings), Zeitschr. d. deutsch. geol. Gesellsch. Bd. xxvii. p. 776.

1880. *Polygonosphærites*, F. Römer, Lethæa Palæozoica, Th. i. p. 296.

The typical example of this genus, on which Phillips bestowed the name *Sphæronites tessellatus*, is now preserved in the Jermyn-Street Museum, and from this, and other examples of the same species from Devonshire, the characters described below have been ascertained. The form of the original specimen is incomplete; it appears to have been pear-shaped, but as only a portion of the dome-shaped summit is preserved, it is difficult to determine whether it possessed an entire roof, or whether there was a central aperture, as in *Ischadites*. Other specimens are open, cup- or funnel-shaped, gradually curving towards the base, which terminates in a small bluntly-rounded extremity with no appearance of stem or roots, so that these fossils were clearly free and unattached. The funnel-shaped specimens are frequently hollow, the peculiar granular crystalline matrix not having penetrated into the interior cavity, but their upper surfaces are invariably obscured by the matrix, so that I have been unable to ascertain whether these organisms had a complete dome-shaped roof or not.

The outer surface is composed of an apparently close-fitting covering of spicular head-plates of hexagonal form (Pl. XXXVII. figs. 1, 1 *b*); but though the margins seem to be in intimate contact, narrow linear spaces filled with the matrix are occasionally visible between them, and these interspaces are very generally shown in the granular crystalline examples. The spicular plates are somewhat smaller in the basal portion, but in the middle and upper portions of the organism they are tolerably uniform in size, and, for the most part, regular hexagons in figure. The plates in the type specimen are smooth on their upper surface, nearly flat, and with a small central rounded elevation, which is only seen in the best-preserved specimens; in the majority of examples no trace of it is shown. They also exhibit numerous fine concentric lines, resembling lines of growth, and occasionally their margins are slightly elevated, sufficiently in some cases to cause a slight depression between the margin and the central protuberance. No structure can be seen in these head-plates, and their thickness appears to be inconsiderable. They are arranged in an extremely regular quincunx.

In the hollow specimens (Pl. XXXVII. fig. 1 *a*) the interior surface immediately beneath the summit-plates, is divided into oblong and quadrate spaces by vertical and transverse ridges. The vertical ridges run from the base to the upper portion of the specimen,

generally parallel with each other, and fresh ridges are intercalated as the width of the specimen increases; the transverse ridges are generally less regular than the vertical, and are frequently curved and discontinuous. On closer inspection these ridges are seen to be composed of horizontal spicular rays, and the hexagonal plates above form the summits of the spicules (Pl. XXXVII. fig. 1 *c*). The horizontal rays are thickest at their central junction with the summit-plates, and they gradually taper to their extremities, where they are bluntly pointed. They are not altogether equal in length, and they usually overlap at their ends. The lateral rays are also not unfrequently curved and thus give an irregular appearance to the transverse ridges. Central axial canals are clearly seen in the rays exposed in a polished transverse section of the type specimen. In the character of the horizontal rays, and in their disposition with respect to each other and to the head plates, there is the closest agreement with *Ischadites*. It is doubtful, however, whether the spicules of *Sphærospongia* were furnished with vertical rays like those of *Ischadites*. No clear evidence on this point is afforded by the specimens which I have examined, and their present mineral condition is unfavourable for the preservation of minute details. The only evidence of the existence of a vertical fifth spicular ray is shown by a small knob-like point, projecting towards the interior cavity from the central junction of the four horizontal rays, and this may represent either an aborted ray or the fractured stump of a vertical shaft. There are, as may be supposed from the absence of the vertical rays, no traces of an inner layer, and scarcely a doubt can be entertained that, in this genus, as in *Ischadites*, no inner layer existed.

This genus is characterized by its form and by the regular hexagonal figure of the spicular plates, as well as by the presence of a small central knob in each, and also by the absence of vertical spicular rays.

The first reference to this genus is by Mr. W. J. Broderip in a note to a paper by De la Beche on the Geology of Tor and Babbacombe Bays, Devonshire *. Very good figures are given of the type specimen—which, however, only shows the character of the outer surface—and from these Broderip thinks that it may have belonged to the Tunicata. He did not, however, propose for it any generic or specific name. Some years later J. Phillips copied the figures given in De la Beche's paper, and stated his belief that the fossil was a Cystidean allied to the genus *Echinosphærites*, Wahl. (*Sphæronites*, Hisinger), and he named it *Sphæronites tessellatus*. In 1855 an imperfect example of the same species was figured in the 'Geology of Russia' † under the name of *Echinosphærites tessellatus*. In the same year, also, the late Dr. Bowerbank ‡ instituted a somewhat fanciful comparison between *S. tessellatus*, Phill., and the small calcareous sponge *Dunstervillia elegans*; and T. Austin §, referring to

* Trans. Geol. Soc. (1832), ser. 2, vol. iii. pl. xx. f. 1, 2.

† By Murchison, Verneuil, and Keyserling, p. 381, t. 27. f. 7.

‡ Ann. & Mag. Nat. Hist. 1845, vol. xv. p. 299. § Id. p. 406.

Dr. Bowerbank's paper, states that there can be no doubt that *S. tessellatus* is the calcareous skeleton of a spongiform body, and that *Ischadites* is of similar origin. In 1850–56 the brothers Sandberger * figured two specimens from Vilmar and referred them to the proboscis of a crinoid.

Hitherto only the characters of the outer surface of the fossil had been known; but in 1861 † Mr. W. Pengelly described the interior of a cup-shaped specimen as "divided into a network of quadrilateral meshes by the interlacing of what may be termed horizontal ribs, the primary extending from the bottom to the top of the cup, and secondary springing from various heights in the sides or wall." Though Mr. Pengelly did not recognize the spicular character of the ridges or ribs, he believed the organism to be a sponge, and gave it the name of *Sphærospongia tessellata*. In the same year (1861) the late Mr. J. W. Salter ‡, in the course of some remarks on *Amphispongia*, referred to the great *Sphæronites pomum* (=*S. tessellatus*, Phill.) from the Devonian rocks, as a sponge allied to *Grantia*, and he also proposed the term *Sphærospongia* for the Devonian species. He adds that the Caradoc fossil is of the same genus. No further reference to or description of this Caradoc fossil, thus stated to be congeneric with *S. tessellatus*, Phill., is given, nor need I further refer to it here beyond stating that it appears to be a fossil which has been named later *Sphærospongia hospitalis*, Salt., and that it has neither generic nor family characters in common with the species, which, alike by Salter and Pengelly, is put forward as the type of the genus. In order to determine, if possible, the question of priority, as both the references to the name were published in the same year, I inquired of Mr. Pengelly, who informed me that he could not be certain after such a long interval of time, but he thought it probable that the name was suggested to him by his friend Mr. Salter. As, however, the interior characters of the fossil were first described and figured by Mr. Pengelly, and the generic name definitely applied to this species, it seems to me only just, in the absence of decisive evidence as to the priority of publication, that he should be regarded as its author, even though Mr. Salter may have suggested the appellation to him, and this course is further to be recommended on the ground that Salter does not appear to have had any clear ideas of the structure of the type species, since he afterwards included in the genus *Sphærospongia* a variety of forms which have no relation whatever with the type species. Whether, however, Pengelly or Salter be regarded as the author of the term, there is no doubt of the fact that *S. tessellatus*, Phill., is the typical species, and therefore the doubtful forms afterwards placed in the genus by Salter and other authors have no claim to remain in it.

Kayser § refers the *S. tessellatus*, Phill., to Billings's genus *Pasceolus*,

* Die Versteinerungen des rheinischen Schichtensystems in Nassau, pp. 384, 385.

† Geologist, vol. iv. p. 340, pl. v.

‡ Mem. Geol. Survey, "Geol. of Edinburgh," p. 136.

§ Zeitschr. d. deutsch. geol. Gesellsch. 1875, p. 780, t. 20.

with which, however, it has, in my opinion, no relationship. His specimens only show the exterior surface, and from this he judges that the organism must be a "Foraminifer like *Receptaculites*."

Ferd. Römer * states that the relationship of *S. tessellatus*, Phill., to *Receptaculites* cannot be doubted after Pengelly's observations on its interior structure. He states, moreover, that Pengelly discovered in the interior of this form a *canal*-system consisting of horizontal and vertical tubes, thus regarding the ribs mentioned by Pengelly as canals. F. Römer rejects the term *Sphærospongia* on the grounds that even if the fossil could be shown to belong really to Salter's genus, yet, as the name indicates a relationship to Sponges, it is inappropriate; he therefore proposed to substitute the term *Polygonosphærites* instead. As, however, the type form seems to me to be a sponge, Römer's objection to its name loses its force.

Genus Acanthochonia, Hinde, gen. nov.

I propose this genus to include some shallow cup-shaped specimens from the Silurian strata of Bubowitz near Prague in Bohemia, where they occur in beds of the Étage E of Barrande. Though apparently very abundant, several specimens being oftentimes present in a single hand specimen of rock, only the outer surface is exposed to view; but, judging from the exceptionally favourable state of preservation of the surface of these cup-shaped examples, and the invariable absence of any traces of summit structures, there seems good reason for supposing that they retain their original and complete form. I have not, however, been able clearly to make out the natural margins of the cup, which are always enclosed by the matrix, and only indistinctly shown, even in vertical sections through the specimens. The base is either evenly rounded or with a shallow concavity in the centre; there is no trace of any attachment, and the forms were evidently free (Pl. XXXVII. fig. 2).

The outer surface is composed of spicular plates, usually rhomboidal in form, though in some cases the proximal and distal angles of the rhomboids are slightly truncate and the plate becomes approximately hexagonal. The outer or upper surfaces of the plates are flat, smooth, and exhibit the same horny lustre as in the Djupvik examples of *Ischadites*. Concentric lines of growth are also apparent, though not so clearly marked as in *Sphærospongia*; and occasionally there are traces of a central knob-like elevation in the plates, as in this latter genus. At the nucleus or centre of the base there is a small circle of eight spicular plates arranged in a star-like form. The mode of arrangement of the plates in spiral curves, as well as the insertion of fresh rows, is precisely similar to what has been already described in *Ischadites*. The spicular plates fit at their margins, but not so closely as to preclude the possibility that a narrow channel may have existed between them originally, and this

* Leth. Pal. Th. i. p. 297, fig. 54.

is also indicated by the delicate concave casts of the outer surface, in which the individual plates are marked out by thin raised ridges, which are the filled-up spaces which existed originally between them. The slightest degree of weathering also is sufficient to clearly expose the intermarginal channels and tenuity of the edges of the plates. In this form, too, the distal spicular rays, that is, those which point to the margins of the cup, project in some instances beyond the distal angles of the summit-plates, and extend to nearly the centre of the plates immediately in front. Owing, however, to the calcitic replacement which has taken place, both the rays and the plates over which they extend appear as if welded into one continuous mass.

