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REPORT

OF THE

STATE GEOLOGIST.

REPORT.

Office of the State Geologist,
Room 32, State Hall,
Albany, N. Y., *March* 5, 1895.

To His Excellency Levi P. Morton, *Governor of the State of New York:*

Sir.— I have the honor to submit the annual report of the State Geologist, embracing an account of the work done by himself and assistants both in the field and office, including the work upon the geologic map and the Palæontology of New York.

In the absence of any appropriation from the Legislature very little work has been accomplished during the past year toward the completion of the geologic map. A small area in Oswego and Lewis counties has been surveyed and the results incorporated with the general geology upon the map of the State.

Preliminary Geologic Map of the State of New York.

Through the generosity of Major Powell in the outset, and the continuation of the same disposition on the part of his successor, Mr. Walcott, present Director of the U. S. Geological Survey, copies of the geologic map will be distributed to all the colleges and normal schools and to schools of higher education in the State, without cost to the State of New York. Although the map is incomplete in the representation of the geologic formations in some portions of the State, it is yet sufficiently perfect to serve the purpose of a student's map for general reference as to the limits and distributions of the geologic formations within its area. The map is designated as a "Preliminary Geologic Map of the State of New York," and it will require the labor of many years in the field, before the word "PRELIMINARY," now standing at the head of the title, can with propriety be erased and the map appear as a completed geologic map of the State of New York. I would most earnestly recommend that some law be passed authorizing the completion of this map and appropriating a small sum annually for defraying the field expenses of a competent assistant or assistants for determining the limits of certain formations which are now imperfectly delimited. Moreover, such a work may well be done as field exercises by a professor and his students during the college vacations, the whole being carried on under competent direction with a definite purpose for a final consummation of the work. The description of the geologic formations of the State as represented upon the map will form a part of a future report, and it is intended that separate copies of this description shall be sent to all the institutions and individuals who shall receive copies of the map.

I would, moreover, earnestly recommend that in the continuation of the work upon the geologic map especial attention be given to the economic aspect of the science. For many years the Legislature has liberally supported the publication of the Palæontology as a part of the Natural History publications of the State, according to the original plan of that work. There has been no organized plan for developing a knowledge of the mineral resources of the State, as might have been done through annual reports and local geologic maps of the counties, had there been some small appropriation for field work. Among intelligent people there is, at the present time, an urgent demand for practical geologic work, and I believe it should be most seriously considered in connection with the completion of the geologic map.

During the past twenty years the State of Pennsylvania has expended an amount of more than $1,500,000 in her second geologic survey, which has been chiefly carried on with a view to economic results. The State Atlas contains colored geologic maps of every county in that State, each county map being accompanied by a special report given to the geology and economic resources.

I have endeavored to introduce a similar plan in my work upon the geologic map of New York, and the report of last year contains a description of the geology and an account of the economic resources of Albany and Ulster counties.

We have now on hand, waiting for publication, certain colored maps of portions of the State, especially the maps of Albany and

Ulster counties, together with the Helderberg escarpment, which it is very desirable to publish for the full illustration of the geology and economic resources of these portions of State.

Faulted Region of the Mohawk Valley.

A paper* entitled "A Preliminary Description of the Faulted Region of Herkimer, Fulton, Montgomery, Saratoga and Adjacent Counties," communicated by Mr. N. H. Darton with this report, will give information in detail of this region of country, which was originally described by Mr. Vanuxem in his report on the Ge logy of the Third District. The paper by Mr. Darton is the result of work done in the field during the season of 1893, as a part of the work preparatory for the geologic map of the State. The results of this work, and of all his other field work up to 1894, have already been transferred to the geologic map which is being prepared for publication by the U. S. Geological Survey in Washington.

This paper gives an account of the general relations of the faults, and describes in detail those at Little Falls, on the East Canada Creek, St. Johnsville, the Noses, Fonda, Tribes Hill, Broadalbin, Hoffman's Ferry, Saratoga and Lake George. Some of these had been previously described by Vanuxem in his Report on the Third Geological District, but are here discussed at much greater length. This region of country was explored by the writer and Prof. W. J. McGee, of the U S. Geological Survey, in the autumn of 1884, and the field notes of these investigations, combined with farther observations by Mr. C. E. Beecher and Mr. C. E. Hall, were incorporated in the Report of the State Geologist for 1885 in a paper of three pages, accompanied by a map of the Mohawk Valley. This paper is here inserted as a note to show the state of our knowledge previous to the work of 1893.†

The region is a general monocline, with sediments of slightly varying dip, and the faults traversing this monocline, accompanied by certain features of local disturbance, have considerably modified its regularity. As a rule these displacements do not make conspicuous features in the topography, but one of them,

* Being accompanied by a colored map which could not be published at that time, this paper was deferred till the present report.

† See note at end of this paper.

at Little Falls, gives rise to one of the most striking features in the scenery of the Mohawk Valley.

Two faults of small throw and not great extent on the East Canada Creek, recorded by Vanuxem, are re-described. The writer finds, that of two previously described dislocations at St. Johnsville, one branches and curves in a remarkable manner. The great uplift at the "Noses," just east of Canajoharie, gives rise to a great ridge of calciferous sandrock rising abruptly from the moderately elevated Utica slate region on the east. The faults at Fonda and Tribes Hill bring up the limestones of the Trenton group, but appear to be neither very profound nor of great extent. The Broadalbin fault is not very clearly pronounced; that at Hoffman's Ferry is the easternmost in the region and brings up the Calciferous, Birdseye and Trenton limestones over a wide area, extending up the river as far as Amsterdam.

The faults at Saratoga are of much interest, as it was long ago recognized that the mineral springs at this place issue along a line of dislocation which brings up the Calciferous sandrock to a moderate altitude above the plains to the eastward. One of these faults extends to the Lake George region.

These descriptions recount all attendant phenomena and are illustrated with twelve figures, two plates and a map.

Geology of Seneca County.

In continuation of the plan of county surveys I communicate the accompanying report on the structural and economic geology of Seneca county by Dr. D. F. Lincoln. The subject is covered under three general divisions: 1. Surface Geology; 2. Stratigraphic Geology; 3. Economic Geology. Under the first head are given detailed accounts of the topography and also of superficial accumulations, their nature and distribution. Under the latter are notices of the general character of the plateau, hills, ravines; of the alluvial belt, drumlin belt, sand ridges, kame district, delta deposits, old channels, glacial deposits and striation, springs, etc.

The stratigraphic geology considers each formation in succession, from the Salina beds to the Portage group of rocks, the highest in the county. The local development and variation of each is given with fulness and precision. Faunal characters are touched upon to some extent, no wide difference in these respects from adjoining regions being noted. The writer, however, describes a calcareous layer at the very base of the Portage shales, not elsewhere observed, but of especial interest from the fact that it contains species of the typical Portage fauna commingled with those of the Ithaca group. The dip of the rocks is considered at some length and shown to be quite variable from local or general disturbances.

Under the head of economic geology are considered all the rock products of the county, their mode of exploitation, treatment and economic value. These are clay, brick, tile, limestone, sandstone, plaster, road metal, natural gas and water power.

The paper is abundantly illustrated with photographic views, sections and maps.

General Palaeontology.

It has been considered desirable to incorporate in this report a translation of the work of Felix Bernard, the nature of which is indicated by the following brief synopsis.

THE PRINCIPLES OF PALAEONTOLOGY.

BY FELIX BERNARD.

[Extracted from Bernard's Éléments de Paléontologie, Paris, 1895.]

This lucid and full presentation of the principles and objects which inspire palaeontologic investigations of the present day has been translated by C. E. Brooks, and is incorporated in this report for the benefit of American students to whom Bernard's entire work may not be accessible. No other writer has succeeded in setting forth so clearly the actual condition of the science, its relations to other departments of knowledge and the inherent importance of the problems with which it is wholly concerned. The subject is treated in five chapters, each with its subordinate divisions, and the following statement of contents will convey an idea of the scope and importance of the work:

Chapter 1. The Object of Palaeontology. Historical Sketch.

Sec. 1. The Relations of Palaeontology to the other sciences. *Definition; Palaeontology and Biology; Palaeontology and Geology.*

Sec. 2. History of Palaeontology.

of the Cretaceous; Climate of the Tertiary; Climate of the Pliocene and Quaternary.

Chapter 5. Process of Fossilization.

Conditions necessary for Fossilization; Fossilization of Animals; Fossilization of Plants.

Graptolitidæ.

Mr. R. Ruedemann, of Dolgeville, has communicated a very interesting and important paper on the Development and Mode of Growth of the Genus Diplograptus, McCoy.

This paper covers the author's detailed investigation of the structure and mode of development of species *Diplograptus pristis*, Hall. The observations are based upon material in a remarkably perfect condition of preservation, obtained from the Utica slate of Dolgeville, N. Y. It is shown that these graptolites, generally occurring as isolated stipes, were actually colonies composed of a large number of such individual stipes, growing radially from a center. The structure of the central part of the colony is shown to consist in, (1), a central floating sack or pneumatocyst, demonstrating that the colony was unattached; (2), a verticil of spherical gonangia, within which are found masses of young graptolites or siculæ attached to a central axis; beneath the gonangia are, (3), the radiately-arranged graptolite stipes attached by long, bare extensions of the axial rod or virgula of each stipe. The mode of growth of the stipe is such that the thecæ or individual cells are, in their normal position, directed inward. This is due to the fact that the first theca forms at the distal extremity of the young stipe or sicula, and in all later growth the increase in cells is at the proximal extremity of the stipe. The siculæ may either become wholly free of the present stock and commence the growth of independent colonies or may remain attached to the original stock. Some of them seem to always follow the latter course, and hence successive generations of gonangia give rise to the successive generations of stipes apparent in every well-preserved colony. Individual siculæ departing from the parent, as soon as their independence is attained, are shown to be provided with minute floating disks which eventually become the pneumatocysts of adult colonies. The paper is illustrated with three plates of highly instructive drawings.

Revision of the Sponges and Cœlenterates of the Lower Helderberg Fauna.

Mr. George H. Girty, of Washington, has communicated an interesting and important paper under the title, A Revision of the Sponges and Cœlenterates of the Lower Helderberg Fauna of New York.

In this paper the known species of the groups mentioned are redescribed and some important additions are made of heretofore undescribed forms. Opportunity is taken to elaborate certain structures, as the genera Hindia and Receptaculites, some new features of significance with reference to the latter being brought out. The following list of species considered will convey a conception of the contents of the paper.

SPONGIÆ.
- HINDIA.
  - *Hindia sphæroidalis*, Duncan.
- LYSACTINELLA, gen. nov.
  - *Lysactinella Gebhardi*, sp. nov.
  - *L. perelegans*, sp. nov.
- ISCHADITES.
  - *Ischadites squamifer*, Hall.
- RECEPTACULITES.
  - *Receptaculites infundibuliformis*, Eaton.

CŒLENTERATA.
- *Dictyonema crassum*, sp. nov.
- *Monograptus Beecheri*, sp. nov.
- *Syringostroma centrotum*, sp. nov.
- *S. foveolatum*, sp. nov.
- *S. microporum*, sp. nov.
- *S. Barretti*, sp. nov.
- *S. consimile*, sp. nov.
- *Clathrodictya Jewetti*, sp. nov.
- *Duncanella rudis*, sp. nov.
- *Streptelasma strictum*, Hall.
- *Zaphrentis Roemeri*, Edwards and Haime.
- *Favosites Helderbergiæ*, Hall.
- *F. Conradi*, sp. nov.
- *Alveolites explanatus*, Hall.
- *Pleurodictyum lenticulare*, Hall.
- *Striatopora Issa*, Hall.
- *Cladopora Clarkei*, sp. nov.
- *C. Halli*, sp. nov.
- *Aulopora subtenuis*, Hall.
- *A. Schoharie*, Hall.
- *A. tubula*, Hall.

The paper is accompanied by seven plates of drawings, giving figures of all new species and illustrations of structural details in the genus RECEPTACULITES.

Brachiopoda of Vol. VIII, Palaeontology of New York.

The new species of Brachiopoda described in Palaeontology of New York, Volume VIII, Parts 1 and 2, 1892–1894.

During the progress of the work upon Volume VIII of the Palaeontology of New York, it became necessary to describe or incidentally refer to a considerable number of new species of Brachiopoda. The volumes of the Palaeontology are not accessible to a large portion of students in Palaeontology, and Volume VIII, Part 2, has been published only in 100 copies. In order to make the descriptions and figures more accessible, it has been thought advisable to republish them in this report.

These species to the number of 106 are here brought together, with descriptions and illustrations. They are as follows:

Lingula compta.
L. scutella.
L. flabellula.
L. paracletus.
L. tæniola.
L. linguata.
Lingulops Granti.
Monomerella Greenei.
M. Kingi.
M. Ortoni.
M. Egani.
Rhinobolus Davidsoni.
Siphonotreta (?) Minnesotensis.
Orbiculoidea ovalis.
O. numulus.
O. Herzeri.
Lindstroemella aspidium.
Schizocrania Schucherti.
S. (?) Helderbergia.
Crania agaricina.
C. pulchella.
C. granosa.
C. favincola.
Craniella Ulrichi.
Pholidops calceola.
P. patina.
Orthis Panderiana.
O.? glypta.
O. flabellites, var. *spania.*
O.? Holstoni.
O. loricula.
O.? Saffordi.
O. arcuaria.
O. superstes.
O. Oweni.
O. senecta.
Orthostrophia dolomitica.
Strophomena Conradi.
S. Winchelli.
Orthothetes desideratus.
Derbya ruginosa.
D? costatula.
D. Broadheadi.
D. Bennetti.
D. cymbula.
D. affinis.
D. (?) biloba.
Streptorhynchus Ulrichi.
Triplecia Niagarensis.
Christiania subquadrata.
Leptaenisca adnascens.
L. tangens.
Chonostrophia Helderbergia.
Strophalosia Rockfordensis.
S. cymbula.
Strophonella costatula.
Plectambonites producta.
Spirifer crispatus.
S. Canandaiguæ.
S. mucronatus, var. *posterus.*
S. disjunctus, var. *sulcifer.*
S. Williamsi.
S. Newberryi.
Cyrtia radians.
Cyrtina umbonata, var. *Alpenensis.*
C. lachrymosa.

Syringothyris Missouri
Athyris densa.
Seminula Rogersi.
S. Dawsoni.
Trynifer criticus.
Rhynchospira scansa.
Trematospira Tennesseensis.
Meristella Walcotti.
Merista Tennesseensis.
Clintonella vagabunda.
Zygospira putilla.
Atrypina Clintoni.
Glassia Romingeri.
Camarophoria rhomboidalis.
Parastrophia divergens.
P. Greenei.
P. multiplicata.
P. latiplicata.
Liorhynchus robustus.
L. Lesleyi.
Conchidium exponens.
C. scoparium.
C. obsoletum.
C. Greenei.
C. crassiplica.
C. Georgiæ.
Pentamerus oblongus, var. *Maquoketa.*
P. oblongus, var. *subrectus.*
Capellinia mira.
Barrandella Areyi.
Gypidula Romingeri.
Sieberella Roemeri.
Rensselaeria Cayuga.
R. ovatum.
Oriskania navicella.
Selenella gracilis.
Cryptonella sub lliptica.
Beecheria Davidsoni.
Dielasma obovatum.

Bryozoa.

Mr. George B. Simpson has communicated a memoir containing descriptions of the genera of the North American Palaeozoic Bryozoa, with an introduction upon the structure of living species, intended as a hand-book for the use of students, illustrated by 26 plates and numerous text illustrations.

The first portion of this work is devoted to the recent Bryozoa and contains the history of observations upon these organisms from 1599 to the present time, followed by a bibliography in which 135 titles are cited, and an illustrated detailed account of the anatomy under the headings, 1, the Cell; 2, Opercula; 3, Avicularia and Vibracula; 4, the Animal; 5, Alimentary Canal; 6, Lophophore and Tentacles; 7, Perigastric space; 8, Muscular system; 9, Nervous system; 10, Reproductive organs; 11, Embryology; 12, Statoblasts.

The second part is devoted to the fossil forms from the Palaeozoic rocks, and contains a scheme of classification, the bibliography of the Palaeozoic species of America, a list of all the genera and species described, with references to authorship and the geologic formations in which they occur. The genera described number 156 and the species enumerated are about 1,100. The main portion of this second part is devoted to diagnoses of the genera, illustrated by about 200 figures in the text and by 25 plates.

This paper was originally commenced by the writer, at the request of the Secretary of the Board of Regents, to fill the place of Bulletin No. 1 of the State Museum publications by the Regents of the University. The plan of the work, at that time proposed, was mainly a description and illustration of the Palaeozoic genera of Bryozoa which had been illustrated in volume 6 of the Palæontology of New York. This work was carried on at my personal cost nearly to completion; 22 of the proposed 24 plates having been prepared for the lithographer, with the manuscript essentially complete, but when offered to the Secretary for publication it was declined, and the matter left on my hands. The work has since been turned over to Mr. Simpson to be completed in his own way, while the generic descriptions and the explanation of plates of the original paper still remain in the writer's possession.

In completing this memoir Mr. Simpson has elaborated the work, adding thereto the discussions upon the recent Bryozoa, with full illustrations, and the entire work in its present form is communicated as a part of the report of the State Geologist.

The Palaeozoic Reticulate Sponges of the Family Dictyospongidæ.

A Family of Palaeozoic Hexactinellid Sponges, with Descriptions of the Genera and Species.

This work is a monograph of a single family of thin-walled reticulate silicious sponges whose life was restricted to Palaeozoic time. These fossils were early described as remains of marine algæ and a few species from the latter Devonian rocks became pretty well known to the collectors of New York State fossils. Their true sponge nature was recognized about fourteen years ago by Prof. R. P. Whitfield, from the study of specimens found in the soft calcareous shales of Crawfordsville, Indiana, which retained the pyritized spicular skeleton of the sponge.

In several preliminary papers published in the Annual Reports of the State Museum or of the State Geologist, beginning in 1863,* the writer has described a number of species from the Devonian and Carboniferous rocks; many of these descriptions, however, being brief and incomplete, and without illustration.

In this memoir all known species of this family from American rocks are brought together; the previously described species, forty-six in number, are re-described, and a large number of new forms are added, sufficient to make the total number of known species of this single family something more than one hundred. The work opens with a chapter on the general and spicular structure of these organisms, their relation to other sponges, their mode of growth, distribution and preservation. Following this is an extended bibliography of these fossils and the detailed descriptions of the genera and species, those of each principal geologic formation being considered by themselves.

The 108 species now known are divided among 27 genera, 16 of which are new. The paper is illustrated with many text figures showing spicular structure, and with 64 lithographic plates.

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* 1863. Sixteenth Annual Report of the State Cabinet of Natural History. Ten species were described and illustrated.

1884. Thirty-fifth Annual Report on the State Museum of Natural History. A brief description of the genera Cyathophycus, Walcott, and Dictyophyton, Ectinodictya, Lyriodictya, Thamnodictya, Phragmodictya, Cleiodictya and Physospongia, Hall, and Uphantænia, Vanuxem, were given, together with a revision of the species described in the Sixteenth Annual Report, and including those described by Professors C. D. Walcott and R. P. Whitfield, T. A. Conrad and L. Vanuxem.

1890. In the Ninth Annual Report of the State Geologist two new genera of this family, viz.: Actinodictya and Cryptodictya, together with 10 new species of this family of fossils, were described; thus making the entire number of species recognized up to that date, 46.

PALAEONTOLOGY OF NEW YORK.

VOLUME VIII, PART II.

Of the titles of works communicated in my report of last year as being then in progress, the following has been completed:

Volume VIII, Part 2, being an Introduction to the Study of the Genera of Palaeozoic Brachiopoda, has been completed and published. This volume contains 420 pages with 65 plates, and the text is illustrated by 232 wood-cuts, showing the interior structure and other characteristics of the several genera described.

Since this volume brings to a close the publication of work in this Department as a part of the series of Natural History publications of the State, I take the liberty of communicating, with this report, the preface as already published.

PREFACE.

The present volume brings to a close the publication of the "Palaeontology of New York," as a part of the "Natural History of the State of New York," according to the plan proposed and inaugurated by Governor William H. Seward during his administration, 1839–1842.

At the time of the organization of the survey the question of publication had not been seriously considered; the annual reports made to the Governor and communicated to the Legislature were necessarily published in the ordinary octavo document form.

Hon. John A. Dix, in his report preceding the organization of the Geological Survey, had stated that "it is supposed that the entire account of the survey may be contained in three octavo volumes of 700 pages each," together with an atlas, which should contain the maps, "with the necessary drawings of fossil remains." This was the only suggestion regarding the final publication of the results of the survey. In November, 1839, the Board of Geologists made a special communication to the Governor, calling his attention to several matters of interest to the

Geological Survey, and concluding as follows: "The Board would also suggest to the Governor, as matters which will soon require attention, the mode and manner in which the final reports are to be published, and the number and style of maps, geological sections and diagrams."*

At a later period it was decided that the entire work should be published in quarto form.

The order of the several departments, as set forth in the first published volume of the Natural History, was as follows: General Introduction, by William H. Seward; Part I, Zoölogy, by James E. De Kay; Part II, Botany, by John Torrey; Part III, Mineralogy, by Lewis C. Beck; Parts IV and V†, Geology and Palaeontology, by William W. Mather, Ebenezer Emmons, Lardner Vanuxem and James Hall.

Agriculture was not prominent in the original plan of the survey, and representations coming from the State Agricultural Society, in 1842, led Governor Seward to recognize its importance in this relation. He decided that Agriculture and Palaeontology should be considered as departments to be continued and completed as a part of the Natural History of the State of New York.

The Department of Agriculture was placed in charge of Dr. Ebenezer Emmons, who retained his position as State Geologist, and was also the custodian of the entire collections of the Geological Survey, which constituted the State Cabinet of Natural History; to the latter position he had been appointed by Governor Seward.

Mr. Timothy A. Conrad, who occupied the position of Palaeontologist to the Geological Survey from 1837 to 1842, had published only such preliminary annual reports as were required of each department. At the latter date (1842) so little progress had been made in the work that only a small portion of the characteristic fossils had been named or described The geologists, therefore, found it necessary to give names to most of the fossils used in illustrating their reports, these species being the more common and characteristic forms of each group of the New York geological series.

* Assembly Document 50, January, 1840.

† After 1842 the Department of Geology was designated as Part IV, Agriculture as Part V, and Palaeontology as Part VI.

In the spring of 1843 the writer was placed in charge of the Palaeontology of the State, while still retaining his position as State Geologist.* At that time there were practically no collections of fossils available for use in the work, nor appropriations of money for making such collections. There were no artists, either for original drawings or for lithography, and there was very little in the way of books on Geology and Palaeontology.

Mr. Conrad had estimated that a volume of 100 quarto plates would be required to properly illustrate the fossils of all the formations in the State of New York. After the first year of exploration by myself and personal assistants, covering the entire series, from the Potsdam sandstones to the Chemung group inclusive, it was found that no satisfactory account of the fossils of the whole series could be given in a single volume, and that it would be necessary to confine attention to those coming from the lower rocks.† From that time forward efforts were directed to the preparation of descriptions and illustrations of fossils characterizing the lower division of the "New York system," which appeared in the first volume, published in 1847, containing 362 pages and 99 plates of illustration.

In that volume due recognition was made of the sources from which material had been obtained for illustrating the work. Since that time acknowledgments have been duly expressed, not only to amateur collectors of fossils, but also to professors in colleges and scientific gentlemen generally, both within the State and beyond its borders, for their willing aid in the progress of the work. Without such aid some portions could not have been properly illustrated (as I was compelled to depend solely on my own purse for collections made in the field during the preparation of the earlier volumes). These volumes (I, II, III), therefore, present a less complete illustration of the faunas of the geological formations to which they refer, than do the later volumes, which were published after the State had furnished means for making field collections.

Volumes I and II should be revised and republished with all the added knowledge of these faunas obtained during the past third of a century.

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* See preface to Volume I, Palaeontology of New York.

† At the end of the first year (in 1844) the question of continuing the Departments of Agriculture and Palaeontology was brought before the Legislature, and an extension of time allowed for the completion of the work, but no appropriation beyond the salaries of the officials was granted.

This work, from its commencement in 1843, has been prosecuted amid many difficulties, and often under conditions which would have justified its final abandonment. These hindrances have been overcome, and a series of volumes has been published and accepted as a contribution to the scientific literature of the world.

The work in the agricultural and palaeontological departments was carried on in the old State Hall (State Cabinet of Natural History) on State street, until 1845, when the authors were compelled to remove themselves and their work from the building. This requirement proved seriously burdensome to the Palaeontologist, necessitating at once the erection of a building of moderate size with ordinary working rooms; and afterward (when the Legislature began to make appropriations for collections of fossils), two extensive buildings were found necessary; these were erected at my own cost and fitted up with about 4,000 drawers, for the proper disposition of the immense collections brought in from the field, together with rooms and conveniences for the preparation, study and arrangement of fossils, and offices for draughtsman and lithographer; and they were occupied as a museum and laboratory till the end of 1886. Prior to 1871 the Legislature made no provision for the expenses of these or any other working rooms, nor for clerk hire and incidental outlay.

From 1850 onward for several years no appropriations were made for carrying on the work, and even the author's small salary was discontinued. From 1850 to 1855 the work, except the printing and lithography, was carried on entirely at the author's personal expense, and it was abandoned early in the latter year.* Afterward, in the same year, Hon. E. W. Leaven-

* The following extract from the preface of Volume III will give a more clear idea of the then existing conditions:

"This department of the Geological Survey of the State was committed to my charge in 1843; Volume I was completed and published in 1847; and Volume II, so far as regarded my own labors, was completed in 1850, and the work of the third volume was at that time in progress. In the spring of that year legislative enactment removed the direction of this work from the Governor of the State, and placed it in the hands of the Secretary of State, who was 'authorized and directed to take charge of all matters appertaining to the prosecution and publication of the Geological Survey of the State;' and in the third section of the same law it was made 'the duty of the Secretary of State and the Secretary of the Regents of the University to report to the next Legislature a plan for the final completion of the said survey, and to submit the estimate of the cost of such completion.'

"In the report from this Commission to the Legislature a proposition was made to pay the Palaeontologist 'two thousand five hundred dollars' on the 'presentation of each successive volume, commencing with the third, to the Secretary of State;' which volume was to 'contain the manuscript letter-press ready for printing, and be accompanied with the very fossils described.'

"This 'proposition' was 'deemed *a just and liberal one*,' and it seems to have been anticipated that the work would go on under such conditions. The sum of money here proposed to be paid to defray worth, Secretary of State, undertook to re-establish the work upon a proper basis, and the author was induced, by an appeal to his patriotism, to take it again in charge. To do this he declined a position which would have insured him security of place and a life of quiet investigation in geological science. Under the new arrangement, for the first time in the history of the work, means were provided for the collection of fossils to illustrate the volumes still to be published. Because of these collections the work was necessarily much extended, and Volume V, originally planned as a single volume, including text and plates, has been expanded to four volumes. Volumes VI and VII and all subsequent work have profited by the collection of fossils made from 1856 to 1865 inclusive, when appropriations for such collections ceased.

This final volume (VIII, Part II, Brachiopoda), after being held back for one year through want of an appropriation, was printed to page 317 in the autumn of 1893. At that point the printing was again suspended. In order to have a record of the date of the completed work there was issued, in July, 1893, a fascicle containing the text, from page 1 to 176; embracing descriptions of the spire-bearing genera; and a second fascicle in December, 1893, carrying the text to page 317, including descriptions of the rhynchonelloids, pentameroids and terebratuloids. At that time the concluding chapter or summary was in type, but the appropriation having been exhausted the printer was compelled to sus-

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the entire expense of collecting the fossils and the study and description of the same, together with the labor of superintending the drawings and engraving, was in fact entirely inadequate to pay for the collection of the fossils necessary for a single volume, and left, besides this, more than four years of labor to be performed by the Palaeontologist without any remuneration whatever. Under these circumstances the work could not go on, and it became by this act virtually suspended in the early part of 1850.

"From the commencement of the work the expenses of making the collections had been borne by myself. These collections, made up to that time, not only embraced most of those of the first and second volumes, but the greater part of the third volume, as well as extensive collections in the higher rocks of the New York series for the succeeding volume. Besides these I had made large collections of fossils in the same series of strata in the West, for the purpose of comparison with the New York species. In this way, as well as in examinations of the rock formations *in situ* over a large part of the Western States, for the purpose of determining the parallelism of the formations, I had already made great pecuniary sacrifices in carrying on the work. Under these circumstances, therefore, and with the new aspect presented by the law of 1850, and the action of the Commission relative thereto, I could no longer devote myself to its prosecution, and consequently made other arrangements for the occupation of my time, which, however, left me still some opportunity to continue my investigations in this work. As the contracts between the State and the engravers continued in force, the engraving, after 1851, was carried on somewhat slowly; my frequent and protracted absence rendering it impossible for me to give that personal attention to it which a work of this kind so fully demands. In order to prevent its entire cessation I employed a person as an assistant (who afterward became my draughtsman); the lithographer volunteering to contribute to pay a portion of the expense of such assistant, that his own work might not cease entirely. In this way the work was continued till 1855, no compensation whatever being paid to the author during this period."

pend all work upon the volume; so that this chapter, bringing the text up to 350 pages, together with accompanying and concluding matter, was laid over to the present year.

In the original scheme of the work on the Brachiopoda the generic descriptions were to be accompanied with illustrations of the microscopic structure of the shell, but it was found inconvenient to accomplish this plan during its progress; though a large number of sections were prepared for microscopic study. This part of the work is postponed for the present, and probably will not be taken up again by the writer.

The great length of time since these studies were resumed in 1888 has enabled those assistants who were with me in the earlier preparation of the work to advance their investigations in the same line of concept, and to anticipate some of the results which have been reached in these volumes. While the final result in this direction is still distant, it is encouraging to see the work advancing in what the writer believes to be the only true method of studying every class of organisms.

In the preface to Part I of Volume VIII the author made acknowledgments to many personal friends, to collectors of fossils, to museums and geological surveys; he wishes to repeat these acknowledgments in the preface to Part II, since this will probably be his last opportunity of connecting their names with the progress of the "Palaeontology of New York."

During the 51 years which have elapsed since the commencement of this work, I have had many assistants who directly or indirectly have aided in, or have contributed to, its progress. Among the earliest of these was Mr. Fielding B. Meek (afterward Palaeontologist to the United States Geological Survey of the Territories), whose services were largely given to the drawings for the plates of Volume III, which were lithographed by Mr. Frederick J. Swinton, the latter continuing his connection with the work till 1872, enriching the volumes by his excellent artistic work. During the early part of the same period Mr. Ferdinand V. Hayden, who subsequently became Director of the U. S. Geological Survey, was my assistant, and, together with Mr. Meek, made a survey of the Mauvaises Terres of Nebraska, at my personal expense. Dr. Charles A. White, now of the National Museum at Washington, who had been my assistant in the Iowa Survey, was, for one year, engaged in the service of the Palaeontology of New York, in making field collections and obtaining geological data. Mr. Robert P. Whitfield, now Curator of Geology in the American Museum of Natural History, was associated with me as preparateur, draughtsman and general assistant in the work for 20 years (1856 to 1876). After this date Mr. Charles D. Walcott, now Director of the U. S. Geological Survey, became my assistant for two years. In the final revision and publication of the four volumes, which constitute Volume V, I had the assistance of Mr. Charles E. Beecher, now professor in Yale University, from the commencement of the Cephalopoda to the completion of the Lamellibranchiata, from 1878 to 1885. Mr. George B. Simpson, who has served the work for many years as draughtsman, has made himself very familiar with the Bryozoa and Corals of our geological formations, and has given very essential aid in the preparation and publication of Volume VI, as well as in other work connected with the Palaeontology. In the capacity of my private assistant, the services of Mr. Charles Schuchert, now of the U. S. National Museum, were given to the forwarding of Volume VIII, as already stated in the Preface to Part I. Professor J. M. Clarke, who came into the work in 1886, has given essential aid in the preparation of Volumes VII and VIII, as already related in the former volume, and also in Part I of the present volume, and has remained with me to its conclusion.

From the beginning of the work it has been the ambition of the author to secure accurate and artistic illustrations of the subjects under discussion. In the earlier part of the work these conditions could not be obtained, but in later years the style and accuracy of the representations has left little to be desired. In the preface to Part I of this volume, I made acknowledgments to the draughtsmen and lithographers who have been engaged upon this work. The original drawings have been continued by Mr. Ebenezer Emmons and Mr. George B. Simpson, and the lithography by Mr. Philip Ast, who have attained a degree of perfection in their work of which it is my duty as well as my pleasure to speak in praise. My thanks are due to the printers, Messrs. Charles Van Benthuysen & Sons, now the veteran printing house of the country, with an uninterrupted intercourse to the fourth generation; covering a period of more than 50 years.

To the many successive Legislatures of the State of New York, as well as to the Chief Executives, the scientific public is indebted for the volumes which have been published under the title of Palaeontology of New York. In every Legislature the author has found gentlemen who were interested in science, and who were in sympathy with this work. Not only among members of the Legislature but among those who had previously held legislative and executive offices, as well as other prominent citizens of the State, the work has found encouragement and support. The people of the State may have the satisfaction of knowing that no other State Legislature has sustained, through so many years, a scientific investigation carried on for the sake of science itself, and without anticipating direct economic results. For all this good will and liberality to science, the writer desires to express, for himself and his scientific co-laborers, the most profound acknowledgments.

JAMES HALL,
State Geologist and Palaeontologist.

ALBANY, N. Y., *December* 5, 1894.

It is a great satisfaction to the author to report this work executed according to the plan originally conceived, but which is nevertheless incomplete owing to the large amount of material which time and experience has accumulated, and which, at the outset, could not have been anticipated or included in any plan. The completion of this volume will still leave a large amount of material in other departments than those already discussed and published, and it is proposed to publish the results of the investigation in the annual reports, or as memoirs, in such manner as may be considered most desirable. As an earnest of such work to be continued in the future a memoir upon the reticulate fossil sponges, as already stated, is in a forward state of preparation, and more than 20 imperial quarto plates have been lithographed, still leaving more than 30 plates to be done. The manuscript is in an advanced condition and can be put to press during the present year. After the Dictyospongidæ the most important subject for consideration and publication is that of the fossil Corals from the several geologic formations, and especially of the Devonian, of which New York affords a remarkable development and an abundance of species in the great limestone formations extending from the Hudson to the Niagara rivers. Although work upon these fossils has been suspended from 1881 to the present time, it is still the hope of the writer that some plan may be adopted by which these interesting and important fossils may be published for the benefit of science, for the scientific prestige of the State of New York, and as a contribution toward the completion of the publications of the natural history of the State, which now number 30 quarto volumes.

Very respectfully,

Your obedient servant,

JAMES HALL,

State Geologist and Palaeontologist.

March 5th, 1896.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGIC MAP.)

A PRELIMINARY DESCRIPTION

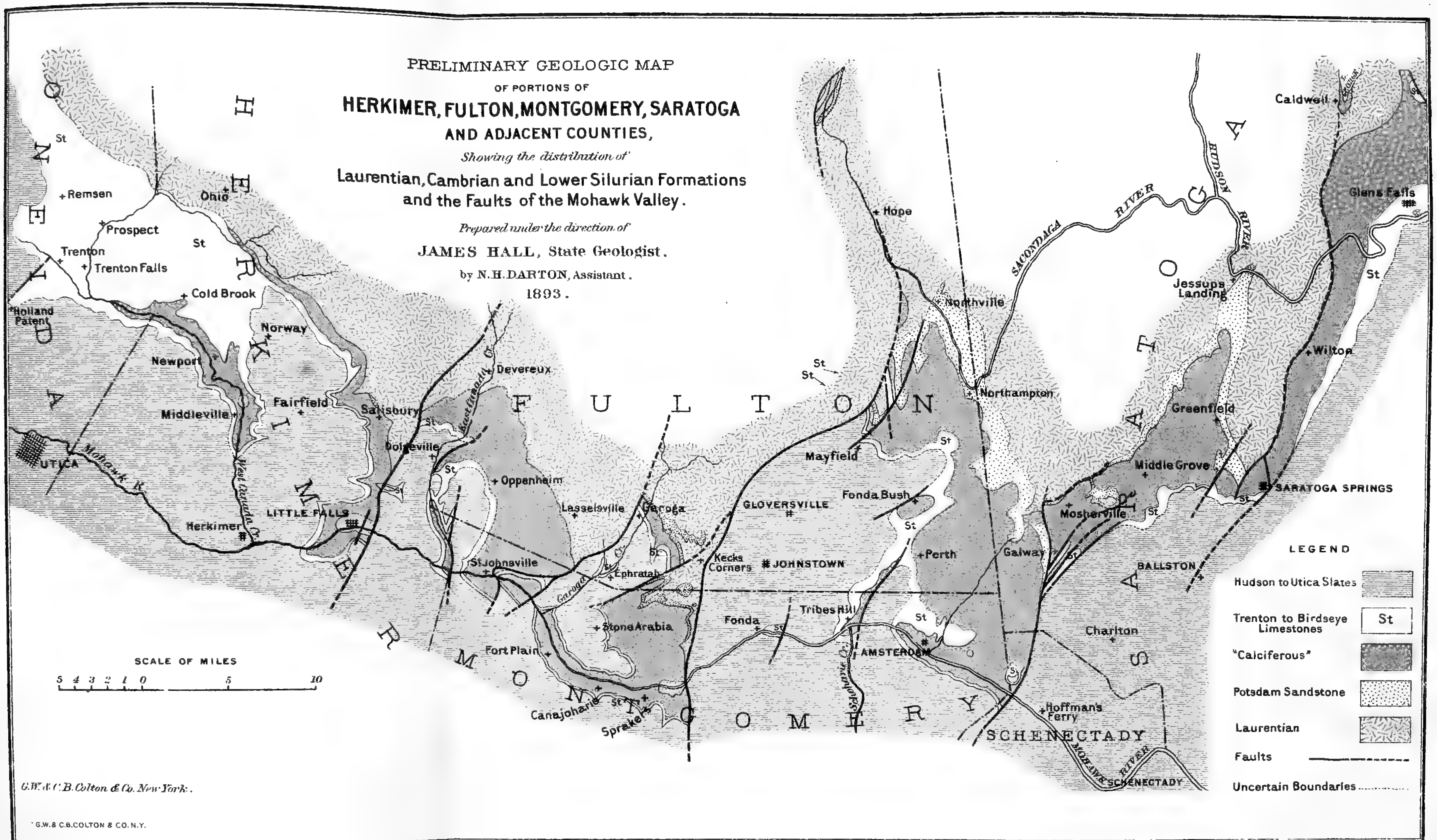
OF THE

Faulted Region of Herkimer, Fulton, Montgomery and Saratoga Counties.

JAMES HALL,
STATE GEOLOGIST.

N. H. DARTON,
ASSISTANT.

1896.


PRELIMINARY GEOLOGIC MAP
OF PORTIONS OF
HERKIMER, FULTON, MONTGOMERY, SARATOGA
AND ADJACENT COUNTIES,
Showing the distribution of
Laurentian, Cambrian and Lower Silurian Formations
and the Faults of the Mohawk Valley.
Prepared under the direction of
JAMES HALL, State Geologist.
by N. H. DARTON, Assistant.
1893.
LEGEND
Hudson to Utica Slates
Trenton to Birdseye Limestones
St
"Calciferous"
Potsdam Sandstone
Laurentian
Faults
Uncertain Boundaries
SCALE OF MILES
5 4 3 2 1 0 5 10
ONEIDA
HERKIMER
FULTON
MONTGOMERY
SARATOGA
SCHENECTADY
Remsen
Ohio
Prospect
Trenton
Trenton Falls
Cold Brook
Holland Patent
Norway
Newport
Middleville
Fairfield
Salisbury
Devereux
Dolgeville
UTICA
Mohawk R.
West Canada Cr.
LITTLE FALLS
Herkimer
Oppenheim
Lasselsville
Garoga
St Johnsville
Ephratah
Stone Arabia
Fort Plain
Canajoharie
Sprakers
Kecks Corners
JOHNSTOWN
GLOVERSVILLE
Mayfield
Fonda Bush
Perth
Fonda
Tribes Hill
AMSTERDAM
Hope
Northville
Northampton
SACONDAGA RIVER
HUDSON RIVER
Caldwell
Glens Falls
Jessups Landing
Wilton
Greenfield
Middle Grove
SARATOGA SPRINGS
Mosherville
Galway
BALLSTON
Charlton
Hoffman's Ferry
MOHAWK RIVER
SCHENECTADY
G. W. & C. B. Colton & Co. New York.
G.W. & C.B. COLTON & CO. N.Y.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGIC MAP.)

A Preliminary Description of the Faulted Region of Herkimer, Fulton, Montgomery and Saratoga Counties.

BY N. H. DARTON.

CONTENTS:

Introductory.

This report is an account of studies made during the summer of 1893 of the relations of the faulted Lower Silurian and Cambrian members in eastern Central New York. The primary purpose of the work was to determine the distribution of the formations for the recently published geologic map of the State, but data were also obtained bearing on the relations of the faults, and the stratigraphy.

The principal faults cross the Mohawk river between Schenectady and Little Falls. These faults appear first in the Utica slate at no great distance south of the river and extend northward with a gradually increasing throw, bringing up the Trenton, Calciferous and crystalline rocks. Several of them continue into the Adirondacks.

Vanuxem* described the principal features of the faults in the immediate vicinity of the Mohawk river, but gave little information regarding their northern extension. On the New York geologic map of 1842, some of the more general effects of these faults are represented, but their nature was not indicated Some further light was thrown on the relations along the Mohawk

* Geology of New York, Part III, comprising the Survey of the Third Geological District, 1842.

river in a brief report and map by Mr. C. E. Hall, published in 1886.*

Besides the faults which extend to the Mohawk, there are a number of others northward, of which several are important, and there is a series of prominent dislocations in Saratoga county. It has been known for many years that the springs at Saratoga rise along a fault plane, and some features at this locality were described by Mather† and Emmons.‡

General Relations.

The sedimentary formations of the region are a succession of sandstones, limestones and shales lying,§ on a floor of crystalline rocks. They dip to the southward and southwestward at a very moderate rate, constituting a general monocline. The amount and direction of the dip is not uniform, but the variations do not materially affect the general relations. The faults traverse this general monocline and give rise to wide offsets in its regularity, and local tilting of greater or less amount. Adjacent to the fault planes there are also certain features of local disturbance, such as upturning of the beds on the down-thrown sides. The distribution and relations of these faults are indicated in the map and in plates 2 and 3. In plate 2 I have attempted to represent the relative positions of the fault blocks restored or bared at the ideal surface of the Trenton limestone. In A and B, plate 3, cross-sections are given, indicating the principal features along the Mohawk Valley and along a zone about eight miles north, respectively. From these illustrations it will be seen that the faulting seems to have taken place along vertical planes, and to have been accompanied by a sharp drag of the strata on the down-thrown side of the blocks. In the following pages the evidence on this point will be given in detail, with a description of the features of the several faults.

The occurrence of crystalline rock at Middleville has given rise to a supposition that there is a fault at this locality. Owing to the existence of this view I have made a careful examination

* Field notes on the Geology of the Mohawk Valley, Fifth Report of the State Geologist for 1885, pp. 8-10. (See note at end of this paper.)

† Geology of New York, Part I. Comprising the Geology of the First Geological District, 1843.

‡ Agriculture of New York, by Ebenezer Emmons, 1846.

§ A description of these formations was published in the Report of the State Geologist for the year 1893, pp 409-429, plates 1-14. Albany, 1894.

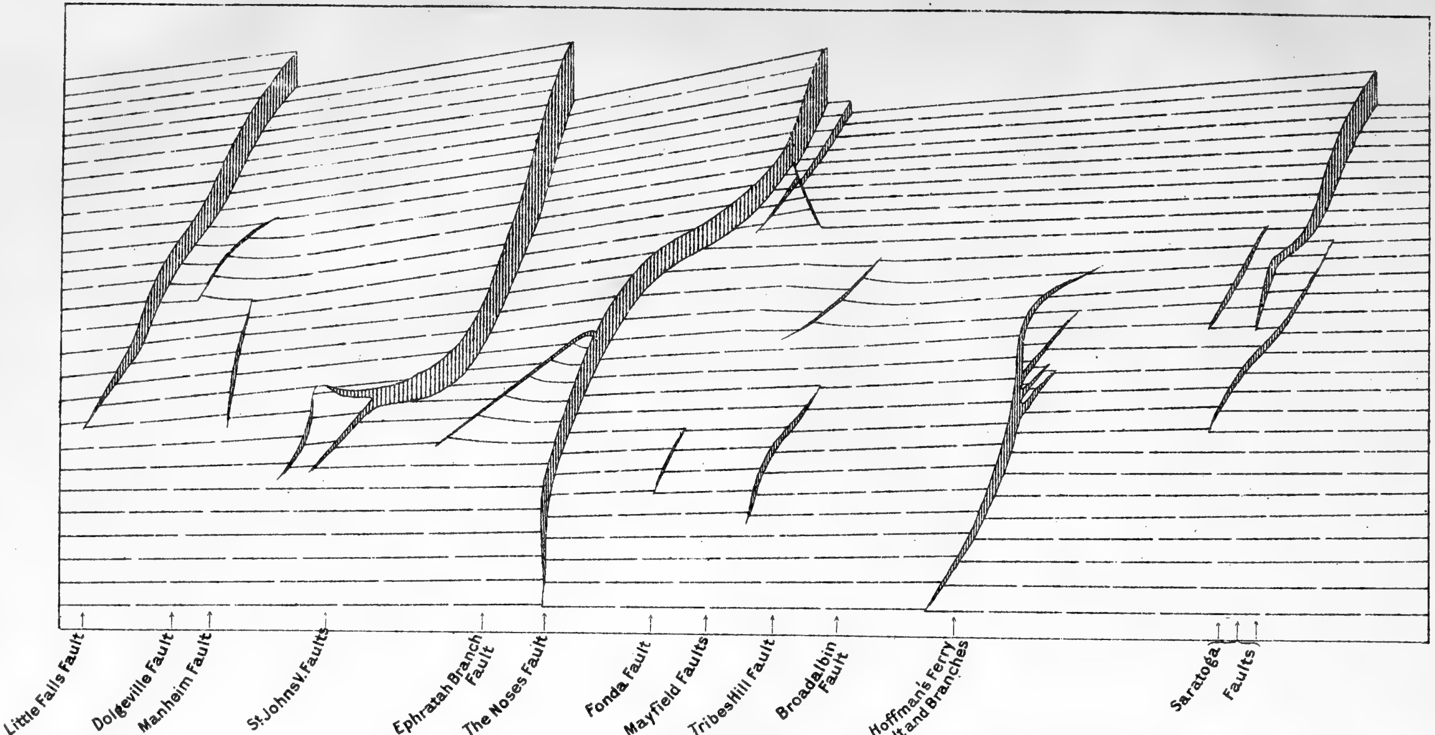


DIAGRAM OF FAULTED AND TILTED BLOCKS IN FULTON, MONTGOMERY, HERKIMER AND SARATOGA COUNTIES, N.Y.
LOOKING NORTH, VERTICAL SCALE GREATLY EXAGGERATED.

G.W. & C.B. COLTON & CO. N.Y.

of the relations, and find that no fault exists. The overlying formations are continuous around the valley, and they are exposed in many outcrops. The supposition that there is a fault at this point may be due to the fact that in the bank along the east side of the stream there are clays containing a very large amount of Utica slate *débris* which might be mistaken, on casual observation, for Utica formation in place. At a short distance east, however, there are continuous vertical outcrops from the Calciferous to Utica beds, matching those on the west side of the valley. The presence of the small inclosed area of crystalline rocks is due to a slight anticlinal in this vicinity, which has brought the crystalline rocks within reach of the creek for a few hundred yards. Down stream the southwesterly dips carry the formations beneath the surface in regular succession. To the northwestward there is first a slight downward slope in the strata and in the underlying surface of the crystalline rocks, beyond which the stream runs along the strike, so that in ascending the valley we finally rise high into the Trenton formation at Trenton Falls.

Faults.

The Little Falls Faults.—The nature of the uplift at Little Falls is shown in the following figure.

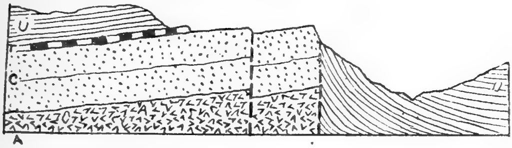


Figure 1.—Cross section of faults at Little Falls, N. Y., north side of the Mohawk, looking north. *U.* Utica slate. *T.* Trenton and Birdseye limestones. *C.* Calciferous sandrock. *A.* Archean. Vertical scale somewhat exaggerated.

This uplift gives rise to the most conspicuous topographic feature of the Mohawk Valley. Approaching Little Falls from the east the long gentle slopes of the hills of Utica slate are abruptly terminated by a high ridge crossing the valley from south to north. The river cuts through this ridge in a deep, relatively narrow gorge, lined with high cliffs of Calciferous sandrock and crystalline rocks. In the eastern end of the gorge the crystalline rocks rise in cliffs 100 feet high, to a high terrace surmounted a short distance back by cliffs of Calciferous sandrock 200 feet high. This formation constitutes another terrace surmounted in turn by a low terrace of Trenton and Birdseye limestones and rounded slopes of Utica slate. These terraces all slope southwestward with the dip of the formations and merge in succession into the bottom of the valley above Little Falls. The terrace on the surface of the crystalline rocks is wider on the north side than on the south side of the gorge, and it is on this wider terrace that the village of Little Falls is built; about midway through the gorge. The following section is through the central portion of the village, and illustrates the relations of the terraces, although they are here somewhat diminished in altitude above the river. In figure 3 they are shown in their maximum altitude.

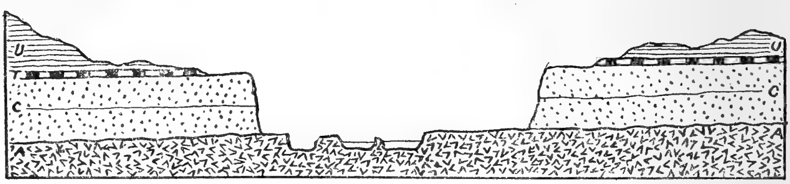


FIGURE 2.— Sections across the gorge of the Mohawk at Little Falls, N. Y., looking westward. *U.* Utica slate. *T.* Trenton and Birdseye limetones. *C.* Calciferous. *A.* Archean. Vertical scale somewhat exaggerated.

About two miles above Little Falls the Calciferous terrace and cliff gradually disappear beneath the river, the valley widens and the slopes of Utica slate extend to its bottom. The relations along the fault plane are shown in figure 3.

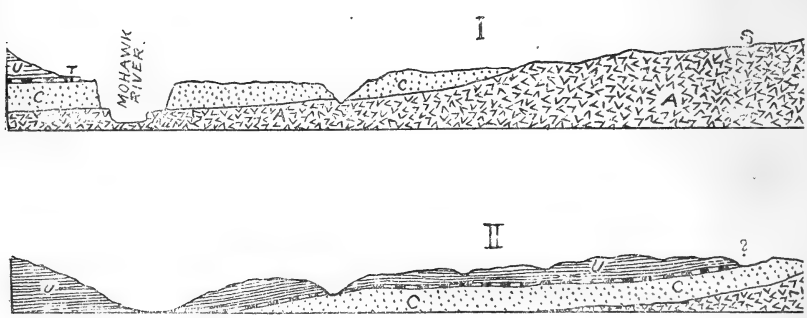
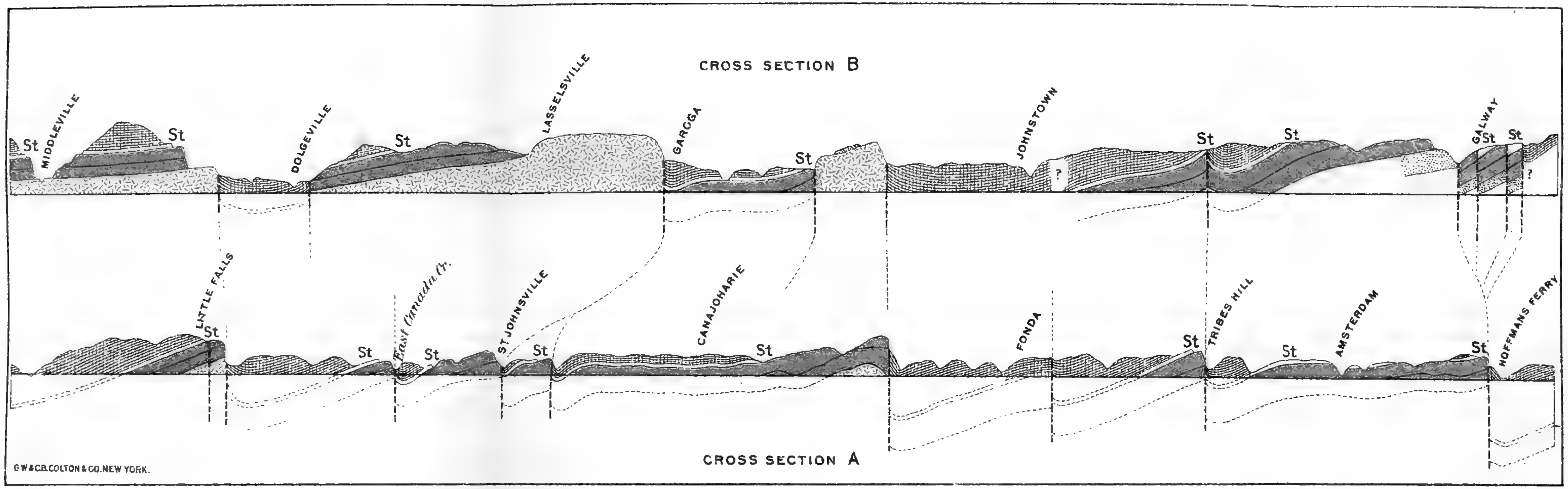


FIGURE 3.— Sections along the fault plane from southeast of Little Falls to north of Salisbury Centre. *U.* Utica slate. *T.* Trenton and Birdseye limestones. *C.* Calciferous. *A.* Archean. *S.* Salisbury Centre. *I.* Eastern face of uplifted block. *II.* Western face of downthrown block from the east. Vertical scales somewhat exaggerated.



CROSS SECTIONS OF FAULTS OF HERKIMER, FULTON, MONTGOMERY AND SARATOGA COUNTIES

Looking North, A. along the Mohawk River: B. along a zone from 8 to 10 miles north of A.

Horizontal Scale about five miles to an inch; Vertical Scale greatly exaggerated

Utica Slate | Trenton to Birdseye Limestones (St) | Calciferous | Potsdam Sandstone | Laurentian | Faults ------

At the eastern entrance of the Little Falls gorge the crystalline rocks and overlying Calciferous sandrock present a precipitous front to the eastward. In a short distance to the south and to the north this front becomes flanked by slopes of Utica slate which rapidly rise to above the level of the upper surface of the crystalline rocks. A short distance south of the river the Calciferous and Trenton dip beneath the Utica slate and the fault is lost in the high hills of the Hudson river formation to the southward.

The actual fault plane is obscurely exposed at several points on the north side of the river and if not vertical it is very nearly so. The shales in the adjoining slopes are bent up against the fault at angles from 40°–70°, averaging 60° in greater part. This steep eastward dip rapidly decreases to the east, and in exposures a half mile below the mouth of the gorge a gentle southwest dip is observed at several points near the river.

Northward from the river valley the presence of the fault is marked by a cliff of Calciferous, rising to greater or less height above the rounded hills of the Utica slate region eastward.

Three miles north of the Mohawk the fault is crossed by a small depression which cuts through the Calciferous and a short distance into the crystalline rocks on the west side of the fault, and through Utica, Trenton and Birdseye beds to the top of the Calciferous on the east side. The relations at this point are shown in longitudinal section in figure 3. The upturn of the beds here is very moderate as the dips are not over 6°. The actual fault plane is not exposed but there are outcrops within a yard or two of it. At Little Falls there are no means for estimating the amount of the uplift for we do not know the thickness of strata lying against the thrown side of the fault. At this locality the presence of the Trenton on both sides, and the moderate dips, afford all necessary data. An estimate made from fairly accordant aneroid readings with the estimated allowance for dip, gave an average of 310 feet.

On the north side of this depression the Utica slate lies against the fault, with the usual cliff of Calciferous on the west side of the uplift. A short distance west of the crest of the cliff are the low terraces of Trenton limestone surmounted by rounded hills of Utica slate. A mile and a half farther north the fault has increased considerably in amount and the crystalline rocks are brought up. Thence northward they constitute the cliff along the fault scarp and the Calciferous and Trenton extend to the northwestward by Salisbury Village and Diamond hill as terraces surmounted by high hills of Utica slate.

A typical section of the relations near the point at which the scarp of crystalline rocks begins is shown in figure B, plate 3. Farther northward the crystalline terrace widens greatly and increases in height. The fault plane was not observed in this region, but its presence is everywhere characterized by cliffs and steep slopes of crystalline rocks over which, at Salisbury Center, a branch of East Canada creek falls in a series of cascades aggregating nearly a hundred feet in descent. The adjoining Utica shales are seen at several points west of Dolgeville within fifty yards of the fault, dipping to the eastward from 10° to 30°. Just north of Salisbury Center the northward pitch of the monocline east of the fault brings up the crystalline rocks as shown in II in figure 3, and northward the fault is entirely in crystalline rocks. I followed it to a short distance above Devereux where its presence is marked by a continuous line of cliffs and steeper slopes.

Faults on East Canada Creek.— There are two faults on and near East Canada creek, and although their throws are not great nor the effects particularly conspicuous, their features are so clearly exposed that they are of special interest. They were both described in considerable detail by Vanuxem in his report on the Third Geological District.

The southernmost fault crosses the Mohawk river at the mouth of East Canada creek as shown in plate 2. On the north side of the river there are, on the east bank of the East Canada creek, nearly horizontal beds of Utica slate, and the west bank is a cliff of Calciferous. On the south side of the river the Utica slate on the thrown side of the fault abuts against Birdseye limestone. A short distance south, the Birdseye and Trenton limestones pass beneath the Utica slate and the fault is lost in the hills near Minden. The fault extends up East Canada creek for about a mile when its trend changes to a course slightly more eastward and it passes into the eastern bank of the creek. Here the fault plane is superbly exposed at the foot of a long series of rapids and falls over the Calciferous which the fault has brought up. In plate 4 the character of the exposure and some of the relations are shown. In the following figure an explanatory diagram is given.

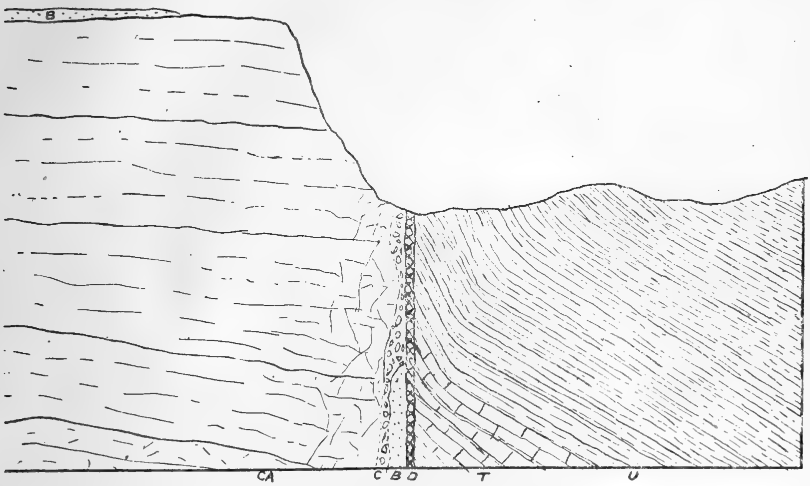


FIGURE 4.— Diagram of fault phenomena and dike shown in plate 4. East Canada creek, N. Y., looking north-northeast. *U.* Utica slate. *T.* Trenton limestone. *D.* Dike. *B.* Birdseye limestone. *C.* Breccia. *CA.* Calciferous.

In these illustrations there should be noted the vertical fault plane, the presence of the dike along the fault plane, the typical unbending of the Utica slates and Trenton beds against the fault, and the breccia which includes a large fragment of Birdseye limestone.

The Calciferous wall on the west side of the dike is considerably fractured and the general southerly dip of the formation, in the fine series of exposures up the creek, gives place to gentle undulations shown in part in plate 4. The breccia comprises angular fragments of Calciferous sandrock (some but slightly out of place) and of Birdseye limestone, in a matrix of sand from the Calciferous beds. The thickness of this breccia varies from three to eight inches. The relations of the large fragment of Birdseye limestone are not clearly exposed, but it appears to be in the breccia and not in regular sequence with the Trenton beds cut off by the dike.

The dike was recently described by C.H. Smyth,* who incidentally refers to some of its relations. Its thickness in this exposure is from eight to ten inches, and it is accompanied by a thin adjoining vein of calcite, carrying pyrite and galena. An adit was run in on the vein some years ago in the hope that it might be found metalliferous, and, according to Smyth, it was found that the dike ends at about sixty feet. Its extension along the surface southward was not found owing to drift and débris. The rock is described by Smyth, and in a supplemental paper† is stated to be alnoite, containing the rare mineral melilite in considerable amount.

The amount of displacement of the fault is about sixty feet, not counting the upturn of the beds on the downthrown side. This upturn extends for about 100 yards from the fault and gradually gives place to gentle southwest dips. The Trenton limestone exposed is nine feet in thickness, in layers three to eight inches thick. It is abruptly terminated by Utica slate beds with a six-inch layer at their base. In its extension northward, the fault diverges from the creek at a small angle and appears to be lost in Utica slates in the hills west of Crumb creek, but owing to heavy drift cover, it could not be followed any great distance.

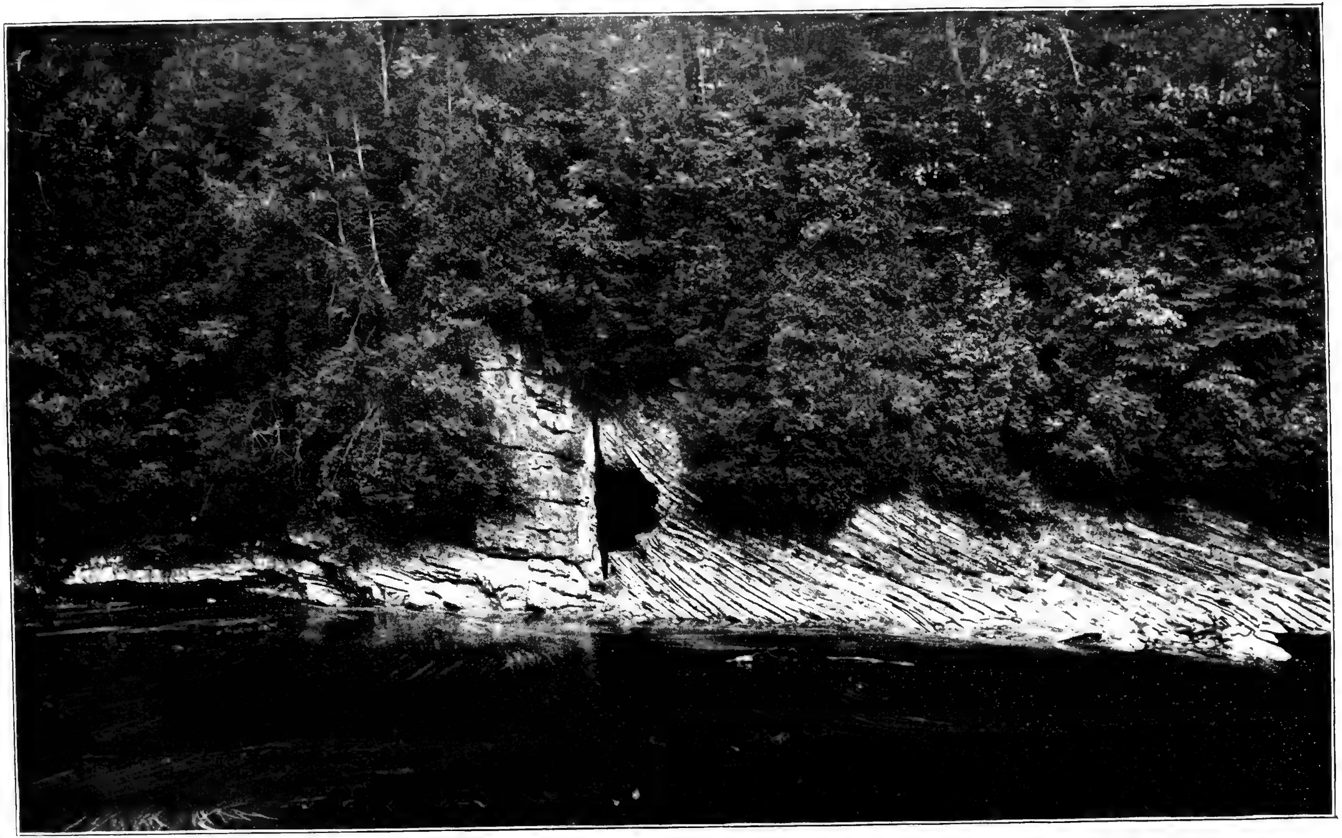
Ascending the creek above the fault, there is the fine series of exposures of Calciferous shown in plate 8, with others extending to Ingham's Mills, all dipping gently southwestward. Above the mills the Birdseye, Trenton and Utica formations extend across the creek in succession. Half way between Ingham's Mills and Dolgeville, the dips suddenly change to northeast, and increasing rapidly in amount, bring up the Trenton, Birdseye and Calciferous beds in succession on the east bank of the creek; a fault also developing which increases rapidly northward. This fault is shown on plate 2.

In the following figure the four sections illustrate the development and relations of this uplift. It will be noted that this fault differs from the two others described, in having the uplift on the eastern side. The upturned Utica slates are finely exposed along the high eastern bank of the creek to the high falls below Dolgeville. North of the falls there is a low cliff of Calciferous which

* Am. Journ. Sci., 3d Series, vol. 43, pp. 322-327.

† Am. Journ. Sci., 3d Series, vol. 46, p. 104.

PLATE 4.



Fault and dike at old adit in east bank of East Canada Creek near Manheim, New York. Utica and Trenton beds on the right, Calciferous sandrock on the left.

may be traced for a short distance, but the relations east and north from Dolgeville are hidden under a wide area of heavy drift cover.

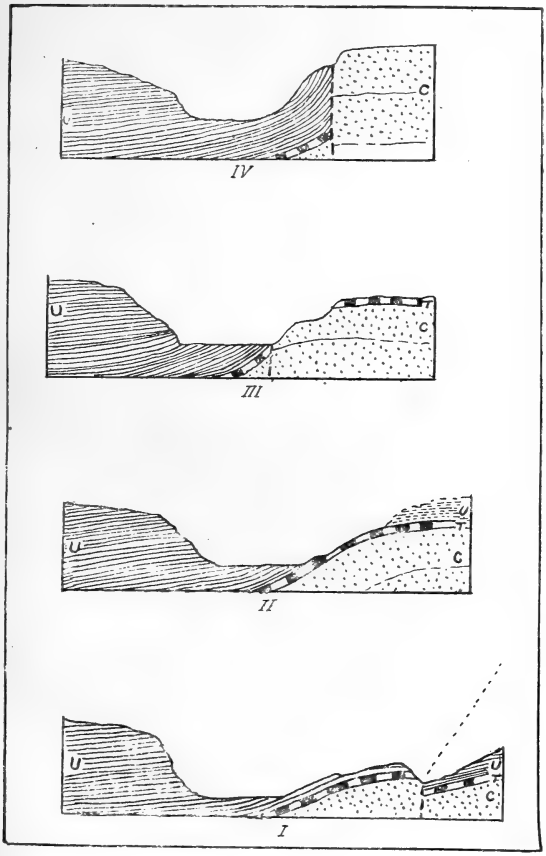


FIGURE 5.— Cross sections along East Canada creek, below Dolgeville. *U.* Utica slate. *T.* Trenton and Birdseye limestones. *C.* Calciferous.

St. Johnsville Faults.— Vanuxem described some features of the St. Johnsville region and recognized two, if not more, series of uplifts, but stated that there was considerable obscurity in their relations which he had not had time to unravel. It appears that there is one fault which branches and curves in an unique manner for a dislocation that is apparently not due to overthrust. The relations are fairly well exposed, and I believe the true nature of the dislocation is shown in plate 2.

The relations of the fault which branches to the southward, are plainly exhibited particularly along the road and in quarries three miles east of St. Johnsville, and also in the slopes and in an old quarry south of the river. This dislocation brings the middle beds of the Calciferous up to a horizon about 100 feet above the base of the Utica slate.

The Utica slate east of the fault dips eastward at angles averaging about 20°, but this upturn dies out rapidly in a few rods. The river valley is cut across the eroded block into the Calciferous with Trenton and Birdseye beds lying on the higher terraces, and the Utica slate above. Along a portion of the north side of the block the latter has been removed and the Trenton and Birdseye beds abut against the Calciferous along the main fault. The following section illustrates the relation of this inclosed block:

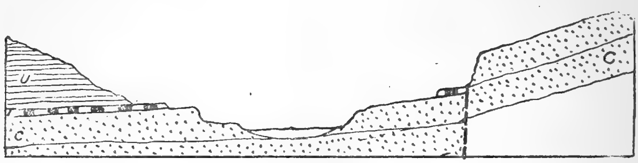
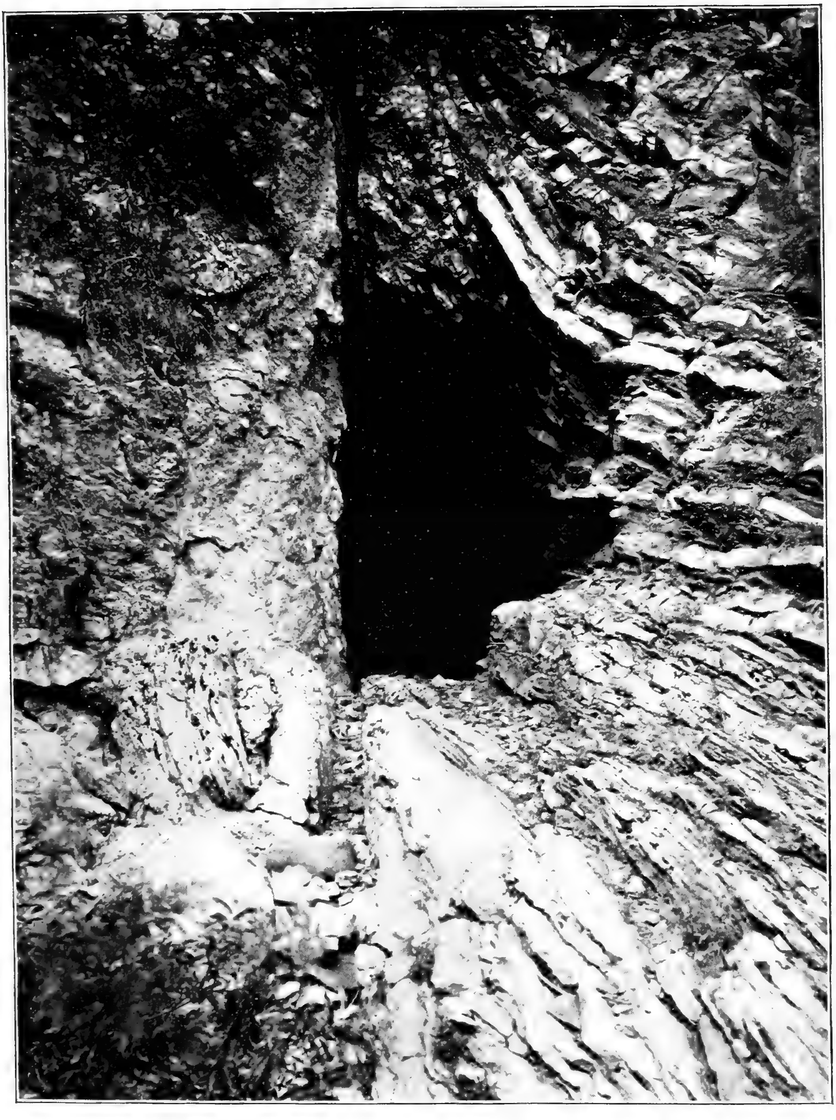


FIGURE 6.— Section across the Mohawk river, two miles below St. Johnsville, looking west. *U.* Utica slate. *T.* Trenton and Birdseye limetones. *C.* Calciferous. Vertical scale slightly exaggerated.

The beds in the inclosed block dip westerly, and at St. Johnsville the Utica slates come in and underlie the upper portion of the village. These slates are penetrated by a well at the condensed milk factory on Zimmerman's creek, and according to Vanuxem they were once exposed, together with upturned edges of Trenton and Birdseye limestones, in the creek, near the side of this factory. The Calciferous rises abruptly in cliffs just beyond and curves around to the west and south on the upthrown side of the fault. Vanuxem states that "the slate was also exposed at the little bridge near by, in the bottom of the creek, inclining away from the Calciferous, which rises 100 feet above it. The slate dips to the south at an angle of about 45°. It shows much white carbonate of lime and some pyrites. The Calciferous at its junction with the slate is in one part fractured, the parts cemented forming a breccia."* Below this are heavy

* Geology of New York, Part III, comprising the survey of the Third Geological District, 1842, p. 206.

PLATE 5.



Fault and dike at old adit in east bank of East Canada Creek near Manheim, New York; near View.

beds of clay and boulders. This exposure is now covered and is no longer accessible. The course of this main fault is very clear nearly to the point at which it bends to the southeast to cross the Mohawk, where it is covered by drift. The relations in this vicinity, so far as known, are shown in the following section which crosses the loop in the main fault.

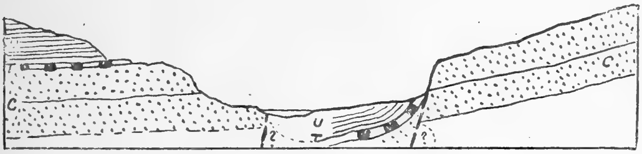


FIGURE 7.— Section across the Mohawk just above St. Johnsville, N. Y., looking west. *U.* Utica slate. *T.* Trenton and Birdseye limestones. *C.* Calciferous.

The relations of the recurved portion of the fault on the south side of the river are clearly exhibited in every detail. The fault plane is not exposed, but the Utica slate and Calciferous are seen within a few feet of each other in the west bank of a small brook, and the course of the fault is seen to be due north-northeast down to the mouth of this brooklet. The slate is tilted back to the eastward in the usual manner, for several rods from the fault. The Trenton and Birdseye limestones on the uplifted side dip to the southwest, which carries them from an altitude of 150 feet above the river near the fault to below the river a short distance east of the East Canada creek fault. Both the main and branch faults are lost in the high region of Utica slate a short distance south of the crest of the southern bank of the Mohawk

To the northward, the principal fault increases in amount and brings up the crystalline rocks in an area which widens and rises rapidly in the next few miles. Along by Garoga the scarp of crystalline rocks is very high and precipitous. The Utica slate east of the fault underlies the depression eastward. North of Rockwood the crystalline rocks come up on the east side of the fault. North of this vicinity the fault was not traced, but it probably extends far into the Adirondacks.

The "Noses" Fault.— This great uplift crosses the Mohawk river five miles below Canajoharie. It is very similar to that of Little Falls, giving rise to a great ridge of Calciferous, rising abruptly from the moderately elevated Utica slate region eastward.

Through this ridge the river has cut a narrow gorge with high walls of Calciferous, which are seen to be underlain for a short distance by crystalline rocks. The river winds slightly in the eastern portion of this gorge, and the short, sharp spurs of the high cliffs have given rise to the appellation of the "Noses," which is well known to travelers along the Mohawk as a particularly wild and picturesque part of the valley. This dislocation is shown in plate 2. The fault is not so great in amount as that of Little Falls, and the crystalline rocks are not so extensively exposed, but owing to oscillations in dip, the walls of Calciferous extend much farther up the river. The Trenton and Utica formations extend continuously along the south side of the gorge, beginning in an upper terrace lying a short distance back from the crest of the Calciferous cliff. On the nort side of the river these formations extend to nearly opposite Spraker's Basin, below which the Calciferous extends widely to the north, and eastward to the fault, where it ends in a prominent scarp. This scarp is elevated high above the rolling surface of the Utica slate region eastward. The crystalline rocks at the "Noses" on the Mohawk do not extend quite to the fault, but, as shown in section A, plate 2, rise in a low anticline just west, to an extent of about forty feet above the river on the south side, and seventy-five feet on the north side. Possibly in the river trough, where the Calciferous is deeply eroded, the crystalline rocks may extend to the fault.

South from the river the relations of the fault are well exposed on the road to Currytown, which crosses it three times. The Calciferous rises as a wall or steep slope, with the Utica slates abutting against it and dipping away at angles, for the most part averaging 50°. This dip rapidly decreases eastward and finally gives place to the gentler general southwesterly inclination. The essentially vertical position of the fault plane is clearly exhibited between Currytown and the river, not only in many small exposures of a perpendicular fault scarp but in its straight course up the long slope, aggregating over 200 feet in ascent. Half a mile north of Currytown the Trenton and Birdseye limestones are seen overlying the Calciferous and, in a short distance up the slope, the Trenton limestone passes beneath the Utica slates. The Calciferous along the fault is often considerably broken and crushed. Its usual dip at and near the Mohawk is gently to the east; near Currytown it is west, for the most part gently, but at one point 40°. The amount of dislocation along the fault is about 300 feet at the Mohawk river.

North from the river the great scarp to which this fault gives rise extends for many miles as a high wall along the west side of the great Utica slate area of Johnstown and Gloversville. For the first six miles this wall consists of the Calciferous sandrock with underlying crystalline rocks occasionally exposed where brooklets cut into the Utica slates. With the general upward pitch to the north and some increase in the throw of the fault, the surface of the crystalline rocks gradually increases in altitude, and southwest of Johnstown it extends to the crest of the fault scarp. The Calciferous then trends off to the west as a terrace and the crystalline rock area expands into a wide high plateau capped by a few small outliers of Potsdam sandstone. The Utica slates lying to the east of the fault are exposed at many points with the usual sharp dip to the eastward in the immediate proximity of the fault plane. On the turnpike, at a point about three miles west of Johnstown, the average dip of the shales is 40°, and in several exposures south of here dips of 60° were noticed. This disturbance was found to extend from 5 0 to 800 yards from the fault, the eastward dip gradually dying out and giving place to the general monoclinal inclination to the southwest. Although the fault plane was not observed in this region, there are several exposures in which it is clearly seen to be vertical or very nearly so. One is in the banks of a creek which falls over the fault scarp of crystalline rocks in a long succession of cascades. Near the bottom there is a bank in which a sheer wall of crystalline rocks is seen along the fault plane. There is much debris banked against it but the Utica slate outcrops at several points near by in the gorge and within a few inches of the contact in the road above.

In the region west of Johnstown, I found a branch fault extending southwestward from the main dislocation to a point south of Ephratah. Its relations are shown in section B, plate 3, just under the B and also on plate 2. The downthrow is on its western side and it gives rise to a conspicuous scarp of crystalline rocks and Calciferous, facing northwest. Its maximum throw is near the centre of its course, at a point about due east of Ephratah, where the amount is 250 feet, and the Utica slate is seen abutting against the crystalline rocks South of this point the crystalline rocks dip beneath the Potsdam sandstone and Calciferous, the throw decreases gradually and the fault dies out in the overlying Trenton limestones, a mile north of Stone Arabia. To the northward the Trenton and Birdseye limestones, the Calciferous, the Potsdam, and the crystalline rocks are clearly exposed, coming up in succession along the dip on the west side of the fault. The continuation of the fault through the crystalline area to the main fault is not clearly exposed and the amount of throw appears to diminish in the interval.

West of Gloversville the course of the "Noses" fault gradually curves around to northeast and near Mayfield its trend is nearly due east. Then it turns to the northnortheast again and extends up the Sacandaga valley. Along the fault scarp in this region a high cliff and steep slopes of crystalline rocks are presented to the eastward and southeastward rising high above the plain on which Gloversville and Mayfield are located.

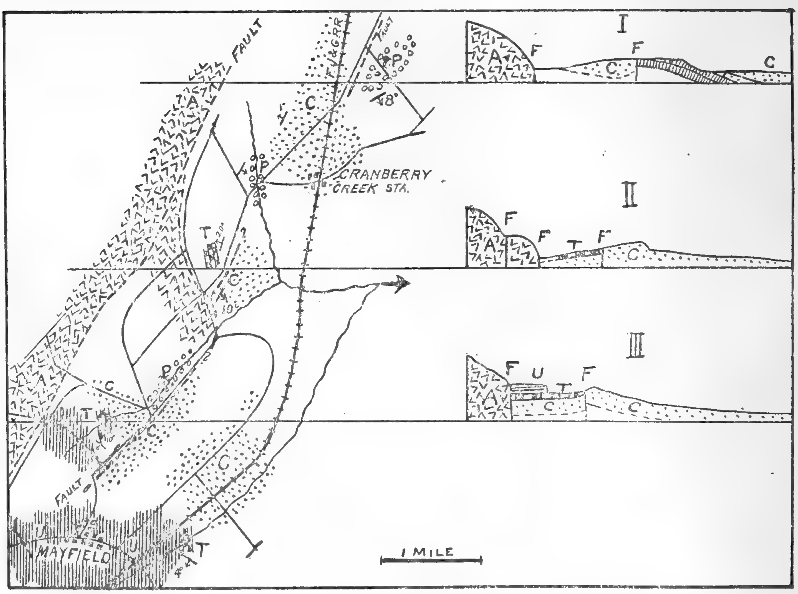


FIGURE 8.— Sketch map of region north of Mayfield, and sections illustrating the relations of the faults. Horizontal scale two miles to one inch. *U.* Utica slate. *T.* Trenton limestone. *C.* Calciferous. *P.* Potsdam sandstone. *A.* Crystalline rocks. *F.* Faults.

PLATE 6.

Looking down the Mohawk river from near Spraker's Basin, N. Y.; the "Noses" to the right.

North of Mayfield the Trenton, Birdseye, Calciferous, Potsdam and crystalline rocks are brought up in succession by the southerly dip, east of the fault and the wide Utica slate area ends. In this vicinity it was found that there is a branch fault to the southward from the main dislocation, and a parallel fault which is intersected by this branch fault. Some of the relations are shown in plate 2. The amount of these minor faults is not great and they appear to affect a relatively small area. The outcrops upon which my knowledge of their relations is based are not as numerous as could be desired, for there is considerable drift over the region. The outcrops observed and the structural deductions are represented in the map and sections on page 46.

There are some indications in the topography that the minor parallel fault extends across the Sacandaga and up the depression in which Hope Falls are located. North of Northfield both faults are entirely in crystalline rocks and their courses were not specially studied. Two miles west of Northfield there is a small area of Calciferous apparently completely surrounded by crystalline rocks and abutting against the "Noses" fault on its west side.

Fifteen miles north of Northfield, at Wells village, in the Sacandaga valley, an area of Paleozoic rocks was found lying against a fault scarp on its western side, and possibly faulted on the east side also. Its relations are shown in the following figure.

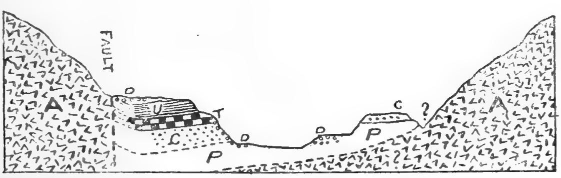


FIGURE 9.— Cross section of Sacandaga valley at Wells, Hamilton county, N. Y., looking north. *U*. Utica slate. *T*. Trenton limestone. *C*. Calciferous. *P*. Potsdam. *A*. Crystalline rocks. *D*. Drift.

The Utica and Trenton formations are characterized by an abundant fauna. The Calciferous and Potsdam formations have their usual characteristics. The Utica slate and Trenton limestone are exposed very near the crystalline rocks on the west side, and they dip gently westward.

Fonda Fault— The small uplift east of Fonda brings up a small area of Trenton limestone in the Mohawk valley, mainly in the north bank, where the formation rises thirty or forty feet above the river. The fault plane was not precisely located nor were any attendant phenomena observed. Its relations were shown in section A, plate 3, and on plate 2. The upthrow is on the western side, and the displacement amounts to about 125 feet. Heavy drift hides its northern extension. It may pass through the Utica slate area northward, and possibly be continuous with the fault at Mayfield, but I have no positive evidence on this point.

Tribes Hill Fault.— This fault is not of great prominence, but the limestone beds which it brings up have been extensively quarried, so that it is of considerable economic importance. The relations of the fault are shown in section A, plate 3, and in plate 2. The exposures are quite clear in the vicinity of the river and for some distance northward. To the south it is soon lost in the drift of the Schoharie valley or the adjacent hills of Utica slate and Hudson river. The Utica slate is exposed in the immediate vicinity of the fault at several points along its course, with the usual narrow zone of upturned beds varying in dip from 40° to 60°, which die out gradually to the eastward. The amount of the displacement on the Mohawk river is about 200 feet. In the high hills about Perth the fault is heavily covered by drift, and its northern extension could not be traced. It appears to die out in this region.

Broadalbin Fault.— This fault is similar to the uplifts east of Ephratah and near Dolgeville, in having the downthrow on the northwestern side. Its location is shown in plates 1 and 2. It is somewhat north of section B, plate 3. It trends east-northeast and west-northwest, passing half a mile north of Fonda's Bush, and apparently it soon dies out to the east and west. Owing to heavy drift along its scarp its relations are for the most part concealed. In the creek, a half mile north of Fonda's Bush, the slate is seen tilted northeastward or obliquely away from the fault at an angle of 40°. The amount of dislocation at Fonda's Bush is about 200 feet. The Calciferous is exposed on the hill a few rods to the southwest of the village,

PLATE 7.

Looking toward Lake George from north of Saratoga Springs, N. Y. Fault along east side of Mt. McGregor on the left; French Mountain in the middle distance; drift topography in foreground.

over an area of about half an acre, and the fault scarp is distinctly traceable in the topography for a short distance to the northeast. The Calciferous appears again at Steven's mill, and the overlying Birdseye and Trenton limestones are exposed in a quarry a few rods east, and again at the next bridge above.

Hoffman's Ferry Fault.— This is the easternmost of the faults on the Mohawk. It brings up the Calciferous, Birdseye and Trenton formations over a wide area which extends up the river to two miles above Amsterdam. The prolongation of the uplifted beds so far up the river is due to exceptionally low dips and a number of undulations, as in the case of the "Noses" fault in the Canajoharie region. Neither the eastern front of the uplifted block nor the cliffs of Calciferous along the river gorge are so prominent as at the "Noses," or about Little Falls, but they are conspicuous features. A series of gentle arches in the Calciferous is finely exposed along the railroad and canal on the south side of the river, a mile below Cranesville. The Calciferous does not extend far south of the river, but is capped a short distance back by a low terrace of Trenton limestone, with high hills of Utica and Hudson river slate just behind. On the north side of the valley the Calciferous extends up the dip to a somewhat greater altitude than on the south side, and occupies a wider area. Behind Amsterdam, and for some distance east, it is capped by Trenton limestone in a relatively narrow tongue, which slopes southward. Near the fault there is an outlier of Trenton limestone bearing a low mound of Utica slate of small extent. To the north of these areas the Calciferous is bare over many square miles in a wide plateau which extends to the Sacandaga. The fault plane was not observed, but its course is clearly marked. It crosses the river just above the mouth of the little creek which empties from the north, a few hundred yards west of Hoffman's Ferry. This creek flows over Utica slates which here dip steeply away from the fault. A mile and a half from the river the fault scarp is exhibited by thick-bedded Trenton limestone, with a small showing of Calciferous below. In a short distance farther the Trenton area ends, and the Calciferous gradually rises into a cliff which is sharply elevated above the Utica slate country eastward. The Calciferous continues for the next ten miles in a line of cliffs and steep slopes of considerable prominence. At a point about eight miles from the river, the mono clinal dip, aided possibly by the increased amount of the fault, brings up Potsdam sandstone. This formation emerges to a thickness of 100 feet near Galway, but the fault then decreases somewhat in amount and extends into the crystalline area east of Galway, where it becomes obscure. It is largely marked by a heavy drift cover in this vicinity, and its relations are not well known. A short distance south of Galway the fault sends off three successive branches to the northeast. They are of the same type as the main fault, with uplift on the western side, and are clearly exhibited in the relations of two wedges of Trenton limestone, the easternmost of which rises above the Utica slate to the east along the scarp of the first fault. These relations are shown near the left-hand end of section B, plate 3, and also on plate 2, in both cases on a considerably exaggerated scale in order to render them distinct. These faults appear to finally die out to the northward, but there is much obscurity in this country due to heavy drift cover. Just south of East Galway there is a small inclosed area of crystalline rocks with cliffs of Potsdam sandstone just north, which is probably cut off by a continuation of one of these faults.

Saratoga Faults.—The fact was long ago recognized that the springs at Saratoga issue along a line of dislocation which brings up the Calciferous to a moderate altitude above the plain eastward. The Calciferous occupies a considerable area about Saratoga and dips beneath the Trenton limestones to the southward. To the northwest the dip brings up the Potsdam sandstone and crystalline rocks in succession, but to the northeast these are cut off by another fault along which the Calciferous abuts against the crystalline rocks. Farther west there is another fault of smaller amount which somewhat offsets the belts of the several formations.

I am informed by Mr. Walcott who is familiar with this region that there is another fault in the western part of the village of Saratoga which breaks the continuity of certain Calciferous members for some distance, and Mr. McGee, who made a visit to the region some years ago, states that, at that time, there was evidence of a small branch fault extending from the Spring fault at

PLATE 8.

Looking up East Canada Creek above the fault near Manheim, N. Y. Falls and cliff of Calciferous sandrock.

an angle of 60°, along the base of the cliff of Calciferous just north of the point at which the railroad crosses Broadway.

The following three sections show the principal relations in the Saratoga region.

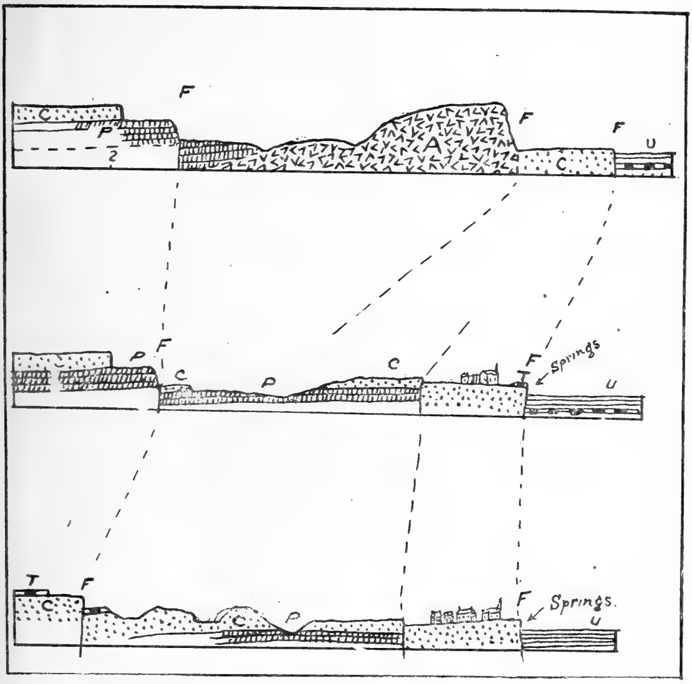


FIGURE 10.— Cross sections through the Saratoga region, looking north. *U.* Utica slate. *T.* Trenton limestone. *C.* Calciferous. *P.* Potsdam. *A.* Crystalline rock. *F.* Faults.

The fault planes are not exposed so far as I could find, but in outcrops in their immediate vicinity no evidence of upturning of limestone or sandstone was observed. East of the Spring fault the country is covered by drift, and there are no outcrops of Utica slate until in the vicinity of Saratoga lake.

The faults of the Saratoga region trend approximately northeast and are essentially parallel. Their northern extension has not been fully determined, but the one which passes west and north of the village appears to follow the base of the steep front of crystalline rocks which crosses the Hudson river five miles west of Glens Falls and extends to Lake George. There are several exposures in this belt in which the Calciferous is exposed abutting against the crystalline rocks, although the precise contact was not found. It may be an overlap along a steep shore line, but its relations and the known presence of the fault southward strongly suggest a long dislocation. To the southward it gradually dies out a short distance southwest of Saratoga. The easternmost, or Spring fault, appears to extend southward to Ballston, if the continuation of the line of springs is an evidence of its existence, which is probable. It is entirely in Utica slate south of the Kissingen spring of Saratoga, for at that point the Trenton limestone on the west side of the fault dips beneath the Utica slate. The westernmost fault in the Saratoga region is prominent for about three miles, as shown in the sections in figure 10. It extends into the crystalline rocks northward and into the Utica slate area southward, but these extensions were not followed.

Lake George Fault.— The middle fault of the Saratoga region, as stated above, appears to extend to Lake George and along its eastern shore. For many miles its prominent scarp of crystalline rocks rises abruptly from the great sand plain eastward. For some distance south of Lake George the dislocation is entirely in crystalline rocks, but at the south end of the lake a small area of Calciferous is seen, and farther up the lake at Hill View and Bolton there are other small outliers of sedimentary rocks. The lower part of the lake basin appears to be excavated in the Calciferous, for several outliers along its sides and others constituting the southern islands indicate an extensive area of this formation. There is a long strip of Calciferous on the east side of French mountain, probably cut off on the east by a fault which continues along the east shore of Lake George from Kattskill bay. At a point two miles south of the East bay a small area of Trenton limestone also abuts against this fault. The following section is intended to show the relations in this region.

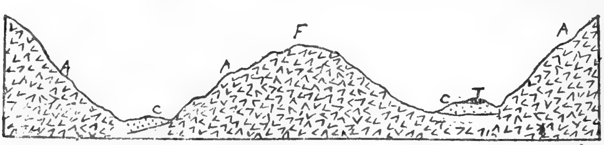
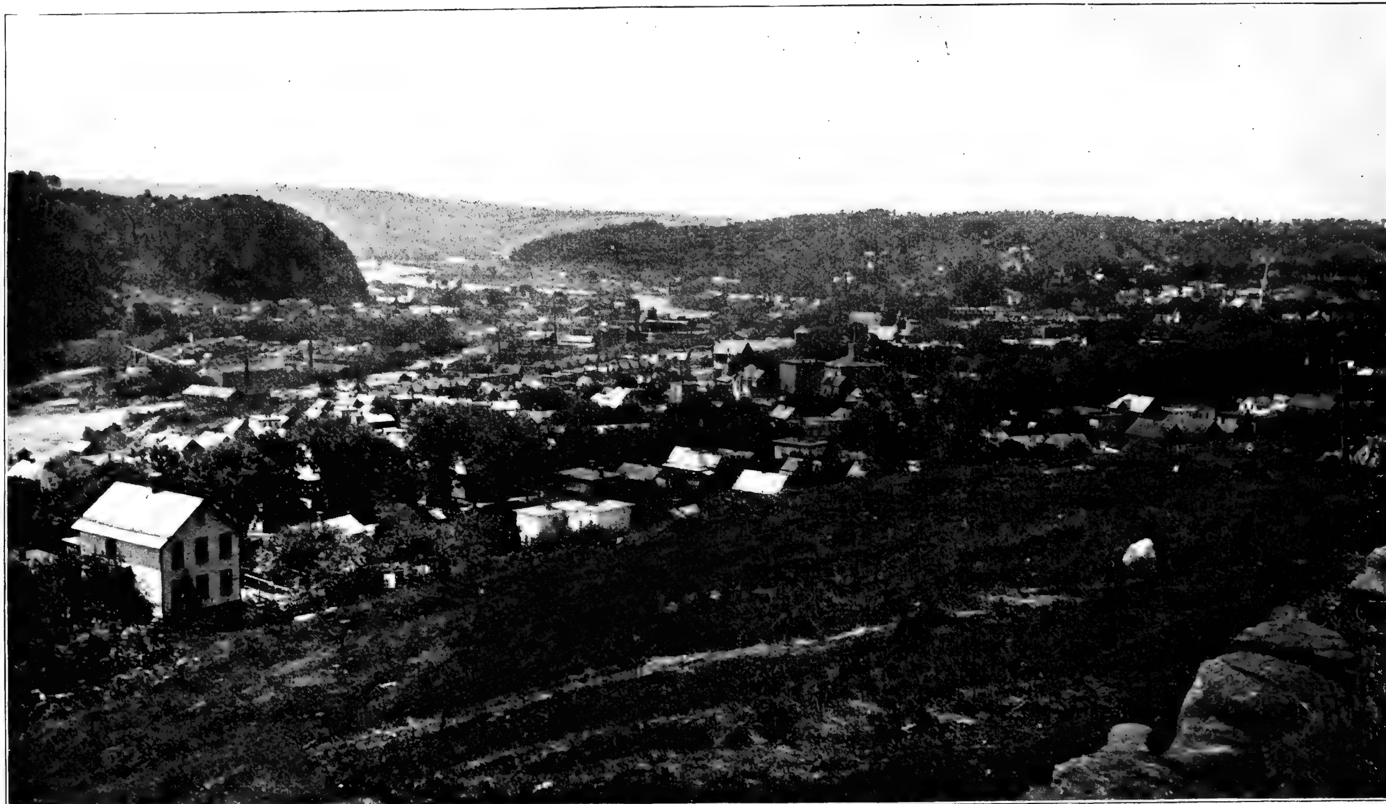


FIGURE 11.— Section from the south end of Lake George, eastward through French Mountain, looking north. *T.* Trenton limestone. *C.* Calciferous. *A.* Crystalline rocks. *F.* French Mountain.

Holland Patent.— There is a small fault exposed east of Holland Patent, which extends to a short distance west of Trenton. The amount of displacement is not over sixty feet at greatest,

PLATE 9.



Looking up the Mohawk river from the eastern part of Little Falls, N. Y. Crystalline rocks in bottom of gorge; cliffs of Calciferous sandrock in foreground; hills of Utica slate in background.

and the fault brings the middle beds of the Trenton limestone against the Utica slates, probably not far from their base. The relations are shown in the following figure:

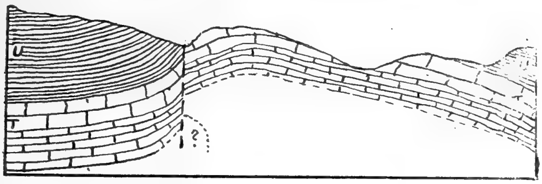


FIGURE 12.—Cross section, one mile north of Holland Patent. *U.* Utica slate. *T.* Trenton limestone. Looking north. Horizontal scale, one mile to one inch. Vertical scale exaggerated.

NOTE

Field Notes on the Geology of the Mohawk Valley, with a Map.

(From the Annual Report of the State Geologist for 1885, pp. 8–10.)

At Little Falls there are two parallel faults extending 45° east of north. One of these intersects the village and crosses the New York Central railroad at the high stone wall built up from the river at the lower end of the village. The same fault crosses the West Shore railroad just above the deep cut through the Labradorite, and this point is also occupied by an extensive filling and stone wall built up from the river level.*

The second fault forms the eastern termination of the escarpment of gneiss and Calciferous below the village and is a monoclinal.

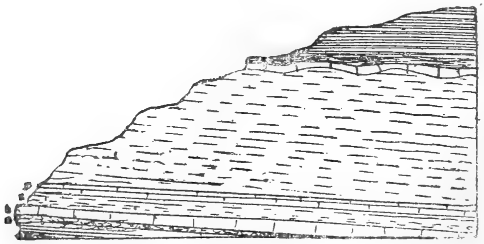
Another monoclinal fault crosses the valley of the Mohawk river above the mouth of East Canada creek and brings up the Trenton limestone dipping to the west.

An anticlinal fault occurs just above Fort Plain. The Calciferous dips to the west, and across the line at Fort Plain the Birdseye limestone is found dipping to the southeast. Just below the bridge at the last-mentioned locality is an exposure of Birdseye limestone, which preserves the remains of former pot-holes at a level of ten feet above the river, showing that at one time there was a natural dam and fall at this point.

From Fort Plain to the "Little Nose" the strata lie in a broad synclinal with Canajoharie situated nearly in the center.

Sections of the strata at Canajoharie and Spraker's Basin are presented and make an interesting comparison.

Section along creek entering the Mohawk river at Canajoharie, N. Y.



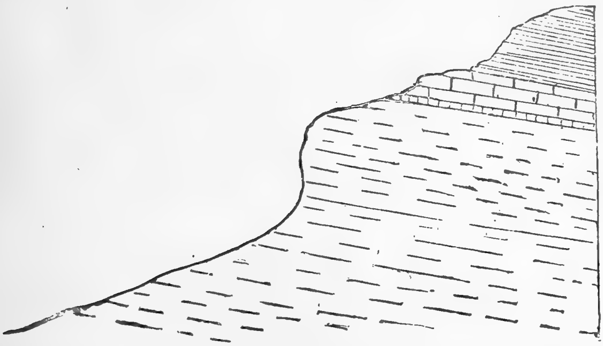
At Canajoharie the Calciferous is comparatively thin, bringing up underlying beds of limestone as shown in this section. Upon the undulating and worn surface of the Calciferous there is a very thin bed (1–3) of Trenton limestone without any intervening

*The significance of the artificial structure mentioned may not be apparent at first sight. A line of fault is a line of weakness. The rocks along such lines are usually much broken and eroded ; and the place of many faults in New York is indicated by lines of swamps, lake beds and river valleys. At Little Falls the strata are nearly everywhere exposed, and only along the line of this fault has it been necessary to fill in extensively and build secure foundations for the roadbeds.

formations. The limestone is followed by the Utica slate, which is well developed.

At Spraker's Basin the Calciferous is quite extensive, forming the major part of the section, and is followed by a thin bed of limestone, which represents the Chazy limestone. Following this is the Trenton limestone, reaching a thickness of from ten to fifteen feet.

Section along creek entering the Mohawk river at Spraker's Basin, N. Y.



Between Spraker's Basin and Randall there is a very marked anticlinal fault, bringing up the gneiss in the bed of the river and giving origin to the "Noses." On the east side of the fault the gneiss is found more than 150 feet above the river, rising as high as the Calciferous does on the opposite side of the fault line.

Near the eastern line of this fault there is a cutting on the West Shore railroad, at a point known as the "Little Nose," through the gneiss and Calciferous, showing the line of junction between these formations. This absolute line of junction is very interesting, geologically, on account of the great rarity of such exposures.

The interval from the gneiss to the Calciferous represents the Huronian, Primordial and Potsdam, and is, comparatively speaking, one of great duration. These formations, represented elsewhere by many thousand feet of sediments, are here represented by from a few inches to several feet of breccia and loose chloritic and ferruginous material

The material occupying this interval is derived from the decomposition of the gneiss and from some slight sedimentation, and contains a small per cent. of gold and silver, and is the first authenticated discovery of these minerals in the Mohawk valley. The amount of the metals is much too small to be of any particular importance, but their occurrence is an interesting geological fact.

Following this loose material is a bed of breccia of variable thickness carrying fragments of crystalline limestone and Potsdam sandstone.

The details of the junction of the gneiss and Calciferous are given in the following section:

Section in cut of West Shore railroad, at the "Little Nose," Randall, Montgomery county, N. Y.

The Calciferous sandstone at the "Little Nose" has a considerable thickness and carries some small beds of hornstone, and contains many cavities, lined with quartz crystals similar to those of Little Falls, but not in such abundance or perfection. Some of the crevices in the rock have been filled with lime, by infiltration, forming a calcareous tufa, and contain many bones of small animals and the shells of recent species of Helix.

From the "Noses" to the escarpment crossing the Mohawk above Hoffman's Ferry the rocks lie in a broad synclinal, with some minor folds. This synclinal includes, along the river, the Calciferous sandstone, Trenton limestone and Utica slate. It is terminated at Hoffman's Ferry by a line of fault parallel to the other faults here described.

Further details of the occurrence and distribution of the rock formations are given in the map accompanying this report, which records the observations made during the past season, no attempt having been made to incorporate it with the published geological maps of this region.

Geological Survey of the State of New York — Geological Map

REPORT

ON THE

STRUCTURAL AND ECONOMIC GEOLOGY OF SENECA COUNTY

JAMES HALL,
State Geologist

D. F. LINCOLN, M. D.,
Assistant

1895

REPORT.

James Hall, *State Geologist:*

Sir.— In accordance with the request which you addressed to me last July, I have prepared an account of the Geology of Seneca county, from both a scientific and economic point of view. This I now have the honor to present.

In treating of geological matters proper, I have given much attention to topography and drift phenomena. In studying the palaeozoic rocks, the determination of boundaries of formations has been the principal object. Economic resources are spoken of under the heads of Quarries, Clay industries, Gas wells, Water-power, etc.

A geological map is added, and original photographs, sketches and sections are employed in illustration.

I desire to tender thanks to the Hon. A. M. Patterson, Hon. D. H. Evans, Hon. Diedrich Willers, Messrs. King and Robinson, Harrison, Chamberlain and others, who have rendered essential service to my work.

I remain, very respectfully,

Your obedient servant,

D. F. LINCOLN.

Geneva, N. Y., *November* 12, 1895.

GEOLOGICAL SURVEY OF THE STATE OF NEW YORK.

(GEOLOGICAL MAP.)

Report on the Structural and Economic Geology of Seneca County.

BY D. F. LINCOLN, M. D.

CONTENTS:

The county of Seneca, selected for the present report, is fairly representative of central New York in point of geological development and in respect to its economic resources.

Geologically, it presents the upper number of the Silurian formations, with the lower, middle and part of the upper Devonian. The formations exposed are the following:

Devonian, upper: Portage sandstone and shale; Genesee shale.

Devonian, middle: Tully limestone; Hamilton shale and limestone; Marcellus shale.

Devonian, lower: Upper Helderberg limestone.

Silurian: Water lime; Salina.

Map of the County.

The map here given is reproduced from a wall map of Seneca and Cayuga counties, published in 1859 by A. R. Z. Dawson, Philadelphia.

In the copy, roads are denoted by single lines. Except in the northern part of the county, they are introduced sparingly, for the purpose of marking geological points. Hamlets are marked with a doubled cross. Dotted lines are used to outline two of the swampy districts, and the kame district. The direction of the meridian is given by the western boundary of Junius. Quarries, with slight exceptions, belong either to the Upper Helderberg or the Portage; they are marked with a cross. Special marks are used for other outcrops of the Lower Helderberg, Marcellus, base of Hamilton (H), Tully, Genesee, and Portage; those for the Marcellus and Genesee shales being parallel lines, those for flagstones being oblong figures. Dotted lines mark supposed boundaries of formations. The outlines of the Upper Helderberg, in western Waterloo, are hypothetical, being drawn straight in the direction of the marsh exposures in Phelps. Many streams are omitted; cataracts are not marked.

The Portage, Lower Helderberg and Salina groups do not display their whole thickness in Seneca county. The fauna of the former is intermediate between that of Ithaca and that of the Genesee region, but is essentially a part of the former.

Glacial geology is well represented by drumlins, sheet till, striations, eskers, kames, delta-terraces, and large deposits of clay and sand.

The economic resources comprise building stone (limestone, flags), cement-rock, rock for the lime-kiln, gypsum, gravel and sand, road material, clay for making brick and tile, gas wells, water-power, mineral springs, swamp deposits.

The section of Seneca county (fig. 30) illustrates (1) the changes in angle of dip; (2) position of Seneca lake, beginning at the outlet; (3) the inferential position of strata at a distance below the lake-bottom, assuming that the Hamilton formation remains of uniform thickness.

Topography of the Plateau.

The land surface of Seneca county comprises somewhat over 300 square miles; the length from north to south is 32 miles, the breadth from 7 to 14. On the north and south the boundaries are artificial; on the east and west they are formed by Cayuga and Seneca lakes with their northward extensions.

Seneca county does not compose a geographical unit, but embraces parts of the New York plateau and of the low plain which stretches to Lake Ontario. The passage from one to the other of these two geographical features is at this point exceedingly gradual. Farther eastward they are sharply demarcated by the Helderberg escarpment, of which the western extremity may be conceived as reaching to Union Springs, Cayuga county. In Seneca county the change occurs by a slow and equal rise of about 400 feet along 14 miles of nearly plain country between Seneca Falls and Ovid. The first great rise occurs at Ovid village, where the Portage rock forms an escarpment of 150 feet, without cliffs, but sloping steeply to the north and west.

The country may also be considered as a section of the *Finger-lake region* (fig. 1). This name is applied to that portion of the plateau which extends from Lake Conesus on the west to Lake Otisco on the east, and is bounded southward by the divide between the St. Lawrence and the Susquehanna watersheds. The divide is marked more or less continuously by masses of moraine material, filling the valleys in places to the depth of many hundreds of feet, but becoming inconspicuous on higher ground. The moraine, as a whole, has been considered by some as corresponding to a "second glacial period."

The region thus indicated is deeply cut by a series of ancient (pre-glacial) river-valleys, roughly parallel and converging to some northern point. Seneca county lies between the deepest of these, Seneca and Cayuga lakes. It occupies the middle or axial part of the Finger-lake region, which is also the lowest. Its outlines appear to indicate great erosion during the Ice Age, with general flattening, which has probably removed all distinctions of relief and depression north of the outcrop of the Corniferous limestone, though a few hills remain, greatly flattened, on the south.

The mean depth of Seneca lake valley, measured from the Lodi plateau, is 1,000 feet, of which one-half is below the water of the lake.

The distinction between plateau and valley is striking when one stands on high ground. From the surface of the lakes the valley alone is visible; this is especially true of Seneca lake.

Hills.

The trough-like appearance of the lake-valleys of this region has often been remarked. They appear destitute of side-hills; or rather this feature does not come in sight except by close study.

Figure 1. Map of the Finger-lake Region, the dotted line showing the water-shed.

Such hills as exist scarcely rise more than 100 feet above the level country anywhere in this county, and their forms are so flattened that they make little impression on the eye. There is an exception to this at the southern border of the county, where the topography changes; great flat hills rise several hundred feet above the table land, with fine valleys, leading south to a series of interlacing valleys, which characterize the country back of Burdett, and are repeated east and west beyond the lakes, adding greatly to the picturesque beauty of Schuyler and Tompkins counties.

FIGURE 2.