The horizontal rays beneath the summit-plates are but seldom exposed in the specimens of this genus, but in a few instances in which the plates have been weathered, they exhibit the same character and arrangement as in *Ischadites*. In vertical sections, passing through the centre of the base of the specimens, there is shown, immediately beneath the outer surface, a continuous layer, from 1 to 3 millim. in thickness, of crystalline calcite, in which no structure whatever can be seen; projecting beyond this mass, however, there are numerous straight or slightly curved tapering shafts or rays which terminate acutely. These rays are smallest in the basal portion, and reach their maximum size about halfway between the base and the margins of the cup. They project at right angles to the summit-plates from beneath which they originate. These rays are completely surrounded by the hard matrix of greenish grains and fragmentary organisms, and the natural terminations of several can be distinctly seen. As in *Ischadites*, they end quite free in the concavity of the cup, without being attached to an inner layer as in *Receptaculites* (Pl. XXXVII. fig. 2*e*). The thick band of crystalline calcite surrounding the interior of the cup appears to have been produced by the amalgamation into an undistinguishable mass of the summit-plates, the horizontal rays, and the basal portion of the vertical rays.

The distinguishing character of this genus is an open cup-like form into which the vertical spicular rays project. It resembles *Ischadites* in structural details, but differs therefrom in the absence of a covered-in summit, enclosing a central cavity. From *Sphærospongia* it is distinguished by the generally rhomboidal form of the spicular plates, and the well-developed vertical rays. The absence of an inner layer marks this genus off from *Receptaculites*. For the type species, which appears hitherto to have passed under the name of *Ischadites Kœnigii*, I propose the specific name *Barrandei*. The specimens from which the above description is taken are in the British Museum of Natural History.

The only previous notice of this form, of which I am aware, is by Ferd. Römer *, who remarks that it differs specifically, if not generically, from *Ischadites Kœnigii*, to which it had usually been referred.

* Leth. Pal. Th. i. p. 292.

Genus RECEPTACULITES, Defrance, 1827.

Receptaculites, Defrance, Dictionnaire des Sciences Naturelles, t. 45, Atlas, pl. 68.

The typical examples of this species to which the author gave the name of *R. Neptuni* were from Devonian strata at Chimay in Belgium, and consisted, judging from the figures, of two individuals, one cup-shaped and the other a flat disk-shaped specimen. The characters of these specimens were evidently very imperfectly preserved, and the author merely refers to an outer surface of rough markings and protuberances arranged in regular curved lines, and an upper surface exhibiting round shallow holes. Succeeding writers, with the exception of Salter and Billings, have based their descriptions of the genus upon specimens of the same species from Belgium and Silesia, whilst these latter authors have referred more particularly to species from a lower geological horizon in Canada and Australia, which, in some structural details, differ from the Devonian forms described by Dames, Gümbel, and others; but it is doubtful if these differences really exist or are merely owing to the imperfect preservation of the specimens. The following description is from the study of specimens from Devonian strata in Belgium, Silesia, and Canada, and from Silurian strata in the United States, Canada, the Arctic regions, and the Baltic.

In outer form the examples of this genus are open cup-shaped or flattened expansions with a circular outline and sometimes with slightly incurved margins. Numerous gradations occur between cup- and platter-shaped examples of the same species. In some specimens there appears to be no tendency to an incurvature at the margins, even in very large forms, such as those of *R. occidentalis*; while in others there is a short upward curvature, so that when complete they must have resembled a wide, shallow, dish. The nucleus, or starting-point of growth, is usually a small obtusely conical projection, which in no wise served as a point of attachment, and the organism is invariably free. Whether the margins of the cup were open or covered in any way is uncertain, as in no case is the structure of the upper edge clearly shown. There seems no evidence in favour of the supposition of Mr. Billings that the complete specimens of this genus possessed dome-shaped or conical summits similar to those of *Ischadites*, for though platter- and cup-shaped examples are abundant in certain strata, and apparently perfect as regards their outer form, yet in no single instance has an upper portion been discovered in connection with them; and if we take into consideration the numerous instances in which the smaller and more delicate forms of *Ischadites* still retain their complete form and conical summits, the conclusion appears justifiable, as Gümbel has already remarked, that the specimens of *Receptaculites* were originally of the form in which they are now found as fossils. No specimen has yet been found to correspond with the diagrammatic representation which Mr. Billings * has given of a supposed complete example of the genus.

* Pal. Foss. vol. i. p. 378, f. 353.

Taking first into consideration the structure of the outer or under surface of the fossil, we find that it consists of a layer of rhomboidal spicular plates of the same character and disposed in precisely the same manner as those in *Ischadites* and *Acanthochonia*. I have not been able to ascertain definitely the precise form of the nucleus or commencement of growth of the spicules, but it is probably similar to that of the genera already described; the plates in the centre are the smallest, whilst those in the central and peripheral portions of the organism are the largest. The outer surface of the spicular plates is flat, and their margins are very thin and delicate; the central portion was firmly united to the rest of the spicule immediately above the horizontal rays. There appear in this genus also delicate linear interspaces between the margins of the plates, which are particularly conspicuous in silicified specimens which have been freed from the calcitic matrix; the interspaces, however, in these forms may be partly owing to the destruction by the acid of the delicate edges of the plates. No structure is visible in the summit-plates; when silicified they are apparently compact, whilst in the calcareous forms, when the surface is gently rubbed and polished, radiating fibrous crystals of calcite, oftentimes intermingled with iron-peroxide, are exposed.

According to Gümbel *, the spicular plates (Kalkplättchen) of *Receptaculites* consist of three distinct layers—(1) of a thin carbonaceous layer, (2) of an upper layer of crystalline calcite, and (3) of an under layer of the same material; and there seems therefore a notable discrepancy between his observations and my own that the plates are composed of a single, relatively thin, structureless layer. This discrepancy is, however, more apparent than real, since the spicular plates as I have defined them correspond to only the second or upper calcareous layer of Gümbel. The carbonaceous surface-layer, which Gümbel describes as extending completely over both the outer and inner surfaces of the organism, appears from his description to be of a very dubious character. From what I have seen of the Ober-Kunzendorf specimens in which it is said to occur, I should judge that it would arise from a slight mineral deposit incrusting the surface of the fossil; but if, as Gümbel asserts, one or two layers of cellular structure are shown in thin sections of this surface-layer, they would, to me, rather indicate the presence of an incrusting coral or polyzoan than, as Gümbel supposes, an original outer covering of a coriaceous or keratose consistency. No mention of this carbonaceous layer has been made by any other independent observer, or in any examples from other localities than Ober-Kunzendorf, and Gümbel himself does not attach any particular importance to it. In the upper calcite layer of Gümbel, which is the equivalent of my summit-plates and the ectorhin of Billings, this author does not appear to have observed more than radiating fibrous grooves, probably of mineral origin. The lower calcitic layer of Gümbel's *Kalkplättchen* comprises the horizontal spicular rays, and I agree with Billings in regarding these structures, which

* Beitr. p. 21.

are only united with the summit-plate at the common centre of the spicule, as distinct from the summit-plate itself.

The horizontal rays, the equivalents of the stolons of Billings, the Stützarme or Epistyle of Gümbel, are only seen when the summit-plates of the spicules have been partially or entirely removed by natural or artificial means, and they then appear as four short rays radiating from a common centre, which also coincides with the centre of the head plate. Their arrangement is precisely similar to that in *Ischadites*, but they are very much smaller and slenderer in proportion to the dimensions of the vertical ray of the spicule, than in this latter genus, and consequently less resemble normal hexactinellid spicules. The horizontal rays of each spicule, as in *Ischadites*, are distinctly free from the rays of adjoining spicules, and very frequently they overlap each other and rest side by side. This fact is clearly recognized by Gümbel*; but Billings† supposed that they were connected with the rays of adjoining spicules, though they are shown in his diagram as meeting each other, but not in contact.

In the silicified specimens of *R. occidentalis* from which Billings's description was taken, the extremities of the spicular rays appear to be invariably incomplete after treatment with acid, so that he had himself no opportunity of observing their natural termination. In the same specimens, the peculiar fact is shown that the horizontal spicular rays are not all strictly in the same plane, or at right angles to the vertical ray, for while this is the case with the lateral rays, the distal and proximal rays are slightly oblique, so that the proximal ray, or that pointing to the nucleus, projects slightly upwards, while the distal or opposite ray extends slightly downwards (Pl. XXXVII. figs. 3 *l*, *m*). The four horizontal rays are traversed by axial canals, which unite with each other and with the canal of the vertical ray at the central point of junction of the spicule. I have not been able to detect more than four horizontal rays with their corresponding canals in any of the specimens of *R. occidentalis*, and Gümbel refers to four only in the specimens which he examined; but in the cast of a specimen from Ober-Kunzendorf figured by Dames‡, and which through the kindness of Prof. F. Römer I have had an opportunity of seeing, there are, in addition to four well-marked horizontal rays, small subordinate rays apparently radiating from the central point of junction of the spicule, in a similar manner to those of certain spicules of *Holasterella conferta* §, Carter.

It will not be necessary to again describe the different aspects of the surface of the organism in different conditions of fossilization, since the subject is referred to in treating of *Ischadites*, and there is no difference in the aspect of *Receptaculites* under similar conditions; but whilst no silicified examples of the former genus are known, they are not uncommon in one species of *Receptaculites*

* Beitr. p. 29, t. A. fig. 4 *b*. † Pal. Foss. vol. i. p. 380.
‡ Zeitsch. d. deutsch. geol. Gesellsch. Bd. xx. p. 484, t. 10. f. 1.
§ See Cat. Foss. Sponges, Brit. Mus. p. 152, t. 32. f. 2.

and exhibit the structure more clearly than any of the calcitic specimens.

The vertical spicular ray in *Receptaculites* (the cylindrical tube or hollow spicula of Billings; the Säulchen of Gümbel) is usually straight, and nearly cylindrical for the greater part of its length, but near its junction with the horizontal rays it somewhat suddenly contracts to form a short neck, and above this it expands and gives off the four horizontal rays already described, which are capped by the summit-plate. At its opposite extremity, the vertical ray is modified to form the substance of the inner layer. In most, if not all, of the species of *Receptaculites*, the vertical ray exhibits the same peculiar neck-like contraction. In none of the silicified specimens which I have examined are there any traces of the so-called "intermediate small connecting stolons along the columns" mentioned by Salter *, which probably arise from chance fragments of silica in the interspaces between the columns. The surface of the vertical ray appears to have been smooth, although in some cases the mould exhibits slight transverse furrows, but whether these markings arise from the fossilization, or indicate constrictions in the rays, I am unable to determine. The vertical ray is also penetrated by an axial canal which connects with the canals of the horizontal rays above and with the horizontal canals of the inner layer below. The rays are, in conformity with the thickness of the specimen, relatively short near its nucleus, and of greater and nearly equal length in its central and peripheral portions. As seen in sections of decalcified specimens, the vertical rays appear as so many curved rows of vertical pillars, each of which is separated from those surrounding it by an interspace of about half its own thickness, and each spicule composed of the vertical and horizontal rays and the summit-plate is entirely independent except at its basal end, where, as already stated, it is united to and forms part of the inner layer.

The structure of the inner or upper layer of *Receptaculites* (endorhin of Billings; innere Hülle, Gümbel) has not been ascertained so definitely as that of the exterior portion of the organism, owing to the rare cases in which it is preserved. The descriptions given of it by Dames and Gümbel, which have been taken from thin sections or etched surfaces of *R. Neptuni*, do not agree with those of Billings, which are based on the study of silicified specimens of *R. occidentalis*. In specimens of *R. Neptuni* from Belgium which I have seen, this inner layer is only shown in vertical sections as a thin delicate line of iron peroxide in which no structure whatever is visible; but in a Canadian example of apparently the same species, the inner layer, though only consisting of iron peroxide, exhibits well-marked perforations, the same as in *R. occidentalis*. Again, in another specimen of this species from Devonshire, the inner ends of the vertical rays appear to pass into circular or rhomboidal plates, but I cannot determine if these are united together to form a continuous layer.