The sketch (fig. 2) represents the east side of Seneca lake, southern half. It was taken from a high point above Watkins village. The apparent point of land on the left is formed by the descent of Lodi and Ovid townships to the lake. Three or four long hills, from 400 to 600 feet high, are seen occupying the plateau; their valleys are high above Seneca lake, and do not communicate with it as valleys, but send their streams down the steep lakeside in thread-like gorges, too small to be drawn here. The hill farthest to the left projects (as just stated) into Seneca county under the name of Prospect, formerly Butcher's, Hill.

Collectively, these large hills indicate a second lift in the level of the plateau. The formation continues to be Portage. The flatness of their summits is characteristic. Prospect Hill comprises about one-third of a mile of ascent on each side (E–W), with half a mile of almost dead level on top, the outlines being essentially formed of rock. The hill is a type of the southern half of the county, which is like a house-roof, flat over the top and pitching rapidly toward the eaves. The lakeward slopes each way occupy two miles or less of the breadth of the county. They are in many places subdivided into several terraces or steps, each with a nearly perfect level surmounting a short rise.

The smaller hills, lying south of the "Outlet" (Seneca river), deserve attention, as representing an extreme degree of glacial action. As a rule, they are not of drift, but of the country rock; those of the Canoga region being probably an exception. A number are composed of Marcellus shale, e. g., the one on which the Swan farm stands, near the outlet of Seneca lake, which is rather steep northward, with a thin coating of till, while southward it has but a slight descent, emerging into a tract with heavier drift. There are several hills of Marcellus shale to the eastward, with a tendency to the ridge form, bluff northward, and merging into levels southward; they are hardly continuous enough to be called an escarpment, though occupying an alignment along the northern limit of the formation. They project much more prominently than the Corniferous limestone exposures, which lie to the northward.

Marcellus shale, capped with basal Hamilton limestone, forms the elevated mass (200 feet above the lake) two miles south of the Swan hill. It is steep northward, with a long fall of 100 feet to the south. Both of these hills form on the west broad, low slopes of rock running to Seneca lake, where they are cut off in cliffs.

A large hill of Hamilton shale lies southeast of the latter hill, near MacDougal's. Its base is about 170 feet above the lake.

East of these three hills the flat valley of Kendig's creek is an obvious feature, bounded on the east by continuous table land, chiefly rock. The table rises into several hills, peculiarly grouped, on the west of Bearytown (Fayette) village, composed in part of moraine (?).

The very large and striking hill of Hamilton shale which rises at the side of Cayuga lake, northeast of Hayt's Corners, belongs in the present category; there are also a few slight ridges in the central table land, but nothing more of special note north of the outcrop of Tully limestone.

As before hinted, these hills, with Kendig's valley, appear to form the remains of a topography which may have existed in a much bolder form previous to the Ice-Age. Their distribution is not inconsistent with a drainage topography.

The forms are all so flattened and the breadth so great as to make photographic representation difficult. Seen as a whole, from high points in Geneva, the county presents a continuous horizontal sky-line as far to the south as Ovid.

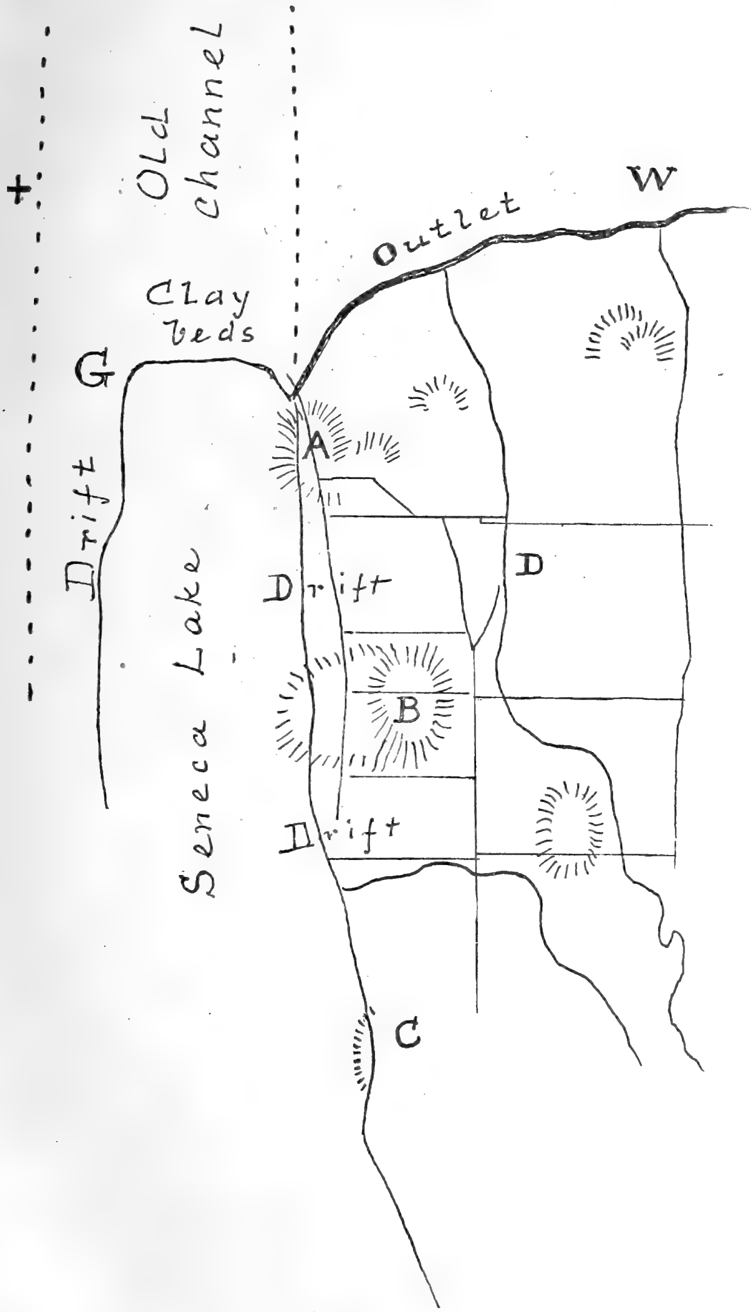


FIGURE 3.

Let figure 3 represent the neighborhood of the northern end of Seneca lake. G = Geneva village. On the west the lake is filled with drift, found by borings to be 212 feet deep; but on the east the floor of the lake is here mostly rock. Opposite A and B, on a still day, one may see the flat surfaces of shale, with geometric joints, under the water, at 350 feet from shore, the water being there three and five feet deep in the present low condition of the lake (October, 1895). The rock bluffs are 20 and 30 feet high, respectively, indicating a slope of 1:15 and 1:10 prior to the modern lake erosion which gave rise to the cliffs.

The summits of A and B are elongated north and south. Their lower bulks of rock run down into the lake, with axes more E–W, which is a normal attitude of side hills toward the main valley, i. e., the lake bed. The supposed ancient valleys of side streams tributary to the river occupying the lake bed are indicated by "Drift," between A–B and B–C. One still carries a stream; the other does not. The drift is of moderate thickness, probably a couple of feet, on the lifts of rock, and exceeding 30 feet in places in the sags.

This case is not isolated, but presents the key to the excessively flattened lakeside topography. All along the lake the rock alternately forms low lifts and depressions of a mile or two in length, rising from 5 to 60 feet and more, and sinking correspondingly beneath the lake. The dip beneath may equal the rise above the lake, northerly; but from Willard, south, the only important dip is at Lamoreaux, the rest being a wall of cliff.

There are no bends, synclinal or anticlinal, of sufficient importance to account for these hills. Farther to the south there is a slight anticlinal of 15 feet in the heavy green shale of the "hog back" in the eastern part of the Willard Hospital property, west of Ovid. This ridge runs E–W, and is divided by a 30-foot cut through which the Lehigh Valley road passes.

Other E–W hills occur west of Bearytown. In this curious group the eastern half consists mainly of shale. There is a very good exposure of the basal Hamilton limestones in the creek which bisects the group; and roadside exposure of shale (with glacial striæ) farther west, on the N–S ridge. The three-branched cluster has the aspect of being composed of drift; and its S–E prolongation to and across the brook strongly

PLATE 1.

Figure 4. Taughannock Falls.

reminds one of a moraine ridge: the material where exposed being till.

At Ovid village there are several drift hills, taking more or less the form of ridges (not N–S). Some six or seven miles S. E. of the village there are a number of till ridges running approximately N. W.—S. E.; with a general excess of drift material along the eastward slope of the country.

Ravines.

The most striking and beautiful natural features of this region are the ravines, formed by the rapid descent of a great number of short streams to the lakes on each side. They are, of course, of post-glacial origin, and the comparative shortness of their existence is seen in the retention of vertical sides, in the shales equally with the sandstones. The joints traverse all the formations alike, from the Corniferous limestone upward; being, for the two main directions, N. 20°–30° W., and N. 75°–85° E., and nearly vertical; these joint planes often delimit the entire wall of a glen, aided by minor and less constant ones. Their effect upon the rock scenery is shown in the views of Taughannock and Lodi glens, and King's Ferry cliff. (Figs. 4, 5, 6.)

The height of the unbroken fall of water at Taughannock is given at 215 feet. Until recently it fell over a straight edge of rock, but this has been broken in the manner shown in the view. There is a considerable and picturesque fall just above the main one, but concealed from sight. This, being the highest fall of water in the State (Niagara = 165 feet), should not pass unmentioned, although it lies a mile or two outside of the boundaries of Seneca county.

A still more remarkable effect is produced where the stream falls over the Tully limestone, with a good thickness of Hamilton shale beneath. In such cases the stream is often hardly more than a sloping ditch in the field above, and would attract no attention; it has been unable to excavate the limestone. Its fall is most unexpected; the limestone is broken into a square face, jutting cornice-like over a deep jug-like chasm hollowed in the shale beneath. This is repeated in many streams on the Cayuga lake side of the county. The type for the Portage formation is a high vertical wall, as at Taughannock, with a small ravine above

The basal limestone of the Hamilton is marked by a high fall 40 feet) at Big Hollow creek and several smaller ones elsewhere.

The photographs were taken during the dry season of 1895, and for that reason fail to give a just impression of the beauty which many of the glens display at other times.

The view of the rock-wall (Portage shale and sandstone) at Lodi (fig. 5) was taken from the top of the opposite wall, looking south. It includes a great part of the height or near 150 feet. The fissures of the joints may be seen traversing equally the upper (Portage) and the lower (Genesee) rock. The front of the waterfall, which is not given here, is so divided into blocks and steps that when dry it can be ascended to the top. The change in tint from light to dark at a certain distance from the top indicates the occurrence of shales resembling the Genesee in the lower Portage.

The cliff at King's Ferry (fig. 6), though outside of the county, represents more perfectly than any other view known to me the vertical cleavage of the Hamilton shale. The surfaces are not weathered, but are fresh exposures made by widening the road-bed of the railway. With these should be compared the view of the Portage shales near North Hector (fig. 7), which show long weathering.

Alluvial Belt.

The preceding descriptions apply only to the southern half of the county, including the township of Varick. The Corniferous tract presents no ravine scenery; the Salina only in the lower part of Seneca river and a little of Black Brook. In the north these districts are covered with drumlins, while Waterloo, Seneca Falls and Fayette are chiefly an alluvial plain, covered with clay, sand and swamp.

The clay belt is two miles wide at East Geneva at the foot of the lake, increasing to twice that width as it goes eastward. Seneca river runs obliquely through it. Where exposed by sections the clay does not seem to exceed 10 or 12 feet in depth, and is often much less.

Sand is found interstratified between upper and lower beds of clay at Waterloo and near Geneva. It bounds the clay on the north, covering a great part of Waterloo, except such tracts as are swampy. Near its southern limit it may often be observed

PLATE 2.

Figure 5. Contact of Genesee and Portage beds; larger glen, Lodi.

to overlie the clay-sheet. It is disposed in irregular ridges and low hills, which are conspicuous as one travels by rail from Waterloo to Geneva, and, in fact, over most of Waterloo; but southward, near the Seneca river, its contours are chiefly due to local drainage (swales and ridges). These sands are continuous with kame deposits on the north.

Further remarks on the clays are deferred to a later section.

The northern half of Seneca Falls township is neither clay nor sand in the main, but largely till or "loamy and moderately stony."

Drumlin Belt.

To complete the account of the sand deposits, it would be necessary to describe those surrounding the kame and those fringing the drumlin belt along its southern edge. These will be mentioned in place.

The two townships of Junius and Tyre are nearly covered with long ridges of till for the most part, straight and narrow, with axes nearly N–S. They belong with the series described by Johnson in 1882, and which is well known as covering a large part of Monroe and Wayne counties. They extend much farther west, however, than Monroe, and form an important part of the geology from Auburn to Syracuse.

When observed, the material of these ridges consists of till of a buff-brown color, containing striated subangular stones as is usual. A thin layer of sand is sometimes seen on the top. Much of the level ground is also stony, with evidence of till, though clay is found in many spots and a moderate amount of vegetable deposit or muck.

The country, irrespective of these ridges, is nearly level, but has a slight fall to the north and a moderate fall in all directions from the West Junius kames.

The largest of these ridges is much inferior to those of Wayne county, but may reach 80 to 100 feet in height. From this they grade downward to little ridge-like elevations of five feet in height and a furlong in length. Even these are quite distinct to the eye, rising from the uniformly level plain. The north ends are often bluff and the south ends tail off to a general equality with the plain. When they happen to be short this justifies the name of "tadpole hills." Some, however, by their length suggest that they belong rather to the esker class. The post-road at McGee's Corners runs north over a low ridge of this sort, just wide enough at top for a road, and very gradually increasing in height to about 30 feet, when it descends suddenly. South from the Corners it runs another mile. This ridge appeared to be of till, however.

Fig. 8 shows the north end of a ridge, rising directly from a clay plain, and displaying correctly the steep angle which the sides often take. Fig. 9 is not over 15 or 20 feet above the plain. Fig. 10 gives "Whisky Hill" (a title now inapplicable), with ruined tavern and well kept schoolhouse. The ridge is hard to distinguish from the rest of the landscape, but forms a wall across the picture; a slope at the left (north) and right may be noticed.

FIGURE 11.— Drumlin or ridge seen from Kame, in north-west corner of Junius. Left hand, north; line of sight, north-east.

The absence of drumlins south of the southern boundary of Junius and Tyre requires an explanation, which I have not to offer. Westward, across Seneca lake, they push into and far to the south of Geneva. Eastward, they run along Cayuga lake in Seneca county, until opposite Cayuga village, where again there are many east of the lake, on the road to Auburn. The theory that the drumlin belt is the remains of a moraine does not seem to coincide with this geographical distribution, for a moraine ought to have pushed farther south, along this meridian of low levels, by probably 20 miles, and should have left plain residua in Varick and Romulus.

The southernmost drumlins in the county are these: One of large size two miles N. E. of Seneca Falls village, north of the canal bridge, and another of less height, south of the bridge, three-fifths of a mile long and 30 feet or less in height, over which the road to Bridgeport runs.

The prolonged valley of Cayuga lake runs as marsh land northward between walls of drumlins on either side.

PLATE 3.

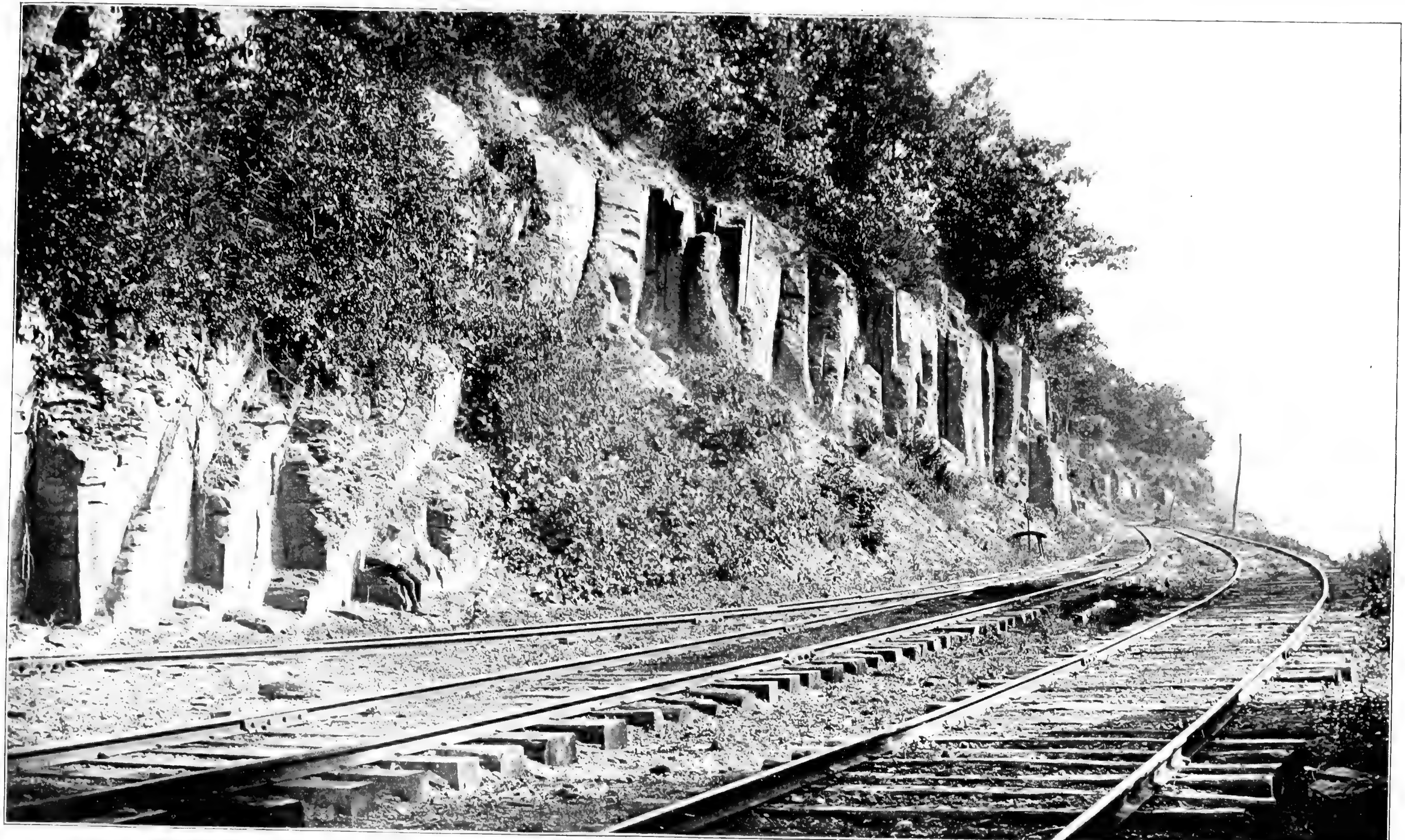


Figure 6. Hamilton shales, showing vertical cleavage; Kings Ferry, Cayuga county.

The map of the drumlins here given (fig. 12), is a reproduction from a map of Seneca county, made in 1852, by William T. Gibson, surveyor, known by repute as a careful, painstaking and accurate man. So far as I have been able to compare his work with observations of my own, it is correct; and as a whole it certainly gives a clear and faithful idea of the singular topography of the country. The meridian line crosses the ridges at a small angle. It is not asserted that all these hills are of till. Of many that have been inspected, one has been found to consist of sand and gravel along its southern half, as indicated. The kame hills are omitted; they are very complicated and are not well given by Mr. Gibson.

Sand Ridges.

The association of sand with these ridges deserves attention. Light deposits of sand and gravel are frequent on their summits, as is the case in New England, and would suggest that at some stage (probably quite late in the disappearance of the ice sheet) super-glacial streams flowing southwards frequently occupied crevasses in the ice coinciding with the tops of the ridges. Physical reasons might be suggested for the preference of ice-crevasses for the tops of earth ridges.

At Mr. David H. Evans's, in the northeast corner of Tyre, is a ridge, proved by the cutting, to consist of till, at least at that point. The outline of the ridge is unlike that of a typical drumlin, it being carved deeply and irregularly by water to the north; but southward it develops to a straight ridge, becoming very sandy and yielding, with a parallel ridge adjoining, of similar nature, quite humpy and irregular, with axis about N. 5° W. magnetic.

A couple of miles north of Seneca Falls village, west of Black Brook, the road partly follows a train of sand deposits which runs two miles to the State road, east of Magee's. The direction taken, on the whole, is N. 5° W. magnetic. It begins southward in low sand hills, nearly continuous, which diverge from the line of road and become higher at a point where excavated for sand and gravel. Here they form a group of hills some 20 feet above the plain. The continuity is interrupted northward for short distances, but at last the line changes from hillocks to a straight single ridge, which becomes more abundant in stones, and after crossing the State Road presents a top soil well filled with typical drumlin material. Smaller sand trains lie parallel to this, east and west. A mile to the eastward lies a large ridge of similar material and extent (see Gibson's map), which near its southern end develops into a veritable little kame-group of sand hills, covered in parts with several feet of gravel dipping at a high angle from the center. Here is another "sand quarry", used for many years to supply building material for the neighboring country. Farther to the east there are undulations for a mile or two, of the same character. Westward, the plain toward Waterloo looks unbroken, but other exposures of sand (probably similar) exist on the westward line north of that village.

Kame District.

The above series of ridges of modified drift, forming a fringe to the drumlin district, must probably be connected with that much larger group of kame hills which lies at the western boundary of Junius, opposite Mitchell's station on the Geneva and Lyons railroad.

This latter group is about two miles in diameter in either direction, consisting of gravel and sand hills, 0 to 50 feet high, embracing deep basins which contain several lakelets. The topography is very irregular and is well shown in the view, Figure 13, which gives only one of the ponds. Around the region of hills lies a belt of sand on the east, south and west, which evidently belong to it. In many places the sand is gullied very deeply, especially on the steep slope westward to the outlet of Canandaigua lake, which runs in a rather deep valley for these parts. The rise from the surface of the stream to the high gravel hill at the north face of the kame is, by hand-level, 150 feet. Several other high points are of nearly equal elevation. Figure 14 shows a part of the sand-slope toward the outlet. To the east the descent is much less, and the swales are of lesser size. Southward, the sand runs about six miles, stopping a couple of miles before reaching Seneca lake; it is continuous S. E. to Waterloo and W. to Oaks Corners. The large sand hills

PLATE 4.

Figure 7. Portage cliffs, lowest beds; North Hector.

in and immediately around the kame diminish to hillocks farther south.

The sand is a buff red, of various shades, quite fine, composed of angular and partly rounded grains of quartz with reddish clayey matter adhering to them. Its fertility is variable. Rather numerous stones are found on the surface and in sections, in the main portion, growing scarce at the border.

Mr. Boughton, surveyor, of Waterloo, informed me of a belt of "white sand" running E–W in the low ground north of Black Brook. "The Pines" is a popular name for a part of this district; its scenery suggests the southern Atlantic coast. The sand is gray from admixture of vegetable matter; its loss of color is probably due to the deoxidizing action of the latter upon the iron of the red sand. It is commonly considered very poor land, but it has good crops of vegetables if well treated.

The scenery of the kame district is very irregular. The gravel is mostly in the north center, in ridges and humps. The sand hills on the south are in part high E–W ridges, occasionally two or three running parallel with narrow valleys between. The features are morainic; except where drainage has evidently governed, as is the case in the westerly sand-slope with its parallel channeling.

We may assume that this group of deposits marks the debouchement of some ice river at the edge of the ice-sheet, into an enlarged and deeper Seneca–Cayuga lake. If so, the signs of the river must be sought in fluviatile deposits on the north.

Two lines of such deposit are traceable, running nearly N–S, and ending in or near the kame. Sand and gravel are found in each; the deposits of the two materials being distinct and unmingled.

Beginning two miles north, the eastern line begins with rolling hills of small height, followed by an abrupt hill of gravel, of morainic shape, much higher. This gravel-bluff pushes south as a high, flat ridge of very sandy till-material, or sand with many till-stones; the sides very much incised with channels of drainage; descending to the plain just before reaching the kame.

The western line comprises one or more drumlins coincident with trains of sand and gravel. Beginning two miles north and tracing it south:

10

1. A railway cut of a few feet in depth traverses the ridge at a low point. The narrow ridge rises rapidly to the south; barely wide enough for a wagon; gravelly. Reaching the height of 50 (?) feet it becomes very sinuous and humpy, with steep sides; wanders a short distance about on a table-like hill (200–300 feet wide), and is lost.

2. The table, some way southward, descends; continues as a straight, well-rounded ridge 25 feet high, apparently composed of till, S. 5° E. for a quarter of a mile; then widens and becomes knolly for half a mile.

3. A long, straight N–S valley splits the ridge in two. The west branch becomes much higher and takes on the habit of a till-ridge, descending when near the kame, and marked on its well-rounded top with a longitudinal groove 200 feet long. The east branch diverges very slightly, remains low (30 feet ?), has a sandy soil with a number of stones, and a rolling surface. Finally it changes at once to a very narrow, tortuous ridge of heavy gravel, which runs (with a short break in the swamp) half a mile to the central parts of the kame.

The gravel ridge begins exactly where the sand ridge ceases, with a partial disconnection of continuity, and indications as if the former emerged from the pond just at that point.

Delta Terraces.

The "points" at Sheldrake and Lodi afford excellent examples of the formation of modern deltas. They correspond with two of the largest local streams, and represent the drift and rock brought down by the streams since the lake has stood at its present level. Projecting a quarter of a mile into the respective lakes, with a greater breadth, at points where the descent of the bottom is steep, they indicate a very large amount of filling.

Along the sides of these and most of the other streams we find important accumulations of the same materials that compose the modern deltas. In part, these masses form low walls or embankments running continuously for long distances on both sides of the gullies. This may be seen in the region of steep slopes south of Kidder's ferry. The streams here run parallel and very near each other, so that there is but a moderate space between two

PLATE 5.

Figure 8. Drumlinoid ridge displaying end to north, Junius.

neighboring embankments; a space which at first and for a moment suggests the notion that one has to do with a valley, the embankments being its walls.

In other places the gravel is accumulated in terraces like cushions to the right and left of the ravine, having steep slopes crowned with little plains. In the section of the main ravine at Lodi falls this is seen to occur several times, while the upper deposits are more irregular and run together. (Fig. 16)

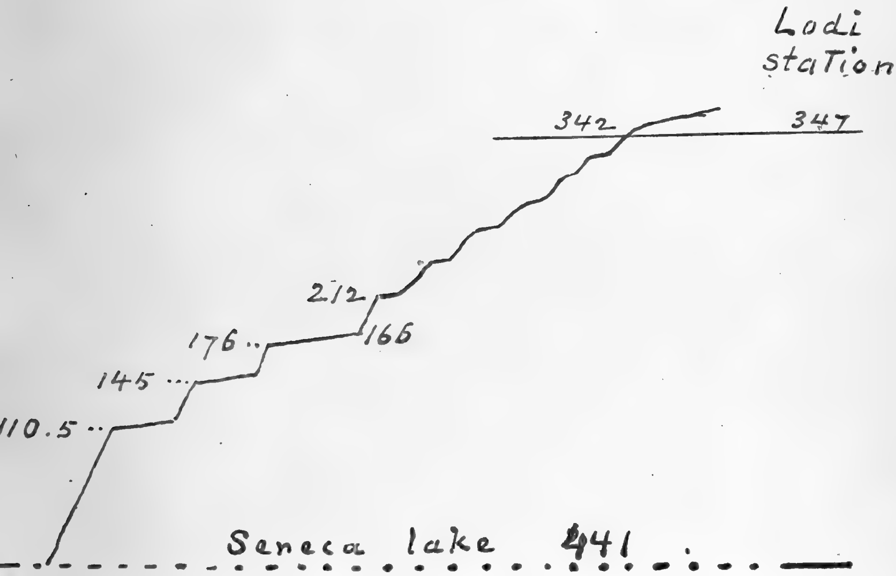


FIGURE 16.— Levels of raised delta terraces on north side of Lodi glen. (The elevation of Lodi is 785.1′ A. T., or 344′ above lake.)

The photographs (figs. 19, 20), taken at Willard a few years ago, represent sections of terrace-masses of this description. Those here given are on the lake front, and rise to the height of 50 feet above the water. The main bulk is made up of gravel and sand, with two or three thin strata of clay. The excavation, made for obtaining sand, was then recent.

A very large section of one of these delta-terraces has been recently made along the main line of the Lehigh Valley railway, at North Hector. The station at that point is 872.7 feet above mean high tide = 432 feet above Seneca lake. The deposit, which is in full view and close to the station, rises 100 feet higher = 973 ft. This is decidedly above the divide at Horseheads, near Elmira, and probably nearly corresponds with the highest point that the lake attained. It should be compared with the level of the country at Watkins, given by Fairchild as 961 A. T.

The terraces consist mainly of gravel, with some sand and clay. Among the pebbles are many which retain the form and to a slight extent the markings of till-stones, having been transported but a short distance.

The most acceptable theory of the origin of these delta-terraces is that which refers them to a former higher level of the water of the lakes. The highest deposits of this class attained an elevation which would imply that all of the county north of Ovid was under water (or ice), so that the two lakes may have formed one body of water.

The period to which this is referred is the close of the Ice Age, while the ice-sheet was melting back from its southern limit, the moraine. At first the water would be confined to the valleys south of Ithaca and Watkins; the outflows occupying independent channels by which they were led to the Susquehanna valley. With the recession of the ice, a point would be reached where the two lakes could communicate with each other; as soon as this occurred, a rush of water from Cayuga to Seneca lake would occur, reducing the level of the former by 140 feet, since the outlet for Seneca lake at Elmira was 900 feet above tide, while that of Cayuga (Fairchild, Gilbert) is 1,040, at Spencer Summit. At this stage Seneca lake would be even higher than when it had only its own drainage to provide for. The mass of water derived from the melting ice was incomparably greater than that now known to us; sufficient to have converted the lake into a flowing stream three miles wide.

A third stage began when the recession of the ice front had carried it so far north that an outflow became possible to the eastward into the Mohawk valley. During this stage the lakes appear to have sunk, sometimes by a continuous slow depression, at other times with stages of rest. To the continuous sinking would correspond the lateral ridges of deposit fringing the streams; to the stages of rest, the terraces with nearly level tops.

PLATE 6.

Figure 9. Drumlinoid ridge of small height, Junius.

Each stream has cut through its own terraces successively in seeking lower levels, carrying away large amounts of drift to add to the new delta.

It is probable that, during the latter part of this (third) stage, toward its close, there was one rather protracted period of rest or equilibrium, with the water 100 feet above its present level, or not much higher. For this view there are several coinciding bases. 1. The clay at Geneva rises to the level of 100 feet, scarcely more, and then thins out or disappears. Traced westward along the Lehigh Valley railroad, it rises to about the same height, giving place to sand hills about half a mile S. E. of Oaks Corners station. (This station is 564.3 A. T.; that at Geneva is 491.1, making a rise of 7.3 feet; Oaks Corners is 123 feet above Seneca lake.) 2. The elevation of the kame deposits is very near 100 feet above Seneca lake. These deposits represent the discharge of a glacial river at a late period into the conjoined Seneca–Cayuga lake. 3. The lowest terrace at Lodi is 110 feet above the lake.

The delta-terraces are confined to the southern half of the county. On the west side of Seneca lake they run much farther north; there is a well-marked one four miles south of Geneva (mouth of Slate Rock Glen).

Lines of beach connecting the delta terraces have been sought for by various observers with little or no success. Wave action is of subordinate effect in narrow waters. Beach ridges fringing delta-terraces are not found, as far as I know, in Seneca county but are handsomely shown at Kashong creek, eight miles south of Geneva. Elevated lines of cliff have not been found as yet.

A study of the terraces, limited to Seneca county, would have comparatively little value. In their best development they occupy the upper half of both lakes and extend south up the valleys of inlet. Their relations to each other and to the points of outflow require much study, based on complete and accurate measurements, which have yet to be made.

The section of the Lodi terraces is based on hand-level measurements, the total error of which was small, the estimate being 347 feet of elevation above the lake, while that of the L. V. R. R. is 344.

Drift-filled Channels.

The most important are the channels of the two lakes, which are evidently choked with deposits. The Nester well, sunk at Geneva three years ago, about five feet above the lake, along the north shore, one-sixth of a mile from the proper border of the lake valley, struck rock at 212 feet. The mixed deposits comprised blue and other clay, sand, gravel, till-stone and large bowlders.

The Seneca river, leaving the lake of the same name at its N. E. part, flows over Corniferous rock for a mile at Waterloo; and again for two miles over Salina rock at Seneca Falls. There is some reason to believe that a much deeper ancient channel, parallel with Seneca river, or crossing it in places, is concealed under the drift.

The evidence consists in the statement of those under whose care the gas wells at Seneca Falls were drilled; to the effect that the three wells, Nos. 7, 5 and 6, lying nearly in a straight line in the north part of the village, struck rock at 70, 60, 75 feet respectively. This line protracted eastward strikes a part of the river where the cliffs of plaster rock disappear, reappearing farther east. To this add, that in well No. 7 it is said that gravel was encountered at intervals below 70 feet, until a depth of 200 feet was reached.

Till, in general.

The character of the till varies in correspondence with that of the underlying rock, as is usual. This is most plainly shown in the till which covers the Upper Helderberg rocks, where the amount of limestone is sufficient to give a decided blue tint to the clayey mass seen in gross. The shales mostly disappear in the till. The high lands near the southern border of the county begin to show impoverishment, due to the presence of large quantities of sandstone.

Bowlders do not form a conspicuous part of the scenery; stone fences are rare. Gullies cut through till display a fair assortment; the large ones either belong to the Archaean formations, or to the Upper Helderberg limestone. The largest seen were two, both of the latter class, each 11 feet long, in a ravine south-east of Bearytown, three miles south of the outcrops.

PLATE 7.

Figure 10. Whisky Hill, Junius.

The distribution of the till is rather irregular. The presence of drumlins in the northern part does not, however, imply a great excess of deposit. Their materials, equally distributed, would not produce a layer more than 10 feet thick over the surface of Junius and Tyre. This must be added to a considerably greater amount in the form of a sheet, which may be 20 feet thick on the average.

The Seneca lake section has a very thin deposit for most of the distance; thick drift occurs only in the depressions, described under the head of Topography. On Cayuga lake, in the towns of Fayette and Varick, the rock is concealed by heavy deposits. The eastern shore of the lake shows rock exposures much more freely. The agreement in this respect between the lower part of Seneca and Cayuga lakes is quite worth notice; it is necessary in both cases to go inland a long distance on the west shore to find exposures, while the east shore is cliff-lined.

The presence of a large amount of drift in the high land south and south-east of Ovid village has been noted as an obstacle to quarrying.

The process of the formation of till is well illustrated in sections at the side of the Lehigh Valley railroad, south of Willard. The cut passes through a bed of shale, five feet thick at most and 600 feet long, on which lies a confused mass of blocks of the same shale, piled up to the thickness of five feet, the blocks measuring up to three or four feet in size, wedged together in all positions. Over all is a layer of two or three feet of common till.

Glacial Striation.

The following unpublished notes, though few in number, may properly be recorded here:

Top of hill north of Prospect hill, three miles from county line; slab of sandstone 25 feet long covered; N. 40° W.

Steep lakeward slope, north of Lodi station, 340 feet above lake, sandstone in roadside, N. 20° E.

Beach opposite Geneva, Marcellus shale freshly stripped of till, 1,000 feet south of the outlet; N. 45° E.

Directly north of outlet, freshly uncovered Marcellus shale, N. 40–50° E.

Compare the following: Lehigh Valley R. R., one-half mile south of Oaks Corners station, Corniferous, N. 5° W. and E–W. Beyond Oaks Corners, north. Beyond Flint Creek, N. 20°+ E. for a considerable distance.

Thomas' quarry near Waterloo, N. E. end, all, N. 12° E. N. W. end, mostly N. 41° E., very regular; also some N. 12° E., deeper cut. West side, N. 5–10° E., smoothly and well cut.

Frank's quarry, N. 5° E.

Emmet's quarry, N. 45° E., coarse, not parallel.

Rorison's quarry, N. 6° E.

Roadside shale west of Bearytown, N. 10° E.

The readings are magnetic. Allow about 5° westerly deflection.

Swamps and Marshes.

Three considerable tracts of land are comprised under this head; the Montezuma marshes, the Black swamp and the Cranberry swamp, besides swampy lands of small extent in various other places, notably the Canoga shore.

The Montezuma marshes occupy a broad space on the eastern border of Tyre, and farther down along the Seneca river to the distance of over 40 miles from the foot of Cayuga lake. Near the lower end, at Jack's Reefs, there is a fall of 4.3 feet in the stream. The money of the State has been used on several occasions for the procuring of a better outlet, but the result is not yet attained.

The town assessors of Junius (which at that time included Tyre) in 1825 reported the amount of land of this description within the town limits, as follows:

	Acres.
Marsh	4,449
Swamp	2,463
Intermediate	1,167
	8,079

The amount is probably nearly the same at present.

This land was then assessed at 25 cents an acre for marsh and $1 for swamp. Delafield, in 1853, wrote that "not less than 6,000 acres" were then "useless" in Tyre. This adjective gives an incorrect impression for the present day. Marsh land is

PLATE 8.

Figure 13. Kame District, West Junius.

now assessed in Tyre at $2 an acre; swamp land at $3 to $10, according to the amount of timber upon it.

My correspondent, Hon. D. H. Evans, defines marsh as localities in which flag and coarse grass grow, but no trees; swamp is where elm, soft maple and ash trees grow, though seemingly as low as the marsh. Flag is cut in large quantities along the streams running through the marsh, and sold at good prices, so that men make from $2 to $4 a day at it. The marsh is also used for pasture. Much of the coarse hay is cut; hundreds of tons this year. It is pressed and shipped, and used largely for bedding for stock and for packing earthenware; much is also used for feed. The value of the swamp depends on the amount of timber, large quantities of which are cut every year.

There are a good many bits of ill drained land in the drumlin region of Tyre and Junius, some of which are named in Gibson's map from the trees which abounded in them — cedar, pine, hemlock, black-ash swamps.

The report of the State Commissioners, in 1825, stated that the water of Cayuga lake used to rise from July to the time of frost, owing to the summer's growth of weeds in the stream choking the outlet. This is not now the case, for the streams supplying the lake are mostly dry during this time of the year. It is certain that the introduction of drain tile has caused the water to flow off from the tilled lands much more rapidly than was formerly the case after rains and during the spring floods. Deforesting has contributed to the same result. In great floods the water sometimes stands three feet deep over the marshes from Mosquito Point up to Cayuga lake, a distance of 16 miles; but this continues only a few days at a time.

It appears that the region was formerly subject to malaria. The Commissioners, in 1825, state that not only was this true of the immediate borders of the stream, but that for many miles the air was injuriously affected. Mr. Evans, however, living in a tract surrounded by these marshes, writes me that at present the neighborhood of the marshes is not at all subject to fevers.

The "Black Swamp" is drained to a considerable extent. Much of the soil is a deep layer of pure vegetable mold. A large part is still covered with trees. Further improvement in drainage could doubtless be effected.

The "Cranberry Swamp" is almost entirely a forest, growing in black muck, into which I easily thrust a stick three feet; it is said to be much deeper in places. The timber is that characteristic of such places — elm, soft maple, etc. By consent among the owners it might doubtless be drained at a reasonable expense.

In connection with this subject it may be added, that beneath the layers of muck a heavy deposit of marl is often found, composed entirely of minute fragments of modern shells. In the Montezuma marshes, it is found along river beds, in places, 10 or 12 feet thick; its thickness diminishes on receding from the rivers, and at last only the underlying bed of clay remains. Valuable as this material is for a fertilizer, it has been found that the expense of seeking it under four feet of muck is sufficient to prevent its extensive use.

Springs.

The writer has not found recorded analyses of any spring in Seneca county, excepting the statement that the gas escaping from the Canoga spring is pure nitrogen.

This spring forms a pool occupying a long oval basin of 30 x 90 feet, more or less sunk six feet below the plain. The bottom is covered with sand, through which the water boils up with occasional bubbles of the gas. The taste is that of other good well water of the region, viz.: slightly limy, like Seneca lake water. Within a stone's throw a ledge of Upper Helderberg limestone crosses the road. A considerable flow was noticed at the dryest time of the severe drought of 1895. The stream has supplied power to two mills, one of which is disused. Springs of iron and sulphur are found in the low grounds at Canoga.

A spring of sulphurous odor was tasted in a ravine half way between Willard and Lodi, north of Highland station. Other than the slight odor there was little to remark; the taste was pleasant. This spring is reported to have been formerly used for medicinal purposes by visitors resorting to the place.

The taste of iron is noticed in isolated cases in the country well water. Good water is characteristic especially of the Portage and the Upper Helderberg districts. In the northern part of the county the water is occasionally brackish.

PLATE 9.

Figure 14. **Overwash sand-plain, connected with Kame district, West Junius.**

Several mineral springs have proved to have a commercial value on the west side of Seneca lake and on the east side of Cayuga lake. The possibilities are equally good for Seneca county.

Seneca Lake.

This body of water as far south as North Hector lies within the boundary of Seneca county. The greatest depth, 618 feet, given by the Cornell University survey, is at the southern part of the county; a depth of 400 feet or over is maintained for 28 miles. Its surface is 441 feet above tide; its bottom, therefore, is 177 feet below the surface of the sea. The depth and volume of the water maintains it at a comparatively equable temperature. It is usually open all winter and is cold in summer.

The water partakes of the character of its sources, containing rather large amounts of gypsum, with carbonates of the earthy bases, giving it a "hard" character and causing the formation of crusts on the inside of boilers.

Dredging, undertaken for the purpose of recovering the bodies of drowned persons, was carried on to a slight extent this summer at points near the middle of the lake opposite Willard. The water there is 530 feet deep. It was reported that the dredge encountered no opposition from unevenness of the surface; that there was a foot of very soft ooze, under which was blue clay. The ooze contains a variety of diatoms, of species known to inhabit the fresh waters of the neighborhood.

Superficial currents of very moderate rapidity and changeable direction were observed in places near shore. A more important current is indicated near Geneva, by the muddy streak which it makes at a distance of from a quarter to half a mile off shore. The peculiarity of this current is, that it pushes southward in the face of the violent and continued south winds which are of frequent occurrence in winter in this part of New York. On the first day of such a wind the north end of the lake is muddied by the breaking of the waves on the shore; on the second day a part of the muddy water moves slowly southward in a narrow column or streak on the surface, requiring many hours to accomplish the distance of about two miles, beyond which I have not observed it to extend. Accompanying this southerly movement is a northward flow of the muddy water from a brook just south of the village; this streak being rather near the shore.

Salina Group.

The tract of country north of the valley of the outlet (Seneca river) is within the outcrops of the Salina or Onondaga salt group, and embraces about one-half of the width of its exposure.

This group was divided by Prof. James Hall (Report Geology N. Y., 4th District, 1843) into four sections, viz., 1, and lowest, red shale of Wayne county; 2, green and ashen marl with small quantities of gypsum; 3, gray or ash-colored marls and shales, with thin-bedded shaly limestones, usually of the same color, containing gypsum and salt beds; 4, silico-argillaceous limestone or cement-rock. Nos. 1 and 2 are not seen in the county; No. 3 is seen in Black Brook (Tyre) and at Seneca Falls; No. 4 at Seneca Falls at two points.

The exposures in Black Brook contain only the third variety. A short distance south of Tyre Center it forms the bed of the creek for a considerable distance, with one cliff 15 feet high. The rock is in rather firm slabs of the usual grayish tint.

The most important exposures are at Seneca Falls along both sides of the canal east of the village, where it forms cliffs 20 feet high. In many places the face of the cliffs displays the peculiar method of quarrying for gypsum, by gouging into the rock to secure the lumps of the mineral. Much of the rock has in late years been taken out to lay on the roads, where it forms a solid bed in summer, but in wet weather "turns to slush."

The gypsum is found in the lower part of the cliff, forming irregular whitish masses; there are also thin seams of satin spar and minute crystals of selenite. The shale in which it occurs is of a grayish drab color, weathering into small pieces with a dusty look. The upper layers are more solid, but they have become softened by weathering and break readily in irregular bits. They contain small narrow cavities arranged horizontally.

The best exposure is found on the south side of the canal, west of the cemetery, where an unusual dip of 5°–10° exist. Here 50 feet may be exposed, beginning with the layers already described and closing with some 15 feet of rock belonging to the upper or fourth division, the cement-rock. This is in part a slab-shale, but there are thick courses which fracture irrespective of bedding and expose fine conchoidal surfaces. The rock is very tough and rings under the hammer; it is an argillaceous limestone, dark

PLATE 10.

Figure 19. Delta section, Willard.

buff and bluish, with some lamination streaks. When compared with the exposures at Phelps, Ontario county, it appears to correspond with a series found in the bed of Flint creek at the dams, where contact with Lower Helderberg limestone is found, which is wanting at Seneca Falls.

A very similar rock, in slabs of an inch or two in thickness, has been newly exposed by the roadside, half way to Waterloo, 500 feet west of Kingdom bridge, on the south side. This is the most southern exposure known to me. It is doubtless very near the southern limit (see Upper Helderberg).

A gas well in the southern part of Seneca Falls village is said to have struck Niagara limestone at 980 feet. If we allow 16 miles for the width of the formation, and a northward fall of the land of 60 feet, we have an average dip of 57½ feet per mile to the south. ($\frac{980-60}{.16} = 57\frac{1}{2}$).

This well, known as No. 2, is the southernmost, and is probably not far from the border of the formation. It may be compared with that described by Prosser (Amer. Geologist, Oct., 1890), which is half a mile to the north and considerably east.

	No. 2.	Prosser's.	
Elev. A. T.	445	— 385	= 60
To Niagara rock	980	— 950	= 30

If these data are reliable the dip is here northward.

A comparison of well No. 2 with one three miles north of the village at nearly the same elevation gives a local dip of 40 feet per mile southward. The well in question reached Niagara rock at 860 feet = 120 feet less than well No. 2.

The following is Prosser's statement in full:

"SECTION OF WELL DRILLED .... IN THE SENECA RIVER VALLEY IN THE EASTERN PART OF THE VILLAGE. ALTITUDE, APPROXIMATELY, 385′ A. T.

	Depth.	Thickness.	
		200′	Drab colored, impure limestones.
Salina group.	200′	......	
Salina group.		100′	Blue marls with an occasional red and green chip.
Salina group.	300′	......	
Salina group.		400′	Greenish-gray marls and drab-colored limestones.
Salina group.	700′	......	
Salina group.		250′	Mostly bright red shale, but some mottled red and green shale.
Salina group.	950′	......	
		400′	Dark blue limestone in the upper part, with greenish shales at the base. Niagara and Clinton groups.
	1350′	......	
		150′	Red shales and sandstones of the Medina group.
	1500′	......	Bottom of well."

SECTION OF WELL DRILLED AT ITHACA, TOMPKINS COUNTY, N. Y. LOCATION IN THE VALLEY, ONE-FOURTH OF A MILE SOUTH OF ITHACA. ALTITUDE 396′ A. T.

Depth.	Thickness.	
	340′	Portage shales and sandstones.
340′	....	
	100′	Genesee black shale.
440′	....	
	30′	Tully limestone.
470′	....	
	1142′	Hamilton shales and sandstones.
1612′	....	
	82′	Marcellus black shale.
1694′	....	
	78′	Corniferous limestone.
1772′	....	
	13′	Oriskany sandstone.
1785′	....	
	115′	Lower Helderberg limestones. Approximate top of the Salina group.
1900′	....	
	1285′	Salina group, a part.
3185′	....	Bottom of well according to the contractor, Mr. Rust.

PLATE 11.

Figure 20. Delta section, Willard.

It should be noted that the gas wells struck salt water in the Salina group, and that one well, three miles north of the village, struck a 15-foot layer of salt at 565 feet.

Contact with the succeeding formation is nowhere seen. The width of the interval between the respective exposures is a quarter of a mile N–S. The line of contact lies in the valley of the outlet of Seneca lake, covered with till and sediment.

Lower Helderberg Group.

This important series of rocks, prominent among the formations of the eastern part of the State, mostly disappears before reaching the longitude of Seneca county. For an enumeration of the components of the series, reference is made to the Report on the Geology of New York, Fourth District. The only member of the series of which mention need be made is the Waterlime group. This is found, as stated in the report, in the bed of Flint creek, at Phelps, about four miles west of the border of Seneca county. It there consists of a black, shaly, hard limestone, about three feet in thickness. No fossils were observed.

In Seneca county reference should be made to the description of strata underlying the Onondaga limestone at McQuane's quarry. The waterlime is to be found here, if at any place in the county. The rock is a very argillaceous limestone, in parts very finely laminated and splitting readily in thin sheets; it was not observed to contain fossils.

Oriskany Sandstone.

This formation is well marked at Flint creek, Ontario county, and in several localities in Cayuga county. In Seneca county its absence at the base of the Upper Helderberg limestones is to be noted at the only point where the base is exposed, viz., McQuane's quarry.

Upper Helderberg Group.

This term, as here applied, includes as subdivisions the limestones known as Onondaga, Corniferous and Seneca, this being the order of superposition, with the Onondaga at the base.

The Onondaga limestone is found at one spot, a few feet in area, in Seneca county, with characteristic appearance.

The Corniferous limestone is of a darker color, less abundant in fossils, and contains much hornstone in courses, from which it derives its name. It is sufficiently distinct in appearance to be separated from the Onondaga, though the latter also often contains hornstone.

Seneca limestone is a term given to those courses which overlie the Corniferous layers in Onondaga and Cayuga counties (Vanuxem) and Seneca county (Hall). It is nearly free from hornstone, though certain layers contain it, and the upper tier abounds in it. The presence of certain brachiopods (*Chonetes lineata*) in large numbers is the mark originally proposed as diagnostic. The term is now scarcely used.

Since all these parts of the Upper Helderberg formation occasionally contain hornstone, the word "Corniferous" may properly be applied to the whole. But as hornstone occurs in other geological periods, the preference is given to a geographical name.

The *Onondaga limestone* is described in the Report for the Fourth District as of a light gray color, often approaching white, more or less crystalline in structure and containing numerous fossils; in many instances it seems almost entirely composed of broken and comminuted fragments of crinoidea and corals.

The only exposure in the county is a piece, now reduced to the length of five feet, forming the top layer at McQuane's quarry, two miles S. W. by W. of the centre of Seneca Falls village. It is two feet thick, covered with a few inches of dirt. It corresponds in every respect with exposures at Phelps; is very tough (more so than the Seneca limestone); its surface is weathered to a deep rusty brown, and is roughened by the projection of great numbers of fragments of crinoids, etc. It contains many entire cyathophylloids, and is destitute of flint nodules.

The exposure is apparently an isolated one, scarcely rising above the level of the clay plain, at an approximate elevation of 465 feet A. T. The quarry has been worked in the subjacent rock a length of 150 feet, and a depth of 20 feet, giving favorable exposures. Beginning at the lowest exposed layer there are (A) two feet of a strong limestone, described as of a good quality for building, in one course, which has a tendency to split horizontally; next (B), six and one-half feet, containing considerable impurity, not

PLATE 12.

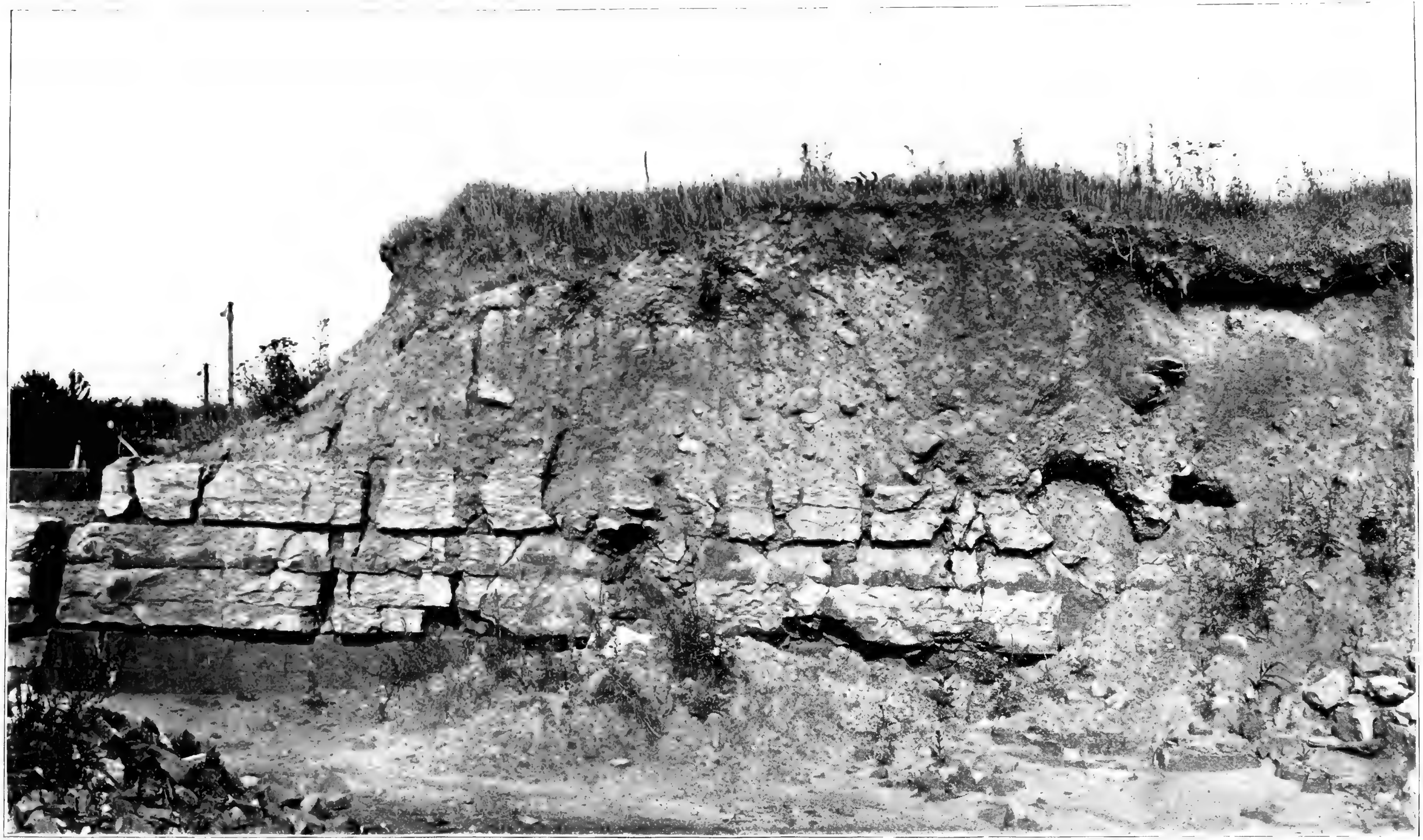


Figure 21. Corniferous Limestone, Thomas' quarry; showing upper flinty layers and till.

separable in layers, breaking transversely and finally crumbling into small blocks, like the Tully limestone, when exposed to the air. C is two feet of tough, fine-grained limestone, somewhat earthy in its upper part. A and B abound in large coral forms, plainly showing in outline on the surface of blocks, but hard to identify and ill-preserved. They are most abundant in the upper two thirds of B, and hardly occur in C, which, however, presents a few forms of small size. This gives $10\frac{1}{2}$ feet of blue limestone in three courses.

Above this is seven feet three inches of a highly argillaceous limestone (D), not found to contain fossils; readily separating into flat pieces an inch and upwards in thickness, especially in the upper parts. When fresh much of it is clear dark blue, sometimes ringing when struck. Weathering gives a buff tint, softens the surface at joints to an earthy consistency, showing the laminæ in earth, and has reduced the top layers (one to five inches) to a sort of yellow ochre. The owner says that C and D are good for making cement.

The junction of D and E was carefully searched, but not a fragment of material resembling the Oriskany sandstone was found. Its absence from this county was noted by Prof. Hall (Rept. 4th Dist., p. 456). The upper layers of D are in thin slabs, weathered to ochreous dirt to different depths, and in places displaying their form up to the level of contact with E. The under side of E is also badly weathered, crumbled into small pieces of an ounce or two. It seems important to have something positive or negative as to the relation of these blue limestones to the Lower Helderberg. They have in part the lithological aspect of that rock as found by S. G. Williams, at Union Springs, but the total difference of fauna is noteworthy.

The Onondaga limestone (E) is unquestionably *in situ*, and quantities lie about among the other rock, evidently recently removed.

The strata dip moderately S. W.

The Oriskany sandstone, an abundant and prominent component of the drift south of Auburn, derived from well-known exposures, is certainly not at all common in the drift of Seneca county, though easily recognized on account of its peculiar aspect.

Corniferous and Seneca Limestones. The outcrop of this rock is near the southern part of the alluvial plain of the outlet, and consists chiefly of a line of quarries, running nearly straight S. E. by E. for seven miles. The rock forms a level sheet near the surface for a considerable space in two or three places. Northward it mostly descends in a slight escarpment to the clay levels. The exposures represent the same strata, or nearly so, in all the quarries. The easternmost, near Canoga (but on higher ground), may be estimated as standing 470+ feet above tide; the westernmost, the same, at the top layer. This is consistent with the supposition of a general dip S. W. by S., the rock being cut off level on the line of strike.

Little can be inferred from the local dips in the quarries; some are to the north, others southerly, while small synclinals of four feet with N–S axis occur in Frank's quarry, and a dip to N., S. W., and S. E., diverges from a common center in Thomas' quarry.

Contact with the Marcellus shale on the south is not observed; exposures approach each other within moderate distances. On the north the only determining point is at McQuane's quarry, which gives a probable width of two and one-half miles on the meridian, or two miles southwest to the nearest Marcellus exposure.

The layers of truly Corniferous rock, rough and ugly with protruding masses of hornstone, which appear near the base of this division in the well-known section along Flint creek, in Phelps, Ontario county, and which may be seen in bowlders abundantly to the westward, are not visible at any section or exposure in Seneca county. The quarries here represent a section of 32 feet, apparently at or near the top, all showing the same horizon; they are practically free from flint in the lower two-thirds of the section. A strip of one and one-half miles of territory lies north of them, unrepresented, except by one exposure at the Waterloo falls.

The Waterloo rock has been largely uncovered during the late drought, in the bed of the stream. The upper two or three feet are tolerably firm, in thick courses with some hornstone, and cavities showing weathering out of fossils. The five feet next below are mostly a disintegrating mass of worthless shaly material; with

PLATE 13.

Figure 22. Corniferous limestone, Thomas' quarry. Actual working.

thin layers of flint in the upper part, near which was found *Styliola fissurella* and a small variety of *Ambocœlia umbonata* in abundance. The lower part of the five feet was comparatively firm, in part pyritiferous and with vermicular cavities.

The geographical site of this exposure would refer it to the lower layers of this formation.

It seems desirable, in connection with this exposure, to place on record those which lie in a direct line north of Geneva village, comprising three quarries, as seen on the map. The northernmost contains a fine exposure of the Onondaga limestone crowded with many species of coral. The middle one is a close counterpart of that at Waterloo falls, being a very black shale, varying from heavy to fine, with *Styliola* and *Ambocœlia umbonata*, small variety, in near association. Other fossils hardly recognizable. The lower layers become tough, retaining a tendency to split, and at about five feet below the level of the above fossils it contains various forms of *Orthoceras* and *Cyrtoceras*, including *C. trivolve* (or *undulatum*, Conrad); not found elsewhere in Seneca county, and lying below the Waterloo stream exposure. The southern quarry presents nothing unusual.

The system of quarry joints was nearly N. 25° W. and N. 75° E., with slight variations, and nearly vertical. The courses differ in thickness, but maintain their individuality remarkably from one quarry to another.

The position of the courses is conveniently referred to an eight-inch layer of light greenish gray material, called "marl" by the workmen, which is constant; it is found also at the Union Springs quarry. It has somewhat the look but not the feel of soapstone; breaks in small flat, thick bits, and cuts easily. It is not plastic. It is a nonhydrated aluminum silicate; a clay, containing small quantities of lime and magnesia.

Besides the marl, there are one or two thin shaly bands; and a number of layers of hornstone, in part forming sheets of one to six inches in thickness, in part separate nodules.

Thin beds of a very small *Zaphrentis* and other small cup-corals are found at different levels, well displayed by weathering and forming good horizons for observation. *Loxonema laxum* of an amber tinge is characteristic of certain levels. *Chonetes lineata* ranges through most of the beds, in varying amount.

The correspondence of the beds in five principal quarries along line of five miles is shown in figure 23.

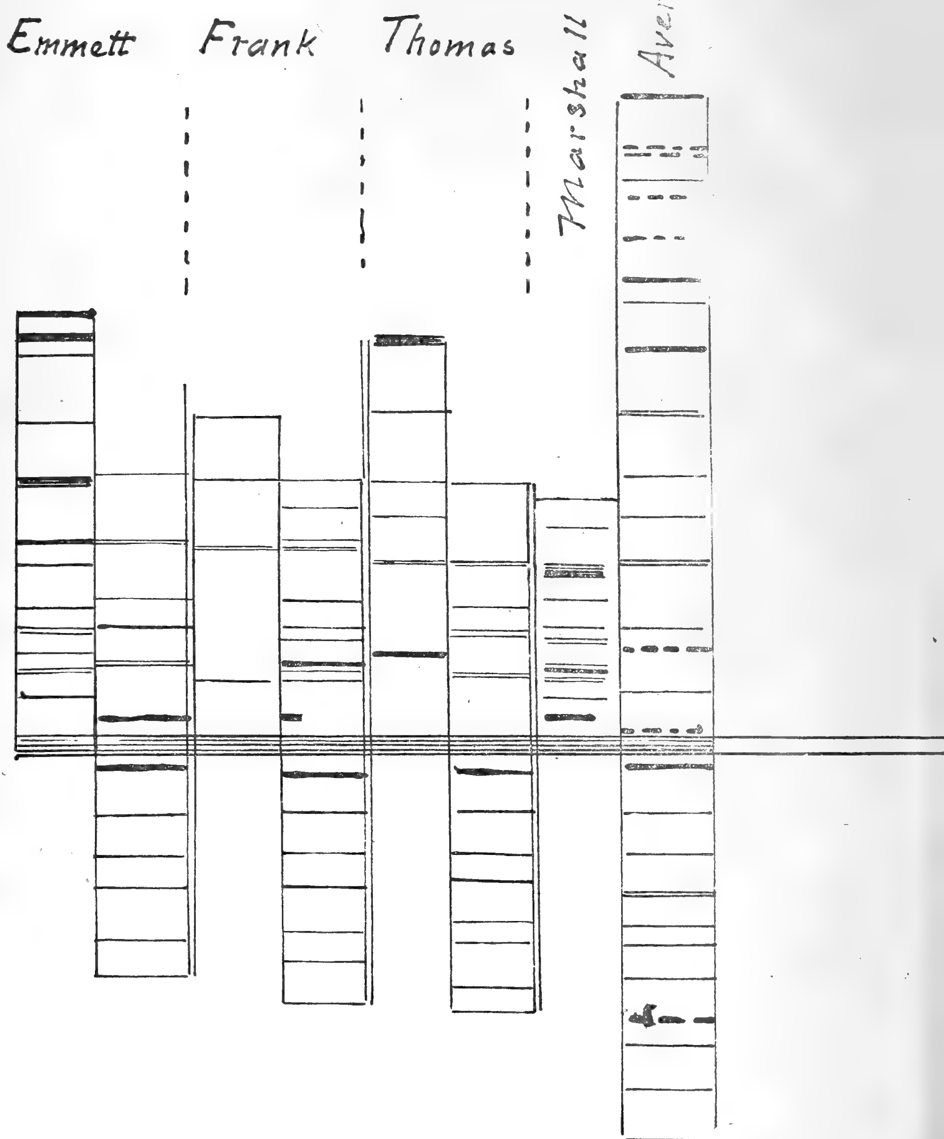


FIGURE 23.

Marcellus Shale.

The nearest approach to a contact of these shales with the limestone is found in a brook running north, one and one-half miles south of Waterloo. Following the stream downward toward the limestone we find (in descending order),

1. The usual black shale (? 20 feet).
2. Crossing the road, eastward, a foot of hard limestone.
3. Blue-black shale, finely jointed, with immense numbers of *Liorhynchus limitaris*, and some *Styliola fissurella*, a few trilobites and orthocerata. Large concretions.
4. Very black shale, sooty in look, with whitish deposit (sulphate of iron); delicate fossil impressions, in part gilded with pyrite. A very fine-grained, tough, nonfossiliferous limestone, two and one-half inches thick, divides this shale in two.

After losing the exposure for some distance, limestone appears in the bed of the brook, in three tiers; the upper two 11 and 4 inches; the lower can not be measured. Upper surface marked with slender curving light streaks, probably of concretionary origin, an inch or two in length; lower tier with hornstone.

This section is typical of the base of the Marcellus in this region. The divisions 3 and 4 could not be measured, but represent only a few feet each.

The thickness of this formation is suggested in several ways. At the northeast corner of Seneca lake it forms the whole base of the hill and rises probably 70 feet along the hill side. The large hill farther south rises 200 feet above the lake; its westward foot in the lake displays cliffs of this rock 30 feet high; its eastward slope of 50 feet is of the same rock.

Two stretches of cliff, previously mentioned, are found along the lower part of Seneca lake, which, with Kendig's creek, form the chief exposures of the Marcellus shales. The belt of country covered is from three to six and eight miles wide — the latter being the distances between extreme exposures on the lake fronts, where for geometric reasons the exposures are prolonged.

Hamilton Shales.

This division comprises two thin beds of limestone and four shales, as follows, beginning at the lowest.

1. Transitional shale.
2. Basal limestone.
3. Olive shale.

4. Ludlowville shale.
5. Encrinal limestone.
6. Moscow shale.

This follows the original division of the reports as regards numbering, with a change of name for the first two, upon which a few remarks are offered.

(*a*) The Marcellus shale retains its character as a dark blue, fissile, handsomely-jointed rock with *Liorhynchus limitaris*, to the top of its beds. The physical character of the shale changes rather quickly to a lighter-colored and more calcareous shale, with a substitution of the Hamilton series of fossils, which becomes so decided as to leave no difficulty in the way of classifying the stratum at six or eight feet above the *Liorhynchus* beds.

(*b*) "A compact, calcareous blue shale, often passing into an impure limestone." (Report of 4th Dist.) The designation "basal limestone," proposed by J. M. Clarke for the strata as observed by him in Ontario county (directly west for 25 miles) is also of practical value for Seneca county. It forms a horizon not easily overlooked by even the inexperienced, on account of its physical contrast with the weak shales among which it occurs. The rock thus designated is physically the same as the transition shale, with increased power of cohesion, and a tendency to form massive blocks, cleavable in clumsy chunks rather than laminæ.

As described in Ontario county it is largely a coral reef. To some extent it retains this character in Seneca county, displaying scattered specimens of *Heliophyllum*, *Favosites*, and other large corals, which do not belong elsewhere near its horizon. Its qualities as a material for road-making have been mentioned to me by farmers. As a geographical factor it is of importance as causing the first series of limitary cataracts, practically marking the commencement of a geological series.

Two such falls have been examined by the writer in the south part of Geneva, in State Rock creek (25 feet fall) and Benton's run (about 10 feet), thus connecting Clarke's observations with the present set.

In Seneca county seven exposures are noted, viz.:

1. For half a mile along the shore of Seneca lake north of Dey's Landing. One or two feet exposed. Impure, easily broken

PLATE 14.

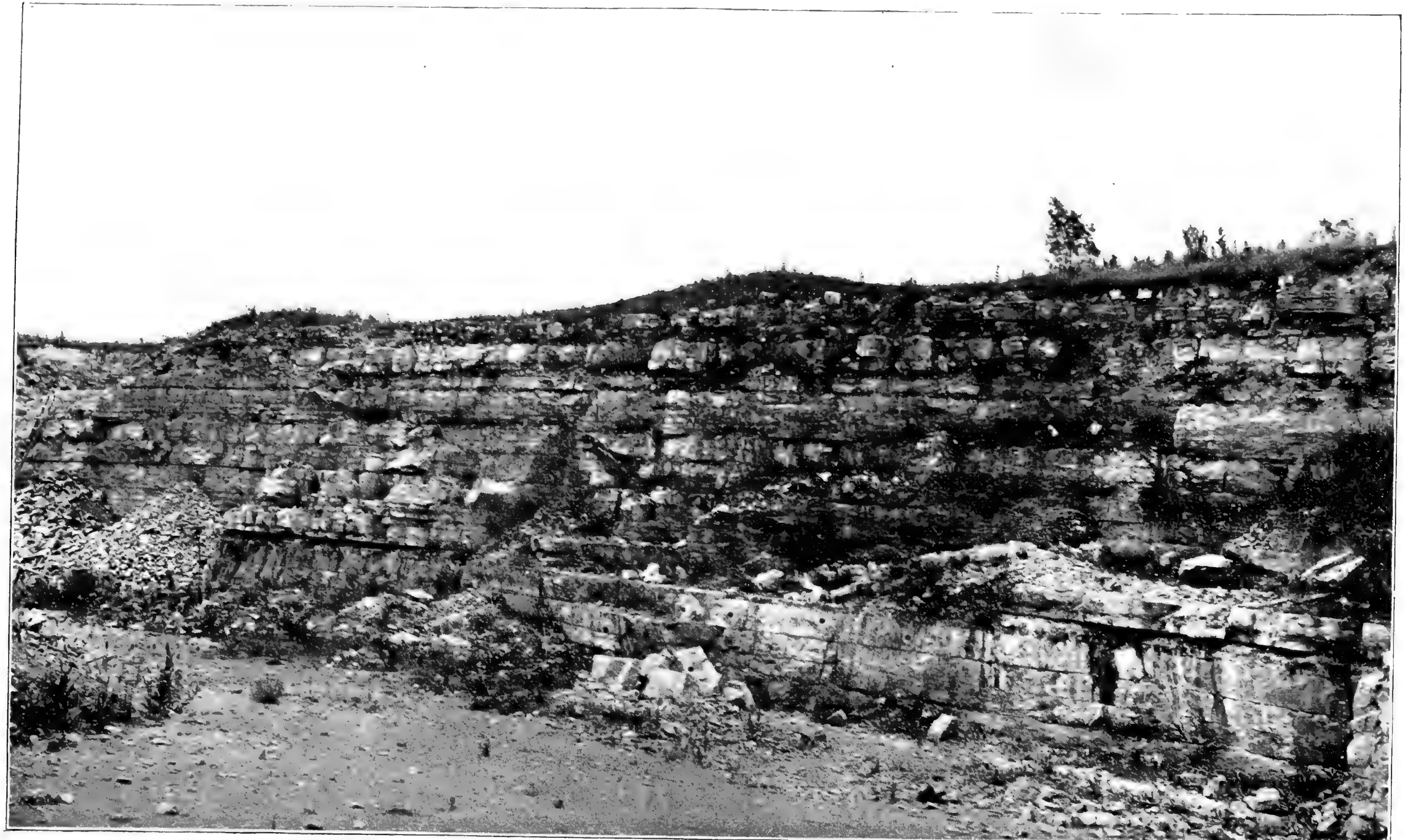


Figure 22a. Corniferous limestone, Avery quarry.

limestone, containing various *Zaphrentis*, *Heliophylla*, etc.; above it, shales with typical Hamilton fauna.

2. Reeder's creek, about 1,000 feet from the latter lake, similar, 8–10 feet thick, with 5–10 feet of transitional shale beneath, and Marcellus at base of bank. *Heliophyllum Halli* frequent. Large favosite. A furlong or so up the stream a fall of four or five feet occurs over this rock.

3. Large hill, N. W. of West Fayette station (MacDougal's P. O.). Here it forms a flat surface on the summit (200 feet above the lake), and an escarpment to the north; numerous corals are to be found in the field, but there is no direct exposure of the ledge.

4. Gully of Kendig's creek, one-quarter mile east of MacDougal's. The underlying Marcellus well displayed in bed. Steep fall of nearly 15 feet with mill (now run by steam). Large favosite; heavy blocks.

5. Creek, a mile west of Bearytown (Fayette P. O.), Hamilton fauna; heavy rock, rapids descending 10 feet.

6. Creek a mile S. E. of Bearytown; an old mill site. Directly above Marcellus exposures are 12 feet of limy rock breaking in irregular conchoidal masses, large and small, with horizontal tendency. Sparse Hamilton fauna. *Heliophyllum Halli* and another coral. Fall about 10 feet.

7. Big Hollow creek, eastern Romulus. Fall of some 30 feet vertically over heavy limestone ledge. Marcellus below down to lake. Hamilton fauna.

The northern boundary of the Hamilton shales is drawn upon these data. Exposure 3 may be insular; it is covered with drift to the southward. The Tully limestone lies seven miles to the southward, which is the width of the Hamilton exposure along the plateau. Along Seneca lake, on and quite near the shore, the Hamilton runs $12\frac{1}{2}$ miles—from Reeder's creek to the landing next south of Lodi Point.

Tully Limestone.

This highly developed limestone formation, lying between the shales of the Hamilton and Genesee divisions, acquires great importance as a geological horizon. Its outcrops have, therefore, been studied with care. (See fig. 26.)

The first one to be mentioned, being the northernmost, is rather more than a mile west of Hayt's Corners, on a rise of ground facing north, and forming a low escarpment. It is represented in figure 24, which is taken looking westward. The impression is correctly conveyed of the level prairie country in which the hill occurs.

The elevation of Hayt's Corners above mean high tide, furnished by the kindness of Mr. Esser, Sup't of Division, Lehigh Valley R. R., is 791.3 feet. The road ascends westward for a half mile, descends slightly and reascends to the same height. With a hand-level the elevation of the top of the rock was estimated at 50 feet above the station, or 840 A. T. There is a chance of an error of a few feet (perhaps five) in this statement. Thickness less than 11 feet, resting on Hamilton shale. The upper part may have suffered loss from erosion. The rock has been quarried to furnish road material.

The next exposure westward is at Willard Hospital, where a cascade falls over Tully limestone near the reservoir. Here the contacts are perfect above and below; thickness at fall 11½ feet. The rock displays a considerable dip, east, west and south, and has been largely quarried for road building. From data obtained at the Hospital the top of the reservoir appears to be 599 feet above tide; top of quarry-rock 45 feet, less, say 554 feet. There is no indication of rock in the conformation of the country between these two exposures, nor between this and following ones, for which we have to depend on cliff and stream exposures. The thickness, measured at Highland station in creek, was 11½ feet; at Lodi, main glen, 13½; Deer Lick Run, 12½.

The rock appears at the Seneca lake front about a mile south of Willard Landing. When first seen it is *emerging from* the lake, reaching the height of 15–20 feet in one quarter of a mile southward and fully displayed. The dip beneath the lake can be but slight, as Hamilton shale is found 200 feet north of the emergence. In the next creek (Highland station) it is found in a waterfall 900 feet from the lake and 50 or 60 feet above it. It caps the cliff for one-half mile, beginning some way south of Highland; height, 40–50 feet. In the next deep glen it is 40 feet above the lake at 400 feet from the shore. At Lodi it comes within a few feet of the lake level.

PLATE 15.

Figure 24. **Escarpment of Tully limestone, north of Ovid (northernmost point).**

A very interesting exposure occurs in the main (southern) glen at Lodi. Near the mouth of the ravine it begins in full thickness, with Hamilton shale below. It forms the bed of the stream for a quarter of a mile, dipping on the average N. W. The view shows the upper beds eroded by the stream, with Genesee shale above. When last visible it presents its upper surface as the bed of the brook with Genesee upon it, having risen about 40 feet.

This anticlinal is seen in the next hollow, its top 55 feet above the lake at 400 feet from it, and in the hollow, a mile south of Lodi landing (at a small wharf), it is again seen at 50 feet at a greater distance back. The shore is here composed entirely of drift. This was the last distinct exposure noted. Genesee shale appears half a mile farther south in the cliff.

Returning to the high point whence we started, we find a low swell of land running E. by S. from the quarry, for some distance very full of the pieces of the rock. Toward Hayt's Corners it has been opened in places. I was told the drift was not thick. At the Corners the Ovid branch railway cuts across the limestone and Hamilton shale a few rods south of the station.

Its further course is determined by a quarry a mile S. E. of the Corners, thence by considerable falls in Grove's creek, Sheldrake creek, the stream next north of Kidder's and the series of streams for two miles south of Kidder's. In two of the latter, the formation is 13½ feet thick. It comes within a few yards of the lake at Bergen's Point, where it forms a fall, about 25 feet in height, in Shepson's gulley. Thence it slowly descends, reaching the level of the lake in about three-fifths of a mile, and entirely disappearing beneath the lake at two and one-half miles, or a mile south of Little Point. The Genesee shale is visible in one or more places on the shore.

Genesee Shale.

This is well displayed in most of the gullies of Ovid, Lodi and Covert. Its base is defined by the Tully limestone. Its upper limit is fixed by two feet or more of harder material, forming the base of the Portage system, to be described hereafter.

The thickness of the formation in the well at Ithaca, as given by Ashburner and Prosser, is 100 feet. Along Seneca lake there is opportunity to allow a larger figure, but owing to the difficulty of determining dip in this rock its precise thickness remains a matter of conjecture. In the creek at Highland Landing, the entire height of the bank (about 120 feet) is exposed in one spot by a road descending into the ravine; the entire section here is within the Genesee. Addition must be made to a moderate but uncertain extent, corresponding with exposures in the bed of the brook for a furlong or more, down to a cascade formed by the Tully limestone.

The exposures in Lodi glen present the same difficulty as regards dip. The Tully limestone dips between N. and N. W. for the great part of its exposure, and the Genesee a little west of (D) the main fall, dips in the same direction for a short distance, but the reverse may be true in the interval C–D. The data of elevation were obtained as follows:

A–B, 20 feet, hand-level, somewhat uncertain.
B–C, 50, the same, more reliable.
C–D, 90, three aneroid observations agreeing closely.
Height of falls, 125, Gibson's map. Includes 7 feet of Genesee.
Chasm above falls, from rails on bridge, 60, aneroid repeated.
Total, 338.

Elevation of track at station close by, 785 A. T. Seneca lake, 441; track above lake, 344; error, 6.

The lake side exposures are poor on Cayuga lake. Those on Seneca lake (fig. 26) begin one and one-half miles south of Lodi Point and disappear under the Portage beds at Faucett's Point, a short distance north of the county line. They do not define the thickness.

In the "Higher Devonian Faunas of Ontario County, New York," by J. M. Clarke, a peculiar layer is described as occupying a position near the middle of the Genesee shale from Canandaigua lake westward. This layer consists of a hard limestone, more or less schistose, a foot in thickness, composed almost entirely of shells of *Styliola fissurella*, and hence named the Styliola limestone. Search was made for this rock along the Seneca lake exposures, but without success. The exposure of

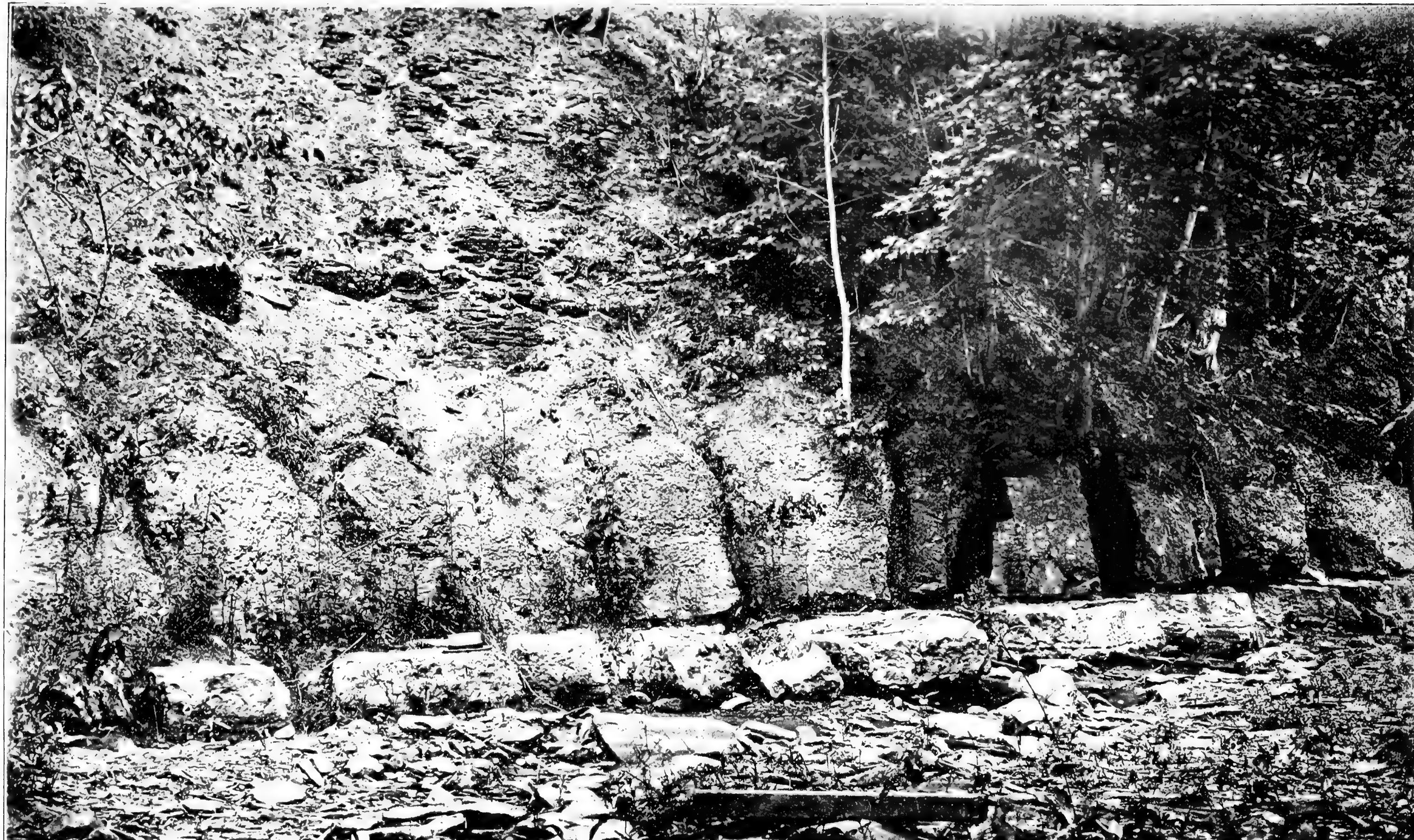


Figure 25. Contact of Tully limestone and Genesee slate; Lodi.

120 feet in the bank of Highland creek ("Sixteen-mile creek" of Gibson's map) is an advantageous one, and was attentively scanned, but with negative results. The possibility remains that it exists in the lower layers in the stream-bed, but its presence is not indicated by any falls, in this or other ravines.

Portage Beds.

The transition from Genesee to Portage in Tompkins county is effected, according to H. S. Williams (Fossil Faunas of the Upper Devonian, p. 10), by "two thick sandstone layers separated by a few inches of shale, the whole about four feet thick; in these sands and shales there are great numbers of pyrite nodules from the size of a pea, or smaller, to an inch and over in length. No fossils were observed in these first beds. Following the sandstone are the sandy shales, characteristic of the Portage group," etc.

The corresponding layers are well shown in the base of the cliff just south of Faucett's Point; also in the two Lodi glens, especially the southern one. At Faucett's, the layers in question are covered with water in some stages of the lake, and hence the rock displays chemical erosion, with cavities marking the disappearance of pyrite. They comprise a mass of heavy gray and green sandy shale, two feet and more in thickness, which is sometimes compacted in nearly solid courses, and sometimes is indistinguishable from the shale above it. The upper part (one foot or more) was not observed to be fossiliferous. The lower foot varied from point to point; now consisting of large concretions of very tough limestone with pyrite nodules (above noted); now embracing considerable masses of small branching coral (cladochonus), which serves to identify the corresponding layers in Lodi glen; and again, consisting of only a thick bedded, irregular sandy shale. The band here described was traced for 1,000 feet north of the Point; still further north its presence was indicated by large fallen blocks containing the coral.

At Lodi the band runs some six to eight feet above the base of the falls. It is difficult to trace it along the wall of the ravine; it varies in apparent thickness and becomes merged in the other shales.

For a description of the fauna of this basal rock the reader is referred to a note kindly furnished by J. M. Clarke.* No distinction was found between the different localities, in respect to fossils.

The "Transition shales," of wide distribution in Ontario, Yates and Livingston counties, are faintly indicated in three or four feet of shale at the foot of the Lodi fall, and a little at the top of the bank in Highland creek. At Faucett's they are absent.

Above this layer there is green sandy shale with a few layers of thin hard sandstone. This material, however, is replaced twice within the first hundred feet, as may be seen in the sections (figs. 26, 27) — first, by 10 feet or more of excessively frail black shale, stained brown by iron, and second, by a 40-foot layer of less fragile black shale quite like the Genesee. Sand-

* NOTE.—This irregular concretionary and impure calcareous stratum which Dr. Lincoln describes as occupying a well-defined position at the top of the Genesee shales carries a fauna of considerable interest. The preservation of the fossils is execrable, and it would be highly difficult to get any conception of the fauna from an examination of the stratum without artificial helps, but a simple process which I have long used for the elucidation of fossils from just such argillaceous limestone as this, has served to bring out a pretty full illustration of the fauna so far as represented in the material which has come into my hands. It may be of use to others if this process be briefly explained. The given condition is an impure argillaceous or arenaceous limestone with the substance of the fossils a semicrystalline calcite. To any manual process employing tools, the elucidation of the fossils in such a matrix would be insolvable. Let small fragments exposing fossils in section be placed in dilute muriatic acid until the calcareous matter is removed to a sufficient depth from the surface to leave all impressions of fossils at the surface perfectly clear. The argillaceous or other impurity of the matrix left after the reaction will be exceedingly soft, but retain the impression, whether external or internal, with exceeding delicacy of detail. The fragments may then be carefully removed from the acid and washed by placing for a moment in pure water. They should then be thoroughly dried, and afterward hardened by cautiously soaking in a very weak solution of glue, care being taken that this solution be sufficiently thin to enter all the ornamental or structural cavities and interstices of the impressions. After again drying, sharp, clean and clear squeezes are to be taken with soft gutta-percha. To preserve the hardened matrix such squeezes must be taken rapidly lest the heat of the gutta-percha soften the glue and cause adhesion. If, however, the destruction of the matrix is not of moment, the gutta-percha may be withdrawn at will and the adhering dirt soaked and washed off at leisure. In my own experience this process has given extremely happy results, detail being reproduced with surprising delicacy. In illustration I may especially quote the calcareous shales of the Hamilton group from which have been obtained many such replicas of well-known species which portray a surface ornamentation in some instances barely suggested in the published illustrations. The following species have been recognized by the use of this method, in this limestone at Lodi Falls.

(*cc*= abundant; *c*=common; *r*=rare.)

Goniatites Patersoni, Hall, small form.................... *r*
G. sp. a small form with sutures like *G. sinuosus*.................... *r*
Bactrites sp.................... *c*
Gomphoceras cf. *manes*, Hall.................... *r*
Palæotrochus præcursor, Clarke.................... *c*
Pleurotomaria capillaria, Hall.
There are two varieties present of this species, one of which surpasses in size that prevailing in the Hamilton shales, while the other is considerably smaller. They are quite distinct in aspect though not separable from the species. Both are abundant.................... *cc*
Loxonema Noe, Clarke.................... *cc*

stone in considerable quantities occurs after the first 100 feet; sparsely below. Rows of concretions occur at frequent intervals in the cliff.

The lower sections, as seen in Ontario county, exhibit a like recurrence of material lithologically similar to the Genesee shale — itself a recurrence of the Marcellus shale. As described by J. M. Clarke they comprise, 1, green shales and a little flagstone, 10 to 15 feet; 2, black bituminous shales, the "lower black band," about 40 feet; 3, greenish soft or sandy shales with flags and many concretions, not less than 150 feet; 4, black shales, 5 to 10 feet; 5, flagstones and sandy shales, 150 feet. Above this lie 600 feet of heavy-bedded gray and greenish sandstones, with some flags near the base.

H. S. Williams estimates that the Portage fauna in the meridian of Ithaca is distributed through approximately 1,300 feet of strata. Clarke estimates the Portage rocks for Ontario county at 600–700 feet.

We may assume 1,200 feet as a large allowance for the thickness of the Portage beds in the western part of Seneca county.

Loxonema variety, with very fine ribs	r
Styliolina fissurella, Hall	cc
Buchiola retrostriata v. Buch	c
Palæoneilo muta, Hall	c
P. sp.	
Lunulicardium fragile, Hall	c
Atrypa reticularis, Lin	c
Ambocœlia umbonata. Hall	c
Spirifer like *S. subumbona* with minute, erect spinules on the concentric surface lines	r
Chonetes scitula, Hall	c
Liorhynchus mesacostalis, Hall	r
Orthothetes, a small species occurring in the Portage fauna of the Naples section	r
Orbiculoidea, a very small form	r
Lingula spatulata, Hall	c
Cladochonus, a species occurring throughout the central New York sections at the base of the Portage; in the Canandaigua lake section also in the Styliola limestone	cc

After careful examination Dr. Lincoln reports no evidence in Seneca county of the *Styliola limestone* which seems to appear first in Yates county and extends thence westward nearly to Lake Erie; a layer lying in the midst of the Genesee shales and containing many fossils which characterize and herald the fauna of the Portage group.

The fauna of this Lodi limestone is especially to be noted for the following points:

It shows the incoming of a true Portage fauna (fauna with *Goniatites intumescens*), as evinced by *Gon. Patersoni*, *Palæotrochus præcursor*, *Loxonema Noe*, *Pleurotomaria capillaria*, large form. It also carries certain brachiopods which show the continued influences and presence of the Ithaca fauna or eastern representative of the Portage group: *Atrypa reticularis*, *Liorhynchus mesacostalis*, *Spirifer* cf. *subumbona*, species which do not appear in the true Portage fauna. In view of the earlier appearance of a concretionary limestone layer in the Genesee shales (Styliola limestone) in more westerly meridional sections where the normal Portage fauna is developed, in which a true intumescens fauna appears, similar to that here noticed except in the absence of the certain brachiopod elements, as well as the pre-eminent absence of calcareous layers from the arenaceous Portage beds, I should be disposed to regard this layer as the final stratum of the Genesee division.

J. M. CLARKE.

The highest points in the county are about Prospect hill, and may be estimated (no data being on record) at 1,200 or 1,300 feet above tide = say 800 feet above Seneca lake. From this it appears probable that the highlands of the southern part of the county fall short of the uppermost Portage beds by several hundred (400 ?) feet. The thick-bedded sandstones of the highest beds do not appear on these hills.

Thickness and Dip of Rocks.

The necessity of revising our estimate of the thickness of the formations of central New York has been pointed out by Prosser in the American Geologist for October, 1890.

For the Salina group we have the evidence of several wells drilled for gas, which give a probable thickness of about 1,000 feet, the southernmost well indicating an actual 980 feet. At Geneva the Nester well went 1,200 feet to the Niagara; from which must be subtracted the thickness of the Corniferous and part of the Marcellus, say 100 feet, leaving a probable 1,100 feet.

The thickness of the Upper Helderberg, as far as exposed, is $32+8+2=42$ feet, but is doubtless considerably greater. These figures represent the Avery quarry, the Waterloo river stone and the Onondaga limestone at McQuane's.

The Corniferous limestone measured at the Ithaca well 78 feet.

The Marcellus can not be closely estimated. Clarke considers it about 100 feet thick in Ontario county, but farther west its upper limit becomes very uncertain. Ithaca well, 82 feet. The Hamilton was estimated by Hall at "not less than 1,000 feet" in this region. The Ithaca well gave 1,142 feet. The distance from a mean point in the Hamilton to Ithaca is 25 miles; that from a mean point in the Salina to Ithaca is 42 miles; and the change in the thickness is very great, being perhaps at Ithaca twice what it is at Seneca Falls.

The Tully limestone is not far from 12 feet in thickness. In Ithaca well it was 30 feet, with which compare S. G. Williams's statement that the thickest outcrop at Cayuga lake measures 18½

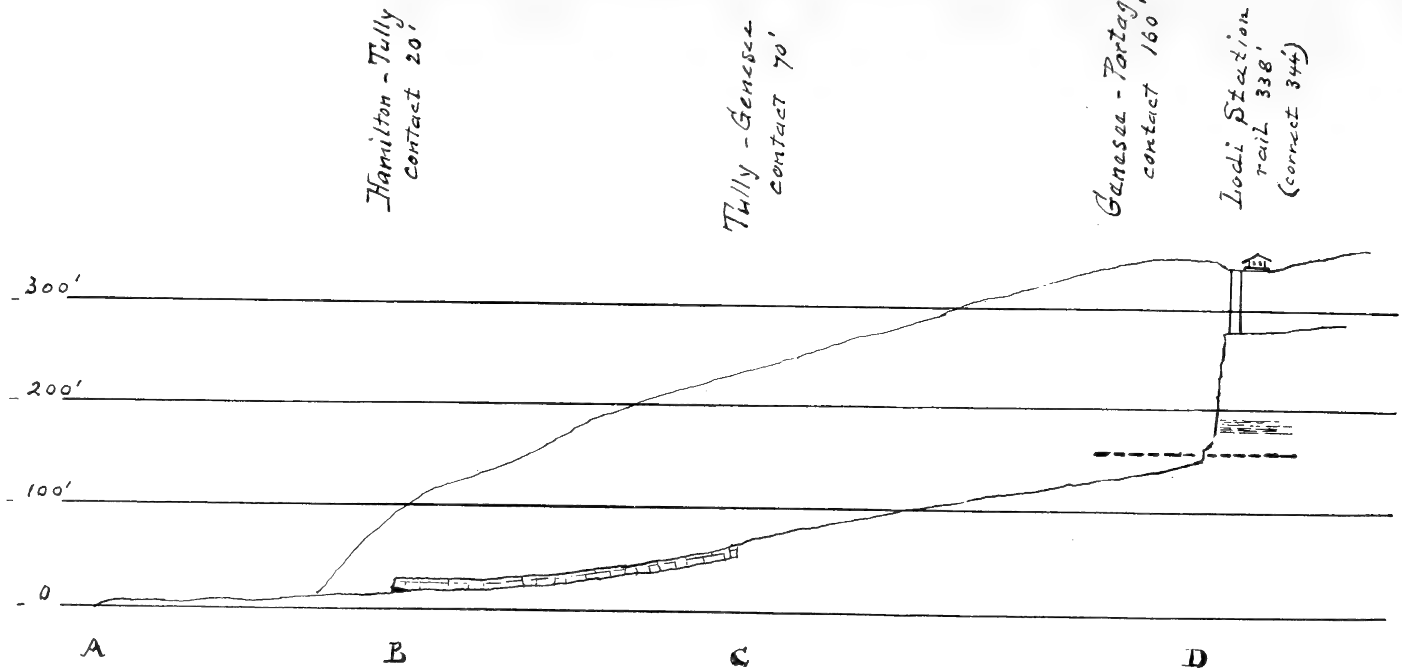


Figure 27. Section of the larger glen at Lodi.

feet; that it is generally thicker in the Owasco valley, one section being 23 feet thick.

For the Genesee shale the Ithaca well gives 100 feet. It appears to be thicker at Lodi and Highland.

The following is a part of the table given by Prosser for the Ithaca well, quoted from Ashburner. It is in the valley one-quarter mile south of the town, 396 feet, A. T.

Depth.	Thickness.	
....	340	(lower) Portage shales and sandstones.
340	....	
....	100	Genesee black shale.
440	....	
....	30	Tully limestone.
470	....	
....	1,142	Hamilton shales and sandstones.
1,612	....	
....	82	Marcellus black shale.
1,694	....	
....	78	Corniferous limestone.
1,772	....	
....	13	Oriskany sandstone.
1,785	....	
....	115	Lower Helderberg limestones.
1,900	....	
....	1,285	Salina (not through).
....	....	Bottom of well.

The *dip of the strata* is also more steep than has been supposed.

Instances of local disturbance and reversal of dip are frequent. Examples: Seneca Falls, river, excessive to S.; Corniferous quarries, dip in all directions; Tully, two anticlines on Seneca lake; quarry at Willard; Genesee, small anticline of 15 feet height in railroad cut at Willard.

A general inclination to the S. W. is commonly noticed by quarrymen in the east side of the county, among the sandstones. The same may be assumed with probability as the cause of the oblique position of the Upper Helderberg beds across level country. S. G. Williams assumes it as representing the dip of the Tully; in which I must concur with him. The leading facts in the case of the Tully are these:

From the most northern exposure the Tully descends 400 feet in four miles, into Seneca lake; then runs four and one-half miles practically on a level; *i. e.*, with two bends of 50 feet, ending at the lake level again. From the northern exposure to a point near Cayuga lake equivalent in altitude to Seneca, brings us to the creeks just south of Kidder's Landing, two miles farther south than the foot of the western dip. It is nearly level for three miles south of this. A line connecting these points runs about W. 15° N., and may be taken as the axis of the fold. A line drawn from the northern exposure vertical to this line would be three miles long, which would give a dip of $\frac{400}{3} = 133$ feet to the mile, at this point, succeeded southerly by nearly horizontal strata for a few miles The important anticlinal south of Trumansburg does not affect the county.

Subordinate in magnitude, but confirmatory, is the dip of the Hamilton in the western part of Fayette and Varick. The single exposure of the base of the Hamilton, in the form of a coral bed or reef on the summit of a hill, 200 feet above Seneca lake, is rediscovered at the lake level four miles S. 15° W.; and at two and one-half miles, perhaps 25 feet above the lake in Reeder's creek. The latter corresponds to a dip of 70 feet per mile.

The general average of thickness for the Hamilton group may be taken between West Fayette station (608 A. T.) and Willard quarry, eight and one-half miles due south (555 A. T.). Allowing 53 feet in addition to 1,142 (Ithaca well), we have, in round numbers, $\frac{1200}{8\frac{1}{2}} = 141$ feet dip to the mile. Using Hall's estimate we have $\frac{1050}{8\frac{1}{2}} = 123$. Measurement along the supposed axis of dip N. 15° E., does not materially alter the result.

It is evident that the dip of the Marcellus and the Upper Helderberg is at a very different angle from the above, unless our estimates of their thickness are altogether wrong. It is uncertain where their upper limit lies. There is a distance of 8 + miles between known exposures, from Waterloo to bluffs north of Reeder's creek, on the same level. On a N–S line 10 miles is not improbable, giving $\frac{160}{10} = 16$ feet of dip per mile.

It is easy to play with figures; but perhaps the fairest average tate ment is the following, which is based on exposures at the

PLATE 17.

Figure 28. **Tully limestone on Cayuga Lake shore, Taughannock.**

water's edge, as near as ascertainable, along the western line of the county:

FORMATION.	Thickness.	Distance.	Dip per mile.
Salina	1,000	6 (+10)	62
Upper Helderberg Marcellus	160	10	16
Hamilton	1,100	9	122
Upper Devonian	250 ?	$7\frac{1}{2}$	33
Mean	2,510	$42\frac{1}{2}$	60

Omitting the Salina and measuring obliquely from McQuane's (Upper Helderberg) to the S. W. corner of the county, we have the same result, viz.: $\frac{1510}{25\frac{1}{4}} = 60$ feet dip per mile.

Clay, Brick, Tile.

Most of the clay in the county is included in the belt previously described, and is of glacial origin. It was deposited when the lakes were much higher than at present; a condition generally referred by geologists to the closing periods of the Ice-Age. In a wider sense, all the clay of this region, including late deposits in isolated hollows, is "glacial," inasmuch as its particles must be derived from the general covering of till.

A distinction is necessary between the clays of the Hudson River region and those of central and western New York in this latitude. Of the former it is noted that the upper layers are yellow; from Syracuse to Buffalo the same layers are deep red.

The under clay, in Seneca county, is called "blue" by those who make brick and tile, but the name is applicable only by a technical fiction. The color is simply a lighter red, varying in shade. When burnt, however, it turns a light buff, while the top, or "red" clay, turns red, increasing in darkness as it is longer baked. This difference doubtless arises from the presence of a considerable amount of lime carbonate (and magnesium carbonate), which has been removed by leaching from the upper layers.

The most interesting section of clay lies a few rods beyond the county limits, to-wit, in the north part of Geneva near the Lehigh Valley station. The top of the bank is here 50+ feet above the lake. As this is a part of the clay sheet of Seneca county, I take leave to describe it, using "red" and "blue" in their ordinary meaning.

SECTION OF CLAY, TORREY PARK, GENEVA.

	Feet.	
Red clay at top, not showing lamination, not effervescing with H Cl	1	1
Red clay, well laminated. Reaction to H Cl, in the lower 1½ feet. Some little stones at 3½–4½ feet	4	5
Sand with some folia of red clay, mostly level stratification	9	14
Purplish-blue and dark blue clay (running 60 feet), 6 inches thick. Sand, 6 inches	1	15
Purplish blue clay 4 inches, runs 90 feet. Mostly sand, about 5 feet	5	20

The blue clays and the sand between them reacted to HCl. This is the only blue clay in the belt from Geneva to Cayuga lake, as far as seen, except at Thomas' quarry. Another typical section gave the following:

	Inches.
Clay of upper part unstratified in appearance.	
Lamination broadly seen at	20
Reaction to H Cl, none, down to	24
Lamination quite plain, reacts well	26
Concretionary layer (clay dogs) begins	30
Tough quality of clay continues to	34
Change to a lighter, buff clay containing much sand, reacting at all points	44
—— Continuing to	75

These sections illustrate the effect of oxidation and leaching, in the following points:

Color, due to formation of hydrated iron peroxyd.

Decalcification, to depth of two to three feet, indicated by loss of reaction to HCl.

Concretions, a usual phenomenon, at a little way below the limit of decalcification. They are mostly from one to four inches in size; soft and impure; of a very light chocolate color; in the form of disks, oddly grouped, placed horizontally, or of fingers, placed vertically.

Loss of lamination, the upper clay becoming a uniform dark chocolate mass, breaking in cubic forms.

Pebbles of limestone generally disappear from the decalcified part.

The channel of a rivulet, 15 feet deep, occurs at this place, bringing the section to an end. The oxidation changes follow the slope down; the physical changes and the reaction-point keeping at the same distance as usual from the surface.

The lamination of the lower or "blue" clay is often marked by delicate folia of the finest sand; by alternations of chocolate, brownish and bluish tints; and by a beautiful alternation of shades from brick red to cream color in the clay when burnt without kneading. By selecting the proper layers of "blue clay" a cream-colored brick of great hardness and good appearance has been produced at Geneva. It is worth while to ascertain whether such material can be used for making ornamental pottery.

A peculiar section was shown at Seneca Falls in excavating for the cellar of the new hotel, about 440 feet A. T., in 1894. Total thickness, 6–7 feet.

1. Loose top-soil, moderate depth.
2. A whitish clayey layer.
3. Chocolate-colored clay in places, not laminated.
4. A whiter clay with distinct lamination.
5. For the lower foot or two the material resembled disintegrated till, being composed of sand, gravel and stones, many of which have the characteristic shape and striations of till-stone. Too little compact for till, and not considered as "hard-pan" by the diggers.

At Thomas' quarry, south of Waterloo village, two sections of clay, etc., upon the limestone knoll, 50 feet (?) above the level of Seneca river and lake. (1) Till, 5 feet; red clay, handsome and well stratified, 18 inches; tawny fine sand, 6 feet. (2) Till absent; darkish, purplish clay, interlaminated with blue, 16 inches; red clay, 30 inches.

The clay at Willour and Pontius' tilery, five miles south of Waterloo, is classed with the other clays of the red belt. It lies in the valley of Kendig's creek; at 100+ feet above Seneca lake.

Rorison's quarry, two miles south of Seneca Falls, is covered with 30 inches of the red upper clay.

The clay at Yerkes' tilery, in Romulus, is a slate blue, associated with vegetable matter and shell deposits.

The eight-inch layer of gray, fossil clay, described as occurring in the Upper Helderberg limestone, is in too small amount for practical uses. It was tried with poor success at the Waterloo tilery; it burns to a light color.

Much clay exists in local sheets and patches, in the uplands, of which I have not been able to take account. In Covert, near the lake, are stated to be thick deposits of yellow clay. The chocolate clay of the delta-terraces has been mentioned; some of that kind was once used for making brick at Willard, but it is not found in sufficient quantity, and their present supply of bricks is made elsewhere. In Tyre there are scattered deposits of clay; bricks were formerly made at Tyre City, but the clay is said to be too sandy, not sufficiently stiff, and not abundant.

Four establishments produce drain tile, two brick (one idle), and one combines the two manufactures. The tile is of excellent quality. The brick is serviceable rather than ornamental.

A. Whartenby, of Waterloo, makes Agricultural Tile.— The first manufacture of this article in New York was commenced by Benj. F. Whartenby, at Waterloo, in 1839–40, using Scotch tiles as models. They were at first made on a wheel, and with his son's assistance in mixing and preparing clay, he was able to make 300 or 400 in a day. This manufacture was begun at the instigation of Messrs. John Johnston and John Delafield, who subsequently (1848–9) imported an English tile machine for Mr. W.'s use, by which 2,000–3,000 could be made in a day. The figures are given from memory by the son, A. Whartenby, who now runs the establishment. This machine was worked by hand; it was used 10 or 15 years, and is now preserved in the Agricultural Museum at Albany. Previous to its purchase the tiles were made by rolling clay into a sheet and wrapping it around a wooden pin.

The work is done at present with an Abr. Latourette's machine, run by horse power, capable of turning out 2,500–3,000 in a day, according to sizes. The kiln holds 10,000–12,000. The men are on reduced time, so that 10 days are required to fill the kiln. Burning takes three days and nights; cooling two days; removal one day. The average product is 50,000–75,000 in a season. Two patterns are used, the horse shoe (from $2\frac{1}{2}$ to 12-inch diameter), and the flat-bottomed (2 to 6-inch). The clay is got from a field on the north bank of the canal, in the western part of the village. The beds run a foot below the water level. They comprise two feet of red clay on top, separated from five feet of blue by a few inches of alternate sand and clay. The strata dip toward the canal, the sand becoming very thick. The clay rests on quicksand. The "blue" is red with a purplish tinge. A portion of red clay is also found five feet below the surface, under the blue. The blue is said to be too "strong," *i. e.*, tenacious and adhesive, by itself, and is improved by admixture of the red.

The clay is put into a bin and used as fast as wanted. It is mixed by hand in the bin, shoveled into the drum of the machine, where it is cut and "tempered" with knives, forced through a screen to remove stones, and at last pushed through a die upon revolving rollers.

The fuel is wood, as is usual in these parts.

It is claimed as an advantage for this tile, that it is more porous than some others.

Wm. M. Culley, successor to Dixon & Whitwell, Geneva Tile Works, address Geneva. Located in Waterloo, near the Geneva boundary, in low land at foot of lake. The red clay at top is three feet thick, the blue is of unknown thickness, and for reasons connected with drainage has been cut only five feet. It is cut in the fall and weathers until required in the spring. The season for making tile is from May 1 to the beginning or middle of September; the moist unbaked tile is spoiled by frost. The two clays are mixed, wet, in a pugging machine run by one horse. No sand is added. Next season it is intended to cut only four feet of blue clay. Stones have to be removed by hand. The tile is made in two Dunning hand machines, each run by two men. It is piled in a Dixon's kiln, holding 30,000, the process requiring two or three days. Burning takes four days and three nights; cooling, three or four days; unloading, two or three days.

There are two kinds made, pipe and horse-shoe; the latter is liked for low-lying grounds, and is set on boards in the trench; is thought not to break. The diameters of the pipes are of five grades, ranging from two to five inches; of the horse-shoes, two and one-half, three and four inches. The length of all is the same, $15\frac{1}{2}$ inches before baking, $14\frac{1}{2}$ after. The total product of the current year is 160,000 of all sorts, nearly two-thirds of the whole being two inch (round) pipe. The average value of all is two cents a piece. The sale is local.

Mr. Whiteside, Waterloo village, makes brick. The yard is east of the village on rising ground. The clay is "red" only, *i. e.*, dark chocolate without lamination, four feet thick, resting on "gravel;" is said to extend two miles back from stream, where it is succeeded by what appears to be till. The owner claims that the clay is superior to that of Geneva, retaining its shape better; it is very "strong" (tenacious), and one-fourth sand is added to make it workable; contains a few striated pebbles and traces of lime concretions. The sand is "red" (buff), and fine, occurring in scattered knolls on top of the clay; not building sand, but equivalent to that of West Junius. A pug engine and crusher are used, which "grinds as fine as coarse meal; a stone as large as a finger nail causes air-slaking and splits the brick."

Production this year, 300,000; none for three years previous; can make 25,000–27,000 in a day, requiring 18 men.

A brick yard was seen at the western boundary of Waterloo, adjoining Geneva, not at present in operation.

Frank Seigferd, Seneca Falls, just outside village on north, ground level, not elevated. Two kinds of clay; upper six feet red, exclusively for brick, the rest down to 10 feet, blue, for tiles only. They are not mixed. Top layer of 10 inches is dark from vegetation; it is included and worked up with the red clay. Brick shrinks one-half inch in "each dimension;" blue clay "shrinks too much for brick making, and is too sticky, adhering to the mould." A machine for tile making and one for brick, horse power; three men. Product not over 225,000 this year.

Willour & Pontius have made tile in Fayette for 25 years. Their plant is in the valley, west of West Fayette station. There is one or two feet of red clay on top, and an unknown depth of blue below it, the drainage allowing only a few feet of excavation. They make "15 kinds of agricultural tile." They state that the possession of two sorts of clay is an advantage, the red being tougher and better adapted to making horse-shoe tile. They employ three hands; were off six weeks this year for farming reasons, and made five kilns = 150,000 tile.

John M. Yerkes, Jr., has a tile works a short distance south of Romulusville, in a very level country. The field was found to be opened in shallow cuts, not deeper than three feet. The clay is dark blue, containing vegetable matter and specks of lime from fresh-water shells; under it is some quicksand and marl. It reacts to H Cl freely. No information obtainable by conversation or letter.

Limestone.

The limestone of this county, quarried in Fayette from the "Seneca" (Upper Helderberg), has a good reputation and may be seen in the walls of many public buildings in the neighborhood. The dam at Waterloo is of this material. The greater part is good stone; weathering from above has more or less affected some of the upper tiers.

The commercial value of this excellent stone is impaired by the want of direct railroad connection. At the time of writing, four quarries were found in actual operation, but with few men. Several at the east end of the line have been long since abandoned owing to their distance from railroad The dip is not sufficient to injure the prospects of the quarries.

The quarried rock is sufficiently handsome for architectural uses. It gradually weathers from dark blue to a whitish gray or lead-color, but its effect is not injured by the change. It is described as "a strong, uniform, hard, ringing stone, containing few fossils; easily trimmed and squared, and adapted to most uses where strength and durability are desired." Many of the layers are free from hornstone, but its presence has not injuriously affected the walls of public buildings erected during the present century in the neighboring towns. The shaly layers described in another place are of bad quality.

The business of lime-burning was once pursued in many places on a small scale; for example, along the line of outcrop of the Tully formation. I found one in operation (Seneca Falls), using the refuse of a quarry in Fayette; there may be others. I heard of no cement manufacture. The increasing scarcity of wood fuel has had much to do with this neglect. It is still possible, doubtless, in some glens to make use of wood cut on the spot for burning the Tully limestone, if farmers care for the trouble.

Sand.

Building sand of good quality is found at the pits north of Seneca Falls, as previously described. It is said that still better is found at Oaks Corners, Ontario county, where very large excavations of 20 feet in depth have been made in the alluvial plain, east of the New York Central station. In connection with the gravel pits at West Junius there are sand deposits used for this purpose and for plaster. For the high lands supplies of sand can be found in the delta-terraces. That near the water's edge at Willard seems to have been used for building within the Hospital grounds, but at present it is found advantageous to draw the supplies from a vast deposit at the lake side, the sand bluffs at Long Point, which lies opposite Willard.

The very extensive deposits of buff sand which cover many miles of land in Waterloo and Junius are not useful for mortar-making. The sand is altogether too fine, and lacks "sharpness," or the quality of setting quickly and strongly. It is used in brick making for coating the inside of moulds. The sand is ferruginous; some of it is highly so, and would bake to a deep cherry red on the surface of the brick. The sand used for making moulds by the iron founders at Geneva is brought from a distance; that of the vicinity does not serve, although similar in appearance — it does not hold together well. Lake sand is dredged from the shallow water of the north end of the lake for making cores for castings; this would also make a fair mason's sand, though not quite coarse enough.

Sandstone.

The sandstone of the Portage group takes the form of slabs or flags. Flagstone quarries have been largely developed, chiefly on the eastern side, and have proved a source of considerable profit in former time, though at present few are worked.

The lower layers, up to at least 100 feet, are not worth working. This is obvious on inspecting the exposure at Lodi falls. A quarry at 140 feet above the base of the formation was mentioned to me as giving stone of insufficient strength for bridges. The disused quarries in Ovid village may be at even a lower level. At Faucett's Point, 200 feet above the base of the forma-

PLATE 18.

Figure 29. **The King and Robinson quarry, Portage sandstone, Trumansburg.**

tion, the product seemed to be what it was claimed to be, very tough and suited to cover culverts in roads.

A series of 14 or more quarries extend along the east shore of Covert for nearly six miles, at the distance of half or three quarters of a mile from the lake, and probably 400 feet above it, which would be 250 feet above the base, if 150 is allowed for the Genesee shale. This, with the neighboring quarries at Trumansburg and Taughannock, forms the district of typical development of the industry. At present only one quarry is worked at this point in Covert, and another is expected to open next season. Those at Taughannock, with some advantages of position, are working.

The quality of the stone varies and much poor material has formerly been disposed of at cheap rates. Some layers, apparently solid, go to pieces under the hammer. Scaling sidewalks and splitting wall stones may be seen. But when well chosen the flags retain their position among the very best materials for walks. The stone is of a very high degree of tenacity and durability, and does not become slippery by wear. Sills and capstones are also made of it. It is found of sufficient thickness for basement story work with rough face, for which it is now being used at Willard's Hospital, and makes a handsome wall.

Quarrying is facilitated in the Covert district by the comparative lightness (1–8 feet) of the drift layer. In the more elevated and central parts the drift is much heavier and has proved a barrier to operations. The largest quarry in the district is the Ogden. There are also some large quarries near Ovid Centre.

Cleaved surfaces are slightly uneven; sawing, for the production of smooth surfaces, has not been put in practice to my knowledge in this county.

The accompanying view gives the quarry of King & Robinson, who state the following in regard to it: The flags range in thickness from two feet two inches down to "nothing." The thick layers are liable to split; in order to anticipate this they are artificially separated by wedges into convenient thicknesses for slabs. The thickest layer that can be relied on not to separate spontaneously is eight inches through. Most of the good flags are furnished by one 20-inch layer; at its greatest thickness this measures 22 inches and runs 40 rods each way (N. and S.), gradually thinning until it is lost, but reappears at one-quarter of a mile farther and increasing to 28 inches. This thickness was found at the Ogden quarry, which was the first opened in the locality.

Above this layer comes six feet of shale ("shuck"); then 4–16 inches of stone divisible in two to six layers, and then 20 feet of shale, flying in fine pieces when blasted, which contains hard streaks (not of much value) from one inch to two feet in thickness.

The marketable slabs are found of almost any length, and in widths varying from 1 to 20 feet. The largest quarried here was, Mr. King thinks, 12 feet 9 inches by 13 feet 9 inches, and was used in the vault of a bank. The largest ever quarried by him were three flags 9 feet 6 inches by 13 feet, which received a premium at Philadelphia in 1876 for strength, texture, natural surface and edges.

A S. W. dip of one and one-half inches in 100 (three inches to a rod) is found here and in other quarries for some miles to the north.

The joints are nearly vertical. A main joint runs N. 15° W. (magnetic), but it recurs at very irregular intervals (6 to 40 feet), and gives very varying dimensions to the slabs. No reliable cross seam exists. Subordinate cleavages ("back seams") traverse the main joints in places, running about N. 10° W. extending not over 100 feet each way from the main seam. Back seams are confined to the lower beds in the quarry. They are well shown in the view. Much injury to the market worth of the product is caused by their presence, but they are fortunately not common.

Another form of objectionable cleavage is found, usually running parallel with the main joint, and limited to a few inches (not over 20) in the thickness of beds. Between two main seams that are, say 30 feet apart, there may be from one to ten such, at from 1 to 10 feet apart. A whole block may be so cut up that the widest piece is not over 20 inches across.

Another source of injury is found in "burl," a formation of concretionary origin, whose presence is shown by saucer-shaped protuberances and depressions and circular discolorations.* Around the perimeters of burl the stone is of excessive hardness,

* It turns brown against the greenish sandstone when weathered.

PLATE 19.

Figure 29a. "Burl," or concretionary effect in Portage sandstone.

and there is a strong tendency in the stone to crack or break in a ring at this line. No marked change in composition is apparent in the rock at these points.

Among the causes for the abandonment of quarrying in this region are the following, in order of importance: Competition of cement pavement and of Ohio flags; increased difficulty of quarrying as the work progresses landward (it has been carried in as far as 350 feet); seams and burl; difficulty of drainage; distance from railroad. The latter is not of prime importance, perhaps, but its bearing is seen in the continuance of work at the Taughannock quarries, which are directly on the line of railroad. At the latter point, also, the waste is easily dumped into the chasm.

The product of the quarries of Seneca county has largely been consumed locally, *i. e.*, within 50–100 miles of production. The qualities of the stone are still appreciated, for sidewalks, but it appears that for its production on a large scale greater facilities are offered at Taughannock. I have, however, met several proprietors who were working small quarries in connection with some farming. The enterprise of the King's Ferry proprietors (Cayuga county) is commendable. They are sending out picked flags of large size, accompanied by their own workmen, for the purpose of fitting and laying them.

Plaster Rock.

The report of the fourth district (1843) states that at that time five or six thousand tons of rock were annually quarried as a fertilizer at Seneca Falls. The memory of this once thriving business has passed from the minds of this generation. I found but one man who knew of its former existence, his father having been engaged in quarrying 55 years ago. The industry still exists at Springport (now Union Springs) and Phelps, but the "phosphates" of commerce have largely superseded plaster.

A word in regard to the uses of plaster may be here in place. Only the impure article is likely to be obtained from these beds, if reopened; its only use, that of a fertilizer. In this capacity it is at present mainly employed to give bulk to substances which in themselves are too concentrated for use, as nitrogen compounds, potash and the phosphoric acid of phosphates, which are the substances mentioned in the New York law regarding fertilizers. It appears that the plaster *per se* no longer exercises the beneficial influence upon the soil that it formerly did; its function being to liberate potash from combinations, its application for a number of times exhausts the capacity of the soil for yielding its potash, and the beneficial effect is no longer observed.

Road Metal.

From a strictly practical point of view Geology offers no results of more immediate concern than those bearing on the question of road building. Attention has been constantly directed to this point in the course of these investigations. A large part of the county, even in the elevated tracts, has a clayey soil, on which the attempt to make good roads has proved a failure.

It must be confessed that the true principles of road-making are seldom if at all followed. It is well known that deep side ditches, culverts for prompt discharge of side water, under-drainage and arching of the roadbed, are at the basis of all success in road construction; but in practice they are quite neglected. One seldom sees a properly made dirt road; and good road metal is commonly wasted by laying it on a poor basis, and by neglecting to crush to size.

The best road metal is trap, granite and the like, which are out of the question for country roads here.

Gravel is rather a rare product in this district. Lake gravel is usually shale worn round, and is then little better than shale. It is here suggested that river gravel can be found in considerable quantities in some of the ravines, some of which may prove suitable for roads.

The country north of Seneca river has no rock, not even shale. That on the south has at least two belts of limestone, much shale and at the south sandstone.

The application of the well-known black shale to the roads has a good effect for a time, but the material eventually becomes reduced to its original element, mud. I have known a fine road kept in good order by frequent coats of common Hamilton shale (Moscow shale) applied until a great thickness was accumulated; this was at Kidder's Ferry, where no heavy produce teams pass. In general this material may safely be recommended for avenues. No deliberate and well-conducted experiments upon the value of this very common material seem to have been made; if successful they would confer a great benefit; but the probability seems to be against success.

Shale, the refuse of quarries of Portage sandstone, has been applied to roads near Trumansburg by Mr. King, but, as he informs me, with no great success. It grinds up to sand and mud.

The sandstone of that region is expensive to quarry; nor is sandstone recommended as a road material.

Certain parts of the Hamilton formation consist of a heavy rock intermediate between shale and limestone. Such rock is found at one or two points along the northern border of the formation; it is what has been termed the "basal Hamilton limestone." At or near Bearytown, I am informed, this material has been employed successfully in mending roads. The experiment deserves to be repeated. Failure at one locality need not discourage a trial at another, as the amount of lime in the rock doubtless varies from point to point. The material is much firmer than the common black shale or "slate." Exposures are marked H on the map.

The belt of quarries in "Seneca" stone would furnish excellent material. The "stone road" between Geneva and Ovid is roughly macadamized with this stone, and is certainly a fair road. In the quarries which have been discontinued, owing to distance from transportation, a limitless supply of serviceable material is ready to the hand, which at present is practically worthless. For road metal, blasting answers as good a purpose as the slow and expensive use of bars and wedges. A plant for stone crushing would be absolutely necessary.

The Willard Hospital has constructed on its own premises, at practically no expense, a mile and a half of Telford road, using as sole material the Tully limestone quarried in the ravine, a few hundred feet from the lake. This bit of road is of importance in several ways. It illustrates the value of hitherto unused and wasted forces — the work, both of quarrying, transportation and road-building, having been performed by the patients, with the aid and direction of the hospital assistants. It forms a permanent addition to the property of the State. And it is hoped that it may prove an object lesson, productive of direct benefit to the neighboring population, by calling attention to their own resources.

Two points are of capital importance here. *First*, the road is a perfect success. Five years of constant use, in the main avenue of a population of 2,500, has not injured it; the work is sound, and the *material is perfectly adapted to its purpose.* It forms an unbroken, probably water-tight arch. It is not slippery. It produces a moderate amount of dust, which is the case with all limestone. The impurities of the rock appear to be of a similar nature to those found in hydraulic limestone, and probably aid in establishing compactness by consolidation of stone with stone.

Second, the material can be had in almost *unlimited quantity*, with but a light covering of dirt, on high ground, centrally situated, and with a railroad running over a mile of it. It is of small value as a building stone. The rock forms an outcrop at the Thompson Johnson farm, where, as we have seen, it is nearly 11 feet thick. Thence to Hayt's Corners it forms a shoulder of land, known to neighbors as concealing limestone; in places it has so little covering of earth that its crumbling has completely filled the soil with bits of stone. No close estimates have been made of the amount of soil to be removed; it doubtless varies. There is enough material just in this spot to pave the roads of the county.

Something may properly be said in this place in regard to the manner of using road material. The Telford is a perfect road; but its cost may deter others from imitating the details of its construction. Before entering upon that matter be it permitted to say that exceedingly good results may be had from very simple methods. The rock must be broken to a nearly uniform size. The bed must be properly leveled. A sufficient thickness of material must be used, and as of absolute importance, good drainage must be insisted upon.

No reasonable man can claim or predict anything in favor of roads in which these points are neglected.

A rock crusher will be required. It is now needed, irrespective of theory of road building; for who can have seen the heaps of

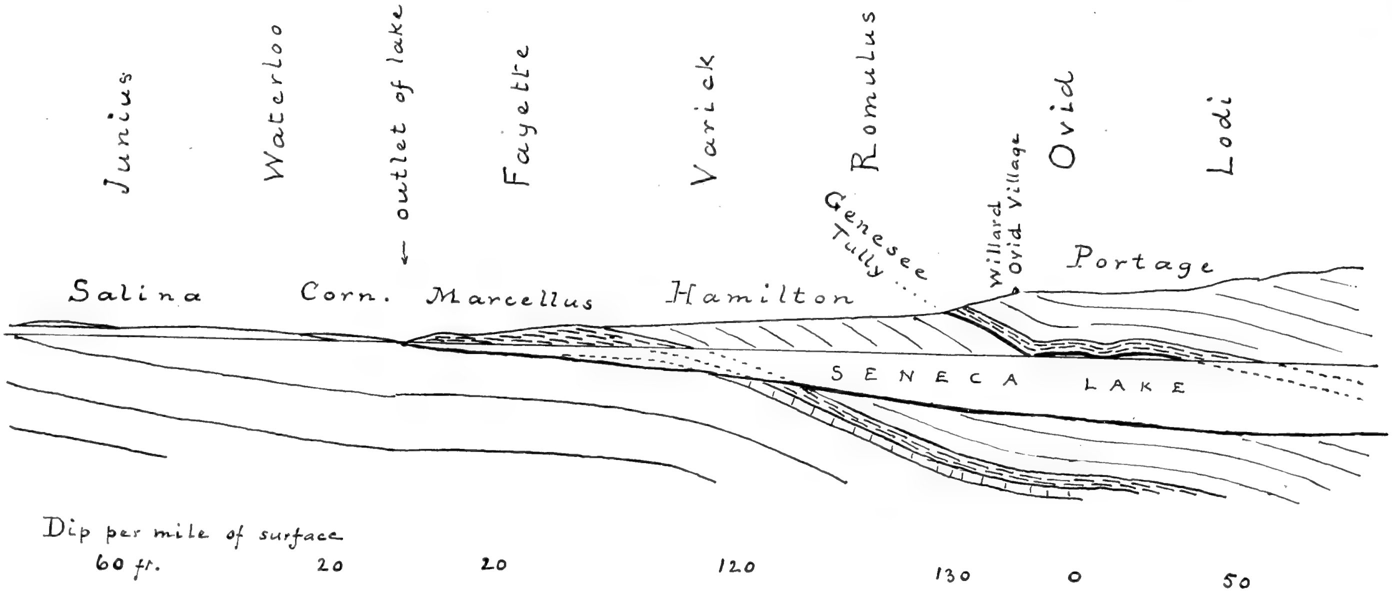


Figure 30. North and south section through Seneca county, along its western face; showing changes in angle of dip.

angular quarry refuse of all shapes and all sizes up to 20 pounds that I have seen on a road in this country this summer, and not have wondered whether such road-cobblers knew the value of a horse's feet and legs?

In places where the roadbed has a good natural drainage to both sides, the simplest possible use of proper-sized material in liberal amounts will produce a good road in two or three years by repeated application of small stones in a thin top layer.

Where drainage is impossible, the only resource left is to build a bridge. Where a road lies in a swamp (*e. g.*, Cranberry swamp), a deep ditch on each side will hold the surplus water in summer; but drainage of the swamp solves the question for the year round.

A clay road, if allowed to remain wet, is plastic, and lets road-metal sink into it; if drained dry it is as firm a foundation as can be needed. The solidity of *dry* clay is shown by *adobé* houses; or, to take an illustration near at hand, by the new embankments supporting the Lehigh Valley railroad tracks across the low grounds east of Geneva.

The Telford road, at Willard, was built in the following manner: A flat bed was first dug 15 inches deep, 21½ feet wide; on this were laid, in shallow trenches, lines of drain tile, placed lengthwise, four feet from each side; these were connected by cross-drains every 25 feet, and outlets were made of tile every 75 feet each side to the edge of the road *under* the gutter and away to some point of discharge. The first layer of stone is of largish pieces, fitted together and made 12 inches high in the crown, three inches high at the sides. The second layer is of stones of the size of an egg, roughly; four inches everywhere. The third, four inches of much smaller stones. The second and third courses were of crushed stone. The road was, therefore, 20 inches thick in the middle, 11 inches at each side. It consists entirely of the Tully limestone, and has become so compact as to be "all one stone," to use the words of my informant, Mr. Kitson, who superintended its construction. It is not unlikely that the impurities of the rock, which cause it to split and crumble in the ledge at the surface, contribute somewhat to the compactness of the structure; for it has been found that when burnt, it behaves like cement-rock, hardening too quickly and becoming too hard for brick masonry or for plaster work in houses, but making a good stone mortar. The road was two years in building (the peculiar conditions of an asylum permitting it), and has stood five years on a steep grade with very little wear, being slightly guttered in places, owing to the steepness of the grade. Mr. Kitson informs me, however, that it has not been mended in these five years. A steam roller was not used in making it.

In illustration of the hydraulic properties of the Tully limestone, analyses are here appended. No. 1 was taken from the northernmost exposure (quarry of Thompson Johnson); No. 2, from locality of the quarry at Willard; while No. 3 represents the best "Seneca" limestone (Chamberlain quarry). They are taken from the Transactions of the N. Y. State Agricultural Society, 1850, p. 611:

	No. 1.	No. 2.	No. 3.
Insoluble sand and clay	15.	4.	6.7
Alumina and peroxide of iron	23.	26.	1.4
Carbonate of lime	53.5	60.	90.
Magnesia	2.8	5.5	1.5
Oxide of manganese	......	1.	....
Soluble saline matter	1.2	2.4	1.4

Gas Wells.

A considerable number of wells has been bored in and around Seneca Falls village, with the object of striking gas in the Medina sandstone. The example was set at Waterloo several years ago; a single well was bored with moderate success. In Geneva two were put down (1888, 1892), but neither was turned to account, though the later one was doubtless worth the trouble of saving.

At Seneca Falls the enterprise was begun in 1887 by the "Phœnix Gas Co." This failed to meet obligations, and the property was transferred. The present holders now furnish heat and fuel to 150 families. The illuminating powers are inferior. The daily product may be set down at 30,000 feet, sold at 25 cents a thousand. A cooking-stove heated without intermission would, it was estimated, burn 500 feet of gas in 24 hours.

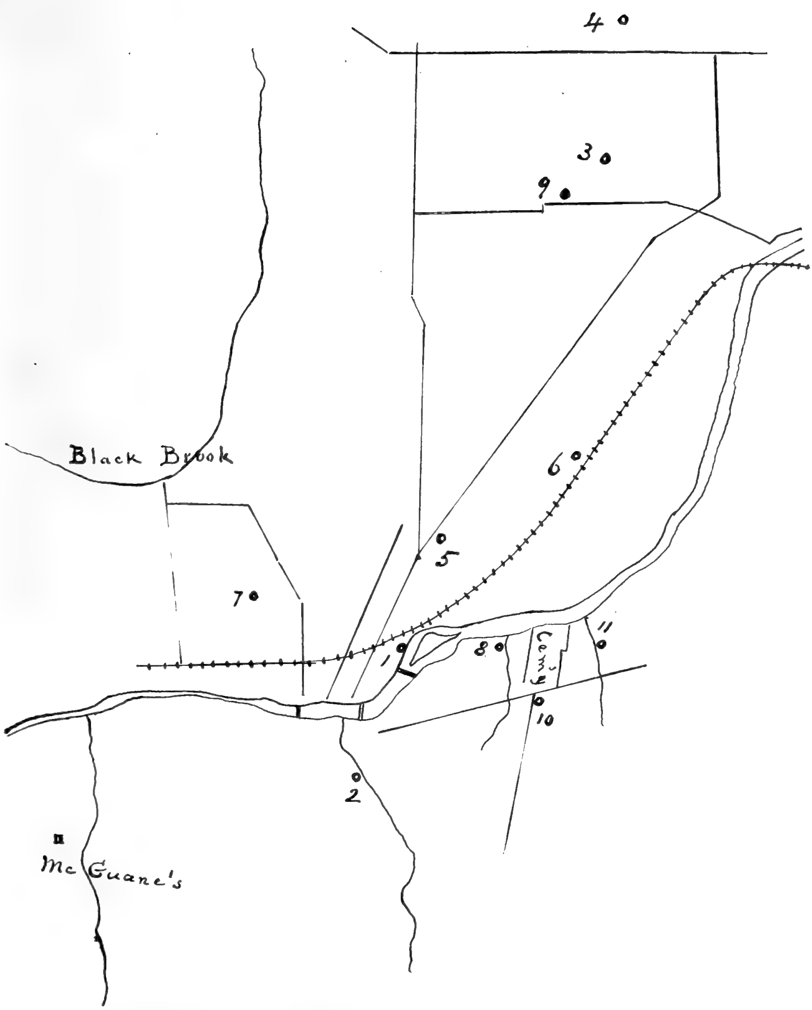


Figure 31. Location of gas wells at Seneca Falls.

The company own 11 wells, five of which are unproductive There is a market for a much larger supply, but the results of the present experiment do not seem to justify an extension. The attempt to reach Trenton rock is under consideration.

Wherever gas has been found in the Medina, in this vicinity, it comes from the "white sand," about 100 feet below the top of the Medina, or a little lower. The layers above this are characteristically, but not always, a strong red, furnishing superior building stone. The "white sand" itself is successfully quarried at Gasport, though in some other places (as Medina) it softens to incoherency under the action of the sun and weather. The oil-bearing rock presents no marked characters; it is a sandstone of medium coarseness, not specially porous, but lacking the firmness of quartzite.

No complete records have been kept. The few data presented are obtained from notes kept by Mr. Frank Westcott. The depth at which the Niagara, Clinton and Medina were first struck are points not hard to discriminate, owing to the marked character of the changes.

Well No. 2 is the property of the brothers Westcott. It is described as going 1,540 feet to gas; giving 8,000 feet in 24 hours, which is 2,000 less than at the start, six or seven years ago.

This well, in the southern part of the village, may be compared with one driven three miles north of the village, on ground not differing much in elevation:

	Southern.	Northern.
To top of Niagara	480	860
To top of Medina	445=1,425	445=1,305
To gas	115=1,540	155=1,460

One of the northern wells (No. 4) is reported as passing through 15 feet of salt at 565 feet. Other wells near this did not strike salt. Salt water was encountered at various depths in most of the wells, in the Salina. No. 2 struck it at 2,040 feet in Medina shales.

To these meagre data may be added the following statement from Mr. Horsley:

	Well 10.	Well 11.
Struck Medina	1,400	1,360
Struck first gas	1,527	1,510
Struck second gas	1,578	1,565
End	1,624	1,620

Mr. Westcott states that he has bored for gas "successfully" in the Medina at Corfu, Genesee county, striking gas 115 feet below the top of the formation. At Alden, Erie county, in five wells, gas was struck at 102, 110, 114, 104 and 141 feet below top. The first discharge of gas was so violent as to throw out the tools; but the supply soon failed. At Allen's Hill, Richmond, Ontario county, 100 feet.

Water Power.

Streams capable of furnishing power to grist and saw-mills are numerous, especially in the southern part of the county. A large number of mills were formerly maintained. Gibson's map designates 50, exclusive of Waterloo and Seneca Falls; all but one or two are placed on streams. Very few continue in use.

Waterloo.— The source of the water power at the above-named villages is Seneca river. Between Waterloo and Seneca Falls the stream forms a part of the Cayuga and Seneca canal. Above Waterloo the same is the case to within half a mile of the lake, where the canal diverges, finally entering the lake at Geneva. The fall is 62 feet (441—379) between the lakes, of which 14 (disregarding fractions) occurs at Waterloo, and most of the remainder at Seneca Falls, a few feet occurring between the latter and Cayuga lake.

The canal was incorporated in 1813. When first opened it admitted boats of three feet draft, but between 1825 and 1857 this was successively increased, and at present it accommodates those of six feet draft, the depth of channel being seven feet. The stream-bed has also been deepened throughout, including the point where it connects with the lake, which is not the original point of outlet. The effect of this enlargement has been the lowering of the level of the lake. The dam at Waterloo is at present the first obstruction to the outflow. It was built in 1795, antedating that at Rochester. There are several concerns using the power at Waterloo, obtaining at times of high water an actual maximum of probably about 450 H. P. The canal is State property, and has a first claim upon the water as far as required for lockage; but the water required for this service is at present but a comparatively small part of the total amount, and is exclusive of the above figure. The amount of power varies greatly with the season, and may fall to about one-half of that named, in times of drought like the present summer, when the level is three feet below that of flood. The wheels are not constructed to make use of the full possible power, as in that case they would be at a disadvantage during low water. Estimates of power capable of being used are necessarily only approximate; the high-water power which *might* be used for short periods may be double the 450 H. P., and is certainly much greater than that figure. There is a natural dependence of the flow upon the season of the year ; yet, there may be dry winters, with continuous low water. A great deal of steam power is used to supplement the water power.

Seneca Falls.— Mr. Harrison Chamberlain, of the Phœnix Mills, gives me as the estimate usually adopted by mill-owners and hydraulic engineers, the amount of 1,000 horse power, for the total average flow of the stream, with a fall of 16 feet, at his mills. Formerly the State used nearly one half of the flow for navigation purposes, but of late years the amount has been considerably less in consequence of falling off in canal tonnage. Below this mill there are three lesser falls, at as many locks, in this village, but the lowest fall has not yet been made available for mill power and privileges. The total turned to account in Seneca Falls is considerably over double the figure given above.

Seventeen concerns were named to me as drawing power from the stream, including three flour-mills ; malt and marble works ; manufactories of fire engines, pumps, paint, paper, knit goods, etc.

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THE PRINCIPLES OF PALAEONTOLOGY.

BY

FELIX BERNARD.

(Extracted from Bernard's Éléments de Paléontologie. Paris, 1895.)

The Principles of Palaeontology.

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CHAPTER I.

Object of Palaeontology.

§ 1. Relations of Palaeontology to Other Sciences.

Definition.— Palaeontology is the study of the animals and plants which existed on the earth in epochs anterior to the present; these have become known to us by their remains, which are buried in the crust of the earth, and which are called *fossils*. As an independent science Palaeontology dates only from the beginning of this century; it may be said to have been founded by Cuvier. Before the time of that great naturalist, fossils had frequently attracted the attention of philosophers, but had never been the object of any profound researches. The immense field in the domain of living nature was still but little explored, and afforded materials easy to obtain and study. The appellation of the science which we are now considering dates from the same epoch, and was proposed by de Blainville. Since that epoch, Palaeontology has progressed with an uninterrupted rapidity. For many years past successive discoveries in all parts of the world have constantly augmented and given precision to our knowledge of the subject. All nations, even those which have most recently attained civilization, possess learned men who count it an honor to themselves to make known to the world the precious remains of the fossil fauna and flora of their own countries. The Rocky mountains, the Pampas of South America, Australia, British India and Siberia are now classic regions of Palaeontology, and have furnished, no less than have the famous strata of France, Germany, England and Italy, materials for the most interesting investigations.

Palaeontology, the new comer in the group of natural sciences, to day counts illustrious adepts, but it has had for a long time to follow step by step the progress of the two sciences with which it is most intimately connected, Comparative Anatomy and Geology. It is due to the efforts of zoölogists, botanists and geologists that it has been enabled to reach an epoch where it is accorded the unquestioned right to rank as a distinct science with distinctive followers — palaeontologists. The interest of this science is twofold; the history of the creatures which lived in past times is intimately connected with the knowledge of those now living; and on the other side, Palaeontology is in close relation with the succession of phenomena which, at different geologic epochs, have modified the configuration of lands and oceans.

Palaeontology and Biology.—As a branch of *Biology* Palaeontology, for various purposes, requires constant comparison between fossil remains and living creatures. The former can never be known with the precision which attends the anatomical and histological analysis of living forms. With rare exceptions, only the hard parts are preserved in fossilization, and even where the soft parts have left certain impressions, the inferences that can be drawn from them are evidently much less exact than those which are afforded by an animal or a plant whether living or preserved in alcohol. In order to interpret the organization of extinct creatures the palaeontologist must have constant recourse to the inductive method. By carefully comparing the material in his hands with the corresponding parts of living creatures, he is often enabled to draw conclusions from the known to the unknown, and to reconstruct the entire organism with all its essential characteristics. It is thus that a palaeontologist, even moderately expert, is able, by examining a shell, to decide whether the animal which inhabited it was, for example, a Pulmonate or Prosobranchiate, terrestrial or aquatic; a simple tooth suffices to show to what group of mammals an animal belongs; a section of vegetable remains will enable him to determine whether the plant was a Cryptogam, a Gymnosperm or an Angiosperm, and he can thus ascertain, without having seen them, what were the characteristics of the reproductive apparatus. The palaeontologist should then be, before all else, a zoölogist or botanist; he must be capable of discerning characteristics which, though trivial in appearance, have often a prime importance, since they enable him to refer the object of his investigation to such or such a group of existing and well-known forms.

The interest of Palaeontology would be but mediocre if this science only led to the discovery of forms identical with those at present existing, or at least analogous to these. But, on the contrary, it has revealed to us an immense number of beings which at present are wholly extinct. Those extinct types are in truth not fundamentally different from those which have survived; and we know, for example, no subkingdom, hardly any class indeed which is represented exclusively by fossils. But there are entire *orders* which are not represented in living nature, and it may be said that if animated nature has not undergone an absolute revolution, it has at least experienced profound modifications. This is precisely the most important fact brought to light by the study of fossils It is well known what an important role the doctrine of Evolution plays at present among the natural sciences. A few students, whom we must in truth count among the foremost, still maintain that living species are immutable, and can in no case be modified and so originate others. But the great majority of naturalists have rallied about the transformist idea. If it is true that both in the animal and vegetable world, species are derived from one another, if there really exist between species, genera, and larger groups veritable ties of derivation, Palaeontology should present us with the best proofs in support of this filiation. The proofs derived from living nature still leave many things uncertain; innumerable gaps occur among the animal and vegetable forms, for these in no wise arrange themselves in strictly continuous series. May we hope to find in Palaeontology new arguments in favor of the doctrine of transformation? Do there exist among the fossils terms of passage which facilitate the establishing of genealogical trees? Can we discover, in fine, in ancient types, the progenitors of these forms whose origin seems still problematical? These are, in fact, the important problems which engage the attention of all naturalists, without exception, who devote themselves to the study of Palaeontology.

Despite the immense increase of material brought to light throughout the world during the last half century, we are far from able to state that extinct beings are known in their entirety. It would be illusory to suppose that all the questions propounded in regard to the origin of created beings have received a satisfactory solution. It may even be observed that new problems have arisen from the discovery of creatures entirely extinct and whose nature or origin remains doubtful. But despite these difficulties, notwithstanding the gaps which still exist, Palaeontology has brought to light almost unexpected solutions of problems already existing, and it may be asserted, without fear of contradiction from any of the students engaged in this science, that it produces every day convincing testimony in support of the doctrine of Evolution.

Palaeontology and Geology.— The relations of Palaeontology with Geology are of another order, but not less close. The knowledge of the phenomena which have modified the surface of the earth, the determining of the relative age of the layers which compose the terrestrial crust, evidently imply a simultaneous study of the beings which have inhabited the lands and the seas, of all the organisms indeed which have been found in the various deposits. The principle on which stratigraphical studies have lately been almost exclusively carried forward, consists in this, that the deposits of the same age contain in general the same kinds of fossils, which is to say that the same beings simultaneously inhabited the various seas during the same periods. As there is no region where the succession of beds is presented without interruption, we are obliged, in order to establish the age of a newly discovered formation, to compare carefully the fauna and flora of any stratum with those of a corresponding stratum of other regions. The formations which contain the same kinds of fossils are considered as dating from the same epoch, and are given the same names, and this principle of the identity of the fauna at any epoch has long been considered as absolute. We shall see further on, that some restrictions are to be admitted, but the result of these is not to lessen the suggestive importance of Palaeontology, but rather to augment it and give it greater precision. The variations of faunas, as they become better known, are found to be closely connected with variations of physical conditions; from the groupings of forms which are found in certain layers, a conclusion can be drawn regarding the conditions in which the deposits were made; the fauna of a deep sea is distinguishable from that of shallow water, shore, estuary, or coral reefs. We can gain some information regarding climatic conditions and can even, for some epochs, form charts to indicate equal atmospheric temperature. It is then easily seen what services Palaeontology has already rendered and still continues to render to Geology, and if this last-named science now possesses other methods of investigation, if it engages in the study of phenomena of a purely physical order, such as the displacements and formation of rocks, it nevertheless constantly profits by the incessant progress which has been made by the study of fossils.

Inversely, Palaeontology can not exist without Stratigraphy, and looks for support to the data of this science. In studying the relationships between organisms, it is requisite to ascertain with the greatest possible precision the epochs at which they have lived. This is no reasoning in a circle, for the relative age of layers is determined primarily by their order of stratigraphical superposition. The geologist discerns in the order in which they present themselves on the same vertical line, the age of the deposits with the faunas they contain.

Palaeontology serves then, so to say, as a bond of union between Biology and Geology, between the study of living beings and that of inanimate nature. Its limits in regard to these two sciences are very difficult to fix. But if the object of palaeontologic researches seems to make this science appear rather as a branch of Biology, various circumstances have led most naturalists to hold a contrary opinion. Geologists have a good right to claim most of the discoveries which were made in Palaeontology until within the last few years.

This fact explains itself; it has been for the purpose of examining the geologic deposits and ascertaining the stratigraphic characters of a region, that naturalists have undertaken the often long and painstaking researches which have resulted in the discovery of fossils. There are geologists who, after having secured from the rocks, often with great labor, the fossils discovered therein, have furthermore carefully prepared them so that no character which could possibly be preserved should elude their investigation. Even in our days it is the geologists who have made the most numerous discoveries in Palaeontology, but many signs indicate that in France as well as in other lands, the time has arrived when pure Palaeontology must occupy the best energies of students devoting themselves exclusively to it.

§ 2. HISTORY OF PALAEONTOLOGY.

Division of the subject.—The history of Palaeontology has been written at various times by eminent students: Brocchi,* d'Archiac† and Lyell,‡ have successively recounted the gradual efforts by which this science was created. Up to the close of the last century its progress was vague; the profound study of fossils was neglected and essays in that direction often lost themselves in purely theoretical discussions. Cuvier brilliantly inaugurated a new period, and must be considered as the true founder of Palaeontology as well as of Comparative Anatomy. Half a century later the acceptation of the ideas of Darwin by the great majority of the learned world gave a new direction to palaeontologic studies; the end to be attained became better defined, the investigations were pushed farther, and adepts in the long neglected science became more and more numerous.

The history of Palaeontology may then be divided into three periods of unequal length and importance. We shall be very brief about what concerns the first essays before the time of Cuvier.

First period.—It is necessary to go back to HERODOTUS to find the first mention of fossils. It is curious to verify the exactitude of the opinion formulated by that ingenious historian; he says the priests of Egypt were acquainted with fossil shells; attributed to them a marine origin, and drew the conclusion that Egypt was formerly under water. This conjecture of ages so long past is at the present day an evident truth. Some scientists have thought to find also in ANAXIMANDER the first indication of the

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* Brocchi, Conch. Foss. Subap.; Disc. sui progressi dello studio....1842.

† d'Archiac, Histoire des Progrès de la Geologie de 1834 à 1835 (1842).

‡ Lyell, Principles of Geology, Ch. I-IV.

idea of transformation. Cuvier, following Eusebius, cites a curious passage on this subject:

"Man must be descended from creatures of an especial form, for while other animals procure their food without difficulty, man alone requires a long time to attain to the power of caring for himself, necessitating a prolonged education; any creature in the beginning who resembled him must have been wholly unable to maintain its existence." And Cuvier takes advantage of this occasion to ridicule these modern scientists who, like Lamarck and Geoffroy Saint-Hilaire, seek to revive the reveries of a Greek poet.

ARISTOTLE, XENOPHON and STRABO were acquainted with fossils and had correct ideas in regard to their origin.

The middle ages and the modern epoch down to the end of the eighteenth century, are filled, especially in Italy and in England, with interminable discussions on the nature of fossils. The current opinion was that these remains could have nothing in common with the animals and plants of our days. The boldest of the learned men, however, advanced the opinion, that the shells had indeed been the habitations of living creatures, and had been deposited on the mountains at the time of Noah's deluge. The principal efforts of the philosophers were directed toward making their theories accord with the Holy Scriptures. From time to time some more singular explanation was put forth. Some imagined a sort of fermentation of fatty matter; many saw in fossils only freaks of nature, or essays more or less successful in creating new forms of life; others saw disturbed movements and exhalations of the earth; and still others supposed the intervention of some plastic power.

Some scientists, distinguished in other branches, had the merit of discovering, in a laborious way it is true, and in connection with some fantastic contradictions, a reasonable explanation of the facts which at the present day appear so simple. We will cite, as a matter of curiosity, a sentence of LEONARDO DA VINCI:

"It is said that the shells have been formed on the hills by the influence of the stars, but I ask where at the present day are stars which form on hills shells of diverse age and aspect? And how can the petrifaction of leaves, plants and sea-crabs on these same hills be thus accounted for?"

FRASCATARO (1517) is the first who affirmed that fossils had really been living creatures. CARDAN, CÉSALPIN, BERNARD PALISSY (1580), admit that the ocean must formerly have covered the mountains. COLONNA had the merit of making a distinction between marine and land shells. STENO, a famous Danish anatomist who lived in Florence, pointed out the identity of the teeth of living and fossil sharks, and discovered a fresh-water fauna (1669). All these learned men are pronounced defenders of the diluvial theory. Their tendencies are clearly explained, as Lyell ingeniously suggests, by the character of the fossils which are found in the museums of Italy; these, in general, belong to the upper Tertiary, and are very analogous to the animals at present living on the sea coast of Italy. Opinion in England, on the contrary, took an entirely different direction; the fossils found there belong in general to more ancient deposits, and the writers of the time saw no analogy between them and any living species. Thus HOOKE (1668) for example, is one of the defenders of the theory of the extinction of fossil forms.

With the beginning of the eighteenth century Palaeontology enters a new phase of existence; the rocks containing fossil remains were everywhere made an object of especial study, and were classified according to their order of superposition; catalogues were made of the fossils characteristic of each deposit, and an attempt made to form an idea of the relative epochs of the appearance of each type. WOODWARD (1695) has the merit of being the first in England to essay a methodical study of this kind. The same work was done in Italy by VALISNERI. The example of these men was afterward followed in Germany by LEHMANN, who established the difference between the azoic and the fossiliferous deposits (1756). In 1780 SOLDANI conceived the first idea of the distinction between the deep-sea fauna and the littoral fauna. He separated the marine and the fresh-water fossils in the Paris basin. Finally WILLIAM SMITH (1790) established an excellent classification of the deposits of England according to the fossils they contained.

In Germany geologists were turned away from the study of fossils by the brilliant teachings of WERNER, which acquired great repute. This scientist and his followers occupied themselves with examining minerals and rocks, to which without exception they attributed a marine origin. The contest between the *Vulcanists* and *Neptunists* occupied the end of the eighteenth century, and palaeontologic researches were relegated to a secondary place.

The real progress achieved during that century was due principally to a return to more correct ideas in the domain of geogenic theory. VALISNERI sought to separate scientific data from the interpretation of Genesis. But the principal honor of the change effected belongs to MORO (1740) and his commentator GENERELLI (1749). This latter recapitulates and admits whatever correct ideas had been suggested before his time. He demands that no one shall invoke divine authority for the support of his own ideas, or suppose miracles for the sole end of confirming his hypotheses.

It is easy to see under what a clear horizon the epoch of CUVIER dawned. The path of the great naturalist was prepared, serious writings on the subject were at hand; still it can not be asserted that Palaeontology was as yet firmly established as an independent science; the fundamental principles which authorize the comparison of fossil remains with existing creatures, were not yet stated. Their discovery is one of Cuvier's greatest titles to honor.

Second Period.— It may be said that the precise and dogmatic genius of Cuvier created Palaeontology and, furthermore, that he for a long while gave it an impulse and an attraction that has with difficulty been modified. It was mainly through the application of the principle of the correlation of forms that Cuvier arrived at his interesting conclusions. He studied in detail the fossil remains taken from the gypsum beds of Paris and its environs, and pointed out the resemblances and diversities between these types and the living forms of our period. He discriminated those forms which we at present consider as ancestral ones, *Palæotherium*, *Xiphodon*, *Dichobune*, etc., and pointed out how each of these reveals characteristics peculiar to diverse groups at present distinct. The discovery of marsupials in the gypsum of Paris was a most important event in the history of Palaeontology and Comparative Anatomy. It inaugurated a new method which was destined to give the happiest results for the study of fossil remains. Cuvier had discovered (1812) part of a skeleton, the jawbone of which seemed to him very analogous to that of a marsupial. By virtue of the principle of the correlation of forms which he had established, he affirmed that bones of a marsupial animal must be found in the deposit. He caused the rock to be excavated in the presence of a large number of persons, in order to disengage the posterior part of the body, and his hypothesis was verified to the great admiration of the contemporary scientific world.

A fact not less important in the history of Palaeontology was the determining, by Cuvier, of the character of a jawbone found in the Bathonian of Stonesfield. He demonstrated in 1818 that this remnant appertaining to the genus *Thylacotherium* belonged to a mammifer of the group of marsupials. This discovery overthrew the theory of the naturalists of that epoch, who were unwilling to believe that a mammifer could be of such ancient date. It was not until thirty years later that marsupial remains were found in the Triassic deposits.

Cuvier devoted himself before all else to establishing the true zoologic nature of fossil animals, especially the mammalia. He proved definitely that before the existence of the present fauna, there existed many successions of diverse faunas. The disappearance of pre-existent forms, and their replacement by new ones was believed to have taken place abruptly, caused by cataclysms which affected the entire surface of the earth. For the hypothesis of a single creation, Cuvier thus substituted that of several creations following each other at longer or shorter intervals. It is unnecessary to add that Cuvier was a firm partisan of the theory of the immutability of species. Incorrect though it was, still the theory of cataclysms was the one that would most naturally present itself to the mind to explain the profound diversities existing between the faunas of successive layers, at least in the regions explored previous to the epoch we are now considering.

The influence of Cuvier was felt during his lifetime, and even his errors proved a point of departure for a progressive movement. Since his time fossils have been studied with a deeper interest, as an idea can now be formed of the living creatures they represent, and attempts be made toward reconstructions, which are frequently most unquestionable; furthermore, it is well understood that variations of detail are of considerable importance since they are characteristic of different horizons. Thus the palaeontologic works of that epoch were carried on with a precision and care, as they continue to be in their entirety at the present day, and are a point of departure for effectual researches in each group.

The progress of Palaeontology during the first half of this century is due to the efforts of scientists who prosecuted their researches in two different ways. On the one hand the theoretic discussions among zoologists which have made so great noise in the world, have for their object the problem of the species, and have given rise to the doctrine of Evolution. On this account they are of direct interest to the palaeontologist. On the other hand, the geologists are engaged in exploring with the greatest care the deposits of all the countries of Western Europe, and describe minutely the fossils they contain. Moreover, scientists applied themselves at an early date to purely palaeontologic investigations, several described from a given geologic division all the material known up to their time, while others devoted themselves to the study of a single group. It will be easily understood that we can not here cite names. The period of which we are speaking is closely connected with the contemporary period, when researches are becoming more and more numerous. In the beginning of his great work, entitled *Enchaînements du monde animal*, M. Gaudry enumerates, by the side of each group, the names of the scientists who contributed most to make it known. "Although these lists contain more than 500 citations, they are far from being complete. . . I should never finish, did I undertake to recount all the intellectual labors that have been expended since the death of Cuvier, to bring to light the generations of living creatures which existed in days gone by."

We shall have occasion, in the course of the systematic part of this work, to mention the most important of those labors.

The problem of the origin of variations in faunas continued to preoccupy the most eminent geologists. The prevailing opinion was that species are absolutely characteristic of the horizons in which they are found, and that no one of them passes from one formation to another. In 1850, D'ORBIGNY, following the ideas of Cuvier, formulated the conclusion that animated nature must have become extinct and been again renewed twenty-seven times. He divided the fossiliferous deposits into twenty-seven stages separated into groups of unequal value and each characterized by its special fauna. This classification was made with such care that in its general terms it has remained to the present day; its denominations have for the most part been retained, although new researches and new ideas have brought some changes into the stratigraphic groupings. The same can not be said of the theories which led d'Orbigny to his conclusions. As early as 1813, VON SCHLOTHEIM refused to admit that each particular layer was the result of a new revolution of nature. BRONN demonstrated that certain species indeed really passed from one formation to another, and though stratigraphic boundaries are often barriers confining the persistence of some form, still this is not an absolute rule, since the species in no wise appear and again disappear in their entirety. LYELL (1832) forever destroyed the hypothesis, up to his time generally accepted, of cataclysms and universal revolutions of nature. His theory of existing causes consists in this, that all the phenomena which have occurred on the surface of the globe during past times are of the same nature with those which are occurring at the present time. We see in the whole, and in parts also, the results of those phenomena, but we must admit that their occurrence must have required considerable time. These new ideas, unreservedly adopted by the whole learned world, opened a most propitious way for the theories of transformation. The changes effected in faunas must have been slow and long continued, as are all geologic phenomena; and it was but one step farther to arrive at the admission that faunas were derived one from another. Sir Charles Lyell, at the beginning a partisan for the immutability of species, rendered, with an impartiality rare among scientists of that opinion, full justice to the essays of Lamarck. The exposition of the doctrine of transformation by Darwin quickly convinced him, and the theory of Evolution has not found among geologists a warmer or more eloquent partisan than the great English scientist.

The theory of Evolution received at first a very unfavorable reception, and was consequently unable to exert any great influence on the progress of Palaeontology. LAMARCK had, moreover, only a very imperfect knowledge of fossils; still he was sufficiently acquainted with them to be enabled to draw from the order of their appearance in the strata an argument in support of his theory of progressive development, which was at that time a novelty, and which overturned the most deeply rooted philosophic ideas. But this does not lessen the importance of the ideas of Lamarck, which were of the very highest order. He was the first who was bold enough to advance the theory that species are not immutable entities, but that they are derived one from another as individuals are, and that fossil creatures are the ancestors of those now existing. The teachings of GEOFFROY SAINT-HILAIRE on the point of which we are treating, tends by different arguments to the same conclusion.

In 1844 there appeared in England an anonymous work entitled *Vestiges of Creation*, which made a great sensation. The author of this, since known (CHAMBERS), brought together all the arguments in favor of the doctrine of the mutation of species, and laid especial stress on the palaeontologic changes which had taken place at various epochs; the author pursuing the subject still farther made a comparison between the stages of development of the higher animals and those reached by the inferior classes which appeared before the former and characterized extinct faunas. Some relative extravagancies, as, for example, the ideas of Lamarck concerning spontaneous generation, were the subject of severe criticism which brought undeserved reproach on the entire book.

It is doing no injustice to the genius of Darwin to recall how much his predecessors had done to open the path for him and to make ready for his labors. Writings capable of serving as supports for the new ideas were much rarer at the beginning of the century than they were toward the middle of it (1850); so that Lamarck and Geoffroy Saint-Hilaire were entitled to greater admiration for having originated so bold a theory, in the face of the violent opposition to which they were exposed. Darwin merits some censure for having failed to do justice to Lamarck, whom he confounds in his preface with more obscure predecessors. Many of the adherents of the transformist school of the present day render to the illustrious scientist the honor he deserves, and adopt, along with the new data, the greater part of his ideas, even those which Darwin rejected. To this latter belongs the honor of having discovered one of the most important factors of Evolution, namely, the phenomenon of natural selection. He has furthermore this advantage, that he fortified his theories with very numerous observations, with long and patient experiments, that he presented them in a deductive form without the intervention of hypothesis, and that he developed them with unanswerable logic. All this, in our opinion, explains the success of Darwin in a matter where his predecessors failed. He certainly followed the best method, since he proved himself able to overcome all opposition, and to him is due the great transformation which the purpose of biologic and palaeontologic researches has everywhere undergone.

Third period.—It would be impossible for us here to cast even a rapid glance over the progress realized during this last period, which, beginning toward the year 1857, continues to the present day. The two following chapters will be devoted to the explanation of the present state of ideas admitted by the transformist school of scientists, in so far as these ideas are confirmed by palaeontologic testimony, or give to the data furnished by this science an especial synthetic character. But it must be said that purely descriptive researches have not ceased to be held in honor, and that the number of types described increases with a rapidity of which it is difficult to form an idea. The *Annuaire Geologique* mentions 735 palaeontologic publications which appeared in 1889, and to this must be added the enormous number of descriptions contained in works especially devoted to Geology. One of the most striking characteristics of the present period is the precision and minuteness with which observations are carried out; efforts are made to derive from the examination of a fossil all that can possibly be known of its morphology, structure or development. A delicate method by thin sections is employed in order to push as far as possible the descriptive analysis, the younger forms are compared with the adults, and no technical difficulty is able to daunt the investigator.

On the other side stratigraphy has made such great progress that the reappearance of forms both in time and place is better understood. Variations of the same species in different localities of the same age can be distinguished from the mutations the species has undergone when found in more recent deposits. The association of faunas is taken into account in reconstructing the average conditions in which they existed, and we can form an idea regarding the zoologic and botanic geography of the diverse epochs of geologic periods.

Finally, scientists at the present day much prefer the synthetic method in treating of the results acquired, and endeavor to affiliate the countless forms of extinct creatures which are constantly being brought to light. This new science, Phylogeny, rests in great measure on palaeontologic data, and in return supplies these with their greatest attraction. Its importance in the present condition of our knowledge is such that we are obliged to examine in some detail the principles on which it is based and the problems which it solves.

This brief historic sketch makes manifest the fact that Palaeontology, like every other science, but in a more pronounced degree, remained for long centuries in an almost rudimentary state. Some men of genius, in the early part of this century, stated the principles which have raised the study of fossils to an independent science. At the present day Palaeontology is progressing with rapid steps. It proceeds, by successive approximations, as its object naturally indicates. We shall have occasion, in the course of this work, to make manifest the importance of the results achieved, and to point out the problems which still remain to be solved.

CHAPTER II.

Palaeontology and the Doctrine of Evolution.

§ 1. *The Species. Its Variations.**

The profound change which Palaeontology has undergone since the transformist ideas have been so almost universally adopted, is due to two causes: On the one hand the doctrine of Evolution has occasioned a very rapid progress in the study of fossils, and on the other this study has supplied new arguments in support of the new doctrine, whose upholders are naturally led to push palæontologic researches farther and farther. We have now, therefore, to point out how the fundamental principles of the theory of Evolution both receive confirmation from the study of extinct forms, and also throw new light on the history of the succession of these forms. The relations of Palæontology to the study of the *Variations of forms* will then be the subject of this chapter.

Definition of species.—The definition of species is founded on current observation made in all countries, of the evident resemblance of certain forms among themselves and the marked differences between them and forms most closely allied to them. Up to the time of Lamarck, it was held that a species was an immutable entity, limited by an absolute law. The clearest definition was that of Cuvier: "A species is an assemblage of all organized creatures which have descended one from another or from common ancestors and of all those which resemble them as closely as they resemble each other."

In treatises on Zoology and Botany details may be found relating to the difficulty encountered in giving precision to these definitions and in applying them to living creatures. Works on Zoologic Philosophy discuss also the various criterions proposed, such as the fecundity of hybrids, etc.

* E. Perrier, *Traité de Zool.* fasc 1, 1890 Wallace, *Darwinism*, ch. VII. Huxley, *Evolution* in Brit. Encycl. vol. VIII, and *Evolution and the Origin of Species.* Geddes, *Variation*, idem vol. XXIV.

It was Lamarck who first conceived the idea that species are not immutable but were derived from one another. Philosophers, such as Chambers, G. Saint-Hilaire, Grant, von Buch and some others, considered by Darwin and Wallace as the precursors of transformism, occupied themselves in demonstrating, not the non-existence of species, but their variability. We know that Darwin and Wallace were the first who accumulated numerous prooft of variation in living species and demonstrated how arbitrary as times is the distinction made between species, races and varieties.

In Palaeontology the problem of the limitation of species is still more difficult. We no longer have at our service the criterion, which, moreover, is rarely used in Biology, that is the sterility of hybrids, as a proof of difference in species; and we have no means of ascertaining whether the individuals observed come from the same parents. We are forced then to take for our guidance the principle of continuity; we bring together in one species those individuals which resemble each other in essential characters and differ only in secondary characters, such as among living creatures determine varieties and races. We appreciate how profoundly arbitrary such a definition is. One variation may seem fundamental to some palaeontologists while to others it may not appear of sufficient consequence to justify the creation of distinct species. The particular tendencies of each one will exert their influence, just as in Zoology and Botany the discussions up to a recent epoch have been incessant between students who were inclined to multiply specific denominations and those who, on the contrary, wished to restrict them.

Practically, we generally endeavor to group under the same specific denomination those forms which show among themselves gradual transitions. When the passage forms are wanting we make a division. This presupposes that we have under consideration a considerable quantity of material, whilst in fact most species were originally established after the examination of but few specimens, and this is the case now in regard to many new species.

Continuous series of forms.— While the examination of these questions is the order of the day, biologists are constantly discovering many instances of continuous transitions between extreme forms which have hitherto been considered very dis similar. Examples abound in actual nature. Palaeontologists have resolutely entered on this path and the results they have obtained are most interesting.

The first works in which large numbers of individual specimens were brought under notice are those of Hilgendorf and of Waagen. The former of these writers* took up the study of the minute shells belonging to the genus *Planorbis*, which are found by myriads at various horizons in the calcareous rocks of the Upper Miocene of Steinheim (Würtemburg). These shells present forms so varied that they seem entitled to be classed in different genera. They are smooth, carinated, umbilicated, turriculated, rounded, furrowed, etc., etc. Bronn had united them all under the name of *Paludina multiformis*. Hilgendorf and, following him, Hyatt discovered all the transitions between the diverse forms and assert that they were derived one from another. It must, however, be stated that these two writers did not group them in the same manner.

Not less important is the memoir of Waagen on "The Series of Forms of *Ammonites subradiatus*." The author here describes a great number of related forms which he groups under the generic name of *Oppelia*, and he calls attention to an important distinction not hitherto remarked. The variations of one of these forms are of two kinds. The one kind extend from one locality to another in deposits of the same age; Waagen calls these *variations*. The other kind make their appearance in successive deposits of the same locality; he calls these *mutations*. In describing diverse species, Waagen establishes the filiation of all these species in time, and their variations according to localities.

As a third example of classification, we may cite the history of the Paludinas of the Upper Miocene, studied by Neumayr,† to which we shall have occasion to again refer.

These works were a point of departure for a marked reaction against the former tendency, which was to multiply illimitably the number of species. If many scientists still persist in overloading scientific nomenclature with a multiplicity of specific denominations difficult of practical application, the greater num-

* *Monatsber. Berl. Akad.*. 1866.

† Neumayr und Paul, *Die Congerien und Paludinen-Schichten Westslavoniens*. (*Abhandl. Geolog. Reichsanst.*, VII.)

ber of palaeontologists of the present day are otherwise engrossed. When they possess a sufficient quantity of materials, they study minutely the variations exhibited by each separate form, and establish "series of forms," keeping in view both variations and mutations. The analysis is carried farther than it formerly was, but the synthetic conclusions are what complete it successfully. The denominations and divisions may afterward undergo some change, according to the preferences of authors, but the important facts remain established, and the evolution of the group with all its important details is understood.

These delicate researches recorded in works of difficult reading, but whose conclusions are of the greatest interest, have been carried on thus far principally in the class of Mollusks. We shall farther on point out the significance of the recent work of Hyatt on an important family of Ammonites. Buckman has gradually brought into notice the Ammonites of the Bajocian studied from the same point of view. Analyses of a similar nature have had an especial bearing on the following groups: Among the Mollusks, the Cancellarias (Hoernes), the Inocerami, *Halobia*, the Unionidæ of the Slavonic deposits (Penecke), a very great number of Brachiopods (Davidson, Œhlert); among the sea-urchins, the genus *Ananchytes;* the plants considered as the progenitors of living forms (de Saporta). These researches are more fertile in results than those which confine themselves to distinguishing more than a hundred species of *Unio* in French waters, or to creating unconsciously several species out of two branches of the same plant.

What conclusion is to be drawn then from all that has been said on the subject of the limitation of species in Palaeontology? At the present hour every criterion is at fault. The limitation of species is, as has often been remarked, a matter of appreciation. We group under one denomination the most closely related forms, those which are united by many degrees of transition, but all separable from different forms by an appreciable interval. Frequently the transitions are defective between the forms which are found in different layers of the same locality, whilst most horizons are characterized by especial species for every group of fossils. We shall presently see the cause of this phenomenon, which everywhere presents numerous exceptions.

Natural Selection.— The principle of *natural selection*, discovered by Darwin and Wallace, explains how individual variations accumulate and intensify among the descendants of one and the same form until they produce at first varieties, and in the end distinct species. This principle, so well known at present that it is unnecessary to explain it in detail, consists in this: that the struggle for existence permits the survival and perpetuation only of those forms capable of resisting changes in their environment which are often disadvantageous; the varia tions which are of utility, transmitted by heredity, will result in the preponderance of the form which exhibits them, and will become more pronounced with each succeeding generation. When the differentiation is pushed far enough, the new form can no longer cross with that from which it sprang, and a species is established; the primitive form may either entirely disappear, or may persist without modification, or may evolve in several different directions.

Palaeontology can bring no direct argument in support of the principle of selection. But this principle is the foundation of the entire transformist doctrine, the various propositions of which constantly receive from Palaeontology demonstrative verifications.

Intermediate forms. — We must pause here to consider an objection which is made to the hypothesis of the evolution of forms. It has been observed that if species are derived gradually, one from another, one ought always to find intermediate types, and the two extremes must embrace a series of forms strictly continuous To this it may be replied that the very principle of natural selection supposes that the intermediate forms could not be of very long existence, since they lie, so to say, between two fires. It is then a natural consequence that in existing nature there should not be found any transition forms between different species, unless in the case of a new form whose evolution is not yet completed. This occurs in fact in cases which the progress of observations has shown to be more and more frequent.

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* Wallace. *Darwinism*, 1891. Weismann, *Essay on Heredity and Natural Selection*. Fr. trans., 1892.

But a new objection presents itself which brings us back directly to our subject. In the examination of successive geologic beds, we ought always to be able to find transition types between two distinct species, either under the form of local varieties, or else under the form of mutations. But, on the contrary (as it is claimed), Palaeontology fails to furnish any such indications.

Darwin replied to this argument by laying stress on the insufficiency of geologic documents, an insufficiency concerning both the difficulties of fossilization and the relative scarcity of materials acquired. Since that period, attention having been directed toward this class of studies, the transition types discovered have become more and more numerous. We have cited some of these, and in the course of the following chapters we shall, little by little, give descriptions of them. Still it remains an indisputable fact that in the most thoroughly explored regions, those where the fauna is best known, as, for instance, the Tertiary of the Paris basin, the species of one bed often differ widely from those of the preceding, even where no stratigraphic gap appears between them. This is easily explained. The production of new forms usually takes place within narrowly limited regions. It may happen in reality that one form evolves in the same manner in localities widely separated from each other, and farther on we shall see examples of this; but this is not generally the case, the area of the appearance of species is usually very circumscribed. This fact has been established in the case of certain existing butterflies and plants.* The diversity having once occurred, the new types spread often to great distances, and may be found near the present form without crossing with it or presenting any trace of transition.

The same phenomenon must have taken place in former epochs. It is then only by the merest chance that geologists are able to locate the origin of the species they have under consideration; if, furthermore, the phenomena of erosion or metamorphism have destroyed or changed the locality in question, direct observation will not furnish any means of supplying the missing links of the chain. Nevertheless in certain places rich in fossils, where the superposition of the deposits is without interruption, some

* Bates, *The Naturalist on the Amazons*. London, 1863.

special localities have been found where the appearance of new forms have been carried forward with a certain intensity. Thus Hyatt*, after having studied thousands of individuals from the principal deposits of Europe, decides that the cradles of the various branches of the Arietidæ are the basins of the Côte d'Or and of Southern Germany.

Transitions between genera and between the larger groups.— The preceding remarks relating to the causes of the insufficiency of palaeontologic documents are applicable also to the terms of transition which must have existed among the more extensive groups, as genera, families, orders and classes. If the principle of evolution is correct, forms the most isolated in appearance, the most specialized types, must be connected by transition stages with ancestral forms, whence other groups were derived. Palaeontology brings to light a great number of these intermediate types which have at the present day entirely disappeared. Thus among the Echinoderms, the group of Cystidians embraces forms which must have given rise to the types so well defined at the present epoch, Asteroids, Echinoids and Crinoids. Among the Vertebrates we recognize transitions between the Reptiles and the Batrachians; the most ancient of the Crocodilians, Lacertilians, etc., differed less than do the living forms, and approach nearer to the lowest type of the class, represented at present by the genus *Hatteria.* The most ancient birds known had very marked reptilian characteristics. Palaeobotany furnishes also conclusive examples in plants; the primitive forms of the Gymnosperms and Angiosperms are at present known.

Palaeontology thus furnishes important arguments in support of the continuity of animal or vegetable forms. Nevertheless, considerable gaps still exist. As in the case of species, these gaps are gradually narrowed by the recent discoveries of exotic beds. Thus, until the last few years, it was a matter of surprise to see the Ammonites suddenly appear in the Trias, in forms already very complicated, and with no apparent connection with the Goniatites of the Carboniferous. But the recent investigations of Gemmellaro upon the fauna of Sicily, those of Waagen on the fauna of India, have made known transition forms in the

* Hyatt, *Genesis of the Arietidæ* (*Mem. Mus. Comp. Zool.* Cambridge, 1889.)

Permo-carboniferous age, and have demonstrated that the evolution of the Ammonite type must have taken place in the southern and eastern Mediterranean zone.

Whilst acknowledging the importance of the new results with which Palaeontology has enriched the history of the evolution of organisms, it must be allowed that this science so far has not done all that was expected of it, especially as to what concerns the origin of the great subdivisions of the animal kingdom. Thus the Brachiopods, Insects and Mammals appear isolated, notwithstanding that their remains have been found in more and more ancient deposits; the representatives of the ancestral forms of these groups thus far have not appeared. Frequently some especial cause for each particular case can be assigned for these gaps. Thus, for instance, the ancestors of the Vertebrates were probably soft animals, as seems to be proved by the existence of *Amphioxus;* naturally they would not leave any traces in the rocks. The same may be said of the progenitors of the Batrachians, which were cartilaginous. Or, again, the group in its entirety is not aquatic, and leaves but few representatives, as is the case with birds and insects. Lastly, it may happen that the hard parts which are of much importance in affording us an acquaintance with a large number of individual fossils, still do not permit of any precise determination of anatomical details, as in the case of the Crustacea, the Gasteropoda, and many of the Cœlenterata.

Saltation.*— The insufficiency of materials, so often invoked, partly explains then the gaps observed, and weakens the importance of the arguments deduced from those against evolution. Nevertheless, this idea is not sufficient; it does not explain, for example, why the Acephala are never found in the Cambrian,† while the Gasteropoda are numerous there; and why they appear suddenly in the middle Silurian in various forms and bearing all the essential characteristics of a group. Neither does it explain why, in more recent epochs, important gaps exist between families in groups whose representative fossils are very numerous and well preserved. If we examine the succession of life in time, or study the contemporaneous forms of any given epoch,

* Eimer, *Entstehung der Arten*, Jena, 1887.

† Later studies of these faunas by Walcott and others, show the presence of Acephala in the lower Cambrian.—ED.

nature everywhere seems to give an emphatic denial of the celebrated formula so long considered an axiom, *natura non facit saltus.* The continuity is sometimes manifest, evident to the point of rendering it almost impossible to form distinct groups, for example, of those contained in a large genus; but the intermediate forms are more and more rare between genera, families, orders and classes. There are times when evolution seems to have proceeded by leaps more and more abrupt. There is a much greater difference between the Acephalate and the Gasteropod which resembles it the most closely, than there is between the two extremes of the series of Acephala, or between the two extremes of the series of Gasteropoda. Between the Reptiles and Mammals only two or three intermediate forms are found, and these are doubtful and aberrant. But if the appearance of this last type had been as gradual as its ulterior evolution, millions of transition forms must have existed in a long series of geologic beds, and it would have been impossible for them to have left so few traces.

A great majority of the transformist school of the present day interpret these important facts by admitting that evolution must have taken place sometimes very rapidly; this is the hypothesis of *Saltation*, especially maintained by Cope and Haldeman. It is incontrovertible that the rapidity of evolution in the same group presents extreme variations; thus, on the one side we see the type of *Lingula* existing without any important modification from the Cambrian [Ordovician] epoch to the present, while among the Terebratulas and Rhynchonellas the species is constantly *losing its bearings*, as Vilmorin has picturesquely expressed it. It is well known also that the essays of experimental transformism have demonstrated that very appreciable variations can be obtained in the course of a few generations. Saltation consists in this, that these rapid variations of a given type may be continuously produced in one and the same direction, so as to effect a notable modification of the primitive type. There must have been, in some sort, an accumulation of "progressive forces" and the "conservative forces" yielding suddenly, finally permitted the production of the evolution, for which preparation had been made during the course of generations. This idea of the discontinuity of the effect despite the continuity of the effort has abundant illustration in all the physical sciences.

Advocates of the transformist doctrine had this hypothesis long in mind, but only recently has it been definitely formulated, and it is still at the present day difficult to give any very precise proofs of it. We have thought it desirable to make particular mention of it for the reason that it adapts itself in a remarkable manner to palaeontologic data, and explains many difficulties.

§ 2. Causes of Variation.*

Insufficiency of the theory of selection.— Without recanting any of the doctrines which he had so firmly established, Darwin, toward the close of his life, became convinced that natural selection, all sufficient for the fixation of variations and the production of divergencies, was not sufficient to explain the cause of these variations, and was not the sole phenomenon which played a part in the mechanism of evolution. More of a Darwinist than Darwin himself, Wallace has always attributed to natural selection an exclusive influence; he admits that individual variations are spontaneous, multifold and produced in every sense at hazard, and that a very small proportion of them are transmitted by selection, and are of no utility in introducing any other force.

One of the most interesting questions on the subject under consideration is this, whether individual variations are really spontaneous or whether they are due in some degree to the direct action of the medium in which the organism exists. We know that Lamarck attributed a preponderating influence to the conditions of the surrounding medium. He found the explanation of the mechanism of variation in the development of those organs which were frequently exercised, and the reduction of such as were not used. This is the phenomenon which Ball calls, for the sake of brevity, the *heredity of exercise.* This idea was, from the outset, ridiculed by prejudiced adversaries, and judgment was passed on it, as is expressed by Isidore Geoffroy Saint-Hilaire, "without any study having been made of the sources themselves, and following unreliable accounts which are to the views of Lamarck only what a caricature is to a portrait."

Darwin, and especially Wallace, at the outset rejected the ideas of Lamarck without much investigation of them, but they have recently been revived with distinguished success by Herbert

* Riley, *On the Causes of Variation in Organic Forms.* (*Proc. Americ. Assoc. Adv. Sc.* 1888.)

Spencer,* by Semper,† by Cope‡ and the American school of Neo-Lamarckians. Spencer insists on the effects of use and disuse and shows that very small variations in the force of an organ can be of no service to the individual nor thus preserved by natural selection. These objections appear to have much embarrassed Wallace, who replies by the enunciation of a new law due to Galton — the law of the *return to the mean :* When any part has been increased or diminished by selection, there is among the progeny a strong tendency to return to the mean condition whenever the influence of selection ceases to act. The degeneration of the atrophied parts might also be explained by a utilitarian purpose; an organ too weak becomes a source of danger and should disappear by selection.

The whole question becomes reduced to two terms which are easy to define.

1. Are there really individual modifications which are due directly to variations of the medium?

2. If the modifications in question are produced, can they be transmitted by heredity?

Influence of the medium.— The affirmative answer to the first question has been given in particular by Semper, who supports it by numerous examples drawn from the Mollusks. The recent experiments made on plants, particularly by the Botanical School of France, show in the structure of plants important and strictly determinate variations as conspicuous in the higher types as in lower forms, like the Mushrooms. Facts of this kind form the basis for the methods everywhere applied for the transformations of pathogenic microbes in vaccinations. Accurate experiments have been made on beings of much higher organization. Whitfield, Semper, Locard, Clessin, Dall, Baudon, etc., have shown that important variations were effected among Mollusks by changes in the dimensions of the medium, in its agitation, in its pressure.§

These observations are not very easily explicable by the theory of Weismann, which Wallace has accepted, of the *non-*

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* H. Spencer, *Factors of Organic Evolution.* 1886.

† Semper, *The Natural Conditions of Existence as they Affect Animal Life.* London, 1883.

‡ Cope, *The Factors of Organic Evolution; The Natural Conditions of Existence as they Affect Animal Life.* London, 1883. *The Origin of the Fittest.* 1887.

§ See Locard, *L'influence du milieu sur le développement des Mollusques,* 1892.

*heredity of acquired characteristics.** Still it is certain that variations produced directly and artificially are not generally so strongly fixed that the modified type may not return to the primitive type by a return to the first conditions. This notably happened in the famous experiments of Schmankewitz on *Artemia salina.*† This Phyllopod Crustacean normally lives in brackish waters, but being raised in waters more and more fresh, it evolved gradually, and at the end of some generations was transformed into a very different form which had been described under the name of *Branchipus stagnalis*, and which lived normally in fresh water. On the contrary, by augmenting the saltness of the water, *Artemia salina* can be transformed into *A. Milhauseni*, a species which habitually lives in marine waters. But in the case under consideration it is to be seen that, on the one hand, the variation is not sufficiently fixed to prevent the return to the primitive type (whichever of the three species that may be); whilst, on the other hand, the acquired characteristics are highly hereditary, since in a given medium each of the three forms respectively perpetuates itself with a persistency sufficient to form a veritable species.

The direct or indirect influence of the medium on variation is moreover an indubitable fact, but it remains to be determined whether the variations thus transmitted are acquired by exercise or disuse, or whether they are spontaneous variations of the germinative plasma, accumulated through natural selection.

Experimentation alone can furnish a conclusive solution of this problem, which at the present day engages the attention of so many naturalists. Palaeontologists, moreover, have entered into the discussion, and have brought forward arguments more or less theoretic, drawn from the study of fossils.

American Neo-Lamarckism.— The theories of Cope‡ and of Hyatt are enveloped in some metaphysical obscurities which struck Darwin himself.§ The most important points are, first, the acceptation of the influence of the medium; and, next, the

* On this theory (*theory of the continuity of the germ-plasma*) and its consequences see Weismann, *Essay on Heredity and Natural Selection;* Ball, *Are the effects of use and disuse hereditary?* Numerous articles by Vines, Turner, Weismann, Osborn, Mivart, Ryder, Lankester, etc., in *Nature* and *American Naturalist.* 1889, 1890, 1891.

† Schmankewitz, *Zeitsch f. w. Zool.* 1877.

‡ Cope, *Origin of the Fittest. Essays on Evolution.* New York, 1887.

§ *Life and Correspondence of Darwin.*

intervention of a force, not well defined indeed, called *Bathmism*, which appears to be nothing else than a generalization of the laws of acceleration and retardation, a subject which we shall consider farther on. The interest of these works, abstracting from them the purely metaphysical portion, is the application of the theory, just explained, to Palaeontology. Admitting that frequent exercise strengthens organs, Cope points out an easy explanation of cases of interesting variations. The most striking example is furnished by the origin of the structure of the foot in the hoofed animals. Cope admits that the parts which compose the members may become lengthened, under the influence either of reiterated shocks or of tension. Hence originates the length of fingers in the Digitigrades, the length of the tibia among the Plantigrades, the development of the hind feet of the Jumpers, such as the Kangaroos and Jerboas, and the fore feet of the Sloths.

The soldering of the bones and the development of the joints receive a simple explanation, as does also the presence of horns in the Ruminants. The evolution of these organs is followed, step by step, in the fossil types down to the present forms, and is well developed in the sense indicated by the theory. It is noticeable how emphatically the American school reverts to the ideas for which Lamarck was so bitterly reproached, and explains them in almost the same terms. But Cope goes still farther, and considers animal will and intelligence to be primordial causes of these variations;* thus, at the outset, it was because the aquatic animal sought to keep its legs stiff, that those organs lost the power of flexibility in any great degree; so too the Artiodactyls would intentionally draw back the two extreme fingers behind the others in order to protect them, and so on. It is unnecessary to insist on the numerous and definite objections which are raised against these exaggerations. The American school has, moreover, rendered many other services to the transformist cause, and we shall presently see how the works of Hyatt put us in possession so far as one extensive group is concerned, of the mechanism of the production of new forms.

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* Cope, *Origin of the Fittest*.

§ 3. EFFECTS OF EXTERNAL CAUSES.

Adaptation.— The adoption of the hypothesis of the influence of the medium furnishes an immediate explanation of the innumerable cases of adaptation which are observable in the two organic kingdoms. Natural selection alone would, moreover, furnish, in many cases, a sufficient interpretation of the phenomena observed.

Adaptation is the fact that types which, in the sum of their characteristics, manifestly belong to the same group, present differences which are in direct relation to their especial mode of life. Thus the Cheiroptera differ from all the Mammals by their adaptation to aerial locomotion; the Pulmonates are the only Mollusks (with three or four exceptions) adapted to respiration in the air; the limbs of the Cetacea permit only aquatic locomotion, etc.

The phenomena of adaptation have been particularly elucidated by Geoffroy Saint-Hilaire, who demonstrated that in the same group the organs adapted to diverse functions are referable to one and the same type. He established, for example, the homology of the parts of the skeleton of the vertebrates, whatever the functions to which they are applied in the diverse forms. From this it is but one step to a reasonable explanation of those diversities by the hypothesis that modifications are actually and gradually produced at the expense of the primitive type. This step Geoffroy unhesitatingly took.

We must include in this order of phenomena all cases of mimicry, premonitory coloring, etc., on which Darwin and Wallace so urgently insisted.

Zoology and Botany display at every step examples of this important phenomenon. Palaeontology places it within our power to grasp this phenomenon of function, and in many cases shows how the gradual transformations are produced.

The most celebrated example is that drawn from the study of the fossil forms which are considered as representing the series of progenitors of the horse. It is well known that among those animals the cubitus and the radius are rudimentary, that each limb presents but a single finger, by the sides of which are two small stylets, which represent, in the rudimentary state, the fingers 2 and 4 of the other Mammals. These fingers are very much elongated.

But there has been found in Europe, and especially in America, at a period later than the Lower Eocene, an entire series of types in which these characteristics of adaptation are more and more strongly marked. The first of these types, *Eohippus*, has one cubitus, and one fibula very distinct, four fingers, and one rudiment on the fore foot, three on the hind foot. This animal, small of size, presents in but a slight degree the differential characteristics of the horse, but through all the succeeding generations the characteristics in question make their appearance little by little, by a very moderate gradation (Marsh, Huxley).*

The adaptation to flight of the anterior limbs of birds is brought about by a process of evolution, several terms of which are known to us. Among ordinary birds the fingers of the anterior extremity are shortened in such a manner that one of the fingers is only a weak stump; the remainder of the hand is reduced to three metacarpals united and bearing one or two phalanges. The extremity of the wing can only execute movements of flexion of small scope. But the most ancient bird known, the *Archæopteryx* of the Upper Jurassic presents a much less degree of regression; three fingers are well represented and separated; the middle finger has three phalanges, the others two, and the fingers terminate by claws so that the hand is adapted to prehension. The embryos of the ostrich possess characteristics between these two extremes. Other details relating to the power of flight are also seen in other organs, and to a less degree in *Archæopteryx* which is closely related to the reptiles, than in the living birds. In the course of this work we shall refer to numerous cases of the same kind.

The organs most apt to undergo modifications are naturally those which serve the animal in its relations with the external world; such especially are the members which are employed in prehension, progression, flight, leaping, swimming, and in the teeth which are adapted to the food of the animal.

But in many instances the entire form of the animal may be modified by causes of the same kind, and Palaeontology sometimes leads to the discovery of the gradual progress of this evolution.

Correlation.— Generally speaking, the adaptation of any type to a determinate mode of existence is not confined to the modification of a single organ; for example, the transformation of a terrestrial vertebrate into an aerial type supposes simultaneous modifications in various parts of the skeleton, in the muscular system of the limbs, and also in other parts of the organism. Thus among adult birds the anterior and posterior extremities

* Marsh, *Lecture on the Introduction and Succession of Vertebrate Life in America.* (*Nature*, vol. XVI, p. 471.)

undergo the modifications already mentioned, but furthermore, the three bones of the pelvis are closely joined, and the caudal vertebræ are united in one bone (coccyx). In the Archæopteryx, on the contrary, the bones of the pelvis are separated, and the tail is formed of 21 vertebræ; the transition manifests itself in young birds, where the bones of the pelvis are very weakly united, and where the vertebræ of the tail are clearly distinct, especially in the Ostrich.

This is a clear example of variations in *correlation.* The principle of correlation was enunciated by Cuvier, and applied by him with a success which has remained a lasting triumph. According to Cuvier, "The parts of a living organism are so closely related, one with the others, that no one can be changed without necessitating change in the others." Hence, given the form of one organ of an animal, it is possible to deduce the form of all the others. This is a consequence of another principle, that of the *conditions of existence*, according to which an animal especially created to live in certain conditions, must have all its organs adapted to this end.

Cuvier, a strenuous partisan of the creation and immutability of species, did not seek to investigate the cause of the principle he enunciated, but confined himself to illustrating it by examples. He showed, for instance, how among the carnivorous mammals the teeth are incisive, and the jaw so articulated that only vertical motion is possible; among the herbivora, on the contrary, the teeth are cuspidate, adapted to grinding, and the articulation of the condyle of the jaw is so elongated as to favor a lateral motion. These characteristics with others are always associated in the same individual.

We shall presently see what estimate we should make of the general application of this law.

The question here concerns, as is understood, different organs adapted to the accomplishment of the same function.

But it frequently happens also, that variations appear in correlation without the preceding condition being realized. Let us consider, for example, the series of fossils of which the horse is the last term.

The study of the dentition shows a series of progressive differentiations from the molars with omnivorous tubercles in *Eohippus* to the molars with herbivorous lamellæ in the living horse. There exists a correlation between these variations and those of the framework of the extremities, and it furnishes a new proof applicable to other animals. Among the Ruminant Artiodactyls there exists a quite analogous series of fossils in which the number of fingers passes from four to two by a gradual regression of the two lateral fingers, while the molars exhibit modifications entirely analogous to those in the horse. There is then a correlation between the adaptation of the members of the ungulates to running, and the specialization of their teeth to an herbivorous diet.

In both the cases mentioned, each of the characters separately, distinguishing a perfect condition for the species, is explainable by the theory of natural selection; whilst some other instances of correlation, perfectly authenticated, are more difficult to explain. Certain characters which are apparently useless to the species, present sometimes a great variability; these are the characters which the Darwinian school calls *Morphologic characters.* But it is undeniably established that they are in correlation with characters of recognized utility to the species, varying as these vary, and thus coming under the law of natural selection. Such, for example, are the secondary sexual characteristics, such as the beard of men, the long hair of women, etc.

Rudimentary organs.— According to Cuvier the principle of correlation of forms was in contradiction to a great number of facts which find their explanation only in the theory of selection. If the animal possesses all that is necessary and nothing that is superfluous for its existence in the condition in which it lives, one can not conceive that it can possess organs which are manifestly of no service to it, and which are found better developed and in a functional state in allied groups. Thus there sometimes exist in man certain muscles which are at other times wanting, but which are found well developed in the monkey. These *rudimentary organs* are innumerable both in the animal and the vegetable kingdoms.

Palaeontology often explains to us the significance of these. The two stylets which are found on either side of the foot of the Horse correspond to the two fingers, provided with all their parts, of the Tertiary Equides. The Parrot possesses in the alveolus embryonic teeth which never develop. But the three birds so far known from the Secondary Epoch, *Archæopteryx*, *Ichthyornis*, and *Hesperornis*, had conical, sharp-pointed teeth like those of reptiles. We are acquainted, too, with instances of limbs, in a rudimentary state, hidden under the skin of certain serpents, and the existence of a very reduced pelvis in certain Cetacea, which are furthermore, like the others, destitute of posterior limbs.

A curious instance, recently brought to light, is that of the pineal eye of Reptiles There is found among certain Lacertilians, on the top of the head and on the median line, an organ which in cases of the greatest differentiation has the structure of an eye, with retina, crystalline humor and optic nerve which passes through a perforation of the parietal bone. But this organ is concealed under an opaque scale, and in no case can be used for sight. It is, moreover, generally very small.

But a number of Reptiles of the Primary and Secondary epochs, especially those of the lower groups, present a parietal opening situated exactly like that of the Lizards, with a much larger aperture. It appears then almost certain that at that epoch the pineal eye must have fulfilled the function of an eye, and its presence is quite inexplicable in actual types where its situation is such that it can not serve for seeing, unless we allow the admission that these existing forms have descended from ancient types where this organ served a useful purpose. It is a curious fact, moreover, that the animal in which the pineal eye is the least reduced, the genus *Hatteria*, belongs to the most ancient group known in the whole class of Reptiles (Rhynchocephala).

To sum up this subject, the existence of rudimentary organs is one of the most conclusive arguments in favor of the theory of Evolution.

Parallelism and Convergence.—The attentive study of the variations of organs among forms living or fossil, has brought to light another important phenomenon which in a marked degree restricts the importance of the principle of Cuvier regarding the correlation of forms. It has been observed that in some groups, whether allied or very diverse, the series of modifications was produced in the same method and along parallel lines. Further, in certain cases, if we examine through successive strata forms originally dissimilar, we find that they evolve in such a manner as to diminish their differential characters, so that the derived forms of each series resemble each other much more than do primitive forms. These are the phenomena of *Convergence.*

In regard to forms very closely allied, it is natural that we should find similar conditions producing similar modifications. Natural selection, or the direct influence of the medium, suffices to explain this. Thus, in very extensive basins, the Paludinas, though smooth and with inflated volutions, have, at various epochs and different points, evolved into carinated and tuberculous forms.

It frequently happens that an analogous process induces modifications in the same direction in very distinct animals. For example, one of the flying Reptiles of the Upper Cretaceous, *Pteranodon*, is toothless and has a sharp beak, which probably was covered with horn. If Cuvier had seen this head he would, without doubt, have considered it that of a bird; and he would, on the other hand, have assigned the two toothed birds of the same deposit to the Reptilia. The disappearance of teeth and the presence of a beak are then characters which have affected in the same manner very different types, Pterosaurians and Birds, both adapted to the same mode of life.

Among the primitive Batrachians of the group of Stegocephala, we find the first tendency of the four-footed type to elongate the body, multiply the number of vertebræ, diminish or lose limbs, to assume, in a word, the aspect of Serpents (*Dolichosoma*). But the *serpentiform types* appear in very different groups. Among living animals, true Batrachians (Cecilians), animals which have throughout the anatomical characteristics of the Lacertilians (*Amphisbœnæ*), also assume the same vermiform appearance. There existed in the Cretaceous epoch, among the Lacertilians, gigantic swimmers possessing more than a hundred and thirty vertebræ, and with very small limbs, thus evincing a tendency in the same direction. The Ophidians also form a branch of the Lacertilians, in which modification has affected the external organs.

An instance often cited is the profound analogy in limbs transformed into swimming expansions almost identical among Reptiles such as Ichthyosaurus and Plesiosaurus, and the Mammalia such as Cetacea.

The invertebrates furnish numerous examples of convergence. Among the Ammonites, for instance, the shell often presents a considerable difference both in form and ornamentation between the first volutions of the spiral, and those which appear later when the animal has reached a considerable size. But frequently the differential characters of species, genera, and even of families, disappear when the animal attains its full size, so that sometimes it is no longer possible to determine by external appearance, for the Ammonites of the Cretaceous for example, to what group the animal belongs, without breaking the shell and examining the internal volutions. We shall see what bearing this fact has on the establishing of the genealogical tree of the Ammonites.

Among the *Gasteropoda* the form of the shell usually corresponds as a whole with the exterior form of the body. But we must beware of drawing any conclusions from the variations of the form of the shell as to the variations of the internal organs. A classification founded on the shell would bring together the most heterogeneous types. Still variations of the shell are produced only in very few directions, and the modifications follow the same law in groups anatomically farthest removed from each other. A shell normally spiral or turbinate may in developing become simply conical, making the transition by a cowl-shaped form; or it may uncoil so as to become a straightened tube, or again the later volutions may entirely cover those preceding as is the case in the Cypræidæ. Lastly the shell passing beneath the mantle may regress and more or less completely disappear. These same phenomena are found in all the types of Gasteropoda; Prosobranchia, Opisthobranchia, Pulmonata, and Heteropoda.

These processes of evolution may be compared to those which, in the Cephalopoda, manifest themselves at notably different epochs, in the two very distinct groups of the Tetrabranchiates and the Dibranchiates. Forms more or less completely uncoiled and precisely parallel have appeared among the Tetrabranchiates of the Silurian, and the Ammonitidæ toward the Cretaceous epoch. It is thus that the *Baculites* of the Maestrichtian reproduce the *Lituites* of the Silurian. It would seem that the same law of deformation of the normal type presided over the evolution of these forms and announced their approaching decadence.

Of the irregular Echini some are provided with jaws, others are destitute of them. No transition term exists between the two types as regards these important organs. But in regard to the exterior form, gradual modifications appear in the two groups to such a degree that for a long time the groups of the Gnathostomes and Atelostomes were confounded.

The Corals, both the perforate and the imperforate, between which no transition exists, display also a certain number of simple or colonial forms which are reproduced in the two groups with a parallelism sometimes so complete as to make us doubt whether the division should be made thus between the perforate and imperforate, or whether we should consider as allied to each group of imperforate corals a corresponding group of perforate forms derived from them, perhaps, by regression.

The same remark is applicable to the *Foraminifera*, perforate and imperforate, which often present exactly the same exterior forms.

It may be seen from the foregoing remarks, that when we seek to establish the real affinities of the various groups, that is to say, their genealogical tree, great attention must be paid to these phenomena of convergence and parallelism, and it must be kept in mind that the same causes have sufficed to produce the same modifications among beings which in other respects had no immediate kinship one with the other.

Aberrant and synthetic types.—A second important exception to the principle of correlation is drawn from the fact that the various series established by taking into account only the variation of a given structure, do not often fuse into a single series, as the principle of correlation would require. This fact leads us to a new conception of great importance.

We say that an animal of a certain group is *aberrant* as to one of its organs, when this organ, through its structure, cannot be admitted into any of the morphologic series constituted for homologous organs in the group in question. It is best to restrict, as we have done, this term, which is somewhat misused; the evolution of an organ can take place in divers directions, and we are not to consider as aberrant a series which, though less extended than another, may be quite as normal.

Of the forms which are well represented in a fossil state, we may cite among Crinoids the genera *Barrandeocrinus*, *Eucalyptocrinus;* among the Echini, the Dysasteridæ; among the Mollusks the Teredinæ, the Rudistæ, the Trigoniidæ, the Anomiæ. The Arthropoda will furnish the Limuli; the Fishes, numerous types as the trunk-fishes, the genus *Amphysilene*, etc. Among Reptiles we find *Triceratops;* among the Mammalia, *Dinoceras* and many others. Comparative anatomy shows many examples of animals which by nearly all their characteristics are naturally ranged in a determinate series, but which in one or more organs differ widely from the forms nearest to them.

Among these aberrant types the most interesting are those which present in association the characters of several distinct groups, without on that account taking a place precisely intermediate between any two of these groups. The fossil Echinoderms present very instructive examples. The exclusively palaeozoic class of the Cystidiæ is a polymorphic group, which presents instances of transition more or less distinct with the Asterias, Echinoids, Crinoids and Blastoids. These four classes, on the contrary, are very clearly defined among themselves, and it is almost impossible to maintain that they are derived one from another. But there exists a curious type, *Tiarechinus*, which presents at once the characteristics both of the Blastoids and the Echinoids. This type, entirely isolated, is limited to the Trias; that is to say, it appears long after the extinction of the Blastoids and after the type of the Echinoids has undergone an important evolution. It is a synthetic type of the most singular kind.

The existence of such forms which can not be assigned to any of the natural series, often causes a complication in the relations we suppose to have existed among organisms in the course of time, and often, too, explains the divergencies manifested in the views of different authors. It brings in evidence a principle which at first appears diametrically opposed to the principle of the correlation or simultaneous evolution of organs. It proves, in effect, that there exists, to a certain degree, a *relative independence in the evolution of organs;* in other terms, a system of organs in this type will be manifestly either behind or in advance of the stage of evolution which it will have acquired in the majority of the group to which the type in question belongs; or indeed the organ in question will present characteristics entirely isolated.

A simple remark will enable us in many cases to refer these phenomena to principles already known and demonstrated. Frequently aberrant forms constitute terms of transition between two groups well marked and defined by the sum of their characters. This is the case in regard to the *Prosobranchia monotocardia* and *diotocardia*, which are delimited by important differences in the nervous system, the gills, the kidney, the heart, the pallial sensory organs, etc. There are at least five or six forms which are intermediate between the two groups in one or more of these organs; but, in these transition forms, one at least of the organs which does not possess these characteristics of transition is aberrant in regard to both groups.

Another example may be drawn from types known only in a fossil state. In the living world there is no term of transition between the Arachnids and the Crustaceans. In the palaeozoic epoch lived the Gigantostraca, of which the Limuli are at present the last and much modified representatives. These animals are in many characters intermediate between the Crustaceans and the Scorpionidæ, but at the same time they differ from each of those. Between the Gasteropoda and the Acephala there is no type of transition known, either extinct or living; the only type which presents indifferent characteristics is *Dentalium*, which is, moreover, very ancient, and is so aberrant that an especial class has been erected for it.

We will also mention the three types of the family, Gnetacea, intermediate between the Gymnosperms and the Angiosperms.

The genus *Welwitchia*, in particular, with its two peculiar large leaves, is one of the most curious types of the vegetable kingdom.

From the Darwinian point of view, these facts, provided they are general enough to claim consideration, are capable of an easy explanation. It is known that the intermediate types in general disappear rapidly in cases where the evolution determines a marked superiority of the new types over those from which they are derived. These latter may, however, subsist, provided the difference between them and the new forms is sufficiently great, so that the vital concurrence is not too unfavorable for them, that is to say, provided the evolution takes place so rapidly that the new forms soon become distinct. As to the intermediate forms, placed, so to say, between two destructive causes, they must, in order to maintain themselves, undergo a special evolution, in a sense peculiar to themselves, and that will occur only if variations appear in an organ which has not been already affected by the evolution of the principal type. Thus protected, so to say, they may persist during long periods without any important modifications; this is the case with all the types we have just cited. Such modifications will the more readily occur, as we have seen, as the evolution is more accelerated during the periods when the new types are in process of formation.

§ 4. General Tendency of Evolution.

Hypothesis of the vital force in different groups.—We have already planned to pursue still farther this philosophic synthesis of the phenomena of evolution. The *mechanism* of Evolution is considered sufficiently known to justify us in turning attention to the determination of its general significance.

One of the most interesting hypotheses which has been proposed is that which considers the various groups, such as the species, genus, family, as having a peculiar individuality, and as presenting the same vital phenomena as do single individuals. A given group must then, according to this theory, necessarily come into existence, grow, reach a climax, decrease and finally die, after having in some cases reproduced themselves in some way, by giving origin to other groups of the same value and a little different, so perpetuating the form with a slight modification. This ingenious hypothesis would explain why, with no apparent reason, groups flourish and then irrevocably disappear, after having presented characteristics which have been compared to the degeneration of old age. There would then be a *vital force* for the species and higher groups as for the individual, and the lifetime of such a form would be limited, as is that of an individual.

Against this hypothesis serious objections can be raised. The characters compared are not of the same order. Instead of looking to the higher races of animals where reproduction takes place by means of the egg, it would be more reasonable to look for our terms of comparison, for example among the Zoophytes or Protozoa, where increase takes place by the division of the individual itself into two parts. It is indeed just in this way, by a sort of division, that species multiply. Nothing is more indefinite than the notion of old age among such animals, where death seems only to arrive through some accidental cause. (Weismann, Neumayr.)

But at the same time there exist groups which seem endowed with an indefinite longevity; from the most ancient epochs they have perpetuated themselves with very slight variations. The Brachiopoda, for instance, have changed so little that the genera from the Cambrian [Ordovician] are still existing. The differences between the oldest form known, Lingulella, and a Lingula of the present day, are quite insignificant, and the Lingulas, properly so called, together with the Discinas, have existed almost without modification since the Cambrian [Ordovician] epoch. The same may be said of the articulated Brachiopoda, such as the Terebratulas and the Rhynchonellas. There is no Brachiopod, in fact, at the present epoch which has not had almost identical representatives from the earliest palaeozoic periods.*

* [Recent study of the generic evolution of the Brachiopoda does not confirm these statements. No evidence could be more conclusive than that now public of the rise, culmination and decline of a very large number of generic groups both of the inarticulate and articulate Brachiopods. *Lingula*, *Crania* and perhaps *Rhynchonella* do, indeed, represent types of great stability and vigor, which have perpetuated themselves through geologic time with the minimum of variation; they are not merely remarkable cases among the Brachiopods, but they are exceptional instances among organisms generally. But it is not difficult to point out structural features wherein the recent forms of these genera differ from their early representatives, even though such differences be not now regarded of generic consequence. The final statement of the above paragraph could not be more erroneous, and it is most unfortunate to find it promulgated here. *None* of the existing types of Brachiopods were present in the earliest palaeozoic periods; not more than *two* generic types have continued from the palaeozoic to the present, and it is safe to say of existing Brachiopods generally hat they are for the most part highly complicated culminant forms or simple decadent expressions of types introduced during the post-palaeozoic and later periods of the earth's history.—ED.]

The examples of these persistent forms, which have remained unchanged from the Cambrian, lessen the value of the argument in question. [See foot-note.] In reality any form may sometimes carry within itself some source of weakness; it may be doomed to disappear soon or late, conquered in the struggle for existence; but this fatality seems to depend in each particular case on special causes, often discoverable, and not to an irresistible law, an universal fatality which embraces all the individuals beyond a certain organic level.

Finally we will add, that so far as species are concerned, the problem seems of little interest. If a form undergoes a rapid transformation, are we justified in saying that it dies? On the contrary is not the process itself the very condition of life?

Law of improvement.—A more exact idea is obtained by a simultaneous examination of the order of appearance and of the degree of organic elevation of the leading types in the two kingdoms — animal and vegetable. From this examination there results, at first sight, a fact which has made a strong impression on naturalists of every era; organisms have been constantly improving from the first periods in which they are found in a fossil state.

This general law finds immediate application when we consider the order of appearance of the large groups of the animal kingdom. In the Cambrian are found Sponges, Cystideans, Brachiopods, Worms, Gasteropods, Crustaceans. In the Ordovician appear the Crinoids; in the Bohemian [Silurian], Arachnids, Insects, Fishes; the Batrachians, not yet of high degree, are found in the Devonian; and the Reptiles, still represented by the lower forms of the group, in the Carboniferous. Not until we arrive at the Trias do we find the first Mammals, and no birds appear before the Upper Jurassic.

The first Mammals are all Marsupials, and it is only in the Eocene epoch that the first Placentals appear. If we consider a smaller group, for instance, the Cephalopoda, we see that the Tetrabranchs precede the Dibranchs; the succession of the Gasteropoda and the Acephala shows, as we shall see in detail, an analogous phenomenon.

Some remarkable exceptions have been found to this rule otherwise so general. These exceptions are precisely those which, as we have seen, present the comparison of groups with individuals. Very many ancient forms have remained without modification, so that if we confine our attention to the characteristics of families or large genera, the ancient epochs are poor in special types. The ancient types have indeed put forth many progressive branches, but a vast number of their descendants have remained without important evolution. There is then in this nothing absolutely fatal, and the gradual improvement of one form of a group in no way implies the disappearance of the lower form.

Another objection against the generality of this law is drawn from cases of evident regression, which are so well known that it is unnecessary to cite them in detail. The majority of parasites are, in the adult state, in marked regression to a determinate stage of their embryogenic development; it is the same with many attached animals, like the Ascidians. The regression, moreover, is not in general anything more than the result of an adaptation to a peculiar mode of life.

The palaeontologic objection to the hypothesis of improvement drawn from the simultaneous appearance of forms of unequal grade in very ancient epochs, does not appear to us conclusive, on account of the insufficiency of evidence concerning the Silurian period. In fine, if we confine our attention to the grand lines, Palaeontology on the one side elucidates the general law that the most differentiated forms have almost always succeeded the others, and on the other side it makes known the fact that certain types have persisted without any important modification, and that consequently improvement does not necessarily imply the disappearance of the ancient forms inferior in organization. Some forms then remain unchanged, but the greater number evolve in a progressive direction.

In order to explain this general tendency toward improvement which thus manifests itself in all groups and affects all their organs, some have thought it necessary to suppose an especial force, a force innate in the living creature, a *vital phyletic force*, the effect of which would be precisely the gradual and final progression of the organisms which are derived one from the other. The advantage of this theory is that it supplies a solution of the difficulties which the doctrine of selection fails to solve, an explanation of these phenomena of the correlative progress of organs, of these modifications parallel and forced, as it were, in distinct groups, of these laws of improvement which are in fine few and constant.

To sum up a phenomenon in one word is not to explain it, and the objection to this new idea is that it announces in brief terms a known fact, but does not elucidate it. Furthermore, the existence of this force is not constant, since on the one hand we are acquainted with groups in which no tendency toward improvement has ever shown itself, while in other cases improvement has only manifested itself in a portion of the individuals which have undergone evolution, and again another portion may have existed for long periods without appreciable modifications.

At the present day we are often obliged, in studying the problems connected with evolution, to confine ourselves to seeking through synthetic approaches the enunciation of phenomena, leaving their explanation to a future day when more conclusive facts shall be known, which will throw light on whatever remains obscure in these difficult questions.

CHAPTER III.

Phylogeny.

§ 1. Natural Classification and Phylogeny.

Definition.— Since the idea of the evolution of species is no longer a simple conjecture, but is based on certain scientific data, the investigation of genealogic trees of living organisms or of fossil forms has acquired considerable importance, and there is scarcely any systematic work either on Zoology or Palaeontology, which does not conclude with a more or less extended essay in that direction. Darwin contented himself with establishing on a solid basis the principles of the doctrine of transformation, and left to his successors the task of deducing the consequences. He demonstrated that species are derived one from the other, and that consequently there exist between all organisms, both living and extinct, veritable relations of parentage more or less removed. *Phylogeny* is the determination of these ties; it is the investigation of the descent, not only of allied species, but also of the most extensive groups, in fine of every form, both of the animal and vegetable kingdoms.

Principles of classification.— The problem of Phylogeny is only a new form, due to new ideas, of the problem of natural classification, which has confronted us from the time when living organisms first began to be objects of serious study. Buffon opposed every idea of classification, while Linné, the first who established a substantial classification, considered the taxonomic method simply a convenience for abridging the exposition of characters and for facilitating researches. Nevertheless toward the close of his life he indicated the path to be followed in order to arrive at a more rational principle. Jussieu was the first to establish in an authoritative manner the principles of a natural classification. He devoted his energies to presenting as faithfully as possible a demonstration of the relations which exist among all the types of the vegetable kingdom. In order to realize this idea of natural classification we must no longer allow ourselves to appeal to any single characteristic no matter how convenient or easy of observation it may be; we must take into account as far as possible the entirety of the organism. Classifications where the divisions are founded each on a single character may afford a certain means for facility in quick determinations; these are *systems.* The word *method* should be reserved for the natural classification. This could only be finally established if all organisms, both living and fossil, were completely known, but we can strive toward its attainment by successive approximations.

The transformist doctrine has suddenly thrown much light on the problem of classification; it has freed the idea of natural classification from whatever was obscure and metaphysical. The principle of descent once established, affinities explain themselves by the relations of parentage, and natural classification is nothing else than Phylogeny.

It is easy to understand the interest which attaches to the discovery of the genealogic tree of organisms which exist or have existed in remote epochs. One of the most illustrious teachers of the transformist school, Haeckel, has won great distinction by his essays in this direction, and his principal works, "*Anthropogeny*" and "*Natural Creation,*" raised polemic discussions, the echoes of which have not yet ceased.

Palaeontology stands in the first rank among the natural sciences which have advanced our knowledge of Phylogeny. At every page we shall have occasion to indicate to what point we have actually attained in the connection of extinct forms either with each other or with forms now living. We must, therefore, bestow some attention on the processes whereby the relations of parentage among organisms are determined. These processes may be referred to three general methods, two of which apply equally to living or extinct types, while the third, founded solely on the relations of Palaeontology and Stratigraphy, is consequently applicable only to fossil forms.

§ 2. METHOD OF COMPARATIVE ANATOMY.

Evolution of organs.— If there really exists a filiation between the creatures of the present day and those of former times; if, as is supposed by the fundamental hypothesis of the transformist doctrine, there is a continuity existing between all forms, including those which are extinct, this continuity should appear in the disposition and structure of all the organs in the various types of one and the same series. Consequently the gradual variations of the same organ in forms sufficiently near to each other, are in direct relation to the filiation of the animals or plants of the group in question. In order to apprehend this evolution of organs, we often find it necessary to recur to the principle of the *unity of structural plan.* The celebrated theory of Geoffroy Saint-Hilaire, stripped of its exaggerations, applied and restricted carefully in the limits of groups which are not too extensive, thus becomes a point of departure for a method rich in important results.

From this may be seen how Comparative Anatomy can furnish a solid basis for the construction of phylogenic systems. It appears, even at first sight, that the problem demands only the examination of an organ sufficiently characteristic and variable, and that from the relations between the forms of such an organ a conclusion can be arrived at as to the filiation of the types themselves. If this were the case nothing would be easier than to convert an artificial system into a natural and consequently phylogenic classification. This is what many naturalists are still doing, attributing to organs or systems of organs which they have studied, a preponderating importance, sometimes employing it exclusively for the establishing of genealogical trees. Unfortunately the essays in this direction are often far from being in accord with each other, nor can we always explain these divergencies by insufficiency of material or faults of interpretation.

We must indeed appeal to those phenomena which we have already cited and which have often complicated the laws of organic evolution. We know that organs may undergo parallel modifications in groups sometimes widely separated from each other, and much more may they in series near each other yet independent, and this may give rise to phenomena of convergence. In this case, if we take as the basis of our estimates one of the systems of organs in question, we incur the risk of confounding in the same series forms quite distinct. Thus, if we should rely exclusively on the form of the limbs in Quadrupeds, we would be led to associate Reptiles like the Ichthyosaurus and Plesiosaurus with the Mammalia like the Whales and Seals, on account of the fact that in them the limbs are transformed into swimming organs. In many cases the inexactitude in the result is less evident than in the example just cited.

It will then often be found difficult to determine which are the organs whose diverse aspects are a decisive indication of all the stages of the evolution of a group. We should, therefore, turn our attention not to one single organ, but to the whole assemblage of the more important organs. We shall often see a type which, belonging to a determinate group by the sum of its characters, is at the same time separated from it by some one character which we call aberrant. In this case the difficulty can sometimes be easily explained; in determining the general expression of the evolution we can deduce the particular history of a given organ which presents especial difficulties.

This method is applicable in Palaeontology only at the cost of great labor. The organs preserved in a fossil state are usually few in number, and it is well understood that it is not always possible to conclude from the external form what the internal structure is. The question of the state of preservation holds an important place, and even under the most favorable circumstances, great skill is required in order to study, for instance, the brachial organs of the Brachiopods; the masticatory organs and ambulacral zones of the Echini; the ventral surface of the Crinoids. The discoveries made in this direction, in other words, the application of the method of Comparative Anatomy to fossil forms, has effected a marked progress in Phylogeny. We shall see a striking example of this in the chapters which treat of vegetable Palaeontology. The knowledge of the organs of reproduction, the simultaneous study of the stems and roots of the plants of the Carboniferous epoch, have made possible the complete anatomical study of these plants; has filled an important gap between the vascular Cryptogams and the Gymnosperms, and has marked out with an almost absolute certainty the general progress of the evolution of vegetable forms.

§ 3. EMBRYOGENIC METHOD.

Law of the parallelism of Ontogeny and Phylogeny.— The second method appeals to researches still more delicate and in which less advance has been made. *Embryogeny* is a recent science, whose progress must necessarily follow our knowledge of adult forms. But already in many cases it has enabled us to elucidate questions which Comparative Anatomy left unsatisfied. Even palaeontologists have for some years past been earnestly seeking for the results which this science furnishes.

The importance of Embryogeny rests entirely in the application of a law which has been the point of departure of most of the researches lately made on the subject of the development of organisms. Discovered by Kielmeyer and Geoffroy Saint-Hilaire, formulated by Serres in regard to the human species, defined more precisely and generalized by Haeckel, this law, verified and restricted by later researches, is still one of the most fecund principles of the transformist doctrine. It consists in this, that in a general manner, before arriving at the adult state, animals, in the course of their development, pass through the diverse stages which marked the progress of the evolution of their ancestors. In other words, according to the celebrated formula of Haeckel, "Ontogeny is the abridged reproduction of Phylogeny." If this law is strictly true, it is evident that no other criterion is needed to reconstruct the entire genealogic tree of the animal, since the diverse "forms constitute a gallery in miniature of the portraits of their ancestors."

In default of a direct verification, which, in the present case, is evidently impossible, this law may be considered as proved by numerous facts which admit of no other explanation. Many animals reproduce in the course of their development the series of the lower forms of the group. Such are, to confine ourselves to classic examples, the anourous Batrachians, decapod Crustacea, the Comatulas, etc. Examples of analogous facts are innumerable; we shall give in detail only a few selected from the domain of Palaeontology.

Embryogeny of fossil forms.— The earliest results in this order of ideas are due to Würtemberger who, in 1873, applied these principles to the Ammonites.

In examining the forms of the group of *Perisphinctes* we see in the oldest types the shell ornamented with ribs, two or three times branched; among the somewhat more recent forms the points of the ramification swell out into tubercles. Later a second range of interior tubercles appears, and at the same time the ribs show a tendency to disappear. The interior range of tubercles, and afterward the exterior range diminish in turn, and the shell becomes almost smooth. This last stage is attained in *Aspidoceras cyclotum.* If the external whorls of an adult specimen of this species are removed so as to bring to light successively the more and more elementary whorls, we see that the same individual has presented successively all the preceding aspects, and even on the earliest whorls we find bifurcated projections which finally disappeared. The Ammonite then has passed in succession all the stages attained in the adult state by species which formerly existed.

Metamorphoses such as these are absolutely general in the group of Ammonites. The ornaments are constantly modified with age and the youngest stages are always identical with the adult forms of more ancient epochs. It is quite necessary, therefore, in order to determine exactly to what group an Ammonite belongs, to be acquainted with all the stages through which it has passed, for it frequently happens that forms notably different in youth lose little by little their differential characteristics in virtue of the phenomenon of convergence which in this group manifests itself with a peculiar intensity. This embryogenic method is now in current use for the study of this class, one of the most important for palaeontologists; by means of this method light has been thrown on the mass of writings accumulated by the former researches of both earlier and later authors, and Phylogeny is now the only process of classification employed on this subject.

This order of ideas is carried even farther, and, in examining the most primitive stages, we have in many cases come to know in what way a determinate series of Ammonites descended from the more ancient and more simple forms known as *Goniatites.* The successive septa which, as the shell increased in size, bounded the living chamber of the animal, were attached to the shell itself by lines of *suture*, the shape of which is very important. But the sutures of the earliest septa among the Ammonites are extremely simple, and bear a strong resemblance to those of the Goniatites of various families. The forms of the most ancient Ammonites recently discovered in the Upper Carboniferous, establish precisely in the adult state the transition between the two groups.

A similar attempt has been successfully made by Jackson in regard to the Acephala. This author has seen in living species the young forms of the Oyster and Pecten, and has shown that these forms were provided with organs such as the byssus, the anterior muscle, etc., which are wanting in the adult, and the disappearance of which is accompanied by considerable modification in the general shape of the body. He has followed out the modifications in diverse types and demonstrated that these temporary stages were attained in a permanent state in extinct forms which must be considered as ancestral.

The embryogenic study of fossil forms is still in its infancy, and presents always greater difficulties than does the study of living organisms. It is impossible, indeed, to take a direct view of the development of the embryo, and the organism seldom bears traces of the forms it has passed through in its embryonic state. We are obliged, then, to content ourselves with carefully comparing the forms which are considered as successive phases of the development. Despite these obstacles the path is so fertile in results that palaeontologists do not hesitate to enter on it; we shall see, even in the Vertebrates, that many types described as separate species, are now considered to be embryonic forms of organisms which are found in the adult state in the same layers, and that this discovery has furnished valuable conclusions for phylogenetic data.

Cases of regression.—The law of the parallelism of Ontogeny and Phylogeny makes possible, then, the elucidation of many questions left undecided by Comparative Anatomy. This law, indeed, is able to indicate the right explanation of variations which may admit of various interpretations; for instance, we are often perplexed in comparing various forms of unequal grade of organization to decide whether their filiation marks progress or, on the contrary, regression; in the latter case the form the most simple in appearance may bear traces in the embryonic state of primitive complication; we have just shown this to be so in regard to certain Ammonites.