In *R. occidentalis*, the inner or upper layer appears to be funda-

* Canad. Org. Rem. dec. 1, p. 45, t. 10. f. 4*a*, *b*.

mentally composed of modified extensions of the basal ends of the vertical rays of the spicules. Instead of tapering to a pointed extremity as in *Ischadites* and *Acanthochonia*, the vertical rays, in this species of *Receptaculites*, continue cylindrical to near their basal extremities, and then abruptly expand into horizontal plates. These plates have four straight sides, but at each of the corners there is a semicircular or semielliptical vertical hollow. Each plate appears also to be traversed by four horizontal canals, which radiate from the centre, where they are in connection with the canal of the vertical ray. The inner surface of the plate is flat; the upper surface, or that which is exposed in the cup or disk, is oftentimes convex and deeply ridged and furrowed (Pl. XXXVII. figs. 3 *c–g*). These plates are intimately united together so as to form a continuous inner or upper layer. The delimitations of the separate plates in this layer are not always preserved; in many specimens they appear to have been completely obliterated, and the layer resembles a continuous plate with numerous cylindrical or elliptical canals which penetrate through it at right angles. These canals are formed by the apposition of the vertical hollows in the corners of the plates of which it is primarily built up. On the inner side of the plate, facing the interior cavity, the canal-apertures are evenly circular or elliptical, but on the outer surface they frequently enlarge and extend into irregular open channels, which run between the canals and across the intermediate surface. The horizontal canals in the substance of each plate also appear, when the plates are amalgamated together in one layer, to intercommunicate together. This inner layer, though primarily formed of plates developed from the basal ends of the spicules, appears, when complete, to form an independent membrane, and to be distinct from the vertical rays, which readily break off at their junction with its inner surface. It is thus entirely different from the spicular plates which compose the outer or under surface of the organism, which are clearly distinct from each other and form the head of each separate spicule. The inner surface of a silicified example, when freed from the matrix, shows indeed, at a superficial glance, an apparent division into component plates, but when closely examined this effect is seen to be produced by the regular lines of perforations and the deep furrows connecting them.

It will be seen that my observations of the structure of the inner layer or endorhin of *R. occidentalis* agree with those of Mr. Billings. The diagram* which this author has given of the body-wall of *Receptaculites*, conveys an erroneous idea of the structure of the inner wall on account of the greatly exaggerated distances between the columns or vertical rays. In reality these are only about one half their own diameter apart; and if, in the limited interspaces between them, room is allowed for the vertical canals, it will be seen that the horizontal canals are necessarily very short.

Gümbel's† description of the inner layer of *R. Neptuni* varies

* Pal. Foss. Can. p. 382, fig. 357.

† Beitr. pp. 30, 31.

considerably from that of *R. occidentalis*. He states that the vertical spicular rays (Säulchen) increase in thickness towards the inner integument, near to which they contract and again expand to form a support to the calcareous plate proper of the inner layer. The expansion however is not decidedly four-armed, but a greater number of thicker irregular branches, with apparently lateral branchlets, radiate from the pillar. These are not united by growth with the main plate. Small canals also run through the plates, though they are only recognizable with difficulty. Thus the plates of the inner integument consist of a principal calcareous layer and a radiating under layer extending from the pillars. There is also a very thin surface layer of dark carbonaceous material resembling that of the outer integument, but with a distinctly marked granular surface. Gümbel further states that, after repeated careful observations, he is firmly convinced that there does not exist any perforations in the angles of the plates of the inner integument of *R. Neptuni*, and that these perforations cannot be considered as one of the characters of the genus. He thinks, however, that communication with the exterior took place by means of small channels between the sutures of the plates, into which also the branching canals from the pillars certainly extended.

Notwithstanding the apparently fundamental differences in the structure of the inner layer of *R. occidentalis* and that of *R. Neptuni*, I am still of opinion that the characters shown in the silicified examples of the former species probably represent with greater accuracy those of the genus than those which Gümbel has described in *R. Neptuni*. It is quite possible that in the replaced calcified specimens, which can only be seen in sections or etched surfaces, the real characters of the inner layer may be so concealed or altered as not to be recognizable, and that therefore greater dependence should be placed on the silicified examples, in which all the other characters of the organism are better preserved than in the examples with skeletons of crystalline calcite.

The characters of the genus *Receptaculites* may be briefly summed up as follows:—Cup- or platter-shaped bodies of considerable size, with walls of definitely arranged spicules. The outer surface is formed by the rhomboidal head-plates of the spicules; beneath these are the horizontal rays, and robust subcylindrical vertical rays, which are connected with an inner layer or perforated plate. Communication with the exterior was carried on between the margins of the summit-plates of the spicules on the outer surface, and through the cylindrical canals of the inner surface layer, or, according to Gümbel, through intermarginal canals.

From all the other genera of the family, *Receptaculites* is distinguished by the possession of an inner layer.

It seems unnecessary to give a detailed history of the genus, since this has been sufficiently shown in the previous part of the paper. By the earlier authors, Defrance and Eichwald, the hollow casts of the vertical spicular rays were regarded as polyp-cells and the form was placed amongst the Corals; it was next placed by

Salter amongst the Foraminifera, as allied to the family of the Orbitolitidæ; Billings placed it with Sponges on account of a supposed resemblance to the gemmulæ of *Spongilla*; it was again relegated to the Foraminifera by Dames, who placed it as the type of a family near the Orbitolitidæ; and later Gümbel retained it in the same order, but included it in the family of the Dactyloporidæ. But since the typical forms of that family have been proved to be calcareous Algæ, the systematic position of *Receptaculites* has been regarded as very doubtful, though F. Römer still retains it provisionally amongst the Foraminifera, as also does such an authority on this order as Rupert Jones. Zittel, however, rejects it from the Foraminifera, and leaves its position uncertain.

IV. The Affinities and Systematic Position of the Receptaculitidæ.

The different genera of this family have been variously referred, by those who have studied their structures, to such widely diverse divisions of the animal kingdom as Foraminifera, Sponges, Corals, Cystideans, and Ascidians, and they have also been supposed to belong to the vegetable kingdom and referred to fossil cones. It is not necessary to dwell on their supposed relationship to the three last-mentioned groups of animals, since it is now generally recognized to have been based on an entire misconception of the true structure of these fossils. The resemblance to Corals originated in the idea that the hollow cylindrical cells, which are really only the casts of the vertical spicules, were in fact the cells inhabited by the polyps; and their supposed likeness to Cystideans and Ascidians arose from a fancied similarity in the character of the spicular plates of the outer surface to those constituting the external skeleton of these animals. Later writers have either referred them to Foraminifera or Sponges. The prevalent opinion of palæontologists to within a recent period has been in favour of their alliance to the first of these two orders; but since the particular division of the Foraminifera in which Gümbel placed them has been shown to be of plant and not of animal origin, the opinion has been expressed that this family should be considered as an extinct group without any recognizable near affinities to any other division of the animal kingdom. It seems difficult to understand the reasons for ranging any of the genera of this family under Foraminifera, since in no single important feature is there any resemblance to typical examples of this group; neither in form, size, nor internal structure is there any correspondence with either fossil or recent Foraminifera, and only on the supposition of Salter* that the now solid parts of the organism were originally filled with living sarcode, whilst the intermediate spaces were occupied by the calcareous skeleton, could a strained resemblance be found between *Receptaculites* and the family of the Orbitolitidæ. Salter† himself,

* Canad. Org. Rem. dec. 1, p. 46.
† Mem. Geol. Survey, 1861, p. 136.

however, afterwards relinquished this comparison, and ranged this genus under Sponges. Even accepting Gümbel's own definition, that the skeleton in this genus consists of outer and inner walls composed of individual plates supported by pillars extending between them and enclosing the sarcode, there does not appear to be any feature distinctively resembling foraminiferal structure, for no undoubted Foraminifer possesses walls of individual plates and a relatively enormous interior cavity without any partition into chambers. If, however, in *Receptaculites* no resemblance to Foraminifera is manifest, still less support for this comparison is afforded by the structure of the other genera of the family, in which, as we have seen, there is no skeletal inner wall.

It cannot be said, however, that those who advocated the relationship of this family to Sponges brought forward any satisfactory proofs of the alliance. Thus, for example, *Sphærospongia tessellata*, Phill. sp., was regarded by Dr. Bowerbank and Mr. Austin as a calcareous sponge, on the ground that the spicular plates of the outer surface were similar in structure and arrangement to those of *Dunstervillia* (*Sycandra*, Häck.) *elegans*, though there is no reason for supposing that the plates of *Sphærospongia*, like those of *Dunstervillia*, were made up of a multitude of microscopic acerate spicules; and further, whilst in the former genus there are large spicular rays beneath the plates, in the latter there are cylindrical or conical tubes bounded by spicules; nor can any definite homology be shown between the structure of *Receptaculites* and its allies and that of the gemmulæ of fresh-water sponges, with which it was compared by Mr. Billings. Independently of the enormous disproportion in size, in no case do the minute birotulate spicules of these latter bodies assume the regular form of the spicules in the Receptaculitidæ, that is of a summit-plate, with four horizontal rays beneath, and an elongated vertical ray either terminating freely or connected with a continuous inner plate. It is only in the genus *Ischadites*, moreover, that there is an approximation in outer form to the gemmulæ of *Spongilla*, for we have seen that in *Acanthochonia*, *Receptaculites*, and probably also in *Sphærospongia*, the outer form is either cup- or platter-shaped.

But though Mr. Billings's comparison of *Receptaculites* to these minute gemmulæ cannot be entertained, yet to him is due the merit of having recognized a resemblance between what he termed the cylindrical shaft and stolons of this genus and the spicules of sponges. He states * that "each tube, with its cylindrical shaft and plate at each extremity, resembles not remotely a birotulate spiculum, or it might perhaps with more probability be described as consisting of two spicula united at their points. Thus the ectorhinal plate with the four stolons may be a peculiar form of the foliato-peltate spicule. The cylindrical shaft may be a spiculum approaching the acuate or acerate varieties, with its point inserted into the nucleus of the foliato-peltate spiculum."

The knowledge that has been gained in the last few years of the

* Pal. Foss. Can. p. 387.

structure of recent and fossil siliceous sponges, makes it easier now to institute a comparison between them and the Receptaculitidæ than at the time when Mr. Billings wrote, and I now propose to show the extent of the resemblance.

First as regards the outer form. Though this is such a variable feature in sponges that but little importance can be attached thereto, yet the fact that in outer form the various members of the Receptaculitidæ are either platter- or cup-shaped, or conical, enclosing a central cavity with a summit aperture, is not without its significance when we consider that these are the commonest forms assumed by both recent and fossil sponges. Another feature too in which the Receptaculitidæ show a resemblance to undoubted Palæozoic sponges is the uniform absence of any point of attachment, so that the organism was perfectly free; thus contrasting with the usually attached Mesozoic and recent sponges. Ferd. Römer * has called particular attention to this fact in connection with the Palæozoic genera *Astylospongia*, *Aulocopium*, and *Astræospongia*, and also to the further circumstance, that the Palæozoic sponges do not form united colonies, but are distinct individuals, and this is the case also with all the members of the Receptaculitidæ.