The same remark applies also to the evolution of each organic system individually considered. The embryogenic development displays in many cases organs which at first develop according to the rules normal for the group under consideration, then the development is arrested, and the organ retrogrades. Thus are formed the *rudimentary organs* of which we have spoken in the preceding chapter. The existence of these organs in no way implies an inferior rank for the animal itself, but it may lead to specialization, to the adaptation to some particular mode of life.

In this case the regression may be simply explained by the action of natural selection. As a striking example, we may cite the case of birds. The wing and the foot of the bird are in a state of regression in relation to the normal type of the limbs of Vertebrates; various bones are found in a rudimentary state, the teeth do not exist in these animals in an adult condition. But phylogenic evolution demonstrates clearly how this regressive adaptation gradually established itself. The most ancient bird known at the present day, the *Archæopteryx*, possesses limbs much nearer these ancestral type, and teeth of the same kind as do the birds of the Cretaceous, which are even more specialized than the *Archæopteryx*. If now we take into consideration the results furnished by embryogenic development, we see that the limbs of the ostrich in the young state show characters resembling those of these ancient forms; we see that very young parrots have in the alveoles teeth which do not develop and which among other birds seem never to have existed at any period. In this case the parallelism of Ontogeny and Phylogeny is striking, and furnishes a clear conception of the mechanism of regression.

After the discovery of the law of parallelism it appeared as though the definitive method of phylogenic classification had been found, and numerous systems have been proposed, founded exclusively on the characters of development, for example, on the position or nature of the vitellus and of the coverings of the egg. If one of these systems rested on a basis strictly exact in theory, we ought to put aside the inconvenience it might present of being always difficult or impossible of application in Palaeontology, and do our best in our endeavors to conform to it.

But this is not the case, and the bearing of the law of Serres and Haeckel is restricted by other phenomena, which we will now consider.

Embryogenic acceleration.— Very often two proximate forms, for instance, two species of the same genus (or more frequently two proximate genera) develop in very different modes. No person would for a moment conclude from this that the ancestral series of these two forms were distinct, the more so as the differences appear most generally in the earlier stages. It must indeed be admitted that in these cases the normal development, which should faithfully reproduce the phylogenic evolution, is modified by the intervention of a new force distinct from heredity.

It is evidently for the advantage of the species that the embryogenic development should take place as rapidly as possible, since during the embryonic stages the young individual is more exposed than in the adult state. The law of embryogenic acceleration is then a consequence of natural selection. It consists in this, that the highest forms in each group develop with more and more rapidity; the stages corresponding to ancestral forms notably differing from the definitive form, may in some cases be skipped. This occurs more especially in the first stages of development. In species even very closely allied these stages present such a diversity that we are often unable to utilize them in seeking for remote ancestral forms. Accessory circumstances, such as the greater or less quantity of accumulated nutritive materials, or the appearance of protecting membranes, or the structure of the temporary larval organs, allowing transient adaptation to the medium where this period of development is passed, alter the normal succession of the phases, and conceal the normal embryogeny.

In Palaeontology, embryogenic acceleration has been especially proved among the Ammonites, for the embryonic stages are so preserved that the successive volutions represent the different stages through which the animal has passed. The characters of a given form will be reproduced, in the development of the descendants of this form, in stages more and more precocious, and may end by never appearing again. We may notice the argument which Hyatt has drawn from these facts for the filiation of the Arietidæ. In this class of Ammonites the septum of the primary chamber is seen to resemble exactly that of the lower forms of Nautilus; in the higher forms this first septum presents a slight curve which, in the immediate ancestors, appears only in the second septum; finally, higher still, to this first curve now become more accentuated, there is added on each side a lateral angulation which reproduces the third septum of the ancestral forms (Branco).

The embryogeny of the Trilobites, studied by Barrande, shows that the acceleration in this order attains a very variable degree according to the genera considered. The normal development of a Crustacean is at present well known and has been determined for very different groups; the animal grows by the successive appearance of new segments in front of the last segment. But among the Trilobites the three divisions of the body — head, thorax and pygidium — undergo differentiations more or less rapidly according to the cases, and often consist each of one piece. Acceleration takes place in very various degrees.

Acceleration of regression.— It is easy to understand that the existence of such a phenomenon does not result in simplifying the phenomena of Phylogeny already so complex.

The theory of embryonic acceleration, when applied to organs greatly modified, can be pushed too far in considering forms remote from the ancestral type. And if the form under consideration is a regressive form, such as we have seen examples of, it may happen that the most recent animal has the semblance of being the most ancient. We will add, however, that in most cases the acceleration of regression only occurs in a determinate organ or system of organs; the rest of the organism may enable us to reconnect the links of the chain and to arrive at a knowledge of the meaning of the evolution.

An interesting example of the embarrassment resulting from the existence of such phenomena is furnished by the group of Chelonians. The osseous carapace which covers the body of the Turtle is formed of different pieces; some of these constitute the independent dermal bones, not homologous, whilst others are only flattened expansions of the ribs and spiny apophyses of the vertebra, uniting one with another. The existence of this carapace, which at the maximum of its development is continuous and without interruption, constitutes the principal trait of specialization of the Chelonians, and distinguishes them from all other Reptiles. It is natural to look for the primitive forms of a group among those in which this process is most slightly indicated. But in one group of Turtles, both living and fossil (*Atheca*), the costal plates are but little developed and are far from being united; the dermal plates, which form the ventral plastron, are also separated from each other, there lying between them empty spaces or *fontanelles*. Among more specialized forms, the *Trionychidæ*, the *Chelydrida*, etc., we find the ossification of the carapace more pronounced; among the Emyda, the Testudinida, etc., it is fully attained in the adult state. It is an interesting fact that among the large fresh-water Turtles and others also, the closing of the buckler takes place very late, the fontanelles remaining for several years. The tendency of the evolution shows itself here without a possibility of ambiguity. Unfortunately the data of Palaeontology do not seem to be in accord with this evidence. All the living families of Turtles are represented in the fossil state by forms but little differing from those existing. But the most ancient of all, the *Psammochelys*, of the Trias of Würtemberg, belongs to the group of the *Pleurodira*, which is the most differentiated and farthest removed from the modern type of Reptiles.

The Turtles of the Jurassic and Cretaceous epochs would appear to be less and less ossified, the oldest of the Atheca dates from the Upper Cretaceous, and the lowest type of the group (*Dermochelys*) is at present existing.

Consequently, Rütimeyer, Baur, and after them Zittel, believe that the evolution of known forms must have been produced in an inverse order. All the known forms which have the carapace partially developed, whether in fossil state or living, would be regressive, derived from specialized types. According to this, the true progenitors of the Turtle would be unknown to us. If this is really so, Embryogeny can scarcely demonstrate it, for it is difficult to conceive that an osseous carapace should exist in an embryonic state, then be absorbed, and the development be forcibly arrested. Nevertheless, the sum of the anatomical characters tends to prove that the Atheca are really a lower form of the Turtles; many traits of their organization bring them near to other Reptiles, for example, the Rhynchocephala. If these are not primitive types, regression has at least so influenced various parts of the skeleton that the entire animal would very much resemble its remote progenitors.

Geratology.— Acceleration not only influences the earliest stages of development, but its action extends also to later acquired characters. It may happen that the definitive adult state of certain species is only a temporary condition for other allied species. This state will exist for a considerable time, during which the animal continues the functions of reproduction. Later, when the animal has attained an advanced age, modifications will appear. These generally consist, in a more or less marked regression, in a suppression of the highest characters recently acquired, and in a general simplification. Cases of senile degeneracy are frequent in living nature. Generally they exert no influence on the evolution of the group, though this is not always the fact.

Late-acquired or *geratologic* characters, to use an expression of Hyatt,* assume a great importance when they affect, not a few

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* Hyatt, *Genesis of the Arietidæ* (*Mem. Mus. Compar. Zool. Cambridge*), 1889.

individuals, but the entire species, and come thus under the law of acceleration. They appear at first sporadic, and seem related to pathologic phenomena; they indicate a change unfavorable to the average conditions. But presently, in formations immediately above, the geratologic alterations become very frequent, which is explicable by the fact that the same physical modifications will produce identical effects on animals of the same species (*law of morphogenetic equivalence* of Hyatt). The geratologic form, at first exceptional, thus becomes normal, and shows a constant tendency to manifest itself earlier; thus a distinct species is established. The evolution of fixed forms or parasites seems to find its explanation in this phenomenon. But it is particularly striking in the Cephalopoda, where it has undergone a thorough investigation. It is seen both in the Tetrabranchiata in the Silurian, and among the Ammonitidæ, in the course of the secondary period. From it are deduced important conclusions concerning the evolution of the group.

In general, forms thus modified are affected with a sort of congenital weakness which renders them less fit for the struggle for life, and deprives them of any long line of descendants; this occurs in the uncoiled Cephalopoda, which attain considerable magnitude, and then suddenly disappear; this phenomenon is observable at diverse epochs and at the expense of distinct groups. It is especially noticeable during the Cretaceous period. It seems, at the close of that period, as though the entire group had been affected with some malady; the unrolled forms multiply; the septa are simplified and frequently present the appearance of those of the Ceratites of the Trias; the ornaments become heavy, thick, and often disappear in the adult, and the entire group ends by dying out and leaving no descendants.

But this is not always the case. Geratologic phenomena sometimes produce simplifications not always unfavorable to the species; they may cause a convergence toward the primitive forms of the group, and the types thus constituted may in turn be the point of departure for new series in regard to which they will hold the relation of primitive forms or *radicles*. In this event the law of embryogenic acceleration will strongly come in force. All the stages which have led to the constitution of the new radicle form will be passed through with a celerity proportionate to the distance gained from that form; this is readily understood. The radicle form being itself regressive, finds itself situated by its characters near a form much more primitive; matters are conducted thus as though nature, seeking to economize time and force, avoided the circuitous route through forms which, though higher and more complex, are not enduring. But the earlier types of this new series still may show, in the history of their development, some traces of this complicated evolution.

The history of the various branches of the Ammonitidæ presents a certain number of these radicle forms with simplified characters; thus *Psiloceras planorbe* is an Ammonite destitute of ornaments, with rounded volutions not embracing. This is the primitive stock of the long series of Arietidæ. But the suture lines of the adult are less complicated than those of the young (Neumayr).

If these phenomena allow us to separate, in certain cases, relationships within the limits of a given series, and to connect the series one with another, they also leave us confronted by new difficulties in the solution of the problem. The apparent resemblance between regressive geratologic forms and the simple primitive forms sometimes gives rise to a perplexity in the determination of radicle forms, the point of departure for new series. This is the condition at the present day in regard to the Ammonites of the chalk, which only recently have been studied in their entirety with as profound analysis as have the Ammonites of the Jurassic.

§ 4. METHOD OF GEOLOGIC CONTINUITY.

Application of the principle of continuity.—The third method applies perhaps less than the other two to objections of a speculative order, but in practice it also presents numerous difficulties. It consists in the investigation of the correlation of the series of fossil forms with the order of succession of the layers containing them; in other words, it is the historic and chronologic study of the group. If we have sufficient material at our disposal, and if, on the other side, the chronologic order of the deposits is well established, we ought to be able to follow the transformations of all the types through the epochs, to determine whether any one form is derived by progression or regression from a more ancient one, to discover at what epoch and by what process the distinct groups, between which passage forms are wanting in living nature, came into existence. It will be understood that when the question concerns the establishing of relationships between genera and families, and especially between species of the same group, such a study can only be entered on with some chance of success, when the materials for comparison are very abundant, when they come from numerous localities and are in a good state of preservation.

For a group where any one of these conditions is wanting, it would be illusory to seek to draw from the stratigraphic succession conclusions of phylogenetic order. This, for example, is the case for the Crinoids. These Echinoderms are abundant only in very few regions, and it is improbable that they were everywhere evolved on the spot. For the Ammonites, on the contrary, the method of which we are speaking, combined intelligently with the preceding two, has already succeeded in giving interesting results, for the specimens collected up to the present are innumerable and gathered from all parts of the world; moreover, they can be collected any day, as many as are desired for any especial object. The Echini also are common fossils and present numerous characteristics which can be utilized for affiliation. M. Munier-Chalmas has for many years followed step by step their evolution, and has made a study of all the terms of transition which have come under his observation. He has seen that sometimes continuous modifications can be followed through a long series of forms, while the heads of certain series appear suddenly, making it impossible to form any judgment as to their origin except a hypothetic one. On these points of stratigraphic and morphologic discontinuity, he established the great divisions of his classification. The result of these researches, which have not yet been published, we are authorized to present in the chapter which treats of the classification of these animals.

Continuity is then our principal guide in synthetic researches of this kind. Unfortunately in a great number of cases the evidence to be had is not sufficient to warrant the attempt to apply this principle. We have seen in the preceding chapter, that in consequence of the very progress of the phenomena, we shall never possess the intermediates between all the species.

But naturalists are less ambitious, and often evidence even wanting in precision is sufficient for nearly exact conclusions. They would be extremely fortunate to ascertain the terms of transition which must have existed between the grand divisions, and which would permit the establishment, otherwise than by theoretic inductions, of the origin of classes and orders. But it is precisely these interesting forms which are oftenest wanting. This is the case with the Birds, Chelonians, Lamellibranchs, Cephalopods, Brachiopods, Trilobites, Corals, Sponges, not to mention those whose ancient types are known with some detail. The method of geologic continuity is, in such instances, altogether defective.

Order of appearance of new forms.— The difficulty is sometimes even still greater, and the chronologic order of appearance is in complete discordance with what we might be permitted to expect from the method of Comparative Anatomy applied to Palaeontology. If the ontogenic evolution is unknown, and if we can not bring in evidence any fact of regression, we are obliged to reserve our conclusion for the epoch when new evidence shall permit us to elucidate the question; until then we should formulate hypotheses with great reserve. Thus the succession of forms among the Brachiopods, the appearance of the orders of Mammals, etc., raise difficulties of this kind.

In a general way, the result of recent discoveries has been to cause us to refer to epochs more and more remote the presumable date of appearance of the various groups. To confine ourselves to facts most recently brought to light, we will cite the discovery, by Brady, of Nummulites in the Carboniferous; that of Ammonites in the Permo-carboniferous system (Waagen, Gemellaro); that of Sponges, belonging to the types of Hexactinellids and of Tetractinellids in the Cambrian (Hinde); of the Arachnids and Insects in the Silurian; of the Myriapods in the Carboniferous (Scudder, Hagen, Ch. Brongniart, Fayol); Fishes have lately been found in the Middle Silurian (Rohon).

It can be seen how dangerous it is to attach an exclusive importance to the order of appearance; every theory which in any way rests on these data, when the question concerns the primordial forms of large groups, incurs the risk of being ere long contradicted by some unexpected discovery.

The uncertainty grows in measure as we approach the more and more ancient deposits. The fossils of the primary epoch which are known at the present day are, it is true, very numerous, yet various circumstances should convince us that the palaeozoic faunas are still less completely known than those of the Secondary, and still more, those of the Tertiary epochs. The primary strata have naturally undergone more changes than the others; erosions at successive epochs have removed considerable extents of the deposits, and displacements have frequently modified the nature of the rock and occasioned the disappearance or alteration of the fossils contained in it; so much so, that for many years primary fossils in a good state of preservation have been found only in few localities; it is only recently that the discoveries made in America, Russia, India, etc., have made possible the definition of the analogies and differences between the faunæ of those countries and those of western Europe already known. Furthermore, many groups which had appeared at remote epochs were represented at first by individuals few in number and of a lower organization, the remains of which are rarely found.

The first fauna.— As has been said, uncertainty increases as we approach more and more ancient deposits. It reaches the maximum when the question concerns the most ancient fossiliferous beds, those from which we might hope to draw some knowledge regarding the actual origin of organisms. The earliest deposits in which fossils are positively known to occur are the Cambrian. The fossils found there are a few Mollusks, belonging to three classes of the group; Trilobites, belonging to diverse families (*Paradoxidæ*, *Olenidæ*); Crustacea (*Leperditia*, *Hymenocaris*); Brachiopoda (*Lingulidæ*, *Discinidæ*, *Orthis*), some Cystids, some Hydroids (*Dictyonema*), Medusæ, *Hexactinellid* and *Tetractinellid* Sponges (*Archæoscyphia*, *Protospongia*). We must add also the impressions of organisms whose determination is uncertain (*Oldhamia*, *Eophyton*, *Bilobites*, *Fucoides*, etc.). This fauna, rich both in genera and in species, embraces a small number of groups, which in reality are not high types of the animal kingdom; but nevertheless they are far from representing the primitive ancestors of animals. The Brachiopoda, in particular, are organisms which must have undergone an extremely complicated evolution, as is proved by the embryogeny of the existent forms, some of which are almost identical with the Cambrian species. The well authenticated animal discovered in one of the oldest layers is justly ranked as a Lingulid, *Lingulella primæva*.* At a yet more remote epoch are found traces which have been attributed to the Annelids. I do not speak at present of the bodies called *Eozoon*, which probably have not an organic origin.

It is then very evident that we do not really know the true primordial fauna. That which characterizes the lowest Cambrian has, it is true, an expression of decided simplicity, for no Mollusks are found there except shells of doubtful relationship (*Theca*), neither are Echinoderms, nor Corals nor Vertebrates; these forms which appear suddenly and without apparent preparation, in the upper Cambrian or the Ordovician, may perhaps have existed in the lower Cambrian, but they were then destitute of the hard parts (shell, test or skeleton), which would prove their state of inferiority, or they existed in regions which possessed a different facies not yet discovered.

Origin of life. Precambrian deposits.— We know nothing whatever in regard to the origin of the Cambrian fauna, found to be almost identical in every part of the globe.

The Cambrian deposits nevertheless are not the oldest of the sedimentary formations. At a lower horizon there exist, in diverse regions, layers which have been formed in the sea; such are the enormous deposits of Canada formed by the Laurentian and Huronian stages, which together are more than 20 kilometres in thickness. The Precambrian terrane of the country of Galles, also very thick, is found under the Lingula flags. In Canada, in the Laurentian period, besides the famous Eozoon, Dawson found carboniferous matter and tubules which he attributed to the worms. The presence of thick masses of bitumen and graphite in the Precambrian beds has a considerable importance. Among the chemical phenomena which living nature presents, the only ones

* [See previous foot note. *Lingulella* is always a distinctly more primitive type than *Lingula*, as shown not only in its ontogeny, but also in the close relations of its actual characters to *Obolella*. Beecher's determination of the radicle of the Brachiopod shell, *Paterina*, in the Cambrian, and its close relation to such pre-eminent members of this fauna as *Obolus, Obolella* and *Lingulella* indicate that the evolution of these forms may have been more simple and direct than the author here supposes.—ED.]

which effect the separation of carbon from the bodies with which it is combined are carried on in living organisms. Carbon, in all its forms, except perhaps the diamond, results always from the modification of materials of organic origin. It is then possible that the carbon and the carburets of the Precambrian deposits represent all that remains of that ancestral fauna whose existence is proved by the most simple process of reasoning.

It remains now to explain how it happens that no relics of those primitive organisms have remained to our day. It is because the deposits of that epoch, once formed, were subjected to great modifications, both mechanical and chemical, which constitute the process of *metamorphism.* The sedimentary layers were pierced with eruptive rocks, among others granite, which spread over them or extended under them and filled their interstices. Either by direct contact or more frequently by the action of water superheated and charged with salts in solution, the sedimentary rocks underwent a sort of baking, which developed numerous minerals not before existing therein, and which sometimes give to them the appearance of eruptive rocks. It is easy to understand how the schists thus metamorphosed preserved no traces of the fossils they may have contained.

A purely mechanical overturn also sometimes suffices to make the discovery of fossils impossible. Thus M. Gaudry tells us that the English geologists, Sedgwick and Murchison, explored the Cambrian beds for a long time without discovering fossils. They observed that almost every part of the rock was fissured or at least cracked perpendicular to the direction of the stratification. In examining places where, on the contrary, the cracks were parallel with this direction, they found numerous fossils well preserved. We should not give up the hope that at some future time geologists may succeed in finding in the Precambrian layers places where metamorphism has not made itself felt. Until that time arrives we can draw no conclusions from geologic data concerning the origin of life, and we must content ourselves with the theories which embryogenic and comparative studies furnish.

In conclusion, it is seen that the study of the filiation of organisms rests on methods the precision of which increases with the increase of our knowledge of the laws of evolution. These laws are complicated, and their application presents considerable difficulties. We have sought to place these difficulties in a clear light, in order that the student may not be surprised at the uncertainty which still exists in regard to many points of this great problem; the discussions which still constantly arise, and the discordance among the theories propounded, should not be invoked as an argument against the doctrine of evolution itself. The method of the natural sciences is unfortunately subordinate to the acquisition of the necessary materials, and in Palaeontology more than in any other science, progress depends on the increase of collections.

CHAPTER IV.

Distribution of Organisms in Geologic Time, with Reference to Their Physical Environment.

§ 1. Definition of Facies.

We have now to consider a new category of problems resulting from palaeontologic studies, problems which pertain more especially to the relations of that science with stratigraphic Geology; they arise from the comparison of fossils of different groups which have existed at the same epoch in different localities. It has long been admitted as a fundamental principle of Stratigraphy that, in a general sense, deposits of the same age present the same fossils. But it is evident that at the present epoch such a principle could not be applied; the faunas and floras are localized in more or less extended regions, and there are only a few forms whose distribution is universal. It has been thus at all epochs; never have the fauna and flora of the globe been identical over its whole surface.

Biologic provinces are defined for any given epoch by the condition that at least one-half of the fauna and flora be distinct.

The term *facies* is applied to the entirety of the lithologic and palaeontologic characteristics resulting from the external conditions which determine the existence of any particular fauna or flora for a given region. These characters are defined by physical conditions, such as climate, altitude or bathymetric depth, the geological or chemical nature of the medium. We may add, also, indirect factors relating to the preceding. By virtue of the laws of the struggle for existence, the variations of every living being depend in a certain measure on the nature of the entire assemblage of the beings which live with it; the general characteristics of the fauna or flora of a region therefore influence the conditions of existence of each of the organisms which compose it, so that the differences which, in consequence of the influence of the medium, appeared in a slight degree among the progenitors, increase more and more in consequence of the biologic reactions which exist among organisms.

We may find, for instance, for any one epoch, a littoral, pelagic, fresh water, estuary, lacustrine or corallic facies; so also we may find an arctic, temperate, tropical, etc., facies. We shall briefly investigate what indications Palaeontology furnishes for the determination of these facies; in other words, we shall show how the study of the associations of fossil forms often enables us to attain a knowledge of the conditions of the surrounding medium.

§ 2. INFLUENCE OF THE DEPTH OF SEAS.

The distribution of animals in the present seas is classed according to five zones, which are pretty clearly defined.*

1. The *Littoral zone*, which is covered and uncovered with each tide.

2. The *Zone of Laminarians* (0 to 27 or 28 metres).

3. The *Zone of Nullipores and Corallines* (calcareous Algæ) (28 to 72 metres), also inhabited by large Gasteropoda.

4. The *Zone of Brachiopoda and Corals* (72 to 500 metres), to which descend the Corals such as Dendrophyllia and Oculina, the Echini, such as Spatangus, Brissopsis, etc.

5. The *Abyssal Zone*, below 500 metres.

It is seldom possible to determine with precision these zones at different geologic epochs; but the indications with which this excellent classification furnishes us may be utilized for the research of the bathymetric facies in geologic deposits. We can, in general, distinguish from this point of view three principal facies: the *littoral*, the *pelagic* and the *abyssal*.

Littoral facies.— The littoral facies is often indicated by the lithologic nature of the rock; conglomerates and coarse sandstones, can only be formed in the immediate vicinity of the shore. But the palaeontologic characteristics are also very important in determining ancient sea-bottoms.

An excellent criterion is furnished by the *boring shells*. It is known that at the present epoch, Lamellibranchs belonging to various groups can pierce the hardest rocks; these forms exist,

* Fischer, *Manuel de Conchyliologie*, chap. III.

moreover, only in shallow water, mostly in the zone alternately covered and uncovered by the tides. Such are the Pholads, the Teredos, the genera *Saxicava*, *Venerupis*, *Lithodomus*. But all these forms have representatives in the fossil state; the holes formed by them are frequently met with either with or without the shell in their interior (for example, in the Bathonian of the Ardennes, the Faluns of Pontlevoy, etc.). Their presence is a certain indication of the existence of a littoral zone of a rocky character. This particular facies presents also numerous forms which pertain to it exclusively, as the Patellas, Littorinas, Balani and various forms of Trochus.

Oysters, Mussels, Plicatulas, etc., which live attached to the rocks, either directly by one of their valves, or by means of their byssus, are associated with forms which characterize the highest marine zone; they may, indeed, descend deeper in a zone which is never exposed, and where they are accompanied by the Echini and Brachiopoda. The great majority of deposits of this nature contain animals which have lived fixed, or which crept on the bottom, mixed with the remains of swimming animals which could live in the deep sea and also approach near the coast, and whose shells fall to the ground after death; such are the Cephalopods. The Nautilids, the Ammonites and the Belemnites are found side by side with the Gasteropoda, the Acephala and the Echini.

The expression *Littoral facies* has then, in Geology, a broad signification, and is applied to a more extended zone than that which at the present epoch is called the littoral zone. It indicates simply that the formation in question was produced in the vicinity of a coast. It may present pelagic elements, but it is characterized by the presence of the littoral elements which we have cited.

Pelagic facies.— We call *pelagic animals* those which are adapted by their structure to the function of swimming in the deep sea without resting on the bottom or on the shores. Of this class there are at present the Cetacea, Fishes, Cephalopoda, Pteropoda, Medusæ, many Foraminifera and Radiolaria. In many regions deposits of great depths have furnished organized remains of only such as belonged to these groups, and derived from animals which lived either at the surface or at various depths.

The expression *Pelagic facies*, in Geology, should not be understood in the same sense; there are no ancient deposits in which the fauna consists exclusively of swimming animals. A pelagic fauna at the present day might inhabit seas whose bottoms are very variable in depth; it might reach to the vicinity of the coasts or, again, might extend over the deep abysses; it is evident that in geologic deposits such a fauna might be associated with the elements of all the zones.

The idea then of the pelagic facies is broadened, and we refer to this facies the deposits formed in the deep sea, at a considerable distance from the shore, but not in the abysmal depths; they are characterized by the absence of the elements of the fauna of the littoral zone, and by a mixture of forms adapted to swimming, such as Cephalopods, Pteropods, Fishes, with creeping or fixed forms (Echinoderms, Brachiopods, Gasteropods, Lamellibranchs), the species of which differ from those living near the shores.

Pelagic forms, well adapted for swimming, have naturally an area of distribution much more extensive than the littoral forms, and very much more so than the fixed and sedentary forms. This results not only from the fact that these animals being able to traverse large areas become distributed more easily, but also from the fact that the seaward conditions are much more constant than those near the shores. Thus it is that the species of Ammonites and Belemnites, in the secondary epoch, are found at the same horizon in places far distant from each other, and consequently hold an important place in the chronologic correlation of deposits. The European and American forms are almost identical, whilst the reverse occurs as regards the Lamellibranchs of the same epoch.

Abyssal facies.— Submarine explorations which have everywhere been matters of much attention, have resulted in clearing up the mystery of the conditions of life in the great depths.* It is now known that there exists at the bottom of the sea a very rich fauna, with special characteristics, but without close relations to

* *Reports of the Challenger Expedition; Narrative of the Cruise.* E. Perrier, *Les Explorations sous-marines.* 1886, chap. VIII.

the littoral fauna. There is scarcely any form, indeed, which can not be referred to families already known. Representatives of forms considered extinct have been found there, but thus far efforts have not brought to light any remains of the palaeozoic faunas which it was hoped would be discovered.

The fauna of the coast, in its most extended sense, descends to about 400 meters. It embraces the *calcareous sponges*, *Gorgonia*, *Comatula*, *Cidaris*, *Diadema*, *Bryozoans*, *Oysters*, *Cytherea*, *Gasteropoda* of every group. It is this which is the most generally represented in preceding geologic epochs.

Lower down, from 400 to 1500 metres, are found the siliceous *Hexactinellida*, the *Sea Stars* with great marginal discs (*Pentagonaster*), the *soft Echini;* special forms of *Crustacea*, such as *Gnathophausia* and the *Polychelidæ*. Among fishes, *Eurypharynx* and *Bathypterois*. The *Hydrocorallines* and the *Alcyonaria* disappear toward 1000 metres.

From 1500 metres to 3000 metres occurs the transition from this fauna to the real abyssal fauna. The *simple Polypi* and the *Pentacrini* dominate, whilst the silicious sponges become more and more rare; toward 2500 metres the simple Polypi in turn disappear, and beyond 3000 metres the fauna is represented exclusively by the *symmetric Holothurians*, with ventral flattening, the large *Pycnogonidæ* and the blind *decapod Crustaceans*.

The most important zone as regards the object of our present consideration is that which extends from 400 to 2000 metres. This is the *Verticordia* zone of M. Fischer. It contains, with types clearly affiliated to the actual littoral types, forms which seem peculiar to the secondary period; these are, for example, the peduncled *Crinoids*, belonging to genera well represented at this epoch, as *Pentacrinus* or other genera which are very closely allied to extinct forms. The soft Echini, as *Calveria*, recall with exactitude the Echinothuridæ of the Chalk; the *Salenidæ*, characterized by the presence of a centro-dorsal plate quite exceptional among the Echini; the *Holasteridæ*, represented by *Pourtalesia*, which recalls the genus *Infulaster*, and especially the *Crustacea* such as *Willemoesia* which represents the *Eryon* of the Jurassic, are manifestly the last remains of a part of the secondary fauna which, on our coasts, has completely disappeared or has been radically transformed. Most naturalists have at once concluded from these facts that the basin of the Atlantic has not emerged since the Cretaceous period, and that the fauna of that epoch had maintained itself there in part without transformation. In other words, the bottom of the sea has remained, to a certain degree, since the Cretaceous period.

This induction is justified to a certain extent, but we must add furthermore, in order to form an exact idea of the fauna of that zone, that it contains numerous elements of much more recent origin, and that forms which evolved on the littoral zone must have migrated toward the deep sea at various successive epochs; this is especially proved by the entire absence of transition types between the archaic types and the others in the region in question.

It would be natural to suppose, *a priori*, that the extreme depths of the ocean would reveal phenomena of the same order. It was expected that the zones lately explored below 3000 metres, would show us forms recalling the most ancient types. It is not so; not only is the abyssal fauna destitute of palaeozoic elements, but even the mesozoic types have disappeared. The inhabitants of the deep abysses are representatives of some of the most specialized types of diverse classes. These forms, few in number, bear marks of a special adaptation. It is manifestly a fauna which has migrated from a recent epoch. As to the types which have persisted since the palaeozoic period, as *Lingula*, the *Arcas*, the *Aviculas*, the *siliceous sponges*, the *Gasteropoda diotocardia*, the *Nautili*, etc., it is at a much shallower depth, and even on coasts that they are to be sought.

From what precedes it is evident how difficult it will be in Palaeontology to find a solid basis on which to rest an estimate of the characteristics of the deep sea fauna; the middle zone, from 1500 to 3000 metres has, as a principal characteristic, a mixture of very ancient forms, (the littoral excepted), with recent forms. One can conceive how perplexing this criterion is for the older geologic epochs.

Another and a more suggestive characteristic is furnished by the especial adaptation of the organisms to the conditions of light below a certain depth. It is known that the solar rays do not traverse the thickness of a body of water of more than 400 metres. Below this depth, however, there does not exist complete obscurity, since many animals are phosphorescent; some, like the Fishes, have even special luminous organs which enable them to illuminate themselves. But the light in certain regions is often very feeble. In these conditions a double adaptation may intervene; sometimes the organs of sight assume a considerable size, as is the case for the Fishes of the genus *Ipnops*, and among the Crustaceans of the genus *Cystosoma* where the eyes cover the entire upper surface of the head; sometimes, on the contrary, the eyes are rudimentary, or even in some cases disappear altogether after having been represented in embryonic life; this occurs with *Pecten*, various Gasteropods, and a great number of decapod Crustaceans. These last-named animals supply the absence of the visual organs by an extreme development of the appendages which transform themselves into organs of touch.

But these interesting facts are not without analogies in the ancient epochs. The Trilobites of the Cambrian period show this same mixture of almost or quite blind forms (*Agnostus*, *Trinucleus*), and of forms provided with unusually large organs of sight (*Æglina*).

Barrande has even shown that a species blind in the adult state (*Trinucleus Bucklandi*) possessed normal eyes in its early age; sometimes even (various forms of *Paradoxides*) the ocular peduncle remains while the sensorial part is wanting, which actually occurs in the deep water *Cymonomus*. This proves at least that the forms in question existed in conditions where the light was distributed in the same way as it is at present in the profound depths Still other particularities, as the absence of strictly littoral forms and also the absence of the primordial forms of the diverse groups which appeared later suddenly and in an advanced condition of differentiation, lead us to think that the marine forms of moderate depths were very clearly defined, and that we do not as yet know what was the the littoral facies of the Cambrian, or at least the fauna which characterized it. (Suess, Neumayr.) This opinion, it must be stated, is not accepted by the majority of French palaeontologists.

It has been supposed that in the chalk deposits the formations of the deep sea would be found; but we have seen that the analogy of certain fossils of that age with the fauna of the present *Verticordia*-zone proves nothing; the organisms of that epoch have a clearly pelagic character, and they must have ulteriorly descended into the depths, as did those which appeared later.

One of the most interesting characteristics of the Cretaceous epoch is the abundance of siliceous sponges of the type of the Hexactinellida which now exist in deep water. Close study of the actual distribution of these organisms shows that they occur in very different zones, one of which is not very deep, as it reaches from 60 to 400 metres.

§ 3. INFLUENCE OF THE NATURE OF AQUATIC CONDITIONS.

Fresh water facies.— The most precise characteristics of fresh water faunas are furnished by the Mollusks. The genera *Paludina*, *Bithynia*, *Planorbis*, *Limnæa*, *Physa*, *Succinæa*, among the Gasteropoda; the genera *Unio*, *Anodonta*, *Dreyssentia* among the Lamellibranchiata, have been associated in fresh water formations from the beginning of the Jurassic. But to this list must be added also all the terrestrial or aerial animals, whose remains have been carried down by the water courses, or which have been deposited on the shores; the lacustrine beds of the Tertiary contain as much of *Helix* and *Cyclostoma* as of *Limnæa*; in the lacustrine deposits, also, are found the great majority of the skeletons of known birds, as well as many reptiles and mammals, which were not necessarily swimming animals.

Most fossil plants also belong to formations of the same nature; not only the aquatic species, but all those which grow near water courses, are associated in the same deposits. This is almost the only way in which the purely terrestrial fauna and flora have been, in certain cases, preserved to our day.

As an example of well known lacustrine formations may be cited the little coal basins of the Central plateau (France); the lake of Commentry with its fauna, its flora and its shores has been, so to say, restored by M. Fayol. At the commencement of the Eocene the lake of Rilly occupied a vast area east of Paris; a watercourse fell there in cascades, and M. Munier-Chalmas has reconstructed all the details of that singular locality; plants which love moist places, such as *Marchantia*, *Asplenium*, there covered banks overshadowed by lindens, laurels, magnolias and palms; there also were found the vine and the ivy; mosses (*Fontinalis*) and *Chara* sheltered the cray fish (*Astacus Edwardsi*) and the Edriophthalmas (*Heterosphæroma*). Insects and even flowers have left their delicate impressions in this travertine. Among other lakes also well known, we may cite the lakes of Armissan and of Aix, at the Oligocene epoch, where the succession of deposits is so clear, that by studying the plants and insects, we can form an idea of the alternation of the seasons. Again, we may cite the lakes of Beauce and of Limagne during the Oligocene, those of Œningen and of Radoboj during the Miocene, etc.

Brackish water facies.— The same phenomenon of transportation, the effects of which have just been mentioned, has often resulted in the mingling of the terrestrial and fresh water fauna and flora with the salt water fauna. This mingling is one of the essential characteristics of the facies of estuaries and lagoons. Everywhere at the mouth of rivers, and wherever marshy lands or lagoons border the sea, shells, bones and vegetable remains even though not inhabitants of those localities, have accumulated and been fossilized. These places have generally a special fauna which we call a *brackish water fauna*, consisting of species which are able to bear great variations in the saltness of the water, and to exist in a muddy medium. Various forms of *Cardium*, *Mya*, *Cyrene*, *Cerithium*, particularly those of the genus *Potamides*, and Crustaceans near to *Sphæroma*, are the principal types of this brackish water fauna. In these localities are often found skeletons of mammals and reptiles, sometimes also of birds. The return of the sea from time to time brings marine forms whether or not these could live in such localities, while the descending rivers drag down the remains of the fresh water and terrestrial flora and fauna. From these changes result frequent alterations in the character of the deposits which, moreover, were accumulated with great rapidity.

As an example we may cite the Franco-Belgic coal basin, where the coal beds with the fresh water bivalve genus *Anthracosia*, often alternating with marine sediments, indicate the frequent return of the sea in the lagoons where the vegetable remains accumulated.

The London clay, the Upper Eocene of the Paris basin, the Oligocene and Miocene south of Bordeaux, etc., also show characteristics of these brackish water or estuary deposits.

In the *Sarmatic* beds, which in France are referred to the Upper Miocene, we find the best type of brackish water deposits. At that epoch a vast sea extended from the neighborhood of Vienna to Turkestan. The Black sea, the Caspian sea, the sea of Aral, are the feeble remains of that immense sheet of water. The saltness seems to have undergone considerable variation; it may have varied also in different parts, and numerous lagoons must have occupied the borders of this interior sea.

The earliest deposits are clearly marine (beds with *Cerithium pictum*), with *Buccinum*, *Tapes* and *Mactra*; they constitute the Samartian stage. Higher (Pontian stage) are found enormous quantities of *Congeria* or *Dreissena* and *Melanopsis*, fresh water forms able to exist in waters slightly salt; they are associated with Cardiidæ of peculiar genera (*Adacna*, *Monodacna*), which have continued to exist in the Caspian sea and the sea of Aral.

The most abundant representative of the Gasteropods is an aquatic Pulmonate provided with plications, the genus *Valenciennesia*, which attains a considerable size.

These beds show, throughout a considerable extent, a curious mixture of marine types capable of withstanding a diminution of the normal saltness; and of fresh water forms capable of adapting themselves to a somewhat salt medium. Mammals also are found there, such as Dinotherium and the Mastodon.

A little later, the waters become less and less salt, and the fresh water types more and more preponderate. The Congerias and Cardium retire into the narrow basins, and almost the entire region is occupied by an immense lagoon, inhabited by Paludinas, Melanopsis, the Unionidæ, and other fresh water types. But it is a curious fact that the Unios, Paludinas and Melanopses, living over a very extensive area, assume the angular aspect of marine forms, and acquire plications or tubercules.

Muddy facies.—Corallic facies.—Let us now return to the clearly marine formations, and see what varieties they present. A factor, almost as important as the condition of the water holding salts in a state of solution, is the nature of the substances *held in suspension;* this characteristic is naturally connected with the geologic nature of the sediment, and the direction of the currents. For example, we know that at the present epoch the presence of Mussels on a rock indicates in general, muddy waters, and that many forms which abound not far away in clear waters, vanish as soon as the Mussels appear.

The nature of the bottom is one of the causes which produce great changes in the facies, and that in localities often quite near each other. The best example can be deduced from the study of *coral reefs.* This study will demonstrate how an entire and complicated fauna, formed of the most diverse elements, is wholly modified under the influence of the same variations of the medium.

The conditions which the reef-constructing polyps actually require for their development are well known: These are a moderately high temperature, a depth not more than 40 metres and lastly the presence of a very pure sea water, that is to say, not mixed with fresh water and free from mud. It is proved that whatever may be the differences of the groups to which these animals belong, these conditions remain the same through all the different geologic epochs The calcareous masses where coral structures are found are always very pure and saccharoidal in texture, and the interstices of the polyps show no trace of marl or clay. The same conditions are requisite for the existence of numerous forms belonging to all the classes of the animal kingdom which live on the corals and appear and disappear together with them.

The coral formations of the Upper Jurassic are found mostly within the circumference of the Paris basin, in the Jura, in Switzerland and in Suabia. Wherever those deposits are not represented, there exist deposits of marl or clay rich in Ammonites or Lamellibranchs. The earlier school of geologists admitted that all the deposits of coral origin were contemporary, and united them under the name of *terrain corallien;* the formations of other origin were referred either to an anterior epoch (Upper Oxfordian) or to a more recent epoch (Infra-Cretaceous). The works of Oppel, Niosch, and more especially of the Abbé Bourgeat* have demonstrated that these reefs were formed at various epochs, and that for every different coral facies are always found corresponding muddy facies and pelagic facies, of the same age, but very different in the character of the fossils.

The reef of Valfin, which dates from the Pterocerian epoch, may be taken as the type of these formations. It extends for about 30 kilometres; its form is very irregular in every sense; on one vertical line are found lateral expansions which rest on successive deposits, like caps and columns. The mass of the reef is a limestone of corallic origin; here and there in the irregular mazes is found the especial fauna of the reefs, which is here very abundant. The polyps embrace no less than 62 species; toward the center arborescent forms predominate, sometimes over one metre in height, such as *Aplosmilia*, *Stylosmilia*, *Calamophyllia*, etc. Massive asteriate forms are also found, as *Thamnastræa*, mæandrinoid forms (*Pachygyra*, *Dendrogyra*). Lastly the simple polyps, represented by *Montlivaultia*, are especially abundant in the rocks with the rest of the fauna. This fauna is particularly rich in forms having a thick test, which is in accordance with the fact that the corals, growing in regions beaten by the waves, must necessarily be provided with a strong power of resistance. Small sized species having a thinner covering are only found in well sheltered places.

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* E. Bourgeat, *Recherches sur les formations coralligènes du Jura méridional*, 1887.

These forms are altogether characteristic of the reefs; there are of the Gasteropods, numerous Nerineas, Cerithiums, Naticas, Turbos, Pleurotomarias; of the Acephala, *Diceras* (13 species), *Lima*, *Pecten*, *Trigonia*, *Corbis;* regular Echini of the family of Cidaridæ. Altogether more than 260 species of fossils.

If we leave the reef of Valfin and go eastward, we find the Oolitic coralligenous facies changing, and passing by intercalation into marls more and more mixed with clay. We arrive at deposits formed of marls and rough calcareous matter whose fauna is quite different; no more polyps are found; *Nerinea* and *Diceras* also have entirely disappeared; in place of these we find fossils characteristic of the Pterocerian of the Boulonnais or of the Calvados, as *Pteroceras Oceani*, *Thracia*, *Pholadomya* and *Ceromya*. Some fossils common to the coral zone and the muddy zone, such as *Cidaris glandifera*, *Ostrea pulligera*, indicate, nevertheless, as is proved by the remainder of the stratigraphic arrangement, that we have here contemporary deposits. The intermediate zone shows the gradual modification of the fauna. When we approach the reef the Pholadomyas give place to the Trigonias and *Cardium; Pteroceras* and *Cidaris* become more rare, whilst the Nerineas, *Diceras*, and finally the Polyps appear.

This region corresponds to the lagoon region extending from the barrier reefs to the shore, which was not far to the eastward. This muddy lagoon is not favorable to the development of the Polypi nor the fauna which accompanies them; the latter, on the contrary, develop with vigor on the side of the open sea, and their maximum of vitality is found westward of the reef. There they disappear suddenly. We are in the presence of the abrupt boundary of the reef; immediately after commences a facies altogether different, which extends far toward the south in the open sea; this is the pelagic facies, characterized by Ammonites (*A. polyplocus*, *A. trachynotus*), Belemnites, Brachiopods and Echini, a facies which persisted in these regions for some time without modification.

Upon examination of the succession on a vertical line at the center of the reef, we see that the advent of the muddy waters is in correlation with the sudden disappearance of the coral facies; this last, moreover, may reappear later, but in its entirety it is carried farther toward the west of the deep-sea side.

What has been said would apply equally, changing the name of the species, to the other reefs of the Jura; everywhere we find the threefold facies; the lagoon facies of marl, which is represented in other regions, as in Charente, Normandy, Barrois; the corallic facies, which has also its equivalents in Normandy, in Yonne, etc.; lastly, the pelagic facies, especially developed in the south and east of France. The coral horizons of the Upper Jurassic are now distributed in five zones, which present all these three facies; these zones characterize the Rauracian, Astartian, Pterocerian, Virgulian and Portlandian deposits.

The same phenomena present themselves later in other localities. The Neocomian and the Gault have a corallic facies called Urgonian; the Turonian is represented in the south by the facies with Hippurites, for which also a distinct horizon has been named. Finally, if we turn our attention to the more ancient deposits, we see that the corallic horizons, formerly referred to the Devonian and Carboniferous as especial zones, have been recognized as the equivalents of the schistose formations which surround them.

§ 4. INFLUENCE OF CLIMATE.

Effect of temperature.— Temperature exercises a considerable influence on the distribution of animals; the factor which at the present epoch seems the most important in this regard is the maximum of cold attained during the winter.* We have, therefore, drawn on the terrestrial maps lines called *Isocrymal*, which mark the mean temperature of the coldest 30 days of the year. The distribution of animals is in direct relation to the lines so determined, which notably diverge from the geographic parallels. In this way principal zones are established, which can be enumerated for each hemisphere; the arctic, the boreal, the cold temperate, the warm temperate and the tropical zone. The limits of these zones are more clearly indicated than would at first sight be believed.

Effect of natural barriers.—It is a known fact that the latitude is not the only factor which determines the climate of a region. Every one is aware that the climate is much more uniform and temperate on the sea coast than in the interior of the great continents. But in regard to the sea itself, the mean temperature may vary considerably in places quite near each other, consequent upon the presence or absence of a barrier furthering or impeding communications with colder or warmer waters. This is the reason why at present the Red Sea and the Mediterranean have very differing temperature, notwithstanding their proximity. The presence of barriers of solid ground, either

* This factor is more important from the biologic point of view than the mean temperature of the entire winter which determines the Isochimenal lines.

complete or incomplete, is then, in different degrees, an indirect cause of the specialization of marine faunas. But it is evident that it is also a direct obstacle to the diffusion of a fauna already specialized through the action of other factors.

The currents have also a double effect which opposes that of barriers; on the one hand every current established between two regions of different climates will result in producing a sort of mixture between the bodies of water influenced by different temperatures, and it will affect also the ærial climate; the example of the Gulf Stream is too well known to make it necessary to emphasize this point. But on the other hand these currents will bring with them the larvae of various animals which will penetrate more or less into a zone where they were before unknown. This migration of faunas may occur without any very notable change in the general climate, provided the current does not put in motion any considerable masses of water; thus the current of Gibraltar introduced into the Mediterranean during the Pliocene epoch, forms belonging to the Atlantic, and those forms have remained in the Mediterranean, although the mean temperature there is now much higher than that of the Atlantic.

It is easy to understand that in studying geologic eras it is very difficult to form an exact idea of the influences of barriers and currents. When we have established the presence of two distinct faunal zones which display no differential characteristics in the respects mentioned above; when in the same region we note the appearance of a fauna which before this period existed in other basins, we are sometimes perplexed as to the influence to be assigned to variations of climate, or to barriers and currents. We may succeed sometimes by closely comparing the results furnished by the marine fauna with those afforded by the study of the flora and of the fresh-water, terrestrial or even ærial fauna.

The problem of the determination of climates at ancient epochs through the data of Palaeontology is by no means insoluble; it has been the object of profound and ingenious researches, the results of which already attained deserve our attention for a moment.*

* Neumayr, *Erdgeschichte*, vol. II. Heer, *Le Monde primitif de la Suisse*.

Climate of the Silurian and the Devonian.— Since the epoch of the Cambrian we can distinguish in Europe, as demonstrated by Barrande, two different zones — a northern and a southern; the fauna is almost identical in Russia, in Scandinavia, as well as in the regions farther toward the south, such as southern Poland, Galicia, Thuringia and England; a distinct fauna is found in the Montagne Noire, in Sardinia, in Spain and in Portugal. This second facies is identical with that of Bohemia. The same genera are represented in the two bands; but the species differ. In America, where the Cambrian covers considerable areas, in Siberia, in China, the northern facies alone has so far been discovered.

These facts prove incontestably the existence of climatic zones at the most remote epochs; to undertake to explain them by the existence of natural barriers is to carry back the problem without explaining it, for if the fauna possessed this difference during the Cambrian, it is because it acquired the difference from the Precambrian, and it is at that time that the temperature would have exercised its influence.

It is probable that the climate was warm at the beginning of the Palaeozoic epoch. This seems to be proved by the existence of coral reefs which make their appearance after the Middle Silurian, and which are particularly abundant in the upper part of the stage, in Gotland, in the Baltic provinces of Russia, in the United States and in Canada. The groups which form the present reefs had not yet appeared; in their place we find Tetracorallia, Favositids and Stromatoporas. It would be somewhat hazardous to suppose that these forms required precisely the same conditions of temperature as do those of the present; but the other conditions of depth and purity of water appear to have been palpably the same.

At the Devonian epoch we find again two facies; the ordinary marine facies and a northern facies, the Old Red Sandstone, which characterizes the north of England, Scotland and to some degree the northern part of America. But here other considerations besides that of temperature must intervene; the Old Red Sandstone presents the character of a coastal or interior basin deposit, which forbids our insisting here on points as yet obscure.

We may add that the corals of the Devonian are found also in very high latitudes; in the Ardennes, Eifel, Canada and the State of New York.

Climate of the Carboniferous epoch.— At the Carboniferous epoch a new factor makes its appearance The terrestrial flora, which has already representatives in the Devonian, assumes an importance which warrants our introducing it into our present argument.

It is known that the geographic distribution of plants is strictly related to the divisions of the climatic zones. But the area of the distribution of species at the Carboniferous era is, so to say, universal. The same forms exist in the most widely separated localities, where they appear and disappear simultaneously.

The flora of Europe, of Siberia, of North and South America, of the Polar regions and of Tasmania present the closest analogy. The greater part of the forms which compose this flora attain a gigantic size; these are the Lycopodiacea, Equisetacea, Ferns and arborescent Cycads. The examination of this flora has led us to conclude that the temperature at the Carboniferous epoch was considerably elevated and uniformly distributed through all the regions where the deposits of that age exist. But we no longer hold to the hypothesis that that temperature was precisely torrid; neither is it necessary to suppose, as has been advanced, that the atmosphere at that time was charged with vapor. An elevation of some degrees suffices to explain the presence of arborescent forms. The entirety of the characteristics of the coal flora, which has its maximum of importance between 30° and 50° north latitude, appears to indicate a maritime climate; Europe and North America must have been a sort of archipelago, in the lagoons of which existed a warm and moist temperature.

Several indications demonstrate moreover, that the preceding data are not incompatible with the existence of climatic zones. Still, the coal formations disappear south of 30° of north latitude, and we have no means of judging what transpired in the Equatorial zone. Furthermore, there are some slight diversities found in the flora of the Arctic regions; the Sigillarias are wanting there.

A new element of discussion has been brought forward by Waagen, who has discovered in the upper part of the Carboniferous system almost indubitable traces of glacier action in India, the Cape region, and southern Australia; the flora of those deposits, where are found rocks giving evidence of glacier transportation, possesses characteristics which bring it into relation with the flora of later periods. It is known, moreover, that the presence of glaciers does not imply the existence of any extreme cold; elevated areas for condensation and great humidity are sufficient.

The uniformity of the coal flora is, moreover, a fact which proves less than would that of plants of a higher organization. The wide area of distribution of the Cryptogamia, both the vascular and others, is indeed readily explained by the fact of the lightness and abundance of their spores; it is known also that according to the law of the struggle for existence, localization is much less pronounced in a flora of little variation than in a flora of more varied forms, and that it is especially striking in types of the highest organization. But the Dicotyledons and Monocotyledons, which are the most perfect and most delicate plants, and consequently the most restricted in locality, are wanting at the epoch of which we speak.

But these Cryptogamia are not the only plants of the Carboniferous epoch; the Gymnospermia, already represented by the Cycads and Cordaites, furnish us with more exact information regarding climate.* It is known that the Dicotyledons and Gymnosperms in the structure of their stems and roots present traces, recorded continuously, of the influence of annual climatic variations.

Every yearly deposit of wood consists of an interior porous layer, formed in the spring, and a more dense external one, produced in the autumn; the thickness of the entire layer varies moreover, according as the year was favorable or otherwise. The differences of the annual layers are slight when the climate is uniform, and they indicate nothing more than periods of humidity and dryness.

But in examining the trunks of the Conifers, at epochs more and more remote, we find that the tissue becomes more and more homogeneous, and at the coal epoch, the lines of demarcation are scarcely indicated; it is then especially at that epoch that the climate must show the greatest uniformity.

To sum up; actual researches reveal a strongly marked tendency to reduce the great differences which were thought to have existed between the coal epoch and the present. Nevertheless, it remains conceded that the climate must have been very warm, as is shown by the coral reefs which exist in the same localities as during the Devonian, and which are also found as far north as Nova Zembla and Spitzbergen.

Climate of the Jurassic.—At the Permian and Triassic epochs, the differences in the faunas are mostly in the pelagic and littoral facies. Little is known concerning the climate of those periods. It is during the Jurassic that we find, for the first time, certain proofs of the existence of climatic zones. The marine fauna is distributed in seas, the contour and facies of which are relatively well known, so that we know how much to attribute to the influence of temperature. An arctic zone is indicated principally by the absence of Ammonites of the groups of *Lytoceras*, *Phylloceras* and *Simoceras*, by the presence of Acephala of the genus *Aucella*, by the frequency of certain Belemnites (*B. excentricus*) and the absence of Corals. This cold sea sends arms toward the south, the most important of which is the basin of Moscow, which communicates by straits with a vast mediterranean sea, in which the terranes of Western Europe appear as an archipelago. This interior sea is divided into two parts by the limit of the climatic zones. The northern portion forms the transition between the arctic zone and the southern region. This latter presents the facies called *Alpine*, extending through southern France, Spain, Italy, the Alps, the Carpathians, and the Dobroudja; it has its southern limit in

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*Renault, *Cours de Botanique fossile.*

Algiers and in Asia Minor; it extends through Egypt as far as Mozambique, Madagascar and the Indies. It is defined by the abundance of Ammonites already mentioned and by the development of coral reefs. These diverse facies extend throughout the entire globe, in corresponding latitudes, notwithstanding the barriers formed by vast continents. Toward the south, in the southern hemisphere, the temperate facies reappears, and we find even the Aucellas in New Zealand; the Cape country, South America and Australia belong to this antarctic temperate facies. (Neumayr.)

The Corals more and more approach existing forms, and seem to require the same conditions of temperature to form considerable reefs.

Their northern limit notably trends toward the south; the phenomenon is a very general one, and does not depend, as might be thought, solely on the elevation which is apparent, for instance, in the basin of Paris at the close of the period, and the result of which is the appearance of a muddy condition unfavorable to the building of reefs. Toward the Rauracian epoch, the Coral reefs are already much farther to the south than during the Carboniferous. They abound around the Paris basin, in the south of England, in Switzerland, in Suabia and in Galicia. During the Tithonic period they are found in the region of the Jura and the Alps.

Climate of the Cretaceous epoch.— The Cretaceous, and especially the Upper Cretaceous, shows, in all that regards the marine fauna, precisely the same climatic zones as the Jurassic, but still more clearly defined; the boundaries are the same in their general lines, but their contour becomes more regular, and tends to approach the geographic parallels.

The zones of distribution of the flora, also, are no less clearly defined; this, as has been seen, had given no very interesting results later than the Carboniferous epoch. Now, on the contrary, the evolution of vegetable forms becomes more marked, and their distribution becomes important. The Firs make their appearance in Greenland, at 70° of latitude, and the first Angiosperms, as yet but little differentiated, appear in the Cretaceous of Portugal (de Saporta, 1891).

The Coral reefs continue to recede toward the south; the Turonian limestones with Rudistes, where they are represented in their finest development, appear in the Corbières, in Provence, in the Salzkammergut and the Styrian Alps. They are not found at the end of the Cretaceous period, since the regions in question are occupied by lacustrine or salt water formations.

Climate of the Tertiary epoch.— In the Tertiary the evidence becomes more and more abundant and precise.

During the *Eocene* and *Oligocene* the northern limit of the Corals remains sensibly the same as during the Cretaceous; they are found in the Corbières, in Switzerland, in the Vicentin, etc.; they gradually approximate exististing forms. The plants which are considered characteristic of a tropic climate, as Palms and the Banana, do not extend beyond the northern parts of England and of Germany.

The *Oligocene* and the *Miocene* have been the object of profound discussions from the point of view which we are considering In central Europe, the Mammals and Corals show tropical characteristics. The marine Mollusks are tropical with forms which have remained in the present Mediterranean; the fresh water and terrestrial Mollusks, the insects and the plants are subtropical in the Oligocene and the Lower Miocene, then they assume the characteristics of the fauna of southern Europe; the birds differ little from the present species, but include also tropical forms. To sum up, the climate was warm, and the winters were mild, as is proved by the distribution of the fossil plants in the annual deposits of the lakes of the south.

The northern regions possessed at this epoch a temperate climate; the plants of Grinnell land, 83° of north latitude, those of Iceland, Spitzbergen, etc., studied by Heer, are Pines, Elms, Nymphacea, Cyperus, Carex and Potamogeton. In Spitzbergen, at 70°, we find even Magnolias and the Gingko, which are characteristic of the warm temperate flora. Heer has pointed out that this flora requires a moderately high temperature, from 17.5° to that attained at the present day, and the difference reaches even as far as 28° for Grinnell land.

But, as is demonstrated by Neumayr, these conclusions hold good only for Europe. The lowering of the temperature at the Miocene epoch is much more marked in North and South America; Europe at that time had probably a much milder climate than existed in other parts of the world. In the central portion of North America, and in Chili especially, the temperature appears to have been very little higher than it is at present.

After the period of the *Upper Miocene* the reef corals definitively disappeared from Europe; the last of them are found in Malta and in Asia Minor. During the *Pliocene* they are found only in the Red Sea, that is to say, they reached the limit which has been their boundary to the present day. The Pliocene flora of France, with its Bamboos and Laurels, is still a warm flora; the plants which at present do not pass beyond 35°, reached at that time to 40°. But the temperate elements which exist now in the same regions are already abundantly represented.

Climate of the Pliocene and Quaternary—We now come to an epoch very near our own, where the elements of comparison are directly drawn from living nature, and thus allow more precise inductions.

In England, the marine deposits succeed each other uninterruptedly at certain points, starting from the Pliocene. But on the one hand almost all the marine shells of the Pliocene and

Quaternary are identical with, or at least very similar to forms actually existing. Of these forms, some are now localized in the northern seas, which they already inhabited at that epoch, others have persisted on the same coasts; lastly again, others have migrated southward. A most interesting point for consideration is the order of succession of these forms. At the beginning of the Pliocene epoch in the Coralline crag, the species belonging to the warm seas had already entirely disappeared; in their place are found the temperate forms (*Terebratulina caput-serpentis*, *Voluta Lamberti*, *Astarte Omalii*). Gradually the Arctic forms make their appearance with *Trophon antiquum* in the red crag, *Cyprina islandica* in the Norwich crag, and at the same time such forms as *Cardium edule*, *Turritella communis*, which have continued to exist in the same seas.

The crag of Anvers, with forms of the present temperate seas such as *Chenopus pes-pelicani*, *Isocardia cor*, *Saxicava artica*, shows also species of cold seas, such as *Lucina borealis*. The existence of cold currents coming from the north, and bringing progressively arctic forms, can not, therefore, be questioned. Still, notwithstanding the gradual cooling, the temperature of the solid land was yet, at the epoch of the *Forest-bed*, quite as warm as at present; this is proved by the study of the flora and terrestrial shells.

There are found at a still higher horizon deposits of the glacial epoch. The raised beds of Yorkshire, of Scotland, of the Galles country, the bowlder-clay which covers a great part of Russia and northern Germany, contain marine fossils, some of which are identical with the present forms of the same regions (*Cardium edule*, *Ostrea edulis*, *Buccinum undatum*, *Murex erinaceus*); others have a clearly arctic character, such as *Leda rostrata*, *Fusus carinatus*, *Yoldia arctica*.

The phenomenon of the recession of pre-existing forms toward the south, and the arrival of new forms from the north, becomes progressively accentuated during a great part of the Quaternary period. It seems an almost evident conclusion from these facts, that a sensible cooling of the climate and the existence of currents from the north, have brought down the arctic fauna into temperate latitudes. Some naturalists, nevertheless, have thought the facts justified a contrary opinion, namely, that the Quaternary fauna was autochthonic, and by emigration toward the north had produced the actual arctic fauna. This phenomenon, then, would be in accord with that which would people the great depths through colonies from the littoral fauna, and would explain the presence of forms common to the boreal and abyssal zones, such as *Rhizocrinus*, *Brisinga* and numerous Mollusks.

But these ingenious views are not confirmed; they are contradicted by numerous facts. The cooling of the earth at the glacial Quaternary epoch is a fact so general and so well proved that Penck has been able to trace the limit of perpetual snow in the principal mountain regions, and to show that that line was much lower than at the present epoch. The invasion of temperate regions by arctic forms applies not only to the marine fauna but also to the terrestrial forms, especially the flora which here furnishes valuable data; the plants of the glacial epoch, as *Betula nana*, *Hypnum groenlandicum*, *Hypnum sarmentosum*, are arctic plants, successors of the Firs, Yews, etc., which constitute a temperate flora, and which migrated temporarily toward the south to return afterward into our regions.

The hypothesis of the local formation of the arctic fauna could not, in any way, explain the southward migration of the preceding fauna and flora, and the return of a portion of those forms at the end of the period of the great glaciers. The arctic fauna must have begun its existence in the boreal regions.

The conclusion from what precedes is evident and absolute. The study of faunas and floras demonstrates that the surface of the earth has been subjected to a gradual cooling process from the most ancient periods. The climatic zones, at the beginning so indistinct that their existence might be doubted and still is matter for discussion, have become more and more pronounced to the present day. With regard to Europe, the period immediately preceding the one in which we live has been the only one which was some degrees colder.

This law is well known; it has been frequently formulated. But we have thought it interesting to point out that in these last years the palaeontologic comparisons which had for their object the inductions relating to the climatic conditions of ancient epochs, are conducted with minute care by the most experienced observers. It is not deemed sufficient to indicate in general with what expression the phenomena have manifested themselves; the endeavor at the present day is to push precision as far as possible, and to form an idea of the multiplex circumstances which have brought about the constitution of the varied faunas and floras found in the diverse formations of all the regions of the globe.

CHAPTER V.

The Process of Fossilization.

Conditions requisite for fossilization.—*Fossilization* is the sum of the phenomena by which the remains or impressions of animals or plants are preserved in geologic deposits The first condition required, in order that the organic remains may leave some traces, is that the living organisms to which they belonged should not be too long exposed to the atmosphere during the time immediately following their death. The decomposition of all protoplasmic substances is a matter of current observation which it is unnecessary to discuss.

There is only one instance known of extinct animals having been procured intact with their soft parts; that is the example of the Mammoth (*Elephas primigenius*), found in Siberia in a block of ice which had preserved it from all change.

Matter possessing greater power of resistance than does the protoplasmic, such as bones, shells and the cellular parts of plants, also decomposes in the air after sufficient exposure. Neumayr cites as an example the interesting fact noticed by Marcou: The Buffaloes are little by little disappearing from the prairies of North America, and are retiring before the increasing population of those countries. But there are still found scattered over the soil skeletons of those animals throughout the regions which they have abandoned during the last twenty years, while from those portions of the country which they left before that time, their remains have almost wholly disappeared.

The condition essential for the finding of organisms in a fossil state is that the remains should have been either speedily buried in the earth or preserved in water.

The second of these conditions is not in itself sufficient. The cellular parts are exposed in the water to the attacks of bacteria, and may finally decay without leaving any vestiges. The same may be said of the chitinous or horny parts of animals. On the other hand, the carbonate of lime in the calcareous parts of these skeletons, being dissolved by water containing carbonic acid, bones and shells finally disappear, whether in fresh or salt water. Thus, at present, it may happen that the great depths may be found destitute of the shells of Mollusks and Foraminifera, which are abundant at the surface, the remains having been dissolved before they reached the bottom of the sea, though found in great abundance in deposits made at a lesser depth.

It follows, then, that the remains found where they have been deposited from the water, were covered by sediments in a relatively short time, and even thus they are not entirely guarded against destruction. When the fossiliferous deposits are elevated above the water, they are exposed anew to the action of rains, whose dissolving properties are extremely active, and calcareous matter runs another chance of disappearing. We have indicated in fine, that as to animals of the Precambrian epoch the thermic and chemic phenomena have so altered the nature of the rocks that every trace of living creatures has disappeared.

These conditions being understood we will proceed to a rapid exposition of the processes which permitted the fossilization of animals and plants.

Fossilization of animals.—Under the most favorable conditions, the entire organism, including the soft parts, has left impressions which allow the re-establishing of the form, and even the investigation of some points of its organization. The favored localities where these conditions have been realized are celebrated. The best known case is that of the lithographic schists of the Upper Jurassic in Bavaria. At Kellheim, Eichstädt and especially at Solenhofen, there have been found, along with multitudes of the fossilized hard parts of animals, impressions of Medusae of various species, and of naked Cephalopoda, whose ink-bag with its canal is perfectly recognizable, the sepia being transformed into a mass of fine coal-like granulations. The rock consists of a laminated lithographic limestone of very fine texture, which must have been deposited in the form of soft mud in tranquil waters. The lithographic limestone of Cerin, in Ain, has furnished splendid specimens of the same kind. In England the soft parts of Belemnitidæ have also left some impressions.

Ordinarily traces of the hard parts only are found imbedded in the rock. Such substances are divided into two groups.

The first group contains matter of purely organic origin, as *chitine* and *conchioline*. These substances are eventually attacked by disintegrating agents, but they resist these long enough before they disappear to leave hollow casts, or else they change into carbonaceous deposits which faithfully reproduce their forms.

The localities in Bavaria already cited, contain Crustacea, Arachnids and Insects in excellent state of preservation. These last named are found also by thousands in the lacustrine deposits of Aix, Armissan, dating from the Oligocene, of Oeningen (Baden), of Florissant (Colorado), (Miocene). Among the impressions of chitinous substances we must cite the Graptolites, hydrozooid colonies which abound in the Silurian beds of Bohemia, Sweden and America.

Shells, the covering of Echinoderms, and the bones of Vertebrates are composed of calcareous salts mixed with an organic substance, conchioline or ossine. The mineral part consists of carbonate of lime in the state of arragonite or calcite, or of mixed carbonate and phosphate. The organic substance, as a general rule, decomposes quickly after the death of the animal. The remains found, whether shells or bones, then sometimes remain porous. But usually water charged with calcareous salts penetrates into the interstices thus produced and the salts (carbonates or phosphates) are deposited in such a manner that the remains become homogeneous.

Very frequently, during deposition on the bottom where the organic remains lie, the sediment penetrates into the cavities which remain between the hard parts; the interstices in the skeleton of the corals, the visceral cavities of the Sea-urchins, the shell cavities of Mollusks and of Brachiopods are thus frequently filled with a substance identical with the contiguous rock; this may be carbonate of lime, clay, sand, more rarely flint, oxide of iron or phosphate of lime. The original shell may also be preserved, but it often disappears, being dissolved by water charged with carbonic acid. In this case the fossil presents itself in the form of an internal mold. If the covering is thin, the examination of the mold may suffice to give an idea of the shell itself; this is the case notably among the Ammonites, which are generally found in this state; but it often happens, on the other hand, that the interior of a fossil cavity gives only a vague idea of the details of the exterior, and a decision regarding its external features presents great difficulties. Such is the case with many Acephala and Gasteropoda.

A fossil naturally leaves an impression on the rock which contains it; this impression represents the *external mould* of the fossil. There is often an internal mould together with the external one; in this case the original form of the fossil itself can often be artificially reproduced. In order to do this the space left vacant must be filled with soft plaster or wax, and the rock then can be dissolved by an acid or otherwise removed. This delicate manipulation requires great precaution. Such moulds as can be produced by a foreign substance are sometimes made naturally. Waters charged with mineral substances may deposit these in the place of the carbonate of lime which has been dissolved. The fossil, then, is essentially restored in flint or in oxide of ir n. This result is produced, for example, in calcareous Sponges whose spicules are often converted into silica; also in some Mollusks, Polyps, and particularly in the Brachiopods.

In these various cases, by dissolving slowly and carefully the surrounding rock by means of a weak acid, splendid preparations may be obtained displaying details which otherwise would have eluded observation. In the Brachiopods, in particular, when the brachial apparatus is silicious, it can be disengaged in this manner.

An interesting case, and altogether an exceptional one, is that of the preservation of fossils in the *amber* of the Oligocene period. This substance is resinous, and is secreted by a species of pine (*Pinus succinifer*). It was produced in great abundance in such a state of fluidity that it enveloped immense numbers of Insects, Arachnids and Myriopods, which are thus preserved with the minutest details of their organization. Amber forms important deposits in the Baltic provinces, and has been worked there from very ancient times.

Fossilization of plants.— The fossilization of plants takes place by quite different processes, a fact explained by the different nature of their tissues. The cells of plants have their membranes formed of cellulose, either pure or impregnated with various substances, or even more or less completely changed; but only in very rare cases is it encrusted with calcareous matter or silica (Algæ, Equistacea). In the surface of the soil, or in water, these substances decompose, and the plant gradually disappears unless it becomes fossilized.

Moulds of fossil plants are often found. The plants, when they fall on a soil sufficiently plastic, make an impress there. If the vegetable remains are then removed and a new deposit of sediment a little different takes its place it will give a mould in relief of the object that has disappeared. Very frequently, on the contrary, the vegetable remains persist while the deposit goes on. In this case a double impression is found, one concave and one in relief. Between the two it may happen that no remnant of the vegetable matter is left, but frequently also it is transformed into a blackish substance rich in ulmic acid, which, under the most favorable conditions, preserves the structure of the pre-existing tissues. At other times, if the surrounding rock is porous the vacant space left by the decomposition of the organic matter is filled by mineral substances dissolved or held in suspension in the waters which have penetrated the interstices; this is a phenomenon identical with that which we have already considered in the case of fossil animals. The substance in question is usually carbonate of lime; sometimes silicate of magnesia, bisulphide of iron, carbonate of copper, etc., or sometimes of argillaceous or sandy particles. The fossil is found in a much higher degree of preservation when the water holding in solution the mineral substances has been able to penetrate into the interior of the tissues. The silica, the carbonate and phosphate of lime fill all the spaces made by the cavities of the anatomical elements. Such petrifaction takes place sometimes in plants remaining still in their place of growth, sometimes in their remains which are transported and accumulated in lacustrine waters strongly impregnated with mineral substances. In such specimens the cellular parts and their derivatives are sometimes preserved with all their ornamentation, and thinly-cut sections present precisely the same details as do sections cut from living or dried tissues. If, on the contrary, the fossils have been exposed to the air, decomposition has more or less completely destroyed the organic matter, and there only remains a very porous mould of the cavities of the tissue. In this case, before making sections, it is necessary to fill the cavities with some fluid substance which will harden and render the specimen compact.

Plants are often preserved in considerable quantity without the agency of mineral matter, in the state of *lignite*, *peat* or *coal*. These products are made by the incomplete decomposition of the vegetable matter. The microscopic structure in this case is often preserved in a remarkable manner; in order to study this it is necessary to make thin sections which are cleared by chemical processes and studied in transparency under the microscope. Details concerning the technicalities of this process, too complicated to be explained here, may be found in the works of M. Renault and others.

Development and Mode of Growth of Diplograptus, McCoy.

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(Communicated for the Report of the State Geologist, for 1894.)

Development and Mode of Growth of Diplograptus, McCoy.

By R. Ruedemann.

In the picturesque gorge of the East Canada creek, near Dolgeville, N. Y., is found, intercalated in typical black bituminous Utica slate, a very thin brown argillaceous layer which has proved to be covered so densely with the compound fronds of *Diplograptus Ruedemanni*, Gurley,* that those which I have obtained by taking off the overlying shale are counted by hundreds. Some very complete fronds of the same species were found in a piece of limestone on the talus of the cliff, apparently derived from one of the limestone beds which are associated with the shale. The colonies from this rock are especially instructive, because they are not much compressed and show the formation of the frond in relief.

Since this discovery I have given special attention to the search for complete fronds of Graptolites, for such have been described by Prof. James Hall from the Quebec epoch (*Monoprionidæ*). I was rewarded by finding another, unfortunately only temporary, exposure in the Utica slate at Dolgeville, which was very rich in compound fronds of *Diplograptus pristis*, Hall. The fossils of both localities are in such good state of preservation that they reveal many facts regarding the organization and development of Graptolites.

Until the classical memoir of Prof. Hall on the Graptolites of the Quebec group, only simple linear stipes, or stipes which differed little from the linear ones, were known. Hall made us acquainted with numerous species, the fronds of which are connected in the center by a common stem, the "funicle," from which they branch by bifurcation. The simplest forms with the funicle have four stipes. Continued dichotomy of the four branches pro-

* This form, which the author, in a preliminary note (cf. The American Journal of Science, 1895, vol. XLIX, p. 453) had identified as *Diplograptus pristiniformis*, Hall, has been since described as a new species by R. R. Gurley (cf. The Journal of Geology, 1896, vol. IV,).

duced at first eight branches, as in *Dichograptus octobrachiatus*, Hall, sp., and then 16–32 stipes as in *Loganograptus*. In a form from the Hudson River group, Hall counted as many as 40 stipes branching from a common funicle.

In all species, except some of the four stiped ones, the bases of the stipes were found to be united by "a more or less expanded disc or cup of the same substance as the body of the Graptolites." Hall called it the "CENTRAL DISC."* It is described as a thick corneous test, which, in the simple forms, is quadrangular, nearly square, with straight margins, sometimes extended along the margins of the stipes, as if to give strength and support to the bases of the stipes. In forms with eight branches, Hall found an octangular central disc, and in higher forms it becomes a round disc. This keen-eyed observer found also that the central disc is composed of two laminæ which, at least in the central portion, are not conjoined; the spaces between the two, he supposes to have been filled by some soft portion of the animal body. We may still add that Hall observed that the bifurcation always takes place within the central disc; that the disc is not uniform in its proportions; that it does not always appear to bear the same proportions to the strength of the stipes; and that it is often striated parallel to the margins, which are thinner, the substance attenuating from the center. This is about all that is known of the central disc, for, since Hall, 40 years ago, was able to make his observations on the Quebec Graptolites, and to give us a picture of the perfect form of some of these tiny fossils, only few species which show such a growth have been found, and these did not furnish any new facts regarding the composition of the frond.

The genera which are known to have grown in compound colonial stocks belong to the Monoprionidæ with single rows of thecæ, except two, *i. e.*, *Phyllograptus typus*, Hall, with four united basal stipes, and *Retiograptus eucharis*, Hall, from Blue Point Lake, St. John, in which the stipes are united by "slender basal extensions" without the presence of a central disc. The occurrence of a compound frond in this abnormal genus is especially interesting.

The genus *Diplograptus*, however, has hitherto been regarded as producing only simple stipes, because some species which are

* It is absent in some of the sub-bifurcated forms "apparently by accident."

found in countless multitudes in shales on both hemispheres only appeared in single stipes. The specimens which I have found show that this genus also grows in compound fronds. The extension of the axis at the growing end of *Diplograptus* has presented unsurmountable difficulties to the efforts of explanation. The corneous cup which was observed by Nicholson* on *Climacograptus bicornis*, Hall, the vesicular dilatations of *Diplograptus physophora*, Nich., and of *Diplograptus pristis*, Hall, are at the sicular end and are, therefore, other organs than the central disc from which the stipes branch. Neither can the prolonged vesicle in the antisicular prolongation of the axis of *Diplograptus vesiculosus*, Nich., be compared with the central disc.

General Form of the Frond.

Typical views of the complete fronds are given in Pl. I, fig. 1, *D. pristis*, Hall, and in Pl. I, fig. 2, of *D. Ruedemanni*, Gurley. As figure 1 shows, there are in a frond stipes of very different lengths. In this specimen, in which some of the stipes, seem from their dimensions, to have attained their full growth, we notice stipes of three different lengths. Four stipes, lying in two diameters, perpendicular to each other, are the longest. They are accompanied on each side by shorter ones. Stipes of about the same length as the latter bisect the right angles. Between the others, we find the shortest stipes in varying number. The original specimen for figure 1 has 26 stipes; but fronds with as many as 40 stipes have been found, in which most of them have reached the normal length. Very often we find fronds with only one or a few stipes of the first, and numerous stipes of the third length. It is probable that these very different lengths of the stipes in the frond indicate different age and not that it grew out as a whole, thus maintaining always the same proportions in the stipes, as Dr. O. Herrmann† asserts in regard to the frond of the compound Monoprionidæ.

The number of stipes of *D. pristis*, Hall, is considerably greater than that of *D. Ruedemanni*, Gurley; the former showing between 20 and 40, the latter only about 12 stipes. The fronds of *D. pristis*, Hall, therefore, are usually crowded

* Ann. and Mag. of Nat. Hist., 1868, vol. I, p. 55.

† On the Graptolitic Family *Dichograptidæ* Lapw., The Geol. Magazine, 1886, p. 13.

with stipes, the same covering each other, while those of *D. Ruedemanni*, Gurley, appear rather plain.

The Funicle and the Central Disc.

In all known compound fronds, where the branches radiate from a center, their bases are connected by a common branch which has been termed by Hall the "funicle." He found that this connecting stem within the points of bifurcation is not celluliferous, more cylindrical and apparently more solid, the test being, probably, thicker and the common canal less developed than in the other parts of the axes. The figures of Hall and Herrmann represent the funicle as a short cylindrical body, slightly thicker than the axes of the branches Only in *Graptolithes octonarius*, Hall, we see a small expansion of the funicle and a small round node called a "rootlet," by Hall.

The funicles of the two Diplograptidæ appear, if strongly compressed, as small, oblong, black spots with round ends, from which most axes spring (cf. Pl. I, figs. 1, 9; Pl. II, figs 3, 4); in a few cases they are extended to cylinders, similar to those described by Hall. In some specimens, however, the funicle is so well preserved that I have been able to make out its finest details (cf. Pl. I, figs. 4, 6). By these it is made evident that the funicle of *Diplograptus* was a chitinous vesicle, tapering to the two opposite initial points of the main bundles of axes (Pl. I, fig. 6). Vertically to this main extension, where two other bundles leave, the funicle is more or less expanded, sometimes so much as to appear quadrangular (Pl. I, fig. 4). In the excellent specimen represented in Pl. I, fig. 4, and Pl. II, fig. 3, the funicle is burst open and the inside of the almost square base becomes visible. The pits, scattered all over it, apparently lead into axes. The chitinous test must have been very solid, as the excellent state of preservation of this small organ proves. The latter attracts attention by its deep black color in compressed fossils and by its strong sculpture in specimens preserved in relief.

The funicle has been found to be surrounded by a more or less expanded chitinous disc or cup, the "central disc," of Hall. We have observed that Hall regarded this organ as formed of two laminae. He finds it obviously adapted to give strength and support to the bases of the stipes, as in some forms it extends along the axes, but suggests, at the same time, that it may have served still other purposes of the animal economy. In concordance with the first supposition is his observation that the central disc is found where the divisions at the base become more numerous, while it is absent in some of the four-stiped forms; but on the other hand, its "greater or less development is not always corresponding to the size and extent of the stipes." Huxley has compared this organ with the basal plate of *Defrancia*, a Bryozoan, while Nicholson thinks it to be homologous to the "float or pneumatocyst" of the *Physophoridæ*, an order of the *Siphonophora*.

The central disc of the two species of *Diplograptus* which I have before me appears as a nearly square chitinous plate, sometimes drawn out a little at the corners. It is relatively small in regard to the diameter of the whole colony, but must have been a very strong and solid organ as it is mostly distinct, even in poor specimens, where other organs can not be distinguished. That this plate is formed by two laminæ is demonstrated by such specimens as reproduced in Pl. I, figs. 4, 6, 8; Pl. II, fig. 4, where the raised edges and the depressed middle part of the organ prove that it has been burst open. Especially in the specimen represented in fig. 8, the central disc is preserved so distinctly in relief that it can easily be studied with the naked eye. It is here a deep concave chitinous trough, inside of which lie the funicle and the bases of the branches. In Pl. I, fig. 4, we are able to see that the axes, which here give unmistakable evidence of having been canals, pierce the vesicle which incloses the funicle. Where the central disc is not broken, as in Pl. I, fig. 7, its upper side is convex. Funicle and central disc have in our species similar forms, parallel margins and their diagonals coincide; the funicle is always distinctly inclosed in the central disc.

The form, solidity and connection of the central disc with the stipes agree with Hall's suggestion that this organ served to support the bases of the stipes. It was also certainly a protection to the funicle, but probably these were not its only functions. Nicholson's supposition that it was a "float" seems very acceptable indeed, if we regard the large central discs of some of the Quebec forms or of *Dichograptus Kjerulfi*, Herrmann, from the Norwegian *Phyllograptus* shales; but the central discs of the two species of *Diplograptus* seem to me to be relatively much too small to carry the whole colony.*

The Basal Cyst.

In a preliminary note† a basal organ, appearing in most fossils only as a subquadrate impression, has been described as a "pneumatocyst." The latter is often so large as to overlap the other central parts and even the proximal ends of the rhabdosomes. It appears only as an impression in specimens which have the central disc and funicle well preserved as chitinous bodies (cf. Pl. I, figs. 6, 7, 8, 10; Pl. II, figs. 1, 2, 3, 5); in very fair specimens it exhibits only a filiform chitinous border, while in a few (cf. Pl. III, figs. 9, 19) the test itself is visible. It must be inferred from these observations that the test was comparatively thin. The impressions or the scant remains of the periderm would naturally not have been sufficient to be made the object of a description if there had not come under observation, in a number of specimens, large prominences which show that the organ consisted of two segments resting in the middle on both sides of a subquadrate base. This base is formed by a neatly furrowed plate represented in Pl. II, fig. 1. The prominences con-

* I have used so far, on account of some citations from the first authors on Graptolites, the old nomenclature, especially as introduced by Hall. As there are now, however, terms in use which are taken from the Zoology of the Hydrozoans, such as hydrotheca and hydrosoma, I intend to use more zoological terms which, I believe, will facilitate the description and prevent misunderstandings.

There is no doubt that the use of the term *hydrotheca*, if the comparison of the Graptolites with the Hydrozoans is accepted at all, is proper, though the term *theca* is preferable. The term *hydrosoma*, however, means in the terminology of the Hydrozoans, as introduced by Allmann (George Q. Allmann, A Monograph of the Gymnoblastidæ or Tubular Hydroids, vol. I, 1871), "the whole colony." This hydrosoma includes the *trophosoma*, *i. e.* "the entire assemblage of zooids with their connecting basis destined for the nutrition of the colony," and the *gonosoma*, the entire assemblage of zooids destined for the sexual reproduction of the colony. As we shall see, the compound colony of *Diplograptus* contains a central verticil of gonangia which constitutes the gonosoma, the remainder, *i. e.*, the central organs and the assemblage of stipes, branches or polyparies, constitutes the trophosoma. It is evident that the use of the term "hydrosoma" for a stipe would be a synecdoche, the putting of the name of the whole for a part. This difficulty could be avoided by using the term "rhabdosoma," now used generally in the excellent papers on Graptolites of the Swedish palæontologists.

Another misunderstanding may arise from the use of the terms *axis* and *virgula* for the stem which fastens the rhabdosome to the funicle. In the description of the single rhabdosome it is usually mentioned that the virgula is prolonged "distally," or toward the center. This prolongation forms the connecting stem, and is a canal containing, as we shall see in another chapter, in young stages, the virgula of the rhabdosome inclosed in its distal part (cf. Pl. II, fig. 6). The stem is, therefore, not the prolongation of the virgula alone. The application of the zoological term *hydrocaulus* for this canal would dispense with the necessity of referring the latter to any part of the rhabdosome.

† American Journal of Science, *loc. cit.*

sist of shale and are apparently the casts of large vesicles. In the original of Pl. II, fig. 2, a smooth segment projecting from the center of the colony is visible; in the specimen represented on Pl. I, fig. 10, a plate is visible, which has a diameter of 6 mm., and is raised in the middle to about 1 mm. Figure 7 (Pl. II) is taken from a specimen in which the cyst is broken out, leaving only its outline and a wide pit. The central organs are visible at the bottom of the pit, while the rhabdosomes proceed from the base of the little projection of sediment. It must be inferred from this and other specimens that the vertical order of the organs was as follows; basal cyst, gonangia and rhabdosomes, both of the latter proceeding from the central disk and enclosed funicle.

Whether the large vesicle was the upper or undermost of the organs is a problem of great interest on account of its bearing on the question of the function of that organ. The fact that most specimens found on the surface of the shale, show it only as an impression, while on the original of Pl. I, fig. 10, which was taken from the under side of the Graptolite-bearing layer, it is preserved in relief, led the writer to the conclusion that it represents the topmost part of the colony. This conclusion and the fact that the vesicle is often found filled with sediment, and, therefore, may have been hollow, have suggested the comparison of the vesicle with a "float," such as certain *Siphonophora*, viz., the *Discoideæ*, p ssess.

There are other observations which would seem to be in concordance with the assumption that the colony of *Diplograptus* had a floating habit:

1. The extreme length and thinness of the hydrocaulus in certain specimens of *Diplograptus* In the State Museum at Albany, N. Y., the writer has observed a rhabdosome of *Diplograptus* with a length of 4 cm. and a breadth of 3 mm., while the hydrocaulus has a breadth of only 0.1 mm. It is difficult to imagine how such an extremely thin stem could have supported the long and broad rhabdosome in any other than a suspended position.*

* Carl Wiman (cf. Ueber die Graptoliten, Bulletin of the Geol. Instit. of Upsala, No 4. Vol. II, Part 2, 1895, p. 68) has pointed out that the virgula could have served only to strengthen the rhabdosome. This rod extended also, as will be shown later, into the hydrocaulus. An effort at strengthening the latter, however, is strongly suggestive of a sessile mode of life of the colony.

2. If the colonies were sessile, one would expect to find in the great number of colonies observed, some at least attached to shells, pebbles, etc., for the colonies would probably have preferred fixation to foreign bodies to a mooring in the soft ooze, as do the recent Sertularians.*

3. The wide horizontal distribution of the Graptolites and their limited vertical range has made them the basis of a very detailed and persistent division into zones of the Cambrian, Ordovician and Silurian strata such as only the widespread Ammonites have furnished in other ages. Barrois† accounts for this, as well as for their distribution in shale, sandstone and limestone, by their having been floating organisms at an early stage. The writer has observed a few specimens which seem to indicate a floating habit in the siculæ. One of these, reproduced in Pl. III, fig. 2 , shows two siculæ which give the impression of having been arrested by the hydrocaulus, the surrounding surface of the slab being free from siculæ. But if the siculæ floated, the colonies most probably floated also, as there has not been found any change in the development of *Diplograptus* which would indicate a change in the mode of life of these organisms.

On account of these observations, the writer held the opinion which he expressed in the preliminary note, that *Diplograptus* was a floating colony. A short time ago, however, a discovery was made which shows evidence not compatible with a floating mode of life. The specimen is a large slab exhibiting at one end upward of a hundred colonial stocks of *D. Ruedemanni.* The latter are all in a fair state of preservation, spread out regularly, about equally distant from each other and arranged in a well-defined area, outside of which only a few broken rhabdosomes are found (cf. Pl. V, which is a representation of part of the slab). The improbability of such an array of nicely ordered, apparently undisturbed stellate groups having been drifted together, is obvious.

It is further worth mentioning that most of those colonial stocks which show only the central disc and funicle, are sunken in the center, a feature which, it seems, could be easily explained

* Allman (*op. cit.*, Vol. I, p. 27) says: "In almost every case the general colony, as hydrosoma, is attached to some foreign body, such as rocks, shells of mollusca and crustacea, seaweeds, floating timber, etc., to which it is fixed by some part of its surface."

† Memoire sur la Distrib. des Graptolites en France.

by assuming that the sediment which gathered around the central organs and under the ascending rhabdosomes, caused the latter to be buried finally at a somewhat higher level than the central disc. This explanation, however, presupposes that the central parts were attached to the ground. There have also been observed quite a number of siculæ, the basal appendages of which lie in another level of the matrix and appear, therefore, on the surface of the slabs in a pit or on a little node.

The argument has been repeatedly advanced that because of their rigidity the Graptolites can hardly have been adapted to a pelagic mode of life. The profuse occurrence of broken rhabdosomes of *Diplograptus* throughout the Utica slate is sufficient proof that the hydrocauli and rhabdosomes of *Diplograptus* possessed only a very slight flexibility. Such a lack of flexibility must have endangered the colonies wherever the water was moved. But there must have been motion in the depths in which the sediment constituting the Utica slate settled, for the broken rhabdosomes on most slabs lie in a parallel direction; hence the relative scarcity of entire colonial stocks in comparison with the enormous multitudes of broken rhabdosomes. The two localities near Dolgeville which furnished the colonies of the two species of *Diplograptus* would then represent areas which were free of disturbing bottom currents at the time of the formation of the thin, colony-bearing intercalations.

If the colonies of *Diplograptus* were indeed moored in the mud, the organ which I compared with Hall's central disc, would have been much too small to serve as an apparatus for fixation. The question of the means of fixation and the function of the vesicle described in this chapter and termed the "basal cyst," would arise. May the latter, perhaps, not have been the topmost part of the colony, as supposed by the writer, and the vertical order of organs, from below upwards, have been; basal cyst, gonangia, rhabdosomes? May it, further, have been a contrivance, which, by being buried in the detritus, served to procure that stability for the colony which otherwise only a large disc like the central disc of the *Monoprionidæ* could have provided on the soft, loose ooze? Since the discovery above mentioned, the writer has not had opportunity to study the material of *Diplograptus* so thoroughly with reference to this problem as will be necessary.

THE GONANGIUM.

Among the complete colonies of *D. pristis*, Hall, found in the shale, I happened to notice one of more than common interest. It is a rather small specimen, the rhabdosomes of which are very short, but, although much compressed in the rock, it reveals all details with remarkable clearness. Moreover, the chitinous substance remains on both slabs; the exact observation of each detail can, therefore, be tested by the counterpart.

This specimen, one-half of which is represented in Pl. I, fig. 5, shows, besides five rhabdosomes and a very small central disc, an oval group of siculæ (g), all of which have their broad ends directed outward. The proximal ends of the siculæ radiate from an axial club-shaped projection, which is surrounded by a groove. The basal siculæ are very distinct and well developed; they make their connection by thin hair-like processes, such as are observed on well-preserved detached siculæ. Toward the distant end of the group they become more crowded and apparently smaller. On the siculæ lies a thick oval chitinous ring, which forms the margin on one side of the group, whereas, on the other side, it overlies the siculæ. It is apparently the remainder of the capsule which inclosed the siculæ and burst in becoming compressed, allowing the siculæ to be pressed out.

There is no doubt that we have here an organ in which the siculæ originated, the details all being so clear that they can be seen by the naked eye. After this discovery I searched all compound fronds in my possession for these organs, and was rewarded by finding them in numerous colonies, both of *D. pristis*, Hall, and of *D. Ruedemanni*, Gurley.

One of the best specimens observed is represented in Pl. I, fig. 8. It is especially interesting, because the "gonangia," as these organs are provisionally termed, are very large (they have a diameter of 4 mm.) and because the fossil is not so much compressed but preserved in relief. It is a compound frond of *D. pristis*, Hall, the rhabdosomes of which are mostly crowded on one side. In a deep pit in the center, we notice the base of the chitinous central disc with the funicle. Around the central disc there are four, subcircular remains of gonangia, which are as distinct as the rhabdosomes. In the center of the gonangia, projecting on three sides, are round nodes, on the fourth (right-hand side) is a corresponding impression. They are surrounded by a deep furrow, from which, in one of the gonangia (g), the surface rises in a projecting ring. The latter is apparently the section of a central vesicle which did not contain any solid substance at the time of the burial of the colony, therefore has been filled with sediment and is now preserved as the solid central node, whereas the test of the vesicle became flattened and separated from the matrix. Outside the central node we see radiating siculæ. Near the left gonangium is a group of impressions of siculæ which apparently sprung from it. The right gonangium shows radial and concentric wrinkles, the former of which are probably impressions of siculæ, the latter may have been wrinkles of the gonangial test.

Another specimen which aids essentially in obtaining a complete conception of these organs is reproduced in Pl. I, fig. 9. It shows seven, more or less oval, not very distinct impressions of gonangia, and is remarkable for the multitude of siculæ covering the slab in the near neighborhood of the center. The position of these siculæ gives evidence that they came from the center of the colony, and were apparently set free shortly before the burying of the colony by sediment.

I have before me a great number of complete colonies with distinct gonangia. The number of the latter organs ranges from four to eight, the majority of the hydrosomes, especially the younger ones, bearing only four gonangia.

In older colonies the chitinous test is rarely distinctly perceptible because of the crowding of the hydrocauli and rhabdosomes toward the center. Only in specimens like that represented in Pl. II, fig. 4, where the parts above the gonangia are broken away, are the test and form of the gonangia clearly visible. Young colonies, in which the center is less obscured by overlying rhabdosomes, show the still closed gonangia as oval, concentrically wrinkled, chitinous plates. (cf. Pl. III, figs. 15g, 20g, 21g, and the chitinous rings in fig. 24, which probably are remains of gonangia.)

Some specimens of *D. Ruedemanni*, (Pl. II, fig. 3g), show a very nice preservation of the form of the gonangia. The proximal parts of the rhabdosomes are covered by round plates which have somewhat raised edges and a lighter color than the surrounding rock. They consist of compressed sediment of finer grain than the matrix. The sediment apparently entered the space between the gonangia and the stipes and preserved thus the impressions of the gonangia.

An indication of the original form of the gonangium in its uncompressed state is given by a very excellent specimen (Pl. I, fig. 3), where the gonangia left deep, almost globular pits, which the eye can not fail to see in looking at the frond-covered slab. These impressions suggest a globular form of the gonangia, an indication which is confirmed by a frond on a piece of limestone (Pl. II, fig. 2) from the *débris* of the cliff which furnished the fronds of *D. Ruedemanni.* The piece comes from a layer of limestone, interpolated in the shale. The fossil shows two gonangia preserved as solid globular projections.

Observations as to the proximal end of the gonangia could be made in only a few specimens.

From the originals of Pl. I, figs. 5 and 8, we might infer that the gonangia were connected with the hydrosome by the central vesicles. An excellent insight into the construction of the gonangia and their connection with the hydrosoma is given by the original of Pl. II, fig. 4. Three gonangia are visible as deep impressions of dark color, from the bottom of which rise club shaped projections. The proximal ends of the latter are connected by a disc, which overlaps also part of the funicle. Both the projections and the disc are not chitinous, but consist of shale. Therefore they are fillings of hollow organs, the test of which has not been preserved. The disc is apparently the filling of a tubular organ from which the gonangia radiated, its cavity being directly connected with the central vesicles of the gonangia. The tube itself was apparently connected with the central disc and funicle, and by this with the system of somatic cavities.

The result of the study of all these specimens is that there were in the species *D. pristis* and *Ruedemanni*, around the center of the compound frond, globular or oval vesicles, numbering from four to eight or more, the test of which was horny.

Each vesicle inclosed a capsule varying from oval to club-shaped, which had a rather solid test and did not contain any obstruction to its being filled by the sediment. But the most important fact is that the vesicles contained the so-called "siculæ." Since J. Hall discovered these tiny fossils and demonstrated that they are the initial points of the growth of the rhabdosomes, there has been no doubt that they represent a very young growth-stage. It is, therefore, obvious that the described vesicles are reproductive organs.

It remains now for us to see how they compare with the reproductive organs of the Sertularians, which have been regarded as the living relatives of the Graptolites.* A glance at the reproductive organs of the Hydrozoa is sufficient to demonstrate the great similarity between them and those of the two Diplograptidæ. The gonophores and sporosacs of the Hydrozoa appear in just such verticils of spherical or oval vesicles as the gonosome of the two Graptolites, and they contain in the "spadix" an organ similar to the central vesicles, from which the siculæ radiate. But the gonophores, which directly produce the generative elements, are only covered by a thin pellicle, and are found only in those Hydrozoans which have a thin, not chitinous perisarc; whereas the Sertularians, like all those Hydrozoans which are provided with protective receptacles for the hydranths, inclose their sexual buds, the gonophores or sporosacs, again in peculiar horny receptacles, the gonangia. The latter are mostly oval capsules, formed by a layer of ectoderm which secretes an external chitinous investment, that varies greatly in thickness. "In every instance," says Allmann, "where a gonangium exists the hydranths also are protected by a hydrotheca, while the absence of a gonangium is always associated with the absence of a hydrotheca." As we have in our Graptolites, just as in the *Sertularians*, chitinous thecæ and also a chitinous gonosome, we must term their reproductive organs "gonangia." The gonangium of the Sertularians contains a cylindrical column, the "blastostyle," bearing the gonophores as buds upon its sides, and being generally expanded at its summit into a conical plug or disc by which the gonangium is closed. We have a very similar organ in the club-shaped hollow central vesicle of the gonangia of *Diplograptus.*

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* Cf. George J. Allmann: A Monograph of the Symnoblastidæ or Tubular Hydroids. Vols. I and II., 1872.

G. J. Allmann: Report on the Hydroidea of the Gulf Stream. Museum of Comp. Zoology, Harvard College. Vol. V, 18877.

Challenger Reports. Hydroidea, by Prof. G. J. Allmann.

It is true it does not show the conical plug or disc on top, but neither is this always present in the recent Sertularians.

I have not been able to find how the gonangia opened. The clusters of siculæ which appear on young colonies (Pl. III, figs. 15, 16, 17, 20) lead to the supposition (as we shall see more extensively later) that the basal siculæ remained attached to the colony, while the more distal ones were detached. This, in its turn, would suggest an opening at the top of the gonangium.

The gonangia of *Diplograptus* resemble in all more important features, *i. e.*, the shape of the gonangium, the substance of the periderm, the possession of a blastostyle, its shape and position, the gonangia of the *Sertularians* so closely that we must regard not only the possession of these organs but also their structure as arguments for the hydrozoan nature of the Graptolites.

Gonangia were described as long ago as 1859, when J. Hall published his fundamental researches on the Graptolites of the State of New York. (Geol of the State of N. Y. Pal., vol. III.) The author describes stipes of *Diplograptus Whitfieldi*, Hall, bearing appendages, which are regularly or alternately arranged in two opposite rows on the stipe, the thecæ being suppressed or the vesicles proceeding from their axils. The appendages appear at first as buds of oval shape, which become later on, apparently by dehiscence or decomposition and absorption, irregulary triangular. They have scarcely any substance except a filiform border. Although there are upon the surface of the slate, where these bodies occur, numerous siculæ, no germ could be found within a sac, and only one apparently attached to such an appendage. Hall compared them with the gonangia of the Sertulariæ and Campanulariæ.

Other appendages have been found and described in England by H. A. Nicholson.* They were found in the Graptolite rocks of Dumfriesshire, attached, in some instances, to the stipes of *Gr. Sedgwicki*, Nich. They differ from those noticed by Hall in being free in the later stages of their growth. They are described as "oval or bell-shaped, provided with a mucro or spine at one extremity and surrounded by a strong filiform border, which ultimately ruptures." Nicholson found these bodies, which

* Cf. Ann. & Magaz. of Nat. Hist., 1868, vol. I, p. 55. Nicholson gave a brief description before this publication in a paper which I have not been able to obtain.

he called "Dawsoniæ," in many instances attached, when small, to the cellules of *Gr. Sedgwicki;* sometimes to the apex of a theca, while sometimes they appear to spring from the common canal or from the under surface of a theca. The author compares them with the "gonophores" of the recent Hydroids, on account of their external processes and their likeness in form, while they differ in having a corneous envelope. He believed that they were attached to the sides of polypites or to gonoblastidia, although he admits that they have not been certainly detected in direct communication with the polypary of any Graptolite.

The gonangia described by Hopkinson in Ann. & Mag. of Nat. Hist., 1871, vol. VII, p. 317, resemble closely the appendages made known by Hall. Hopkinson states, on this occasion, that the connection of Nicholson's graptogonophors with the Graptolite is not proved.

Allmann, who had an opportunity of studying English specimens closely resembling the American ones, denies their having been capsular bodies. They appear to him rather to be hollow laminæ; but, on account of the regularity of their disposition, he does not regard them as accidental growths. He thinks that their connection with the gonosomal system is probable, and compares them with the leaflets which compose the corbulæ of certain *Plumularidæ*, where the gonangia are developed in groups, and each group is sustained in a common, basket-like receptacle, which is a metamorphosed ramulus. He finds his view supported by the fact that in each case where they have been satisfactorily observed, the thecæ became suppressed in that part of the fossil which carries the appendages.

I have not yet found any appendages similar to those discovered by Hall.

As to the "ovarian vesicles," which Nicholson found associated with the Graptolites, Allmann thinks their connection with the Graptolites to be purely accidental, on account of their origin from the walls of the thecæ. Indeed, the fact that Nicholson describes them as being attached to different parts of the rhabdosome, makes it very probable that these vesicles came only accidentally in contact with the rhabdosome. On the other hand, I would like to remark that Allmann himself described later on (in the second volume), in *Synthecium elegans*, Allm., a form from New Zealand which stands apart from all other Hydrozoa in bearing the gonangia upon peduncles springing from within the hydrothecæ, and these hydrothecæ do not differ in a single point from the others.

A highly interesting form has been described by G. Holm * in *Dictyonema cervicorne*, bearing, alternately on the two sides of hay-forklike spines, cup-shaped bodies, "by-thecæ," which the author supposes to have been gonangia. The regularity of their distribution on the thecæ and the complete development of the by-thecæ bearing thecæ, are not quite in accordance with the appearance of the recent gonangia and seem to me to be rather suggestive of a comparison with the nematophores or nematocalyces of the Plumularidæ. These latter appendages, to which Allmann refers all the thecæ of Graptolites, are mostly tube or cup-shaped offsets of the thecæ, containing a sarcode mass which can extend itself in the form of single or branched processes. The latter are, as their thread-cells indicate, adapted to catching food for the colony.

THE SICULA.

Professor Hall succeeded in finding the embryo shells, or siculæ, as they have been called by Nicholson, not only detached but also in connection with the rhabdosome. They have been found in very widely separated spots, sometimes covering the rocks in enormous multitudes. I, too, have obtained slabs densely covered with siculæ and various young stages of *D. pristis*, Hall, while I have only one slab with free siculæ of *D. Ruedemanni*; these tiny fossils evading detection in the field, although they can be easily seen at the ends of the rhabdosomas, and sometimes even within the gonangia. (Pl. II, fig. 4.)

Hall's description of these embryos was so complete and his interpretation of their nature obviously so correct, that both have been only confirmed by later investigations. He saw them, when flattened upon the rock, as a prolonged triangular film, containing a very fine rod, the virgula. Their real form he supposed to be that of a conical sac. He regarded them as

* Gotlands Graptoliter. Bighang K. Vet. Akad. Handl. Bd. 16, Afd. 4, No. 7.
See also: Review by R. R. Gurley in The American Geologist, July number, 1891, p. 35.

primary thecæ and found that those of *Diplograptus* throw off buds from approximately opposite sides near the broad end, and form thus the two series of thecæ characteristic of the Diplograptidæ. He stated that the sicula remains embedded in the so-called proximal end of the rhabdosome, projecting with its broad end, and that the virgula grows out to the central axis.

An interesting contribution to our knowledge of the sicula of *Diplograptus*, has been lately furnished by Carl Wiman.* The author found in a piece of limestone, from Bornholm, half carbonized chitinous siculæ, which he was able to make transparent by means of Schulze's maceration medium. With the aid of his excellent material he was enabled to state that the sicula has the form of a conical tube and consists of two parts, a very thin and transparent "distal," and a thicker and less transparent "proximal" one.

My material has not given me any opportunity to study the details of this cone, but has furnished valuable information regarding the relation of the sicula to the complete colony.

While the profuse covering of certain slabs with siculæ and the crowding of siculæ around some colonies (Pl. I, fig. 9) give conclusive evidence that numerous siculæ left the gonangia, it is suggested by siculæ and by very young stipes attached to adolescent colonies that some siculæ did not sever their connection with the parent colony but grew out into new rhabdosomes. The original of Pl. I, fig. 5, shows one sicula (s_1) with two thecæ and a young rhabdosome (s_2) with a still distinctly visible sicula. Young colonies bear whole bundles of siculæ (Pl. III, figs. 15, 16).

The free sicula generally bears only a very delicate, filiform process, like that by which it is attached to the blastostyle. After I had found that this process on young free rhabdosomes connects with a square chitinous plate, I also examined the free siculæ for these appendages and found them in fair number (Pl. III, figs. 1–3) even on some of the siculæ which apparently had only shortly before been liberated (Pl. I, fig. 9). On the last-mentioned specimen they are visible only outside of the dense crowd of siculæ, the latter obscuring the details about the center. The study of this specimen leads to the conclusion that the

* Ueber Diplograptidæ Lapw. Bull. of the Geol. Inst. of Upsala, vol. I, No. 2, 1893. Translated by Ch. Schuchert in the Journal of Geology, 1894, p. 267.

square appendages were formed either inside of the gonangium or immediately after the detachment of the siculae.

Some of the best specimens bearing these plates are figured on Pl. III. Figure 1 represents the most common appearance of the appendage as the impression of a square plate, slightly raised in the center and sometimes with chitinous test; at the under side of the plate is a small round node, from which the sicula springs with a process of varying length. While the sides are mostly convex, some specimens, in later growth stages, show concave sides (fig. 2), perhaps the result of shrinkage of the still tender organ.

Figure 3 represents a specimen which is remarkable for showing to the naked eye broad radial ribs, and for displaying under the glass a series of fine concentric furrows and wrinkles around the central node. The same regular concentric furrowing can be observed on some older and larger plates (Pl. III, figs. 9, 13, 14). It excludes, by its regularity, the idea that it might be the result of shrinkage, or of the flattening of the bladder-like body.

In seeking an homology of the horny cone or sicula, among the growth stages of a Sertularian colony, we shall be embarrassed by the very fact of the chitinous nature of this embryonic sheath. The horny receptacle of the Sertularians, called gonangium, produces embryos without a horny perisarc, while that of *Diplograptus* produces such with a horny perisarc. And yet, there is a more than superficial similitude between the sicula of *Diplograptus* and the primary polypite of the Sertularians, which is borne on a short hydrocaulus, fastened by a round disc to the bottom and produces the first hydrotheca, whence the whole colony arises by lateral budding (cf. Allmann, l. c.). Supposing this polypite and its disc to be clad from the beginning in the horny perisarc by which the colony begins to protect itself in a little more advanced stage, there would result a first stage of growth strikingly similar to that of *Diplograptus;* there would be a primary theca, a hydrocaulus, a basal appendage and a lateral budding of the first hydrotheca. The earlier beginning of the secretion of the perisarc with the embryo of *Diplograptus* can not be regarded as of principal importance, but there exists a distinctive feature of great importance in the existence of the virgula in the sicula of *Diplograptus.* But even with this difference the homology of the sicula and the primary polypite of the calyptoblastic Hydrozoa is such as to justify its being regarded as an indication of relationship.

DEVELOPMENT OF DIPLOGRAPTUS PRISTIS, Hall.

Plate III.

When the shale which contains the compound colonies of *D. pristis* was exposed last year, I failed to pay sufficient attention to collecting slabs with siculæ. As I found later on, however, some slabs which preserved siculæ and young colonies with attached base, I took advantage of a renewed but unfortunately very brief exposure of the same layer, by the construction of a road, to collect young colonies. The study of these tiny fossils furnished the material for Plate III, in which I have arranged the numerous various appearances of the young colonies of *D. pristis*, Hall, according to supposed successive stages of growth.

Figs. 1–3 are representations of siculæ with their basal appendages. The next stage are siculæ with the first theca (figs. 4–7). The theca buds at the distal wide end of the sicula from a round hole which is sometimes perceptible. The "connecting canal" of Törnquist and the growth lines, described by Wiman, could also be observed on some specimens.

Figure 4 represents a specimen, the basal plate of which has concave outlines, similar to fig. 2. The sicula is distinctly attached to the central round node, as it is also in the following specimens.

Figure 5 belongs to a specimen in an excellent state of preservation. The sicula is preserved as a tube and the basal appendage as a segmental projection with a filiform chitinous border, which is a section of the test. The central node lies on the top of the projection. In fig. 6 the base is broken out, leaving a deep square impression The central node is preserved as an oval chitinous body with a central pit; the latter probably represents a connection between the node and the basal cyst (cf. fig. 6a).

Figure 7 is interesting in several regards. It not only shows the "connecting canal" of the first theca and the hole from which the former sprung, but also the central node on top of an inner plate. The latter is surrounded by four oval projections which are probably the casts of budding sacs representing the gonangia. This would indicate a very early beginning of the development of the reproductive organs.

As the next stage of growth may be regarded those rhabdosomes which bear two thecæ (figs. 8 and 9).

In fig. 8 the basal appendage is preserved as an impression only, darker than the surrounding rock.

Figure 9 represents a primary rhabdosome, the basal cyst of which is preserved as a plate with a chitinous filiform border and part of the chitinous test in the lower right corner. The concentric furrowing observed before is also distinct here; the furrows surround a high square chitinous projection which apparently develops from the original little central node and is the central disc of the grown colony.

A further stage is represented by a rhabdosome on which three thecæ can be counted (fig. 10). The central disc appears as a deep square pit; the basal cyst as a less deep, but very smooth impression with a chitinous film.

In figure 11 we have a rhabdosome with four thecæ, and connected by a rather short hydrocaulus to a central, strongly chitinous node, evidently the "funiculus" of the compound colony. The node lies inside the central disc, a deep impression filled with carbonaceous matter and surrounded by the larger impression of the basal cyst. Besides these impressions, there are present four strongly projecting oval bodies. If these are again traces of gonangia, the latter have already extended beyond the cyst.

The next represented stage (fig. 12) with seven thecæ shows the oval organs still more developed. In one of the latter (at g), there are radiating impressions perceptible, perhaps those of young siculæ.