The only structural elements of the skeleton of the Receptaculitidæ (if we except the inner layer of the genus *Receptaculites* itself) consist of the spicules, and these appear to me to be distinctly homologous with the spicules of hexactinellid sponges. The similarity between the four horizontal rays and the vertical rays of the spicules of this family and the same elements of the spicules of ordinary hexactinellid sponges is so close that it cannot fail to be recognized. The rays radiate at right angles to each other from a common centre; they gradually taper from the centre to their extremities (with the exception of the vertical ray in *Receptaculites*, which connects with the interior plate); and each ray is traversed by an axial canal which unites with the canals from the other rays in the central junction of the spicule. A resemblance (though not to hexactinellid spicules) is also presented by the peculiar neck-like contraction of the vertical spicular ray immediately beneath the horizontal rays in *Receptaculites*, to the spicules of Cretaceous examples of *Geodia*, such as *Geodia clavata*, Hinde †, and *G. coronata*, Hinde, in which there is a similar contraction immediately beneath the head-rays. In *Ischadites* and *Acanthochonia*, five rays of the normal hexactinellid spicule are well developed and terminate freely in obtusely pointed extremities, whilst in *Sphærospongia* and *Receptaculites* only four rays are normal, the fifth or vertical ray in the former genus being apparently represented only by a short blunted process, whilst this ray in the latter genus is not free at its basal extremity, but organically attached to an inner plate.

But though the analogy between the horizontal and vertical rays of the spicules and those of recognized hexactinellid sponges is readily apparent, yet this is not the case with the summit-plate or

* Leth. Pal. Th. i. p. 306.

† Fossil Sponge-spicules from the Upper Chalk, pl. ii.

head of the spicules, which in all the Receptaculitidæ is either rhomboidal or hexagonal in figure, very thin at its margins, but thicker at the central junction of the spicule, where it unites with the other rays. By those who have written on the group, this spicular plate has been regarded as a distinct integral portion of the organism, independent of the rays beneath, whereas it appears to me to have formed a constituent part of the spicule with which it was connected at the central point of junction with the horizontal and vertical rays. If the plate were separate from the rest of the spicule and formed by itself a dermal plate or surface-covering over the organism, it is difficult to explain how it would have been retained in its position; in the instances in which it is absent, this arises from weathering or the effects of fossilization, which have similarly affected the rays beneath.

In no other hexactinellid sponge, so far as I am aware, are there any spicules with similarly constituted head-plates; in many, however, no sixth or summit-ray is developed; but in some of the abnormal spicules of the Carboniferous sponge, *Hyalostelia Smithii**, Young and Young, sp., the sixth ray is in the form of a rounded knob. We have only to consider that the sixth ray in the spicules of the Receptaculitidæ, instead of being contracted to a knob merely, as in the Carboniferous sponge, has been developed in a horizontal direction, and by additions to its margins has assumed the regular rhomboidal or hexagonal figure by which it is adapted to fit in with the adjoining spicular plates to form an exterior layer to the organism. Strong confirmatory evidence of the theory that the summit-plates of the spicules are modifications of the sixth ray in the ordinary hexactinellid spicule, is afforded by the small blunted knob which projects in the centre of these summit-plates in the best-preserved examples of *Sphærospongia*, and traces of which are also present in *Acanthochonia*. In these forms we find the commencement of the sixth or summit-ray in the small central knob, from which, as a centre, the plate is developed horizontally by successive marginal additions.

But though, in regular hexactinellid sponges, spicules with horizontal summit-plates are unknown, yet in certain lithistid sponges there are spicules with specially modified summit-plates, adapted for the outer surface of the sponge, which may, though in a somewhat distant degree, be compared with the spicular plates in the Receptaculitidæ. Thus, in the Cretaceous genera *Plinthosella*, Zitt.†, *Ragadinia*, Zitt. ‡, and *Pholidocladia*, Hinde, and in the existent genus *Discodermia*, Bocage §, the outer surface of the sponge is covered with a layer of minute flat scale-like spicules, some with entire, others with lobate margins. In some a small shaft projects at right angles from the centre of the underside of the spicule, whilst

* See Cat. Foss. Sponges Brit. Mus. pl. 32. f. 1.

† See Hinde, Foss. Sponge-spicules, t. 4. f. 35–46; and Cat. Foss. Sponges, pl. 20. f. 4 *a*.

‡ Cat. Foss. Sponges, pl. 20. f. 5 *b*.

§ See Carter, Ann. & Mag. Nat. Hist. ser. 5, vol. vi. pl. 8.

in others it is absent, and only the plate remains. Now these scale-like spicules are, in reality, modifications of three of the four divergent rays of the normal lithistid spicule, and they vary as much from the usual development of these rays as do the summit-plates in *Receptaculites* from the normal sixth ray of the hexactinellid spicule. These lithistid surface-spicules show at least the possibility that under special conditions the normal cylindrical rays may develop into horizontal plates; and if this is the case in lithistid sponges, there is reason to supose that a similar change might take place in hexactinellids as well. But though it may be conceded that no close resemblance exists between the summit spicular plates of the Receptaculitidæ, and the modified sixth ray of the normal hexactinellids, yet this difference is insufficient in my opinion to outweigh the close similarity which occurs in other rays of the spicules.

In addition to similarity of form, the disposition of the spicules in the Receptaculitidæ closely resembles that in some normal hexactinellid sponges. This is most strikingly shown by a comparison with the Cretaceous genus *Cinclíderma*, Hinde *, in which there is a surface-layer of five-rayed spicules; four of the rays are so arranged horizontally that their extremities overlap each other, and form definite rectangular interspaces, of a similar character to those which are produced by the horizontal rays in *Ischadites*; whilst the fifth ray projects invariably in the same manner as the vertical spicular ray in the latter genus. In the Silurian hexactinellid genus *Plectoderma*, Hinde†, there is also a surface-layer composed of spicules with four horizontal rays and entering vertical ray, but there is not the definite quadrate arrangement present in *Ischadites*. In the Cambrian hexactinellid genus *Protospongia*, Salt. ‡, the surface-squares are formed also by the four horizontal rays, and in this genus the fifth ray of the spicule is not developed, thus resembling *Sphærospongia*. The resemblance of the surface of this sponge to that of *Receptaculites* induced Gümbel to place it in the same group with the latter. The Devonian genus *Dictyophyton*, Hall, has also the same regular arrangement of the surface into quadrate interspaces, and though the spicules in this genus have not yet been discovered, there can hardly be a doubt that they were similar to those of *Protospongia* and *Plectoderma*. It is not without significance that, both by M'Coy and by Ferdinand Römer, examples of *Dictyophyton* have been placed in the genus *Tetragonis*, Eichwald, which, as we have seen, is synonymous with *Ischadites*, Murch.

With respect to the relative dimensions of the spicules of the Receptaculitidæ, and those of recognized hexactinellid sponges, it may be stated that though in some of the species of *Receptaculites* itself, the individual spicules are considerably larger than in any known sponge, yet there is not so great a disproportion as to render a comparison fanciful or extravagant. Thus, in *R. arcticus*, Etheridge, the largest form of the family known, the spicules are from 10 to 18 millim. in length, and about 3 millim. in thickness;

* Cat. Foss. Sp. pl. 28. f. 1 *a–d*.
† Id. t. 31. f. 1. ‡ Id. pl. 28. f. 2.

whereas in hexactinellid sponges of the genera *Hyalostelia*, Zitt., and *Holasterella*, Cart., the spicules reach a maximum length of 9 millim., and a thickness of ·5 to ·9 millim. But, on the other hand, in the genus *Ischadites*, the spicules are not at all larger, and many of them are in fact much smaller than the surface-spicules of Palæozoic and Jurassic hexactinellid sponges.

The only other structural feature which remains for comparison is the inner or upper surface-layer which, as we have seen, is only developed in the genus *Receptaculites*. As already mentioned, the structure of this plate in the typical example of the genus, *R. Neptuni*, is not definitely known, but in the allied species, *R. occidentalis*, it consists of a continuous layer or plate, perforated vertically by canals giving access to the interior of the specimen, and also with short horizontal canals crossing each other at right angles, penetrating its substance, and communicating at their points of intersection with the canals in the vertical rays of the spicules. In its complete form this inner plate appears to me to be analogous to that which forms the inner or upper wall of the Jurassic hexactinellid genus *Porocypellia*, Pomel*.

The circulation of water through the organism in the Receptaculitidæ appears to have followed a similar course to that occurring in sponges generally. It seems to have found admission through the narrow linear apertures beween the margins of the spicular plates of the outer surface, and after passing through the interspaces between the spicules, which in the living state were lined by the sarcode, to have found its exit through the aperture in the summit of *Ischadites*, or through the perforated inner layer in *Receptaculites*, or freely into the open cups of *Acanthochonia* and *Sphærospongia*.

The resemblances referred to above appear to me to justify the conclusion that the Receptaculitidæ constitute a family of siliceous Hexactinellid Sponges. The body-walls are composed of spicules of the hexactinellid type, but modified by the development of regular rhomboidal or hexagonal plates in place of the head-ray of the normal spicule. The spicules are arranged in definite order, so that the summit-plates form oblique, curved, or spiral rows, whilst the four horizontal rays mark radial and concentric lines. In one genus the body-wall is bounded by a perforated inner layer.

The character and position of the spicules ally the family to the Palæozoic genera *Protospongia*, *Dictyophyton*, and *Plectoderma*. As, however, the component spicules of the skeleton do not appear to have been connected together, otherwise than by the sarcode (save in the genus *Receptaculites*), the family would be ranked in Zittel's suborder Lyssakina.

If in some structural features the Receptaculitidæ stand apart from fossil sponges of a more recent geological horizon, other undoubted Palæozoic sponges also exhibit abnormal characters. Thus it is only in the genera *Protospongia*, Salt., and *Dictyophyton*, Hall, that there exists a surface-structure of definite larger and smaller quadrate areas; in *Astylospongia*, F. Röm., the canal and spicular struc-

* See Zittel, Neues Jahrb. 1877, p. 364, t. 5. f. 1 *a*.

tures are of such a character as to render it doubtful whether the genus should be ranked under Hexactinellids or Lithistids; in *Astræospongia*, F. Röm., the form and disposition of the spicules differ so much from those of any other genus, that, though ranged under the Hexactinellidæ, it would be better placed as the type of a distinct order; and, finally, in the genera *Hyalostelia*, Zitt., and *Holasterella*, Carter, there is an extraordinary diversity in the form and size of the spicules. These facts clearly show that the structure of the principal genera of Palæozoic sponges varies widely from that of more recent types of the class, and materially lessen the weight of any objections which may be urged against the inclusion with them of the Receptaculitidæ.