Figures 13 and 14 show primary rhabdosomes with respectively 11 and 13 thecæ. Both are remarkable for the distinct concentric series of furrows and the great prolongation of the basal part of the hydrocaulus.

The next stage (fig. 15) appears very different from the preceding, because the primary rhabdosome is broken off (the basal part of the hydrocaulus is still preserved at p). This specimen shows two oval wrinkled chitinous plates, the gonangia, and between them two bundles of radiating siculæ, which are probably part of the contents of two other gonangia. The appearance of these bundles and of others similar to that represented in fig. 16, suggests the idea that the basal siculæ were not detached, and perhaps, by shrinkage of the blastostyle, gained connection with the central disc and funicle. The existence of bundles of hydrocauli (cf. Pl. II, fig. 3) springing from the base of grown colonies, is in favor of this view. The dense bundles of siculæ on young colonies indicate that most, if not all, of the siculæ remained in connection with the parent colony, while the appearance of the older colonies leaves no doubt that multitudes of siculæ became detached.

These bundles of siculæ now begin to develop, at first, by extending the hydrocauli (fig. 17), after which the production of hydrothecæ sets in (fig. 18). It may be concluded from figs. 17 and 18 that the young rhabdosomes did not all develop alike. While in fig. 17 most siculæ do not yet bear a theca, others have already one and a few have still more, even as many as five thecæ. In the specimen represented in fig. 18 the majority of the siculæ has produced one theca, and in the original of fig. 19 most of the rhabdosomes bear about half a dozen thecæ. In this excellently preserved specimen the hydrocauli no doubt take their origin from the central disc and the inclosed funicle; funicle, central disc and cyst are here preserved with their chitinous tests. The upper rhabdosome is so far advanced that it probably is the primary one. There is no primary rhabdosome preserved on the original of figs. 17 and 18. In such specimens as are represented in figs. 20 and 21 is a more advanced stage. On the former specimen may be observed, besides the young rhabdosome, a complete chitinous gonangium (g), a dense multitude of radiating siculæ at the right and some single siculæ at the lower side. Because of the great difference in age between the siculæ and the young rhabdosomes I am inclined to regard the gonangia and siculæ as a second generation, produced after the first generation had reached a certain age. The basal cyst is preserved in this specimen as in many others as a strong plate with a chitinous border, apparently the result of the filling of the empty bladder with sediment.

The beginning growth of a second generation is more clearly visible in the excellent original of figs. 21 and 21a, where the hydrocauli of the already highly-developed first generation of rhabdosomes are turned to one side, thus uncovering the well-preserved little chitinous gonangia (g). The latter with their interior radiation, which probably is to be referred to siculæ, are easily perceptible to the naked eye. The primary rhabdosome is turned to the right.

A more advanced stage is that shown by fig. 22, where the gonangia, preserved as impressions only, are larger than the cyst, and a few siculæ of the second generation are still connected with the apparently incomplete colony. This specimen shows the two different kinds of siculæ: the detached siculæ, two of which have been arrested in their motion by the hydrocaulus, and the nondetached siculæ.

A similar stage of growth is represented by fig. 23, which is remarkable for its having two generations of rhabdosomes, for the chitinous basal cyst, which is separated from the center, and for its central disc, which shows a central pit.

The difference betweeen the two generations of rhabdosomes is very obvious in the specimen represented of natural size in fig. 24. The three longest rhabdosomes are left from the first generation (the one on the left side is perhaps the primary rhabdosome). The verticil of rhabdosomes, marked II, is evidently the second generation, and a third generation is indicated by the oval chitinous rings, the apparent traces of gonangia.

The original difference in size between the rhabdosomes is later on obliterated by their unequal growth, and perhaps also by the loss of the older rhabdosomes. The beautiful specimen, represented in Pl. I, fig. 1, still exhibits three generations of rhabdosomes and one generation of gonangia. There is a dense verticil of almost equally long rhabdosomes found in a few very large colonies.

For the sake of completeness I add the figures (figs. 25 and 26) of two specimens which seem to stand outside of the line of development, as they show two and four siculæ on one central disc. Three siculæ have also been observed. As, however, the complete development of the central organs, the presence of funicle, central disc and basal cyst indicate, these strange little colonies are most probably the relics of already farther developed colonies. There are a few other relics of colonies with a strange appearance, as for instance a central disc bearing one large rhabdosome and one sicula.

The following is the development of *Diplograptus pristis*, Hall, given in a more comprehensive form:

1. The detached sicula is provided with a basal appendage, to which it is attached by means of a little round node.

2. The node becomes the central disc and funicle. The sicula produces at first one theca, then a second, a third, etc.

3. With the budding of the first thecæ, the growth of the gonangia already begins, with usually four small oval capsules.

4. The further growth is marked by a remarkable lengthening of the hydrocaulus and a continued budding of thecæ at the proximal end of the primary rhabdosome, along the hydrocaulus and toward the center.

5. At last the gonangia mature and open. Many, or perhaps all of the siculæ, remain connected to the parent colony. The colony consists now of a rhabdosome, about half developed, which is the primary one, bearing a basal cyst, central disc and funicle, and on these, bundles of siculæ.

6. These siculæ grow out to rhabdosomes, the process beginning again with a lengthening of the hydrocauli.

7. After this first generation of rhabdosomes has reached a certain age, a second generation of gonangia begins to grow.

8. These latter open again and produce a new set of siculæ around the center. The colony consists now of the primary rhabdosome, a verticil of young rhabdosomes, and another of siculæ. This process is continued, the successive generations of gonangia producing siculæ, which, in turn, develop into verticils of rhabdosomes.

The different size of the rhabdosomes, in all hydrosomes apparently still growing (Pl. I, fig. 1); their equal length in the hydrosomes with the longest and most numerous rhabdosomes; the common occurrence of one mature rhabdosome and numerous young ones in the same colony, are all facts giving evidence that the hydrosome began to grow with one rhabdosome, and that the number and length of the rhabdosomes increased with the age of the whole colony.

Dr. O. Herrmann,* in the description of *Dichograptus Kjerulfi*, Herrm., contends that fronds of *Dichograptus* with a different number of rhabdosomes (from 5 to 14) do not represent different ages, as it has been thought; on the ground that no difference in the thickness and length of the rhabdosomes is to be detected; that no younger rhabdosomes are perceptible when they had just sprouted and before they reached the margin of the central disc; and that young individuals occur with eight, nine and twelve rhabdosomes, just as in full-grown specimens.

It is certainly not analogous with *Diplograptus*, for the colony of *Diplograptus* does not grow as a whole with a given number of rhabdosomes, but the number of the latter is constantly increasing by the development of new rhabdosomes from siculæ. This view is supported by Hall's observation that the number of rhabdosomes is no specific character and that there is apparently no law of branching in forms with many rhabdosomes.

There was no difference in the mode of growth between the primary and the following rhabdosomes. In both the sicula lies in the oldest part, and both grew, as it were, backward toward the center, forming new thecæ at the basal end. One could compare this mode of growth with that of a leaf, the oldest part of which is the most distant point, while the youngest part, where the leaf is growing, is the base of the blade.

As long as only the detached rhabdosomes of *Diplograptus* were known it was natural that the sicular end, where the growth of the rhabdosome begins and which at first was thought to be attached to the ground, was called the "proximal" and the opposite the "distal" end. But where we have a funicle and central disc, *i. e.*, a point of attachment of the rhabdosome, we must follow, in order to avoid confusion in the nomenclature, the usage of the authors on modern Hydrozoans and define with Huxley "the attached extremity of the fixed hydrosoma or its equivalent in the free one as the proximal end, the opposite, as the distal end." The sicula-bearing end of the rhabdosome of *Diplograptus*, therefore, is really the "distal" end, as is the point of the leaf.

Wiman holds that the virgula does not begin to develop its proximal part until the sicula has been taken into the rhab-

* Dr. O. Herrmann: On the Graptolitic Family *Dichograptidæ*, Lapw., Geological Magazine, 1886, p. 18.

dosome, and that the virgula does not protrude beyond the proximal end, unless the periderm of the rhabdosome is broken away, leaving the virgula free. This, however, is different in my material, which shows the virgula to extend beyond the proximal point of the sicula into the hydrocaulus, and even beyond the proximal end of the rhabdosome into the hydrocaulus. A very interesting specimen bearing on this question is represented in Pl. II, fig. 6. The virgula, a shining, chitinous rod, contrasts with the thinner film of the hydrocaulus. The latter is broken at *m;* the more solid and inflexible virgula, however, has separated from it and lies now partly outside of the canal, still preserving its natural position in the sicula.

Nicholson, too, claims to have seen in *Diplograptus pristis* the common canal "without denticles" continued on each side of the prolonged rod; and Allmann states that if the virgula, as variously observed, extended beyond the young growing portion of the stipe, it must have been included in a cœnosarc and this confined in a perisarc, "which was probably still so delicate as to be incapable of preservation, its thicker rod-like portion being the only part preserved." As the above described specimen shows, this thin perisarc, the hydrocaulus, has been preserved under favorable conditions.

Wiman further came to the conclusion that the sicula was either open or had a very thin wall at the pointed end. The study of my specimens of siculæ furnished evidence that the sicula was attached with this pointed end by means of a filiform process either to the parent colony, or, when the sicula was free, to the central node of the basal appendage. In both cases the rhabdosome developed along this hydrocaulus toward the center of the colony. That might induce the notion that the hydrocaulus became the common canal of the rhabdosome. Wiman, however, has demonstrated that a common canal, as progenitor of the hydrothecæ, does not exist, but that the common canal is the result of the growth of the thecæ. The results of Törnquist's* excellent researches agree with Wiman's observations regarding the structure of the distal end of the rhabdosome and the growth of the common canal. Both authors assert that the formation of the common canal goes hand in hand with the budding of the thecæ. Such a mode of growth

* S. L. Törnquist. Observations on the structure of some Diprionidæ. Lund's Univ. Arsskrift, Bd. 29, Lund. 1892-93.

of the rhabdosome would exclude the pre-existence of the common canal in the hydrocaulus. Therefore the interesting question arises: What became of the hydrocaulus of the sicula? I hope that my material of young rhabdosomes with hydrocauli will permit an answer to this question later.

GENERAL APPEARANCE OF THE COLONY AND ITS SYSTEMATIC RELATIONS.

The restoration of the colonial stock of *Diplograptus* given in Plate II, fig. 5, was drawn with the assumption of a floating mode of life in *Diplograptus*. Since then material has been found (cf. Pl. V) which does not justify such a supposition, and, therefore, the writer presents this sketch only as an illustration of the relative vertical succession of the parts, without regard to the question of their absolute position, for there is a possibility that the order was the reverse of that given in the figure, and that the basal cyst was the undermost part of the colony.

It is a fact of special importance that the uniform association, stated by Allmann, l. c., of the horny receptacles of the hydranths (hydrothecæ) with the horny receptacles of the generative organs (gonangia) among the Hydrozoa, is also found in *Diplograptus*. As this association is the specific character of the *Calyptoblastea* (*Plumularidæ* and *Sertularidæ*), its observation on *Diplograptus* would seem a strong argument for placing *Diplograptus* near the *Calyptoblastea*. But in spite of this homology between *Diplograptus* and the Sertularians in particular, the former, like the other Graptolites, has to be separated from the Sertularians on account of the horny sheath of the embryo, and, what seems more important, the horny axis of the rhabdosome.* These differences justify the grouping of the Graptolites into a separate class, the *Rhabdophora*.

It is my pleasant duty to express my most sincere thanks to Profs. James Hall, John M. Clarke, C. E. Beecher and R. P. Whitfield, who, by their kind advice and by generously placing at my disposal literature and collections, have enabled me to complete this paper.

* Allmann states, as another distinction, the differing communication between the hydrotheca and central cavity. The living Hydroids have only a constricted point of communication or even an imperfect diaphragm, while the point of communication of the Graptolites is regarded as not constricted, though the latter needs verification, as there are indications of a slight constriction in some species. For instance, Tullberg observed, in slides of *Diplograptus palmeus*, Barr., that "the thecal partitions are in all sections well marked and provided with thickened inner edges."

The writer has been highly gratified at having placed in his hands, by the courtesy of Prof. James Hall, a large slab bearing a colony of *Diplograptus*. The fossil is not only interesting because it adds a new locality and a new horizon — the Hudson River group, the slab coming from a railroad-cut near the Abbey, south of Albany, N. Y.— but also on account of the remarkable size and mode of preservation of the colonial stock. The size of the fossil can be taken from the figure on plate IV which is a reproduction in approximately natural size. One rhabdosome measures 80 mm.; another 70 mm., the latter reaching a length of 40 mm. The diameter of the whole colony, therefore, may easily have been 200 mm. The slab, however, is covered with broken-off rhabdosomes of still larger dimensions, and especially with longer hydrocauli. One of these rhabdosomes is 72 mm. long and is attached to a hydrocaulus 67 mm. in length. This example illustrates the remarkable length of the hydrocauli of some rhabdosomes, the bearing of which fact on the question of the mode of life of the colony has been discussed in this paper. A comparison of this rhabdosome with those of the colony makes evident that there was a great difference in the length of the hydrocauli of nearly equally long rhabdosomes; and the profuse occurrence of detached long-stalked rhabdosomes indicates that the colony, as we see it now, may have lost a great number of them. The latter supposition is supported by the presence of a dense intricate mass of hydrocauli near the center of the colony. It is probable, therefore, that while the remains of 30 rhabdosomes can be counted now in the colony, the latter, when alive, was composed of a considerably greater number.

The center is so much obscured by the superposition of several rhabdosomes that it appears as a solid film in which only the outline of the central disc can be discerned with difficulty.

A remarkable feature of the colony is the great variety of aspect presented by the rhabdosomes, according to the direction in which they became compressed, and the different states of preservation. Though the majority of the rhabdosomes of this colony, from their general appearance, might be identified as *D. pristis*, Hall, it would seem that the dimensions of the rhabdosomes are such as to constitute a difference from the forms of *D. pristis*, Hall, as found in the Utica slate. Moreover, some of the rhabdosomes, if found detached, would certainly be identified as *D. quadrimucronatus*, Hall; and others approach *D. mucronatus*, Hall. It is probable that a closer study of the colonies of *Diplograptus* occurring in the Utica and Hudson River slates will necessitate a revision of the species of this genus. The strangeness of the appearance of many stipes is still increased by irregularly distributed aggregations of pustules which have their origin in crystallizations of iron pyrite within the rhabdosomes.

Addendum.

To my regret, Wiman's important paper, "Ueber die Graptoliten," was received too late to be given the deserved appreciation in this paper. I will, however, not miss this opportunity to thank the author for the full reproduction of my preliminary note as well as for the publication of his highly developed methods of preparation, which, I hope, can be applied successfully to my material. Besides, the writer wishes to make a few remarks on some objections raised by Wiman.

Regarding the objection to the use of the terms which Hall introduced for the compound colonial stock of the *Dichograptidæ* (called by mistake compound *Monograptidæ* instead of compound *Monoprionidæ*), I think that the development of the colonial stock of *Diplograptus*, published in this Report, will justify the application of the terms in so far as it shows that the "central disc" of *Diplograptus* originally lies at the sicular end of the colony, for it is among the earliest outgrowths of the sicula. The fact that this sicula, in later stages of growth, wanders outward, away from the disc, budding thecæ between the two, is a later complication which, in my opinion, does not materially affect the homology of the discs of *Dichograptus* and *Diplograptus*. In case the thecæ of the primary rhabdosome would not grow in the direction of the initial part of the sicula, but away from it, as in *Dichograptus*, then the primary sicula would remain always at the disc; or, in other words, the disc would continue to lie at the sicular end of the rhabdosome. The "central discs" of *Dichograptus* and *Diplograptus* therefore are, genetically, identical. The difference between the two comes in when the colonial stock of *Diplograptus*, by means of "gonangia," produces new stipes, while in Dichograptidæ the latter are formed by branching. If the siculæ, remaining in connection with the parent colony, had developed their own central discs, the latter must appear, by analogy with the primary rhabdosome, at the first central disc, where, however, no indications of such secondary central discs have been observed. The antisicular ends of the secondary stipes connect directly with the antisicular end of the primary stipe, thus forming that connecting stem for which I adduced Hall's term "funicle." While the central disc of *Diplograptus*, though not in secondary position, but in origin, is identical with Hall's central disc, Wiman is certainly right in disapproving the application of the term "funicle" for the connecting stem of *Diplograptus;* for, while the latter, in *Diplograptus*, is apparently formed by the connection of the antisicular ends of the secondary stipes, that of the *Dichograptidæ* is the product of branching.

Wiman objects to the comparison of the siculæ-bearing capsules with gonangia, and sees in them gemmating individuals, evidently referring to his interesting observation of gemmation within individuals among the *Dendroidea*. In the apparently complete series of growth stages of *Diplograptus pristis* described in this report, under the assumption that the "gonangia" were only organs of asexual propagation, and the siculæ consequently only buds; sexual generation would on this supposition be entirely eliminated, and this is most improbable. If it be supposed now that gonangia, which are not preserved, existed somewhere on the hydrothecæ (the appendages observed by Hall might be adduced here), and that these sexually produced larvæ, then it is inconceivable that these could have developed anything but siculæ; for the growth of the whole colony, as well as that of the stipes, starts clearly from siculæ. Hence we would have the same product, siculæ, by sexual generation and a sexual gemmation, which is improbable again. The capsules agree, as their description shows, wholly with the gonangia of the *Sertularians* in their general features. The fact, also, that the larvæ reached such a high stage of development within the capsules is not without analogy among the *Hydrozoans*, e. g., *Sertularia cupressina* discharges larvæ already ciliated; *Tubularia coronata* even "actinulæ" with tentacles. Retaining the comparison of the *Graptolites* with the *Sertularians*, the budding of the colony of *Diplograptus* from the sicula is certainly homologous to the budding of the Hydroid colony from a sexually produced larva.

While it thus appears that there is a great similarity between the "gonangia" of *Diplograptus* and their products, and those capsules of the calyptoblastic *Hydrozoa* which inclose the sexual glands and their products, there is none at all between "gonangia" and thecæ, such as the gemmation individuals observed by Wiman possess. Neither is the possible objection that the gonangia ought to appear on thecæ sufficient, for there are living forms enough among the Hydrozoans in which the sexual glands appear on the hydrocaulus. The discovery of siculæ only in the gonangia does not exclude the possibility that the latter before that contained male or female generative buds which sexually produced eggs, these developing into siculæ. Neither the generative buds nor the eggs, which are both always very soft, could be expected to be preserved, while the blastostyle from which these generative glands sprung, and which later gave attachment to the siculæ, is sometimes observed. There is no need of supposing parthenogenesis in the gonangia as the whole difference between the recent and the fossilized gonangia may consist in the non-preservation of the generative buds within the latter, and the longer continued existence of the gonangial test for the purpose of brooding the larvæ.

I expected that the "pneumatocyst" would be objected to. Yet I thought it my duty to publish the supposition which the described organ and its peculiarities so strongly suggest. As stated in this report, the pneumatocyst is by no means a heavily chitinized organ; it can not compare in this regard even with the gonangia. It is true the rhabdosome was inflexible, but this was not in my opinion possible, only because the colony was moored, but it was so in spite of the floating habit of the colony, because it could not be avoided as long as the animals sought protection by a chitin us periderm which was not articulated. There are *Sertularidæ* and *Campanularidæ* to-day which are attached to floating objects, and which have a chitinous periderm. The virgula which, according to Wiman, kept the rhabdosome in an upright position, may as well have served to protect the fragile, because inflexible, rhabdosome from breaking; for if the latter was once stiff, it certainly was of advantage to resist breaking so far as possible. While Wiman finds it difficult to imagine how stiff tufts of *Monograptidæ* a meter long could have been suspended, I encountered the same difficulty in trying to imagine how the long and heavy rhabdosome of *Diplograptus pristis* could have been supported by the very slender and often very long hydrocaulus. I may be also allowed to refer here to the disproportion between the rhabdosome and the thread-like process of the sicula in *Mœandrograptus* (Moberg, *l. c.*). The waves were of no danger to the little colony, as the latter probably kept in deeper water. It also would be strange that complete hydrosomes are so rare when they would have been moored and could have been buried in situ; and supposing that the fragility of the rhabdosome forbade the preservation of the rhabdosomes in connection with the center, the former ought to be found, at least, often in stellate arrangement.

Explanations of Plates.

Legend. f. funicle.
c. central disc.
g. gonangium.
pn. basal cyst.

Types of figures on Plates I–III from the Utica slate of Dolgeville, N. Y.

Plate I.

Fig. 1.—*Diplograptus pristis*, Hall. Natural size.

Fig. 2.—*Diplograptus Ruedemanni*, Gurley. Natural size.

Fig. 3.—*D. Ruedemanni*, Gurley.
Gonangia preserved as pits. × 4.

Fig. 4.—*D. Ruedemanni*, Gurley.
Central disc with inclosed funicle; part of the specimen represented on Pl. II, fig. 1. × 22.

Fig. 5.—*D. pristis*, Hall. × 4.
g.—Gonangium, filled with siculæ.
s_1.—Sicula with two thecæ.
s_2.—Rhabdosome with discernible sicula.

Fig. 6.—*D. Ruedemanni*, Gurley. × 10.
f.—Inside of funicle.
c.—Inside of central disc.

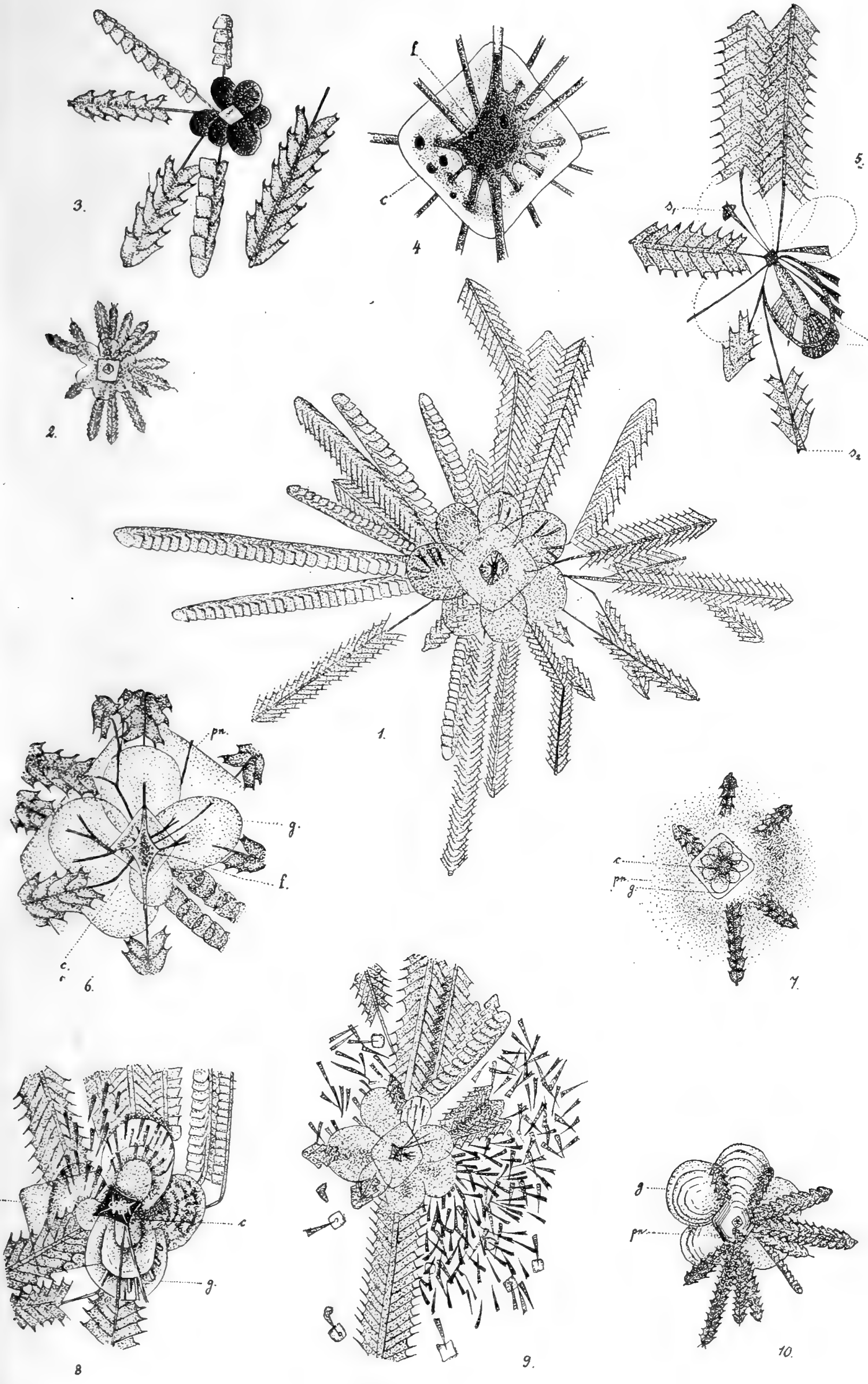
Fig. 7.—*D. Ruedemanni*, Gurley. × 2.
The basal cyst is broken out.
pn.—Impression of basal cyst.

Fig. 8.—*D. pristis*, Hall. × 3.

Fig. 9.—*D. pristis*, Hall. × 2.

Fig. 10.—*D. Ruedemanni*, Gurley, × $\frac{6}{5}$.
View of the under side.

PLATE 1.



Diplograptus.

Plate II.

Fig. 1.—*D. Ruedemanni*, Gurley. × 6.
Shows middle plate of basal cyst.

Fig. 2.—*D. Ruedemanni*, Gurley. × 6.

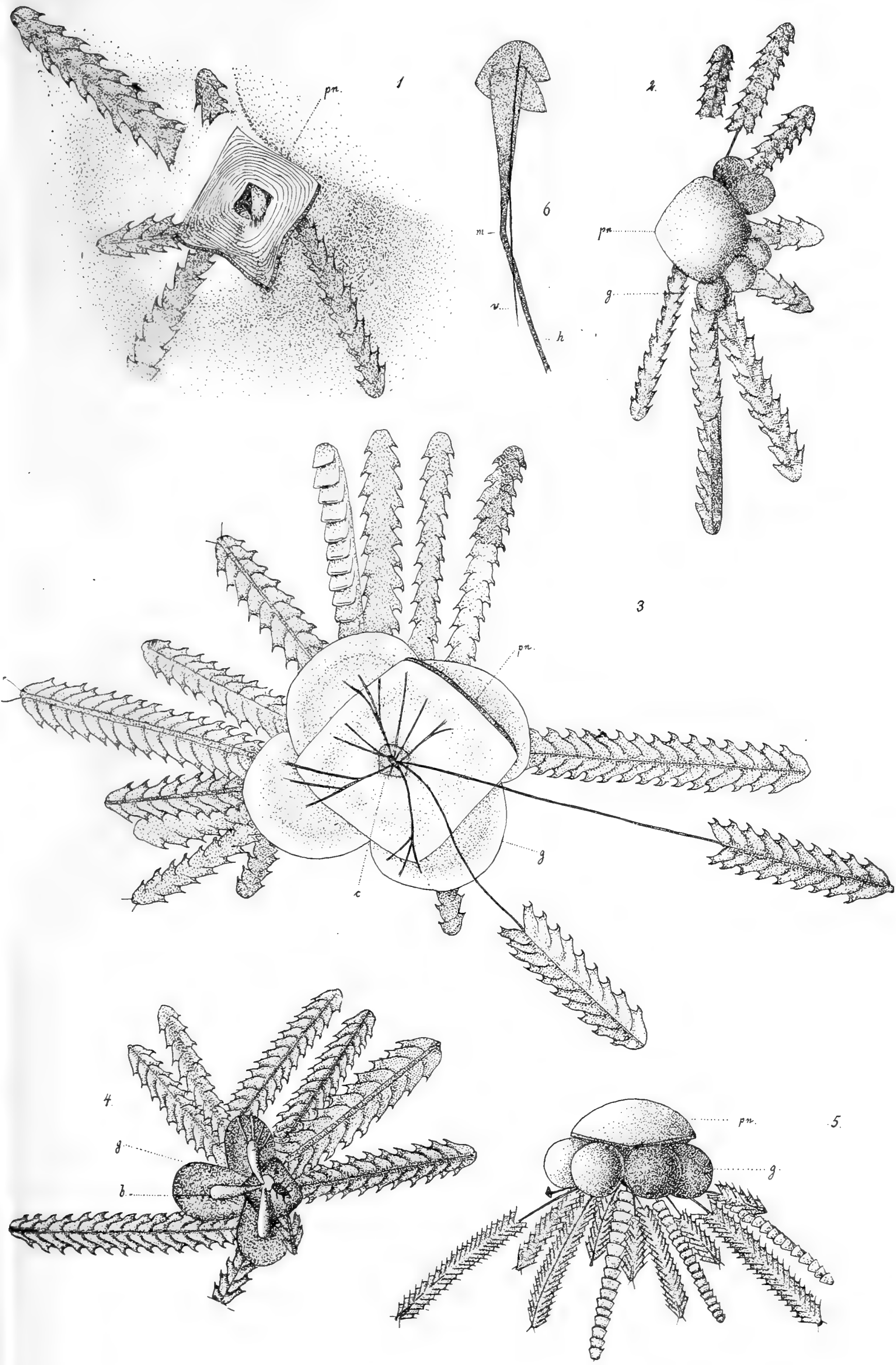
Fig. 3.—*D. Ruedemanni*, Gurley. × 7.

Fig. 4.—*D. Ruedemanni*, Gurley. × 10.
b.— Blastostyle.

Fig. 5.— Restoration of *D. pristis*, Hall. Natural size.

Fig. 6.—*D. pristis*, Hall. Young rhabdosome. ×
h.— Hydrocaulus.
v.— Virgula.

PLATE 2.



Diplograptus.

Plate III.

Diplograptus pristis, Hall.

Figs. 1, 2, 3.— Siculæ. × 2.
  Fig. 3a.— Natural size.
  Fig. 3b.— Basal cyst. × 6.

Figs. 4, 5, 6, 7.— Young hydrosomes. × 2.
  Rhabdosomes, with one theca each.
  Fig. 6a.— Basal cyst. × 6.
  Fig. 7a.— Basal cyst. × 4.

Figs. 8, 9.— Young hydrosomes. × 2.
  Rhabdosomes, with two thecæ each.

Fig. 10.— Young hydrosome. × 2.
  Rhabdosome with three hydrothecæ.

Fig. 11.— Young primary hydrosome. × 2.
  Rhabdosome, with five thecæ.

Fig. 12.— Young primary hydrosome. × 2.
  Rhabdosome with seven thecæ.

Fig. 13.— Young primary hydrosome. × 2.
  Rhabdosome with 11 thecæ.

Fig. 14.— Young primary hydrosome. × 2.
  Rhabdosome with 13 thecæ.

Figs. 15, 16.— Hydrosome with first generation of siculae. × 2.
  h.— Hydrocaulus of primary rhabdosome.

Fig. 17.— Hydrosome with first generation of siculæ. × 2.
  The hydrocauli have grown longer.

Fig. 18.— do. The siculæ have begun to produce thecæ. × 2.

Fig. 19.— Hydrosome, with first generation of rhabdosomes. × 2.
  a.— Primary rhabdosome.

Fig. 20.— Hydrosome with second generation of gonangia and siculæ. × 2.

Fig. 21.— do. × 2.
  Fig. 21a.— Center of hydrosome. × 4.

Fig. 22.— do. Natural size.
  Fig. s.—Sicula, arrested by hydrocaulus.
  Fig. 22a.— × 2.

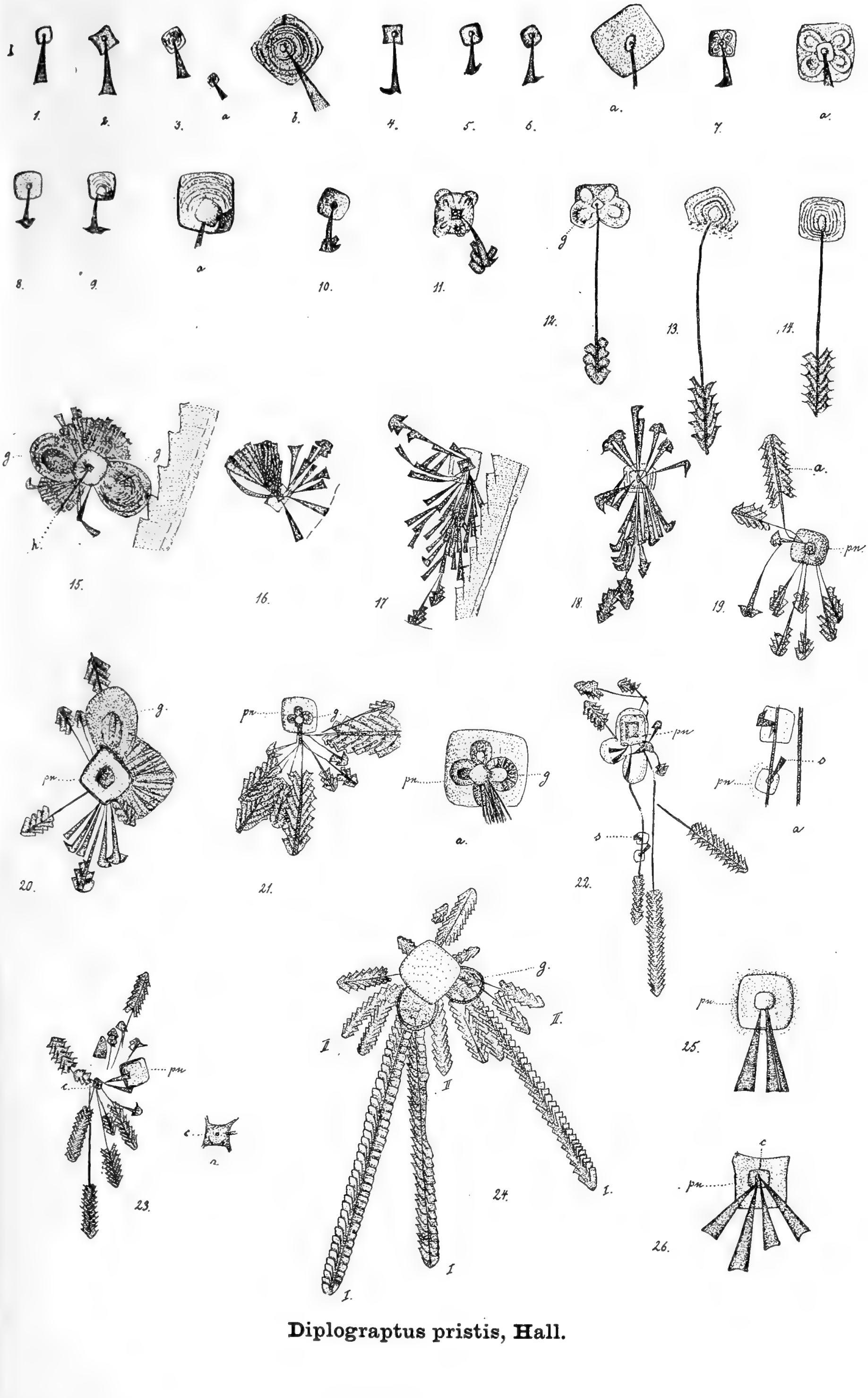
Fig. 23.— do. Natural size.
  Fig. 23a.—Central disc with pit. × 2.

Fig. 24.—Adolescent hydrosome. Natural size.
  Two generations of rhabdosomes (I and II) and one of gonangia (g).

Fig. 25.— Central disc with two siculæ. × 4.

Fig. 26.— Central disc with four siculæ. × 4.

PLATE 3.

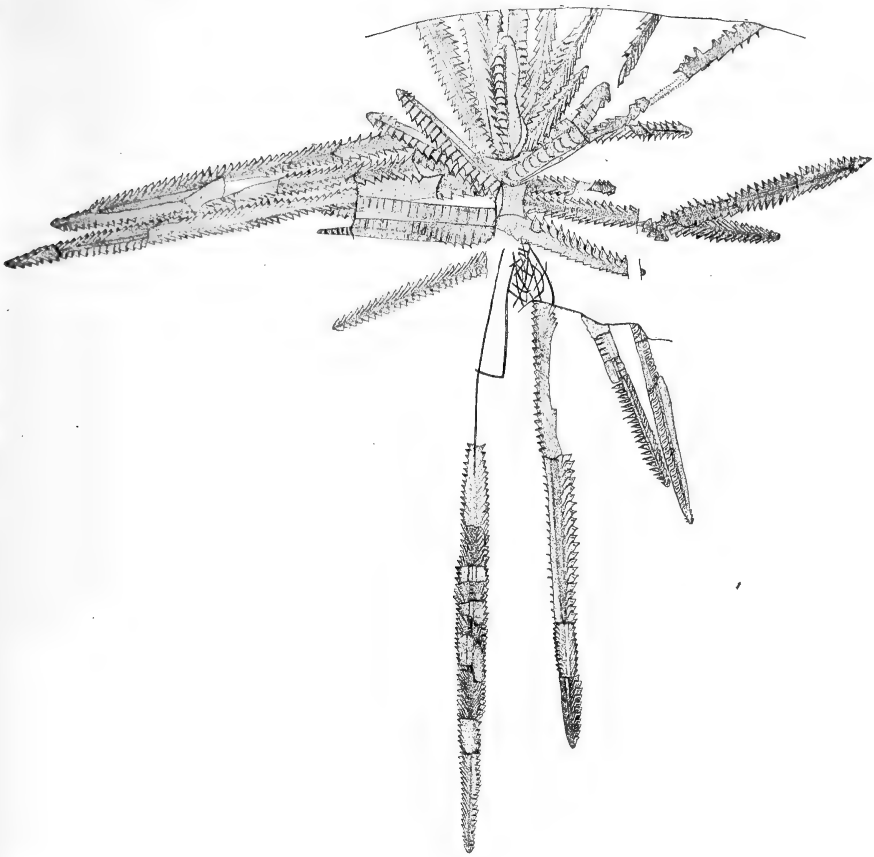


Diplograptus pristis, Hall.

PLATE IV.

Fig. 1. *Diplograptus pristis*, Hall. Natural size. Hudson river shale, Albany, N. Y.

PLATE 4.



Diplograptus pristis, Hall.

Plate V.

Fig. 1. *Diplograptus Ruedemanni*, Gurl. Natural size. Part of slab with colonies in natural position. Utica shale, Dolgeville, N. Y.

PLATE 5.

Enlarged 1½ diameters (explanation of plate in error)

Diplograptus Ruedemanni, Gurley.

A Revision of the Sponges and Cœlenterates of the Lower Helderberg Group of New York.

By George Herbert Girty.

A Revision of the Sponges and Cœlenterates of the Lower Helderberg Group of New York.

By GEORGE HERBERT GIRTY.

Since 1861, when Prof. James Hall published volume 3 of the Palaeontology of New York, no systematic review of the Lower Helderberg fauna has been attempted. During that time the fossils of this period have been much studied, not only in New York but elsewhere, and many additions have been made both in genera and species.

Specimens from the Lower Pentamerus and Tentaculite beds of the New York series are generally difficult to manipulate, on account of the refractory nature of the very hard and sometimes siliceous limestone which forms their matrix. On the other hand, those from the Shaly limestone are usually somewhat crushed. However, in certain layers of this horizon exposed at the Indian Ladder, in the Helderberg mountain, the fossils occur very perfectly silicified, and at the same time the matrix is more calcareous than is usually the case. This fortunate concurrence renders it possible to etch the rock successfully, and specimens obtained in this way compare not unfavorably with the products of recent dredgings. Delicate fronds of Fenestella, arborescent Bryozoans and spiny forms of Crania are not uncommon, together with sponge spicules, annelid teeth, embryonic trilobites, and other minute organisms which could not be obtained by ordinary methods, since they would not be observed in the field.

The fauna itself is remarkable in many ways. In certain geological horizons, probably owing to contrasting physical conditions, the different zoological groups were markedly localized. With the Lower Helderberg Group it is different. The conditions seem to have been congenial for the growth and preservation of nearly all kinds of marine life at different periods during the deposition of these strata, and in a single locality as many as 500 species are known to occur, representing all, or nearly all, the fossil families then existing. Certain forms also enjoyed a remarkable development, notably the trilobites, in ACIDASPIS and wonderful types of LICHAS and DALMANITES.

This group of beds is of especial interest in view of its position, transitional between the Silurian and Devonian ages, and its possession of strong and very interesting faunal relations with the Niagara and Oriskany periods. Recent discussions have brought these faunal relations into prominence and have, to a certain extent, necessitated a revision of this fauna.

With a few exceptions the specimens upon which the following observations are based all come from typical localities in the Helderberg mountains of Albany county, N. Y.

In this paper I have covered the ground only as far as the Echinoderms, but have endeavored to include all species described up to the present time from the Lower Helderberg strata in New York. A few new species are described, and wherever the material has afforded data as to unknown or questioned structures, this class of facts is also added. This is especially noticeable in the case of the genera HINDIA and RECEPTACULITES. Of the structure of the latter, a remarkable specimen has suggested a new standpoint for the interpretation of its structure In the case of HINDIA, nothing is added to our present knowledge, but RAUFF's views have been completely corroborated in a few disputed points. The work done in this review, while it includes some of the more perplexing organisms among invertebrate fossils, does not, from its incompleteness, warrant any conclusions as to the geologic age of the Lower Helderberg fauna, but may form a starting point for investigations which will definitely determine that question.

NEW HAVEN, *June* 1, 1894.

SPONGIÆ.

Order LITHISTIDA.

Suborder EUTAXICLADINA.

Family Hindiidæ, Rauff.

Hindia, Duncan.

Hindia fibrosa, Roemer, (sp.) 1860.

Calamopora fibrosa (not *C. fibrosa*, Goldfuss), Roemer, 1860. Fauna des Westl. Tenn., p. 20.

Astylospongia inornata, Hall, 1863. Sixteenth Rept. New York State Cab. Nat. Hist., p. 70.

Sphærolites Nicholsoni, Hinde, 1875. Abstract, Proc. Geol. Soc., p. lxxxviii. In Q. J. G. S., vol. 31.

Hindia sphæroidalis, Duncan, 1879. Ann. Mag. Nat. Hist. (5), vol. 4, p. 84.

Hindia fibrosa, Miller, 1889. N. Amer. Geol. and Pal., p. 160.

Hindia sphæroidalis, Ulrich, 1890. Geol. Surv. Illinois, vol. VIII, p. 226 *et seq.*

The first name which this sponge received is *Calamopora fibrosa*, Roemer. Although the term arose from an incorrect identification of one of Goldfuss's species, this is no reason for rejecting the specific name in favor of one of later date, especially as these two species belong to widely different genera.

The structure and position of Hindia have for years been the subject of considerable contention, but it may at least be affirmed that Hindia is a siliceous sponge, and belongs to the order of Lithistida. Yet this conclusion does not stand without a challenge. Duncan asserts the calcareous nature of the sponge, and only recently Steinmann* has denied that it is a sponge at all but considers it a Favosite coral.

As to the nature and mode of union of the spicular elements, the later investigations of Hinde "confirm the careful descriptions of Hindia given in Rauff's paper in nearly every respect,"† but his conclusions as to its systematic position are not the same. While Hinde considers the genus more nearly related to the

*Steinmann, 1886. Neues Jahrb. Min. I, 1 Heft, p. 91.

†Hinde, 1887. Ann. Mag. Nat. Hist. (5), p. 75.

Anomocladina (l. c.), RAUFF refers it without hesitation to the *Tetracladina.*

ULRICH'S observations and conclusions "respecting the minute structure of the sponge agree very closely with those of both RAUFF and HINDE," but he follows the former in placing HINDIA with the *Tetracladina.* He describes the structure of the sponge as follows:

"The individual spicules have four rays or arms extending from an inflated center. Three of the rays are nearly straight, of nearly equal length, with their extremities expanded mostly in a vertical direction. By their union a tripod-shaped body is formed, from the upper surface of which the short fourth ray projects.

"The connected structure of the skeleton is easily understood after we have once determined the true form of the individual spicules. In the first place the spicules form rather regular concentric layers, in which the individuals are arranged alternately so that any one portion of each spicule is placed directly over or beneath the corresponding portion of the spicules of the third, fifth, seventh and ninth layers. The stumpy fourth ray is always directed toward the exterior, while the three tripodal rays extend toward the central nodes of three adjacent spicules of the layer immediately beneath. The upper portions of the expanded terminations in each case clasp about one-third of the fourth ray of the latter, while the lower portion extends downward in a recurving manner to the node or fourth ray of the spicule directly beneath it."

This description differs in two particulars from the structure as worked out by RAUFF* and corroborated by HINDE. RAUFF showed that the union of the spicules does not take place by the junction of the frilled ends of their rays with each other, as stated by DUNCAN, at first accepted by HINDE,† and as the above quotation certainly implies. Their mode of union is well shown in figure 2, plate II.

The tripodal rays are smooth on the inner and toothed on the outer side.‡ The union is effected in the following manner: The

* H. RAUFF, 1886. Sitzungsber. Niederrh Gesellsch. zu Bonn.

† HINDE, 1883. Cat Foss. Sponges of Brit. Mus., p. 57.

‡ — "und dass die Verbindung in die Weise geschieht dass das ausgebreitete und gezähnelte Köpfchen des einen Armes gegen das in derselben Kanalflächen liegende convexe, ebenfalls gezähnelte Armmittelstück desjenigen seitlich benachbarten Elementes stösst, dessen Knotenpunkt nicht mit den Ersten auf demselben Querschnitt liegt, sondern gleichsam in einer halbe Knotenentfernung (halbe Mäschenhöhle) darüber oder darunter (RAUFF, l. c. p. 5).

expanded and dentate terminus of one arm is supported upon the central dentate portion of the arm belonging to the spicular element laterally adjacent, whose center does not lie in the same canal face as that of the first, but half a mesh-length above or below it. (RAUFF l. c.) He explains DUNCAN's figures (Ann. Mag. Nat. Hist., 1879, vol. IV, pl. IX, figs. 1a, 2, 2) by supposing that they have been drawn from a tangential section of the sponge in which the real union of the spicules can not be distinguished.

Neither HINDE nor RAUFF makes any mention of the recurvature of the tripodal ray to the node of the second row beneath or toward the center, as described by ULRICH. RAUFF does say, however, that possibly the aborted fourth ray may, in some cases, be prolonged outward to join the node of the next spicule above, on the same corner of the canal, thus strengthening the connection and materializing the angle. He thinks, in fact, that he has observed this prolongation in one instance. On the other hand, the atrophy of the fourth ray seems natural, if it is considered that the inflated terminations of the arms are often so strongly prolonged that they impinge upon the central node of the spicule with which they are bound. This lateral outgrowth in the course of time must stunt the fourth arm (RAUFF l. c.).

My own observations on HINDIA confirm those of RAUFF in every essential particular. The only exception is that the spicules in the Lower Helderberg specimens seem a little more slender, and the whole spicular net-work more light and elegant in consequence. Neither have I seen the prolongation of the fourth ray above alluded to.

Upward of 175 specimens of *Hindia fibrosa* have been examined by me, and I have observed the individual spicules well preserved in but one instance. In this example, the character of the spicules themselves and of the whole spicular framework, has been maintained with a fidelity and perfection that leaves little to be desired. The specimen in question has an outer coating of pyrite. The interior is limonite, becoming somewhat ochreous toward the center. The sponge skeleton appears as a polished and exceedingly perfect cast in which the shape and mode of union of the constituent spicular elements are clearly portrayed.

A few examples exhibit a singular condition of preservation, and show a striking resemblance to a minute Favosite coral. The radiating canals appear to be bounded by walls of silica, which are pierced at regular intervals by pores. The walls, however, are seen to be double, preserving between them an imperfect cast of the spicular framework. This framework evidently had been overlaid by a siliceous deposit, then the colloidal silica of the spicules replaced by calcite, and the whole sponge filled in with the muddy sediment which now forms its matrix.

In a large majority of specimens, the original siliceous elements of the sponge have been imperfectly replaced by calcite. When not decomposed, sections of these show well-developed walls, in which the spicular mesh is indistinguishable from the secondary deposit.

All stages exist between specimens where the walls of the radiating canals are well preserved and prominent upon the surface, suggesting a globular form of CHÆTETES, to others in which the tube walls have been dissolved out, and the shaly matrix reduced to a soft and somewhat ochreous mass. Silicified examples exist chiefly as casts. The radiating canals are represented by radiating pillars, and these are connected with one another by trabecular processes representing the pores which originally connected the canals into a common system. In a few specimens, traces of the original spicules seem to be preserved.

I doubt if in any of the Lower Helderberg specimens, there is a true replacement by pyrite, where the iron in solution replaces the original material, molecule for molecule, thus preserving the minute structure of the organism. However, in specimens coming from a certain layer of the Shaly limestone, a crude pyritization occurs, and such specimens can be nicely etched. Inasmuch as the pyrite is granular and the structure no better preserved than in other examples, it seems probable that small crystals of pyrite are really embedded in or cemented by silica. This conclusion is substantiated by a specimen, half of which is preserved in this way as pyrite, and the rest appears as an encrusting shell of silica in the manner above described.

In a specimen to which reference has been made, and the only one which preserves the original structure of the sponge, nearly the reverse of this process seems to have occurred. The spicular framework was probably overlaid with pyrite while it was still in a perfect condition. The spicules themselves were then dissolved out, and a deposition of pyrite over the exterior sealed up the structure from further alteration. An oxidization of the pyrite at the center to limonite finally reduced the specimen to the condition in which it is now presented.

The evidence afforded by the Lower Helderberg specimens as to the original composition of HINDIA is anything but conclusive, and at first sight seems to contradict the siliceous nature of the sponge. Specimens of LYSACTINELLA, the undoubted Hexactinellid genus described below, are represented in the majority of cases by amorphous pyrite, while HINDIA, as before stated, is never so preserved. On the other hand, a few examples of LYSACTINELLA are replaced by crystalline pyrite, and no calcareous tests occur pyritized. Thus, while HINDIA differs in preservation from most examples of a known siliceous organism, it is also unlike the brachiopods and other calcareous forms from the same beds which are usually silicified. In view of its structure, which is clearly Lithistidan in type, and of the facts adduced by HINDE and RAUFF, despite its ambiguous preservation-characters, the preponderance of evidence is plainly in favor of the position taken by those writers, that HINDIA is a siliceous sponge of the order LITHISTIDA.

The smallest specimen observed by me in the collection is 6 mm. and the largest 64 mm. in diameter. This shows a much greater range in size than noticed by HINDE, whose measurements are 13 to 45 mm., or by RAUFF who gives 10 to 45 mm.

Formation and locality.—Lower Pentamerus and Shaly limestones of the Lower Helderberg group, at Clarksville, Indian Ladder, and other localities in New York. The same species is cited from the Silurian of Russia, Scotland, Germany, New Brunswick, Indiana, Kentucky, western Tennessee and Minnesota.

Order HEXACTINELLIDA.

Suborder LYSSACINA.

Lysactinella, gen. nov.

The presence in the Lower Helderberg Group of a hexactinellid sponge, belonging to the Lyssacine order, was first made known from casts of spicules in a phosphatic nodule coming from the Shaly limestone. For more than four years Professor C. E. Beecher has had in his possession such nodules, free spicules, and sections of an entire specimen from the same horizon.

It has been the custom to place in *Hyalostelia* dissociated hexactinellid spicules of various forms. The type of this genus is *Hyalonema Smithi*, Young and Young,* from the Carboniferous strata of England. The spicules described by these writers are of three kinds, "(*a*) nail-like, some with four tapering generally unequal arms, a fifth projecting at right angles to these, others approaching the sexradiate type by the projection of a rounded, sometimes stalked process, opposite to the fifth; (*b*) sexradiate, with the arms of various sizes but always projecting, and of various number, either by reduction or by the adhesion of other spicules; (*c*) long, smooth, slender, tubular rods (the *Serpula parallela*, M'Coy) tapering toward the extremity and ending in the anchoring hooklets, the tip of the rod being either not, or only slightly inflated."

The spicules thus enumerated and described were referred by the writers to the existing Lyssacine hexactinellid, HYALONEMA. In 1879, two years later, ZITTEL† recognized *Hyalonema Smithi* as a distinct form and proposed for it the name HYALOSTELIA. In 1883 HINDE‡ proposed to limit the type species "to the simple hexactinellid spicules, which are the most abundant forms in the beds at Cunningham Baidland, and to the spicular rods with or without four anchoring hooks at their termination." The abnormal spicules were shown to belong to a form, subsequently described by CARTER as *Holasterella conferta*.

The form of the sponge in HYALOSTELIA and the range of its spicular elements are unknown. The fundamental conception of the species by YOUNG and YOUNG seems to have been its stalked condition wherein it resembles HYALONEMA. The Lower Helderberg species here discussed is from a widely different horizon. Since, moreover, there is no evidence that it once possessed anchoring spicules, it seems impossible to refer it to HYALOSTELIA.

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*YOUNG and YOUNG, 1877. Ann. Mag. Nat. Hist. (4), vol. XX, pp. 425–432, Pls. XIV and XV. Referred to by the same writers in 1876 as *Acanthospongia Smithi*, Y. and Y. Cat. of West. Scot. Foss.

†ZITTEL, 1879. Handbuch der Palæontologie, Bd. 1, II, Lief.

‡HINDE, 1883. Cat. Foss. Sponges of Brit. Mus. p. 150.

Therefore to receive this and allied forms, I have proposed the generic name LYSACTINELLA.*

The material on which this genus is established consists of spicular casts in phosphatic nodules, isolated spicules, and an entire sponge. The free spicules are preserved mostly as pyrite, but, in a few examples, they are silicified. Two types of these spicules are recognizable ; one extremely ornate, the other simple and without spines. The complete specimen mentioned contains only the simpler sort of spicules. In the large collection of Lower Helderberg sponges examined, no other entire specimen of LYSACTINELLA was found. This must fairly represent the various constituent spicular elements of the sponge, and probably its original form.

In shape it is a flattened sphere, and in this particular is indistinguishable from the ordinary HINDIA. A polished section, however, clearly distinguishes the two types of structure, and the regular radiating canals of HINDIA are very characteristic.

This genus will also include a number of Silurian hexactinellid sponges, known only by scattered spicules, especially when there is no reason to believe that they were attached by a basal tuft of anchoring spicules, as in PATTERSONIA or HYALONEMA. Among such would be numbered ULRICH'S *Hyalostelia solivaga* mentioned as isolated hexacts accompanying *Hindia fibrosa.*† This species may be identical with *Lysactinella Gebhardi*, described below.

Sponge spherical to subspherical, sessile, i. e., without anchoring spicules. Spicules (hexacts, pentacts, tetracts, etc.), without such modifications as in *Holasterella*, obscure the systematic arrangement and number of the spicular axes.

LYSACTINELLA GEBHARDI, sp. nov.

Plate I, figures 1–21.

Sponge flattened-spherical, composed of hexacts, pentacts, etc. Arms of the spicules simple rods, without ornamentation of nodes or spines.

As seen in section, this sponge appears as a mass of uncemented spicules, so great in number that it is difficult to differentiate individuals. These vary considerably in size and also in char-

* λύω, I loose, and ἀχτίν, spicule.

† ULRICH, 1890. Geol. Surv. Illinois, vol VIII, p. 232.

acter. In determining the latter there is a degree of uncertainty necessarily dependent on viewing only one plane, which cuts an object whose members lie in three. The original arrangement of the spicules has doubtless been lost, as they lie in great confusion, but usually, at or near the outside of the section, a number of spicules can be distinguished which may be referred with considerable certainty to the dermal layer. These spicules are larger than the other sponge elements, and appear to be pentacts, which rather favors the conclusion that they were originally of a dermal position and character.

There is every reason to believe that the remaining spicules are hexacts or tetracts, and that monacts also are present. As all the spicules distinguishable in these sections are composed of simple, straight rods, destitute of spines, I have placed in another species the elaborate and spinose forms found free, and have referred to *Lysactinella Gebhardi* the simple elements, whether occurring free or as spicular casts. In section a few of the spicules appear to have five arms in a single plane, with the possibility of two others at right angles to them. This may be the case, or it may be the result of the imperfect orientation of the arms geometrically. This is not uncommon and might permit a section to cut portions of five hexactinellid arms. At all events, the number of such abnormal instances is so small that it can not affect the systematic position of the sponge. An outline, natural size, of a section taken near the center of the specimen is given on Plate II, figure 3. It measures in width 23 mm.; in height 9 mm.

LYSACTINELLA PERELEGANS, sp. nov.

Plate I, figures 22-31; Plate II, figure 1.

Body of the sponge not known. Spicules ornate, with various arrangements of spines, thorns, etc.

Horizon.— Both these species are found in the Shaly limestone at the Indian Ladder, Albany county, New York.

INCERTAE SEDIS.

Ischadites, Murchison, 1839.

ISCHADITES SQUAMIFER, Hall, 1859.

Dictyocrinites, Conrad, 1841. Ann. Rep. Geol. Surv. New York, plate, fig. 22.
Dictyocrinites squamifer, Hall, 1859. Pal. New York, vol. III, p. 135.
Receptaculites squamifer, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. XXIII, figs. 1, 2.

Ischadites squamifer, Hall, 1887. Pal. New York, vol. VI, p. 291, Pl. XXIV, figs. 1, 2.
Receptaculites squamifer, Miller, 1889. N. Amer. Geol. and Pal., p. 164.
Horizon. Shaly limestone. (Hall, 1859.)

Receptaculites, De France, 1827.

RECEPTACULITES INFUNDIBULIFORMIS, Eaton, 1832.

Coscinopora infundibuliformis (not Goldfuss), Eaton, 1832. Geological Text-Book, p. 44, Pl. V, figs. 64, 65.
Receptaculites infundibuliformis (Eaton), Hall, 1863. Sixteenth Rep. New York State Cab. Nat. Hist., p. 67.
Receptaculites infundibuliformis (Eaton), Hall, 1883. Rep. State Geologist for 1882, expl. Pl. XXIII, fig. 10.
Receptaculites monticulatus, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. XXIII, figs. 3-9, 11.
Receptaculites infundibuliformis, Miller, 1889. N. Amer. Geol. and Pal., p. 163.
Receptaculites monticulatus, Miller, 1889. N. Amer. Geol. and Pal., p. 164.
Horizon. Shaly limestone. Helderberg Mountain, N. Y.

Receptaculites monticulatus = *R. infundibuliformis*.—This species, recognized by Hall as a synonym for *R. infundibuliformis*, is retained by Miller as a distinct form.

In 1889, a paper was read by RAUFF, before the Deutsche Geologische Gesellschaft, at the August session, giving briefly the results of his work on RECEPTACULITES, ISCHADITES, and POLYGONOSPHÆRITES, and an abstract of the paper was published in the transactions of the society.* This abstract is summarized by NICHOLSON† as follows:

"1. The Receptaculitidæ are spherical or pyriform bodies, with a central closed cavity, the supposed basin-shaped examples being only fragments of the base.

2. Each of the individual spicular elements forming the wall of the body is composed of six parts, viz.: an external plate of an essentially rhombic form, four diagonally intersecting tangential arms which lie immediately below the outer plate, and a radial arm or pillar which springs from the center of the outer plate on its inner side and is directed perpendicularly inwards.

3. An upper and a lower pole may be distinguished on the exterior surface, the arrangement of the plates at these points being peculiar. The basal pole (the starting point of growth)

* RAUFF, 1888. Zeitschrift der Deutschen Geol. Gesellsch., Bd. XL, Heft 3, p. 606 *et seq.*
† NICHOLSON and LYDEKKER, 1889. Manual of Palæontology, vol. II, p. 1563.

is constituted by a circle of eight or four plates. The apical pole is closed by a variable, but always large, number of plates.

4. Each of the five arms of the skeletal elements or spicules is traversed by an axial canal, the canals of the four tangential arms having a conspicuously fusiform shape.

5. The radial arms or pillars terminate on the inner or 'gastral' side in a conical dilation, which is laterally extended till adjoining pillars touch. This internal thickening of the radial pillars is not furnished with a special plate, corresponding with the external plate, and is not penetrated by transverse canals.

6. The inner or 'gastral' wall of the fossil is imperforate, the pores described by BILLINGS being the result of fossilization.

7. The genus ISCHADITES agrees essentially with RECEPTACULITES in structure, but its skeletal elements are more slender. An apical aperture is in some cases clearly wanting in ISCHADITES, and probably did not exist at all.

8. The genus ACANTHOCHONIA is identical with ISCHADITES.

9. The geological range of ISCHADITES extends to the Upper Devonian.

10. The genus POLYGONOSPHÆRITES (SPHÆROSPONGIA) is similarly constructed to RECEPTACULITES as regards the tangential arms of the spicules, but the radial arms or pillars are wanting.

11. The *Receptaculitidæ* are not *siliceous* organisms, but the skeleton was originally *calcareous*, and the siliceous examples are the result of silicification. The group, therefore, can not be referred to the Hexactinellid sponges, and its systematic position is still entirely uncertain."

These conclusions, as given by RAUFF, embody, in large measure, the results obtained by previous writers on RECEPTACULITES, and furnish a basis for additional investigation.

Upwards of twenty specimens, including fragments, of *Receptaculites infundibuliformis* have been examined by me, exemplifying several different conditions of preservation. Of these, one in which the original tissue has been replaced by pyrite, is of unusual interest. The excellence of pyrite as a medium of preservation for fossils is shown in the recent discovery, in the Utica slate, of Trilobites retaining antennae and other appendages. The specimen in question leaves little to be desired in the way of preservation. It displays details of structure rarely indicated, and may serve to throw some light on the phylogenetic position of this perplexing organism. In section, this specimen, described in detail below, has the outline represented by the diagram on Plate III, figure 1. The edges are ragged, indicating that it is not complete, and probably preserves only the basal portion of a form which, when perfect, had somewhat the proportion of a pine cone (as described by RAUFF). The surface structure consists of ridges which start from a point, the basal pole (RAUFF), and radiate spirally in two directions, after the manner of the engine-rolling on a watch. The ridges are thin, solid, high, and usually continuous. The rhombic depressions which they form are well marked and deep. This description is true of both surfaces, but that one which is here called the gastral surface has the reticulation much reduced, perhaps one-fourth the size of the other. A comparison of the two surfaces may be made by referring to Plate II, figure 4, and Plate III, figure 1. Both faces are retained in an equal state of preservation, an unprecedented occurrence with the Lower Helderberg RECEPTACULITES, the interior of which is rarely preserved at all.

In this incomplete example, the basal pole exists only on the gastral surface, where it is partly covered over. It may be inferred with certainty from other specimens, that a similar pole existed on the outer basal surface, directly beneath the gastral one. In general terms the organism consists of an outer and an inner, or gastral wall, connected by perpendicular processes. Each of these walls has, of course, an outer and an inner surface.

The Outer Wall.

Plate III, figures 2, 3, 4.

The radiating ridges above referred to, intersect at regular intervals and form slender pillars at those points. From each of these pillars, near its outer end, there projects toward the right a peg-like spine, short, cylindrical and blunt. Across the floor of each rhomboidal pit, between opposite angles run two rounded, fusiform channels. These channels extend well into the corners of the pit, where they make slight indentations. In the middle of each pit, at the point of intersection of the channels, is a still further depression. This is circular in outline or sometimes diamond-shaped, contracting slightly as it descends, and, at its base, communicates with a tube which serves to connect the inner with the outer wall.

At one time the tubes were probably normal to the two walls, but in places they now lie nearly tangent to them. This displacement, as well as the absence of the lower basal pole from the field of the specimen, is apparently due to a skewing of the walls as the result of pressure. For the same reason, the spines above referred to may have projected longitudinally instead of laterally. This is shown by the fact that the spines in this specimen bisect the obtuse angles, and that the long diagonal of the rhombus is normally directed horizontally instead of laterally.

Where the tubes join the outer wall, their diameter is about one-half that of the rhomboidal pit, but they diminish considerably in size as they approach the gastral surface. Whether the tubes taper gradually or have a fusiform shape, can not be asserted. They are rather longer and more slender than in *R. Oweni*, and I think are not fusiform. The character of the inner or gastrally directed surface of the outer wall is not presented by the Lower Helderberg specimen.

The Gastral Wall.

Plate II, figures 4 and 6; Plate III, figures 3 and 5.

The points where the connecting tubes meet the inner wall are united longitudinally by low, rounded elevations which a fractured surface shows to be hollow. The channels thus formed probably connect with the interiors of the tubes. The characters of this surface are obscured by the nature of the pyrite which is distinctly granular. The inner wall has a vesicular structure, composed of labyrinthine canals. Each tube terminates immediately beneath the center of one of the gastral rhombic pits, into which, however, it does not open directly, but into the canal network with which the gastral pits connect. Upon the gastral side the rhombic depressions are traversed by horizontal partitions, situated a little below the surface. These are thin and continuous, and undoubtedly represent some real feature in the original organization. It is probably owing to these structures that the radial tubes and the canals of the gastral wall are not filled with the shaly matrix, but with a white crystalline mineral impossible to confuse with it.

Another feature of this specimen should not escape notice. The gastral surface is partly covered, to the depth of 3 mm. in places, by a layer of minute acerate spicules. They lie in a confused mass and evidently are not *in situ*, but, since they are preserved as pyrite, like the test, they doubtless belonged to the organism itself.

Reference has already been made to certain indications of crushing exhibited by the specimen in question. In the region of the basal pole the walls are held apart by the pillars, more or less normal to each. They gradually approach one another and their contact forms the limit of the fossil. That this is not the original condition is proved by a fracture, which shows the tubes lying nearly parallel with the two surfaces. Some of them retain a circular section, others are flattened into an ellipse, while many are broken and biconcave. (Plate III, fig. 8.) Still further evidence is afforded by the condition of the outer surface. Some of the tubes are there seen to have been forced up to a considerable distance through the rhombic pits, and on the same surface the ridges are so broken and crumpled in places that it is impossible to follow them.

Another fine specimen in this collection is that figured by Hall, in Pal. New York, vol. VI, Plate XXIV, figures 3–7.* It is probably a cast representing the inner surface of the outer wall. Like most Lower Helderberg specimens it gives no indication of the nature or existence of a gastral wall. The radiating ridges are mostly absent or else represented by low, triangular, sinuous elevations which often form circular basins about the orifices of the radial tubes, instead of clear-cut rhombic depressions. Sometimes the points of intersection alone are represented by monticules, to which reference has been made by Prof. Hall. The tubes that run from the base of each rhombic pit, form, from their size and depth, a striking feature.

A group of individuals which come next in excellence of preservation were found in the firmer portions of the Shaly limestone. On the whole the regular reticulate nature of the surface is more apparent than in that above mentioned. This is partly due to the fact that although the radiating ridges are not prominent, they are

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* This was the type specimen of *Receptaculites monticulatus* (Hall, 1883. Rep. State Geologist for 1882, expl. pl. XXIII, figs. 3–9, 11), before Prof. Hall considered the species a synonym of *R. infundibuliformis*.

straight and continuous. Furthermore, these forms under discussion are of a comparatively large size, whereas the specimen of the *monticulatus* type is a small one, representing only the circumpolar region, where the reticulations, as they become finer, are less distinctly indicated. The radial tubes appear only as hemispherical depressions, one in the center of each rhomb. No details of structure are well defined. Fractures on several specimens show traces of the extension of the tubes upward, and one preserves indications of a roofing wall. That it is not the inner wall of the basal portion to which it is at present adjacent is shown by the fact, that not only does the upward prolongation of the tubes fall short of the line that indicates the structure in question, but furthermore it is continuous with the outer wall. It is difficult, if not impossible, to determine the exact nature of preservation of these specimens. The fact that they are more or less silicified suggests that they represent the organism itself. On the other hand, since the portion preserved exists only as a surface, apparently without thickness, it seems credible that they are nothing more than casts. Yet this again is contradicted by the detail of the outer surface, which, on the whole, is the same as that of the pyritized specimen. Perhaps the forms in question result from a maceration of the original organism, producing a fossil which presents both internal and external characters at the same time.

These specimens have all been more or less preserved by silica. The group described below comes from the softer portions of the Shaly limestone, and is represented chiefly by casts. Many exist only as reticulate, ferruginous markings on a flat shaly surface, while others have, in addition, rows of rounded elevations, which represent the tubes of better preserved examples. Several have a circular rim which is detachable. As far as can be ascertained from the material at hand, this rim uniformly contains on both surfaces the same characteristics as the silicified specimens, but in a state of poor preservation. The Lower Helderberg specimens, all of which, I believe, had a subspherical or conical shape when mature and whole, are now flattened so that the upper portion is nearly or quite contiguous to the base. Evidence relating to this point is scarce, yet it is thought that the truth of these statements can be established. The loose rim, then, is the lateral portion of the organism, which, being even at first the thickest part of the wall, and now double, proved less destructible than the base and the fragile top.

OBSERVATIONS ON OTHER LOWER HELDERBERG SPECIMENS.

The form of *Receptaculites infundibuliformis* is "usually discoid, sometimes broadly infundibuliform. The upper surface is more or less depressed with frequently a small conical projection in the center."* Whether the specimens are regarded as entire individuals of an original saucer shape, or, as RAUFF claims, are merely basal portions of a cone-shaped test, the orientation of the fossil is attended with few difficulties on account of the curvature of the surface and the starting point of the radiating ridges. The surface uniformly preserved, which is convex in the better specimens, is either the outer or inner surface of the outer wall. That this surface is not the inner wall, is shown by the curvature and by tubes which are seen in traces directed upward from the concave side. Furthermore this circumstance is the natural result of the physical conditions which attend the burial of such an organism. The base would be more or less protected and preserved by the bottom on which it rested, while the upper part, and later, the gastral wall of the lower, would lie exposed to the destructive and solvent action of the sea until covered over by the gradual deposition of sediment. As has been said, which surface of the outer wall is represented can not be determined in all cases.

In the case of the pyritized specimen the curvature of the surfaces is misleading. It suggests that the inner wall is in fact the outer, and that the outer or concave side bounds the gastral cavity. However, the structure of the coarsely reticulate surface corresponds in a general way to that of specimens from other horizons whose orientation is known, showing that it is the outer wall. The reticulations agree in size and character with those of the common Lower Helderberg forms. This fact warrants the identification of this fossil with *R. infundibuliformis*, and at the same time confirms the orientation of surfaces here adopted.

* HALL, 1887. Pal. New York, vol. VI, p. 290.

Conclusions.

Specimens of *R. infundibuliformis*, as ordinarily preserved, are so ambiguous in character that the current views on RECEPTACULITES would probably have been regarded as satisfactory had not a remarkable specimen opened the way to a new interpretation of the structure of this genus.

I. The Form.

That RECEPTACULITES and ISCHADITES were subspherical, when entire, and inclosed, or nearly so, is the position taken by BILLINGS, which RAUFF confirms. HINDE, however, follows SALTER, and considers that ISCHADITES alone had this form, and that RECEPTACULITES was a flat, platter-shaped organism, in which condition it at present usually occurs.

The evidence afforded by the Lower Helderberg RECEPTACULITES is not of a positive character, but, on the whole, seems to support the view of RAUFF and BILLINGS. The regular circular outlines which unbroken specimens maintain might appear to indicate an explanate organism. On the other hand, a homogeneous, top-shaped or spherical test, flattened by downward pressure, would assume the same form. This supposition is further borne out by the specimen with traces of a roofing wall and those with a detachable rim. If the sides were extended so as to completely inclose a central cavity, the upper portion must have been of extreme tenuity.

II. Structural Elements.

(*a*) *The Summit Plate.*— According to the generally accepted construction of RECEPTACULITES, the radiating ridges should represent part of the matrix thrust in between the summit plates of the spicules, the plates themselves being subsequently dissolved away. The radial tube would be interpreted as the perpendicular ray, and there also should be four other rays forming diagonals of the rhombus. Two of the rays would thus be directed lengthwise or meridionally, and the other two at right angles to these. Not only have none of these suppositious summit plates been observed on Lower Helderberg specimens, but there is no evidence that they ever existed. Three suppositions concerning them are possible: (1) they were loose, and, becoming detached before gradual deposition covered the organism, were thus lost; (2) they were of a different composition from the rest of the skeleton; (3) they did not exist.

If these summit plates were detached and lost, some trace of them would surely be found either associated with the original fossil or as separate bodies. Of the twenty or more specimens belonging to the large collection from this horizon, each must have possessed many hundred plates, some of which would certainly have been found.

It seems improbable, however, that one ray of the spicule should have been different chemically from other rays of the same spicule. Furthermore when we consider that the rest of the skeleton is preserved (1) as calcite, (2) as pyrite, (3) as silica, (4) as shaly casts, (5) as ferruginous shadows on shale, it seems incredible that this eccentric ray should have been of such material as to elude all these phases of replacement. Moreover, everything goes to show that the radiating ridges are an integral part of the original skeleton, and not an infiltration or an impression of the matrix. They are too high and regular to warrant this idea, and, furthermore, they are preserved as pyrite like the rest of the organism, while the matrix is shale, and the filling between the two walls celestite(?). The evidence, therefore, seems conclusive that the spicular summit plates claimed for the organism did not exist.

(*b*) *The Tangential Rays.*—The same conclusion is inevitable regarding the four tangential rays. A careful examination of all accessible specimens shows no trace of such structure. They can not be the radiating ridges, for these partake of the nature of partitions rather than of spicules, *i. e.*, they are solid, thin and high. Moreover, the orientation of the ridges, which are not longitudinal and horizontal, respectively, as the spicular rays are said to be, precludes such an interpretation. The only features that bear resemblance to the missing spicules are the short spines which project, one for each rhomb, from the intersections of the radial ridges. If these are the tangential rays, there is no evidence of the three other rays and the summit plate. Further, if this is such a ray it has become disconnected from the "radial arm," and joined to the ridge with which it should have no organic union.

(c) *The Radial Pillar.*—There can be no question that the structure here called the radial tube or canal is the perpendicular spicular ray of other writers. Inasmuch as it has been shown that the five other rays of the spicule did not exist, it seems illogical to denominate this structure in any sense a spicular arm. The fact that the central canal is so large in comparison with the surrounding integument, taken in conjunction with the relation of these bodies to the outer and inner walls, leaves little doubt that they were really tubes and did not partake of the nature of spicules. Moreover, the tubes appear to terminate at the bottom of the rhombic pits, and this character both argues against their original spicular nature, and suggests the probability that they were never connected with a summit plate.

III. The Poles.

In the Lower Helderberg specimens of *R. infundibuliformis* the upper part has been destroyed, but the basal portion has, on both its outer and inner surface, what may be called a polar region. Neither the number nor arrangement of the plates which lie about the lower pole is indicated in specimens accessible to me. If, as RAUFF claims, the basal pole is the starting point of growth, it seems unwise to deny as he does that RECEPTACULITES and ISCHADITES occur as cup-like or saucer-shaped individuals, since they must have assumed these forms as intermediate steps toward a completely inclosed condition.

IV. The Inner Wall.

It is agreed by RAUFF, HINDE and BILLINGS that the endorhin is formed by the dilatation of the inner extremities of the radial pillars. The wall is, then, theoretically, composed of plates, but these are usually more or less united into a continuous surface, and are not equivalent to the summit plates of the ectorhin. HINDE and BILLINGS further agree in ascribing to this wall both transverse and longitudinal canals. The latter are excavated in the substance of each plate, and run between the middle points of opposite sides. The transverse canals or pores are formed by the truncation of the four angles of each plate. The juxtaposition of four plates produces the pore. The canals of adjoining plates communicate with one another, thus forming a reticulation of confluent channels in the wall. The pores served to connect the intermural cavity with the surrounding medium. RAUFF denies the existence of both pores and canals, and I have been unable to find anything analogous in the Lower Helderberg specimens.

V. The Chemical Constitution.

The conclusions to be deduced from the appended table confirm those of RAUFF with regard to the chemical composition of RECEPTACULITES, at least so far as to show that it was originally calcareous and not siliceous, as claimed by HINDE. Specimens of RECEPTACULITES from the Helderberg mountain agree with the Cephalopods in their mode of preservation, and it seems probable that, like them, RECEPTACULITES had a test composed of aragonite.

	Bryozoa.	Brachiopods.	Hindia.	Receptaculites.	Cephalopod.
Natural	Calcareous	Calcar.	Silic.	?	Aragonite.
Etching	Siliceous	Silic.	Pyrite	Casts (colored)	Casts.
Acidaspis shale	Calcareous	Calcar.	Semisilic	Pyrite	Pyrite.
Soft shale	Calcareous	Calcar.	Calcar.	Ferrug. Impress	Pyrite.
Limestone	Siliceous	Silic.	Silic.	Casts (colored)	Casts.

In considering the various features belonging to this species as stated above, the view that the examples of RECEPTACULITES which have been regarded as representing the true structure of the organism, and studied as such, are probably only casts or infiltrations, must have suggested itself. From many considerations, this seems the inevitable conclusion, yet, if the Lower Helderberg specimen is RECEPTACULITES, it is not a cast, but represents the original organism more truthfully than any example yet described.

In some respects the structures referred by different writers to RECEPTACULITES are so analogous to those seen in this specimen, that it seems more than probable that they are casts; yet certain features, as described, are impossible to explain on that basis, and the hypothesis must be, in many cases, considerably modified. Much, however, can be explained by the mode of preservation. The processes of replacement and of fossilization are known only as results. No one has been able to study them in operation. To make *a priori* assertions in regard to them is impossible, since conditions beyond consideration might at any moment change what would seem the probable course. This is especially true in regard to RECEPTACULITES, an organism whose original nature and composition are not positively known. Whether composed of calcite, aragonite or chitine, it is certain that it was not as enduring as most animal remains preserved in the fossil state.

Had the examination of type specimens been possible, many of the present difficulties and contradictions which a comparison with figures alone has entailed, might not have been met, and those still unsolved might be satisfactorily ascribed to preservation or specific differences. The conclusions of HINDE* regarding the structure of RECEPTACULITES agree so nearly in every detail with those of BILLINGS,† that it has been possible to unite the results of these two authors in comparing them with my own. Both writers employed for study representatives of a number of different species, probably in several different modes of preservation. BILLINGS, moreover, seems to have considered ISCHADITES as a synonym for RECEPTACULITES, and studied both genera, though his conclusions refer to RECEPTACULITES alone.

My own observations lead to the opinion that the spicular summit plates mentioned by these writers are an infiltration of the rhombic pits of the outer surface or of their casts. The fact that the summit-plates are admitted to be structureless and of a single layer, enhances the probability of their originating in this way. The four horizontal spicular rays are casts of the four canals or stolons, which, in the Lower Helderberg specimen, run from the radiating tubes into each angle of the rhombic pits. The fact that these rays are said to be in contact with the summit plate coincides with this view. Both BILLINGS and HINDE mention the curious circumstance that one ray, that which points away from the nucleus or basal pole, is sometimes not in contact with the summit plate.

In addition to the stolons which extend into the angles of each pit, a conical spine projects into one angle and above the stolon, penetrating that angle. There is, moreover, only one such spine, and reason has been given for supposing that it pointed longitudinally. The existence of this spine satisfactorily explains the separation of one ray of the cast from the summit plate.

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* HINDE, 1884. Quart. Jour. Geol. Soc., vol. XL, p. 821.

† BILLINGS, 1861-65. Geology of Canada. Palaeozoic Fossils, vol. I, p. 378 *et seq.*

The radial pillars are said to be continuous with the summit plates and they must be preserved and represented in the same way. The summit plates are regarded as casts of rhombic pits. Hence the radial pillars seem only infiltrations filling the radial tubes. On this basis, the spicular canals, the presence of which has been confirmed by many writers, would be the result of an incomplete process of deposition.

The character of the inner wall does not appear to be definitely made out by any of the investigators who have written on RECEPTACULITES. In the case of *R. infundibuliformis*, my own observations are not wholly satisfactory. The salient features of the descriptions given by HINDE and BILLINGS are that (1) it is probably not composed of separate plates like the outer wall, but many examples show a continuous layer; (2) this is pierced at regular intervals by round holes arranged in a quincunx order, and these perforations are sometimes connected by furrows which apparently mark off the surface into rhombic plates similar to those beneath, with which they are joined by the radial pillars; (3) in the body of each plate lie four canals running from the center (the point of union with the radial pillars) to the middle of each side, where they join the canals similarly situated, of the four plates adjoining. RAUFF regards both perforations and canals as the result of fossilization. If RAUFF's conclusion is correct, the endorhin need not be discussed. If, on the other hand, the traces interpreted by HINDE and BILLINGS stand for real structures, the distinction between the ectorhinal and endorhinal canals should be noted.

"The stolons run along the inner surface of the ectorhin, but the endorhinal canals are excavated in the substance of the endorhin."* Since the canals in the Lower Helderberg species run longitudinally and the endorhinal canals spirally, it is difficult to regard the two as identical. Should this, however, be the case, the distinction pointed out by BILLINGS corresponds to a difference between the canals of the outer and inner walls, as shown in *R. infundibuliformis*. In the ectorhin, the canals are trenches in the bottom of rhomboidal depressions; in a cast, they would appear like stolons attached to a rhomboidal plate; yet, in the endorhin, they are enclosed as described by BILLINGS and HINDE.

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* BILLINGS 1861-5. Geol. of Canada, Palæozoic Fossils, p. 382.

Most writers on RECEPTACULITES have reached different conclusions as to its original composition. HINDE believes that it was siliceous; RAUFF that it was calcareous; GUMBEL that it was aragonite, and BILLINGS that it was calcite or in part coriaceous. These variations in results may be explained by the fact that infiltration products only have been investigated, the nature of the material being that which at the time was most plentifully dissolved in the sea-water of a given locality. This notion naturally modifies conclusions reached under such conditions. However, my own conclusions agree either with those of GÜMBEL that RECEPTACULITES was originally composed of aragonite, or of BILLINGS that it was chitinous. The matrix of the pyritized specimen is shaly limestone. The radial tubes and the space between them are filled by calcite or (?) celestite. This feature is in marked contrast with ordinary specimens, for, as BILLINGS says, "the space between the tubes is almost always filled with the rock of the same kind as that in which the fossil is imbedded."

The majority of examples studied by HINDE, BILLINGS, and others, are probably like *R. Oweni*, described below, where the cavity left by the dissolution of the original organism has been filled by a structureless deposition from infiltering waters. It seems as if the more unique details of structure may have been derived from an infiltration, filling the organism itself, or from others where a maceration of the skeleton has left upon the cast traces which usually would not be received. Replacements by silica or calcite may also in some instances have been investigated.

The conclusions of the above writers are of a general character, and it has been possible to discuss them only in a general way. However, specimens of both *R. Neptuni* and *R. Oweni* have been examined and afford a definite basis for comparison.

Receptaculites Oweni.

This species commonly occurs as tabular fragments of the basal portion of the organism. Specimens from Illinois usually have a thickness of 5 mm. near the basal pole, increasing distally to 20 mm. or more, and sometimes attain a very large size. The material is a granular dolomite, having much the appearance of yellowish sandstone. The outer surface is marked off into rhombic areas by two sets of intersecting ridges. Shallow rounded canals transverse each rhombus and connect the opposite angles. Of the four, that which runs between the center and one of the obtuse angles is noticeably on a higher plane than the others, the opposite one being lower than the rest. Nothing similar to this arrangement has been observed in *R. infundibuliformis.* From the center of each rhombus a radial canal perforates the specimen, opening on the gastral side. Just below the surface the canals suddenly expand, then taper gradually, until they meet the inner surface. The diameter where they terminate is considerably larger than that at the starting point. The canals are not terete, but are modified by annular constrictions and dilatations like the growth-lines of a coral. The inner surface, also, is marked by ridges, which, however, do not make a regular rhombic pattern, but wind irregularly among the tubular orifices. Sometimes the openings of the tubes are surrounded by shallow, circular depressions; sometimes there is an appearance as if canals ran from the tube to the acute angles of the rhombus; and sometimes the intersections of the ridges are emphasized by monticules.

BILLINGS calls attention to the fact that in magnesian limestones, where the hard parts of fossils are in general totally removed, so that the cavities once occupied by them remain empty, RECEPTACULITES is found in the same condition (p. 386 *loc. cit.*). This is true of *R. Oweni*, which bears every evidence of being a cast. In most specimens, then, the remains consist of the filling of the intermural space, with casts of the outer surface of the inner wall, the inner surface of the outer wall and of the connecting tubes.

The structures in *R. Oweni* and the pyritized specimen of *R. infundibuliformis* correspond very closely, although the former, as a cast, represents inner surfaces of the skeleton and the latter seems to preserve the outer surface. Details in *R. Oweni* are imperfect in character, and partly obliterated by the granular nature of the matrix.

Another feature, the configuration of the external surface, has been noticed by Prof. HALL.* The specimen representing it is preserved in the American Museum of Natural History, New

* HALL, 1861. Rep. Prog. Geol. Surv. Wisconsin, p. 15.

York city.* This specimen is adherent to the matrix along its outer wall, but a portion has been broken away, and shows the inclosing rock marked off by curving ridges into rhombic figures, which have the characteristic intaglio ornamentation presented in the diagram, Plate VI, figure 4. The ridges on the specimen are opposite to, and continuous with, those on the matrix. It is evident that the outer surface must have had individual opercula or a common investment whose cast is preserved on the matrix. That something of the sort existed is shown by the pyritized specimen also, since the radial tubes are not filled with the shaly matrix (as would be the case if the ends had not been closed), but by a white, crystalline mineral, probably celestite.

Why the matrix appears to be continuous with the specimen along the radiating ridges is a perplexing problem. Perhaps it may be due to the granulo-crystalline condition of the matrix.

The specimens thus far discussed are casts and have been found in the Galena limestone of Illinois and Wisconsin. Another example of *R. Oweni* comes from the same horizon in Iowa, and illustrates a different condition of preservation. It is composed of calcite and represents what has usually been called the true structure of the organism, but what I consider as only an infiltration product of a form like the foregoing. The matrix is dolomite, softer than that from Illinois and less crystalline. The curvature of the specimen affords a clue to its orientation, and the indication thus given is confirmed by the presence on the concave surface of gentle elevations covered with a network of intersecting channels.† Yet the pores which are said by BILLINGS and HINDE to pierce the endorhin between the radial pillars do not exist in this specimen, but they do exist in the ectorhin.

The outer wall is marked off into rhombic plates by thin partitions of the matrix, which is continuous alike with that around the fossil and that between the pillars. The points of intersection of the partitions are represented by rounded pillars. A section of the ectorhin showing these features is given on Plate VI, fig-

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*This specimen is the one studied by Prof. HALL, and will be figured shortly in an illustrated catalogue of the Museum.

†"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, fig. 3, c-g.) HINDE, 1884. Quart. Jour. Geol. Soc., vol. XL, p. 825.

ure 3. The summit plates are structureless and the tangential rays have not been observed in this specimen. The pillars are connected directly with the summit plates, and like them are of crystalline calcite. There is no trace of a central canal. A little below the summit plate the pillars expand suddenly and then taper slightly. They are marked by distinct annular constrictions or lines of growth. At their inner extremities they meet the gastral wall, or expand to form it. At any rate, the wall is continuous, and the demarkation of the plates no longer exists. Opposite the pillars, and occupying nearly the whole of each plate on its outer side, is a rounded elevation covered by anastomosing channels, as described above. This structure seems to be characteristic of the gastral surface. As the inner wall of this specimen exhibits neither the canals nor perforations described by HINDE and BILLINGS, it confirms the observations of RAUFF, who considers these features to be due to preservation. Sections illustrating the various structures of the specimen are shown on Plate VI, figures 1, 2, 3, 4.

Receptaculites Neptuni.

In the American Museum of Natural History, New York city, there is a siliceous representative of *R. Neptuni* (the type species), which in the structure of its outer wall agrees with the pyritized specimen from the Helderberg. The tubes are hollow, their wall continuous with the radiating ridges and their central canals open into the rhombic pits, which are not occupied by summit plates.

The foregoing comparison illustrates the conflicting nature of the evidence afforded by RECEPTACULITES. It shows that specimens apparently well preserved contradict others of the same genus, and that structures were maintained or obliterated as the result of slight changes in the conditions of preservation. The specimen of *R. infundibuliformis* is certainly more trustworthy than any other example of the genus before noticed, and affords a more accurate notion of the original structure and its details. Still the belief is unwarranted that this specimen represents the organism in its entirety, and that nothing further remains to be studied. Enough, however, has been preserved to direct aright the consideration of the affinities and systematic position of the genus.

CŒLENTERATA.

HYDROZOA.

Family Dictyonemidæ.

Dictyonema, Hall, 1852.

Dictyonema crassum, sp. nov.

Plate IV, figures 1, 2.

Shape of entire frond not known. The largest fragment measures 7.5 by 7.5 cm. The branches are marked by coarse longitudinal striæ, or wrinkles, which are not continuous. The dissepiments are nearly equal in size and parallel in direction, forming with the branches a rather uniform reticulation. Both branches and dissepiments are enlarged at their point of union, giving the fenestrules a more or less rounded form. Thickness of branches, .5 to 1 mm. Dissepiments of about the same size. The specimens examined are casts.

The zoarium in *Dictyonema crassum* is coarser than in *D. retiforme*, Hall, of the Niagara group, the dissepiments heavier, and the fenestrules more rounded.

The quality of the material would hardly warrant the description of a new species, were it not that this is the first appearance of the genus noted in Lower Helderberg strata.

Horizon.— Shaly limestone.

Locality.— Clarksville, Albany county, New York.

Family Monoprionidæ.

Monograptus, Emmons, 1856.

Monograptus Beecheri, sp. nov.

Plate IV, figures 3–15.

Stipe linear, minute, with a carination on either side. Surface marked by fine longitudinal striæ, which are not continuous. Denticulations about the same width as the stipe, acute, distant. It is not known whether the stipe is simple or branched.

This species of Monograptus is interesting, not alone as the first example of the genus reported from the Lower Helderberg rocks, but also as the last known representative of this characteristic Silurian genus. Its presence here is important in its bearing upon the position of the Lower Helderberg Group in the geological scale, for similar forms have been found in the earliest Devonian faunas of Germany.

The stipe is cylindrical, sometimes tetragonally prismatic. It is hollow, with thick walls, crossed at intervals by tabulæ, one for each serration, which bound the zoöidal habitations. On opposite sides, there are projecting ridges, or costæ, the plane of the latter being at right angles to the plane of the serrations. Besides the costæ, there are often fine longitudinal grooves or striæ. The teeth are rather distant; the upper side is sometimes at right angles to the stipe, at others acutely inclined to it. The upper surface is somewhat flattened and is pierced by circular or elliptical zooidal openings, situated well toward the stipe. The under surface of the teeth is sometimes flattened, sometimes rounded, the flattened examples at least being provided with a median ridge. The specimens observed are all fragmentary, and the nature of the sicula has not been ascertained. No indications of branching have been noticed, but the zoarium may be bifurcated or even ramose.

Horizon. — Shaly limestone, Indian Ladder, Helderberg Mountain.

STROMATOPOROIDEA.

With the exception of *Actinostroma Ristigouchense*, Spencer, I have been unable to find notices of any American Stromatoporoids from the Lower Helderberg Group. The species described below constitute only a beginning in the investigation of this class of Cœlenterates, which is well represented in the life of this period. But to make an exhaustive study of this portion of the fauna would require a large collection, gathered with that end especially in view.

All the Stromatoporoids in this collection, with the exception of *Clathrodictyon Jewetti*, appear to be formed on one type of structure, and I have referred them, but with some hesitation, to the genus *Syringostroma*, Nicholson. This genus (type *S. densum*) was proposed by NICHOLSON* for some Stromatoporoids from

* NICHOLSON, 1875. Geol. Surv. Ohio, Pal., vol. II, p. 251.

the Devonian strata of Ohio. The original description contains nothing of generic value. *S. densum*, however, is said to be composed of concentric laminæ of very dense, finely cellulose tissue, traversed by numerous horizontal canals. "The upper surface exhibits two distinct sets of apertures—*firstly*, a series of very minute and crowded perforations, which doubtless correspond with the cells of the mass; and, secondly, a larger set of apertures which are very irregularly distributed, and are likewise very numerous." These are said to be almost certainly the apertures of a series of vertical canals (probably such as frequently form the center of astrorhizal systems). The presence of well-marked astrorhizæ is also noticed. The figures accompanying the text appear diagrammatic, and show no new points of structure.

In the Monograph on British Fossil Stromatoporoids, NICHOLSON has brought together his more careful investigations on that group of fossils, and it is to this work that we must look for his latest and best considered results.

Of the genus SYRINGOSTROMA, he gives the following description — "Cœnosteum massive, formed of successive 'latilaminæ.' Skeleton-fibre minutely porous. The skeletal tissue is, on the whole, of the reticulated typ echaracteristic of the STROMATOPORIDÆ, but the radial pillars are distinctly recognizable and some of them are of large size. Astrorhizæ are largely developed." He further states, "In the more minutely porous character of the skeleton-fibre, as also in the essentially reticulate structure of the skeletal tissue, *S. densum* quite resembles the species of STROMATOPORA, Goldf. It has, however, the peculiarity that the cœnosteum is traversed at intervals by large-sized radial pillars which are recognizable in both tangential and vertical sections. I should not have been disposed to regard this feature as of generic value, except that I have recently had an opportunity, through the kindness of Prof. J. W. Spencer, of examining an apparently related form which seems worthy of generic distinction.

"Tangential and vertical sections of this beautiful type show a curious combination of the characters of STROMATOPORA, Goldf., and ACTINOSTROMA, Nich. Thus, the skeleton-fibre has to a marked extent the minutely porous structure which is so characteristic of STROMATOPORA, properly so called; while the radial pillars and their connecting processes are as distinctly and clearly developed as in the type-forms of ACTINOSTROMA. The radial pillars, in fact, are exceedingly large and give off whorls of delicate 'arms' or connecting processes which are emitted at corresponding levels in a radiating manner, and which circumscribe rounded pores representing the zooidal tubes. The astrorhizal canals are largely developed, and we therefor see in vertical sections, as in similar sections of *S. densum*, the large rounded apertures which represent cut ends of these tubes, and upon which the genus SYRINGOSTROMA was originally based. This latter character is, of course, one of no generic importance, as, indeed, present in all Stromatoporoids with large astrorhizal canals."

It may seem unjust to a writer to discuss his work without the advantage of consulting identified specimens, but under the circumstances I have been forced to do so. After a careful study of both text and plates, no other conclusion is possible than that *S. Ristigouchense* is an ACTINOSTROMA of no abnormal type, and if the generic claims of SYRINGOSTROMA rest on the validity of *S. Ristigouchense*, it will have to be united with some other form.

NICHOLSON well says that, in radial section, the structure is characteristically Actinostromoid, but the statement that tangential sections show the minutely porous structure of STROMATOPORA seems ill-advised. The skeleton of the latter genus is porous, and the tissue itself minutely fibrous or vesiculose. Radial pillars are few or absent, and the porous skeletal tissue is not formed by connecting processes springing from the arms, but by independent anastomosing fibers. According to NICHOLSON, however, this structure is represented in *S. Ristigouchense*, and is also typical of the genus ACTINOSTROMA. On this account I have placed the species in that genus. The unusual appearance in tangential section exhibited by *Actinostroma Ristigouchense* seems to be due to the large size of the radial pillars, to which NICHOLSON has called attention, accompanied by a corresponding reduction in the length of the connecting processes. It is owing to the same fact that, in vertical section, the laminated character of the skeleton is not as striking as in other species of ACTINOSTROMA.

On the other hand, SYRINGOSTROMA seems well able to stand as a genus without the support of *Actinostroma Ristigouchense*, if the characters attributed to it by Nicholson from a study of *S. densum* hold good.

The Lower Helderberg representatives of this genus, if correctly ascribed to SYRINGOSTROMA, agree in many respects with *S. densum*. As far as examined, they are all normal and exhibit well-marked Stromatoporoid characters. The division of the cœnosteum into latilaminæ is usually conspicuous, as are also the large astrorhizæ often situated on monticules with a tubular axis. Tangential sections of well-preserved specimens show a doubly porous structure. In the first place, the skeleton is rendered pumicious by the presence of numerous vacuolæ, usually of an elongated or vermicular form. This appearance resembles that common in STROMATOPORA, and is easily seen when slightly magnified or even with the naked eye. Further, the skeletal tissue itself is of a minutely porous character, and appears to be composed of a mesh of anastomosing fibers. This structure suggests the system of radial pillars joined by horizontal arms characteristic of ACTINOSTROMA, but such interpretation is discountenanced by a study of vertical sections. Viewed in radial section, the skeleton is seen to be composed of laminæ and radial pillars, which are continuous and usually of large size. Instead of being dense and granular, as in ACTINOSTROMA, these have the same minutely porous structure as the laminæ. Moreover, although the pillars are usually superimposed and continuous in that sense, they are not the controlling structural element as in ACTINOSTROMA. It often happens that the dark lines which demarkate different laminæ pass continuously through the pillars, cutting them into many sections or drums. Each of these is continuous with the lower portion of the lamina immediately beneath it, and is terminated by the upper face of the lamina above.

Thus, while SYRINGOSTROMA unites structures characteristic of both ACTINOSTROMA and STROMATOPORA, and in an intermediate form between the Hydractinioid and Milleporoid groups of STROMATOPORAS, in typical examples, its separation from any other genus is attended with little difficulty, and its validity as a separate type seems certain. It resembles STROMATOPORA in the poro-fibrose structure of the laminæ, but is without the tabulate zoöidal tubes of that genus. Neither by implication nor by direct statement does NICHOLSON refer this structure to *S. densum.* Moreover, the interzooidal spaces are regularly arranged into columns, and the more minute division into laminæ is conspicuous, which is never the case in STROMATOPORA.

While the radial structure of SYRINGOSTROMA is suggestive of ACTINOSTROMA, the pillars are porous, not granular. They are either confluent with, or terminated by the laminæ.

In most of the Lower Helderberg specimens the laminæ appear in radial section of a darker color than do the radial pillars which support them. In a similar way the monticules are still darker than the rest of the laminæ, and become prominent to the eye on that account. Whether this circumstance is due to a difference in density of the skeletal tissue, or is owing to mechanical causes governing infiltration or replacement, I have been unable to determine.

The preparation of drawings to illustrate the newly described material was attended with some difficulty, for it was almost impossible to depict the sections as they appeared with fluctuations of shade and distinctness, and with the gradations through which the dark fibers of the skeletal tissue passed into the nearly colorless calcite in filtering the vaculæ or chambers. Consequently the annexed figures partake somewhat of the nature of restorations, for they are intended to convey the expression of the original, without faithfully reproducing its defects or deficiencies. At the same time they do not aim to present the organism in the condition in which it perished and became imbedded in the marine deposits.

SYRINGOSTROMA CENTROTUM, sp. nov.

Plate VII, figures 1, 2.

Cœnosteum massive, spheroidal, often attaining a large size. Intermittent concentric growth results in the formation of latilaminæ, which are usually conspicuous. The surface is thickly covered with rounded eminences or "mamelons," and astrorhizæ are numerous but minute. The presence or absence of an epitheca has not been ascertained.

No specimens in this collection are entire, but all evidence points to an originally sphæroidal form for the cœnosteum. One specimen appears to have had a diameter of about 27 cm. when entire. The concentric character of the structure is usually quite striking. Some specimens are readily separated into thin sheets or latilaminæ. In others, more completely infiltered by calcite or less weathered, the latilaminæ are indicated only by darker and lighter bands. When in this condition they are not disjoined by a blow from the hammer, but the specimen chips or fractures like a structureless limestone. Surface characters are best studied under the former condition of preservation. Sections of many Helderberg Stromatoporoids examined show that the original calcareous skeleton of the colony has been replaced by some dark material, probably impure limestone, while the spaces between pillars and partitions are filled by transparent calcite. The definition is nearly always indistinct.

Tangential sections do not remain parallel to the surface in this species, except over small areas, for the curvature is not regular but flexuous, and the latilaminæ are more or less foliaceous and imbricating. Thus extended sections cut the frequent monticules at all angles and appear like panels of curly maple.

In specimens which break along the latilaminæ the surface is seen to be vermiculate and porous, thickly covered with prominent conical elevations. This characteristic vermiculate structure is shown also in tangential sections, and is not due to weathering and preservation. Astrorhizæ are numerous, but small and inconspicuous, as if they were merely the usual porous structure intensified. They are distributed over the surface, and are often to be found on the sides of the monticules. The monticules, as shown by radial sections, are usually superimposed throughout one latilamina, but in two consecutive latilaminæ this may or may not be the case. They are often pierced by straight central canals directed radially. These canals often extend through one whole set of monticules. They have no proper walls and, therefore, cannot be referred to "Caunopora" tubes or tubicolous annelids. When broken transversely the mamelons are seen to be distinctly porous. The pores, or canals, are often arranged in concentric series, coincident with the cut edges of the intersected laminæ, and evidently represent sections of the astrorhizal canals.

Weathered fractures and properly oriented sections show that the radial pillars are strong, parallel, and continuous through several layers of the cœnosteum. They are united at more or less regular intervals by concentric partitions which have the porous structure above described. These concentric laminæ appear to be composed of inosculating fibers forming a reticulate skeleton, and not of lateral arms given off in a whorl around each pillar as in the genus ACTINOSTROMA. Vertical sections through a monticule show that the radial pillars are not parallel as elsewhere, but are inclined at a slight angle away from the imaginary axis of the monticule.

This species agrees well with the figures and descriptions of *Syringostroma densum*, except that the cut ends of the radial pillars are not distinguishable in tangential section. This seems to be the common species at Cedarville, N. Y., and is readily recognized by the number and prominence of the mamelons.

Horizon.— Lower Pentamerus limestone.

Locality.— Cedarville, N. Y.

SYRINGOSTROMA FOVEOLATUM, sp. nov.

Plate VI, figures 8, 9.

Cœnosteum massive and of large size. Outer surface and point of attachment not known. Division into latilaminæ usually apparent. In one specimen the latilaminæ are folded into regular hemispherical elevations, having a diameter of about 50 mm. Radial pillars continuous and usually large. Viewed in vertical section, the laminæ are thick and the interlaminar space narrow. Tangential sections show the laminæ to have a dense structure, but the organism may still be referred to the Milleporoid type. The pores, which in *S. centrotum* appeared as transparent vermiculate patches, in this species are represented only by minute spots, sometimes connected by transparent thread-like bands. The skeleton fibers are large, with fine reticulations, giving the tissue as a whole a dense consistency. The concentric laminæ, likewise, are unusually thick and heavy, the vacuoles of small size and the intercolumnar spaces minute. Astrorhizæ are frequent, and well-developed monticules appear to be present, chiefly associated with astrorhizæ. They are indicated in the section by a darker shading, but their elevation is so slight that tangential sections often show the astrorhizæ equally well on all sides. The monticules sometimes have tubular axes. When weathered, the cœnosteum often develops little pits or conical depressions about 4 mm. apart, which are rather characteristic of the species. *S. foveolatum* differs from *S. centrotum* in its thick and dense laminæ, its low monticules and its conspicuous astrorhizæ.

Horizon.— Lower Pentamerus limestone.

Locality.— Cedarville, N.Y.

SYRINGOSTROMA MICROPORUM, sp. nov.

Plate VI, figure 7.

Cœnosteum massive, latilaminate, shape unknown, probably spherical or subspherical. Surfaces parted along the latilaminæ are covered with numerous monticules, which are, however, of small size. They are usually pierced by axial tubes and provided with well-developed astrorhizæ seldom visible on the lamellar partings. In vertical sections the skeleton is seen to be composed of persistent radial pillars and the customary concentric laminæ. Tangential sections show the laminæ to have a finely porous structure, the skeleton fiber being of the characteristic reticulated tissue common to other Helderberg Syringostromas. Tangential sections through the monticules show only the cut ends of the astrorhizæ. When the section lies in the lateral slope of a monticule, the latter is seen to be provided with an extensively spreading astrorhizal system. The thickness and density of the laminæ in *S. foveolatum* readily distinguishes it from this species in microscopic examination. Furthermore, monticules are here apparent, and there is no indication of a tendency to weather into conical pits, as in *S. foveolatum.*

Compared with *S. centrotum*, the skeletal tissue is much finer, and the monticules less numerous.

Formation.— Lower Pentamerus limestone.

Locality.— Cedarville, N. Y.

SYRINGOSTROMA BARRETTI, sp. nov.

Plate VII, figures 5, 6.

Cœnosteum large, hemispherical, spreading. Latilaminæ distinct, more or less labyrinthine toward the center, on the periphery flowing in broad folds. They end abruptly on the under side, and are attached directly without an epitheca. Laminæ parallel and gently flexuous. Astrorhizæ not numerous, but large and conspicuous. The nucleus of an astrorhizal system is sometimes represented by an axial tube, and the laminæ at that point are often elevated into a low monticule. Skeletal tissue finely fibrous, but a little coarser than in *S. centrotum*.

This species is characterized by the infundibuliform concentric growth and the flat base without an epitheca (?). Without the aid of thin sections, the outer surface of the type specimen appears dense, fine-grained and structureless, except for latilaminæ which separate in unusually thin sheets. Sections near the surface are without monticules, astrorhizæ, and axial tubes, exhibiting only the uniform, porous skeleton and fibrous structure. The same surface characters are presented by the basal portion and suggest an epithecate condition, but it has not the polished surface and concentric wrinkles characteristic of the epitheca in FAVOSITES. The flat base of the specimen is attached to a branching form of DIPLOPHYLLUM. *Syringostroma Barretti* is the common species at the Indian Ladder.

Horizon.— Lower Pentamerus limestone.

Locality.— The Indian Ladder, N. Y.

SYRINGOSTROMA CONSIMILE, sp. nov.

Plate VII, figures 3, 4.

Cœnosteum massive, large, and subspherical. Latilaminate structure shown by sections or on weathered surfaces. The laminæ are disposed in pointed, wave-like folds, which are not superimposed. Skeleton-fiber finely porous; tissue reticulate; astrorhizæ few and very large, sometimes provided with a tubular axis.

This species is similar to *S. Barretti*, but the material examined can be separated with little difficulty by the character of the laminæ, which, in the latter, are gently curved, proximate, and parallel, but in *S. consimile* are angular and independent in their flexures. Thus, *S. consimile* generally lacks the superimposed monticules of the kindred form. The reticulations of the skeleton-fiber are somewhat coarser than in *S. Barretti*, and very much coarser than in *S. centrotum*, while the thinness of the laminæ is also characteristic. The figure which presents a vertical section of this species is drawn to slightly too large a scale, making the columno-lamellose structure of the cut more open than in the original. Comparative study of a series of specimens, however, may prove these two types to be identical, but for the present, at least, it is necessary to regard them as distinct.

Horizon.— Lower Pentamerus limestone.

Locality.— Outlet of Skaneateles lake, N. Y.

CLATHRODICTYON JEWETTI, sp. nov.

Plate VI, figures 5, 6.

Cœnosteum known only as a small fragment. Latilaminate, probably massive. Surface characters not known. Laminæ very conspicuous in vertical section. Radial pillars persistent through one interlaminar space, usually terminating in the laminar partition. Tangential sections show the cut ends of the radial pillars, which are apparently not connected by arm-like processes, but by a continuous wall. Monticules are present, associated with astrorhizæ and axial tubes, but the character of the astrorhizæ has not been determined. The skeleton does not show the "pillar and arm" structure characteristic of ACTINOSTROMA nor the reticulated skeleton common in SYRINGOSTROMA.

The species resembles *C. striatellum*, Nicholson, in many particulars, but the latter is without astrorhizæ, monticules, etc., which form a striking feature in the *Actinostromidæ.* It differs from NICHOLSON'S species, also, in the more normal radial pillars and regular mesh. All the sections studied have been cut from the small fragment which alone represents this species. In none of them do the radial pillars extend systematically through a number of interlaminar spaces; and although an apparent prolongation through two or even three such spaces may occasionally be observed, the occurrence is too rare to influence the generic determination of the specimen.

Horizon.—Lower Pentamerus limestone.

Locality.— Cedarville, N. Y.

Actinostroma, Nicholson, 1886.

ACTINOSTROMA RISTIGOUCHENSE.

Cœnostroma Ristigouchense, Spencer, 1884. Bull. No. 1, Univ. State Missouri, p. 227.

Syringostroma Ristigouchense, Nicholson, 1886. Pal. Soc., vol. XXXIX, British Stromatoporoids, expl. Pl. XI, figs. 11, 12.

I have not been able to examine specimens of *A. Ristigouchense* nor to consult SPENCER's description of the species. Fortunately it is figured and discussed by NICHOLSON (*l. c.*). For reasons given above it has been removed from the genus SYRINGOSTROMA where NICHOLSON places it.

ANTHOZOA.

Family CYATHAXONIDÆ.

Duncanella, Nicholson, 1874.

DUNCANELLA RUDIS, sp. nov.

Plate II, figures 7, 8.

Corallum simple, straight, turbinate, rather evenly and rapidly expanding. Rugæ on the exterior coarse, and not sharply defined.

Horizon.— Delthyris Shaly limestone.

Locality.— The Indian Ladder, Albany county, N. Y.

This species of DUNCANELLA is not a rare form in the higher beds of the Shaly limestone of the Helderberg mountains, and specimens of it may have been heretofore identified as *Streptelasma strictum.* While STREPTELASMA was attached like most cyathophylloid corals, DUNCANELLA was probably in a free condition. The latter also possessed this unique characteristic, that the theca is incomplete at the base, leaving the septa exsert. In STREPTELASMA, they meet in the center and are twisted to form a pseudo-columella, while this structure is replaced in DUNCANELLA by a sort of tube reaching nearly to the base, and formed by the extremities of the septa, which do not extend quite to the center. DUNCANELLA, moreover, is entirely without tabulæ or dissepimental tissue, which seem to be always present in STREPTELASMA, although in varying degrees.

Duncanella rudis differs from *D. borealis*, Nicholson, of the Niagara group, in several particulars. It is erect, not bent or uncinate like the latter, while the apical angle is considerably greater. The rugæ on the surface are much less numerous and less sharply defined, while the parallel, horizontal growth lines, which are rather characteristic of the Niagara species, are very obscure.

Family ZAPHRENTIDÆ.

Streptelasma,, Hall, 1847.

STREPTELASMA STRICTUM, Hall, 1874.

Streptelasma (*Petraia*) *stricta*, Hall, 1874. Twenty-sixth Rep. New York State Mus. Nat. Hist., p. 142.

Streptelasma stricta, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 142.

Streptelasma strictum, Hall, 1883. Rep. State [Geologist] for 1882, expl. Pl. I, figs. 1–10.

Streptelasma strictum, Hall, 1887. Pal. New York, vol. VI, p. 1.

Horizon.— Shaly limestone. Indian Ladder, Catskill Creek, Clarksville, Hudson, Schoharie and other localities in New York.

The genus STREPTELASMA was proposed by Hall* in the first volume of the Palaeontology of New York. At the same time, also, several species were described, but as no type was designated, *S. expansum*, the first described, should be taken as such, although the practice has been to employ *S. corniculum* as the typical form. The original description of the genus is as follows: "Turbinate, gradually or abruptly expanding above; form ike CYATHOPHYLLUM; terminal cup more or less deep; lamellæ vertical or longitudinal, more or less spirally twisted together when meeting in the center."

As the type species (*S. expansum*) still remains uninvestigated, and as the description above quoted is insufficient to distinguish the genus from other Cyathophylloid corals, STREPTELASMA strictly becomes little more than a name.

Unfortunately, owing to the poor preservation of examples from the Trenton limestone where the original specimens of *S. corniculum* were obtained, many investigators, among them EDWARDS and HAIME, ZITTEL and NICHOLSON,† have used for study well-preserved specimens of the species from the Cincinnati group. This species was described as *Zaphrentis Canadensis*. Much confusion, therefore, has resulted. EDWARDS and HAIME, regarding *S. corniculum* as the type, say that STREPTELASMA is distinguished from CYATHOPHYLLUM "by the structure of the wall

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* HALL, 1843. Pal. New York, vol. I, p. 17.

† Both ZITTEL (Handb. der Pal., Bd. I, 2 Abth., p. 228) and NICHOLSON (Man. of Pal., vol. I, p. 297, 1889) figure *Z. Canadensis* as *S. corniculum*. On the authority of ROMINGER (Geol. Surv. Michigan, Lower Peninsula, vol. III, part II, p. 142. 1886) EDWARDS and HAIME are included.

which is destitute of an epitheca and covered by sublamellar costæ."* The statement that *S. corniculum*, whether from the Trenton or Hudson River Group, lacks an epitheca, is incorrect (ROMINGER, *loc. cit.*). The best usage† at present regards STREPTELASMA as a subgenus of ZAPHRENTIS. The two groups pass into each other by insensible gradations, but typical forms differ in this, that STREPTELASMA has a less complete development of dissepimental tissue.

Since the genus STREPTELASMA is in honorable usage as representing an actual coralline type, it seems inexpedient to abandon it at present in view of our inadequate knowledge of *S. expansum*. Should a careful investigation of this species show that it does not belong to the STREPTELASMA type, METRIOPHYLLUM, Edwards and Haime, will probably have to be substituted. METRIOPHYLLUM (type *M. Bouchardi*) is one of the new genera published by EDWARDS and HAIME in 1850, four years after STREPTELASMA was established. The original description (Brit. Foss. Corals, p. lxix) is elaborated as follows: Corallum simple, turbinate, subpedicillate, inclosed in a complete epitheca. Septa appear as well-developed partitions, slightly curved, and extending for the most part to the center of the visceral cavity; they are grouped in four bundles, but the cross formed by the four principal septa, as it exists in other genera of the family, is indistinguishable. Tabulæ well developed, simple and horizontal, corresponding in the different interseptal loculi in such a way as to form complete transverse floors, which are usually marked by the septa, but which show plainly when the latter are partially destroyed.‡ The figures of *M. Bouchardi* and the description above quoted correspond with STREPTELASMA. The only questionable point of identity consists in the regularity of the tabulæ, which in the cut is so marked as to appear almost diagrammatic. The figure shows that *M. Bouchardi* also had a central axis like a columella. Although no specimens of METRIOPHYLLUM have been obtainable, I have ventured to regard it as a synonym of STREPTELASMA. ZITTEL, however, recognizes both genera, possibly because of their

* EDWARDS and HAIME, 1850. Brit. Foss. Corals, p. lxviii. The same idea is repeated Mon. des Polyp. Foss. des Terr. Pal., p. 398. 1851.

† HALL, 1887. Pal. New York, vol. VI, p. xi, "Streptelasma," also ROMINGER, *loc. cit.*, p. 141.

‡ EDWARDS and HAIME, 1851, Mon. des Polyp. Foss. des Terr. Pal., p. 317 *et seq.*, Pl. 7, figs. 1, 1a, 1b, 2, 2a.

distribution, as he refers METRIOPHYLLUM to the Devonian and STREPTELASMA to the Silurian age.

Zaphrentis, Rafinesque, 1820.

ZAPHRENTIS ROEMERI, Edwards and Haime, 1851.

Zaphrentis Roemeri, Edwards and Haime, 1851. Mon. des Polyp. Foss. des Terr. Pal., p. 341.

Zaphrentis Roemeri, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. I, figs. 11–21.

Zaphrentis Roemeri, Hall, 1887. Pal. New York, vol. VI, p. 2.

Horizon.— Lower Pentamerus and Shaly limestone.

Localities.— Clarksville and Indian Ladder.

PERFORATA.

Family FAVOSITIDÆ.

Favosites, Lamarck, 1812.

FAVOSITES HELDERBERGIÆ, Hall, 1874.

Favosites Helderbergiœ, Hall, 1874. Twenty-sixth Rep. New York State Mus. Nat. Hist., p. 111.

Favosites Helderbergiœ, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 145.

Favosites Helderbergiœ, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. IV, figs. 1, 2; Pl. V, figs. 1–3; Pl. VI, figs. 1–8.

Favosites Helderbergiœ, Hall, 1887. Pal. New York, vol. VI, p. 8.

FAVOSITES CONICUS, Hall, 1874.

Favosites conica, Hall, 1874. Twenty-sixth Rep. New York State Mus. Nat. Hist., p. 112.

Favosites conica, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 146.

Favosites conicus, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. III, figs. 4, 6–13.

Favosites conicus, Hall, 1887. Pal. New York, vol. VI, p. 9.

Horizon.— Shaly limestone.

Locality.— Clarksville and Indian Ladder, New York; and Cumberland, Maryland.

A comparison of *Favosites conicus* and *F. Helderbergiœ* shows that these species agree in many important particulars. As regards the structural peculiarities and the measurement of individual corallites, the two species as described by HALL are in almost perfect accord, and it is in the size and shape of the coralla that the most striking differences are shown. Both forms are covered with a strongly wrinkled epitheca. In *F. Helderbergiæ* the mural pores are said to be in one or two ranges, comparatively large, circular, with margins distinctly elevated; the tabulæ frequent, from ten to fifteen in a space of 10 mm. In *F. conicus* the mural pores are comparatively large, circular, with distinctly elevated margins, disposed in one, two, or sometimes three rows. The tabulæ vary from eight to ten in a space of 10 mm. The septa in both forms are represented by longitudinal ridges. HALL describes the walls of *F. Helderbergiæ* as sometimes granulose or spinulose on the inner face. In *F. conicus* the interior of the cells is said to give evidence of numerous spinules or small nodes.

Of *F. conicus*, Prof. HALL says, "The conical form of this species and the irregularity in the size of the cells distinguish it from every other known species of FAVOSITES in the Silurian rocks of New York."* In the same description the diameter of the cells at the surface is said to vary from 1.5 to 3.5 mm. This places their size as a little greater than in *F. Helderbergiæ*, where they range from .66 to 2 mm. My own measurements show the average size of the corallites in either species to be from 1.5 to 2 mm., and in *F. conicus* from about .5 to 3 mm. The collection at my command probably does not present the range of specimens which Prof. HALL studied. It is possible that *Favosites conicus* and *F. Helderbergiæ* both refer to the same organism at different stages of growth and preservation. *F. Helderbergiæ* is found in and at the top of the Lower Pentamerus limestone, in the neutral zone between that and the Shaly limestone. *F. conicus* is obtained from the Shaly limestone itself, but, toward the base of that horizon, the specimens occur silicified, and of a larger size, thus displaying a great resemblance to *F. Helderbergiæ*. The conditions of argillaceous sedimentation are unfavorable to the growth of corals, and it is possible that *F. conicus* simply represents immature or small forms of the larger species, which a change from favorable to unfavorable conditions has uniformly prevented from further growth.

* HALL, 1887. Pal. New York, vol. VI, p. 9.

The smallest corallum of *F. conicus* in this collection is 8 mm. in diameter and the largest 48 mm. The majority of specimens are discoidal, or flattened hemispherical. A few have the characteristic form, being conical or strawberry-shaped.

Formation and locality.— Indian Ladder, Clarksville, Schoharie, Herkimer Co., and Cumberland, Maryland.

FAVOSITES CONRADI, sp. nov.

Plate V. figures 3–5.

Corallum ramose, branches slender. Corallites polygonal, contiguous, of comparatively small size. Pores large, with usually but a single row to a face. Septa represented by spines which are close set and regularly arranged so as to give twelve longitudinal rows, forming at the same time transverse rings. Tabulæ complete, straight, and near. The mature corallite are 2 mm. in diameter, the cells of various sizes. Usually disposed so that each large cell is surrounded by a ring of smaller corallites of about half its size. Tabulæ 1 to 1.5 mm. apart, evenly distributed.

Although the tabulæ are near together, they do not appear so when compared with a closely tabulate form like *F. Helderbergiæ*. The specimens which represent *F. Conradi* are silicified, and the character of the septal spines is not satisfactorily shown. The cell walls are thin, but, near the surface, they are somewhat thickened by silicification. At this point, the septa are represented by parallel coronæ of prominent spines, which are less conspicuous a little below, and eventually nearly or quite disappear. The number of septal ridges is regularly twelve. When, through abnormal growth among the corallites, an epitheca is developed, it is ornamented with fine radiating striæ and delicate concentric wrinkles.

Horizon.— Lower Pentamerus limestone.

Locality.— Indian Ladder, N. Y.

Favosites sphericus = *Chætetes* (*Ptychonema*) *sphericus*, Hall, 1874.

Favosites proximus = *Chætetes* (*Ptychonema*) *proximus*, Hall, 1883.

These two species have been examined with considerable care by means of microscopic sections, and I have been unable to detect the presence of either mural pores or septa. It is, therefore, impossible to retain these forms in the genus *Favosites.* On the other hand, the small size of the cells, the superimposed mode of growth, and, in the case of *Chætetes sphericus*, the presence of maculæ, all indicate an affinity with the Bryozoa.

Alveolites, Lamarck, 1801.

ALVEOLITES EXPLANATUS, Hall, 1884.

Alveolites explanatus, Hall, 1884. Rep. State Geologist for 1883, expl. Pl. 13, figs. 15, 16.

Alveolites explanatus, Hall, 1887. Pal. New York, vol. VI, p. 11.

Formation.— Lower Pentamerus limestone.

Localities.— Cedarville, Clarksville and Schoharie, N. Y.

Pleurodictyum, Goldfuss, 1826.

PLEURODICTYUM LENTICULARE, Hall, 1874.

Michelinia lenticularis, Hall, 1874. Twenty-sixth Rep. New York State Mus. Nat. Hist., p. 113.

Michelinia lenticularis, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 145.

Michelinia lenticularis, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. III, figs. 1, 2, 3, 5.

Pleurodictyum lenticulare, Beecher, 1891. Trans. Connecticut Acad., vol. VIII, p. 207.

Formation.— Shaly limestone, Albany county, N. Y.

Striatopora, Hall, 1852.

STRIATOPORA ISSA, Hall, 1874.

Striatopora Issa, Hall, 1874. Twenty-sixth Rep. New York State Mus. Nat. Hist., p. 114.

Striatopora Issa, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 144.

Striatopora Issa, Hall, 1883. Rep. of State Geologist for 1882, expl. Pl. III, figs. 14, 15.

Striatopora Issa, Hall, 1887. Pal. New York, vol. VI, p. 6.

Formation and locality.— Shaly limestone, Helderberg mountains, Albany county, and Becraft's mountain, Columbia county, N. Y.

Cladopora, Hall, 1852.

CLADOPORA CLARKEI, sp. nov.

Plate V, figure 1.

Corallum compact, ramose. Branching, bifurcate infrequent. Cells in five longitudinal rows, comparatively large, distinctly labiate. Diameter of the branches varies from .2 to 4 mm.

The branches of this species are unusually small, and the bifurcations infrequent. One specimen measures 46 mm. from a broken end to the point of branching; another measures 42 mm. The apertures also are comparatively distant and are regularly arranged in five longitudinal rows. The corallites are long, nearly parallel to the axis of the branch, with a slight outward curvature as they approach the periphery. The plane of the orifice is nearly perpendicular to the cell wall. This, taken in connection with the acute angle at which the corallites meet the surface, gives the cell mouths a somewhat labiate appearance. Above each orifice the branch is slightly flattened or convex, causing it to have a subangular or nodose form. The surface of the branches is without ornamentation, very smooth and dense. A cross section of the branches shows that the cells have been distorted by mutual pressure. They are not, however, polygonal as in FAVOSITES, but have become more or less cresent shaped. No tabulæ have been observed. The mural pores are small and very distant.

Horizon.— Shaly limestone.

Locality.—The Indian Ladder, Albany county, N. Y.

CLADOPORA HALLI, sp. nov.

Plate V, figure 2.

Corallum dense, branching. Ramification bifurcate. Branches usually flattened, of larger size than in *C. Clarkei*, varying from 7 x 5 to 5 x 3 mm. in diameter. Cells smaller, more closely set, not labiate and not serially arranged.

This species can be readily distinguished from *C. Clarkei* by the large size of the branches and by the small cells, thickly and indiscriminately placed without being disposed in vertical series. The projection of the outer wall, which gives to *C. Clarkei* a labiate appearance, is not a well-marked character in this species.

Horizon. — Shaly limestone at a slightly higher level than *C. Clarkie.*

Locality.— Clarksville, N. Y.

Vermipora, Hall, 1874.

This genus has been usually regarded as a coral, closely allied to AULOPORA, a sort of vertical aggregation of AULOPORA tubes. Such a classification, however, overlooks several important structural characters, which, if duly considered, would place it among the *Bryozoa*, in close proximity to HEDERELLA.

The genus AULOPORA, Goldfuss,* is said to have neither tabulae nor septa,† although most species are found to possess them. HALL states that the type species of VERMIPORA is without both septa and tabulae, and my own observations confirm the statement. In this particular and also in its system of budding VERMIPORA agrees with HEDERELLA. In the latter genus there is a central stolonal rhachis, which sends off buds pinnately. The stolon is often very long, and the buds may also reach a considerable length in some species. In AULOPORA the system is quite different. There is no long central axis, but each cell grows for a short distance in the line of such axis, then bending upward, puts forth one or two buds, which in turn repeat the same process. Each corallite ceases to grow shortly after budding and the rhachis, instead of being simple and homogeneous, is composite.

Therefore it seems advisable to remove VERMIPORA from its position near AULOPORA, and as it possesses points of resemblance to HEDERELLA, I have associated it with that genus. There is, however, another form, CLONOPORA, closely allied to HEDERELLA, but differing from VERMIPORA chiefly in that the buds bend outward from the stem in umbels. It may be a synonym for the latter, and at all events is closely related to it.

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* GOLDFUSS, 1826. Petrif. Ger., vol. I, p. 82.

† HALL, 1887. Pal. New York, vol. VI, pp. XII and 5.

Family AULOPORIDÆ.

Aulopora, Goldfuss, 1826.

AULOPORA SUBTENUIS, Hall, 1879.

Aulopora subtenuis, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 143.
Aulopora subtenuis (pars.), Hall, 1883. Rep. State Geologist for 1882, expl. Pl. II, figs. 9–20.
Aulopora subtenuis, Hall, 1887. Pal. New York, vol. VI, p. 4.

This species is an abundant form at the Indian Ladder, and is represented in the collection by several hundred specimens. It is never found procumbent and attached like other examples of the genus, and there is reason to believe that the corallum grew upright from a single attached individual. Buds are given off along the medial dorsal line, and not somewhat laterally, as is common in AULOPORA. The cells are often turned sidewise instead of upward. Furthermore, the corallites are not flattened and impressed as they would be if they had been once attached and subsequently broken off. These features may prove sufficient for founding a new genus on this form, closely allied to AULOPORA.

Horizon.— Shaly limestone, N. Y.

AULOPORA SCHOHARIÆ, Hall, 1874.

Aulopora Schohariæ, Hall, 1874. Twenty-sixth Rep. New York State Mus. Nat. Hist., p. 110.
Aulopora Schohariæ, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 142.
Aulopora Schohariæ, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. II, figs. 1–6.
Aulopora Schohariæ, Hall, 1887. Pal. New York, vol. VI, p. 3.

Horizon.— Shaly limestone, Schoharie and Clarksville.

AULOPORA TUBULA, Hall, 1879.

Aulopora tubula, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 142.
Aulopora tubula, Hall, 1883. Rep. State Geologist for 1882, expl. Pl. II, figs. 7, 8.
Aulopora tubula, Hall, 1887. Pal. New York, vol. VI, p. 3.

Horizon.— Shaly limestone, Schoharie.

AULOPORA ELONGATA, Hall, 1879.

Aulopora elongata, Hall, 1879. Thirty-second Rep. New York State Mus. Nat. Hist., p. 143.
Aulopora subtenuis (pars.), Hall, 1883. Rep. State Geologist for 1882, expl. Pl. II, figs. 9–20.
Aulopora elongata, Hall, 1887. Pal. N. Y., vol. VI, p. 5.
Horizon.— Shaly limestone, Schoharie.

In concluding this revision I take pleasure in acknowledging my obligation to Prof. C. E. BEECHER, of Yale University, to whom I am indebted for the material studied, for the facts of its occurrence, and for other valuable suggestions and advice.

Explanation of Plates.

PLATE I.

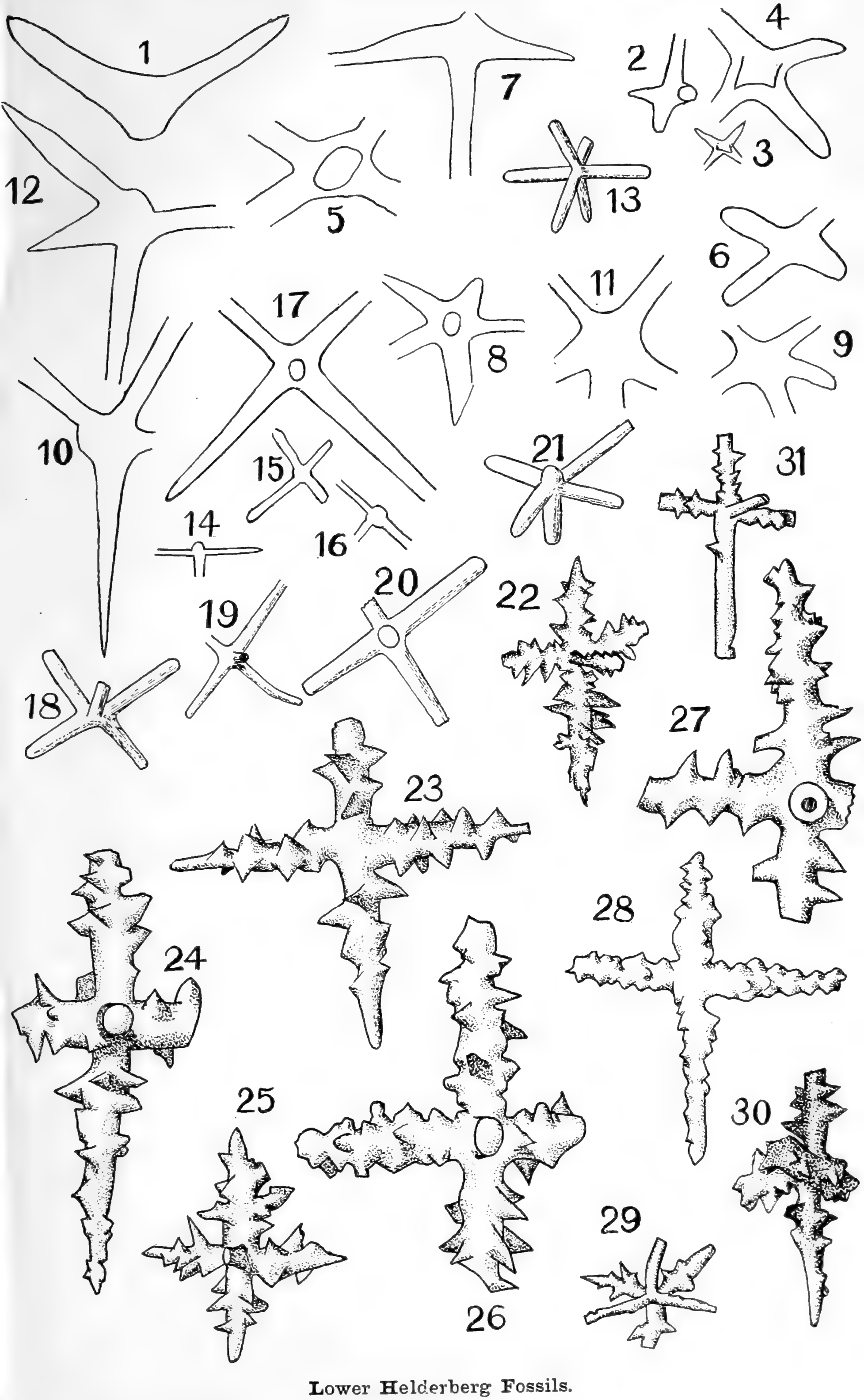
Figs. 1–12. Spicules of *Lysactinella Gebhardi,* as shown in a section through the sponge. × 30.

Figs. 14–17. Spicules of *Lysactinella Gebhardi* preserved as casts in a phosphatic nodule. × 30.

Figs. 13, 18–21. Spicules of *Lysactinella Gebhardi* preserved free as pyrite. × 30.

Figs. 22–31. Spicules of *Lysactinella perelegans* preserved as pyrite. × 30.

PLATE 1.



Lower Helderberg Fossils.

PLATE II.

Fig. 1. Large spicule of *Lysactinella perelegans* preserved as pyrite. × 30.

Fig. 2. Diagram representing the spicular structure of *Hindia sphæroidalis* (after Rauff).

Fig. 3. Outline of *Lysactinella Gebhardi.* Section taken near the center. Natural size.

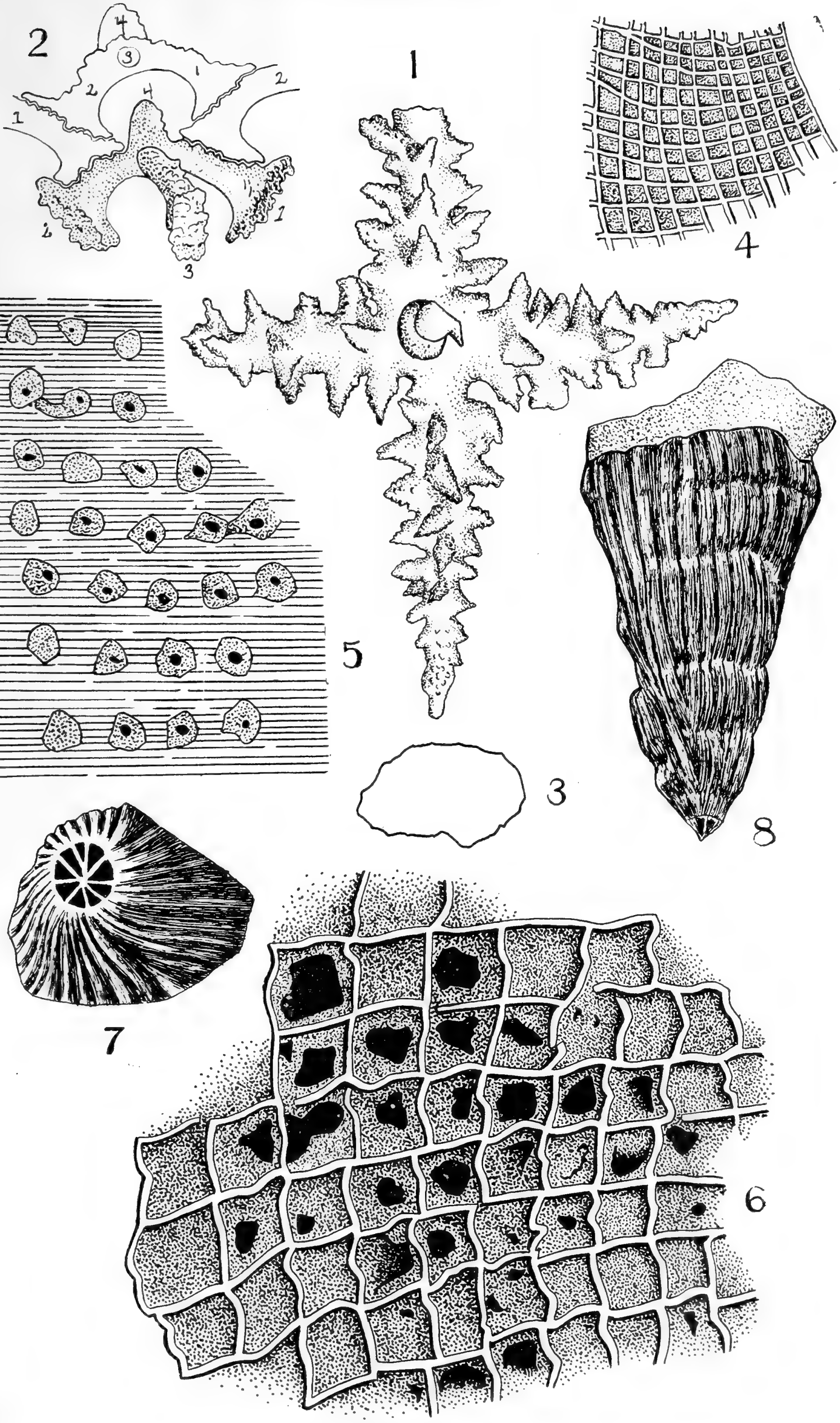
Fig. 4. Gastral surface of the pyritized specimen of *Receptaculites infundibuliformis*. × 8.

Fig. 5. Ends of radial tubes in the same specimen. The tubes are embedded in a white, crystalline mineral which fills the intermural cavity. The fracture is just below the gastral or inner wall. × 26.

Fig. 6. Portion of the gastral surface much enlarged. × 26.

Figs. 7, 8. Two views of a specimen of *Duncanella rudis,* showing the usual characters of the species. × 8.

PLATE 2.



Lower Helderberg Fossils.

PLATE III.

Fig. 1. Diagram representing a section cut through the middle of the pyritized specimen of *Receptaculites infundibuliformis.* ×4.

Fig. 2. A portion of the outer surface of the same specimen, showing rhombic pits, radial tubes, and projecting spines. × 8.

Fig. 3. *R. infundibuliformis.* The inner surface of the gastral wall, showing the broken radial tubes. × 26.

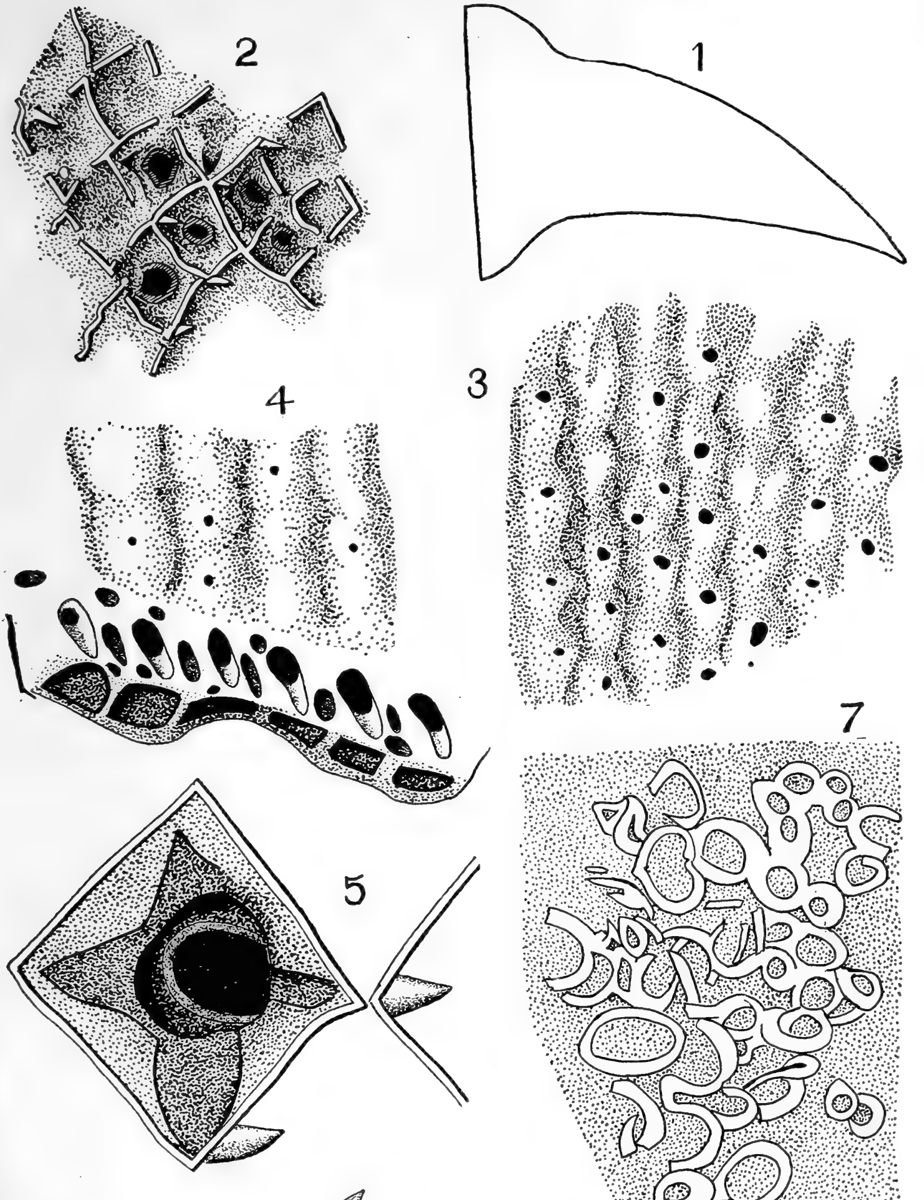
Fig. 4. The same. The ridges belong to the inner surface of the gastral wall, more fully illustrated in the preceding figure. The edge of the specimen is beveled, giving the canals an elongated shape. The large perforations in the lower part of the figure are the rhombic pits of the gastral surface. They are covered over with a plexus of minute spicules, to which reference has been made in the text. × 26.

Fig. 5. One of the rhombic depressions of the outer wall enlarged, showing the diagonal canals and the radial tube at the bottom. × 26.

Fig. 6. Another view of the same. × 26.

Fig. 7. Fractured surface showing the crushed radial tubes. × 26.

PLATE 3.



Lower Helderberg Fossils.

PLATE IV.

Fig. 1. Portion of a frond of *Dictyonema crassum.* × 6.

Fig. 2. Same. The indistinct longitudinal wrinkles which are sometimes seen in this species, are not represented by the figure. × 6.

Fig. 3. *Monograptus Beecheri,* translucent specimen showing tabulation. × 60.

Figs. 4–8. *Monograptus Beecheri.* × 60.

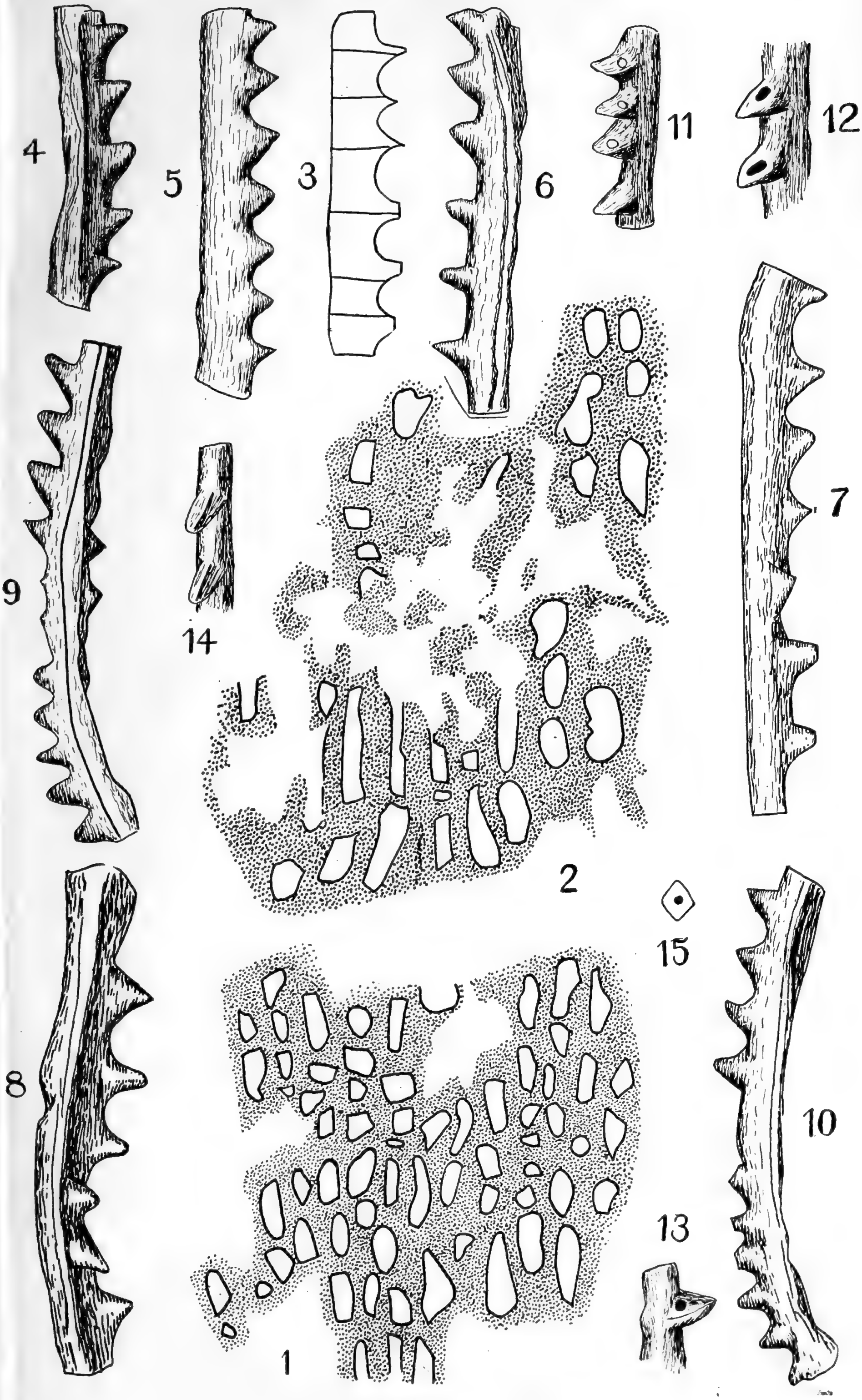
Figs. 9, 10. Two views of an abnormal specimen of *Monograptus Beecheri* in which for a short distance some of the serrations appear on the unserrated side. × 60.

Figs. 11–13. Views of *M. Beecheri* showing character and position of the zoöidal openings. × 60.

Fig. 14. Under surface of the serrations in *M. Beecheri.* × 60.

Fig. 15. End of a specimen of *M. Beecheri* showing perforated stipe.

PLATE 4.



Lower Helderberg Fossils.

PLATE V.

Fig. 1. *Cladopora Clarkei.* A bifurcate stem showing the labiate zooidal openings. × 6.

Fig. 2. *Cladopora Halli.* Portion of a corallum showing the small pores, which are more regularly arranged than is commonly the case. × 6.

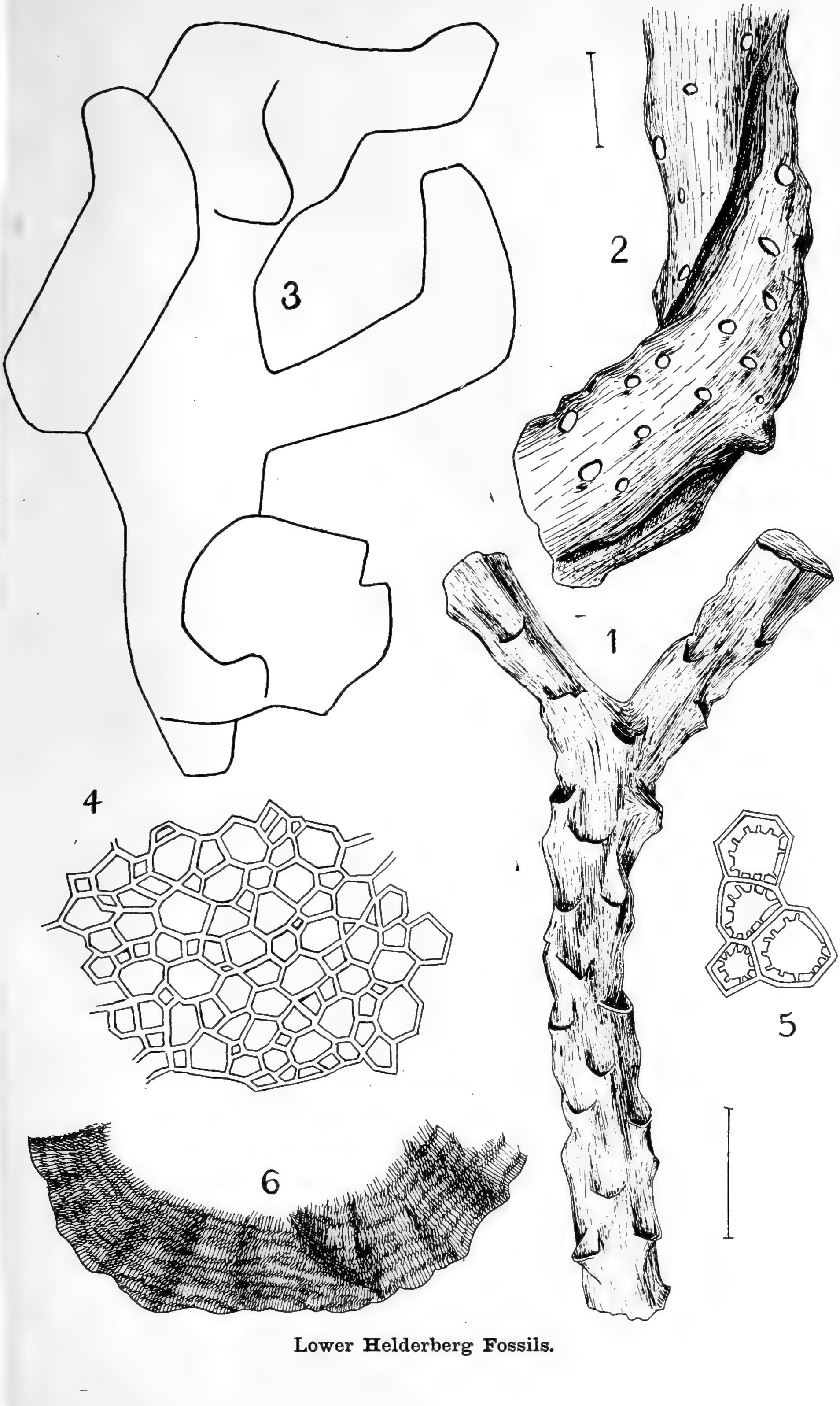
Fig. 3. Outline of a corallum of *Favosites Conradi* showing the branching form. × 2.

Fig. 4. Enlargement of a portion of the surface, showing the sizes and arrangement of the cells. × 4.

Fig. 5. Enlargement of a portion of the surface showing the septal spines thickened by a deposit of silica. × 8.

Fig. 6. Enlargement of a portion of the epitheca showing finely striate and wrinkled surface. × 10.

PLATE 5.



Lower Helderberg Fossils.

PLATE VI.

Fig. 1. *Receptaculites Oweni.* Section transverse to the radial pillars showing the latter to be solid and structureless. × 4.

Fig. 2. *R. Oweni.* Section through the gastral wall near the inner surface, showing by the dark portion irregular, anastomosing channels filled with matrix, and cutting the structureless calcite of the inner wall. × 4.

Fix. 3. *R. Oweni.* Section through the outer wall. The dark portion represents what is generally considered matrix thrust between the summit plates. At the corners of the plates are round pores which are usually supposed to be characteristic of the inner wall. × 4.

Fig. 4. A diagrammatic representation of a relief ornamentation preserved as a cast in the matrix above the rhombic pits of the external surface of a specimen of *R. Oweni*.

Fig. 5. *Clathrodictyon Jewetti.* Longitudinal section showing the discontinuous radial pillars. × 15.

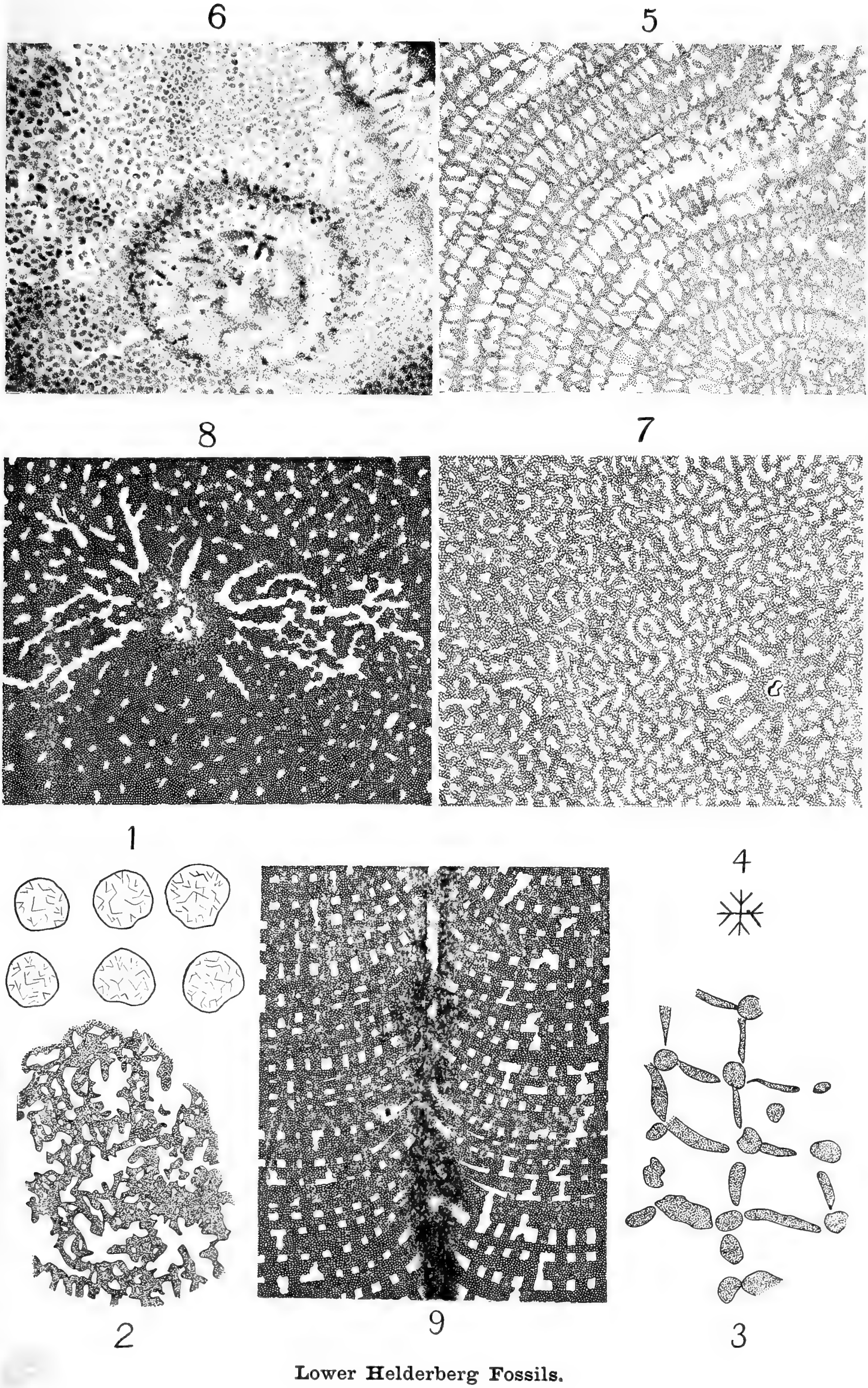
Fig. 6. Transverse section of the same showing the cut ends of the radial pillars which are not joined by connecting processes. The skeleton-fiber is seen to be dense, not reticulated as in the genus *Syringostroma.* × 15.

Fig. 7. *Syringostroma microporum.* This is a transverse section, showing the finely porous structure of the laminæ and the minutely reticulated skeleton-fiber. A mamelon with axial tube and astrorhizal canals is cut in the lower right hand portion of the figure. × 15.

Fig. 8. *Syringostroma foveolatum.* Transverse section showing an extended astrorhizal system, and illustrating the dense character of the skeletal tissue. × 15.

Fig. 9. Longitudinal section of the same. The figure shows the thick laminæ and continuous radial pillars; at the same time it traverses an axial tube and illustrates the superimposed nature of the monticules. × 15.

PLATE 6.



Lower Helderberg Fossils.

PLATE VII.

Fig. 1. Transverse section of *Syringostroma centrotum.* The figure shows two monticules with axial tubes. The concentric groups of apertures probably represent the cut ends of astrorhizal systems. The skeleton-fiber is minutely reticulated. × 15.

Fig. 2. Longitudinal section of the same showing the continuous radial pillars. × 15.

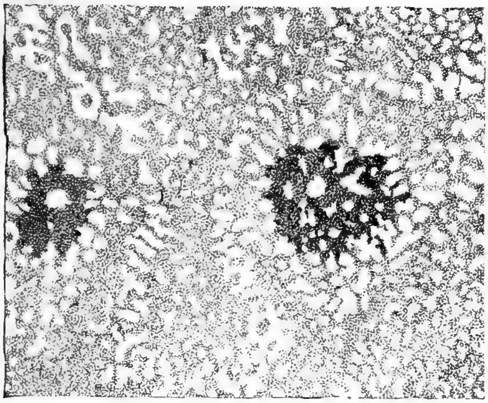
Fig. 3. *Syringostroma consimile.* Transverse section showing a low monticule with an axial tube and a very strong and complex astrorhizal system. × 15.

Fig. 4. Longitudinal section of the same illustrating the independent flexures of the laminae. The radial pillars in this and the following species are not systematically continuous. × 15.

Fig. 5. Transverse section of *Syringostroma Barretti,* which shows a low monticule with its tubular axis, and a very complex, extended astrorhizal system. × 15.

Fig. 6. Longitudinal section of the same. This section shows the reticulated structure of the skeleton-fiber and the wave-like flexures of the laminæ.

PLATE 7.



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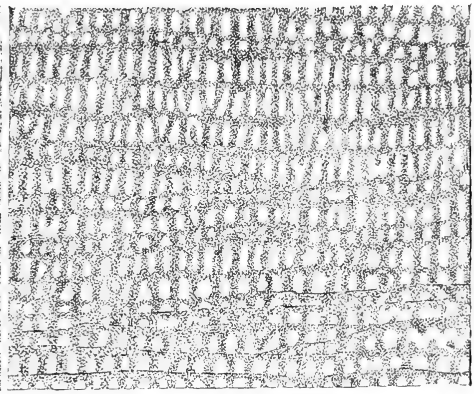

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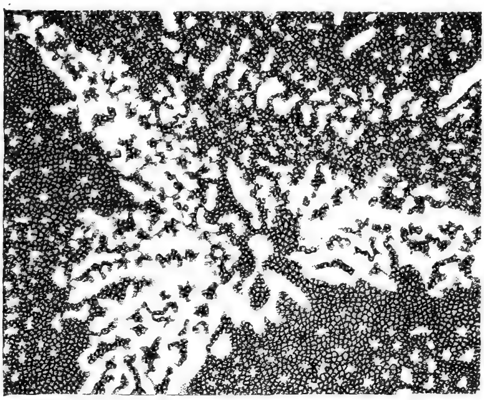

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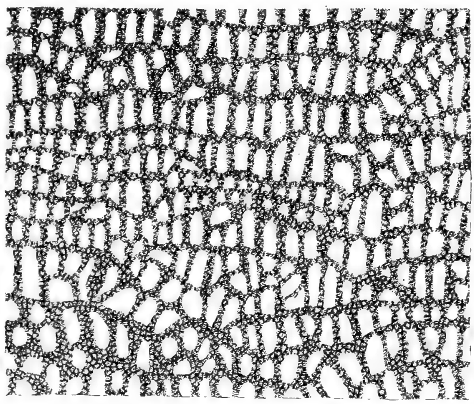

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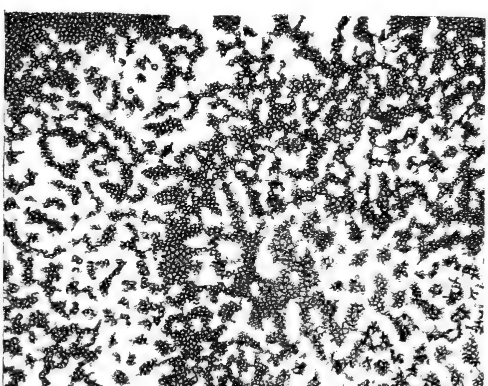

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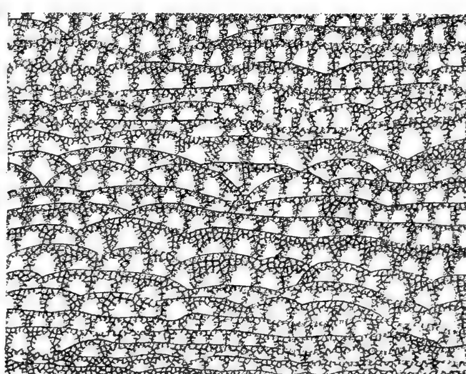

6

Lower Helderberg Fossils.

THE NEW SPECIES OF BRACHIOPODA

DESCRIBED IN

PALAEONTOLOGY OF NEW YORK,

Volume VIII, Parts 1 and 2.

1892—1894.

WITH FOURTEEN PLATES.

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[For the convenience of the student, such new species of Brachiopoda as have been described or figured in Volume VIII of the Palaeontology of New York, in illustration of generic structures, are here brought together in one place, with requisite illustration and description.]

Lingula compta.

Plate 1, fig. 1.

Lingula compta, Hall. Palaeontology of N. Y., vol. VIII, part 1, p. 171, pl. i, fig. 16. 1892.

Shell very narrow, with lateral margins nearly parallel for most of their length; the anterior margin transverse and the posterior less abruptly rounded. Shell-substance thin. Surface marked by fine concentric striæ.

The interior of the brachial (?) valve bears two strong lateral muscular ridges which meet in the median line at about one-third the length of the shell from the anterior margin. A narrow median furrow extends from just behind the center of the valve nearly to the anterior margin. Length of this valve, 9 mm., greatest width, 4.5 mm.

This species is allied to *L. densa,* Hall, but differs in its narrower form and thinner shell.

Hamilton group. *Tichenor's Gully, Canandaigua Lake, N.Y.*

Lingula scutella.

Plate 1, fig. 3.

Lingula scutella, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 171, pl. i, fig. 30. 1892.

Shell broad, subquadrate; lateral margins parallel for a short distance, but soon rounding to the extremities, which have about equal curvature. Length to width as 2 to 3. Surface covered with more or less distinct concentric lines and wrinkles. The interior of the original valve, a cast of the interior, shows a broad central elevation, corresponding to the muscular impressions, and converging ridges over the pallial region, representing the vascular sinuses. Fine radiating lines are also visible over the anterior region. Length of the valve, 12 mm.; greatest width, 8 mm.

Chemung group. *Allegany county, N. Y.*

Lingula (Glossina) flabellula.

Plate 1, figs. 5, 6.

Lingula flabellula, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 172, pl. i, figs. 33, 34. 1892.

Shell large, subtriangular; lateral margins diverging from an acute apex, rounding broadly at about two-thirds the length of the shell, to the slightly transverse anterior margin. Length to greatest width as 6 to 7. Surface convex, sloping more abruptly to the sides than to the anterior margin; covered with low, rather faint and distant concentric lines or wrinkles. Shell-substance comparatively thick, showing fine radiating lines on the inner laminæ. Length of the largest specimen observed, 42 mm.; greatest width, 36 mm.

Waverly group. *Sciotoville and Berea, Ohio.*

Lingula paracletus.

Lingula paracletus, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 172, see p. 12, fig. 8. 1892.

Shell moderately large, broadly spatulate. Posterior margins diverging from an acute beak, rounding slowly to the sides of the shell where the curve is less; the interior margin is subcircular, rarely transverse. The greatest width of the shell is in front of the middle and the proportions of length to greatest width are as 2 to 1.3. Surface ornamented with distant, concentric wrinkles between which are exceedingly fine concentric striæ.

On the interior the valves have a notably broad margin of contact. The internal cast sometimes shows this to be broadest at the middle of the anterior margin; faint radiating striæ are also observable on this cast. The muscular and vascular impressions of the interior are frequently well defined, as described on the page above cited. Length of the original specimen 16 mm., width, 11 mm.

Waverly group; Cuyahoga shales. *Chardon, Ohio.*

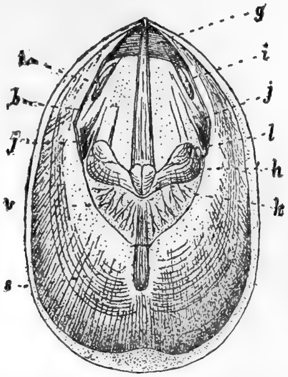


Fig. 1. Lingula paracletus. *h*, centrals; *k*, middle laterals; *l*, outside laterals; *j*, anterior laterals; *i*, transmedians; *g*, umbonal scar.

Lingula tæniola.

Plate 1, fig. 4.

Lingula lamellata, Hall. Palaentology of N. Y., vol. II, p. 55, pl. xx, figs. 4, *a*, *b*, *c*. 1852.

Lingula tœniola, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 173. 1892.

Shell of medium size, with the margins diverging rapidly from the apex for a short distance, thence curving rather abruptly into subparallel lateral margins. The anterior margin is nearly transverse. Surface covered with fine elevated, nearly horizontal ornamental lines, which are crossed in the umbonal region by the concentric growth lines.

Clinton group. *Clinton, N. Y.*

Lingula lingulata.

Plate 1, fig. 2.

Lingula lingulata, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 173, pl. iv k, fig. 5. 1892.

Shell elongate-subquadrate, having somewhat the form of *Lingula oblata*, Hall. Valves very slightly convex. Distinguished from other species by the peculiar deflection of the anterior portion of the shell considerably below the plane of the lateral margins.

Clinton group. *Near Hamilton, Ontario.*

Lingulops Granti.

Plate 1, figs. 7, 8.

Lingulops Granti, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 173, pl. iv k, figs. 14, 15. 1892.

Shell small, linguloid in external aspect. Outline elliptical, subacuminate at the posterior extremity. External surface marked by faint, elevated, equidistant concentric lines. Margin of contact broad and conspicuous about the entire periphery. On the interior of the pedicle-valve the margin is broadest beneath the beak and slightly grooved on its posterior edge for the passage of the pedicle. The central and lateral muscular scars are elevated on a well-developed platform, the ante-lateral margins of which meet each other at an acute angle. In the brachial valve the posterior margin is also broad and faintly grooved, the platform more conspicuously developed both in length, width and height than in the other valve, while the muscular scars have essentially the same arrangement. In neither valve do the specimens at hand afford evidence of the arched parietal impressions seen in the other species of the genus. Length of an average specimen, 5 mm., width, 3 mm.

This species differs from *L. Whitfieldi* and *L. Norwoodi,* not only in the absence of the parietal scars, but also in the development of the muscular area of the pedicle-valve into a distinct platform, and in the absence of the anterior longitudinal septum in the pedicle-valve.

Niagara group. *Hamilton, Ontario.*

Monomerella Greenii.

Plate 1, figs. 9–14.

Monomerella Greenii, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 174, pl. iv d, figs. 5–10. 1892.

Shell enlongate-subovate. Valves comparatively shallow; shell-substance relatively thin. Surfaces of contact very broad, especially toward the posterior portion of the shell. Pedicle-valve with an erect but not high cardinal area, which is continuous with the broad margins. Umbonal cavities very short, rarely reaching to the hinge-line and sometimes scarcely more developed than in DINOBOLUS. Cardinal slope well defined and divided by a deep longitudinal groove. Cardinal buttress faint. Platform scarcely developed; the scars upon its surface usually faint, but the lateral impressions sometimes sharply defined. Crescent and terminal scars generally distinct. Pallial sinuses usually discernible. Brachial valve with a low, rotund beak and transversely striated area. Umbonal cavity deep. The deep groove of the crescent is followed within by a sharply elevated ridge extending for the entire length of the cardinal line; terminal scars generally deeply impressed and apparently compound. Platform represented only by a median thickening of the muscular impressions, having the characteristic V-shaped outline and sometimes divisible into the component scars. From the anterior extremity of this muscular area two diverging ridges pass toward the anterior margin; these may be connected with the pallial sinuses.

This shell is readily distinguished from all other described species by the general tendency toward suppression of the platforms and muscular scars, the broad surface of contact, and the diverging anterior furrows of the brachial valve.

From the dolomites of the Niagara group, between *Cedarburgh* and *Grafton*, *Wisconsin*.

Monomerella Kingi.

Plate 2, figs 1, 2.

Monomerella Kingi, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 174, pl. iv d, figs. 1, 2. 1892.

Shell subcircular or longitudinally oval. Pedicle-valve probably with a low cardinal area, as far as may be judged by the size of the casts of the umbonal cavities, which are quite short, mamiform, not extending to the cardinal line. Cardinal buttress strong, produced as a septum nearly to the anterior edge of the platform. Platform well developed, broadly V-shaped; anterior wall vertical, not excavated; surface marked by strong impressions of muscular attachments. Crescent distinct, terminal scars very prominent. Brachial valve with the umbonal region much thickened; the platform sharply V-shaped, its anterior wall being considerably excavated to form imperfect vaults; the whole elevation is situated somewhat further forward than the opposite valve. A faint longitudinal septum extends a short distance forward from the apex of the platform. Crown of the crescent faint; terminal scars as in the pedicle-valve.

From the magnesian limestone of the Niagara group, near *Cedarburgh, Wisconsin*, in association with *Dinobolus Conradi, Monomerella prisca* and *M. Greenii.*

Monomerella Ortoni.

Plate 2, figs. 4, 5.

Monomerella Ortoni, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 175, pl. iv c, figs. 14, 15. 1892.

Pedicle-valve large, with a high cardinal area, which is gently incurved longitudinally and crossed by lamellose growth-lines, upon which the evidences of the deltidial ridges are extremely faint or altogether wanting. Umbonal cavities conspicuous, but much shorter than is usual in *M. prisca.* Cardinal slope large, triangular and divided by an axial furrow. Cardinal buttress broad at the base but not especially prominent. Platform apparent only at its anterior edge where it has a broad anterior slope. Crescent well defined beneath the hinge-line; terminal scars very prominent; central, lateral and anterior impressions discernible on the platform. Pallial sinuses very strong, the outer ramifications from which are distinctly seen. Brachial valve unknown.

From the Niagara dolomitic limestone, at the *Rising Sun quarries, Wood county, Ohio.*

Monomerella Egani.

Plate 2, fig. 3.

Monomerella Egani, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 175, pl. iv c, fig. 16. 1892.

Brachial valve with an unusually high cardinal area, indicating a quite elevated beak. This area is strongly striated transversely, and bears two faint longitudinal depressions corresponding in position to the deltidial ridges of the pedicle-valve. It is continued laterally nearly to the middle of the margins. Crescent very narrow over the crown, lying close upon the cardinal line; at its turn forward it is developed into a deep, narrow, elongate muscular scar, which is continued into a broader terminal impression. Platform sharply elevated at its anterior edge, sloping rather abruptly backward. Its surface bears the usual tripartite arrangement of the muscular scars. Anterior longitudinal septum distinct. From directly behind the crescent to the central muscular impressions is a very broad, smooth, lunate slope, occupying the position of the simple umbonal cavity usual in this valve of MONOMERELLA, and presenting the appearance of an abnormal deposition or callosity.

Though represented by a single specimen only, this form shows features not elsewhere observed in the genus, viz., the great development of the cardinal area, the composite character of the muscular impressions terminating the crescent, and the broad posterior slope.

From the Niagara group. *Near Grafton, Wisconsin.*

Rhinobolus Davidsoni.

Plate 2, figs. 6-8.

Rhinobolus Davidsoni, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 176, pl. iv b, figs. 10-12. 1892.

Shell with a circular outline, except for the prominence of the beak. Pedicle-valve with a moderately high, acuminate cardinal area, upon which the central area, the deltidial ridges and areal borders have each about the same width. Cardinal slope short; crescent sharply defined; terminal scars distinct. Platform broadly V-shaped, sloping less abruptly backward than in *R. Galtensis.* Pallial sinuses faint. Brachial valve with marginal beak and inconspicuous area. Crescent more prominently developed than in the opposite valve, transverse over the crown as in DINOBOLUS; terminal scars large. Platform more sharply angulated than in the pedicle-valve and somewhat more elevated, bearing conspicuous lateral and anterior scars. Longitudinal septum not pronounced. Pallial sinuses quite distinct.

This species is based upon internal casts of opposite valves, which are in entire harmony with each other and are readily separated from *Dinobolus Conradi* and the various species of MONOMERELLA associated with them at the same locality. It is distinguished from the forms referred to *Rhinobolus Galtensis,* Billings, by its more circular outline, less elevated pedicle-umbo, inconspicuous brachial umbo, and broader, though less sharply elevated platform.

Niagara group. *Near Grafton, Wisconsin.*

Siphonotreta (?) Minnesotensis.

Plate 2, figs. 9, 10.

Siphonotreta (?) Minnesotensis, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 177, pl. iv, figs. 37, 38.

Shell subovate in outline. Pedicle-valve more convex than the brachial, slightly flattened along the median line, sloping with equal convexity toward the lateral and anterior margins. Foramen apical (?). Brachial valve depressed-convex, somewhat elevated about the umbo. Surface covered, in the umbonal region, with fine, anastomosing and gently undulating concentric lines, which, in the later portions of the shell, are finely granulose or serrated; at about one-third the length of the shell coarser varices of growth appear, between which the finer lines are retained. Surface covered with hollow spines of various sizes, which appear to have been most closely set over the umbonal region of the pedicle-valve. Here, where the growth-lines are absent, the spine-bases in the original specimen are large and all of about the same size and are disposed without order. Over the other portions of the shell the spines are set along the edges of the varices, small and large being indifferently mixed. The bases of the spines make annular swellings on the interior of the valves The length of the original specimen is 15 mm., width 12 mm.

Trenton limestone. *Minneapolis, Minnesota.*

Orbiculoidea (Schizotreta) ovalis.

Plate 2, figs. 12, 13.

Orbiculoidea (Schizotreta) ovalis, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 177, pl. iv e, figs. 4, 5. 1892.

Shell subelliptical in outline. Valves with apices situated a little behind the center. Lower valve with the apex erect or inclined slightly forward. External foraminal groove narrow, extending for about one-half the posterior radius of the valve. Surface about the foramen convex, but elsewhere slightly depressed in its slope from apex to margin. Upper valve more elevated than the lower, apex inclined backward, posterior slope gently concave. Surface marked by elevated nearly equidistant concentric striæ. Shell-substance thick, the inner laminæ showing fine radiating lines over the anterior region. Length of the original specimen, 8 mm., width, 6 mm., thickness through the apices of the conjoined valve, 3 mm.

Trenton limestone. *Middleville, N. Y.*

Orbiculoidea numulus.

Plate 2, fig. 11.

Orbiculoidea numulus, Hall. Palaeontology of N. Y., vol. VIII. pt. 1, p. 178, pl. iv e, fig. 14. 1892.

The original specimen is a lower valve, having a nearly circular outline. The apex is subcentral, elevated and directed anteriorly. The external groove of the foramen is moderately broad and extends one-half the length of the posterior radius. The posterior slope is convex while the anterior is depressed or slightly concave. Surface smooth about the apex, thence outward marked by a few distant, elevated, concentric lines or ridges, between which are numerous fine concentric lines. Length and width, 12 mm.

Lower Helderberg group (Waterlime). *Marshall, N. Y.*

Orbiculoidea Herzeri.

Plate 2, figs. 14-20.

Orbiculoidea Herzeri, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 178, pl. iv e, fig. 19, and pl. iv f, figs. 9-13, 30. 1892.

Shell subcircular in outline. Upper valve with an eccentric apex, situated less than one-fourth the length of the shell from the posterior margin, and directed backward. Surface gently convex, sloping evenly forward from the apex, but abruptly depressed on the post-apical region. Lower valve with the apex much nearer the center; shell almost flat. Pedicle-aperture, in the primary stages of development, a triangular opening extending from the apex to the margin; this gradually closes with advancing growth, the external groove at maturity extending from one-half to two-thirds the length of the posterior radius of the valve. On the interior, the groove is frequently more or less enveloped by the development of testaceous deposits. Surface of both valves ornamented by crowded concentric lines and wrinkles. The internal surface of the lower valve sometimes shows fine radiating lines and faint vascular sinuses. Length and width of an adult individual, 14 mm.

Waverly group (Cuyahoga shales). *Berea, Baconsburg and elsewhere, Ohio.*

Lindstrœmella aspidium.

Plate 3, figs. 1–4.

Lindstrœmella aspidium, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p., 178, pl. iv e, figs. 25–28. 1892.

This species is readily distinguished from *Orbiculoidea* (*Rœmerella*) *grandis*, its associate in the fauna of the Hamilton shales, and the only form with which there is danger of confounding it, by the convex pedicle-valve, the distant, elevated, concentric surface-ridges, which have a peculiar undulation as they approach the margins of the foramen. The internal characters of the shell are at once distinctive. (See discussion of these features on page 134, *op. cit.*) Length and width of a mature specimen, 50 mm.

Hamilton group. *Leonardsville, Hamilton, Darien and Canandaigua Lake, N. Y.*

Schizocrania Schucherti.

Plate 3, figs. 5–7.

Schizocrania Schucherti, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 179, pl. iv g, figs. 31–33. 1892.

Shell small, usually found unattached; marginal outline subovate. Surface of pedicle-valve flat or slightly concave; concentrically striated. Pedicle-aperture broad and sharply triangular. Brachial or upper valve strongly convex, often laterally compressed. Umbo full and rotund, incurved at the apex, which is almost, but not quite, marginal. Surface covered by numerous simple, sharply elevated, uninterrupted striæ, frequently crossed by concentric wrinkles. On the interior of this valve only the strong posterior muscular impressions are distinctly shown.

Hudson group. *Cincinnati, Ohio.*

Schizocrania (?) Helderbergia.

Plate 3, figs. 8, 9.

Schizocrania (?) *Helderbergia*, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 179, pl. iv g, figs. 34, 35. 1892.

Shell subcircular in outline. Upper valve convex; apex posterior and marginal. Surface covered with fine, closely crowded, elevated, radiating lines, which extend to the apex, and increase by intercalation. Lower valve flat and of less diameter than the upper. Apex subcentral, posterior. Foramen apparently a narrow triangular slit extending to the margin. A short median septum extends forward from the apex. External surface covered with low, crowded and rather faint concentric lines. On the interior, the surface bears a series of distant, deep but narrow radiating furrows, about twenty-five in number; these do not reach the apex, and increase in number toward the margin. Between them are very fine radiating lines. The animal was parasitic in its habit, attachment being considerably aided by the overlapping margin of the upper valve. Length and width of an average adult; upper valve, 9 mm., lower valve, 7.5 mm.

Lower Helderberg group. *Near Clarksville, N. Y.*

Crania agaricina.

Plate 3, fig. 10.

Crania agaricina, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 180, pl. iv h, fig. 2. 1892.

Shell small. Apex posterior, slighly elevated. Surface covered by a few coarse, elevated, radiating lines, of which about twelve reach the apex. These increase by intercalation toward the margin to about thirty. The edges of these ridges appear to be minutely granulose. Length of the original specimen (allowing for its incurvature upon the surface of attachment), 5 mm.

Lower Helderberg group. *Near Clarksville, N. Y.*

Crania pulchella.

Plate 3, fig. 14.

Crania pulchella, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 180, pl. iv h, fig. 3. 1892.

Shell like that of *C. agaricina*, but larger and with much finer, more numerous radiating ribs. These are about sixty in number at the margin of the valve. Length of the original specimen, 8 mm.

Lower Helderberg group. *Near Clarksville, N. Y.*

Crania granosa.

Plate 3, figs. 11, 12.

Crania granosa, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 180, pl. iv h, figs. 19, 20. 1892.

The original specimen is an upper valve, quite irregular in its growth, with a nearly central beak and strong convexity. The surface is completely covered with closely set granules which are somewhat coarser toward the margins. A few concentric wrinkles of growth are also visible. Diameter, 18 mm.

Hamilton group. *Centerfield, N. Y.*

Crania favincola.

Plate 3, fig. 13.

Crania favincola, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 181, pl. iv h, fig. 33. 1892.

Two interiors of the lower valve attached to a colony of *Favosites pirum* have very strongly developed muscular and vascular impressions. The posterior scars are large and their strongly elevated margins unite with the broad lateral border of the shell. The anterior scars are situated in front of the center and are partially enveloped by the great elevation of the anterior and median fulcra. The vascular sinuses are broad, slightly undulating grooves, extending from the median region to the anterior border. Length, 17 mm., width, 21 mm.

Hamilton group. *Crab Orchard, Kentucky.*

Craniella Ulrichi.

Plate 3, figs. 15, 16.

Craniella Ulrichi, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 181, pl. iv i, figs. 1, 2. 1892.

Shell moderately large. Outline normally circular. Apices subcentral, slightly posterior, inclined backwards. Upper valve with the posterior scars large and the adjustors well defined; anterior scars subdivided, the outer or posterior portion possibly representing the insertion of the brachial muscles. The vascular sinuses make a 3-shaped curve on the lateral portions of the valve, with the crest of the double arch toward the center; narrowing rapidly, becoming indistinct over the anterior region. Lower valve regularly convex, evidently unattached at maturity. Anterior adductors very large, situated on a thickened posterior area. Posterior adductor and adjustor scars very faint, lying just within the margin. The vascular sinuses are a series of low grooves extending forward in subparallel lines from the anterior and lateral margins of the central muscular area. External surface of the valves smooth or covered with concentric sub-lamellose growth-lines. Length of an upper valve, 11 mm.; width, 12 mm.; diameter of a lower valve, 16 mm.

Trenton shale. *Minneapolis, Minnesota.*

Pholidops calceola.

Plate 3, fig. 20.

Pholidops calceola, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 182, pl. iv i, fig. 30. 1892.

Shell small. Outline subelliptical, the posterior margin being narrowed by the extension of the beak, which is long and acute, slightly elevated above the plane of the margin. External surface marked by concentric lamellose growth-lines, which extend about the posterior side of the beak. Muscular area central; posterior margin divided into a broad central and two lateral arches, from the latter the outline extending in a regular curve to the anterior margin. Adductor scars sharply defined. The dorsal (?) valve only is known. Length of the original specimen, 3.5 mm.

Corniferous limestone. *Falls of the Ohio.*

Pholidops patina.

Plate 3, figs 17–19.

Pholidops patina, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 182, pl. iv i, figs. 27–29. 1892.

Shell comparatively large; outline elongate-ovate or elliptical. Length to width as 3 to 4. Apex posterior. Surface covered with lamellose concentric growth-lines, which are crossed by fine, interrupted radiating striæ. The interior of the ventral (?) valve has the anterior and posterior adductors well defined, the latter being lobate. The median scars are well developed and the parietal impression acutely angled at the center. In the opposite valve the anterior edges of the muscular area are sharply elevated, both pairs of adductor scars prominent, and the parietal scar extended posteriorly.

Corniferous limestone; from boulders of decomposed chert. *DeCewville, Ontario.*

Orthis Panderiana.

Plate 4, figs. 1–3.

Orthis orthambonites, Billings. Palaeozoic Fossils, vol. I, p. 77. 1862.
Orthis Panderiana, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, expl. pl. v, figs. 1–3, and foot-note.

This shell was identified by BILLINGS with the *Orthis calligramma*, var. *Orthambonites*, de Verneuil, under the designation *O. orthambonites*, Pander. PANDER, however, did not employ this term in a specific, but in a generic sense, though it was subsequently taken by von BUCH and von EICHWALD as a specific designation to cover all the species referred by PANDER to his genus ORTHAMBONITES. As a specific term it must be accredited to von BUCH, and it is synonymous with some one (it is impossible to say which) of PANDER'S species. The American shell is quite distinct from the Russian *O. calligramma* var. *orthambonites* in its smaller size, fewer and coarser ribs.

"*Pointe Lévis. In the upper part of Limestone No. 2. Quebec group.*" (BILLINGS.)

Orthis? glypta.

Plate 4, figs. 5, 6.

Orthis? glypta. Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 359, pl. lxxxiv, figs. 8, 9. 1894.

Shell small, transverse, with long, straight hinge, making the greatest diameter of the shell; short along the median axis; marginal outline transversely subelliptical. Pedicle-valve with a broad and low median sinus and generally depressed surface. The exterior bears from twelve to sixteen low, flat plications, separated by narrow sulci, and sometimes with a fine groove on the surface of each. These extend from apex to margins, and are crossed by fine, undulating, subconcentric lines apparently in two oblique sets, producing a peculiarly reticulated or wavy surface, similar to that occurring in the Swedish Silurian species, *O. Loveni*, Lindström. The muscular area of the pedicle-valve is small. Length of an average pedicle-valve, 12 mm., width, 18 mm.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Orthis flabellites var. spania.

Plate 4, fig. 4.

Orthis flabellites var. *spania*, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxiv, fig. 10. 1894.

Shell with the general aspect of *O. flabellites*, Hall, but with very coarse plications, scarcely more than one-half the number usual in that species.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Orthis ? Holstoni (*Safford*), *Hall.*

Plate 4, figs. 19–21.

Orthis ? Holstoni, Safford. Palaeontology of N. Y., vol. VIII, pt. 1, p. 340, pl. v a, figs. 35–37. 1892.

Shell transverse; outline semicircular. Hinge-line long and straight. Pedicle-valve with a high, vertical, cardinal area, transected by a very broad, uncovered delthyrium; beak not incurved; surface sloping evenly toward the margins, slightly rounded in the median line, and faintly depressed toward the cardinal angles. Brachial valve depressed convex, nearly flat, with a broad and low median sinus.

Surface of both valves covered with fine, elevated, radiating striæ, crossed by faint, concentric, cancellating lines which have a slight retral bend on the striæ.

This shell has very much the aspect of a CLITAMBONITES, but of the two specimens examined, neither has evidence of a deltidium plate, and a transverse section across the umbo of one, shows that the dental lamellæ, though strong and convergent, did not unite to form a spondylium. Received from Professor SAFFORD.

Trenton horizon (Glade limestone). *Near Nashville, Tennessee.*

Orthis (Plæsiomys) loricula.

Plate 4, figs. 7–9.

Orthis (*Plœsiomys*) *loricula*, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 341, pl. v a, figs. 32–34. 1892.

Shell strophomenoid in outline; reversed convex. Hinge-line long and straight, making the greatest diameter of the shell. Cardinal areas narrow, subequal. In the pedicle-valve the delthyrium is covered by a convex plate extending for one-half its length; the area is erect, the beak not prominent. The valve is slightly convex in the umbonal region, but is depressed outward in all directions, most strongly in the median line. The brachial valve is depressed about the beak, convex over the pallial region and divided in the median line by a shallow sinus. The interior characters of the valves are essentially the same as those in *Orthis subquadrata.*

External surface covered with numerous fine, elevated striæ, alternating in size and crossed by finer concentric lines.

Length of an average specimen, 18 mm.; width, 21 mm.

Trenton horizon. *Fountain, Minnesota.*

Orthis ? Saffordi.

Plate 4, figs. 10–12.

Orthis ? Saffordi, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 340, pl. v a, figs. 38–40. 1892.

Shell semielliptical in outline; valves subequally convex, the pedicle-valve being the more elevated at the apex. Hinge-line long and straight, giving the shell a strophomenoid appearance. Cardinal area low; delthyrium uncovered.

Surface covered with numerous rounded, sharply elevated striæ, increasing by intercalcation, and crossed by exceedingly fine concentric lines. The details of the interior are not known, but the relations of the shell to ORTHIS are demonstrated by the open delthyrium and simple cardinal process, slightly lobate on its posterior face.

Length of the type specimen, 17 mm.; width along the hinge, 22 mm.

Trenton horizon. *East Tennessee.*

Orthis (Dalmanella) arcuaria.

Plate 4, figs. 13, 14.

Orthis (Dalmanella) arcuaria, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 341, pl. v c, figs. 20, 21. 1892.

Shell with a general similarity to that of *Orthis elegantula*, Dalman, but having the marginal outline more circular, the pedicle-valve more evenly convex, the umbo more prolate, and the brachial valve considerably more convex. The pedicle-valve bears a broad fold, and the brachial a shallow sinus, in the median line. In the interior of the pedicle-valve the muscular area is elongate and very deeply impressed, the umbonal portion of this valve being considerably thickened.

Surface covered with numerous very fine radiating striæ.

Length of the type specimen, 19 mm.; width, 18 mm.; depth, 9 mm.

Hudson River group. *East Tennessee.*

Orthis (Dalmanella) superstes.

Plate 4, figs. 15–18.

Orthis (Dalmanella) superstes, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 342, pl. v c, figs. 44–47. 1892.

Shell of small size and having the general form and expression of *O. hybrida*, Sowerby. Hinge-line short, beaks but slightly elevated. Marginal outline varying from subquadrate to subcircular. Valves about equally convex. In the pedicle-valve the beak is somewhat inflated and slopes evenly in all directions for nearly one-half of the shell; from this point onward is a broad, low median sinus, which is most conspicuously developed in old and gibbous shells. In rare instances there is a low elevation in the bottom of this sinus. The opposite valve also bears a median sinus which takes its origin at the beak. In the interior of the pedicle-valve the muscular area is sharply defined, subquadrate in outline, the adductor scars small and the diductors well developed. In the brachial valve the cardinal process and crural plates are prominent; the muscular area well defined and quadruplicate.

The external surface of the valves is covered with fine, elevated striæ, of which twenty of the coarsest reach the beak; this number increasing by intercalation to about fifty at the margin. Near the margin very fine concentric striæ are visible.

Length of normal individual, 12 mm.; width, 13 mm.; depth, 9 mm.

Chemung group. *Near Howard, Steuben county, N. Y.*

Orthis (Rhipidomella) Oweni.

Plate 4, figs. 24–26.

Orthis (Rhipidomella) Oweni, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 342, pl. vi, figs. 19–21. 1892.

Shell having somewhat the outline of *O. Vanuxemi*, but more elongate transversely and gently sinuate or emarginate on the anterior edge. The shells are usually flattened, but where the form is retained the pedicle-valve shows a hinge-line whose length is somewhat less than one half the transverse diameter of the shell. The beak is acute, the umbo full but not conspicuous. Along the center of the valve is a broad, low sinus, frequently very inconspicuous. The interior of this valve is characterized by the relatively small area covered by the muscular scars, a feature in which it resembles *O. Peloris* of the Schoharie grit. The pallial region is pitted or covered with faint, closely anastomosing ridges. On the brachial valve the median sinus begins at the apex and becomes very pronounced as it widens anteriorly. From the ridges forming its lateral margins the surface slopes rather abruptly and without much curvature. On the interior the cardinal process and crural plates are not prominently elevated; the muscular area is small, quadripartite, the lateral pairs of scars being separated by a broad, thick ridge.

Surface of both valves covered by a great number of fine radiating, hollow striæ, from 110 to 130 in number, which are crenulated by minute concentric lines and crossed at intervals by coarser lines of growth. The surface was originally covered with short spinules, which are rarely preserved. This shell has heretofore been commonly referred to *Orthis Michelini*, Léveille.

Keokuk group (Knobstone formation). *Button-mould Knobs, Kentucky.*

Orthis (Schizophoria) senecta.

Plate 4, figs. 22, 23.

Orthis (*Schizophoria*) *senecta*, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p 343, pl. vi a, figs. 23, 24. 1892.

Shell subquadrate or transversely elliptical, resupinate, unequally biconvex. The pedicle-valve is depressed convex in the umbonal region and develops a broad, low median sinus toward the anterior margin. The brachial valve is the more convex and slopes evenly toward the lateral margins, the median region being rendered slightly more prominent by an obscure fold.

Internal markings as in other members of SCHIZOPHORIA.

External surface covered with fine, subequal, closely covered radiating striæ.

Length of a typical example, 17 mm.; width, 21 mm.

Clinton group. *Reynale's Basin, Niagara county, New York.*

Orthotropia dolomitica.

Plate 6, figs. 4–8.

Orthotropia dolomitica, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxiv, figs. 3–7. 1894.

Shell known only from internal casts, which are somewhat elongate, biconvex; the pedicle-valve having a prominent and slightly arched umbo, and a distinct, triangular cardinal area. The hinge-line is straight, but shorter than the greatest width of the valves. Both valves are most convex in the umbonal region, and slope to the anterior margin, each with a median sinus. The delthyrium is open; the muscular impression of the pedicle-valve short, deep and restricted to the rostral region. Its margin is elevated and a short vertical median septum extends from its anterior margin. In the brachial valve the muscular impression is very narrow, also has elevated edges and a median septum.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Strophomena Conradi.

Plate 4, figs. 27–30.

Strophomena Conradi, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 344, pl. ix a, fig. 3, and pl. xx, figs. 32, 33. 1892.

Shell semiovate in outline; hinge-line straight and forming the greatest diameter of the shell. Cardinal area narrow on both valves; broader on the pedicle-valve and but slightly elevated at the umbo. Delthyrium covered; deltidium perforated at the apex. Pedicle-valve convex in the umbonal region, but becoming deeply depressed and concave over the middle of the shell and again elevated about the margins. The depression of the valve is most conspicuous along the median line and on the anterior margin where it produces a subnasute extension. The brachial valve is flat or slightly concave at the umbo, becoming convex over the pallial region; it reaches its greatest convexity at about the middle of the shell and is thence deflected gradually in the median line and more abruptly on the lateral slopes.

Surface of the shell covered with radiating striæ, arranged in fascicles of 4 to 7 fine ones between each pair of coarser ones. There are no concentric rugæ on either valve, but the radiating striæ are crossed by exceedingly minute concentric lines.

Width of the original specimen along the hinge, 23 mm.; greatest length, 19 mm.

Trenton limestone. *Jacksonburg, N. Y.*

Strophomena Winchelli.

Plate 4, figs. 31-33.

Strophomena nutans, Hall. Rept. State Geologist N. Y. for 1882, expl. pl. (ix) 39, figs. 10, 12-14. 1883.

Strophomena Winchelli, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 344, pl. ix, figs. 10, 12-14, and pl. xx, fig. 26, 1892.

Shell elongate semiovate; strongly convexo-concave. Hinge-line straight and making the greatest diameter of the shell. Cardinal angles sometimes extended. Pedicle-valve with a moderately broad area and deltidium; apex slightly elevated, the valve becoming deeply concave over the pallial region and reflected at the margins. The teeth are strong and divergent, and from their bases extend elevated curving ridges which form the margin of the subcircular or subovate muscular area. Diductor scars broad, inclosing an elongate and narrow adductor. Within the anterior and lateral margins of the valve is a thickened ridge which is crossed by branches of the vascular sinuses. Brachial valve flat in the umbonal region, very convex over the median portion and sloping gradually to the margins. The cardinal process consists of two slender and short apophyses which are united at their base with the crural plates. The latter are very divergent and extend in a broad curve subparallel to the hinge-line. The muscular scars consist of two pairs, the posterior being broad and striated, the anterior narrow and close to the median line. The members of the pairs are separated by a low median ridge. Surface of the shell covered with numerous very fine filiform striæ, regularly but not conspicuously alternating in size. Delicate concentric striæ are sometimes discernible.

Trenton horizon. *Clifton and Janesville, Wisconsin.*

This shell has been referred to the *Hemipronites nutans*, James (Meek), of the Hudson River group, which it resembles in its general expression. It differs from this species in its internal characters and more finely and abundant striated exterior.

Orthothetes desideratus.

Plate 5, figs. 1, 2.

Streptorhynchus, sp.? Hall. Rept. State Geologist N. Y. for 1882, pl. (xi a) 42, figs. 26, 27. 1883.

Orthotetes desideratus, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 345, pl. ix a, figs. 26, 27. 1892.

The original specimens of this species are internal casts of a form with a subcircular marginal outline, very gibbous brachial valve which has its greatest convexity central and slopes evenly to the margins, though with a slight tendency to depression toward the cardinal extremities; a strongly and regularly concave pedicle-valve, elevated at the beak and about the margins. The cardinal area on this valve is moderately high and erect, the hinge-line being slightly shorter than the greatest diameter of the valves. The surface of both valves is covered with numerous fine radiating striæ. The general form and contour of the species is very similar to that of *Orthothetes umbraculum* of the Eifel.

Waverly group. *Medina county, Ohio.*

Derbya ruginosa.

Plate 5, figs. 12–14.

Derbya ruginosa, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 346, pl. xi a, figs. 25–27. 1892.

Shell subelliptical in outline. Hinge-line short, its length being about two-thirds the greatest diameter of the shell. Pedicle-valve shallow; cardinal area moderately high, its lateral slopes being slightly more than one-half the length of its base; apex scarcely prominent; surface depressed or flat in the umbonal region, becoming irregularly concave anteriorly. Entire valve very irregular in growth, with concentric ridges and furrows. Brachial valve very convex; apex depressed, but the umbonal region gibbous, the greatest convexity being reached at the center of the valve. This valve is also of irregular growth, though the irregularities are not so strongly developed as on the opposite valve. The original specimen is an internal cast in chert to which portions of the inner laminæ of the shell adhere. There are evidences of a flabellate muscular scar on the pedicle-valve and a short ovate muscular area in the brachial valve.

The traces of the surface striæ preserved show them to have been very fine and numerous.

Keokuk limestone. *New Providence, Indiana.*

This species is similar in some general respects to *Derbya Broadheadi*, but differs in its narrower and lower cardinal area, less convex umbo on the brachial valve and in the absence of a median sinus on this valve. It may be compared with the *Streptorhynchus crenistria*, var. *senilis*, Phillips (Davidson), from the lower Carboniferous of Great Britain.

Derbya? costatula.

Plate 5, fig. 9.

Derbya? costatula, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 346, pl. xi b, figs. 16, 17. 1892.

Shell small, outline semioval. Hinge-line nearly equal to the greatest diameter of the valve. Cardinal area moderately high, with a prominent deltidium very wide at the base. Pedicle-valve with an elevated beak from which the surface slopes to the margins with a tendency to irregular growth. Brachial valve faintly depressed at the umbo, but otherwise pretty regularly convex, the most elevated point being a little behind the middle of the valve. There is a faint median sinus over the anterior region.

Surface marked with a few coarse radial ribs, between each two of which are implanted one, two or three much finer ones. These ribs are crossed by a few distinct concentric varices of growth.

Chester limestone. *Crittenden county, Kentucky.*

This species is readily distinguished by the character of its surface ornamentation, and though the interior features of the shell are as yet unknown, a very closely allied form from the upper Coal Measures near Kansas City has a well developed median septum in the pedicle-valve, and is hence to be referred to the genus DERBYA.

Derbya Broadheadi.

Plate 5, figs. 15, 16.

Derbya Broadheadi, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 347, pl xi a, figs. 23, 24. 1892.

Shell with irregularly suboval marginal outline. Hinge-line short, its length not exceeding and usually less than one-half the greatest diameter of the valves. Cardinal area of the pedicle-valve high, sometimes regularly triangular, often distorted or somewhat incurved; deltidium broad at the base and rapidly tapering with a faint median groove on its surface. Pedicle-valve convex in the umbonal region, irregularly rugose and depressed over the pallial area. Brachial valve very gibbous at the umbo, the greatest convexity being behind the center of the valve. From the umbonal region the surface slopes evenly toward the lateral and anterior margins, but is more abruptly depressed toward the cardinal extremities where it forms short subalate expansions. The valve is but slightly unsymmetrical and is bilobed by a conspicuous median sinus which takes its origin near the umbo, and widens to the anterior margin.

Surface covered by fine radiating striæ which are of subequal size over the umbonal region, but toward the margin became arranged in fascicles on account of the addition of finer striæ as growth advances. Concentric rugæ and growth-varices are frequent, especially on the pedicle-valve.

Upper Coal Measures. *Near Kansas City, Missouri.*

Derbya Bennetti.

Plate 5, figs. 3-8.

Derl ya Bennetti Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 348, pl. xi a, figs. 34-39. 1892.

Shell subtrihedral in general aspect, quite irregular in its growth. Hinge-line short, its extremities on both valves being auriculate. Pedicle valve much the more irregular in growth, sometimes retaining the scar of attachment at its apex. Cardinal area unusually high, narrow, erect or slightly incurved, and frequently distorted; delthyrium curved. General surface of the valve depressed-convex in the middle, sometimes rapidly sloping in all directions, at others concave in the umbonal region; as a rule very unsymmetrical. The brachial valve is deep, more regularly convex and has a full rounded umbo and a conspicuous median sinus. On the interior the pedicle-valve bears an extremely high median septum which is united with the dental ridges near the apex. The cardinal process is high, erect and deeply bilobed, each of its apophyses being strongly grooved on its posterior face. Other internal characters unknown.

The surface of both valves is covered by fine, elevated, thread-like striæ increasing very slowly by intercalation. The edges of these striæ bear numerous minute asperities which may be due to the crossing of fine concentric lines. Irregular lines and wrinkles of growth are abundant near the margins.

Upper Coal Measures. *Near Kansas City, Missouri.*

Derbya cymbula.

Plate 6, figs. 1, 2.

Derbya cymbula, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 348, pl. xi b, figs. 2, 3. 1892.

Shell large; marginal outline transversely subelliptical. Hinge-line straight, its length being about two-thirds the greatest diameter of the shell. On the pedicle valve the cardinal area is high, its base being one-third longer than its sides, and it may be somewhat unsymmetrical from distortion. Its surface is finely striated both longitudinally and transversely, and is divided into an outer and inner portion by two lines diverging from the apex and meeting the hinge-line halfway between its extremities and the edges of the deltidium. Deltidium broad at the base, rapidly narrowing for one-third its length, whence tapering more gradually to the apex; its surface is marked by a well defined median groove for its entire extent. The surface of the valve is elevated in the umbonal region and slopes somewhat irregularly to a low depression over the pallial region and about the margins. The brachial valve is broadly concave at the umbo, but rapidly becomes regularly convex, the greatest convexity being in the middle of the valve, whence it slopes almost equally in all directions. There is no evidence of a tendency to irregular growth in this valve. Surface covered with numerous fine, sometimes irregular striæ, increasing by implantation. Over the umbonal and pallial regions these striæ are of about equal size, but about the margins the tendency to fasciculate arrangement is more apparent. Interior structure, except the existence of a median septum in the pedicle-valve, unknown.

Upper Coal Measures. *Near Kansas City, Missouri.*

Derbya affinis.

Plate 5, figs. 10, 11.

Derbya affinis, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 349, pl. xi b, figs. 4, 5. 1892.

Shell subsemicircular in outline, somewhat transverse. Hinge-line straight, nearly equaling the greatest diameter of the valves. Cardinal area of the pedicle-valve high, its greatest height being about equal to one-third the length of the hinge-line; divided by diverging lines as in the preceding species and crossed by conspicuous horizontal and fainter vertical striations. This area is often much distorted. Deltidium having a width at the base equal to one-fifth the length of the hinge-line; it tapers evenly to the apex and bears a median groove on its surface. The umbo is elevated, but the surface of the valve becomes depressed, irregular in growth and concentrically wrinkled, though not concave anteriorly. Brachial valve faintly depressed at the apex, but rapidly becoming convex, the greatest convexity being in the umbonal region, whence the slope is quite regular in all directions, being somewhat more abrupt toward the cardinal extremities. This valve also shows a slight tendency to unsymmetrical growth in the umbonal region.

Surface covered by sharply defined, subequal radiating striæ, which increase by implantation. The grooves between these striæ are deep, and both striæ and grooves are crossed by fine concentric lines, which on the former produced a series of sharp asperities. Interior, with the exception of the median septum in the pedicle-valve, unknown.

Upper Coal Measures. *Near Kansas City, Missouri.*

There are many points of similarity in the *Orthis Kaskaskiensis*, McChesney, from the Kaskaskia limestone, *Derbya cymbula* and the species under consideration. All have the same general aspect. In *O. Kaskaskiensis* the brachial valve is most convex at the umbo, the pedicle-valve generally concave and the hinge line equal to the greatest diameter of the shell; in *Derbya affinis* the brachial valve also has its greatest convexity at the umbo, but the hinge line is considerably shorter than in McCHESNEY's species, and there is a notable difference in the character of the surface striæ; while in *Derbya cymbula* the convexity of the brachial valve is greatest at its center, the hinge-line very short and the pedicle-valve concave or depressed only over the pallial region.

Derbya (?) biloba.

Plate 5, figs. 17, 18.

Derbya (?) biloba, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 350, pl. xi, figs. 4, 5. 1892.

Shell small, obcordate in outline. Hinge-line short and straight, its length being considerably less than one-half the width of the shell. On the pedicle-valve the cardinal area is moderately high and slightly arched backward; delthyrium covered. The surface of the valve is somewhat depressed or flattened over the pallial region. The brachial is deeper and more convex, the umbo is full but not elevated, and just in front of the apex there begins a broad and conspicuous sinus which widens rapidly and renders the shell bilobate on its anterior margin.

Surface covered with numerous fine radiating striæ. Interior unknown.

Upper Coal Measures. *Winterset, Iowa.*

Streptorhynchus Ulrichi.

Plate 6, fig. 3.

Streptorhynchus Ulrichi, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 351, pl. xi b, fig. 15. 1892.

Shell of comparatively large size for this genus. General contour subtrihedral. Hinge-line shorter than the greatest diameter of the valves. Cardinal area high, somewhat incurved and distorted; sides considerably shorter than the base. Deltidium broad. Marginal outline of the pedicle-valve, from hinge-line forward, semiovate, somewhat irregular, contracted toward the hinge and expanding in the pallial region. The interior of the pedicle-valve shows strong teeth, the dental lamellæ extending downward and inclosing the posterior portion of an ovate muscular scar. There is no median septum. External surface convex in the upper part, becoming depressed toward the anterior margin; quite irregular in growth, being crossed by more or less conspicuous concentric ridges or varices; covered with numerous fine radiating, subequal striæ, which increase by implantation. Brachial valve not known.

Chester limestone. *Crittenden county, Kentucky.*

Triplecia Niagarensis.

Plate 7, figs. 1–4.

Triplecia Niagarensis. Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxiii, figs. 16–20. 1894.

Shell of medium size with biconvex valves, the pedicle-valve having a deep median sinus, and the brachial an elevated fold. The brachial valve is much the more convex. Both lateral slopes and median fold and sinus are plicated by well-defined rounded ribs.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Christiania subquadrata.

Plate 6, figs. 13–18.

Leptæna subquadrata, Hall. Rept. State Geologist N. Y. for 1882, pl. (xv) 46, figs. 32, 33. 1883.

Christiania subquadrata, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 351, pl. xv, figs. 32, 33; pl. xv a, fig. 36, and pl. xx, figs. 18–20. 1892.

Shell small, elongate, semielliptical in outline, strongly convexo-concave. Hinge-line short, straight, not equaling the greatest diameter of the valves anteriorly. In the pedicle-valve the umbo is full, rounded and incurved, with the apex obscure; the cardinal area is moderately broad and bears an open delthyrium which terminates above in a circular foramen. The teeth are short, divergent and continued into ridges which form the lateral margins of two linguiform, muscular scars, traversing the shell for almost its entire length. These scars inclose two much shorter impressions. In the brachial valve the area is narrow, the cardinal process bipartite on its anterior face, each of the lobes being grooved behind. The crural plates are very long and divergent, the upper portion of each terminating in an elevated extremity; the lower portion produced on each side as a strongly elevated ridge, curving slightly inward on the sides, then outward on approaching the anterior margin of the valve; each branch recurving and passing backward, parallel to the median axis, as far as the base of the cardinal process. The symmetrical spaces thus formed are each divided transversely by a somewhat lower vertical ridge. Between the inner muscular walls in the median line is a low, rounded, longitudinal ridge.

The surface is smooth or covered with concentric, usually somewhat squamous lines of growth.

Lower Helderberg group. *Perry county, Tennessee.*

Leptænisca adnascens.

Plate 6, figs. 26, 27.

Leptœnisca adnascens, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 352, pl. xv a, figs. 22, 23. 1892.

Shell small, very irregular in outline; cemented to shells of other brachiopods, especially of ORTHIS, by the entire external surface of the pedicle-valve. Hinge-line making the greatest diameter of the shell. Cardinal area well developed on the pedicle-valve and bearing a convex deltidium. Internal characters as in *L. tangens.* Brachial valve prominent at the beak, elevated in the umbonal region and slightly depressed anteriorly. Surface smooth or with irregularly concentric wrinkles.

Lower Helderberg group (Shaly limestone). *Near Clarksville, N. Y.*

Leptænisca tangens.

Plate 6, figs. 19–25.

Leptœnisca tangens, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 352, pl. xv a, figs. 24–30. 1892.

Shell transverse; hinge-line making the greatest diameter; contour regularly convexo-concave; attached by the apical or umbonal portion of the pedicle-valve, usually fronds and twigs of bryozoa. Cardinal areas narrow; delthyrium covered. In the pedicle-valve teeth not prominent but continued into strong, converging lamellæ which nearly enclose an oval muscular area; this area is divided by a median septum. External surface convex; bilobed by a more or less conspicuous median furrow. Brachial valve strongly concave.

Surface smooth, with a few inconspicuous concentric growth-lines, and faint radiating striæ on the inner lamellæ toward the margins.

Lower Helderberg group (Shaly limestone). *Near Clarksville, N. Y.*

Chonostrophia Helderbergia.

Plate 7, fig. 11.

Chonostrophia Helderbergia, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 353, pl. xv b, fig. 14. 1892.

Shell tenuous, semielliptical in outline. Hinge-line straight and making the greatest diameter of the valves. Valves nearly flat, the pedicle-valve being gently concave and the brachial correspondingly convex. Cardinal areas very narrow; marginal spines not observed. Teeth of the pedicle-valve well developed on either side of the moderately broad delthyrium; at their bases arises a median septum, strongest at the point of beginning and continuing for one-half the length of the valve. In the brachial valve the crural plates are very short, subparallel to the hinge-line and apparently coalesced with the short cardinal process. No traces of muscular scars retained.

Surface covered with a great number of exceedingly fine, subequal radiating striæ, all of which are apparent on the interior of the shell, even to the bases of the teeth and crural plates.

Lower Helderberg group (Shaly limestone). *Albany county N. Y.*

Strophalosia Rockfordensis.

Plate 7, figs. 6–10.

Strophalosia Rockfordensis, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, p. 353, pl. xvii a, figs. 1–3. 1892.

Shell semielliptical in outline, somewhat elongate. Hinge-line scarcely as long as the greatest diameter of the valves. Cardinal area well developed on each valve, that of a pedicle-valve bearing a convex deltidium; scar of attachment on the pedicle-valve covering only the apical region.. Surface regularly convex, depressed toward the cardinal angles; bearing scattered spines, of which there is a well-defined row of six or seven on the cardinal margin. There are faint, irregularly concentric wrinkles among the spine-bases. Apex of the brachial valve convex, but the valve rapidly becomes concave, being of somewhat less curvature than the opposite valve. Surface with conspicuous, irregular, concentric corrugations, and a few short spines over the pallial region.

Length of the original specimen, 9 mm.; width along hinge-line, 10 mm.

Upper Devonian. *Rockford, Iowa.*

Strophonella costatula.

Plate 6, figs. 9, 10.

Strophonella costatula, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 359, pl. lxxxiv, figs. 15, 16. 1894.

Shell subsemicircular in outline; hinge-line straight or slightly arched; surface depressed concavo-convex.

Pedicle-valve elevated at the beak, becoming rapidly depressed anteriorly, the median depression continued upon the short linguiform extension at the anterior margin. Corresponding to this depression is a broad anterior fold on the opposite valve. The surface of both valves is covered with a few coarse, round, sharply elevated ribs, which rapidly bifurcate or multiply by implantation. These are more or less irregular or sinuous, elevated at the concentric varices and crossed by faint concentric lines.

The typical example has a length of 21 mm., and a width on the hinge of 24 mm.

Niagara group. *Louisville, Kentucky.*

Plectambonites producta.

Plate 6, figs. 11, 12.

Plectambonites producta, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 360, pl. lxxxiv, figs. 23, 24, 25. 1894.

The original of this species is an internal cast of the pedicle-valve, with short, straight hinge; rather narrow, depressed umbo, the shell becoming highly convex and greatly produced anteriorly. The sides of the valve are somewhat appressed medially and the anterior margin slightly expanded and suboval in outline. The cast shows the impression of short, divergent dental plates and a moderately broad muscular impression. The width of the shell on the hinge is 10 mm; its length, 23 mm; its convexity from the posterior margin, 8 mm.; from the anterior margin, 28 mm.

Niagara dolomites. *Yellow Springs, Ohio.*

Strophalosia cymbula.

Plate 7, fig. 5.

Strophalosia cymbula, Hall. Palaeontology of N. Y., vol. VIII, pt. 1, expl. pl. xvii a, figs. 3, 4, 8, 9. 1892.

Shell of medium size, convexo concave, hinge-line, cardinal area, deltidium and chilidium well developed. Brachial valve smooth, pedicle-valve spinose, with a distinct scar of attachment confined to the apex.

Keokuk group. *Lebanon, Kentucky.*

Spirifer crispatus.

Plate 7, figs. 12, 13.

Spirifer crispatus, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 360, pl xxxvi, figs. 9, 10. 1894.

Shell small, with moderately high, incurved area, scarcely extended on the hinge; well-developed median fold and sinus, and three coarse plications on each lateral slope. The surface is covered by conspicuous concentric lamellæ.

Niagara group. *Maryland.*

Spirifer Canandaiguæ.

Plate 7, figs. 14–16.

Spirifer Canandaiguæ, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 360, pl. xxxvii, figs. 23, 24, 26. 1894.

Shells of rather small size, having somewhat the aspect of an elongate and umbonate *S. fimbriatus.* Umbo of pedicle-valve prominent, narrow and closely incurved at the apex. Hinge-line quite short, cardinal area small, incurved. Median sinus deep, produced on the anterior margin, its anterior width being nearly equal to the length of the hinge. On each lateral slope are from two to four low radial undulations or plications, all of which are sharply defined at the umbones. Surface covered with very fine, closely crowded concentric lines which are granulous and were originally fimbriate. Length of typical specimen, 21 mm.; greatest width, 22 mm.; length of hinge, 10 mm.

Hamilton group. *Centerfield and Canandaigua Lake, N. Y.*

Spirifer mucronatus, CONRAD, var. posterus.

Plate 7, figs. 20-24.

Spirifer mucronatus, Conrad, var. *posterus*, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 361, pl. xxxiv, figs. 27-31. 1894.

A late variety of the typical Hamilton form, characterized by its small size, usually narrow bodies and acuminate cardinal extremities.

Chemung group. *Tompkins county, N. Y.*

Spirifer disjunctus, SOWERBY, var. sulcifer.

Plate 7, fig. 27.

Spirifer disjunctus, Sowerby, var. *sulcifer*, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 361, pl. xxx, fig. 16. 1894.

This variety is distinguished by the sharply defined median sulcus on the folds of the brachial valve. It has heretofore been embraced within the limits of *S. disjunctus*, but the character referred to appears to be persistent.

Chemung group. *Near Olean, N. Y.*

Spirifer Williamsi.

Plate 7, figs. 17-19.

Spirifer Williamsi, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 361, pl. xxxvii, figs. 20-22. 1894.

Shells of the form of *Spirifer increbescens*, Hall, and varying but little in size. Median fold and sinus well developed. The latter bearing usually three, sometimes four plications, finer than those on the lateral slopes. Of these the median plication is generally the strongest. This, however, is not always the case, the arrangement of these plications being frequently quite irregular. The median fold generally bears a median groove and one lateral plication on each side. On each lateral slope of the shell are seven or eight plications.

A normal example measures: Length, 15 mm.; width on hinge, 24 mm.

Chemung group. *Allegany county, N. Y.*

Spirifer Newberryi, Hall. 1883.

Plate 7, figs. 25, 26.

Spirifer Newberryi, Hall. 2nd Ann. Rept. State Geologist, pl. (xxxi) 56, figs. 9, 10. 1883.

Spirifer Newberryi, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 362, pl. xxxi, figs. 9, 10. 1894.

Shell moderately large, with sharp cardinal angles. Surface plication consisting of numerous fine simple or duplicate ribs which cover the median fold. On each lateral slope there are twenty-five to thirty of these plications. The plications and the grooves between them are covered with fine radiating lines.

Waverly group. *Ohio.*

Cyrtia radians.

Plate 7, figs. 28, 29.

Cyrtia radians, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 362, pl. xxviii, figs. 4, 5, 50, 52; pl. xxxix, fig. 33. 1894.

The typical form is of medium size, with high area, incurved umbo and general cyrtiniform aspect. Its outer surface is characterized by an absence of plications and fine radial striæ. Median fold and sinus well developed.

Clinton group. *Rochester, N. Y.*

An allied but larger form, here referred to this species, occurs in the Niagara dolomites, near Milwaukee, Wisconsin.

Cyrtina umbonata, Hall, var. Alpenensis.

Plate 8, figs. 9–13.

Cyrtina umbonata, Hall, var. *Alpenensis*, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 362, pl. xxviii, figs. 16–20. 1894.

Cyrtina umbonata, Hall, from the original locality in Iowa, is a small shell, often obscurely plicated; this variety possesses the contour of *C. umbonata*, but is a larger and more robust shell with broad and well-defined plications, smooth median fold and sinus.

Hamilton group. *Alpena, Michigan.*

Cyrtina lachrymosa.

Plate 8, figs 1–3.

Cyrtina lachrymosa, Hall. Palæontology of N. Y., vol. VIII, pt. 2, p. 362, pl. xxviii, figs. 36, 37, 47. 1894.

Shells small; cardinal area high, more or less incurved. Surface with low and rather narrow median fold and sinus, on each side of which are two or three low, faint plications. Lateral margins of the cardinal area broadly rounded. Surface covered with elongate pustules, some of them coarse, but the greater number quite fine.

Height of an average specimen, 5 mm.; width and length 6 mm.

Waverly group. *Richfield, Ohio.*

Syringothyris Missouri.

Plate 8, figs. 14–16.

Syringothyris Missouri, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 363, pl. xxxix, figs. 29–31. 1894.

Shell small, cyrtiniform; cardinal area high, slightly incurved toward the apex; lateral cardinal margin broadly rounded, rendering the definition of the area quite obscure. Median fold and sinus neither wide nor highly developed. Surface of both smooth. Each lateral slope with five or six low plications. Interiorly the pedicle-valve bears strong divergent dental lamellæ which are attached to the surface of the valve for fully one-third of its length. There is no median septum. The transverse delthyrial plate is thin and is developed into a delicate but distinct tube. Shell substance highly punctate on the inner laminæ. Height of original specimen, 13 mm.; cardinal width, 18 mm.; length, 15 mm.

Choteau limestone. *Choteau Springs, Missouri.*

Athyris densa.

Plate 9, figs. 3–9.

Athyris densa, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 364, pl. xlvi, figs. 6–12. 1894.

Shell transversely elongate, valves compressed; median fold and sinus not conspicuously developed. Pedicle-valve shallow, with broad, sharply angled cardinal slopes, greatly thickened interiorly. The anterior margin is frequently extended into a linguate process at the termination of the median sinus. Brachial valve the more convex, with an indistinct, flattened, and sometimes broadly grooved median fold with regular and even lateral slopes. In the interior of the valves the form of the muscular scars is normal, though there is a notable variation in the size of the diductor scars.

St. Louis group. *Washington county, Indiana; Colesburgh, Kentucky.*

Seminula Rogersi.

Plate 9, figs. 10–13.

Seminula Rogersi, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 364, pl. xlvii, figs. 1–4. 1894.

Shell rather small, suboval in outline. Valve subequally convex. Pedicle-valve with a low, broad median sinus and brachial valve with a corresponding fold, both becoming more distinct toward the anterior margin. Lateral slopes depressed-convex. Umbones not conspicuous; deltidium concealed.

External surface smooth.

A normal individual measures 15 mm. in length, and 13 mm. in greatest with.

Pendleton sandstone (Schoharie grit). *Pendleton, Indiana.*

Seminula Dawsoni.

Plate 9, figs. 14–16.

Seminula Dawsoni, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 364, pl. xlvii, figs. 32–34. 1894.

This species was originally identified as *Athyris subtilita*, Hall, by DAVIDSON (Quarterly Journal of the Geological Society of London, vol. XIX, 1863). Its differences from this species are indicated on the pages referred to.

Carboniferous limestone. *Windsor, Nova Scotia.*

Torynifer criticus.

Plate 9, fig. 1.

Torynifer criticus, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxiv, figs. 34, 35. 1894.

Shell but imperfectly known. The pedicle-valve has a smooth exterior, narrow cardinal area and unclosed dilthyrium. On the inside it bears a short but well defined spondylium supported by a median septum, and strong recurved teeth. This structure is unlike that of any other genus.

St. Louis group. *La Rue, Kentucky.*

Rhynchospira scansa.

Plate 9, fig. 2.

Rhynchospiras scansa, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. 1, fig. 45. 1894.

Pedicle-valve large, with prominent,, somewhat arched beak, cardinal slopes extending about one-half the length of the shell, anterior margin semioval. Surface with a sharply defined median furrow bearing a single small plication, the lateral slopes having eight or ten broad and rounded plications. Shell known only from an internal cast of the pedicle-valve.

Waverly group. *McKean county, Pennsylvania.*

Trematospira Tennesseensis.

Plate 8, figs. 17–19.

Trematospira Tennesseensis, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, pl. lxxxiii, figs. 21–23. 1894.

Shell small, subelliptical or subcircular in outline. Valves coarsely plicate, the pedicle-valve bearing six, with a small median plication at the bottom of the sinus, the brachial valve having the median fold divided by a low furrow, and with three plications on each lateral slope. Valves subequally convex. Apex of the pedicle-valve slightly elevated, truncate; deltidial plates coalesced. Surface with distant concentric growth-lines.