V. Geological Distribution.

The earliest known member of the group has been described by Billings from the Calciferous (Ordovian or Lower Silurian) of the Mingan Islands, Lower St. Lawrence. In the Trenton limestone of Canada, and its equivalent, the Magnesian or Galena limestones of Illinois and Wisconsin, examples of *Receptaculites* are abundant, and the genus *Ischadites* makes its appearance here, and in Lower Llandeilo beds in Wales. *Receptaculites* also occurs in the Orthoceratite limestone of Esthonia and in Lower? Silurian of the Arctic regions.

In the higher division of the Silurian proper, the genus *Ischadites* is the most abundant. It is present in Wenlock and Ludlow strata in North Wales; in the Dudley and Malvern areas; in the island of Gotland and the Russian Baltic provinces; in the Niagara group of Ohio, Wisconsin, and Illinois, and at a slightly higher horizon at Gaspé, Gulf of St. Lawrence. *Receptaculites* is present in the Upper Silurian of Australia, and doubtfully also in Canada. The genus *Acanthochonia* occurs in the Silurian proper, Etage E. of Barraude, in Bohemia.

In the Devonian formation the genus *Receptaculites* is present in the middle division; in Mudstone Bay, Devonshire; in Belgium, the Eifel district, and also in the Rhenish province on the right side of the Rhine; at Ober-Kunzendorf in Silesia, and in Canada. The genus *Sphærospongia* occurs in Devonian limestones near Plymouth, also in Nassau and the Eifel, in Germany, and in the Urals, in Russia. *Ischadites* has not yet been found in the Devonian.

From Carboniferous strata only a single species of *Receptaculites*? from Silesia has been recorded by F. Römer, and no member of the group appears at any higher horizon.

All the examples of this family occur in limestone or in fine calcareous shales or mudstones, which probably indicate a habitat of deep or moderately deep water. It is evident, also, from the perfect manner in which the lightly attached spicules are preserved in their respective positions that the organism must have lived and been interred at undisturbed depths.

VI. Genera not belonging to the Group, but usually included therein.

A notice of the family would be incomplete without referring to certain other genera which have been, by various palæontologists, included in it, and indicating the reasons for their omission. Beginning first with Eichwald*, we find that, in addition to the genera herein recognized as proper to the family, he has included two others, *Mastopora* and *Eschariporα*, Hall. The former genus is undoubtedly congeneric, if not identical, with *Nidulites favus*, Salt., and will presently be mentioned in connexion with *Cyclocrinus*; the latter name is applied by Hall to a Polyzoon, but the form which Eichwald regarded as identical with Hall's type species has certainly no relation to it, nor to the Receptaculitidæ, though I am unable to judge from the figure and description to what group it may belong.

F. Römer† has embraced in the Receptaculitidæ, besides the recognized genera, the following: *Cyclocrinus*, Eichwald (=*Nidulites*, Salt.), *Pasceolus*, Bill., and *Archæocyathus*, Bill., though he acknowledges that these forms stand in very various degrees of relationship to the typical genera of the group. To these Zittel‡ has further added *Goniolina*, D'Orb., *Archæocyathellus*, Ford, and *Protocyathus*, Ford.

From an examination of specimens of *Cyclocrinus Spaskii*, Eichw., from the Silurian at Anticosti, and of *Nidulites favus*, Salt., from Lower Llandovery strata at Haverfordwest, and from Mullock Hill, Ayrshire, I am unable to see any structural resemblance in them to any of the Receptaculitidæ. The type of *Cyclocrinus* is a spherical body whose outer surface is covered with regularly arranged cup-like depressions, rounded below, with a small central circular aperture which opens into the central hollow body-cavity, and with pentagonal or hexagonal margins. Fitting into these small cup-like depressions are short, hollow, prismatic cells with rounded bases, which, like the cups, are perforated. I have not seen in the cups any traces of the short rays figured by Eichwald §; their absence, however, may be owing to the fossilization of the specimens. There is no feature in these fossils analogous to the spicules of the Receptaculitidæ; the structures which F. Römer compares to the vertical spicular rays in *Ischadites* appear to me to be prismatic cells, or short tubes with open surface-apertures. Though convinced that *Cyclocrinus* and its equivalent, *Nidulites*, have no connexion with *Ischadites* and its allies, I am not prepared to offer any suggestion as to their real characters.

The genus *Pasceolus*‖, Billings, is just as enigmatical as *Cyclocrinus*. It has been compared with *Sphærospongia*, Pengelly; but

* Lethæa Rossica, vol. i. pp. 434, 435. † Lethæa Pal. Th. i. p. 286.
‡ Handb. der Pal. vol. i. p. 728.
§ Leth. Rossica, vol. i. p. 638, Atlas, t. 32. f. 21 *b*.
‖ Can. Geol. Surv. Rept. 1856, p. 342; Pal. Foss. Can. vol. i. p. 390, f. 366; Cat. Silur. Foss. Anticosti, p. 69.

after studying very carefully examples of Billings's type species, *P. Halli*, which I collected myself from Silurian strata at Anticosti, I can positively assert that there is nothing in common between the structure of this species and that of *Sphærospongia*. I am also able to affirm the correctness of Billings's latest description of this form, that its surface consists of small convex elevations, composed of a very thin minutely wrinkled layer, which is sometimes translucent. There is no evidence that this surface-layer was divided into distinct plates, or that the elevations were perforated. Certainly, in *Pasceolus* there is nothing to correspond with the spicules of the Receptaculitidæ, and no analogy appears to me to exist between these forms. I may also here mention that two forms placed by Salter in the genus *Sphærospongia*, *S. hospitalis* * and *S. melliflua* †, have no affinity with the type of this genus, *S. tessellatus*, Phill. sp., but are probably related to *Pasceolus*, Bill. No reliance can be placed on Salter's figure of *S. hospitalis* which is evidently diagrammatical only.

F. Römer has ranked *Archæocyathus*‡, Bill., in the Receptaculitidæ from its possessing an outer and inner wall connected by vertical lamellæ which are thought to correspond with the connecting pillars, or vertical spicular rays of *Receptaculites*. There is, however, no real analogy between these structures, and it seems to me probable that, if a sponge at all, *Archæocyathus* will be found to be composed of minute spicules similar to those figured by Billings in *A. minganensis*. *Archæocyathellus* §, Ford, and *Protocyathus* ‖, Ford, appear to be closely allied to *Archæocyathus*.

I am unable to express any opinion as to the resemblance of the genus *Goniolina*, D'Orbigny ¶, to members of this group, since the description given of it by that author is limited to the surface-characters of the fossil.

VII. Revision of the Species.

In the absence of any satisfactory generic definitions, the same forms have been placed by different authors sometimes in one and sometimes in another genus. I have below endeavoured to arrange them in accordance with the characters which I have assigned to the different genera. It will be seen that in several instances I have comprehended in a single species forms which have hitherto been placed under several; but the numerous gradational differences in minute details of outer form and size in the large suite of specimens which I have examined, clearly show that these variations are not of the specific value which has been placed on them.

* Cat. of Cambr. & Silur. Foss. Univ. Cam. p. 40.
† Pal. Niti, p. 48, t. 5. f. 4, 5, 6.
‡ Pal. Foss. Canada, vol. i. p. 354, figs. 342–344.
§ Amer. Journ. Sci. 1873, vol. v. p. 211.
‖ Id. 1878, vol. xv. p. 124. ¶ Prodr. de Pal. vol. ii. p. 41.

Genus Ischadites, Murch.

Ischadites Kœnigii, Murch. (Pl. XXXVI. figs. 1, 1 *a–o*.)

1839. *Ischadites Kœnigii*, Murch. Silurian System, p. 697, t. 26. f. 11.

1842. *Receptaculites Bronnii*, Eichw. Urwelt Russlands, 2 Heft, p. 80, t. 1. f. 9.

1852. *Selenoides iowensis*, D. Dale Owen, Geol. Survey of Wisconsin, &c., p. 587, t. 2 B. f. 13.

1858. *Receptaculites Eichwaldi*, Schmidt, Die silur. Formation von Ehstland, &c., p. 232.

1860. *Receptaculites Bronnii*, Eichw. Lethæa Rossica, vol. i. p. 429, t. 27. f. 2 *a*, *b*.

1860. *Ischadites Eichwaldi*, Eichw. id. p. 436, t. 27. f. 3 *a*, *b*, *c*.

1865. *Receptaculites Jonesi*, Bill. Pal. Foss. Can. vol. i. p. 385, f. 363, & p. 389, f. 365.

1865. *Receptaculites iowensis*, Bill. id. p. 385, f. 364.

1866. *Ischadites antiquus*, Salt. Mem. Geol. Surv. Gt. Brit. p. 282, f. 4.

1867. *Ischadites tessellatus*, Salt. MS. (see Siluria), 5th ed. p. 509.

1868. *Receptaculites globularis*, Meek & Worth. Geol. Surv. Illinois, vol. iii. p. 301, t. 2. f. 2 *a*, *b*,

1868. *Receptaculites* —— sp.?, Meek & Worth. id. p. 301, t. 2. f. 1 *a*, *b*.

1873. *Ischadites Kœnigii*, Salt. Cat. Sil. & Cambr. Fossils, Cambridge, p. 100.

1875. *Receptaculites ohioensis*, Hall & Whitf. Geol. Surv. Ohio, Pal. vol. ii. p. 123, t. 6. f. 1.

1875. *Receptaculites subturbinatus*, Hall, 27th Annual Report State Museum, t. 3. f. 1, 2, 3.

1875. *Ischadites Kœnigii*, Gümb. Beitr. p. 43, t. A. f. 28, 29, 30.

1878. *Ischadites Kœnigii*, Nich. & Ether. Silur. Foss. Girvan, p. 20.

1878. *Ischadites Kœnigii*, Quenst. Petref. Deutsch. Bd. v. p. 592.

1880. *Ischadites Kœnigii*, Zitt. Handb. der Pal. vol. i. p. 728.

1880. *Ischadites Kœnigii*, F. Römer, Leth. Pal. Th. 1, p. 291.

1882. *Ischadites Kœnigii*, Jones, Cat. Foss. Foram. Brit. Mus. p. 2.

Sponges either ovate, or more or less depressed, conical; small individuals measuring 4 millim. in height by 6·5 millim. in width, and large, 40 millim. by 45 millim., with numerous gradations between these extremes. The base is either conical with an obtuse termination, flattened, or concave. In the examples with flattened or concave bases, the greatest width is attained near the base itself; whilst in the forms with a conical base the specimen is widest about midway between the base and the summit. The summit is generally slightly truncate or evenly rounded; occasionally there is a short elevated neck. The summit-aperture varies from 2 to 5 millim. in width. The summit-plates of the spicules vary from 2 to 4 millim.

in width in the zonal region, where they are largest, to from ·25 to ·4 millim. in the vicinity of the summit-aperture. The character and position of the spicules are referred to in the generic description. The longest of the vertical spicular rays which I have seen vary from 7 to 10 millim.

This species varies considerably in size and in details of outer form; but in the large collection which Prof. Lindström sent me from the isle of Gotland there are numerous transitional forms between the extremes, so that it is impossible to regard them as more than a single species, and in this gradational series there are specimens closely corresponding, not only to Murchison's type, but also to the forms which by Eichwald, Salter, D. Dale Owen, Meek, Billings, and Hall have been described as distinct species. The diversity of synonyms given to this single species can be further explained by the extraordinary difference of aspect which it presents under different conditions of preservation.