Lower Helderberg group. *Perry county, Tennessee.*

Meristella Walcotti.

Plate 8, figs. 26–31.

Meristella Walcotti, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 365, pl. xliii, figs. 16, 17; pl. xliv, figs. 6–11, 23, 32. 1894.

Shell elongate-ovate, valves convex, regular. Pedicle-valve with umbo moderately full and beak incurved; foramen generally concealed at maturity. Cardinal slopes concave and well delimited by divergent cardinal ridges. Dorsum more or less distinctly ridged in the umbonal region, broadly convex anteriorly and slightly extended on the anterior margin, but with no median sinus. Brachial valve with the median elevation somewhat more strongly defined, especially in the umbonal region. Umbo-lateral slopes rather more abrupt than in the other valve.

Internal structure normal for the genus.

Oriskany sandstone. *Cayuga, Ontario.*

Merista Tennesseensis.

Plate 8, figs. 20–25.

Merista Tennesseensis, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 365, pl. xlii, figs. 1–6. 1894.

Shell subpentahedral in outline, transverse, rarely elongate. Valves subequally convex, with broad, low fold and sinus developed on the anterior portion of the brachial and pedicle-valves respectively. Umbo of pedicle-valve not conspicuous, apex truncated at maturity by a circular foramen. Deltidial plates concealed by incurvature. Umbo of brachial valve full, apex acute. External surface smooth. Dimensions of an average example: length, 17 mm.; greatest width, 19 mm.

Upper Silurian. *Perry county, Tennessee.*

Clintonella vagabunda.

Plate 9, figs. 17–26.

Clintonella vagabunda, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 160, pl. lii, figs. 1–11. 1894.

Shells small, suboval in outline, valves subequally biconvex, the axis of greatest convexity being oblique. Pedicle-valve with a small umbo, which is compressed laterally, the apex being slightly incurved. Delthyrium wide, without traces of deltaria. The umbo merges anteriorly into a sinus which makes a deep flexure at the margin and bears two plications, both of which reach the beak. The lateral slopes bear from four to eight radial plications of smaller size. On the interior the teeth are prominent and strongly recurved. The muscular impression is moderately large, flabellate in outline and deeply impressed. The brachial valve has an inconspicuous beak; the umbonal region is depressed for about one-third the length of the valve, but anteriorly the median fold becomes prominent. The hinge-plate consists of two flat processes, inclined toward each other but not meeting. A stout median ridge supports this plate and divides the muscular area. Spirals are present but their direction is undetermined.

Clinton group. *Drift block in Western New York.*

Zygospira putilla.

Plate 9, figs. 31, 32.

Zygospira putilla, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 365, pl. liv, figs. 35-37. 1894.

Shell small, elongate-suboval in outline. Pedicle-valve the more convex; umbo narrowed, apex acute, delthyrium unclosed. Medially this valve is elevated by a strong double plication, the parts of which diverge anteriorly, leaving a flat, low depression between them, and in this lies a single faint plication. The lateral slopes are considerably depressed, and each bears from four to seven coarse, often irregular plications, only a part of them reaching the beak.

The brachial valve is depressed convex, with a conspicuous median fold, grooved longitudinally and bounded by deep marginal depressions. The lateral slopes are more convex than on the other valve, but are similarly plicated.

Surface of the valves usually without concentric growth-lines.

An average example has a length of 8 mm. and a greatest width of 7 mm.

Hudson River group. *Near Edgewood, Pike county, Missouri.*

Atrypina Clintoni.

Plate 9, figs. 27-30.

Atrypina Clintoni, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 162, pl. liii, figs. 7, 17-19. 1894.

Shell small, subplano-convex. The pedicle-valve projecting slightly at the apex, with short oblique cardinal margins and nearly circular periphery. This valve has a low median sinus bearing a median plication, and four or five somewhat stronger plications on each lateral slope. The brachial valve is slightly convex in the umbonal region, and has but a very faintly developed median fold. The surface of both valves bears rather distant concentric lamellæ. On the interior the pedicle-valve has moderately strong teeth and a large flabellate muscular impression. In the brachial valve the hinge-plate is divided into two flat lobes, supported by a thickened median ridge extending nearly the full length of the valve.

Clinton group. *In the drift of Western New York.*

Glassia Romingeri.

Plate 9, figs. 33-36.

Glassia Romingeri, Hall. Palæontology of N. Y., vol. VIII, pt. 2, p. 152, pl. lxxxiii, figs. 32-35. 1894.

Shell small, subequally biconvex, obcordate in outline. Surface smooth, with a median depression on both valves, which gives the shell a bilobed appearance on the anterior margin and over the anterior region. On the interior are introverted spirals whose primary lamellæ are united by a posterior jugum.

Trenton limestone. *In a drift boulder, Ann Arbor, Michigan.*

Camarophoria rhomboidalis.

Plate 9, figs. 37-40.

Camarophoria rhomboidalis, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 366, pl. lxii, figs. 25-29. 1894.

Shells of rather small size, subtriangular in outline with cardinal margins extending for half the length of the valves. Pedicle-valve with apex scarcely elevated, incurved, with deltidial plates usually concealed; slightly convex about the umbo, broadly depressed medially, forming a sinus which makes a linguiform extension on the anterior margin. This sinus may bear one and sometimes traces of two other low plications. The lateral slopes are smooth, except at the margins, where there is faint evidence of one or two plications on each. The brachial valve is convex and broadly rounded with abrupt umbo-lateral slopes; broad, low median fold, apparent only in the pallial region, and bearing a median plication. Traces of two lateral plications are visible at the margin of the valve, and these are somewhat more distinct on the surface than on the opposite valve. Surface smooth or with fine concentric lines. The interior structure of the shell is normal for this genus.

Corniferous limestone. *Cass county, Indiana.*

Parastrophia divergens.

Plate 10, figs. 11–14.

Parastrophia divergens, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 366, pl. lxiii, figs. 4–7. 1894.

Shell of medium size with strongly convex brachial valve and depressed convex, anteriorly concave pedicle-valve. The beak of the pedicle-valve is erect, but not conspicuous; from the gently convex umbo the surface slopes gradually to the lateral margins, and abruptly to the front, forming a broad and deep sinus, which is sharply defined at the sides, and bears from two to four angular plications. Two or more smaller plications occur on each lateral slope. The brachial valve is well rounded in the umbonal region, but the median fold is defined only near the anterior margin. It bears from three to five plications, with three on each lateral slope. All the plications, as well as fold and sinus, become obsolete in the umbonal region, and in old and thickened shells the latter can be distinguished only at the anterior margins of the valves. In the interior there is a supported spondylium in the pedicle-valve, but in the brachial valve the septal plates do not unite.

Hudson River group. *Wilmington, Illinois.*

Parastrophia Greenii.

Plate 10, figs. 1–5.

Parastrophia Greenii, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 367, pl. lxiii, figs. 17–20, 22. 1894.

Shell robust, with convex brachial valve and shallow pedicle-valve, convex in the umbonal region, but concave anteriorly. Beaks not prominent; that of the pedicle-valve low but erect; that of the brachial valve full and incurved. Cardinal slopes sharply defined on pedicle-valve. Median fold and sinus on brachial and pedicle-valves not strongly defined except at the anterior margin. The brachial valve bears six broadly rounded plications which are obsolete in the umbonal region; four of these belong to the median fold, the other two to the lateral slopes. The pedicle-valve has five plications, with three in the median sinus. Interior with a median supporting septum in each valve.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Parastrophia multiplicata.

Plate 10, figs. 15–17.

Parastrophia multiplicata, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 367, pl. lxiii, figs. 15, 16, 21. 1894.

This species differs from *P. Greenii* in its more conspicuously developed median fold and sinus, flatter and larger plications, and the greater number of the latter on the lateral slopes. The usually sessile spondylium of the brachial valve may also prove a distinguishing feature.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Parastrophia latiplicata.

Plate 10, figs. 6–10.

Parastrophia latiplicata, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 368, pl. lxiii, figs. 23–27. 1894.

This species is distinguished from the two preceding by its smaller size, less robust form, two broad plications on the fold and one in the sinus, with but a single pair on the lateral slopes.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Liorhynchus robustus.

Plate 10, figs. 18, 19.

Liorhynchus robustus, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lix, figs. 30, 31. 1894.

Shell large, with highly convex brachial valve and shallow pedicle-valve. Median fold and sinus well developed on brachial and pedicle-valves respectively. Surface abundantly plicate. Species is known only from an internal cast, which shows very perfectly the muscular scars and vascular sinuses.

Chemung group. *Steuben county, N. Y.*

Liorhynchus Lesleyi.

Plate 9, figs. 41–43.

Liorhynchus Lesleyi, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 368. pl. lix, figs. 34–36. 1894.

Shell of medium size with shallow pedicle, and deep brachial valve. Median sinus on the former well defined; median fold on the latter broad and not sharply delimited. Surface of both valves sharply and abundantly plicated.

Upper Devonian. *Pennsylvania.*

Conchidium exponens.

Plate 10, figs. 20–23.

Conchidium exponens, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxvi, figs. 6–9. 1894.

Shell elongate, subtriangular in marginal outline; valves subsequently convex. Median fold distinct over the anterior region of the pedicle-valve. Surface with numerous fine, rounded plications which are more or less obsolete over the lateral slopes and umbonal region of the valves. The pedicle-valve bears a spondylium extending less than one-half its length, while in the brachial valve the septal plates do not unite.

Niagara group. *Louisville, Kentucky.*

Conchidium scoparium.

Plate 11, figs. 8, 9.

Conchidium scoparium, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxvii, figs. 6, 7. 1894.

Shell with biconvex valves; marginal outline subcircular. Pedicle-valve with prominent, suberect umbo, slightly incurved at the top, with gradually expanding sides. Surface without median fold or sinus, but covered with numerous fine plications.

Guelph dolomites. *Durham, Ontario.*

Conchidium obsoletum.

Plate 11, figs. 1, 2.

Conchidium obsoletum, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxvii, figs. 8, 9. 1894.

Shell with highly convex valves and greatly flattened cardinal slopes. Anterior margin broadly curved, subtransverse. Surface with a few obscure and broad plications, obsolete at the sides of the valves.

Niagara dolomites. *Genoa, Ohio.*

Conchidium Nettelrothi.

Plate 10, figs. 24, 25.

Pentamerus Knighti, Nettelroth, Kentucky Fossil shells, p. 57, pl. xxix, figs. 1, 2, 17. 1889.

Conchidium Nettelrothi, Hall. Palaeontology of N. Y., vol. viii. pt. 2, p. 234, foot-note.

Shell somewhat similar in general expression to that of *Conchidium Knighti*, Sow., but smaller, more sparsely and closely plicated.

Corniferous limestone. *Near Louisville, Kentucky.*

Conchidium Greenii.

Plate 11, figs. 5–7.

Conchidium Greenii, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 368, pl. lxvi, figs. 20–22. 1894.

Shell subequally biconvex, ventricose, subcircular in marginal outline. Umbones full and rounded, both incurved, that of the pedicle-valve somewhat elevated. There is no evidence of median fold and sinus. Surface of each valve bearing, over the pallial region, from forty-five to fifty rounded plications, which very gradually increase by implantation and become more numerous anteriorly. These plications are of slightly unequal size, which appears to be due to variation in the rate of their multiplication. In the umbonal regions the plications are obsolete.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Conchidium crassiplica.

Plate 11, figs. 3, 4.

Conchidium crassiplica, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 369, pl. lxvi, figs. 24, 25. 1894.

Shell elongate, subelliptical in outline. Valves subequally convex, depressed above; cardinal slopes broad and abrupt on both. Umbo of the pedicle-valve erect, not prominent, surface slightly elevated medially. Umbo of brachial valve depressed, apex concealed; median region depressed anteriorly; surface of both valves bearing broad rounded plications, separated by deep grooves. Of these plications there are from eight to ten on each valve over the pallial region; by dichotomizing these become more numerous anteriorly.

Niagara group. *Near Louisville, Kentucky.*

Conchidium Georgiæ.

Plate 11, figs. 10, 11.

Conchidium Georgiæ, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 369, pl. lxvi, figs. 18, 19. 1894.

Pedicle-valve unknown; brachial valve trilobed by the development of a strong median fold which extends from apex to margin, and is sharply delimited by abrupt lateral slopes. The sides of the valve are convex, rather narrow, and slope abruptly to the lateral margins. Umbo full and incurved. Surface covered with numerous duplicating plications, of which from fifteen to twenty may be counted on each side at the margins, and twelve to fourteen in the fold.

Clinton group. *Trenton, Georgia.*

Pentamerus oblongus, Sowerby, var. Maquoketa.

Plate 11, figs. 12–14.

Pentamerus oblongus, var. *Maquoketa*, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxvii, figs. 11-13. 1894.

Shells small, with highly ventricose valves; general aspect ovoid. Umbo of the pedicle valve not greatly elevated. Marginal outline suboval. Surface smooth. Spondylium well developed in the pedicle-valve; septal plates of the brachial valve not uniting.

Niagara dolomites. *Near Dubuque, Iowa.*

Pentamerus oblongus, Sowerby, var. subrectus.

Plate 12, figs. 1–6.

Pentamerus oblongus, var. *subrectus*, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxviii, fig. 6; pl. lxix, figs. 2, 3, 8–10. 1894.

Shells with elongate, subquadrate marginal outline, high, subrectangular cardinal extremities, narrow and exsert umbo. Valves subequally convex, the greatest convexity being from umbo to anterior margin along the median axis. Each valve bears a longitudinal impressed median line and two divergent grooves which divide the surface into three divisions or fault lobes. Surface smooth; sometimes with traces of obscure, coarse radial folds in the median region.

Niagara group. *Jones county, Iowa.*

Capellinia mira.

Plate 13, figs. 5–13.

Capellinia mira, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 249, pl. lxx, figs. 6–14. 1894.

Shells large, elongate subovate. The relative size and convexity of the valves normal for PENTAMER S are here reversed, the brachial valve being the larger and deeper, with full, strongly arcuate and incurved beak, the apex of which is concealed within the umbo of the opposite valve. The pedicle-valve has an acute, suberect beak, which is not arched posteriorly but rises directly from the cardinal margins. Below it is a broad delthyrium without evidence of deltidial plates. There is no hinge-line but the margins of the delthyrium make subacute angles with the lateral margins of the valve. Cardinal slopes very broad and abrupt. The pedicle-valve is flattened above, while that of the brachial valve is evenly and deeply convex; it also shows a tendency to trilobation or obscure radial plication. Surface of both valves otherwise smooth. Internal apparatus as in *Pentamerus oblongus.*

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Barrandella Areyi.

Plate 13, figs. 1-3.

Barrandella Areyi, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 368, pl. lxxi, figs. 14-16. 1894.

Shell small, ventricose, with sinus on the pedicle-valve and fold on the brachial valve. Surface on both valves rather sharply and coarsely plicated, the largest plication being in the median sinus, with traces of finer ones on the slopes of the sinus. The median fold bears two well-defined plications with faint traces of others, while on each lateral slope of the valves there are four or five less sharply angular ribs.

Clinton group. *Rochester, N. Y.*

Gypidula Romingeri.

Plate 12, figs. 7-13.

Gypidula Romingeri, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxii, figs. 27-33. 1894.

Shells plano, or subplano-convex; marginal outline circular or subelliptical. Pedicle-valve highly convex, regularly arched from beak to margin. Hinge-line short, straight; cardinal area distinct, narrow, sometimes with remnants of deltaria or deltidium. On the interior the pedicle-valve bears a short, free spondylium and the brachial valve a sessile cruralium which may extend for one-half the shell's length. The surface of both valves is covered with coarse, often irregular and bifurcating plications.

Hamilton group. *Alpena, Michigan.*

Sieberella Roemeri.

Plate 13, fig. 4.

Pentamerus galeatus, F. Roemer. Silur. Fauna des westl. Tennessee, p. 73, pl. v, fig. 11.

Sieberella Roemeri, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 247, pl. lxxii, fig. 6. 1894.

Shell similar in general aspect to *Sieberella galeata*, but somewhat more elongate, less distinctly plicate and always smaller, having, also, the septal plates of the brachial valve united, forming a cruralium resting on a median septum.

Niagara group. *Perry county, Tennessee.*

Rensselæria Cayuga.

Plate 13, figs. 14, 15.

Rensselæria Cayuga, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 370, pl. lxxv, figs. 1, 2. 1894.

Shell lenticular, often of large size; suboval in marginal outline. Valves subequally biconvex, sloping regularly in all directions. Apex of the pedicle-valve scarcely prominent; umbo not conspicuous, somewhat elevated medially. Divergent cardinal ridges and cardinal slopes well defined. Brachial valve with apex depressed and concealed; somewhat less convex in the umbonal region than the opposite valve. Surface of both valves covered with a great number of fine, simple, thread-like, rarely duplicating plications, of which from 70 to 100 may be counted on each valve near the anterior margin.

Oriskany sandstone. *Cayuga, Ontario.*

Rensselæria ovulum.

Plate 14, figs. 15, 16.

Rensselæria ovulum, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxv, figs. 3, 4. 1894.

Shell large, distinguished from *R. ovoides* by its more orbicular form and regularly convex valves, and from *R. Cayuga* by its larger size and greater convexity. Its outline is rather regularly oval, the greatest diameter of the valves being somewhat in front of the middle. Surface covered with fine radial plications.

Oriskany sandstone. *Cayuga, Ontario.*

Oriskania navicella.

Plate 14, figs. 1–3.

Oriskania navicella, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 270, pl. lxxix, figs. 25–27. 1894.

Shell of considerable dimensions, elongate-ovate, plano-convex. Pedicle-valve much the deeper with a prominent median ridge. Surface of both valves smooth. Interior with a broad, triangular undivided hinge-plate, bearing an erect, lamellar unciform cardinal process and stout crural lobes. In the pedicle-valve are well-developed dental lamellæ.

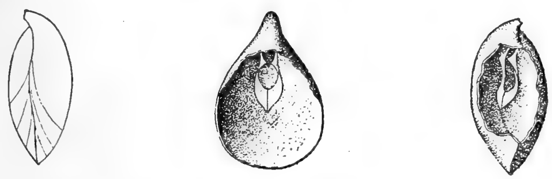
Oriskany sandstone. *Rondout and Hudson, N. Y.*

Selenella gracilis.

Selenella gracilis, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 271, figs. 184–186.

Shells small, elongate-ovate, with attenuate, truncate beak. Valves convex, surface smooth. Interior with a simple centronellid loop.

Corniferous limestone. *Cayuga, Ontario.*



Selenella gracilis.

Fig. 2. Outline profile of conjoined valves.
Fig. 3. Preparation showing the form of the loop.
Fig. 4. An oblique view, showing the upward curvature of the anterior plate.

Cryptonella subelliptica.

Plate 14, figs. 4–6.

Cryptonella subelliptica, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxi, figs. 41–43. 1894.

Shell elongate-oval, broadest near the center of the length; valves convex, smooth. Pedicle-valve with arched and truncated beak.

Waverly group. *Sciotoville, Ohio.*

Beecheria Davidsoni.

Plate 14, figs. 7–11.

Terebratula sacculus (Martin), Davidson. Quart. Jour. Geol. Soc., London, vol. XIX, p. 169, pl. ix, figs. 1–3. 1863.

Beecheria Davidsoni, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, p. 300, pl. lxxxix, figs. 33–36. 1894.

Shells small, terebratuliform, oval, broadest medially, attenuate at the beak. Valves biconvex, surface smooth. On the interior the pedicle valve is without dental plates, and the loop, which is short, is supported by a divided hinge-plate.

Carboniferous limestone. *Windsor, Nova Scotia.*

Dielasma obovatum.

Plate 14, figs. 12–14.

Dielasma obovatum, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxi, figs. 38–40. 1894.

Shell elongate-ovoid, attenuate in the umbonal region. Surface biconvex, smooth, sloping subequally from the median portion of the beaks. Beak of the pedicle-valve broadly and somewhat obliquely truncated.

Coal Measures. *Kentucky.*

Cyrtina neogenes.

Plate 8, figs. 4–8.

Cyrtina neogenes, Hall. Palaeontology of N. Y., vol. VIII, pt. 2, expl. pl. lxxxiv, fig. 41.

Shells having the form of SPIRIFERINA, extended on the hinge, with 5–7 plications on the lateral slopes. Internally with the structure of CYRTINA.

Chart of the Burlington limestone. *Burlington, Iowa.*

Explanation of Plates.

PLATE I.

LINGULA COMPTA, Hall.

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Fig. 1. A specimen of the brachial valve (?); showing the lateral impressions and the median septum extending to the anterior margins. × 2.
Hamilton shales. *Canandaigua Lake, N. Y.*

LINGULA LINGULATA, Hall.

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Fig. 2. The pedicle-valve, from which the epidermal layer is partially exfoliated; showing the peculiar deflection of the anterior margin, which is a constant feature. × 2.
Clinton group. *Near Hamilton, Ontario.*

LINGULA SCUTELLA, Hall.

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Fig. 3. An internal cast, indicating that the muscular region of the valve was depressed instead of thickened and elevated, as is usually the case. × 2.
Chemung group. *Allegany county, N. Y.*

LINGULA TÆNIOLA, Hall.

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Fig. 4. The pedicle-valve; showing the peculiar surface ornament, crossed near the beak by concentric growth-lines. × 1.5.
Clinton group. *Clinton, N. Y.*

LINGULA (GLOSSINA) FLABELLULA, Hall.

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Fig. 5. A very large example from which a portion of the shell has been exfoliated, without showing any traces of muscular markings.
Waverly group. *Sciotoville, Ohio.*

Fig. 6. A similar valve, exposing the inner laminæ of the shell, with faint radiating lines.
Berea grit. *Berea, Ohio.*

LINGULOPS GRANTI, Hall.

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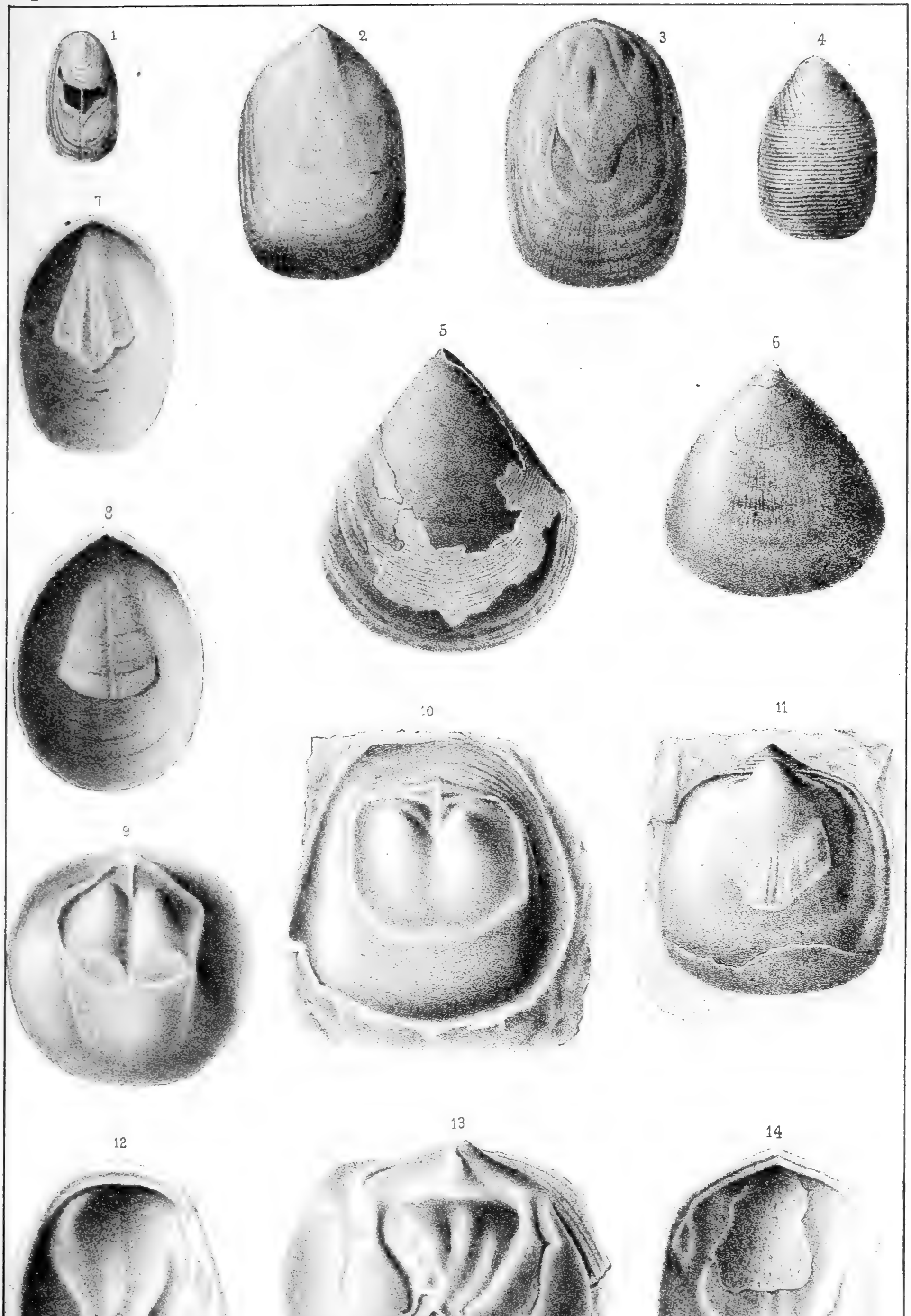
Fig. 7. The interior of a brachial valve. × 6.

Fig. 8. The interior of a pedicle-valve. The muscular area is here developed into a well-defined platform, while in the species *L. Whitfieldi and L. Norwoodi*, it retains its linguloid character. × 6.
Niagara group. *Hamilton, Ontario.*

BRACHIOPODA.



C. Fausel, lith.

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Monomerella Greenii, Hall.

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Fig. 9. An internal cast of the pedicle-valve; showing the extremely small umbonal chambers and the sharply defined crescent, cardinal groove and lateral scars.

Fig. 10. An internal cast of a pedicle-valve; showing the very broad cardinal margin and its lateral extent; also the faint umbonal cavities and the conspicuous cardinal groove and crescent.

Fig. 11. An internal cast of the brachial valve; showing in the matrix the impression of the cardinal area. The platform scars are accompanied by only a very faint thickening of the shell.

Fig. 12. The interior of a brachial valve, from a gutta-percha cast of a natural impression. The crescentic fulcrum is exceedingly strong and the platform very obscure.

Niagara limestone. *Grafton, Wisconsin.*

Fig. 18 An internal cast of the brachial valve; showing a portion of the broad area of contact, the platform scars with the diverging anterior ridges.

Niagara limestone. *Rising Sun, Ohio.*

Fig. 14. The interior of a brachial valve, with sharply defined terminal scars and anterior ridges. From a gutta-percha cast.

Niagara limestone. *Grafton, Wisconsin.*

PLATE II.

Monomerella Kingi, Hall.

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Fig. 1. An internal cast of a pedicle-valve; showing the very short umbonal chambers and the sharply defined muscular impressions.

Fig. 2. Opposite side of the same specimen; showing the internal characters of the brachial valve.

Niagara limestone. *Hawthorne, Illinois.*

Monomerella Egani, Hall.

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Fig. 3. A brachial valve; showing the strongly developed cardinal area, the narrow crescent and the platform scars. The umbonal cavity is filled by a thick deposit of testaceous matter.

Niagara limestone. *Grafton, Wisconsin.*

Monomerella Ortoni, Hall.

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Fig. 4. An internal cast of the pedicle-valve, in which all the characters of the shell are very sharply defined.

Fig. 5. The counterpart of the same from a gutta-percha impression; showing the broad deltidium without evidence of subdivision, the conspicuous cardinal slope and groove, the crescent and platform scars and the pallial trunks with their ramifications.

Niagara limestone. *Rising Sun, Ohio.*

Rhinobolus Davidsonii, Hall.

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Fig. 6. The interior of a brachial valve.

Fig. 7. The interior of a larger brachial valve; showing the undeveloped platform, the crescent and the transverse muscular scars.

Fig. 8. A small pedicle-valve, showing its internal characters.

Niagara limestone. *Grafton, Wisconsin.*

Siphonotreta (?) Minnesotensis, Hall.

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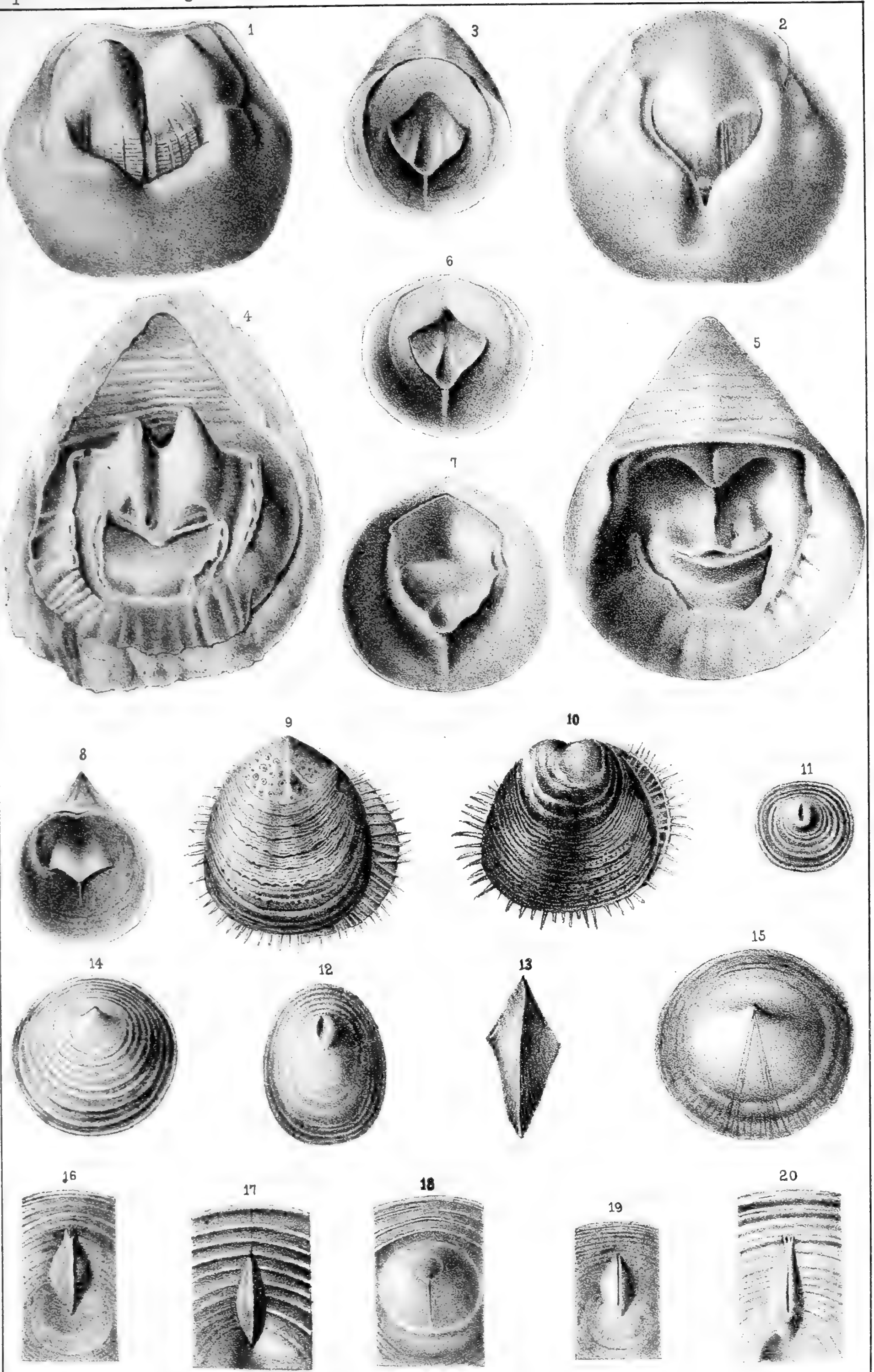
Fig. 9. View from the brachial side of a specimen retaining the valves in juxtaposition, and preserving most of the epidermal layer of the shell. The spine-bases about the beak are notably larger and more closely set than over the rest of the surface, where they occur at considerable intervals along the concentric varices. The entire length of the spines is evidently not represented in the fringe at the margin. × 2.

BRACHIOPODA.



C. Fausel, lith. James B. Lyon, State Printer

Fig. 10. The opposite side of the same specimen. The imperfection of the valve in the umbonal region has rendered it impossible to determine with accuracy the generic character of the species. × 2.

Trenton limestone. *Minneapolis, Minnesota.*

ORBICULOIDEA NUMULUS, Hall.

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Fig. 11. The exterior of a pedicle-valve.

Lower Helderberg group (Waterlime). *Marshall, N. Y.*

ORBICULOIDEA (SCHIZOTRETA) OVALIS, Hall.

Page 332.

Fig. 12. View of the pedicle-valve; showing the short foraminal groove. × 3.

Fig. 13. Profile of the same specimen; showing the valves in juxtaposition. × 3.

Trenton limestone. *Middleville, N. Y.*

ORBICULOIDEA HERZERI, Hall.

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Fig. 14. The exterior of a pedicle-valve. × 1.5.

Cuyahoga shale. *Berea, Ohio.*

Fig. 15. An internal cast of a brachial valve ; showing the impressions of two strong, diverging vascular sinuses (?) and finer markings about the margins. × 1.5.

Cuyahoga shales. *Newark, Ohio.*

Fig. 16. The internal pedicle-area, having the lateral pedicle callosities coalesced, leaving the foramen open but otherwise concealing the structure of the area. × 3.

Fig. 17. A similar structure. × 3.

Fig. 18. The interior of the apical portion of the brachial valve; showing the small median septum, extending forward from the apex. × 3.

Fig. 19. The internal pedicle-area, in which the lateral callosities have not fully coalesced. × 3.

Cuyahoga shales. *Berea, Ohio.*

Fig. 20. A similar structure, the lateral callosities being somewhat more completely united. × 3.

Cuyahoga shales. *Baconsbery, Ohio.*

PLATE III.

Lindstrœmella aspidium, Hall.

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Figs. 1, 2. Interior and internal casts of a brachial valve to which a portion of the shell adheres, showing the strong lateral ridges, faint median septum and obscure muscular impressions.

Fig. 2a. Outline profile of conjoined valves of a smaller example, the pedicle-valve being at the left.

Hamilton group. *Near Hamilton, N. Y.*

Fig. 3. A natural cast of the exterior of a large pedicle-valve; showing the character of the surface ornament and the peculiar undulation of the concentric ridges on approaching the pedicle-area. The pedicle-passage differs from that in the normal mature Orbiculoidea in not being closed, though its margins appear to be in contact.

Hamilton group. *Near Leonardsville, N. Y.*

Fig. 4. A small pedicle-valve, with characteristic ornamentation and strongly developed foraminal groove.

Hamilton group. *Darien, N. Y.*

Schizocrania Schucherti, Hall.

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Fig. 5. A small brachial valve retaining most of the external surface. × 3.

Fig. 6. A large brachial valve, showing the posterior muscular scars. × 3.

Fig. 7. An individual from which most of the upper valve has been removed exposing the flat pedicle-valve. × 3.

Hudson River group. *Covington, Kentucky.*

Schizocrania (?) Helderbergia, Hall.

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Fig. 8. The lower exterior surface of an individual, showing the coarsely radiate surface of the pedicle-valve, and the overlapping edges of the finely striated pedicle-valve. × 2.

Fig. 9. The internal surface of the pedicle-valve, showing a broad pedicle-fissure and the overlapping margins of the upper valve. × 3.

Lower Helderberg group. *Near Clarksville, N. Y.*

Crania agaricina, Hall.

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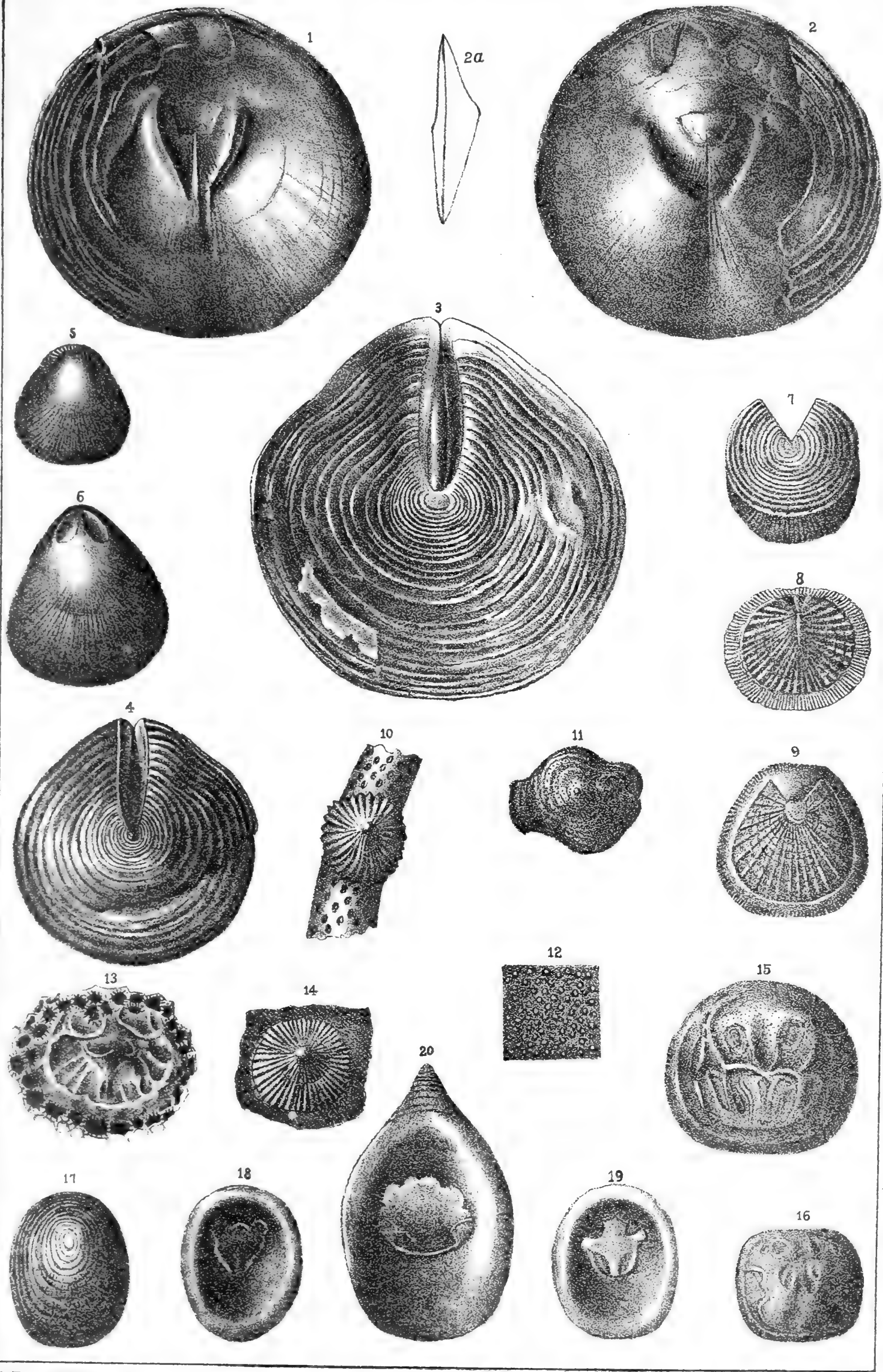
Fig. 10. An individual attached to a branch of Trematopora; showing the sparse and relatively coarse radiating ribs. × 3.

Lower Helderberg group. *Near Clarksville, N. Y.*

BRACHIOPODA.



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Crania granosa, Hall.

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Fig. 11. A somewhat distorted upper valve; showing the finely granulose surface.

Fig 12. A portion of the surface enlarged. × 20.

Hamilton group. *Centerfield, N. Y.*

Crania favincola, Hall.

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Fig. 13. A lower valve, slightly broken about the posterior margin, but showing the very large posterior muscular impressions, the deeply impressed anteriors with sharply elevated margins and median fulcrum; also, the radiating pallial sinuses. The shell is attached to a specimen of *Favosites pirum*, Davis.

Hamilton group. *Crab Orchard, Kentucky.*

Crania pulchella, Hall.

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Fig. 14. An individual attached to a valve of Orthis.

Lower Helderberg group. *Near Clarksville, N. Y.*

Craniella Ulrichi, Hall.

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Fig. 15. A cast of the interior of a lower valve, somewhat restored at the right; showing the strong anterior and very obscure posterior adductor scars and the marks of the vascular sinuses. The shell is convex and shows no evidence of attachment, though the external surface is covered with bryozoan growth. × 1.5.

Fig. 16. An internal cast of the upper valve. The sigmoid vascular impressions are simpler than elsewhere observed. The scars of the dorsal adjustors and of the muscles accessory to the anterior adductors are also shown. × 1.5.

Trenton limestone. *Minneapolis, Minnesota.*

Pholidops patina, Hall.

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Fig. 17. The exterior of a valve, showing the lamellose growth-lines, crossed by fine, interrupted radiating striæ. × 4.

Fig. 18. The interior of a ventral (?) valve. × 4.

Fig. 19. The interior of the opposite valve. × 4.

Corniferous limestone. *DeCewville, Ontario.*

Pholidops calceola, Hall.

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Fig. 20. The interior of a dorsal (?) valve, showing the terminal beak, the subapical area and the character of the muscular scars. × 2.

Corniferous limestone. *Falls of the Ohio.*

PLATE IV.

ORTHIS PANDERIANA, Hall.

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Figs. 1, 2. Exterior and interior of a pedicle-valve. × 3.

Fig. 3. Interior of a brachial valve. × 3.

(From the originals of BILLINGS'S species. "*Orthis orthambonites*, Pander." "*Point Levis; in the upper part of Limestone No. 2, Quebec group.*"

ORTHIS FLABELLITES, var. SPANIA, Hall.

Page 339.

Fig. 4. An internal cast of a pedicle-valve, having the expression of *O. flabellites*, but with scarcely more than one-half the number of plications usual in this species.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

ORTHIS (?) GLYPTA, Hall.

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Fig. 5. A partial internal cast of a pedicle-valve; showing the outline of the shell, its surface ornamentation and the form of the muscular impression.

Fig. 6. A similarly preserved shell with but a single series of radial plications and showing the peculiar reticulating surface sculpture. × 2.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

ORTHIS (PLÆSIOMYS) LORICULA, Hall.

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Fig. 7. The exterior of a pedicle-valve.

Fig. 8. The interior of a brachial valve.

Fig. 9. The interior of a pedicle-valve; showing the character of the muscular area and ovarian markings.

Galena limestone. *Fountain, Minnesota.*

ORTHIS (?) SAFFORDI, Hall.

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Figs. 10, 11, 12. Ventral, profile and dorsal views of the exterior, showing the characters of the species.

Trenton horizon. *Near Knoxville, Tennessee.*

ORTHIS (DALMANELLA) ARCUARIA, Hall.

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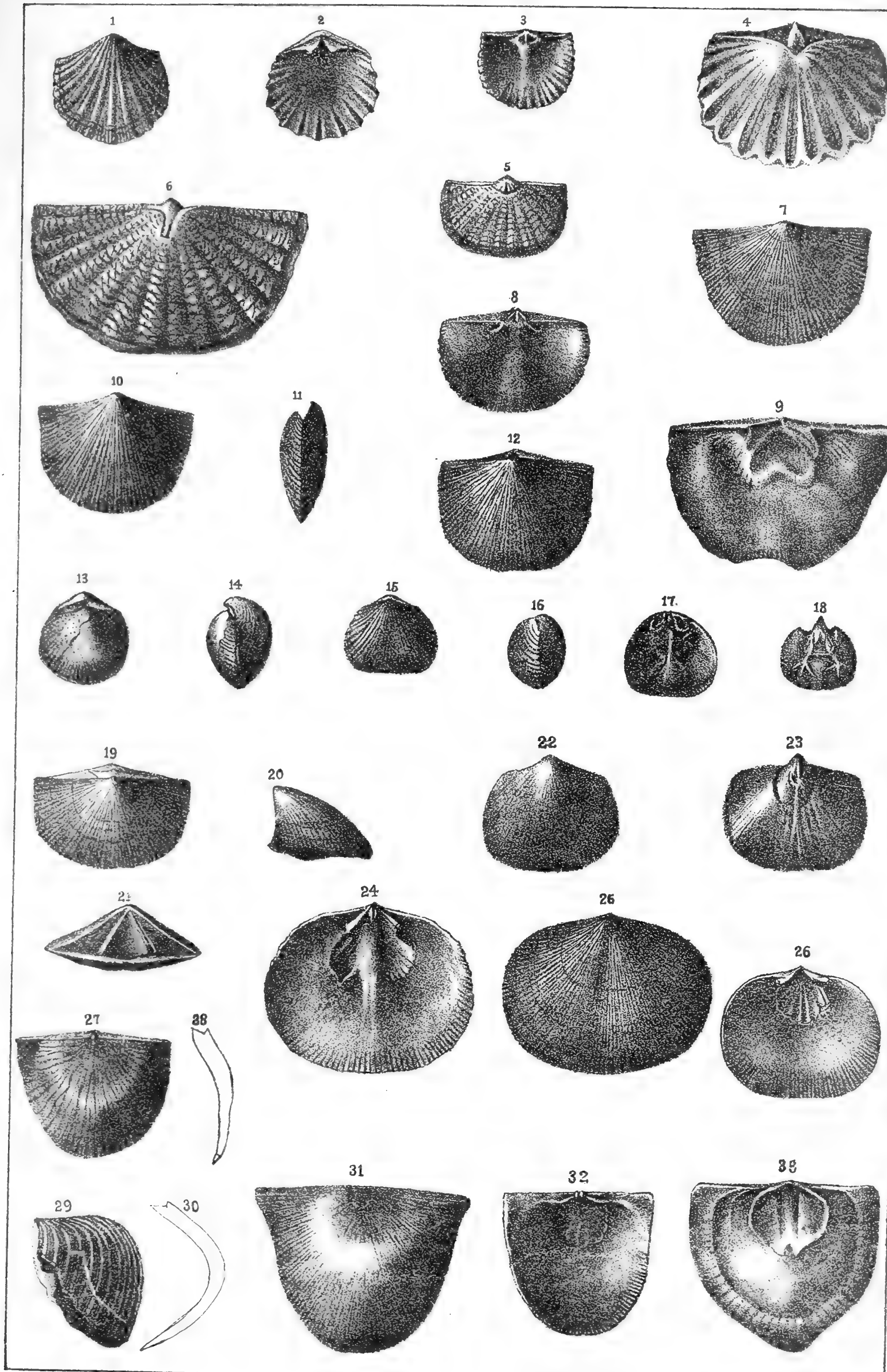
Figs. 13, 14. Dorsal and profile views of a silicified and partially exfoliated shell.

Niagara group. *Perry county, Tennessee.*

BRACHIOPODA.

Report State Geologist, 1894. Plate 4



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Orthis (Dalmanella) superstes, Hall.

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Figs. 15, 16. Dorsal and profile views of the exterior.

Fig. 17. The interior of the brachial valve, showing cardinal process, adductor scars and vascular sinuses.

Fig. 18. An internal cast of the pedicle-valve; showing traces of the vascular sinuses.

Chemung group. *Howard, N. Y.*

Orthis Holstoni (Safford), Hall.

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Figs. 19, 20, 21. Ventral, profile and cardinal views of the type specimen.

Trenton horizon. *Near Knoxville, Tennessee.*

Orthis (Schizophoria) senecta, Hall.

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Fig. 22. The exterior of a pedicle-valve; showing the depression over the pallial region.

Fig. 23. An internal cast of a pedicle-valve; showing the diductor and adductor scars.

Clinton group. *Reynale's Basin, N. Y.*

Orthis (Rhipidomella) Oweni, Hall.

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Fig. 24. The interior of a brachial valve.

Fig. 25. The exterior of a brachial valve.

Fig. 26. The interior of a pedicle-valve.

Waverly group. *Button-mould Knobs, Kentucky.*

Strophomena Conradi, Hall.

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Fig. 27. Dorsal view, showing the reversed convexity of the valves, and the fasciculate striæ.

Fig. 28. Outline profile of the same specimen.

Trenton limestone. *Jacksonburg, N. Y.*

Fig. 29. Profile of a brachial valve.

Fig. 30. Outline profile of both valves of the same specimen.

Trenton limestone. *Trenton Falls, N. Y.*

Strophomena Winchelli, Hall.

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Fig. 31. The exterior of a brachial valve, showing its great convexity and the fine filiform radial striæ of the surface.

Trenton limestone. *Clifton, Wisconsin.*

Fig. 32. The interior of a brachial valve.

Trenton limestone. *Janesville, Wisconsin.*

Fig. 33. The interior of a pedicle-valve, showing the character of the muscular area and the submarginal thickening of the shell.

Trenton limestone. *Clifton, Wisconsin.*

PLATE V.

Orthothetes desideratus, Hall.

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Fig. 1. A cardinal view of an internal cast.

Fig. 2. A dorsal view of the same specimen, showing the dorsal muscular scars.

Waverly group. *Ohio.*

Derbya Bennetti, Hall.

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Fig. 3. Transverse section near the apex of the pedicle-valve, showing the median septum coalesced with a solid callosity filling the apical portion of the deltidial cavity.

Fig. 4. A section of the same specimen nearer the hinge. This shows the dental ridges, tips of the cardinal process and the median septum.

Figs. 5, 6. Cardinal and profile views of the same specimen.

Figs. 7, 8. Dorsal and ventral views of a smaller shell, with a large scar of attachment.

Upper Coal Measures. *Kansas City, Missouri.*

Derbya (?) costatula, Hall.

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Fig. 9. Dorsal view, showing the characteristic surface ornamentation of the species. × 2.

Chester limestone. *Crittenden county, Kentucky.*

Derbya affinis, Hall.

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Figs. 10, 11. Cardinal and profile views of a small individual, with the irregular growth very pronounced on both valves.

Upper Coal Measures. *Kansas City, Missouri.*

Derbya ruginosa, Hall.

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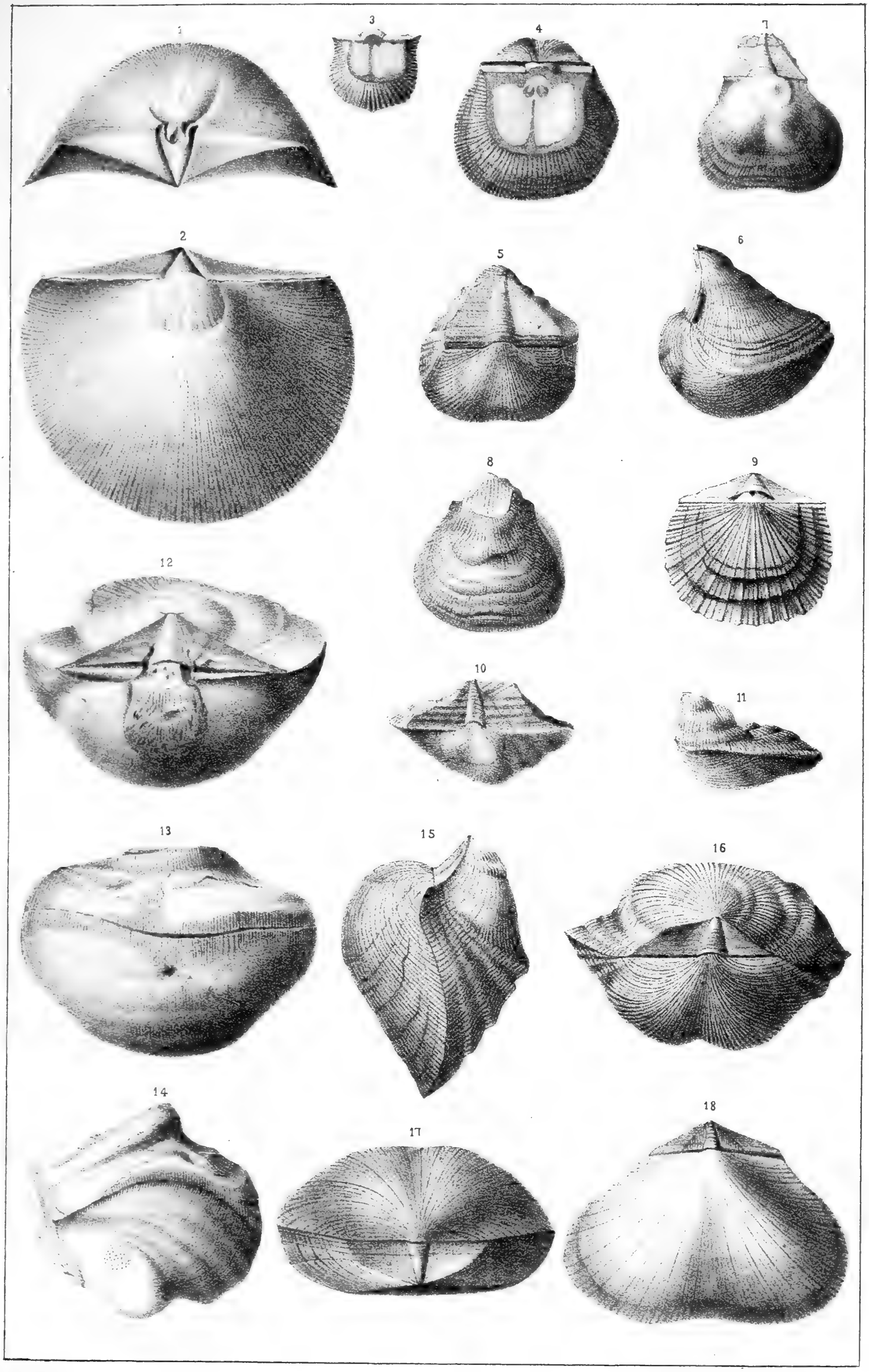
Figs. 12, 13, 14. Cardinal, anterior and profile views of an internal cast in chert.

Keokuk limestone. *New Providence, Indiana.*

BRACHIOPODA.



C. Fausel, lith. James B. Lyon, State Printer.

DERBYA BROADHEADI, Hall.

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Figs. 15, 16. Profile and cardinal views of an entire individual, showing the rugose and somewhat irregular pedicle-valve and the median sinus of the brachial valve.

Upper Coal Measures. *Kansas City, Missouri.*

DERBYA (?) BILOBA, Hall.

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Figs. 17, 18. Cardinal and dorsal views, showing the bilobed contour and obovate outline. × 2.

Coal Measures. *Winterset, Iowa.*

PLATE VI.

Derbya cymbula, Hall.

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Figs. 1, 2. Dorsal and cardinal views of a large specimen.
Upper Coal Measures. *Near Kansas City, Missouri.*

Streptorhynchus Ulrichi, Hall.

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Fig. 3. The interior of a pedicle-valve referred to this genus on account of the peculiar form of the shell and the absence of a median septum.
Chester limestone. *Crittenden county, Kentucky.*

Orthotropia dolomitica, Hall.

Page 343.

Fig. 4. Ventral view of an internal cast; showing the form of the shell, the short straight hinge and the conspicuous muscular scars.

Fig. 5. The interior of a pedicle-valve, showing the cardinal area, open delthyrium, muscular scar and short median septum.

Figs. 6, 7, 8. Dorsal, ventral and cardinal views of an internal cast, showing the form of the muscular impressions, the median septum in each valve and the elevation of the cardinal area. × 2.
Niagara dolomites. *Near Milwaukee, Wisconsin.*

Strophonella costatula, Hall.

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Figs. 9, 10. Dorsal and profile views of the shell, showing the reversed convexity of the valves and the sharp, irregularly dichatomizing plications.
Niagara group. *Louisville, Kentucky.*

Plectambonites producta, Hall.

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Figs. 11, 12. Profile and front views of an internal cast of a pedicle-valve.
Niagara dolomites. *Yellow Springs, Ohio.*

Christiania subquadrata, Hall.

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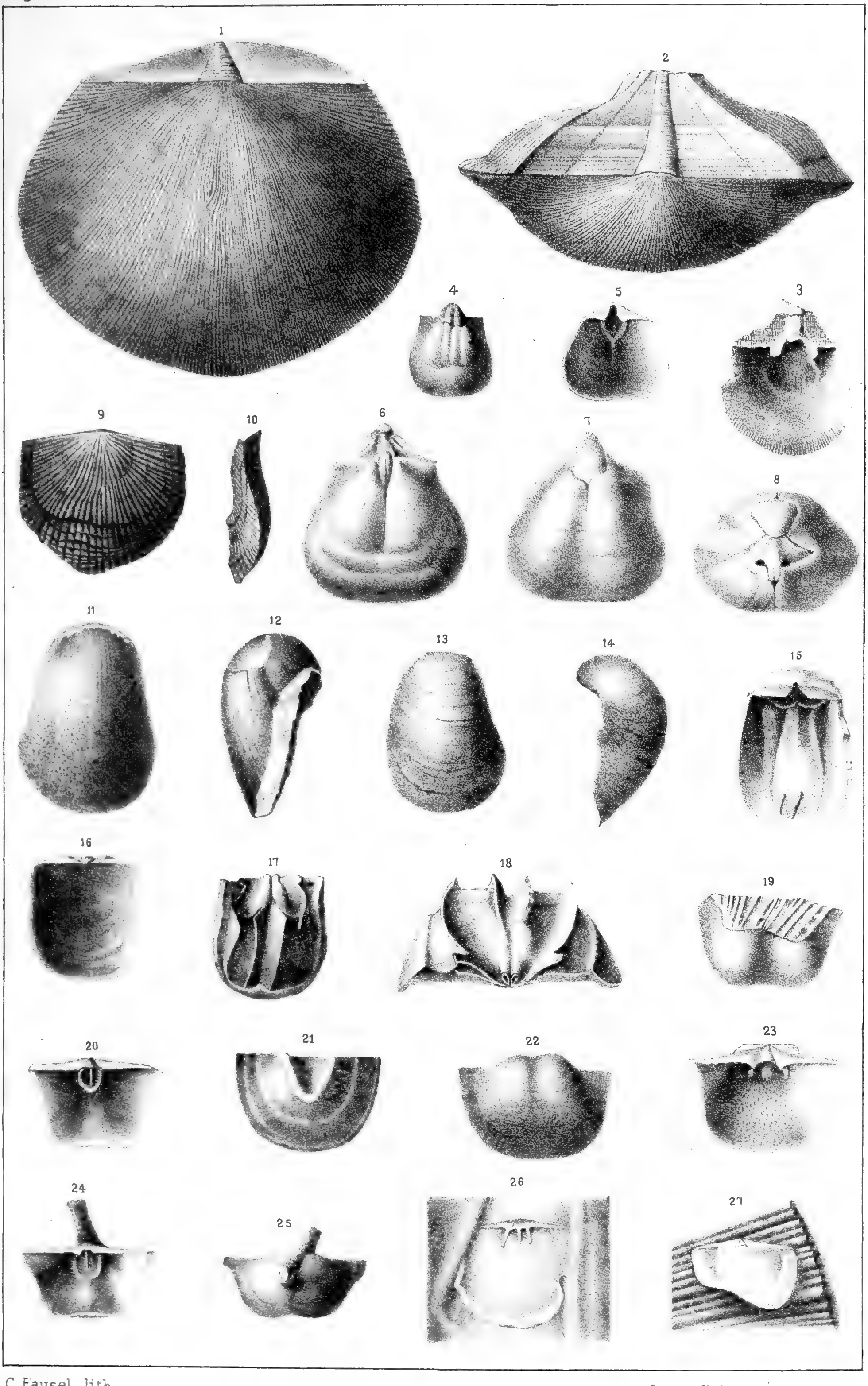
Figs. 13, 14. Two views of a pedicle-valve, showing its elongate form, smooth or squamous surface.

Fig. 15. The interior of a pedicle-valve, with an open delthyrium and showing the muscular walls and scars.

Fig. 16. The exterior of a brachial valve, showing the cardinal process and edges of the crural plates.

BRACHIOPODA.



C. Fausel, lith. James B. Lyon, State Printer.

Fig. 17. The interior of a brachial valve, showing the bilobed cardinal process and the quadruple adductor scar, divided by high, vertical muscular walls.

Fig. 18. Cardinal view of the brachial valve, showing the cardinal process, widely divergent crural plates, and the prominent longitudinal and transverse muscular ridges inclosing the scars of the adductor muscles. × 3.

LEPTÆNISCA TANGENS, Hall.

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Figs. 19, 20. Opposite sides of a pedicle-valve which has been attached to a frond of *Fenestella*. × 3.

Fig. 21. The exterior of a pedicle-valve in which the rugose growth has obscured the median sinus. The deep umbonal cicatrix has been caused by attachment to some bryozoan. × 3.

Figs. 22, 23. Exterior and interior of a pedicle-valve, showing the cicatrix of attachment, deltidium and dental plates. × 3.

Figs. 24, 25. Opposite sides of a pedicle-valve attached to a twig of *Trematopora*. × 3.

Lower Helderberg group. *Near Clarksville, N. Y.*

LEPTÆNISCA ADNASCENS, Hall.

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Fig. 26. A pedicle-valve attached by nearly its entire surface to the interior of a valve of *Orthis oblata*. The specimen shows the dental lamellæ and median ridge dividing the muscular area. × 3.

Fig. 27. A specimen retaining both valves, attached to the surface of *Orthis perelegans*. × 4.

Lower Helderberg group. *Near Clarksville, N. Y.*

PLATE VII.

Triplecia Niagarensis, Hall.

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Figs. 1, 2, 3, 4. Cardinal, oblique cardinal, anterior and profile views of an internal cast, showing the sharply defined median fold and sinus on brachial and pedicle-valves, respectively, the marginal plication and the cavity left by the cardinal process.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Strophalosia cymbula, Hall.

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Fig. 5. The exterior of a pedicle-valve, showing the scar of attachment.

Keokuk group. *Lebanon, Kentucky.*

Strophalosia Rockfordensis, Hall.

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Figs. 6, 7, 8. Dorsal, cardinal and ventral views of a specimen, showing the external characters and size of cicatrix.

Upper Devonian. *Rockford, Iowa.*

Figs. 9, 10. Cardinal and dorsal views of a larger, but incomplete example.

Upper Devonian. *Rockford, Iowa.*

Chonostrophia Helderbergia, Hall.

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Fig. 11. A specimen in which the valves are opened, exposing their internal surface, showing the extremely fine radial striation, teeth and cardinal process.

Lower Helderberg group. *Near Clarksville, N. Y.*

Spirifer crispatus, Hall.

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Figs. 12, 13. Views of the original specimen, showing the coarsely plicate surface.

Niagara group. *Maryland.*

Spirifer Canandaiguæ, Hall.

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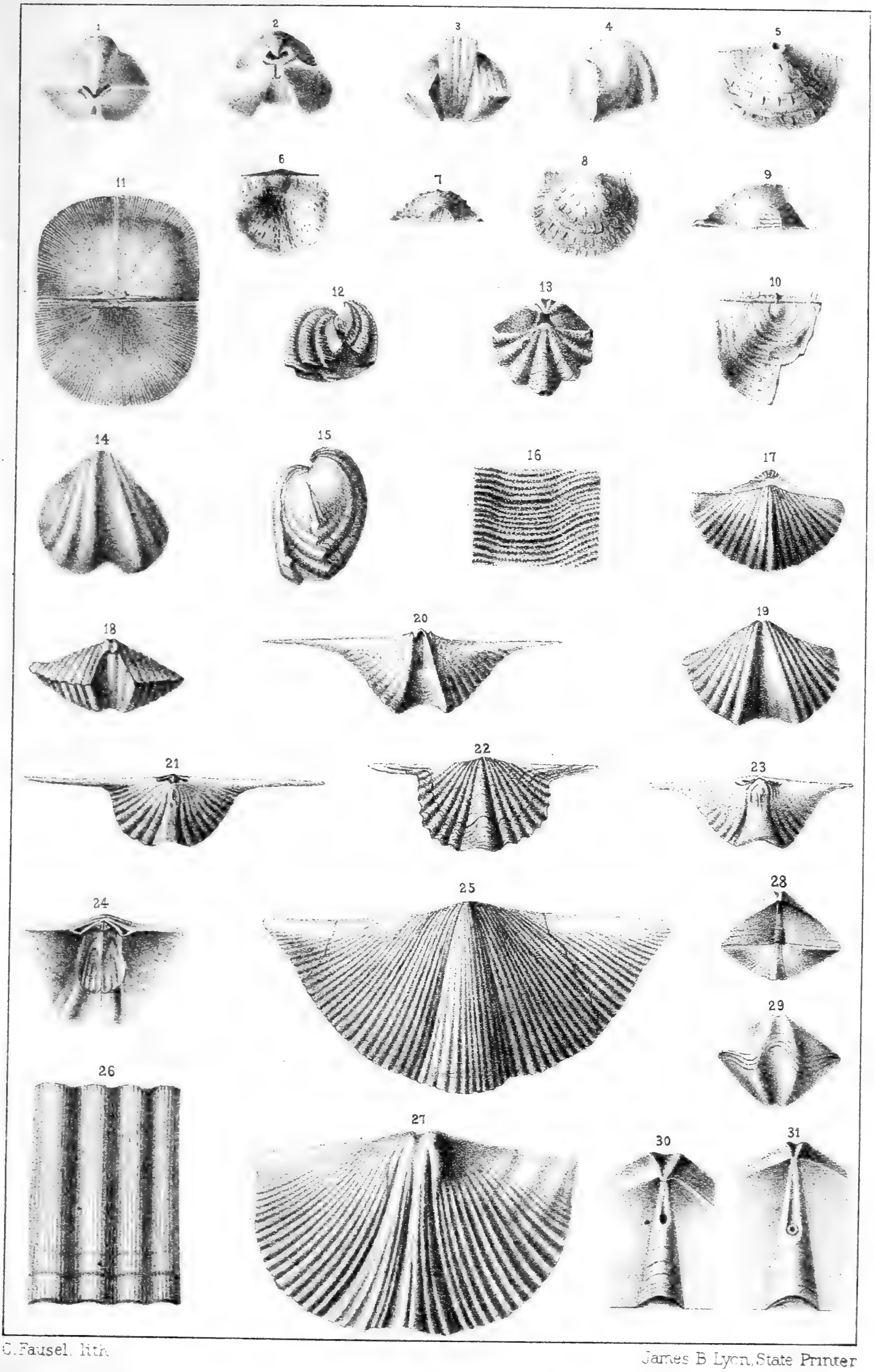
Figs. 14, 15. Ventral and profile views of a somewhat imperfect individual, showing the low rounded lateral plications.

Fig. 16. Enlargement of the surface, showing the closely crowded concentric row of fine granules or spine-bases. ×5.

Hamilton group. *Canandaigua Lake, N. Y.*

BRACHIOPODA.



C. Fausel, lith. James B Lyon, State Printer

Spirifer Williamsi, Hall.

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Figs. 17, 18, 19. Dorsal, cardinal and ventral views of a large example, showing the low, coarse and sparse plication of the fold and sinus.
Chemung group. *Allegany county, N. Y.*

Spirifer mucronatus, Conrad, var., posterus, Hall.

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Fig. 20. An internal cast of the pedicle-valve, showing the impression of the muscular area.

Fig. 21. Internal cast of a brachial valve.

Fig. 22. Exterior of a brachial valve, showing the lamellose surface and extended cardinal extremities.

Fig. 23. Internal cast of a brachial valve.

Fig. 24. The central portion of the interior of a brachial valve, enlarged.
Chemung group. *Tompkins County, N. Y.*

Spirifer Newberryi, Hall.

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Fig. 25. The exterior of the brachial valve.

Fig. 26. An enlargement of the surface.
Waverly group. *Ohio.*

Spirifer disjunctus, Sowerby, var. sulcifer, Hall.

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Fig. 27. The internal cast of a brachial valve; showing the sulcus on the plicated fold.
Chemung group. *Near Olean, N. Y.*

Cyrtia radians, Hall.

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Figs. 28, 29. Cardinal and profile views of the original specimen. The central cardinal area of two examples, showing the direct circular foramen and elongate foraminal groove.
Clinton group. *Rochester, N. Y.*

PLATE VIII.

CYRTINA LACHRYMOSA, Hall.

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Figs. 1, 2. Views of an average example; showing the regular, slightly incurved cardinal area, and the sparsely pustulose exterior. × 2.

Fig. 3. An enlargement of the exterior; showing the large pustules of various sizes. × 5.

Waverly group. *Richfield, Ohio.*

CYRTINA NEOGENES, Hall.

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Fig. 4. The pedicle-valve broken so as to show the median septum supporting convergent dental plates.

Fig. 5. An internal cast of the pedicle-valve.

Fig. 6. Cardinal view of the same specimen; showing the convergent dental plates uniting with the median septum. × 2.

Fig. 7. An enlargement of the external surface; showing the bases of concentric rows of spinules. × 4.

Fig. 8. An enlargement of a portion of the interior of the pedicle-valve; showing the convergence of the dental plates and the projection of the median septum beyond their union. × 3.

Chert of the Burlington limestone. *Burlington, Iowa.*

CYRTINA UMBONATA, Hall, var. ALPENENSIS, Hall.

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Figs. 9, 10. Views of an individual of normal size.

Fig. 11. The conjoined valves split along the median septum; showing the extreme extension of the latter, its acute anterior extremity, and the penetration of its median edge beyond the base of the dental lamellæ.

Fig. 12. Front view of a preparation; showing the normal shape of the spiral cones, and the form of the crura and loop. × 1½.

Fig. 13. A lateral view of another preparation showing the extension of the spiral into the rostral cavity divided by the median septum, and the projection of the loop downward and toward the brachial valve. × 1½.

Hamilton group. *Alpena, Michigan.*

SYRINGOTHYRIS MISSOURI, Hall.

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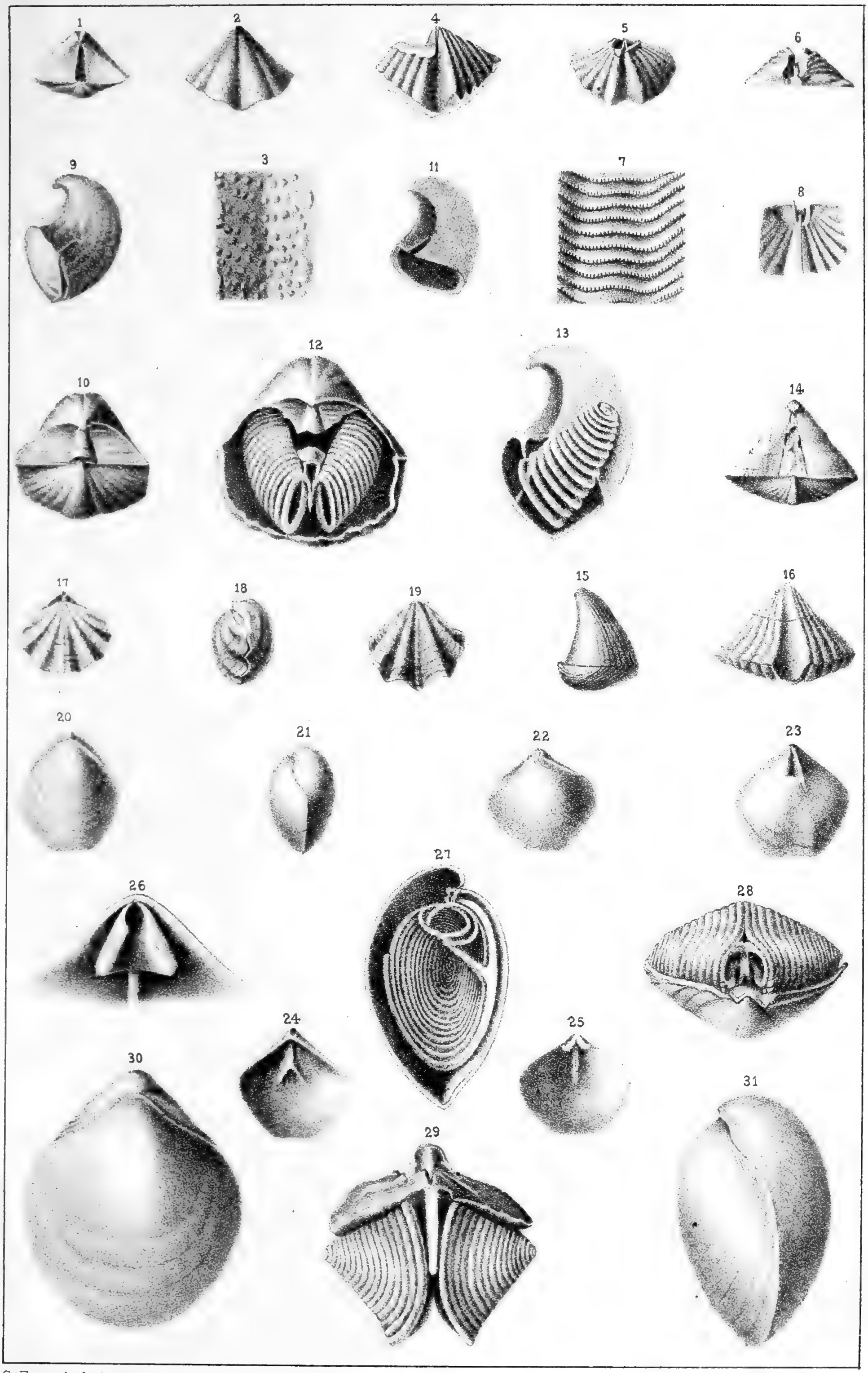
Figs. 14, 15, 16. Three views of the original specimen; showing its small size, elevated pedicle-valve, broadly rounded cardinal margins and coarse lateral plications.

Choteau limestone. *Pike county, Missouri.*

BRACHIOPODA.



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Trematospira Tennesseensis, Hall.

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Figs. 17, 18, 19. Dorsal, profile and ventral views, showing the convexity and coarse plication of the valves.

Lower Helderberg group. *Perry county, Tennessee.*

Merista Tennesseensis, Hall.

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Figs. 20, 21. Two views of the exterior of a somewhat elongate example.

Fig. 22. Dorsal view of a broader example.

Fig. 23. The exterior of the pedicle-valve, showing the cavity left by the removal of the "shoe-lifter."

Fig. 24. The interior of a pedicle-valve.

Fig. 25. The interior of a brachial valve.

Lower Helderberg group. *Perry county, Tennessee.*

Meristella Walcotti, Hall.

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Fig. 26. The hinge-plate. × 3.

Fig. 27. An internal longitudinal view; showing the position and form of the jugum and one of the spiral cones.

Fig. 28. The spirals and jugum naturally preserved by incrustation and viewed from the posterior margin.

Fig. 29. A similar preparation to which a portion of the internal cast of the valves adheres. The specimen is viewed from the dorsal side, and shows the form of the spiral cones and the length of the median septum.

Figs. 30, 31. Dorsal and profile views of the exterior.

Oriskany sandstone. *Cayuga, Ontario.*

PLATE IX.

TORYNIFER CRITICUS, Hall.

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Fig. 1. A fragment of the pedicle-valve with well-defined cardinal area. prominent teeth, convergent dental lamellæ, forming a distinct spondylium, supported by a median septum. × 2.
St. Louis group. *La Rue, Kentucky.*

RHYNCHOSPIRA SCANSA, Hall.

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Fig. 2. A view of the exterior of the pedicle-valve, showing a median sulcus similar to that occurring in typical representatives of the genus.
Waverly group. *McKean county, Pennsylvania.*

ATHYRIS DENSA, Hall.

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Fig. 3. The interior of a small but thickened pedicle-valve; showing the broad cardinal slopes, the deep pedicle-cavity and relatively large muscular impressions.

Figs. 4, 5. Dorsal and profile views of conjoined valves; showing the contour of the shell, the foramen and broad cardinal slopes of the pedicle-valve, the median elevation and low marginal sulcus of the brachial valve.
St. Louis group. *Colesburgh, Kentucky.*

Fig. 6. The interior of a larger pedicle-valve; showing a faint median ridge.

Fig. 7. The interior of another pedicle-valve, showing an umbonal thickening of the shell, and the division of the muscular area.
St. Louis group. *Washington county, Indiana.*

Fig. 8. The interior of a pedicle-valve with relatively small muscular area and linguate extension of the anterior margin, which is much foreshortened in the figure.
St. Louis group. *Lanesville, Indiana.*

Fig. 9. The interior of a pedicle-valve, showing the details of the muscular structure.
St. Louis group. *Colesburgh, Kentucky.*

SEMINULA ROGERSI, Hall.

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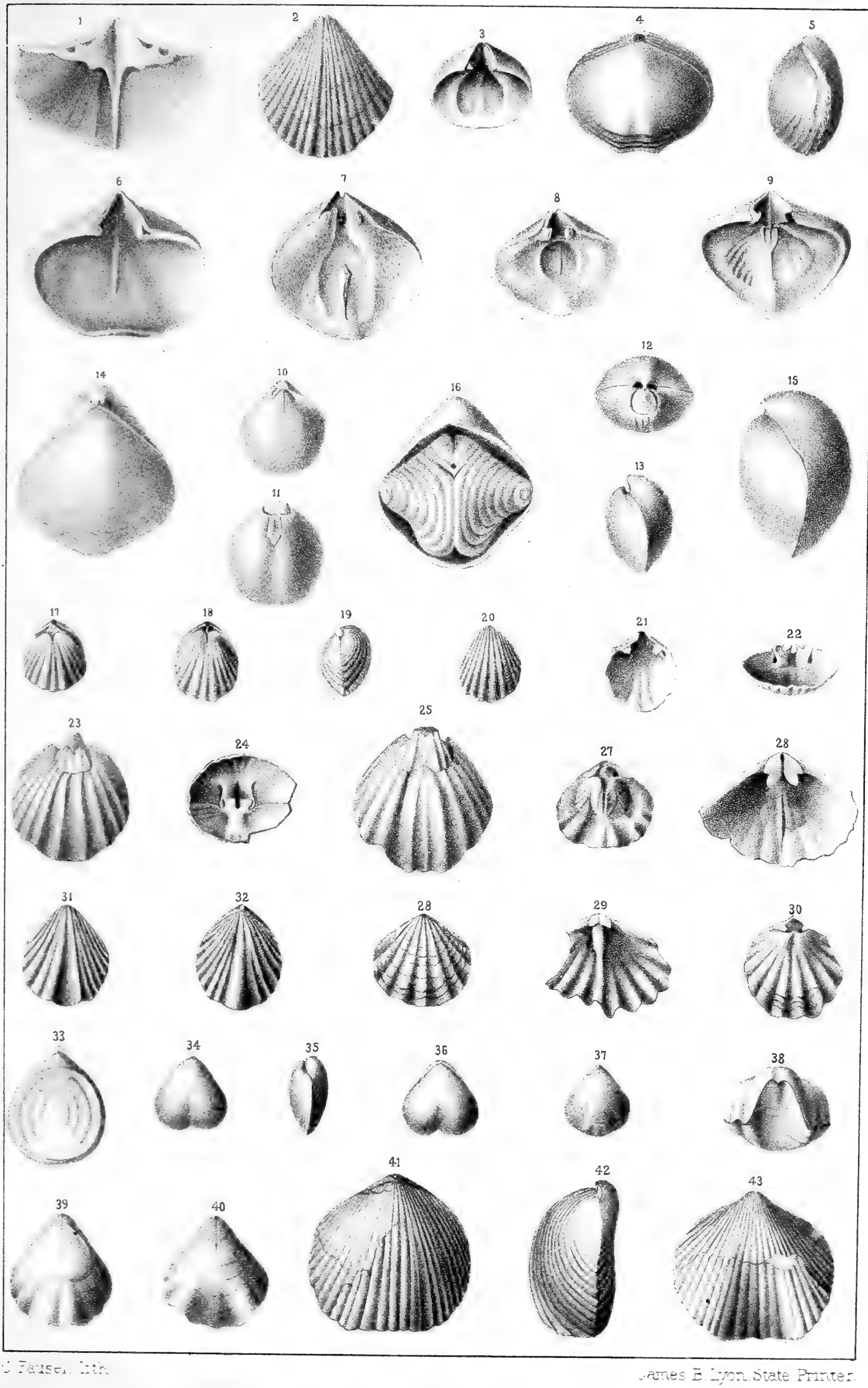
Fig. 10. A dorsal view of an internal cast.

Fig. 11. A ventral view of a similar specimen; showing the cast of the pedicle-cavity and muscular scars.

Fig. 12. Cardinal view of the same specimen.

Fig. 13. A profile of the specimen represented in Fig. 10.
Pendleton sandstone. *Pendleton, Indiana.*

BRACHIOPODA.



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Seminula Dawsoni, Hall.

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Figs. 14, 15. Dorsal and profile views of conjoined valves. × 2.

Fig. 16. A view of the brachidium naturally preserved by incrustation and exposed by the removal of a portion of the valve. × 2.

Coal Measures. *Windsor, Nova Scotia.*

Clintonella vagabunda, Hall.

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Fig. 17. A dorsal view of an internal cast, retaining the shell at the umbo of the pedicle-valve.

Fig. 18. View of another specimen similarly preserved.

Fig. 19. Profile of the same; showing the normal convexity of the valves and the elevation of the median fold on the brachial valve.

Fig. 20. Ventral view of the same specimen; showing the depth of the median sinus.

Fig. 21. The interior of an imperfect pedicle-valve; showing the teeth and delthyrium. × 2.

Fig. 22. The interior of a pedicle-valve; showing the elevation and curvature of the teeth. × 2.

Fig. 23 An internal cast of a pedicle-valve, showing the muscular area crossed by plications of the shell. × 2.

Fig. 24. The interior of the umbonal region of conjoined valves, viewed from in front; showing the mode of articulation and the bilobed cardinal process. × 3.

Fig. 25. An internal cast of the pedicle-valve; showing the division of the muscular scar into adductor and diductor scars. × 2.

Fig. 26. The umbonal portion of the brachial valve; showing the bilobed hinge-plate. × 3.

Clinton group. *Drift of western New York.*

Atrypina Clintoni, Hall.

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Fig. 27. An internal cast of the pedicle-valve; showing the adductor and diductor scars. × 2.

Fig. 28. The exterior of a pedicle-valve. × 2.

Fig. 29. The interior of an incomplete brachial valve; showing the small bilobed hinge-plate and low muscular ridge. × 3.

Fig. 30. A dorsal view of a specimen; showing the internal cast of the brachial valve and the teeth and rostral cavity of the pedicle-valve. × 2.

Clinton group. *Drift of western New York.*

ZYGOSPIRA PUTILIA, Hall.

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Figs. 31, 32. Dorsal and ventral views of a typical example. × 2.
Hudson River group. *Pike county, Missouri.*

GLASSIA ROMINGERI, Hall.

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Fig. 33. A preparation showing the introverted coils and the direction of the loop. × 3.

Figs. 34–36. Ventral, profile and dorsal views of the exterior; showing the smooth surface and bilobed anterior margins of the valves. × 2.
Trenton limestone. *In a drift boulder near Ann Arbor, Michigan.*

CAMAROPHORIA RHOMBOIDALIS, Hall.

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Fig. 37. Dorsal view of a rather small specimen.

Figs. 38, 39, 40. Anterior, dorsal and ventral views of an average adult possessing a sharper median fold and stronger plication and showing the median septum in each valve through the substance of the shell. × 2.
Corniferous limestone. *Peru, Indiana.*

LIORHYNCHUS LESLEYI, Hall.

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Figs. 41, 42, 43. Dorsal, profile and ventral views of a mature shell; showing the rather obscurely defined median fold on the convex brachial valve, the deep sinus of the pedicle-valve and the unusually complete plication of the lateral slopes.
Upper Devonian. *Pennsylvania.*

PLATE X.

Parastrophia Greenii, Hall.

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Figs. 1–4. Ventral, profile, dorsal and cardinal views of an internal cast; showing the character of the plication of the surface and the median septum of each valve.

Fig. 5. Cardinal view of another individual; showing the cavities left by the median septa.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Parastrophia latiplicata, Hall.

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Fig. 6. An internal cast of a brachial valve; showing the few broad plications and the extent of the median septum.

Fig. 7. An internal cast of the brachial valve in which the filling of the spondylium is exposed and the four scars of the adductor impression distinctly retained.

Figs. 8, 9. Profile and cardinal views of the same specimen.

Fig. 10. Anterior view showing the elevation of the median fold and character of the plication.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

Parastrophia divergens, Hall.

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Figs. 11, 12. Ventral and dorsal views showing the spondylium and septa in the umbonal region.

Fig. 13. Cardinal view of a specimen which has been transversely sectioned in the umbonal region, the brachial valve being represented above; showing the spondylia. × 1½.

Fig. 14. Anterior view of the specimen represented in figs. 11, 12.

Hudson River group. *Wilmington, Illinois.*

Parastrophia multiplicata, Hall.

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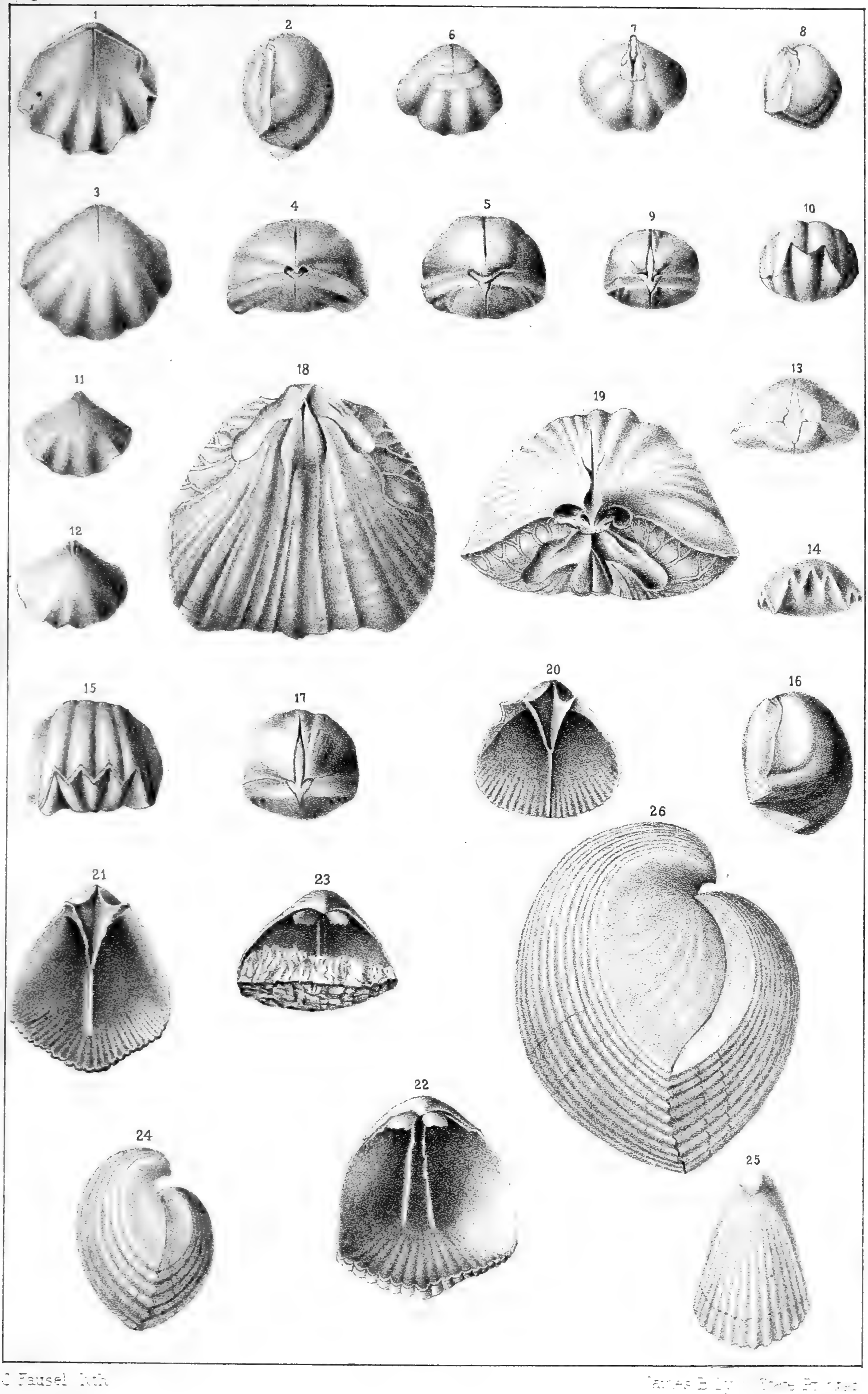
Figs. 15, 16. Anterior and profile views of an internal cast; showing the broad, strong plications, of which there are four on the fold and three in the sinus.

Fig. 17. Cardinal view of another and rather more convex internal cast; showing the cavities left by the median septa.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

BRACHIOPODA.



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Liorhynchus robustus, Hall.

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Figs. 18, 19. Ventral and cardinal views of a sharply marked internal cast of large size; showing the muscular impressions of both valves and the vascular sinuses in the pedicle-valve radiating from the impression left by the umbonal testaceous callosity.

Chemung group. *Steuben county, N. Y.*

Conchidium exponens, Hall.

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Figs. 20–23. Interiors of pedicle (figs. 20, 21) and brachial valves (figs. 22, 23).

Niagara group (Halysites bed). *Louisville, Kentucky.*

Conchidium Nettelrothi, Hall.

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Figs. 24, 25. Dorsal and lateral views. (After Nettelroth.)

Corniferous limestone. *Near Louisville, Kentucky.*

This fossil published by Mr. Nettelroth, under the name of *Pentamerus Knightii* (Fossil Shells of Kentucky), is referred by him to the Corniferous limestone. The form and entire external characters of the species are so similar to those from the Niagara formation in the vicinity of the Falls of Ohio and elsewhere, that the reference to this geologic horizon is probably erroneous. The form is very similar to *Conchidium biloculare,* Linné, from the Island of Gotland; and to some varieties of *Conchidium nysius,* Niagara group, near Louisville, Ky., that one can scarcely doubt its Silurian age.

PLATE XI.

CONCHIDIUM OBSOLETUM, Hall.

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Figs. 1, 2. Dorsal and ventral views of an internal cast; showing the few low and broad plications, the length of the median septum of the pedicle-valve, the septal plates and muscular impressions of the brachial valve.

Niagara dolomites. *Genoa, Ohio.*

CONCHIDIUM CRASSIPLICA, Hall.

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Figs. 3, 4. Dorsal and profile views; showing the ovate form of the shell, the subequally convex valves, short and depressed beak of the pedicle-valve and the coarse duplicate plication of the surface.

Niagara group. *Probably from the vicinity of Louisville, Kentucky.*

CONCHIDIUM GREENII, Hall.

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Figs. 5, 6, 7. Ventral, cardinal and profile views of a specimen somewhat restored about the margin; showing the short, ventricose valves and the fine duplicate plication.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

CONCHIDIUM SCOPARIUM, Hall.

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Figs. 8, 9. Ventral and dorsal views of a specimen retaining much of the shell and preserving a very distinct and rather fine radial plication.

Guelph dolomites. *Durham, Ontario.*

CONCHIDIUM GEORGIÆ, Hall.

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Figs. 10, 11. Cardinal and dorsal views of the brachial valve, characterized by its strong median fold.

Clinton group. *Trenton, Georgia.*

PENTAMERUS OBLONGUS, var. MAQUOKETA, Hall.

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Figs. 12, 13. Dorsal and profile views of an internal cast; showing the ovoid and regularly convex valves.

Fig. 14. Cardinal view of another individual; showing the position and extent of the internal plates.

Niagara dolomites. *Near Dubuque, Iowa.*

BRACHIOPODA.

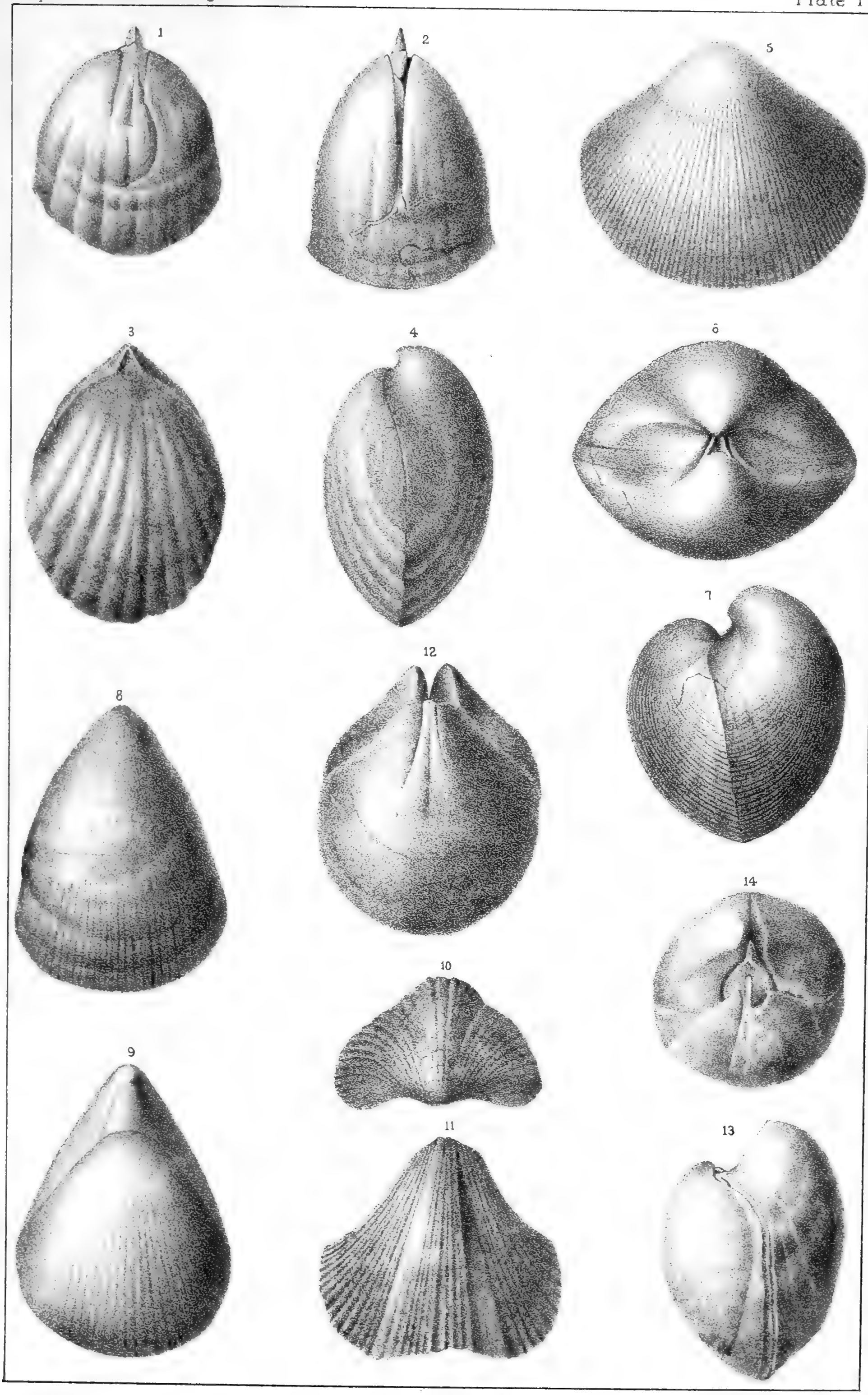

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PLATE XII.

PENTAMERUS OBLONGUS, Sowerby, var. SUBRECTUS, Hall.

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Figs. 1, 2. Dorsal and ventral views of a normal mature individual; showing the characteristic outline, prominent umbo, trilobate exterior and linear median depression on both valves.

Fig. 3. Dorsal view of a large individual, slightly imperfect at the anterior margin.

Fig. 4. A somewhat weathered specimen, in which the valves have been displaced from their normal position, exposing the spondylium of the pedicle-valve, and, by the removal of the rock, also showing part of the united septal plates of the brachial valve.

Figs. 5, 6. Ventral and dorsal views of a small specimen of subquadrate outline, trilobed exterior, and showing the single median septum on each valve.

Niagara beds. *Jones county, Iowa.*

GYPIDULA ROMINGERI, Hall.

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Fig. 7. Cardinal view of a pedicle-valve; showing a well-defined cardinal area, the teeth and the form of the spondylium.

Fig. 8. Dorsal view of the umbonal region of the specimen represented in fig. 30; showing the sharply defined cardinal area, and the deltaria or remnants of the deltidium. × 2.

Fig. 9. Interior of a large brachial valve; showing the size and structure of the spondylium.

Fig. 10. A smaller specimen; showing similar features.

Figs. 11, 12. Dorsal and profile views of a large specimen; showing the characters of the exterior. The surface of the brachial valve is somewhat exfoliated in the umbonal region, exposing the base of the spondylium and the vascular markings.

Fig. 13. An individual of average size with an unusually flat brachial valve and coarse, duplicating plications.

Hamilton group. *Near Alpena, Michigan.*

BRACHIOPODA.

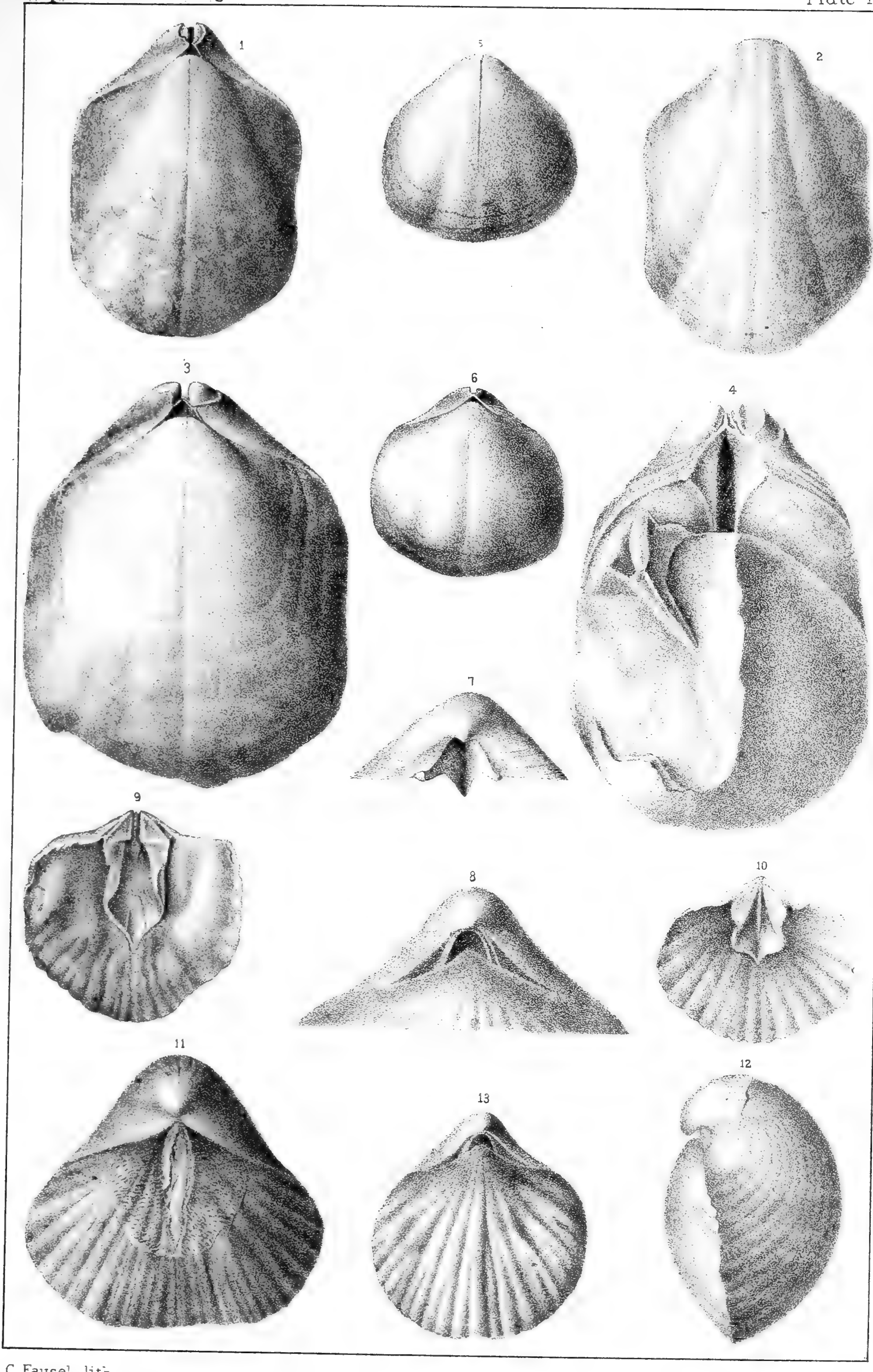

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PLATE XIII.

BARRANDELLA AREYI, Hall.

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Figs. 1, 2, 3. Dorsal, profile and ventral views; showing the strongly plicated fold and sinus on brachial and pedicle-valves respectively, and the sharp plication of the lateral slopes. × 2.

Clinton group. *Rochester, N. Y.*

SIEBERELLA ROEMERI, Hall.

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Fig. 4. Dorsal view of an individual of rather large size; showing the characteristic plication of the sinus and lateral slopes and their obsolescence in the umbonal region.

Upper Silurian. *Perry county, Tennessee.*

CAPELLINIA MIRA, Hall

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Fig. 5. Cardinal view of a pedicle-valve; showing the suberect beak and wide delthyrium.

Fig. 6. Ventral view of the same specimen.

Figs. 7, 8. Cardinal and ventral views of a normal example; showing the predominant convexity of the brachial valve, the smooth surface and the position and extent of the internal plates.

Fig. 9. A brachial valve, showing the length of the septal plates.

Figs. 10, 11. Ventral and profile views of a specimen in which the umbo of the pedicle-valve is abruptly depressed.

Fig. 12. Cardinal view of another example.

Fig. 13. Profile of a normal individual.

Niagara dolomites. *Near Milwaukee, Wisconsin.*

RENSSELAERIA CAYUGA, Hall.

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Figs. 14, 15. Dorsal and ventral views of a specimen which retains most of the shell and shows the fine plication of the valves.

Oriskany sandstone. *Cayuga, Ontario.*

BRACHIOPODA.

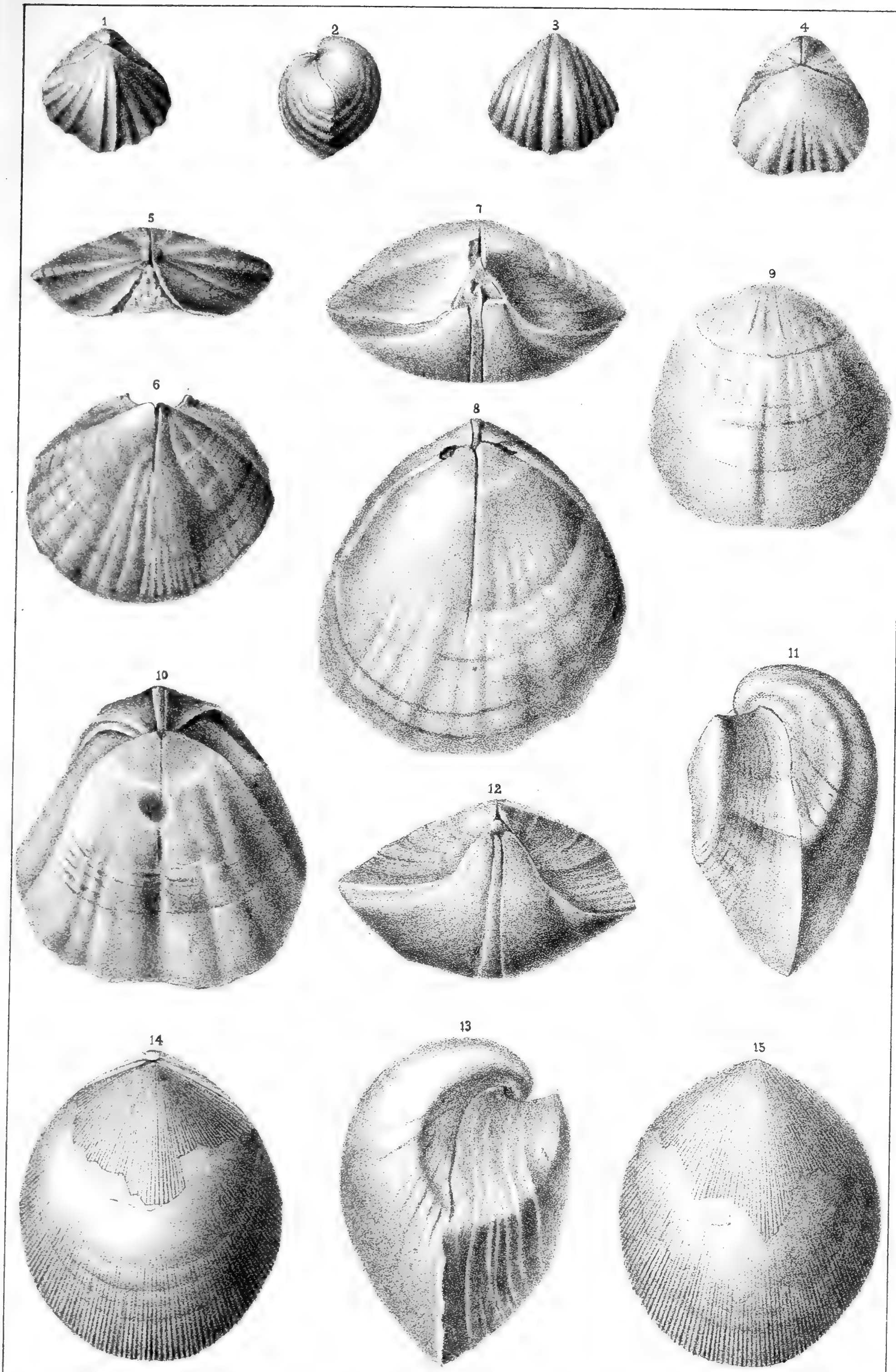

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PLATE XIV.

Oriskania navicella, Hall.

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Figs. 1, 2, 3. Dorsal, profile and ventral views of the exterior; showing the elongate form and plano-convex contour of the species.

Oriskany sandstone. *Rondout, N. Y.*

Cryptonella subelliptica, Hall.

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Figs. 4, 5, 6. Ventral, profile and dorsal views of an internal cast in iron-stone; showing the form and contour and the muscular scars of the brachial valve.

Waverly group. *Sciotoville, Ohio.*

Beecheria Davidsoni, Hall.

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Fig. 7. The internal cardinal structure exposed by the removal of a portion of the pedicle-valve; showing the absence of dental plates and the structure of the loop. × 3.

Fig. 8. Outline profile showing the manner in which the lamellæ of the loop originate from the hinge-plate.

Fig. 9. Dorsal view of an elongate shell.

Figs. 10, 11. Profile and dorsal views of an average specimen.

Carboniferous limestone. *Windsor, Nova Scotia.*

Dielasma obovatum, Hall.

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Figs. 12, 13, 14. Ventral, dorsal and profile views of the original specimen.

Coal Measures. *Kentucky.*

Rensselæria ovulum, Hall.

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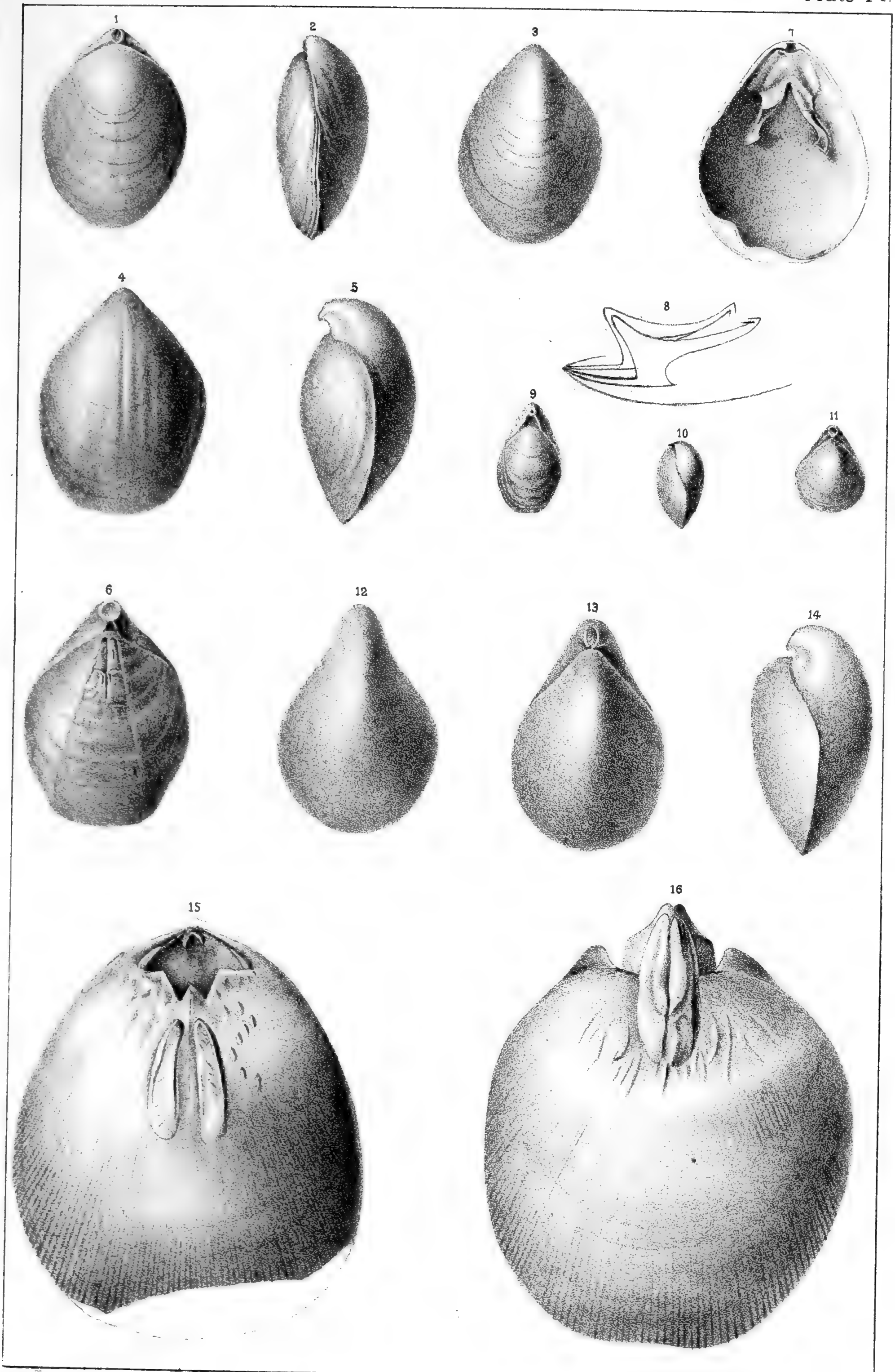
Fig. 15. An internal cast of the brachial valve; showing the muscular scars, the large cavity left by the hinge-plate and the genital workings in the umbonal region.