Eichwald recognizes the similarity of *R. Bronnii* to *I. Kœnigii*, but places it as a different species because it is not compressed, and the surface-markings are absent. The figure of *Selenoides iowensis*, D. Dale Owen, represents the concave basal surface of an individual. *R. Jonesi*, Bill., is a very similar form to Owen's *iowensis*; the figure of its vertical section clearly shows the free termination of the vertical rays of the spicules. *T. antiquus*, Salt., which is in the Jermyn Street Museum, is simply the impression of a portion of the outer surface of an individual which shows no character to distinguish it from *I. Kœnigii*. The MS. name of *S. tessellatus*, Salt., appears to have been given to a specimen which is also in the Jermyn Street Museum, and which cannot be distinguished from Murchison's type. Even if this had been a valid species, the specific name would require to be changed, since it had been previously employed by Winchell and Marcy for an example of this genus.

The specimens figured under *Receptaculites globularis*, and *R.*——? by Meek and Worthen, represent the concave bases and the lateral areas of two individuals. These authors appear to have followed Hall in regarding the base as the summit of the specimen, whilst they describe the summit, which, as shown by the figures, is obscured by matrix, as a broad base of attachment. The *R. ohioensis* of Hall and Whitfield is merely an imperfect cast of an individual of this species. The base of *R. subturbinatus*, Hall, is represented as the summit of the specimen.

Distribution. Lower Llandeilo: Garn Arenig, Wales. Woolhope beds Malvern: near Buildwas. Wenlock shales and limestone: Dudley, Usk, Malvern, Walsall; Balcletchie and Penkill, Ayrshire. Lower and Upper Ludlow: Ledbury and near Ludlow: Pentland Hills. Orthoceratite limestone: Reval. Lowest beds of the Silurian, at Visby, Westergarn, near Klintehamn, Djupvik, in the isle of Gotland. Galena Division of Lower Silurian at Scale's Mound, Illinois, and in Iowa. Niagara group at Waldron, Indiana; Yellow Springs, Ohio. Lower Helderberg Group at Gaspé, province Quebec.

ISCHADITES MURCHISONII, Eichwald, sp.

1842. *Tettragonis Murchisonii*, Eichw. Urwelt Russlands, Heft 2, p. 81, t. 3. f. 18.

1842. *Zamia rossica*, Kutorga, Verhandl. d. min. Gesellsch. St. Petersb. p. 7, t. 2. f. 3 *a–c*.

1860. *Tetragonis Murchisoni*, Eichw. Leth. Rossica, p. 431.

1860. *Ischadites altaicus*, Eichw. id. p. 437, t. 27. f. 4.

1875. *Tetragonis Murchisonii*, Gümb. Beitr. p. 40, 45.

1878. *Tetragonis Murchisonii*, Quenst. Petref. Deutsch. Bd. 5, p. 592.

1880. *Tetragonis Murchisonii*, F. Römer, Leth. Pal. Th. 1, p. 303.

The typical example of this species is elongated pear-shaped; it measures 100 millim. in length, by 58 millim. in width. The base is stated to have a short stem, but this is probably incorrect, as none is shown in the figure, which is slightly concave below; and as the author also says that the basal portion is broken off there seems to be no proof of his asserted stem. The specimen is widest at its lower third, and gradually tapers to the summit, which is curved. The typical example only shows the vertical and concentric lines formed by the horizontal spicular rays, and the perforations of the vertical rays.

Zamia rossica, Kutorga (*Ischadites altaicus*, Eichw.), appears to me from the figures and description of the author to be not improbably a specimen of *I. Murchisonii*, in which the summit-plates of the spicules have been preserved. The specimens figured do not show the characters either of the base or summit. The spicular plates are rhomboidal in the figure, though some are stated to be hexagonal; they vary from 3·5 to 7 millim. in width, and clearly show concentric lines of growth. In a section of a small individual there are vertical spicular rays 10 millim. in length. By Kutorga the form was referred to a pine-cone.

Distribution. Orthoceratite limestone: Reval, Wesenberg, Baltic Provinces of Russia.

TETRAGONIS SULCATA et PARVIPORA, Eichw. Lethæa Rossica, pp. 432, 433, Atlas, t. 27. f. 5, 6.

These two species are, as already remarked by F. Römer, of an altogether different character from the type of the genus, and do not belong to the family.

TETRAGONIS DANBYI, McCoy, Brit. Pal. Foss. p. 62, t. 1 D. f. 7, 8.

TETRAGONIS EIFELIENSIS, F. Römer, Leth. Pal. Th. 1, p. 304, f. 5, 6.

These species are also of a different character from *Ischadites Murchisonii*, and belong to the genus *Dictyophyton*, Hall.

ISCHADITES LINDSTRŒMI, Hinde, n. sp. (Pl. XXXVI. fig. 2.)

Cf. *Ischadites Grindrodi*? Salter, MS. (see Bigsby's Thesaurus Siluricus, p. 4).

Sponges with wide bases, markedly concave in the centre, and with apparently low conical summits. The specimens vary from 50 to 100 millim. in diameter. The spicular surface-plates vary from 3·5 to 5 millim. in greatest width. No summit has been preserved.

This species differs from *I. Kœnigii* in its considerably larger dimensions and the larger size of the summit-plates. I cannot say whether it is the same as the *I. Grindrodi*, Salter, MS., since there is no description or figure of this species. Some specimens of this species in the Jermyn Street Museum are labelled, but not by Salter, *I. Grindrodi*, whilst others precisely similar bear the label of *I. Kœnigii*. It seems best therefore, in the absence of definite knowledge of the type of *I. Grindrodi*, to adopt another name, and I propose to name it after Prof. G. Lindström of Stockholm, to whom I am indebted for the loan of the specimens.

Distribution.—Wenlock shale: Malvern, Lower Ludlow, Ledbury; lowest beds of the Silurian: Petesvik, Hablingbo, isle of Gotland.

ISCHADITES TESSELLATUS, Winchell and Marcy *.

1866. *Ischadites tessellatus*, Winch. and Marcy, Mem. Bost. Soc. Nat. Hist. vol. i. pt. 1, p. 85, t. 2. fig. 3.

Non *I. tessellatus*, Salt. MS., Siluria, 4 ed. 1867, p. 509.

1870. *Receptaculites formosus*, Meek and Worthen, Proc. Ac. Nat. Sc. Phil. p. 23.

1875. *Receptaculites formosus*, Meek and Worthen, Pal. Illinois, Vol. vi. p. 500, t. 24. fig. 1.

1875. *Ischadites tessellatus*, Gümbel, Beitr. p. 40.

The specimen figured is the cast of the lower portion of an apparently pear-shaped individual with a conical base. The rhomboidal spicular plates are from 2·5 to 5·5 millim. in width. According to the author some examples are 62 millim. in height by 43 in width, and thus considerably larger than *I. Kœnigii*, whilst the general form distinguishes the species from *I. Lindstrœmi*.

Meek and Worthen figure a perfect example of this species under the name of *R. formosus*. Its correspondence in form and the fact of its being derived from the same geological horizon and locality place its identity with this species beyond doubt.

Distribution.—Silurian: Niagara limestone, near Chicago, Illinois.

* According to Miller's 'Catalogue of American Palæozoic Fossils' (1877), p. 43, this species is a synonym of *Receptaculites infundibulus*, Hall, Geol. Report Wisconsin, 1861. I have been unable to obtain a copy of Hall's paper either in the library of the Geological Society or in that of the British Museum. I may say that in the absence of figures, mere verbal description, like Hall's, of the fossils of this group, is quite insufficient for the recognition of species, more particularly when the character of the fossil is so little understood by the author that he regards the base of the fossil as its summit, and *vice versâ*. Meek and Worthen (Geol. Illinois, vol. iii. p. 302) similarly express their inability to recognize Hall's species of this genus in the absence of figures, and there are therefore sufficient grounds for rejecting the species described in this paper unless subsequently verified and figured by the author or other writers.

ISCHADITES? INOSCULANS, Salter.

Sphærospongia inosculans, Salt. Pal. of Niti, p. 49, t. 5. figs. 7, 8, 9.

This species is based on a small compressed fragment, 18 millim. long by 13 millim. wide, of an apparently conical individual. The outer surface consists of slightly convex elliptical plates? with small irregular digital projections which interlock with each other. The plates show no structure, nor are there any indications of spicular rays beneath them. Possibly the form may belong to a new genus, but as the only specimen known (now in the British Museum) is insufficient to furnish generic characters, it seems preferable to allow it to remain provisionally under *Ischadites*, which, as Salter remarks, it much resembles.

Distribution.—Silurian: Niti Pass, Northern Himalaya.

Genus SPHÆROSPONGIA, Pengelly.

SPHÆROSPONGIA TESSELLATA, Phill. sp. (Pl. XXXVII. figs. 1, 1 *a–c*.)

1841. *Sphæronites tessellatus*, Phill. Pal. Foss. Devon, &c., p. 135, t. 59. f. 49.

1832. *Tunicate fossil*, Broderip, Trans. Geol. Soc. ser. 2, vol. iii. p. 164, t. 20. f. 1, 2.

1844. *Sphæronites tessellatus*, F. Röm. Rhein. Uebergangsgeb. p. 64.

1845. *Echinosphærites tessellatus*, Murch. Keyserl. Vern. Geology of Russia, p. 381, t. 27. f. 7.

1845. *Sphæronites tessellatus*, Bowerb. Ann. & Mag. Nat. Hist. vol. xv. p. 299.

1845. *Sphæronites tessellatus*, Austin, id. p. 406.

1850–56. *Proboscis of crinoid*, G. & F. Sandberger, Verstein. des Rhein. Schicht.-Sys. pp. 384, 385.

1861. *Sphærospongia tessellata*, Pengelly, Geologist, vol. iv. p. 340, t. 5.

1875. *Pasceolus tessellatus* et *Rathi*, Kayser, Zeitschr. d. deutsch. Geol. Gesellsch. p. 780, t. 20.

1880. *Polygonosphærites tessellatus*, F. Römer, Leth. Pal. Th. 1, p. 297, f. 54.

1880. *Polygonosphærites tessellatus*, Zitt. Handb. der Pal. vol. i. p. 728.

The characters of the type species have been fully referred to in the description of the genus. The specimens vary greatly in dimensions; the typical form, though imperfect, is 85 millim. in height and 115 in width near the summit. The spicular head-plates are from ·5 to 7·5 millim. in width. The average dimensions of a number of specimens in the British Museum are 60 millim. in height and the same in width, and the surface-plates are from 2·5 to 5 millim. wide.

Ferd. Römer places the form described in the 'Geology of Russia' as distinct from this species, but judging from the figure given of it, there does not appear sufficient reason for separating it from *S. tes-*

sellata. Kayser has also constituted a new species *S. Rathi*, which, however, appears to me not to differ from Phillips's species.

Distribution.—Devonian: Newton Bushell, Devonshire; Vilmar, Nassau; Eifel, Germany; River Jolva, near Bogoslofsk, Ural, Russia.

Genus ACANTHOCHONIA, Hinde.

ACANTHOCHONIA BARRANDEI, Hinde, sp. n. (Pl. XXXVII. figs. 2, 2 *a–e*.)

The characters of this species have been given with those of the genus. The specimens vary from 20 to 50 millim. in greatest width, and from 7 to 15 millim. in height. The spicular plates are only 1 millim. in width near the centre of the base, whilst those near the margins of the cup measure 5 millim. across. The summit-plates themselves appear to be thin, though their real thickness cannot be determined from vertical sections as they are fused into a crystalline mass with the horizontal rays and the basal portion of the vertical rays. The vertical rays are about ·5 millim. in thickness and 8 millim. in length, in the lateral portions of the cup, and smaller near the base.

Distribution.—Silurian. Etage E of Barrande, Bubowitz, near Prague, Bohemia.

Genus RECEPTACULITES, Defrance.

RECEPTACULITES NEPTUNI, Defrance.

1827. *Receptaculites Neptuni*, Defr. Dict. des Sci. Nat. t. 45, p. 5, atlas t. 68. f. 1*a*, 1*b*, 1*c*, 1*d*.

1826–33. *Coscinopora placenta* et *sulcata*, Goldf. Petref. Th. 1, p. 31, t. 19. f. 18, 19.

1842. *Receptaculites Neptuni*, Archiac & Verneuil, Trans. Geol. Soc. ser. 2, pt. 2, p. 407.

1844. *Receptaculites Neptuni*, F. Römer, Rhein. Uebergangsgeb. p. 59.

1868. *Receptaculites Neptuni*, Dames, Zeitsch. d. deutsch. geol. Gesellsch. Bd. xx. p. 483, t. 10. f. 1.

1875. *Receptaculites Neptuni*, Gümbel, Beiträge, Abhandl. d. k. bay. Akad. der Wiss. II. Cl. Bd. xii. 1 Ab. p. 169, t. A.

1878. *Receptaculites Neptuni*, Quenstedt, Petref. Bd. v. p. 596, t. 142. f. 20.

1878. *Receptaculites scyphioides*, Quenst. id. p. 586, t. 142.f. 15, 16.

1879. *Receptaculites Neptuni*, Nich. Man. Pal. vol. i. p. 127, f. 29.

1876–80. *Receptaculites Neptuni*, Zitt. Handb. d. Pal. p. 84, f. 20.

1880. *Receptaculites Neptuni*, F. Römer, Leth. Pal. vol. i. p. 290. tlas, t. 35. f. 7*a*, *b*, *c*.

1882. *Receptaculites Neptuni*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 4.

Sponges either shallow cup- or disk-shaped, varying in diameter from 65 to 180 millim. The base in its centre forms a slight conical, sometimes curved, projection. The thickness of the walls varies from 3 millim. near the nucleus to 10, 15, and in one unusually

thick example 20 millim. near the margins of the cup or disk. The rhomboidal spicular plates are from 4 to 5·5 millim in extension; they are usually flattened above, though occasionally through pressure they become concave. The horizontal rays are from 1 to 1·5 millim. in thickness; the distal ray not unfrequently projects from beneath its own plate to the centre of the plate in front of it. The vertical rays or pillars vary from 1 to 2·5 millim. in thickness; they are usually contracted immediately beneath the horizontal rays and then again expand and maintain a uniform thickness to their contact with the inner or upper layer of the wall. The characters of the inner wall in this species are somewhat doubtful. According to Gümbel and Dames it resembles the plates of the outer wall. Its structure is not shown in examples which I have seen from Belgium and Ober-Kunzendorf, but in a Canadian example of the species there are regular rows of perforations as in *R. occidentalis*.

There is a considerable variation in the size of specimens of this species from different localities. Thus the walls and spicules in the Belgian specimens are much less robust than in those from Ober-Kunzendorf.

Quenstedt has placed some examples of this species under the name of *R. scyphioides*, solely on account of a superficial resemblance to the sponge *Tremadictyon (Spongites) reticulatus*, Quenst. sp.

Mr. Champernowne has lately discovered an example of this species in hardened mudstones in Devonshire. It is much compressed and exhibits partially the inner surface.

Distribution.—Middle Devonian: Mudstone Bay, Devonshire. Chimay, Couvin and elsewhere in Belgium; Eifel, Germany; Ober Kunzendorf, Silesia; near Widder, Ontario, Canada.

RECEPTACULITES OCCIDENTALIS, Salter. (Pl. XXXVII. figs. 3, 3 *a–m*.)

1859. *Receptaculites occidentalis*, Salt. Can. Org. Rem. dec. i. p. 45, t. 10. f. 1–7.

1845. *Coscinopora sulcata*, D. Dale Owen (non Goldfuss), Geol. Report, Iowa, &c. p. 25 pl. vii. fig. 5.

1862. *Receptaculites Oweni*, Hall, Rep. Geol. Surv. Wisc. vol. i. p. 46, fig. 2, and p. 429.

1865. *Receptaculites occidentalis*, Bill. Pal. Foss. Can. vol. i. p. 381, figs. 354–356.

1868. *Receptaculites Oweni*, Meek and Worthen, Pal. Illinois, vol. iii. p. 302, t. 2. f. 3.

1875. *Receptaculites occidentalis*, Gümbel, Beitr. p. 7.

1878. *Receptaculites occidentalis*, R. Etheridge, Quart. Journ. Geol. Soc. vol. xxxiv. p. 577.

1878. *Receptaculites iowensis*, Quenst. Petref. Bd. v. p. 589, t. 142. f. 17.

1880. *Receptaculites occidentalis*, F. Römer, Leth. Pal. vol. i. p. 289.

1882. *Receptaculites occidentalis*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 3.

1882. *Receptaculites Neptuni*? T. R. Jones, id. p. 3.

This well-known species grows in flattened disk-like expansions, which, when entire, are from 100 to 200 millim. in diameter. The nucleus or commencement of growth is a small conical projection on the under surface and forms a small pit on the upper. The walls vary in thickness from 4 millim. in the centre to 12 millim. at the periphery of the organism. The spicular plates of the outer surface, with the exception of those immediately round the nucleus, vary from 3 to 5 millim. in width, and the horizontal rays are somewhat more than half the width of the plates. The vertical rays vary from 1 to 2 millim. in thickness. The inner or upper plate is about 1 millim. in thickness; the vertical canals by which it is perforated are about 1 millim. in width. The upper or outer surface of this plate is frequently irregularly furrowed by open canals.

In the massive limestones at Pauquettes Rapids on the Ottawa, the species is very abundant and is partly composed of silica and partly in the state of crystalline calcite. When freed from the matrix by dilute acid, the structure is more clearly shown than in any other example of the genus. The specimens from Illinois, &c., are generally in the condition of casts. This species was referred by D. Dale Owen to *Coscinopora sulcata*, Goldf. = *R. neptuni*, and Hall, in 1861, proposed to change the name to *R. Oweni*. Previously to this, however, Salter described and figured the species and gave it the name which it now bears. Salter suggested that *R. Neptuni*? Hall,* from the Trenton limestone of Carlisle, Pennsylvania, might also belong to the same species, but from Hall's figures it appears to be distinct, and it is moreover stated to be suborbicular or hemispherical. The examples from Illinois and other Western States are usually of somewhat greater diameter than those from the same horizon in Canada, but from a comparison of specimens from these different places I am unable to detect any differences which would justify regarding them as distinct species. Their external aspect is, however, strikingly dissimilar owing to their different states of fossilization.

Distribution.—Lower beds of the Trenton limestone: Pauquettes Rapids, Ottawa River, Canada. Galena limestone: Galena, Dixon, Illinois; various localities in Wisconsin and Iowa. Lower Silurian: Cape Louis Napoleon; Igloolik, Arctic regions.

RECEPTACULITES ORBIS, Eichwald.

1860. *Receptaculites orbis*, Eichw. Leth. Ross. vol. i. p. 428, t. 27. f. 1; cf. *Escharites forniculosus*, Schloth. Petrefactenkunde, 1820, p. 343.

1858. *Receptaculites orbis*, Fr. Schmidt, Silur. Form. von Ehstland, &c., p. 232.

1875. *Receptaculites orbis*, Gümb. Beitr. pp. 39, 41.

1880. *Receptaculites orbis*, F. Römer, Leth. Pal. Th. i, p. 289.

1882. *Receptaculites orbis*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 2.

Flattened disks from 80 to 150 millim. in diameter. The walls

* Pal. New York, vol. i. p. 68, t. 24. f. 3.

near the margins are about 5 millim. in thickness; the spicular plates are from 2·5 to 3 millim. in width. According to Gümbel the inner layer of this species is perforated by canals in a similar manner to that of *R. occidentalis*. I have only seen a single example of this species. It approaches closely to *R. occidentalis*, but the spicular plates and rays appear smaller. Eichwald's figures 1 *b*, *c*, though stated to be of the natural size, are evidently enlarged.

Eichwald states that *Escharites forniculosus*, Schlot., is a synonym of his species; but as Schlotheim's description is altogether insufficient to recognize the form, and is, moreover, not accompanied by any figure, it seems preferable to retain Eichwald's name and authority for it.

Distribution.—Orthoceratite limestone: Odinsholm, Reval, Baltischport, Esthonia.

RECEPTACULITES AUSTRALIS, Salter.

1859. *Receptaculites australis*, Salt. Canad. Org. Rem. dec. i. p. 47, t. 10. f. 8–10.

1878. *Receptaculites australis*, R. Etheridge, jun., Cat. Austr. Foss. p. 3.

1880. *Receptaculites australis*, F. Römer, Leth. Pal. Th. 1, p. 290.

According to Salter this species is mainly distinguished from *R. occidentalis*, Salt., by the imperfectly lobed surface of the spicular plates. Apparently the specimens, like those of *R. occidentalis*, are siliceous, and it is doubtful whether the so-called lobed surfaces of the plates may not be due to irregular accretions of this mineral.

Distribution.—Upper Silurian: Yarradong, New South Wales.

RECEPTACULITES? CANADENSIS, Billings.

1863. *Ischadites canadensis*, Bill. Geol. Canada, p. 309, f. 313, and p. 327.

1865. *Receptaculites canadensis*, Bill. Pal. Foss. Canada, vol. i. p. 384, f. 362.

1880. *Receptaculites canadensis*, F. Römer, Leth. Pal. Th. 1, p. 289.

The specimen thus named consists of only a compressed fragment of an individual, from which it is impracticable to determine if it forms part of a *Receptaculites* or *Ischadites*, and it is quite insufficient to furnish satisfactory specific characters. No description of it is given in the 'Geology of Canada,' where it is first figured, and the only apparent reference to it, on p. 327, states that it is an *Ischadites* allied to *I. Kœnigii*, the first instance of the genus on the continent. In the "Palæozoic Fossils," Billings notes the differences between this form and *R. Oweni*=*R. occidentalis*, which, however, arise from its different state of preservation.

Distribution.—Niagara limestone: Township of Esquesing, Ontario, Canada.

RECEPTACULITES CALCIFERUS, Billings.

1865. *Receptaculites calciferus*, Bill. Pal. Foss. Canada, vol. i. p. 359, f. 346.

The species is founded on a mere fragment, which shows the crossing ridges formed by the horizontal spicular rays. If Billings's figure is correct, the rays and the spicular plates above them must be considerably larger than in *R. occidentalis*.

Distribution.—Calciferous formation: Mingan Islands, Lower St. Lawrence.

RECEPTACULITES ARCTICUS, Etheridge.

1878. *Receptaculites arcticus*, Eth. Quart. Journ. Geol. Soc. vol. xxiv. p. 576.

1882. *Receptaculites arcticus*, T. R. Jones, Cat. Foss. Foram. Brit. Mus. p. 3.

The fragments of this species indicate flattened, platter-shaped individuals with slightly incurved margins. They were evidently of considerable size. The total thickness between the outer and inner walls varies from 10 to 20 millim. The summit-plates reach to 7 millim. in width. No trace of the horizontal spicular rays can be seen; these and the head-plates are merged together into a layer of crystalline calcite 2·5 millim. in thickness. The vertical rays, like those of *R. occidentalis*, are contracted immediately beneath the horizontal rays and then expand again and continue of an even thickness to their junction with the inner or upper plate. The rays are from 2·5 to 3·5 millim. in thickness, and their length corresponds to the thickness between the walls. The characters of the inner layer are not shown. The structure is now entirely replaced by coarsely crystalline calcite.

The large proportions of the form itself and of the spicular plates and rays distinguish this species from all others of the genus.

Distribution.—Lower Silurian: Cape Louis Napoleon, Cape Frazer, Arctic regions (type specimens in British Museum).

RECEPTACULITES? CARBONARIUS, F. Römer.

1871. *Receptaculites carbonarius*, F. Römer, Jahresber. Schles. Gesellsch. p. 42.

1880. *Receptaculites carbonarius*, F. Römer, Leth. Pal. 1 Th. p. 291, f. 53.

The imperfect example of this species is insufficient to determine its originally complete form; the author suggests that the relatively deep cup-shaped body may have been contracted above to a narrow aperture, in which case it would resemble an *Ischadites*. As, however, its interior characters are not known, its generic position remains doubtful.

Distribution.—Carboniferous Limestone: Rothwaltersdorf, Silesia.

RECEPTACULITES? RHOMBIFER, F. A. Römer.

1850. *Receptaculites* } *rhombifer*, F. A. Römer, Palæontographica,
Sphæronites } Bd. iii. p. 30, t. 4. f. 21.

1880. *Polygonosphærites rhombifer*, F. Römer, Leth. Pal. 1 Th. p. 298.

The figured type is a deep cup-shaped specimen, probably imperfect. The spicular plates are for the most part rhomboidal, and this feature would exclude it from *Sphærospongia*. The generic position must remain uncertain until its interior characters have been ascertained.

Distribution.—Upper Devonian: Harz, Germany.

Species which have been erroneously referred to Receptaculites.

Receptaculites? *elegantulus*, Billings, Pal. Foss. Can. vol. i. p. 359, f. 347. The only characters shown are faint ridges arranged in quincunx, marking out small rhomboidal pits. The small proportions and uniform size of these interspaces appear to me to indicate that it does not belong to the present group.

Receptaculites? *insularis*, Billings, Cat. Silurian Fossils of Anticosti, p. 29. Billings recognizes that the characters of this species are altogether distinct from those of the genus under which he has placed it with a query, and he suggests that it is congeneric with *Tetragonis sulcata*, Eichw. Leth. Rossica, p. 432, t. 27. f. 5 *a*, *b*. But this latter species is not a true *Tetragonis*, and probably belongs to a quite distinct group.

Note.—S. A. Miller, in Cat. American Pal. Fossils (1877), refers to *Receptaculites*, *Lunulites dactioloides*, Owen, 1840, and *Orbituloides reticulata*, Owen, 1840, 'Report on Mineral Lands, Niagara Group.' I have been unable to find this work in the libraries of the scientific societies in London, nor does it appear to be quoted in the 'Bibliography of North American Invertebrate Palæontology,' White and Nicholson. F. Römer, in Leth. Pal. 1 Th. p. 289, 290, refers the above species to Miller himself!

In the supplement to the Catalogue (1883) Miller further refers to *Receptaculites sacculus*, Hall, 'Descriptions of new Species of Fossils from Waldron, Indiana,' 1879, and *Receptaculites devonicus*, Whitfield, 'Descriptions of new Species of Fossils from Ohio,' 1882. Neither of the papers containing these descriptions is obtainable in London, nor can I ascertain where they have been published.

EXPLANATION OF PLATES XXXVI. & XXXVII.

Plate XXXVI.

Figures 1, 1 *a–o*. *Ischadites Kœnigii*, Murchison.

Figs. 1, 1*a–c*. Specimens showing differences in form and conditions of preservation. All natural size.

1. A small form, showing a prominently developed central zone, and with the summit-plates of the spicules preserved.

1 *a*. A specimen with an elevated summit, and clearly showing the horizontal rays of the spicules, the summit-plates which originally covered the surface having disappeared.

Fig. 1 *b*. A specimen with a flattened base and depressed summit, showing faint vertical and concentric lines formed by the horizontal spicular rays.

1 *c*. A specimen showing sections of the vertical rays of the spicules, both the spicular plates and the horizontal rays having disappeared.

The specimens are from the lowest beds of Silurian age in the isle of Gotland; fig. 1 is from Djupvik, and the others from the vicinity of Visby. With the exception of fig. 1 *c*, they have been lent by Prof. G. Lindström from the Royal Museum at Stockholm.

1 *d–g*. Showing the characters of the summit-plates of the spicules.

1 *d*. The upper portion of fig. 1, enlarged twice, showing the regular disposition of the spicular plates and the slightly elevated distal angles of those of the zonal region.

1 *e*. Shows the arrangement of the minute spicular plates at the summit of a small specimen, surrounding the central aperture. Enlarged six times.

1 *f*. The base of fig. 1, enlarged three times, showing the eight diamond-shaped spicular plates of the nucleus and the plates succeeding them, each having a clearly marked central spot, indicating the centre of the spicule.

1 *g* is a portion of the lateral surface of a specimen, enlarged four times, showing the extension of one of the horizontal rays of each spicule, from beneath the distal angle of its corresponding summit-plate, over the summit-plate of the spicule in front of it. In the centre of the figure are the modified summit-plates developed at the intercalation of a fresh row of spicules.

1 *h–j*. Showing the characters of the horizontal spicular rays.

1 *h*, 1 *i*, are portions of the lateral areas of two specimens in which the surface summit-plates have disappeared, showing the four horizontal rays of independent spicules. The rays are often incomplete, and they frequently overlap each other. Enlarged three times.

1 *j*. The surface of the upper portion of a specimen in which only three of the four horizontal spicular rays are preserved; the fourth, or distal ray, having disappeared with the summit-plate. Enlarged three times.

1 *k–o*. Showing the characters of the vertical spicular rays.

1 *k*, *l*, *m* are fractured specimens, showing the tapering extension and the free termination of the vertical rays in the interior of the central cavity, now filled with matrix. Natural size.

1 *n* is a smooth vertical section, and 1 *o* a transverse section, similarly showing the extension of the vertical rays.

Fig. 2. *Ischadites Lindstrœmi*, Hinde.

The base of a specimen showing the ridges formed by the matrix between the margins of the spicular summit-plates, which have disappeared; the dark spot in the centre of each rhomboidal area indicates the vertical rays of the spicules; some traces of the horizontal rays are also shown. From Silurian strata at Petesvik, isle of Gotland.

Plate XXXVII.

Figures 1, 1 *a–c*. *Sphærospongia tessellata*, Phillips, sp.

Fig. 1. A specimen, imperfect at the summit, showing the hexagonal spicular summit-plates of the surface. Natural size. From Middle Devonian strata at Newton Bushell, near Torquay, Devonshire. In the collection of the British Natural History Museum.

Fig. 1 *a*. Another specimen from the same locality, also imperfect, showing the interior surface. The vertical and transverse ribs are formed by the horizontal spicular rays, which are now partially amalgamated together. Natural size.

1 *b*. A portion of the outer surface of the typical example of the genus, now in the Jermyn-Street Museum, showing the slightly elevated knob in the centre of each of the spicular summit-plates. Natural size.

1 *c*. A portion of the inner surface of a fragmentary specimen, enlarged three times, showing clearly the horizontal rays and the independence of the spicules.

Figures 2, 2 *a–e*. *Acanthochonia Barrandei*, Hinde.

2. Two nearly entire individuals and portions of two others, partially imbedded in a fractured piece of rock. The bases and outer surface of the specimens are shown. Natural size. These and the following examples are from Silurian strata, Etage E. of Barrande, at Bubowitz, near Prague. They were obtained for the British Natural History Museum from Barrande himself.

2 *a*. The basal portion of an individual, enlarged three times, showing the eight spicular plates forming the nucleus, and the disposition of the summit-plates succeeding them.

2 *b*. A portion of the outer surface of another specimen, enlarged three times, showing the arrangement of the spicular summit-plates, from the nucleus, at the apex of the figure, to nearly halfway to the margin of the cup. In the centre of the figure are shown the two modified spicular plates, one pentagonal and the other triangular, which are developed at the intercalation of a fresh row of spicules.

2 *c*. A portion of the outer surface of a specimen in which the summit-plates are partially destroyed, showing the horizontal spicular rays beneath. Enlarged three times.

2 *d*. A vertical section of two specimens imbedded in the rocky matrix. Natural size.

2 *e*. A vertical section, passing nearly through the centre of a specimen, enlarged three times, showing the extension and the free termination of the vertical rays of the spicules. The spicular plates and the horizontal spicular rays are undistinguishably merged together in a thick outer layer of crystalline calcite (shown white in the figure), and the free vertical rays are now of the same material.

Figures 3, 3 *a–m*. *Receptaculites occidentalis*, Salter.

3, 3 *a*, 3 *b*. Different views of a fragment of a platter-shaped specimen, partially freed by acid from the calcitic matrix. Natural size.

3. Shows the perforated inner or upper layer.

3 *a*. The spicules connected with the inner layer.

3 *b*. The summit-plates of the spicules of the outer or under surface.

Collected by the author from the lower beds of the Trenton limestone at Pauquettes Rapids, Ottawa River, Canada.

3 *c–g*. Different views of fragments of the inner or upper layer.

3 *c*. The upper or exposed surface. Natural size.

3 *d*, *e*. The same surface, enlarged three times, showing its rough channelled character.

3 *f*, *g*. The reverse or inner side of the same fragments. The smaller circular or elliptical apertures are the canals which extend through the inner layer, and the larger shaded circles in figs. 3 *f*, *g* show the places of attachment of the vertical spicular rays to the inner surface of the layer; in some places the broken ends of the rays yet remain.

The delimitation of the plates, originally composing the inner layer, is shown in 3*f*, whilst in 3*g* it has partially disappeared.

Fig. 3 *h*–*m*. Different views of partially detached spicules, enlarged four times.

3 *h*. Two spicules in their natural position, showing at their bases the summit-plates, the broken truncated ends and the canals of the horizontal rays, and the neck-like constriction of the vertical rays; whilst at the top the vertical rays are connected with portions of the inner layer which unites them together.

3 *i*, *j*. Spicules showing hollow canals in the inner layer at their summits.

3 *k*. Spicules in a reversed position, showing in one the thin summit-plate immediately above the truncated horizontal rays.

3 *l*, *m*. Two views of the same spicule, showing the different direction of two opposite horizontal rays; that in 3 *l* pointing downwards, and its opposite, as seen in 3 *m*, directed upwards; in both the rays ar broken, and only their hollow bases remain. At the summit of the spicule is shown the interior of one of the canals which penetrate the inner layer.