Fig. 16. An internal cast of the pedicle-valve.

Oriskany sandstone. *Cayuga, Ontario.*

BRACHIOPODA.



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A HANDBOOK

OF THE

Genera of the North American Palaeozoic Bryozoa.

WITH AN INTRODUCTION UPON THE STRUCTURE OF LIVING SPECIES.

By GEORGE B. SIMPSON.

ALBANY, N. Y., *January* 1, 1895.

JAMES HALL, LL. D., *State Geologist:*

SIR.—Herewith I beg to communicate for your report a paper which I have entitled "A Handbook of the Genera of the North American Palaeozoic Bryozoa," prefaced by some observations upon the structure of living species.

This work is the direct outcome of the investigations made in preparation of Volume VI of the Palaeontology of New York (1887), and has been done by me as a member of the staff of the geological department. The collections made for use in that work, as well as your own private collection, and, through your intervention, those of the American Museum of Natural History of New York, have been freely accessible to my use, and I take this opportunity of expressing my appreciation of the favorable conditions under which my work has been done.

Very respectfully yours,

GEORGE B. SIMPSON.

HISTORICAL INTRODUCTION.

It is scarcely more than one hundred years since naturalists generally recognized the fact that corals belong to the animal kingdom. Though in the year 1599 Ferante Imperato, a naturalist of Naples, in his work, "Histoire Naturelle," asserted that fact, he found few, if any, believers in his statement. In every reference that I have seen to this author he is referred to as an "Apothecary of Naples" — seemingly overlooking the fact that this man as a naturalist possessed knowledge nearly 150 years in advance of any other naturalist in regard to the Zoophytes. To him should be given the honor which is generally accorded to men of the eighteenth century. This book was republished in 1672, but even then attracted little attention, and subsequently seems to have been relegated to oblivion. De Blainville speaks of his work as being one of the most important in zoophytological history.

Whatever had been the importance of Imperato's work at the time, his statements had fallen into complete oblivion at the beginning of the eighteenth century. In 1706, Count Marsigli, or Marsilli as his name is sometimes written, in a letter to the Abbé Bignon, and later in 1711 in "Brieve ristretto del Sagio fisico intorno alla Storia del Mare," Venice, 1711, reasserted the doctrine of the vegetable nature of corals and makes the remarkable assertion that he had seen the plants in full flower mistaking the expanded tentacles for the petals of a flower.

Jean Andre Peysonnelle, a physician of Marseilles, saw the error into which Marsigli had fallen, and in 1727, in a communication to the Academy of Sciences at Paris, reasserted the doctrine of Imperato, that the seeming flowers were animals, and that the hard part was provided for the protection of the animals. This communication was entrusted to the great naturalist, Reaumur, to be presented to the Academy, but so ludicrous did

REAUMUR consider PEYSONNELLE's belief to be, and so great was his contempt for his doctrine, that while presenting it to the Academy, he not only vigorously combatted the idea, but suppressed PEYSONNELLE's name in connection with the article.

At the same meeting of the Academy REAUMUR read a paper explaining the growth of corals in accordance with vegetable physiology. (See Hist. de l'Acad. Royale des Sci. p. 51, and also Reaumur's memoir in the same volume, p. 380.)

In his communication to the Academy PEYSONNELLE maintained that the organisms described by MARSIGLI as flowers were analogous to the ACTINIA, whose animal nature was admitted, and that the hard parts were formed by a fluid deposited by the animal, which afterward hardened, and that in these parts was no trace of vegetable organism, mixing up the principal truth, namely, the animality of corals, with many false conclusions from observations.

PEYSONNELLE seems to be remembered chiefly by this discovery, which, though previously recorded by IMPERATO, was to all intents original, as IMPERATO's writings were at that time practically unknown. According to the Philosophical Transactions "M. PEYSONNELLE, disposed from his youth to the study of natural history, after having qualified himself for the practice of medicine, applied himself with great diligence to the practice of that science, to which his inclination so strongly prompted him, and being a native of, and residing at Marseilles he had an opportunity for examining the curiosities of the sea, which the fishermen, more especially those who fished for corals, furnished him with." According to JOHNSTON (History of British Zoophytes) he was subsequently appointed Physician-Botanist to his "Most Christian Majesty" in the island of Guadaloupe, and had every opportunity for prosecuting his researches on the coast of Barbary. He is the author of two or three communications to the Philosophical Transactions, of which the most interesting is "An account of the visitation of Leprous persons in the isle of Guadaloupe," in the volume for the year 1757.

In the year 1741, ABRAHAM TREMBLEY, while making experiments on the fresh-water Hydra, which had been discovered by LEEUWENHOOK in 1702, especially on its reproductive power, discovered in the fresh waters near the Hague, a plant-like animal, growing in masses, from which proceeded crescent-shaped tentacles. The tentacles were the most striking feature of these animals, and from them TREMBLEY gave the name to the animals of "Polype á panache," the Polyp with plumes. In the Philosophical Transactions for 1742 will be found a full account of this discovery, and in "Mémoirs pour servir á l'Histoire du genre de Polypes d'eau douce," Leyden, 1744, he gives an accurate account of the anatomical details, which have been surpassed by few subsequent observers. He demonstrated an alimentary canal, consisting of œsophagus, stomach and intestine, and also the muscles. He also showed the relation between the animal and its cell, and proved that the latter was created by the former. He further described and fully understood the statoblast. Though recognizing the intestine, he failed to detect its termination.

This species was subsequently found in England by BAKER, who gave to it the name "Bellflower animal" in "Employment for the Microscope," 1753. In this paper is first recorded the termination of the intestine.

In the autumns of 1741 and 1742, BERNARD DE JUSSIEU and GUETTARD visited different points on the coast of France for the purpose of studying the marine zoophytes. They had an opportunity of observing several forms, which had not been seen by PEYSONNELLE, notably SERTULARIA, FLUSTRA and ALCYONIUM, the last of which especially excited their admiration by the beauty of its tentacles which could be seen by the naked eye. LAMARCK speaks very highly of GUETTARD's labors, which seem to have been especially directed to fossil Polypes and Sponges.

The result of the observations of JUSSIEU was communicated to the Royal Academy of Sciences on the 14th of November, 1742, and was published in 1745. His observations were precise and were illustrated by excellent figures. He described four species as illustrating the most remarkable forms, viz.: *Alcyonium digitatum*, *Tubularia indivisa*, *Flustra foliacea* and *Cellepora pumicosa.* In regard to the SERTULARIDÆ in the Mem. de l'Acad. Royal des Sciences, 1742, he says, "Il s'en presentoit ensuite quantité des celles qu'on appelle Corallines, les unes pierreuses dans lesquelles je ne remarquai rien, et les autres dont les tiges et les branches, et ce qui passoit pour feuilles, etoient d'une apparence membraneuse, dans lesquelles je decouvrais que ce qu'on y prenoit pour feuilles disposées alternativement, ou dans un sens opposé, n'etoit autre chose que de petits tuyaux contenant chacun un petite insecte."

The work of TREMBLEY, JUSSIEU and GUETTARD convinced REAUMUR that the views of PEYSONNELLE were in the main correct, and that he had been in error in combatting them. He now advocated the animality of corals (Memoires pour servir à l'Histoire des Insectes, Paris, 1742, tome xvi, Prefatio, pp. 68–80), but so deep seated was the belief in the vegetality of corals that his views made a very slight impression. Dr. VITALIANO DONATI in a work entitled "New discoveries relating to the History of Corals," translated by STACK and published in Phil. Trans., Vol. XLVII, Feb. 7, 1750, gave a minute account of the coral and its inhabitant, but his terms were botanical and his opinions so doubtful that he rather confirmed the advocates of the vegetable theory in their opinion.

A few years afterward (Phil. Trans. 1757, abridg. xi, p. 83), he says: "I am now of the opinion that the coral is nothing less than a real animal with a great number of heads. I consider the polyps of the coral as the heads of the animal. This animal has a bone ramified in the shape of a shrub. This bone is covered with a kind of flesh, which is the flesh of the animal. My observations have discovered to me several analogies between the animals of a kind approaching to this. There are for instance KERATOPHYTA, which do not differ from coral, except that the bone or prop that forms part of the animal is testaceous in the coral and horny in KERATOPHYTA" PEYSONNELLE was still living and in 1751 he sent to the Royal Society a treatise entitled "Traitè du corail, contenant les nouvelles decouvertes, qu'on a fait sur le corail, les pores, madrepores, eschares, litophitons, èponges et autres corps et productions, que le mer fournit, etc., par le Sieur DE PEYSONNELLE, M. D., correspondent de la Royal Acad. de Paris, etc., etc." This manuscript was never published, though a review of it was given by Dr. WATSON in the 47th volume of the Phil. Trans., published in 1752. This treatise was very lengthy and consists of about 400 quarto pages.

In the same year, 1752, we find the following statement in answer to PEYSONNELLE concerning the formation of corals, corallines, etc.: "And indeed it would seem to me much more difficult to conceive that so fine arrangement of parts, such masses as these bodies consist of, and such regular ramifications in some, and such well-contrived organs to serve for vegetation in others, should be the operation of little, poor, helpless, jelly-like animals, rather than the works of more sure vegetation, which carries the growth of the tallest and largest trees, with the same natural ease and influence as the minutest plant." (PARSONS.)

Even LINNÉ could not be convinced of the purely animal nature of corals, but maintained that the stems and branches were of a purely vegetable nature, while the polyps were a sort of flowering which had been raised and perfected to an animal nature.

The conversion from the belief of the vegetable to the animal nature of corals is due to the efforts of JOHN ELLIS, of London, more than to those of any other one man. ELLIS seems to have been ignorant of the labors of his predecessors, and to have imagined that his discoveries were original. In 1755 he published his work "Essay on the Natural History of the Corallines," which, from its fidelity of observations and its correct pictorial illustrations left but little room for doubt as to the true nature of corals. He also contended for the animality of Sponges, in which he was not only opposed by the naturalists of his time, but this theory was not universally accepted for more than one hundred years later.

LINNÉ could not be convinced by the clear descriptions and figures of ELLIS, and wrote to him, as follows: "Zoophyta are constructed very differently, living by a mere vegetable life, and are increased every year under their bark-like trees, as appears in the annual rings in a section of a trunk of GORGONIA. They are, therefore, vegetables, with flowers like small animals, which you have most beautifully delineated. All submarine plants are nourished by pores and not by roots, as we learn from Fuci. As Zoophytes are, many of them, covered with a stony coat, the Creator has been pleased that they should receive nourishment by their naked flowers He has, therefore, furnished each with a pore, which we call a mouth. All living beings enjoy some motion. The Zoophytes mostly live in the perfectly undisturbed abyss of the ocean. They can not, therefore, partake of that motion which trees and herbs receive from the agitation of the air. Hence the Creator has granted them a nervous system, that they may spontaneously move at pleasure. Their lower part becomes hardened and dead like the solid wood of a tree. The surface, under the bark, is furnished every year with a new living layer as in the vegetable kingdom. Thus they grow and increase and may even be truly called vegetables, as having flowers, producing capsules, etc. Yet as they are endowed with sensation and voluntary motion, they must be called, as they are, animals; for animals differ from plants merely in having a nervous sentient system, with voluntary motion, neither are there any other limits between the two."

Notwithstanding the opposition of a few naturalists, the animality of corals was hereafter almost universally admitted, more than one hundred and fifty years after its discovery by IMPERATO.

In 1827, Professor GRANT read before the American Society an account of the structure of FLUSTRA, in which he describes its locomotive embryos. (New Philosophical Journal, Edinburgh, Vol. III, 1827)

In the following year M. AUDOUIN and MILNE-EDWARDS gave a very complete account of the anatomy of FLUSTRA in which they called attention to their close resemblance to the ASCIDIA and the bearing of this resemblance upon their systematic rank.

They called attention to the fact that some of the polypes possessed an anal as well as an oral opening to the canal, and proposed to found a division of the polyps into classes, according to the form of the alimentary canal. He includes moreover sponges in this class.

EHRENBERG in his "Symbolæ Physicæ" published in 1831 divided the polyps into two principal groups, ANTHOZOA and BRYOZOA, according as the alimentary canal had one or two aboral openings. Afterward, in 1834, he modified this division by separating the SERTULARIDÆ and other Hydriform polyps, which he placed in a class called LIMORPHÆA.

In 1830 Dr. JOHN V. THOMPSON, at that time stationed at Cork as deputy inspector-general of hospitals, made a series of observations on the marine fauna of the coast. He examined the animals of *Bowerbankia imbricata*, *Valkeria cuscuta*, *V. pustulosa*, *Vesicularia spinosa* and other allied forms. He also perceived their internal relation with the compound ASCIDIÆ, and separat ing them from corals, gave to them the name, POLYZOA. Being situated in a remote part of Ireland he was seemingly ignorant of the previous work of EHRENBERG, EDWARDS and GRANT. EHRENBERG's papers were printed from 1828 to 1831 (Symbolæ Physicæ) and THOMPSON's in 1830. There is no date printed on the title page, but according to ALLMAN it is to be found on the paper wrapper in which the publication was originally stitched.

It has been, and still is a matter of dispute whether the term BRYOZOA of EHRENBERG or POLYZOA of THOMPSON has priority. The name BRYOZOA has been adopted by many English naturalists, and seems to be growing in favor among them, while it is used by all the naturalists of the world, with the exception of those of England and her colonies, and the use of that term will probably in time become universal.

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THE CELL.*

The typical Bryozoan, (fig. 1) is composed of a sac, with walls ormed of an inner and outer layer, the endocyst, Plate I, fig. 1,

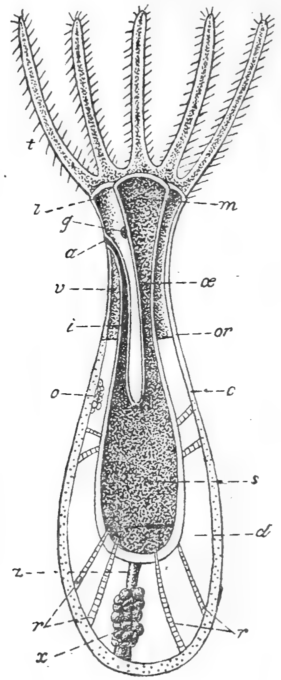


FIG. 1. Diagram showing the structure of a single polypide of a Bryozoan (after BUSK): *t*, Tentacles; *m*, Mouth; *œ*, Œsophagus; *s*, Stomach; *i*, Intestine; *a*, Anus; *z*, Funiculus; *x*, Testis; *o*, Ovary; *r*, Retractor muscles; *g*, Nerve ganglion; *v*, Tentacular sheath; *d*, Perigastric space; *c*, Ectocyst; *or*, Aperture of the zoœcium (after BUSK).

u, and the ectocyst, fig. 1, *c*, and Pl. A, fig. 1, *v*. The outer layer is usually chitinous or calcareous, though in some forms it is gelatinous and sometimes entirely wanting, though this is

* In writing this paper on the recent BRYOZOA I make no claim to original investigation, but have placed the results of the study of the literature of the subject in such a form that the student can readily obtain a clear idea of the morphology of these animals, as at present known.

of very rare occurrence. Within this sac is suspended the alimentary canal, consisting of œsophagus, stomach and the intestine bent upon itself so that the anus is in close proximity to the mouth, as shown in fig. 1 and in the figures on Plates A and B. Around the mouth is a fringe of ciliated tentacles, which serve as respiratory organs and as a means of conveying food. In all the marine species and in the fresh-water genus PALUDICELLA, the tentacles are arranged in a circle around the mouth, but in the other fresh-water genera they are bilateral, the arrangement being in the form of a horseshoe, from which fact this group of BRYOZOA is called *Hippocrepian*.

The mouth and tentacles are protruded from and contracted into the cell by the action of occlusor and retractor muscles. From the fundus of the stomach to the base of the cell is a cord known as the funiculus. This cord extends through the cell, forming a means of communication with the other cells composing the colony. This cord frequently gives off filaments which extend through the walls of the cell, being continuous with similar filaments from adjacent cells (Plate A, fig. 1*r*). The testis is formed on the funiculus, the ovaries being situated on the endocyst much nearer the mouth of the cell (fig. 1, *o*, and plate A, figs. 1, 2). The space between the alimentary canal and wall of the cell is filled with a perigastric fluid. There is a single nerve ganglion, on the side of the œsophagus, near the mouth (fig. 1, *g*), from which filaments proceed in different directions, but principally to the lophophore and tentacular crown. In some forms, as in *Bowerbankia densa*, the ectocyst is chitinous and beautifully transparent, so that all the parts of the animal can be distinguished through it. In most of the forms the ectocyst is calcareous and opaque. Some portions of the cell are frequently more fragile than others. These are usually absent in the fossil stage, the more calcareous portions alone remaining and giving a very false impression as to the original form of the cell. Some species which when living had an ampullate or cucullate cell, with opercula, appear in a fossil state as having polygonal cells, as in a thin section of a Favosite. This condition may also be observed in some of the forms adhering to shells. In the MEMBRANIPORA, a large group of incrusting BRYOZOA, the cells are surrounded by a well-marked and elevated border. The space within this border is called the *area*, and is frequently entirely occupied by a chitinous membrane, in which is the cell-mouth. In the fossil state the membrane has disappeared, the elevated border alone remaining, the whole "area" appearing as the mouth of the cell. The loss of all chitinous portions of the cell and chitinous appendages will, of course, greatly change its appearance, making it much more difficult to classify fossil than recent forms The ectocyst is not, as has often been supposed, a calcareous exudation from the surface of the animal, but is deposited in a tegumentary membrane, forming not a mere calcareous crust, but an integral portion of the animal itself, which, like the cartilage of higher animals, hardens by the deposition of calcareous matter, but still is the seat of nutritive movement.

MILNE-EDWARD has made a number of experiments on the cell walls of ESCHARIDÆ, and the results are here given in translation. In the Ann. des Sciences Nat. Zool., Vol. I, pp. 25–31, he says: "If the stony cells of the Escharidæ were formed by the exudation of a calcareous matter which molded itself on the surface of the secreting membrane, it is evident that the first layer thus formed must be the external one, and that the addition of new quantities of this earthy matter could only augment the thickness of the parietes of the cell and modify the disposition of its interior cavity, without at all changing the exterior configuration of the first formed layer; for here the solid cell completely envelops the animal and is not overlapped by the secreting organ, as in the Mollusca gasteropoda, whose shell changes its form with age, because the deposit of new matter taking place on the border of the part already consolidated continually lengthens it and is molded on the soft parts whose configuration is liable to change.

"To throw some light on the mode of formation and on the nature of the cells of the Eschares, it becomes, consequently, interesting to examine these cells at different ages and to see if their exterior form changed or remained always the same. This study, indispensable for the anatomical and physiological history of these little beings, may also lead to a knowledge useful to zoology and geology, for the determination of the species, recent and fossil, rests principally on the characters furnished by these cells. And we are still ignorant whether or not they can be modified in the progress of age.

"This examination can be made more easily than one might at first imagine; for neither the observation of the same individual, at different stages of its development, nor the collection of a series of specimens so as to represent all the phases through which these little creatures pass successively, is required. Indeed, since these polyps spring from each other, and do not separate from their parents, each polypidom must present a long series of generations enchained to each other, and in each of these series the relative age of living individuals must be indicated by the place they occupy. To resolve the question which we have put, it is sufficient, therefore, to study comparatively the cells situated near the base of the polypidom, in its middle, in its young branches, and toward the extremity of the latter; for we are certain that it is not only in this last place that living polyps are found, as some authors affirm, but that they exist over almost the entire extent of the polypidom.

"After examining in this manner, with a sufficient magnifying power, the cells of the *Eschara cervicornis*, I am quite convinced that the mode of development of these stony cells is not that which is usually admitted.

"Indeed, I have seen that not only does the general conformation of the cells change with age, but also that these changes operate in a great measure on the exterior surface — that is to say, on that side of their parietes, which, in the hypothesis of their formation by layers, must exist from the first, and once consolidated, ought to change no more, unless from exterior and accidental frictions.

"In the young cells whose partitions, although thin, have already acquired a stony consistency, the exterior surface is quite convex, and the margin of their apertures just out so they are easily distinguished; but by the progress of age their appearance changes; their free surface rises so as to efface the deep depressions which marked originally their respective limits, and to raise to the level of the surface the border of the openings. The result of this is that the cells cease to be distinct, or even distinguishable without, and that the polypidom seems to be formed of a stony continuous mass, in the substance of which are excavated certain holes slightly widened interiorly, and disposed in quincunx.

"But differences of this nature can not be formed by the simple juxtaposition of new calcareous layers under those primitively formed, for the soft parts of the animal — the only ones which can be the seat of a secretion of this calcareous matter — do not extend over the surface which is thus modified, and the position of the cells thus immersed in the apparently common mass of the polypidom is often such that we can not attribute their change of form to any operation or friction of foreign bodies.

"It appears evident to us that these facts indicate the presence of life in the substance which composes the parietes of these cells and can only be explained by the existence of a nutritive movement, like to that which in the configuration of bones effects analogous modifications.

"To know better the nature of these cells, I submitted to the action of nitric acid diluted with water a part of a polypidom recently taken from the sea. A brisk effervescence was visible immediately, and in some minutes the cells became flexible and separated from one another. Before treating them thus no distinct membrane was seen on the internal wall of these cells, and when the nitric acid had destroyed all the calcareous carbonate on which their rigidity depended these same parietes still existed and had not changed their form much, only they were formed now of a soft and thick membrane constituting a bag, in the interior of which we perceived the digestive apparatus of the polype. The opening of this bag was no longer truncated, as it appeared when the texture of the membrane was thickened by the stony deposit from which we had just freed it, but the membrane was continued uninterruptedly with the tentacular sheath.

"We see, then, that in the Eschares, the cell in which it is said the polyp retires as into a shell, is a component part of the animal itself, in which it conceals itself, if we may use the comparison, as the hedgehog enters into the thorny skin of his back. It is not a calcareous crust which is molded on the surface of its body, but a portion of the general tegumental membrane of the skin of the polyp, which by a molecular deposit of earthy matter in the meshes of its tissue, ossifies as the cartilages of superior animals ossify, without ceasing to be the seat of a nutritive movement.

"We see, also, that that which is considered generally as being the body of these polyps, constitute in reality only a small portion of it, and consists of little but the digestive, and probably breathing organs, of these little animals.

"The tegumental bag, freed from its carbonate of lime, seems to me formed of a tomentose membrane covered, particularly without, with a multitude of cylindrical filaments, disposed perpendicularly to the surface, and pressed close to one another. It is in the space left between these fibers that the calcareous matter appears to be principally deposited, for if we examine, with the microscope, a transverse cut of the polypidom in its natural state, we distinguish in it an analogous conformation, the external wall of the cells being not composed of layers, but rather of cylinders or irregular prisms placed perpendicularly to its surface.

"As to the operculum, which serves to shut the entrance of the tegumental cell of the *Eschara*, when the animal is wholly concealed in it, it is but a labial fold of that which we may call the skin of the polyp, and of which the projecting margin has acquired a horny consistence, whilst that portion continuous with the general envelope preserves sufficient softness to remain flexible, and to obey the action of the muscles whose tendons are inserted in its thickness.

"The changes which we have indicated above in the external formation of the cells of the Eschares are not the only ones effected by the progress of age in the stony integuments of these zoophytes. The form of their opening is modified considerably, as may be seen by the figures which accompany this memoir; the sinus or emargination situated under the operculum disappears by degrees, and their interior cavity becomes filled up so as not to occupy more than about the quarter of their original diameter. This thickening changes even a little the general appearance of the polypidom; for as it is more considerable in the cells situated farthest from the extremities of the branches, it results that these, at first almost flat, become more and more cylindrical. Lastly, it is not without surprise that we have seen these same cells when they arrived at extreme old age, lose altogether the opening from which the polyp extended its tentacula. In fact, the margins of this opening, swelling more and more inwardly, come at last to touch and to close, so that no trace of its existence is left; but the cell, now a shut cavity, still exists toward the axis of the polypidom.

"Thus, then, the last external mark of the individual existence of these collected polyps disappears before that life is extinct in the interior, and the most remarkable character of the polypidom is lost without hope of recovery.

"Reflecting on the fact we have just noticed, we are naturally led to ask how the nourishment necessary for the support of the secretions on which the progress of consolidation depends, can continue when the cell containing the digestive apparatus of the animal is shut up in this manner. Is it from its neighbors that it receives its nutritive matters, or can it continue to absorb them directly from without through these stony integuments? The nature of this solid shell seems at first sight to oppose great obstacles to this imbibition, particularly to that which would take place by the free surface of the polypidom, but an experiment which is, so to speak, the counterpart of that which has been already detailed, shows that it is otherwise.

"On boiling a fragment of the solid polypidom of an Eschara in a solution of caustic potash, I have extracted the major part of the substance which composes the organized part of its tissue, and I have then seen that the appearance of the polypidom is considerably changed. The external parietes of the cells had become of an almost spongy texture, and its surface, from being simply granular, presented a great number of very distinct pores, which were before concealed by the soft parts with which they were filled.

"We may understand, then, that the organized tissue of the old polyps finding itself without covering in different points of the external surface of the cells, the absorption may continue to be effected directly from without, although the opening by which the nutritive matters penetrate usually into the digestive cavity is obstructed and obliterated." (From Johnston's History of British Zoophytes.)

The Opercula.

Nearly all the forms in the sub-order Cheilostomata are supplied with a chitinous organ for the purpose of closing the mouth of the cell when the animal is retracted. In the fossil Cyclosto-

MATA many forms possess a calcareous plate whose purpose was undoubtedly the same. Fig. 2 illustrates several variations in this organ from the recent cells.

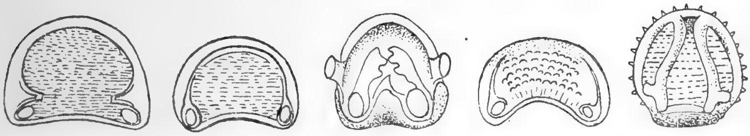


FIG. 2.

In the recent cells the opercula are sometimes composed of a continuous chitinous substance, but generally it is composed of a chitinous frame supporting a membrane; in addition there are sometimes lateral rods and occasionally a complicated frame work. Sometimes the chitinous frame is continuous all around; at other times the lower border is membranous and is continuous with the chitinous ectocyst of the cell. In other forms the opercula are calcified and are preserved in many fossil forms, as in FENESTELLA, CALLOPORA, FISTULIPORA, etc. Usually the opercula are somewhat convex, and concentrically striated; sometimes minutely granulose; at other times, as in *Callopora elegantula*, small ridges radiate from the central portion to the margin, having a resemblance on a superficial examination, to septa or projecting spinules. Sometimes there is a central perforation, at other times there is a central node or projection.

The mode in which the opercula are articulated to the cell varies considerably; when the cells are calcified they are directly attached to the sides of the orifice, usually near the lower border, sometimes above. The articulation is effected by an elastic fibrous ligament, which is generally inserted in a notch on each side of the opercula, but sometimes it is attached to projections which correspond to notches in the margin of the cell.

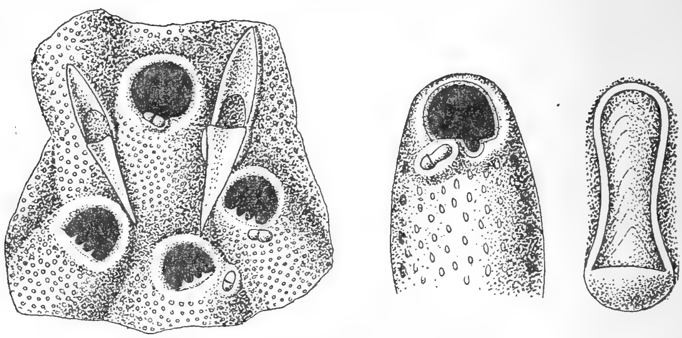
The opening and closing of the opercula is effected by two pairs of muscles, the occlusor and retractor, which are variously inserted in the different forms of BRYOZOA.

The opercula are constant in form in the same species, as are also the avicularia, and form the most reliable means for the identification of species in recent forms. Of course in fossil forms, where the opercula are seldom preserved, such a means of identification is impossible.

The form in recent species varies, but they are all more or less circular or semicircular in outline. The lower border is straight, sinuate or concave, forming a segment of a smaller circle than the upper border, or produced in the middle into a peduncular process, which usually, but not always, corresponds to a notch in the margin of the cell.

AVICULARIA AND VIBRACULA.

The chitinous organs called avicularia were first observed by ELLIS in a species to which he gave the name "bird's head coralline," and it is from their resemblance to the beak of a bird that they take their name. They are supposed to be modifications of the



FIGS. 3-5. Illustrating immersed avicularia.

FIG. 3. *Cellepora Honoluluensis.*
FIG. 4. *Cellepora vagans.*
FIG. 5. An enlargement of the mandible of the latter (after BUSK).

cell proper. There are three distinct forms, the simplest of which is in the rudimentary form of a dwarfed cell, with an enlarged operculum, called the mandible (figs. 3, 4, 5), and is known as the immersed form. The sessile forms (figs. 6′, 7, 8), are those which are situated on the cell walls and have a small chamber and mandible. The pedunculate forms, which are situated at the extremity of a movable stalk, which is frequently jointed, and which is in almost incessant motion (figs. 6″ and 9). These avicularia have a very close resemblance to a bird's head. All the forms may be said to consist of three parts, the chamber, the beak and the mandible. In the chamber are occlusor and retractor muscles, by means of which the mandible keeps up a constant flapping motion. The different parts and the muscles are illustrated in figs. 9, 10, enlargements of sessile avicularia.

In the Report on the Bryozoa of the Challenger expedition, BUSK arranges the avicularia as follows:

As to form:

a. Pedunculate and usually articulate.

b. Sessile.

c. Immersed.

As to function:

a. Prehensile — when the mandible, beak and muscles are adapted for prehensile purposes.

b. Retentive — when the mandible is thin, membranous, and adapted to serve merely as a lid for the cup or receptacle.

As to position:

a. Vicarious — when they represent or replace an ordinary zoœcium.

b. Adventitious — when either attached to some point or other of the zoœcium or interspersed among the zoœcia.

The mandibles exhibit a great variety of form, some of which are shown in figure 12. The prehensile forms are semicircular,

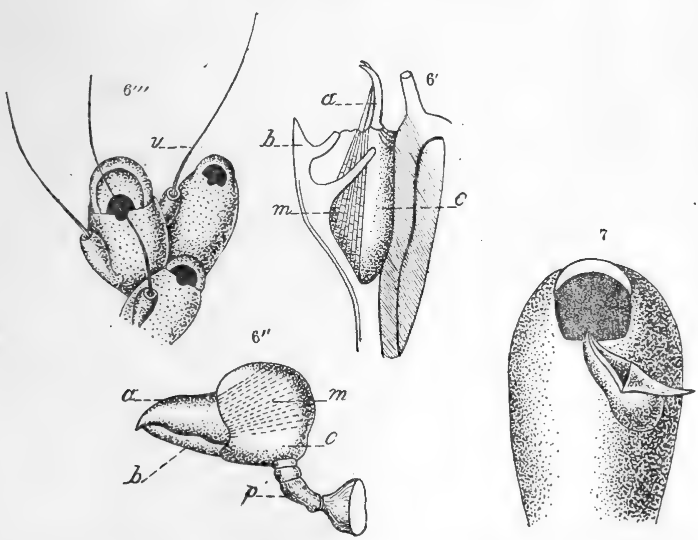


FIG. 6′. Sessile avicularia of *Scrupocellaria scruposa.* *a*, Mandible; *b*, Beak; *c*, Chamber of avicularium; *m*, Muscles; *p*, Peduncle.

FIG. 6″. Pedunculate avicularium, ideal figure.

FIG. 6‴. Three cells, showing vibracula.

FIG. 7. Cell of *Eschara sulcata*, with sessile avicularia (after HINCKS and BUSK).

triangular, elongate or sword shaped. They are formed of a strong chitinous frame and base, by the extremities of which the mandible is articulated to the cup. The space between the frame is occupied by a membrane, nearly always with a foramen, above which the occlusor muscles are inserted. These are usually two in number. The form of the retentive mandible is usually semi-circular or spatulate. They are generally simple, but sometimes bifid or trifid. They are without the continuous chitinous frames of the prehensile mandibles, and consist of a membrane supported only by the base, or by a frame at the sides extending only a short distance from the base; the foramen is generally absent, and the occlusor muscles are much weaker than in the other variety. The purpose of the avicularia is not known. By some it is thought that they procure food, and it is a favorite mode of illustration to picture an avicu-

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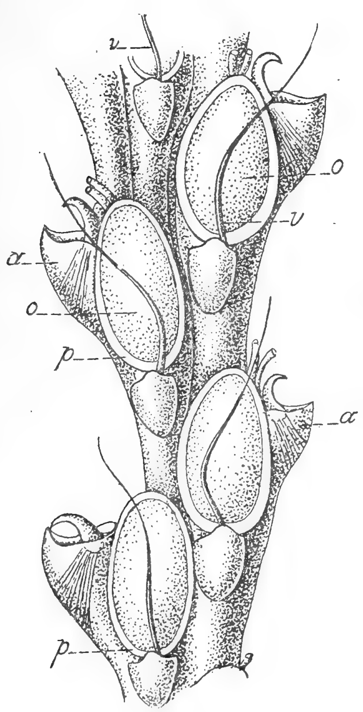

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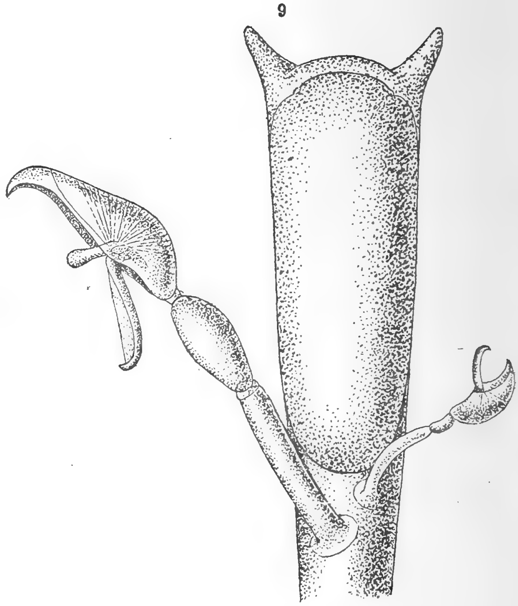
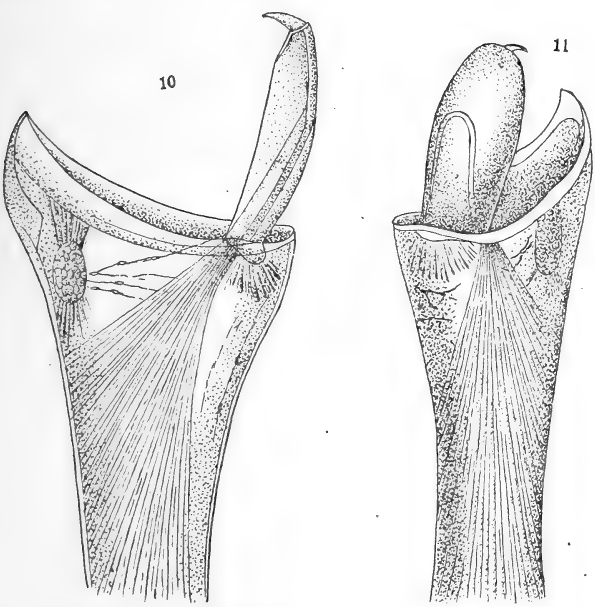


FIG. 8. *Menipea flagellifera.* *a*, Sessile avicularia; *v*, Vibracula; *p*, Peristome; *o*, Opercula.

FIG, 9. *Bugula bicornis*, showing two kinds of pedunculate avicularia, the larger one with the digitiform process (after BUSK).

larium with a captive worm, longer than the polyp cell; of course the avicularia can not convey food to the mouth, and the animal is incapable of swallowing any but the most minute particles. Any capture by an avicularium is clearly accidental, caused by the mandible shutting as the particle floated beneath it, and the constant flapping of the mandible would tend to create a current away from it. According to other authors its functions are purely defensive. "They may either arrest or scare away unwelcome visitors. Their vigorous movement and the snapping of their formidable jaws may have a wholesome or deterrent effect on loafing annelids or other vagrants, while the occasional capture of one of them may help still further to protect the colony from dangerous intrusion." (HINCKS.) But the avicularia occur only on the CHEILOSTOMATA, and as other forms are without them, it shows that they are unnecessary as weapons of defense.



FIGS. 10, 11. Two views of a pedunculate avicularia of *Bicellaria pectogemma*, showing occlusor and retractor muscles (after BUSK).

The vibracula consist of long slender setæ or bristles thickened near the base (figs. 6''' and 8, *v*). They are divided by BUSK into two kinds, as follows:

Simple — consisting of a basal cup without a beak, to which the flagellum or seta is articulated, usually by a double joint, admitting of motion in only one plane.

Compound — in which the seta is continuous with or articulated to a basal mandible, and the cup or receptacle has a more or less distinct beak.

The use of these appendages is not known. BUSK says: "These whip-like appendages serve as defensive and cleansing organs, and may be observed in almost constant motion, sweeping slowly and carefully over the surface of the colony and removing whatever might be detrimental," but as is the case with avicularia, only a portion of the BRYOZOA are furnished with these appendages.

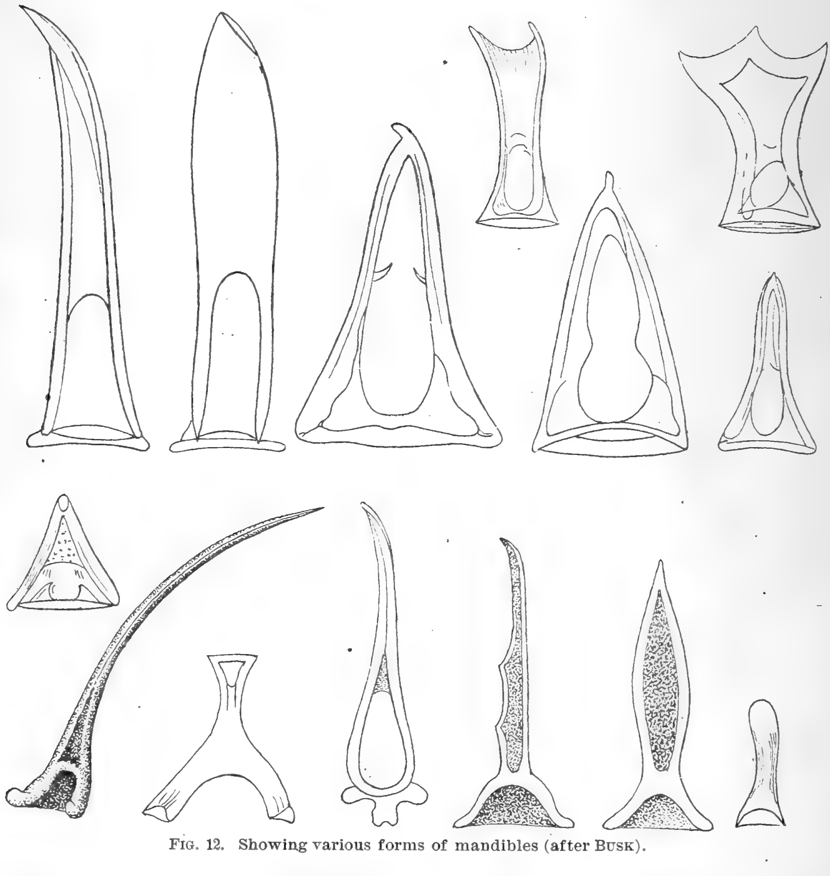


FIG. 12. Showing various forms of mandibles (after BUSK).

The two kinds of appendages are frequently coexistent on the same colony, as shown in figure 8, and surely it is not necessary that some species need a double means of defense, while other species equally fragile are destitute of any.

The compound forms of vibracula may develop into an avicularia, according to HINCKS who, in The Annals and Magazine of Natural History, 1881, cites the case of the nearly ubiquitous species *Microporella ciliata.* Fig. 13, *a*, *b*, *c*, *d*, shows the transition from avicularia to vibracula; *a* shows a cell with a sessile avicularium of the ordinary type; in *b* the mandible is prolonged into a slender spine, in other respects resembling *a;* in *c* the mandible has entirely lost its lid-like character, and is prolonged into a long, slender process, tapering to a point, and analogous to a vibraculum. The beak has also undergone a slight modification, recalling the vibracular cell which supports the movable seta. In *d* another modification is seen; the mandible is prolonged into a narrow spine, and on each side of it there is a membranous expansion, forming a flapper.

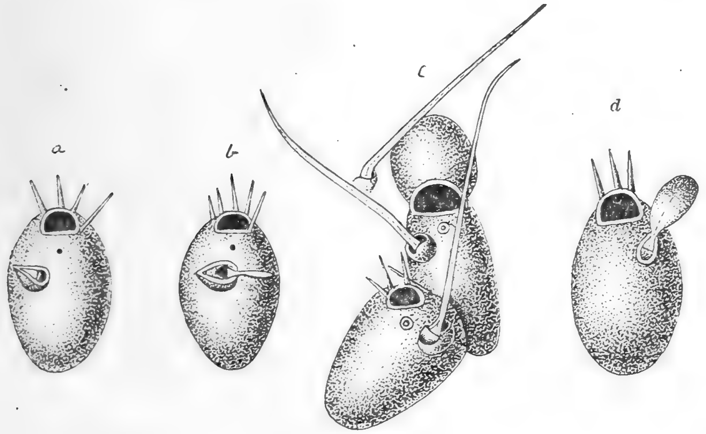


FIG. 13. *Microporella ciliata; a, b, c, d,* showing modifications of a sessile avicularium (after HINCKS).

In the fossil state the obverse or noncelluliferous face of Fenestelloid forms is apparently a solid calcareous layer; but in a thin transparent section it is seen to be penetrated by numerous minute tubuli at right angles to the surface. In a decorticated specimen of the same family, the longitudinal structure is apparently composed of numerous cylindrical fibers. In a cross-section these have the appearance of tubuli. Many of the cells, both in a recent and fossil state, are ornamented with ridges, granules, nodes or spines; the latter frequently hollow. In the course of growth, as illustrated by fig. 14, as layer after layer is added,

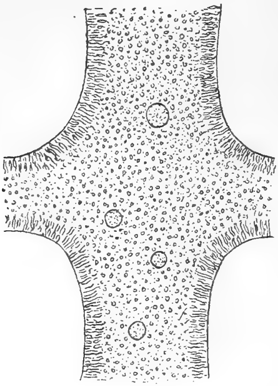


FIG. 14. An enlarged section of FENESTELLA, showing minute tubuli and large pores.

these hollow nodes, as seen in a transparent section, assume the appearance of tubuli. These have been likened by some authors to the "Acanthopores" of the MONTICULIPORIDÆ; but I think that in most cases too much importance has been given to them, and that in reality they are only ornamentations. The deposit of calcareous matter continues after the animals in the immediate vicinity are dead, and all ornamentations of the surface are obliterated, it presenting a uniformly smooth appearance. The difference in appearance between the younger and more aged portions of a Fenestelloid frond, and this applies to other forms also, is often so great that seen in different fragments they would be considered as belonging to two species. In the noncelluliferous face of some Fenestelloid forms there are frequent, small, circular pores with raised margins or peristomes, and in some forms, as FENESTRAPORA and ISOTRYPA, there are more conspicuous apertures, frequently larger than the cell apertures. In FENESTRAPORA the ridge (carina) dividing the two ranges of cells is also poriferous. The purpose of these pores have not been satisfactorily accounted for.

It has been suggested by Prof. NICHOLSON that the larger pores may have been the bases of avicularia; if that explanation should be accepted the smaller pores might be considered as bases of vibracula or of the smaller avicularia. In support of his theory Prof. NICHOLSON gives the following figures :

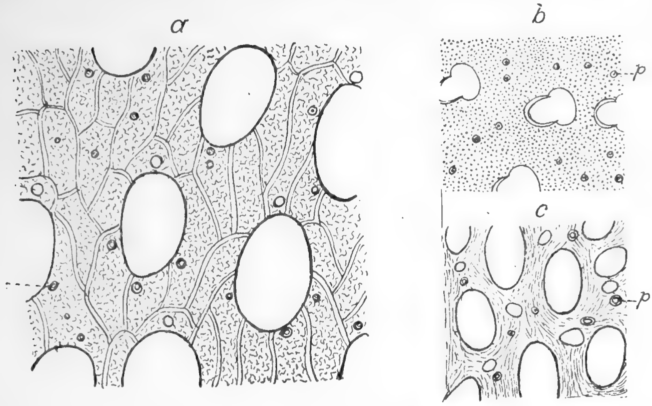


FIG. 15. *a*, A transverse section of a recent species of RETEPORA, taken parallel to the noncelluliferous surface of the frond, enlarged ; showing the thickened tubes *p*, to which the avicularia were attached ; *b*, A section of *Coscinium* (*Coscinotrypa*) *cribriformis*, from the Devonian rocks of Canada, showing similar thickened tubes ; *c*, A section of *Rhombopora* (*Ceriopora*) *Hamiltonensis*, showing similar tubes (after NICHOLSON).

The following discussion is from HINCKS' " British Marine Polyzoa, Vol. I. Introduction, pp. lxiv–lxxxiii, inc., 1880."

" MODIFICATIONS OF THE ZOŒCIAL TYPE.

" The structural type of which the zoœcium is the most familiar representative, exhibits a number of modifications amongst the marine POLYZOA. Of these the most remarkable are the *avicularium* and *vibraculum*. These curious appendages are confined to a single suborder, the CHEILOSTOMATA, within the limits of which they occur in great abundance and variety. The *vibraculum* (probably a derivative from the *avicularium*) is rarely met with as compared with the latter, which is present in a large proportion of the Cheilostomatous genera. The avicularium is best known in its most highly specialized form as it occurs in the genera BUGULA and BICELLARIA.

" This is the true 'bird's head,' an articulated appendage attached to the zoœcium, with a formidable hooked beak and a mandible worked by powerful muscles, perpetually snapping its jaws with a monotonous energy, and swaying to and fro with a vigorous swing on its jointed base, grotesque both in form and movement.

"But in a large proportion of cases the appendage exhibits a much simpler structure, and is totally destitute of the peculiar shape which has suggested its name. It is necessary to study its morphology *in extenso* to obtain a clue to its history; the articulated 'bird's head' bears no resemblance to its associated structures which yet are undoubtedly of its kin; it has assumed an alien form and has parted with all the familiar features of its tribe; its aspect and habits are those of a foreigner, and as we watch it even with its genealogy in our hands, we cease to wonder that it remained so long a mystery and a puzzle to the zoologist. When we come to consider the avicularium, not merely in its more complex and highly organized condition, but in its totality, as it is represented in a long series of gradational forms, we are left in no doubt as to its structural affinities. We can trace the course of its development from the first rudimentary stages, which are hardly distinguishable from the ordinary zoœcium, through a multitude of phases, up to the highly elaborated prehensile appendage in which no family likeness survives. And probably the best way of presenting its history will be to begin with the lowest form in which it occurs, and to follow it through its chief modifications up to the highest.

"It will be desirable, however, first to indicate the essential elements of its structure; and in doing so, it will be necessary to avoid the descriptive terms which might naturally be suggested by the organization and apparent function of the true 'bird's head.' The latter would be a grasping organ, but in a large proportion of the lower forms there is nothing which can properly be called a 'beak,' whilst the equivalent for the mandible is utterly inefficient for prehensile purposes. Every avicularium consists of a chamber, of variable size and shape, in which is lodged an apparatus of muscles; of a movable horny appendage, which is moved backward and forward by the action of the muscles, and of a fixed frame opposed to it, surrounding an aperture upon which it falls when closed. In many cases, if not in all, the chamber also contains a cellular body, which is in all probability the homologue of a polypide.

"These elements may compose a structure very closely resembling an ordinary zoœcium; or they may be so modified as to constitute an articulate and prehensile appendage, armed with curved beak and powerful jaws, and provided with a delicate tactile organ such as we find in the genus BUGULA. In all cases the avicularium is to be regarded morphologically as a metamorphosed zoœcium, though in its more complex form there is little to betray its lineage.

"Amongst our British POLYZOA we find this zooidal form in its most rudimentary condition in such genera as FLUSTRA and CELLARIA. Here it is not a specialized structure attached to one of the zoœcia; it occupies the place of one of them in the colony. It consists of a dwarfed cell, on the upper surface of which is placed the usual oral valve, but which is destitute of a polypide; at the same time the valve is frequently of unusual and disproportionate size, and occupies a large part of the area of the cell. Except in size, however, it has undergone but little change, although a certain variation of form already indicates its plasticity. In one species (*Cellaria sinuosa*) it assumes a triangular shape; in the common *C. fistulosa* it is almost indistinguishable from the ordinary operculum. The degree in which the avicularian chamber (or cell) is reduced in size varies greatly amongst these primitive and rudimentary forms. In *Cellaria Johnsoni* it is a miniature copy of the normal zoœcium, almost its only peculiarity being the elevation and somewhat increased size of the operculum. In other cases the atrophy of the cell is carried to a great extent and the operculum occupies almost the whole of the area.

"As specialization proceeds, the chamber is minimized and the adaptive modification of the valve becomes more and more varied and elaborate. In the mandible of the 'bird's head' appendages it reaches its climax, whilst in this form the zoœcium itself has lost every trace of its original character and function, and merely lodges the machinery by which the curious prehensile instrument is worked.

"Nowhere, perhaps, is the relation of the avicularium to the normal zoœcium more clearly traceable than in a foreign species of MEMBRANIPORA (as yet I believe undescribed), in which a very striking modification of the operculum is combined with the slightest change in the zoœcium itself. In this species a number of zoœcia are scattered over the colony, which, whilst retaining in great measure the usual form, are distinguishable by a remarkable elongation of the oral valve.

"This structure, which is normally semicircular in shape, is here much produced and somewhat elevated above, and stands out conspicuously on the surface of the zoarium. It is fully four times the size of the ordinary operculum, and of course increases very materially the length of the whole zoœcium, which, in other respects, departs very slightly from the normal condition. The aperture is somewhat reduced and the spines are aborted, but in general, these abnormal cells very closely resemble the other members of the colony. The polypide in such cases is probably suppressed. We have here, it would seem, one of the earliest and simplest departures from the normal type of the zoœcium in the direction of the avicularium. In FLUSTRA the change is much more marked, as the cell is merely rudimentary and the movable operculum constitutes the essential feature. These slightly specialized forms, which fill the place of the zoœcium in the colony, may be distinguished as *primary avicularia*.

"They occur under various modifications. In *Schizotheca fissa* the avicularium has an area of the same size and form as that of the zoœcia, the beak and mandible occupying much the same position as the oral opening. Nowhere is its morphological significance more apparent. A striking case of the same kind is presented by *Cellaria tenuirostris*. In *Schizoporella venusta*, on the other hand, the area (which replaces a cell) is reduced to a very diminutive size and has a minute rounded mandible. The next marked stage in the developmental series is characterized by the contraction of the area combined with the assumption of a more or less peduncular character by the hollow portion of the structure. The external resemblance to the ordinary z œcia has disappeared; the cell is commonly represented by a subconical elevation, on the summit of which are placed the beak and mandible. At the same time the avicularium is now, for the most part, a secondary growth and is developed not on the original plane of the colony, but on the zoœcia themselves. There has been a large reduction in the size of the chamber, no longer required for the accommodation of the polypide, and a growing specialization of the mandible and its adjuncts. To a great extent the avicularium has lost its apparent *status* as a distinct zooid in the colony, and become an appendage of the zooecium. The bosses or mounds, so often forming part of it and supporting the mandibular apparatus, are to be regarded as the homologue of the chamber in the normal zooecium. Such forms as I have now described, and others allied to them, may be classed as *secondary* or *transitional avicularia.* We must not suppose, however, that they constitute a clearly defined section; they are connected at all points by intermediate forms with the primary group. Nor are these divisions coincident with any particular genera or families; the various modifications of the avicularia are distributed sporadically over the whole suborder, with the exception of the highest, which occur only in very narrow and definite limits.

"The raised or pedunculate character commonly assumed by the hollow portion of the avicularium in this division becomes very pronounced in certain cases. The beak and mandible are elevated on a distinct stem, and (we may suppose) obtain in this way peculiar advantages for the discharge of their function, whatever it may be. In such forms we recognize an advance toward the peduncle of the true 'bird's head.' A nearer approach to it is met with in the remarkable pedunculate avicularia which occur in one or two species of MEMBRANIPORA. The want of mobility is perhaps the most essential distinction between this form and the avicularium of BUGULA; the beak and mandible are less highly organized than in the latter, but the general character is the same in both, and very slight changes would serve to convert the one into the other.

"In SCRUPOCELLARIA the avicularium is attached to the side of the zooecium by its entire length, but it is truly pedunculate, and if attached only by the base, would bear a close general resemblance to the Bugulan form.

"The mandible is curved in toward the extremity, and the beak is somewhat hooked, so that the appendage has considerable prehensile power. The chamber is not more than sufficient for the lodgment of the muscular fascicles. A still nearer approach to the higher avicularium occurs in the remarkable form described by SMITT under the name of *Membranipora minax*. Here we have the perfect form of the 'bird's head' (a curious anticipation of the organ as it exists in *Bugula Murryana*), but there is no basal joint and the whole structure is *calcareous*. A connection is very clearly established between the simply mammillated avicularium and the articulated through such forms as we have in the true *Membranipora minax*, in *Scrupocellaria ferox* and in the present species.

"In NOTAMIA we have probably the fixed form, which comes, on the whole, nearest to the movable 'bird's head,' and constitutes the most direct link between the two classes of avicularium. Here the hollow portion (or chamber) is borne on a slender stem of considerable length, from which it is separated by a partition; it expands from the base upwards, and on the upper surface is placed the curved beak ('like that of a cuttle fish'), occupying about two-thirds of its length, at the base of which the mandible takes its origin. The latter is much curved and terminates above it in a sharp point. The upper edge of the chamber below the mandible surrounds a semicircular space, closed in by a membrane, which probably represents the aperture of the normal zoœcium. Two new features (both of them present in the 'bird's head') make their appearance in this form. The beak and the portion of the chamber from which it arises are both of a horny material; in the lower form they are calcareous. Between the mandible and the beak, when the former is elevated, a tuft of minute setæ, placed on a slight rising, is visible, which constitutes a tactile organ, and conveys the external stimuli which brings the muscles into play. It is possible that this structure may exist in species in which it has not yet been observed, but so far, I believe, it has only been noticed among the higher forms, which I shall call the *articulated avicularia*, and in NOTAMIA. In all but the fixed condition NOTAMIA agrees with the articulated group. It may, I think, be concluded that it is the concomitant of the more highly specialized form.

"I may add that the avicularia in the NOTAMIA have very much the shape and general appearance of zoœcia reduced in size, and are placed, like the latter, in opposite pairs. We pass now to the articulated forms in which the zoœcial type is completely masked, its elements being so modified as to constitute an elaborate prehensile appendage, charged with a special service in the interests of the colony.

"In the articulated avicularium, the 'bird's head' is supported on a short peduncle with a basal joint, on which it sways to and fro. The head is composed of two portions, a lower which is more or less rounded above, and forms the chambers for the muscles (= the cavity of the zoœcium), and an upper and anterior, which consists of a movable mandible and a curved beak opposed to it. This anterior portion is composed of horny material, whilst the chamber itself is calcareous. The walls of the projecting upper jaw, which terminates in the hooked beak, inclose an aperture, over which stretches a delicate membrane, pierced by a small circular orifice. This aperture represents the mouth of the zoœcium, the mandible taking the place of the operculum. Within the chamber occurs a small circular body, composed of distinct cells, which is connected (in *Bugula flabellata*) with a cup-shaped organ, opening out through the membrane of the aperture. From the bottom of the cup rise a number of setæ, which project beyond the opening and constitute the tactile organ before referred to. The cellular body, in connection with the setiferous cup has been regarded as a nervous ganglion (B SK, SMITT); the two together constitute, according to Nitsche, the homologue of the polypide, which is here reduced, in conformity with the altered significance of the whole structure, into a mere organ of touch. There can be but little doubt, I think, but that the latter is the true view; at the same time it must be regarded as probable that the rudimentary polypide is furnished with its nerve center, by which the powerful muscular apparatus and the sensitive organ may be supplied. Whether the cellular body constitutes the ganglion, we are not at present in a position to decide. The articulated avicularia are always attached to the wall of the cell, and usually at a short distance from the orifice; they are confined apparently to a small number of genera. Some further evidence of the morphological nature of these curious appendages may be briefly noticed. (I.) In some cases I have met with ovicells developed over the upper extremity of the avicularian beak and mandible, clearly indicating their morphological relation to the orifice of the zoœcium. On more than one occasion this *lusus* has occurred to me in *Schizotheca* *fissa.* (II.) The resemblance in minute detail between the avicularian cell and the species to which it belongs, which are not unfrequently met with, have a like significance. Thus, to take a single illustration, in one species a minute sinus occurs on the lower margin of the avicularian mouth, corresponding with a similar sinus in the orifice of the zooecium. Instances of the same kind might be multiplied. The function of the avicularia is difficult to determine; nor indeed can the same function be assigned to all of them. The primary forms are many of them quite unfit for prehensile work. The lid-like mandible, with plain rounded margin, has no power of grasping and could not detain for a second the active worms which are sometimes captured by the articulated kinds. Their service for the colony must lie in some other direction. Even the fixed transitional forms, in which the beak and curved mandible are present, must be inefficient for this work from their want of mobility, whilst in many of them the parts concerned in the act of prehension are but slightly developed. The articulated avicularia are, however, undoubtedly grasping organs, and the presence of the tactile tuft between the jaws must be taken to indicate that capture in some form or other is their function. They have been seen to arrest minute worms and hold them for a considerable time with a tenacious grip as if with some ulterior object, but what the object may be, it is difficult to decide. Dr. JOHNSTON suggested that they may assist in providing supplies of food, seizing 'circumfluent animalcules,' and retaining them until, enfeebled or killed by the grasp, the ciliary currents may bear them to the mouth. But the avicularium is not fitted to capture the extremely minute organisms in which the polypides feed; and even if they could be captured and rendered helpless, there would be many chances, placed as the appendages usually are, against their coming within the attraction of the ciliary vortex. The worms, which seem to be the commonest victims, could only be utilized as food by being retained until decomposition having set in, the particles of decayed matter might diffuse themselves through the surrounding water and find their way, in a greater or less degree, to the stomach of the polypides. But the supplies of nutriment in the waters of the ocean must be ample and unfailing, and no better provision for appropriating them than the ciliary whirlpool can well be imagined. Unless we can suppose that a peculiar diet is necessary for the species furnished with the prehensile appendage, it is hardly probable that the ordinary arrangements would have to be supplemented by the service of such uncertain purveyors. And should they be feeders on dead organisms only (as has been suggested), they would certainly lead a precarious existence if dependent on the chance supplies of the avicularian commissariat. The appendages, it must be remembered, have no freedom of movement; they do not go in quest of prey; they merely oscillate, without variation, to and fro, snapping their jaws at haphazard, or when aroused by some irritation of the tactile setæ. Their captures must be fitful and uncertain, and if the food requires long keeping to be fit for use (and under the conditions this seems to be a necessary supposition), the colony must be in a chronic condition of famine. If *living* animals be the required diet, then the cilia are adequate to the supply of them, and the avicularia are not.

"On the whole (though the question is involved in much obscurity), I am inclined to regard the avicularia as charged with a defensive rather than an alimentary function. They may either arrest or scare away unwelcome visitors. Their vigorous movements and the snapping of their formidable jaws may have a wholesome deterrent effect on loafing annelids and other vagrants, whilst the occasional capture of one of them may help still further to protect the colony from dangerous intrusion. On this view of them, they have a function analogous to that of the other appendage with which the CHEILOSTOMATA are furnished. The *vibraculum*, though morphologically related to the zoœcium like the avicularium, is more immediately connected with the latter; and we find a line of transition forms linking the two together. It consists, in its more perfect condition, of a chamber, in which the muscles are lodged, and a movable bristle, suspended in a kind of cleft at its upper extremity, in which it works backward and forward. The seta (or bristle) is broad at the base and above it slender, and often of considerable length. In some cases it attains an enormous development, and forms either a whip-like appendage or an organ of such a size and strength as to be available for locomotive purposes. On the lower part of the wall of the chamber there is always a small opening, marking the point from which a long tubular appendage (or radical fiber) originates.

"The vibraculum, as already mentioned, is of comparatively rare occurrence. In its most highly specialized forms it is placed on the dorsal surface of the zoœcium, and the movable seta (which, when at rest, is laid back upon the chamber) is swung around at intervals to the front of the cell, sweeping slowly over the surface as if to remove all noxious matter, and then returns to its original position. This movement goes on uninterruptedly during the lifetime of the colony, and there can be no doubt that its object is to scare away dangerous intruders or accumulations of refuse from the neighborhood of the orifice. We have no difficulty in recognizing the equivalent of the avicularian mandible and the operculum of the cell in the setæ. The mouth is here modified in the same sense as the rest of the structure; the raised 'beak' is absent, being no longer useful, but the margin is carried out above into two prominent points, just within which the bristle is articulated, clear of all hindrances, and so as to possess the utmost freedom of movement.

"The homology of the parts becomes more evident when we study the transitional forms. We meet with a developmental stage (corresponding to the *primary avicularium*) in which the vibraculum is developed on the original plane of the colony and occupies the position of an ordinary cell; in some species the vibracular cells alternate regularly with the zoœcia. In such cases the movements of the setæ are of necessity much restricted, and the appendage is rather the servant of the colony than of the individual polypide.

"The direct links between the vibraculum and avicularium are found in those forms of the latter in which the mandible is prolonged and attenuated, whilst the beak is almost rudimentary. Indeed, it is difficult to draw the line between them, unless we regard the total absence of a distinct beak as an essential characteristic of the vibraculum. We have a case of the slight extension and attenuation of the mandible in *Schizoporella spinifera;* in *Membranipora ciliata* the change is occasionally carried still further, but there is a great variability, and the mandible is now of the ordinary form and now prolonged into a vibracular process. In *Schizoporella vulgaris* the mandible is metamorphosed into a seta, but the beak survives and the movement is probably nothing more than the rising and falling as of a lid. In *Mastigophora Hyndmanni*, the mouth is so modified as to give much more play to the seta, which is thrown backward and forward with perfect freedom, and has much the appearance of a lash. In this species the vibraculum is borne on a distinct cell, resembling the zoœcium (on which it is developed), except in size. In yet another case the vibracular cells are still further reduced, and one is placed on each side of the orifice of the zoœcium. When we come to the higher forms, we meet with cases in which the seta resumes the dimensions of the mandible, and loses its free and vigorous swing. The most elaborate form of this appendage is found in the genus CABEREA. There the chamber is large and traversed on the upper side by a channel or groove, in which the seta lies when at rest. The latter is of great length and serrated or toothed along the edge. In this genus the entire dorsal surface of the branch is covered by the vibracula, and the movements of the setæ are synchronous; they act together with perfect regularity, the whole company on a branch swinging to and fro at the same moment, and as if under a common impulse. We can hardly doubt but there must be some intercommunication between the nerve centers of the individual vibracula, on which these combined movements depend, but so far the synchronism has attracted very little attention, and we have no observations that throw any further light upon it. The setæ attain their highest development in the family of the SELENARIIDÆ, Busk; here they are of enormous size and of great strength and assume, in some species at least, a locomotive function, acting probably as oars, and propelling the colony, which is free in the adult state. In the history of these appendages we have a curious illustration of the variety of function that may connect itself with the same morphological element."

THE ANIMAL.

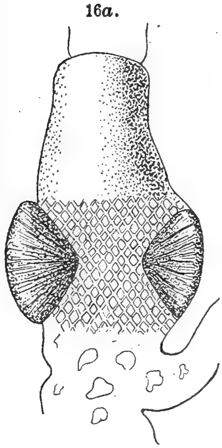
In the GYMNOLÆMATA the principal species studied have been the marine form, *Bowerbankia densa*, and the fresh-water form *Paludicella Ehrenbergi*. These two forms, though differing some in detail, are of essentially the same structure.

For the Hippocrepian forms *Alcyonella fungosa* furnished the principal material.

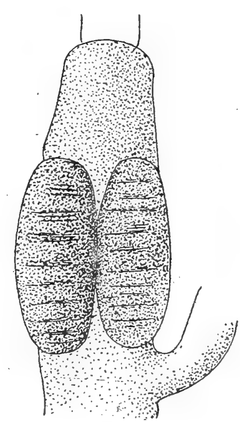
The tentacular crown may be divided into two portions: the disc which surrounds the mouth and to which is given the name lophophore, and the tentacles which are inserted on the margin of the lophophore.

In all the marine species and in one fresh-water species, *Paludicella Ehrenbergi*, the lophophore is continuous around the mouth; the tentacles being arranged in a complete circle. In the other fresh-water forms the arrangement is bilateral. The lophophore is extended in two triangular arms; the tentacles, arranged continuously on the margin of the disc and the arms are disposed in a horseshoe form. From the mouth descends the œsophagus; at first a little expanded, then contracting and continuing nearly straight to its terminus. The upper, expanded portion may be called the pharynx. The walls are thickly studded with minute oval spots. In the marine species the œsophagus leads into an oval sac, which performs the office of a gizzard (Plate B, fig. *a*, 3). The walls of this cavity are thicker than those of any other portion of the alimentary canal. In the walls are two dark bodies, opposite to each other (fig. 16), with radi-

16*a*.



16*b*.



17.

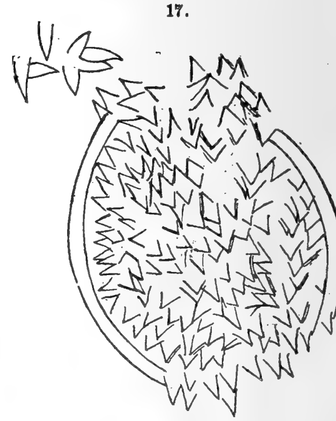


FIG. 16*a*. *Bowerbankia densa*, showing the dark bodies of the œsophagus separated; the cardiac teeth showing between them.

FIG. 16*b*. Showing the dark bodies in apposition.

FIG. 17. An enlargement of the cardiac teeth (after FARRE).

ating lines, and in the walls between these bodies are the cardiac teeth (fig. 17), which present a somewhat regular tesselated appearance. This again opens downward into the true digestive stomach (Plate B, fig. *a*), an oblong cavity terminating below in a blunt extremity. From the upper part of the stomach, near the gizzard, by a true pyloric cavity (fig. 5, *a*), arises the intestine, which continues nearly straight, alongside the œsophagus, and terminates by a distinct anal orifice, close to the outer side of the lophophore. Thus the alimentary canal consists of pharynx, œsophagus, gizzard, stomach and intestine, with distinct oral, cardiac, pyloric and anal orifice.

The whole floats freely in the perigastric cavity, the boundaries of which are the walls of the cell, and which contains the perigastric fluid and the muscles of the animal.

In PALUDICELLA, the upper part of œsophagus is wide (the pharynx) but soon contracts and continues as a long narrow tube, which leads into an oval sac (Plate A, fig. 1, *c*), corresponding to the gizzard of the marine forms and to the cardiac cavity of the stomach of the Hippocrepian forms. This sac is much more distinctly expanded from the large cavity of the stomach (the pyloric cavity) than in the other fresh-water forms. When the animal is completely retracted it is bent backward upon the pyloric cavity (Plate A, fig. 2, *c*). The intestine arises from the upper portion of the pyloric cavity (Plate A, *f*).

In the Hippocrepian forms, the œsophagus becoming narrower and opening into the stomach with a distinct conical projection. In the contraction of the animal within its cell, in these forms, the alimentary canal occupies essentially the same relative position as when the animal is protracted, the œsophagus remaining straight; but in PALUDICELLA and in the marine forms, the alimentary canal is doubled upon itself and its form is somewhat modified (Plates A and B). The lophophore is brought down to the upper part of the stomach; the intestine is doubled upon itself, and the œsophagus is forced down to the side of the stomach, and again turning upward has somewhat the form of the letter S. The stomach is composed of three different layers; the inner one of which has frequently longitudinal ridges (fig. 20, *d*), though this feature is often absent. The layer is composed of easily separable spherical cells, which contain a smaller cell or nucleus, floating in a colorless liquid having yellowish-brown contents (fig. 18, *a*, *b*). These are, in all probability, hepatic follicles, secreting a fluid which colors the stomach and its contents; the inner layer thus being the representative of the liver. The median layer is composed of hexagonal cells, with a brilliant

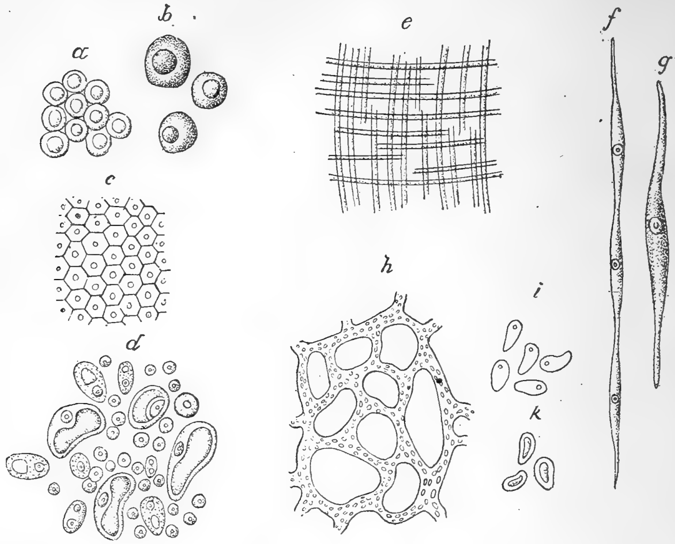


FIG. 18. *a*, Portion of internal or hepatic layer of the stomach; *b*, Three isolated cells, further magnified; each cell contains within it a secondary cell with brownish contents; *c*, Middle layer of stomach composed of cells with colorless contents and brilliant nucleus; *d*, Structure of the endocyst; the tissue has been treated with acetic acid, and presents isolated nuclei, and nucleated cells in various stages of formation; *e*, Muscular net work of the endocyst; *f*, Muscular fibers from the endocyst, treated with acetic acid and more highly magnified; *g*, An isolated muscle cell of the same, still more highly magnified; *h*, Tubular net work occasionally seen in the substance of the endocyst, and containing peculiar corpuscles; *i*, Corpuscles separated from the tubular net work; *k*, The same under the action of acetic acid.

nucleus (fig. 18, *c*). The outer layer consists of a very thin membrane with a cellular structure. It covers the whole of the alimentary canal, and by the application of acetic acid it may be frequently separated from the median layer. Delicate circular striæ may be observed in this layer, in some species very distinctly. They are, in all probability, muscles. These muscles have not been observed in this layer of the intestine, but probably do occur there. In the œsophagus there are only two layers (fig. 19, *c*, *g*), corresponding to the median and external layer of the stomach, the inner layer of the stomach having entirely disappeared and the external layer being much thickened. The mouth and upper portion of the œsophagus are thickly covered with vibratile cilia; apparently disappearing in the lower portion. The structure of the intestine is very similar to that of the œsophagus, with the exception that the cilia are entirely wanting.

In the Hippocrepian forms there are no cilia except at the mouth and upper part of the stomach, but in PALUDICELLA and in

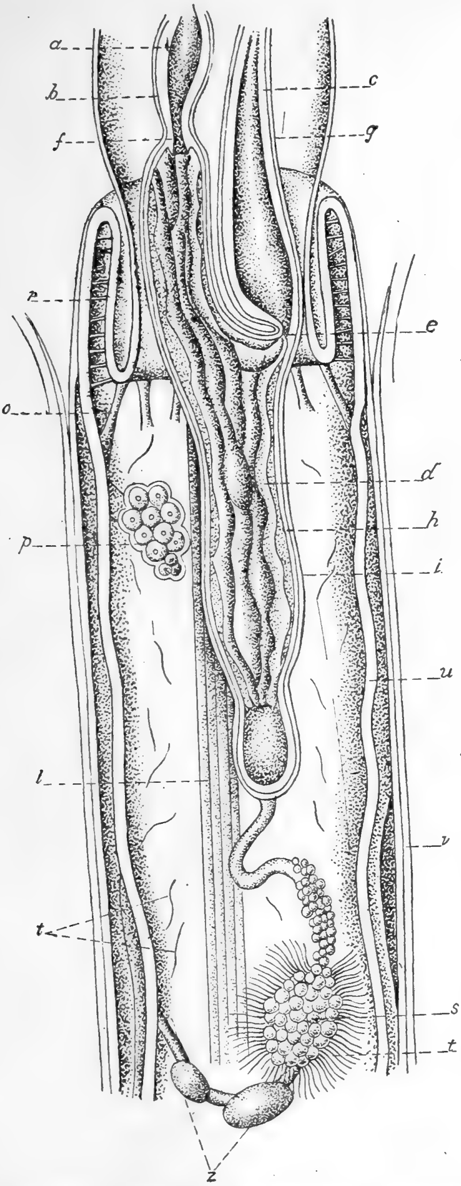


FIG. 19. *Alcyonella fungosa.* *a*, Internal layer of œsophagus; *b*, External layer of œsophagus; *c*, Internal layer of rectum; *d*, Hepatic layer of stomach; *e*, Pylorus; *f*, Cardia; *g*, External layer of rectum; *h*, Medial layer of stomach; *i*, External layer of stomach; *l*, Polyp retractor muscle; *o*, Radial muscles; *p*, Ovary; *r*, Superior radial muscles; *s*, Testis; *t*, Spermatozoa; *u*, Endocyst; *v*, Ectocyst; *z*, Statoblasts (after ALLMAN).

the marine forms there are long vibratile cilia near the pyloric orifice of the stomach.

The œsophagus and stomach are very irritable, and the stomach is in constant motion whenever the animal is exserted. When food is received the contraction of the stomach is very decided; the food remaining in the stomach a very short time, then descending with great rapidity. In the gizzard of marine forms they are subjected to a sort of crushing process, the two dark bodies previously spoken of, being brought in apposition (fig. 16, *b*). After remaining in the gizzard a very short time, the food passes into the stomach, where it is rolled about in a peristaltic motion, being frequently regurgitated into the gizzard. In the upper portion of the stomach, near the pyloric orifice, the food assumes a rotary motion from the action of the vibratile cilia. In some species with very clear walls the motion of the cilia can be very plainly seen by microscopic observations. The alimentary matter passes from the stomach by the pyloric orifice, and in the large portion of the intestine, near this orifice, it is formed into little pellets of excrementious matter, which, by the contractions of the walls of the intestine, is carried to the anus, and passing out is carried away by the current caused by the action of the cilia of the tentacles.

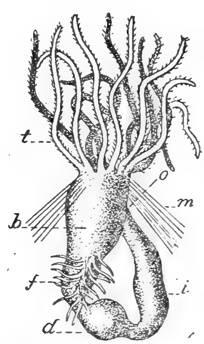


FIG. 20. *Eschara cervicornis*. *t*, Tentacula: *b*, Pharynx; *f*, Filiform appendages; *d*, Stomachal dilation; *i*, Intestine; *o*, Oral aperture; *m*, Muscles (after JONES).

TENTACLES.

The tentacular crown of the BRYOZOA consists of two portions, a disc surrounding the mouth, the lophophore, and the tentacles which are borne upon the margin of this disc.

In the Hippocrepian forms, one side of the lophophore, that on which the anus is situated, is prolonged in two triangular arms. The tentacles are arranged continuously on the outer and inner margins, making a double row (fig. 23), in the form of a horseshoe, a fact from which the name Hippocrepian is given to this class of Bryozoa. This condition is not found in any marine form.

The Hippocrepian forms have also another organ which is absent in those genera in which the lophophore forms a continuous circle. This is a hollow valve-like organ continuous with one side of the lophophore, and is known as the epistome. The interior communicates with the perigastric space by an opening in the lophophore (fig. 22, *k*). The walls which are turned toward the mouth are thick and are covered with a vibratile cilia; the others are membranous and transparent.

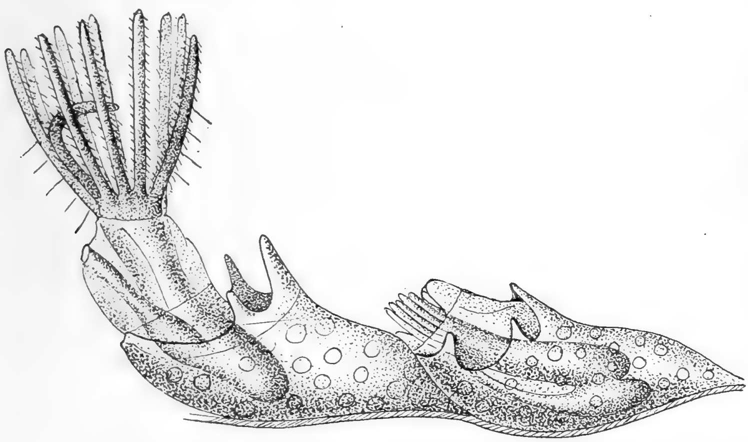


FIG. 21. *Membranipora pilosa.* In one of the cells the animal is partially retracted, in the other it is fully expanded (after FARRE).

When the animal is protruded, this organ is in constant motion, elevated and depressed. The elevation is effected by the action of a muscle (fig. 22, *l*), to be hereafter described; while the depression is probably effected by the antagonistic elasticity of the organ itself, though it may be effected by the action of a muscle not yet observed.

Notwithstanding this organ has been studied by many observers, its purpose has not yet been ascertained.

The fresh-water form, PALUDICELLA, and all marine forms have the lophophore circular and the tentacles arranged in a single row on its outer border, having, when expanded, somewhat the form of an inverted cone. The tentacles are cylindrical, with a blunted extremity. They are hollow and are composed of two layers (fig. 23); the outer layer being composed of comparatively large spherical cells, frequently with a brilliant nucleus, and the inner layer of a very thin transparent membrane, without any trace of a cellular structure.

The exterior of the tentacles has two rows of vibratile cilia, situated on opposite sides, one row vibrating toward the extremity and the other toward the base.

The tentacles are hollow and communicate with the perigastric cavity through the lophophore. In all the Hippocrepian forms the tentacles are surrounded, on their lower portion, by an exceed-

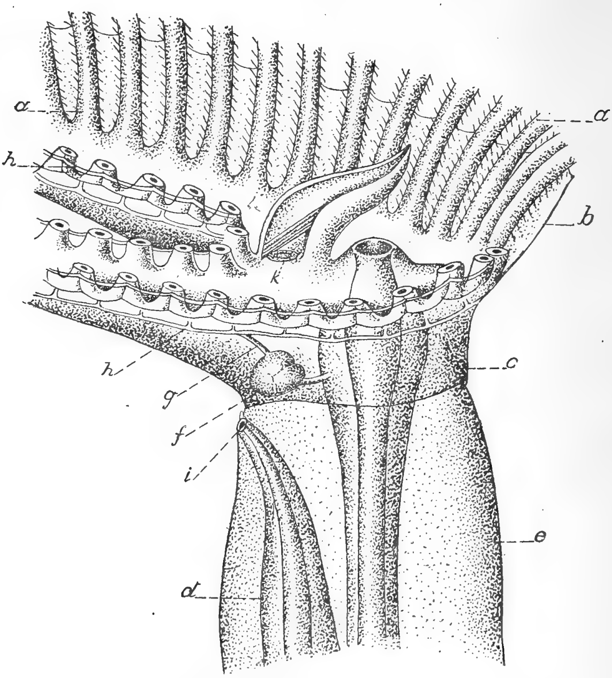


FIG. 22. *Lophopus cristatus.* *a*, Tentacles; *b*, Calyx; *c*, Lophophore; *d*, Intestine; *e*, Invaginated portion of the endocyst; *f*, Nerve ganglion; *g*, Nerve filament to lophophore; *h*, Nerve filament passing around the lophophore; *i*, Anus; *k*, Epistome; *k'*, Orifice in lophophore forming a communication between the cavity of the epistome and the perigastric space; *l*, Elevator muscle of the epistome (after ALLMAN).

ingly thin transparent membrane, a prolongation of the outer margin of the lophophore, fig. 22, *b*, which is known as the calyx. The calyx never exists in forms destitute of an epistome.

Perigastric Space.

The perigastric space is filled with a colorless fluid, which probably fulfils the triple purpose of circulation, nutrition and respiration; the last-named office probably in conjunction with the tentacles, but there is no absolute certainty on this point. The fluid is colorless and the circulation, which undoubtedly takes place, is detected only through the medium of certain small particles, held in suspension in the fluid; but these particles are not necessary for

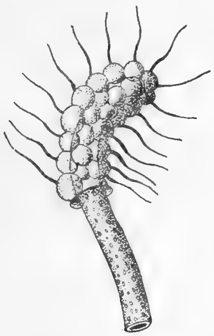


Fig. 23. Tentacle enlarged, showing outer cellular and inner membranous layer,

the performance of the functions of the fluid, because they are frequently absent, and Mr. Hancock thinks that when they are present, it is from some rupture of the walls. Dr. Farre has described and figured parasites occurring in this fluid, but judging from his figure, he mistook the spermatozoa for parasites, and he describes them as moving with a slow, undulating motion, which is characteristic of the spermatozoa.

Allman is of the opinion that the perigastric fluid is chiefly aqueous and supplied from without In that case there must exist pores through the ectocyst capable of being opened and closed at the will of the animal or the water must exude through the alimentary canal. What the other constituents of this fluid may be has not yet been ascertained. Allman says: "That the fluid thus contained in the perigastric space and thence admitted into the tentacles consists mainly of water obtained from without, there can, I think, be little doubt; and yet I have in vain sought for any opening through which the external fluid can gain admittance into the interior. I have allowed the transparent genera CRISTATELLA and LOPHOPUS to remain many hours in carmine without being able to detect a single particle of this pigment in the perigastric space, though I have seen this space rapidly empty itself on the removal of the animal from the water and again fill on restoring it to its natural element. VON BENEDEN believed that he had detected in ALCYONELLA, apertures, which he named 'bouches aquiferes,' at the base of the tentacles; but this distinguished naturalist is certainly here in error, as indeed he himself subsequently admits." MEYEN asserts that an opening exists in the vicinity of the anus, through which he himself had witnessed the escape of the egg of ALCYONELLA, and SIEBOLD corroborates him. But, without doubt, any such aperture was the result of a rupture. One objection to the theory that the water finds its way through tubes in the cell walls too minute to be detected is that in many forms the cell tubes are so closely packed together that no water has access to the exterior of the cell walls.

The perigastric fluid enters the tentacles through the lophophore, and thus becomes aerated by the constant flow of the oxygenating medium over their surface by the action of the vibratile cilia, though if the perigastric cavity can be emptied and filled as quickly as stated by ALLMAN, any special aeration by the tentacles would seem unnecessary. While the aeration of the blood or perigastric fluid can be easily understood when the animal is protruded, it is difficult to understand how the oxygenation can be effected when the animal is withdrawn in the cell, for then the orifice is completely closed by the folding of the sides of the orifice, and there is no communication with the exterior. The only explanation can be that, as is the case with bivalves, a constant aeration of the blood from the air in the water is unnecessary.

There can be little doubt that the perigastric fluid is nutritive, and holds in suspension the results of digestion, which probably exude through the walls of the stomach. It is only on such a supposition that we can understand the nourishment of the walls of the cell and the buds which take their origin in the endocyst, and must be nourished by it until they have acquired such a stage in their growth that they have an external orifice.

THE MUSCULAR SYSTEM.

The following description of the muscular system refers especially to that of a fresh-water species, *Paludicella Ehrenbergi;* but it is almost identical with that of the marine forms, and mention will be made of the details in which it differs.

There are six sets of muscles, three in connection with retraction, two with protrusion and one for the closing of the orifice when the animal has withdrawn in its cell.

Of the retractors one set acts directly upon the orifice, the others upon the tubular orifice of the cell. The former is much the more powerful muscle (Plate A, *l'*). It takes its origin in the endocyst, toward the bottom of the cell, and passing upward, alongside of the alimentary canal, its superior extremities are inserted around the base of the lophophore. It is composed of numerous long, stout fibers, which by their action draw the animal into the cell. In the marine and in the Hippocrepian forms the corresponding retractor muscles differ only in being composed of two fascicles instead of only one.

In the withdrawal of the animal into the cell, the tentacula, which when well expanded are in the form of an inverted cone, are first brought together in a straight line, and immediately begin to descend. The body does not descend in a mass, but becomes folded up so as to be accommodated in the cell. The œsophagus, surmounted by the tentacles, descends first; whilst the integument of the upper part of the animal begins to be inverted, where it has its insertion around the tentacular disc. As the tentacles descend the invagination of the integument continues, forming a close sheath around the tentacles. The withdrawal of the animal continues until the extremities of the tentacles have reached a point level with the top of the ectocyst; that is, to the unyielding part of the cell. The stomach of the animal is now near the bottom of the cell; the œsophagus is bent in the form of a letter S; the tentacles are lying close together inclosed in their tegumentary sheath. It now remains to complete the closing of the orifice. This is effected by the second and third sets of muscles, called by FARRE the opercular muscles, by HANCOCK the tube retractors, and by ALLMAN the antero-parietal vaginal muscles. They have their origin near the top part of the ectocyst, and are inserted in the flexible part of the invaginated tunic (endocyst) on which they act. They consist of four flat bundles of stout linear fibers (Plate A, *i*). The fibers of the muscle are inserted one after another in a straight line, commencing near the point of invagination, and extending some distance down the invaginated tunic. The arragement of the fascicles causes the margins of the orifice to fold in four portions in the retraction of its tube. The end is consequently square, the angles corresponding to the insertion of the muscles. The third set of muscles, the superior tube retractors, consist of only four fibers. They have their origin below the other tube retractors, and are inserted in the tegumental tunic above them. The action of this set of muscles completes the action of the second set. In the marine forms as represented by *Bowerbankia densa*, the muscles are the same, except that they have a triradiate arrangement, and the orifice is puckered into three folds instead of four.

The fourth set of muscles is for the purpose of closing the orifice and was discovered by Mr. HANCOCK. They consist of two sets of muscles passing around the invaginated tunic. One set is made up of several fibers passing around the tunic at the insertion of the inferior tube retractors and is of considerable width; the other consists of only two or three fibers and passes around the tube at the interior of the superior tube retractors. This action is to close the orifice on the retraction of the animal, and also to oppose the tube retractors, which would have a tendency, by their divergence, to keep the orifice open. These muscles exist both in fresh-water and marine forms.

The fifth set of muscles is connected with the endocyst and is called the parietal muscles. They are numerous and strong (Plate A, *m*). Their extremities are probably attached to the ectocyst. They run transversely, each muscle embracing a fourth or a third of the cell, and consist of three or four fibers each. Their purpose is the contraction of the endocyst, assisting in the propulsion of the animal.

The sixth set (the posterior parietal muscles) is for the purpose of preventing the entire invagination of the tunic and tentacles.

It consists of four thin fasciculi (Plate A, *h*). They have their origin in the tunic (endocyst) near the top of the cell, two in the front and two in the back, and are inserted in the opposite surface of the tentacular sheath.

In the Hippocrepian forms the muscles differ somewhat from those just described, principally owing to the difference in the structure of the tentacular crown.

The presence of the epistome necessitates another muscle for its movements. It arises from the tentacular disc, within the cavity of the epistome, and passing obliquely across the cavity is inserted on the inner surface of the oval wall of the epistome (fig. 22, *l*). Its action is to elevate the epistome, raising it from the mouth.

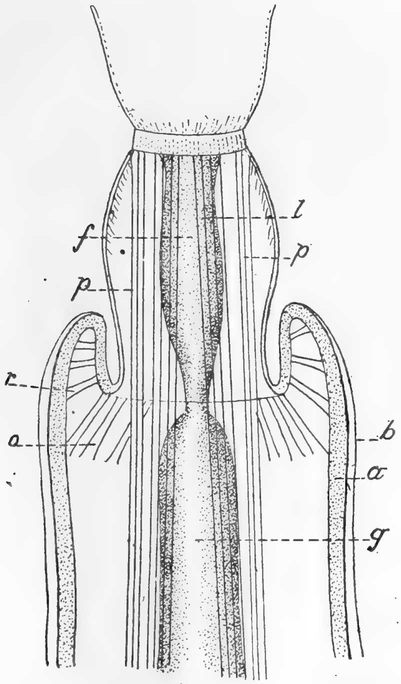


FIG. 24. *Alcyonella flabellum*, *a*, Endocyst; *b*, Ectocyst; *f*, Œsophagus; *g*, Cardiac cavity of stomach; *p*, Rotary muscles of tentacular crown; *o*, *r*, Radiating muscles; *l*, Polyp retractor muscles (after ALLMAN).

The rotary muscles of the crown consist of two fascicles, which take their origin at the same place as the retractor muscle of the animal, and passing upward with that muscle, until within some distance of the lophophore, they separate from it, and continuing to the right and left, are inserted one in each arm of the lophophore. Their action is to rotate the tentacular crown and to depress the lobes (fig. 24, *p*). VAN BENEDEN first directed attention to a set of parallel bands running along the margin of the lophophore. These bands are continuous with one another below, but when they arrive at the space between adjacent tentacles, each band divides in two, apparently running up opposite sides of adjacent tentacles.

These bands do not present any fibroid structure. VAN BENEDEN considered them muscles, and that to their action was due the movement of the tentacles. They have not been observed in the GYMNOLŒMATA, but if they are muscles and the movements of the tentacles are due to them, they will probably be found in all BRYOZOA. There is another set of muscles peculiar to the Hippocrepian forms, which consists of a circle of short, stout radiating fibers (fig. 22, *o*, *r*, and fig. 24, *o*, *r*). They take their origin on the inner surface of the endocyst, on the same plane, and are inserted in the tentacular sheath some distance below the mouth of the cell, on a plane parallel to that of their origin. Their action is to prevent the eversion of the whole of the tentacular sheath, and to keep the mouth of the animal at the proper distance from the cell aperture.

Mr. HANCOCK says in relation to this muscle: "The true value of these muscles will be understood if we refer to the marine genus BOWERBANKIA, in which they are deficient, and of course the tentacular sheath can be wholly everted, and accordingly the animal can reach to a greater distance than it could otherwise have done, but an apparatus of extraordinary beauty is provided to obviate the inconvenience that must have arisen from the greater elevation of the tentacular disc above the support of the horny cell. This is effected by what may be considered an elongation upward of the cell. Numerous setæ, bound together by a membrane, are attached to the lips of the orifice of the cell, so that when the polyp is exserted they stand up in a circle, surrounding the lower portion of the exposed part of the animal (fig. 25, *d*), and give support to it. By this means the far outstretched tentacular disc is brought completely under the control of the muscles for directing its movements.

"We thus clearly see that the set of radiating muscles is a compensation for the absence of setæ.

"On examining an animal of BOWERBANKIA in action it is evident that the use of the setæ is as I have pointed out. The circle of setæ is then seen to encompass the lower part of the extended polyp, and when the tentacular disc moves from side to side the neck always bends from the top of the setæ in a decided angle and does not gradually arch away from the lips of the cell, as might be expected if this contrivance was for the purpose of giving flexibility. The delicate membrane uniting the setæ is strengthened with numerous minute transverse fibers forming the whole into a powerful sphincter, thus giving great firmness to the part.

"By this arrangement BOWERBANKIA is enabled to raise the tentacular disc far above the polype cell and yet to remain as perfectly under the control of the muscles as is the tentacular disc of PLUMATELLA and FREDERICELLA, in both of which it is confined close to the surface of the cell."

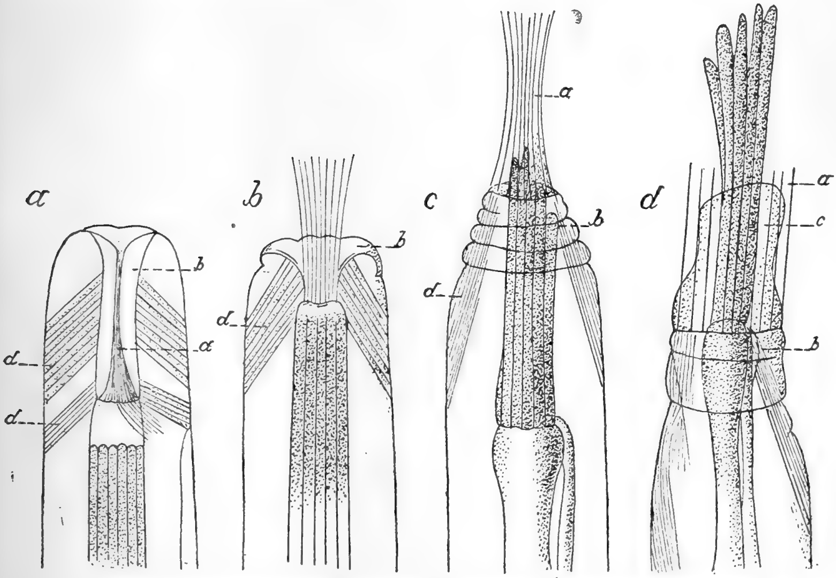


FIG. 25. *Bowerbankia densa*, showing the manner of extrusion of the setæ and tentacles; in fig. *a*, they are entirely retracted; in fig. *d* they are completely extended. *a*, Setæ; *d*, Muscles (after FARRE).

Fig. 25 (*a*, *b*, *c* and *d*) shows the position of the setæ when the animal is contracted and during the process of eversion.

When we compare the muscular system of the fresh-water and marine forms we find a great similarity in them, but also some modifications. In all forms the endocyst continues beyond the ectocyst and is continuous with the margin of the lophophore. In the marine forms, when the animal is exserted, the endocyst or tunic is, of course, carried with the lophophore, and not being held by any muscles is continuous in essentially a straight line with that portion of the endocyst lining the cell. When the animal is retracted the endocyst is invaginated, the evagination and invagination being complete; the evagination being effected in the same manner as if the finger of a glove was pulled in from its inner extremity, the invaginated portion forming the tentacular sheath.

In the fresh-water forms the evagination and invagination is incomplete, a portion of the endocyst being permanently invaginated.

Though the evagination in PALUDICELLA is not complete, yet it in common with the marine forms, is without the small radiating muscles near the orifice and the larger radiating muscles which are connected with the tentacular sheath (fig. 19, *o*, *r*). The polyp retractor muscles are essentially the same in all forms of Bryozoa. The sphincter muscles are present in PALUDICELLA and the marine forms. The parietal muscles are the same in all forms, and the tube retractors are essentially the same. PALUDICELLA is very closely related to the marine forms even in its minute structure.

The protrusion of the animal from its cell takes place as follows: The principal agency to which we must assign the protrusion of the animal is undoubtedly the contraction of the endocyst by the parietal muscles and the consequent pressure of the perigastric fluid upon the body of the animal, making it necessary for it to move in the direction of the least resistance, namely, the orifice of the cell.

FARRE, in his admirable paper on *Bowerbankia densa*, states that the principal cause of the protrusion of the animal is the pressure of the perigastric fluid, and that the straightening of the œsophagus raises the tentacular crown a certain distance, which it undoubtedly does, as the œsophagus has the power to straighten itself without the action of the fluid.

As the parietal muscles contract, the endocyst leaves the ectocyst, especially in the lower part of the cell, and the animal begins, on account of the consequent compression of the perigastric fluid, to move up the cell. The sphincter muscles relaxing affords to the tentacles an easy passage through the inverted endocyst. The tube retractors relaxing the inverted lips of the orifice begin to evolve. As the contraction of the parietal muscles continues, the protrusion goes on until it is complete. In the marine forms the whole of the invaginated endocyst is protruded; in the fresh-water forms with the single exception of PALUDICELLA, nearly all that portion of the endocyst continuing beyond the ectocyst is permanently invaginated, its evagination being stopped by the radial muscles (fig. 18, *o* and fig. 24, *o*.)

In PALUDICELLA there is a more complicated process. The relaxation of the tube retractors permits the endocyst to be evaginated, but only for a short distance, the posterior fibers of these muscles soon checking its further progress, and keeping a small portion of the endocyst permanently invaginated. The second portion of the endocyst, which when invaginated constitutes the tentacular sheath, continues to be evolved by the relaxation of the posterior parietal vaginal muscles, but the relaxation soon ceasing the complete protrusion is prevented. Thus we have two small, permanent invaginations after the eversion is completed as shown in Plate A, fig. 1, one within the other, forming the membranous cup at the mouth of the cell. The retraction can be much more easily understood. The parietal muscles relax; the polyp retractor contracts, pulling the animal in the cell. The superior tube retractors first, and then the inferior contract, and when the animal is withdrawn entirely within the cell, the action of the sphincter muscles closes the orifice. When an operculum exists this is closed by the action of the muscles previously described.

THE NERVOUS SYSTEM.

The nervous system consists of a single ganglion attached to the external surface of the œsophagus (fig. 1, *g*, and fig. 22, *f*), with its filaments.

In the Hippocrepian forms filaments have been distinctly traced by ALLMAN running to the tentacular crown. The ganglion gives off a rather thick cord, immediately running into the lophophore (fig. 22, *g*). It gives forth a band which runs along the root of the lophophore toward the back (fig. 22, *h*), giving off a branch to each tentacle, continuing on the arms to the extremity, giving off branches to each tentacle on the outer margin of the arms; turning at the extremity in its backward course it gives off branches to each tentacle on the inner side of the arms. The ganglion also sends forth a filament which immediately enters the substance of the œsophagus, probably supplying the mouth, epistome and œsophagus, but it has been traced for only a short distance.

REPRODUCTIVE ORGANS.

The ovary and testes occur in the same cell. In certain seasons of the year the ovary may be seen attached by a short peduncle to the endocyst a short distance below the mouth of the cell (Plate A, figs. 1, 2, *p*). It is a rounded mass composed of ova in various stages of growth. The testes are situated on the funiculus, below the fundus of the stomach (Plate A, *s*), and are developed in the form of an irregular mass. It is formed of spherical cells, each of which contains a second cell, which develops into a spermatozoidal filament, escaping by the rupture of the cell. They have a distinct but somewhat sluggish, undulating movement. They are carried about the perigastric space by the current and thus come in contact with the ova. They were observed in 1837 by Dr. FARRE, but were mistaken for parasites.

There are three methods of reproduction, first by the true ova, developing into a free ciliated embryo; secondly, by gemmation, and thirdly, in the Hippocrepian forms by statoblasts, the nature of which will be hereafter described.

The process of gemmation may be observed with comparative ease in PALUDICELLA, and is illustrated by figure 26. In the earliest stages in which the " bud has been noticed, it consists of a slight tubercle on the parent cell, *a*, filled with parenchyma. It soon becomes elongated and has a cavity communicating with the parent cell, *b*. In *c* it has increased in size and consists of an external envelope continuous with the ectocyst of the parent cell, and a thick lining continuous with the endocyst and containing numerous round, nucleated cells. These two features develop into the ectocyst and endocyst of the adult cell. In *d* we observe a thick portion of the endocyst projecting into the cavity. This is the rudiment of the future polyp. Within this

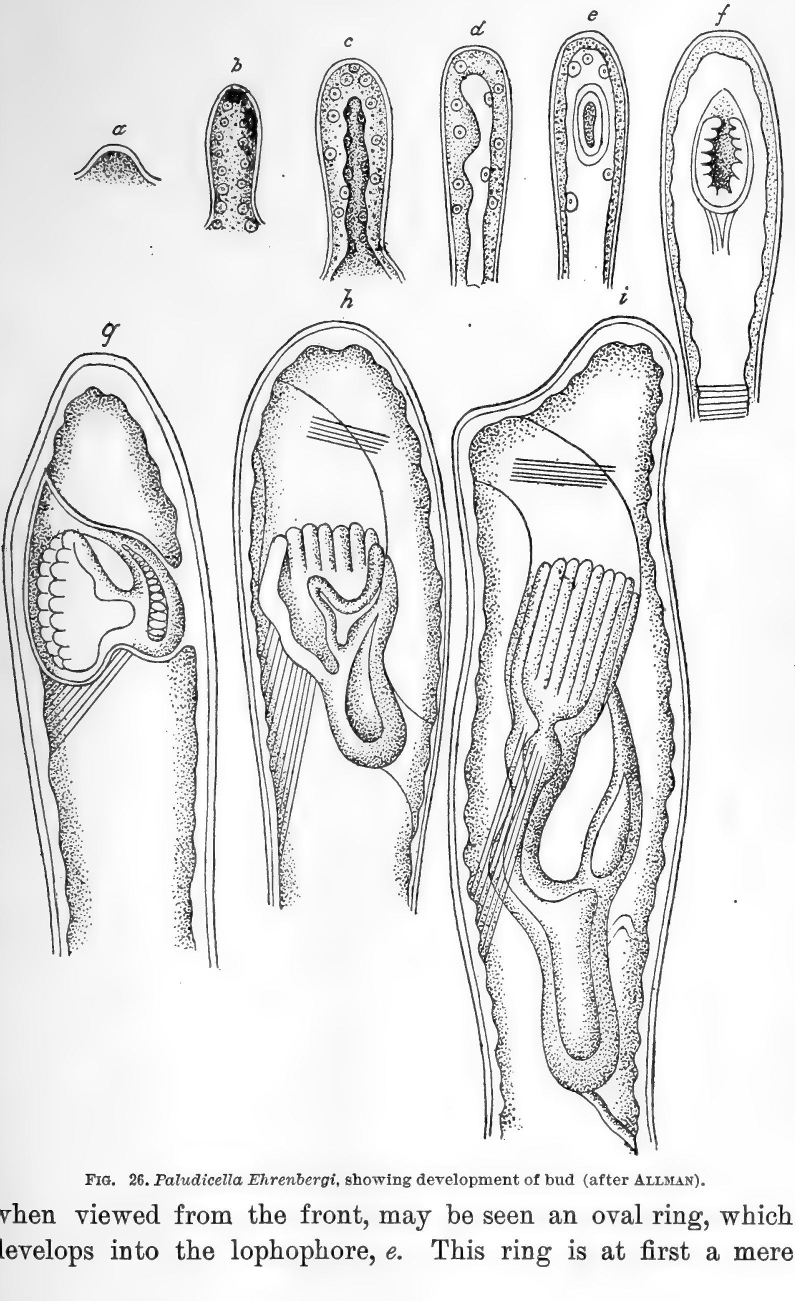


FIG. 26. *Paludicella Ehrenbergi*, showing development of bud (after ALLMAN).

when viewed from the front, may be seen an oval ring, which develops into the lophophore, *e*. This ring is at first a mere fleshy fold, but soon develops on its inner side a series of small tubercles, which become the tentacles, *f*. At this stage the lophophore is bilateral, being prolonged to that side where the rectum is to make its appearance. The space between the rudimentary tentacles is prolonged downward, being the first trace

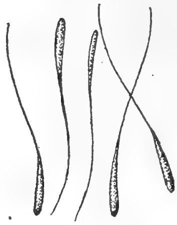


FIG 27. *Paludicella Ehrenbergi.* Free spermatozoa (after ALLMAN).

of the body of the polyp, *g*. The embryo is now suspended in a membranous sac from the walls of the cell. A few minute fibers can be observed, which develop into the polyp retractors. In *h*, the tentacles are much more developed; the body of the polyp is prolonged downward, and we are able to trace the

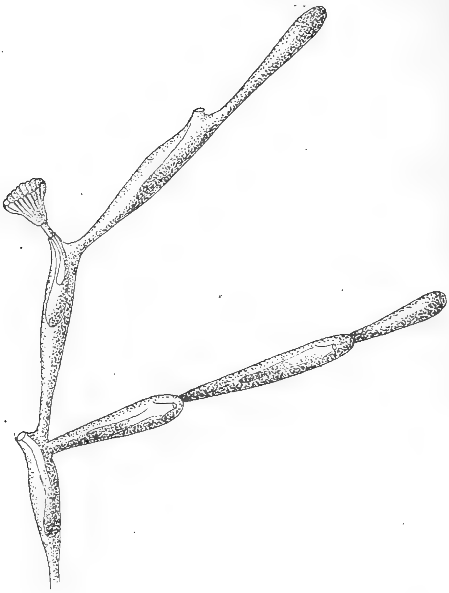


FIG. 28. *Paludicella Ehrenbergi,* showing manner of growth (after ALLMAN).

positions occupied by the œsophagus, stomach and intestine. The tube retractors can now be observed as a few indistinct fibers.

In *i*, the lophophore has lost its crescentic shape and become orbicular; the different portions of the animal are well defined. Hitherto there has been no external opening in the cell, and the nourishment has been effected from the parent cell; but now an opening occurs at the extremity of the young cell; the different organs rapidly become perfected, and the polyp is capable of obtaining nourishment from without.

Fig. 29 represents the development of a free embryo of *Alcyonella fungosa; a* represents the free spermatozoa greatly enlarged; *b* a group of ova; *c* a single ovum much more enlarged. In *d* the ovum has undergone segmentation and a central cavity has begun to show itself. Fig. *e* represents the ovum developed into an oval ciliated sac destitute of an external opening. In *f* the embryo presents an orifice, through which an unciliated portion is protruded by a process of evagination; in this protruded portion a polyp is developed. Fig. *g* shows the polyp isolated from the cell, and further enlarged; the lophophore is yet destitute of tentacles. Fig. *h* shows the polyp more advanced; a few of the tentacles have begun to develop on the lophophore. Fig. *i* shows an embryo containing two polypes; fig. *k* the same more advanced, the polyps having acquired nearly their perfect development. Fig. *l* shows a more advanced stage. The first invagination has become obliterated; the cilia have disappeared from the surface, and the young Bryozoan has acquired its ectocystal investment. A new bud is seen at each side within its cell, near its anterior extremity.

For the knowledge of the development of *Phalangella flabellaria*, a gymnolæmatous bryozoan of the sub-order CYCLOSTOMATA, I am indebted to JULES BARROIS' "Embryologies de Bryozoaires," from which work I have copied the figures on Plates C, D and E. The first stage recognized is that of a morula already well formed and composed of numerous, comparatively large, vitelline spheres (Plate C, fig. 3). The morula does not yet show any trace of a central cavity, and is very easily seen to be composed of a great number of the round cells represented in figs. 1, 2.

In the following stage the morula is slightly enlarged, and the vitelline spheres are segmented into more and more numerous elements.

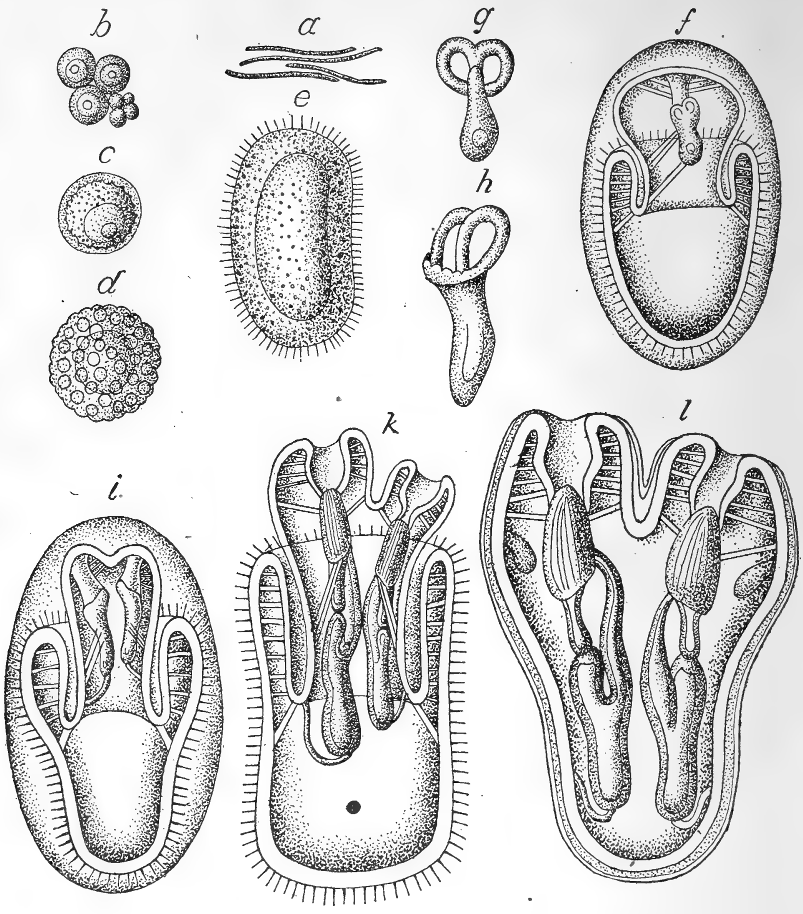


FIG. 29. *Alcyonella fungosa*, showing the development of a free embryo. *a*, Spermatozoa; *b*, A group of ova; *c*, A single ovum, much enlarged; *d*, Showing segmentation and central cavity; *e*, Showing ovum developed into an oval ciliated sac; *f*, Showing rudiment of polyp; *g*, Polyp isolated from the cell and further enlarged; *h*, Polyp more advanced; *i*, An embryo containing two polyps; *k*, the same more advanced; *l*, A still more advanced stage.

A little later (fig. 4) a central cavity is seen, and the vitelline spheres are arranged in a radiating manner around the center. Figure 5 shows the progressive thickening of the egg with an enlargement of its central cavity; the embryo becoming elongated and of oval form. Figure 6 shows the blastula stage well formed. The central cavity is more spacious and the cells more clearly radiatingly disposed. The gastrula stage shows the invagination of the gastrula which here follows the typical method; that is, there is at first a sinking in of a part of the blastula inside the other part, afterward the bringing together of the margins of the depressions thus formed. Figures 1–7 represent the first stage; figs. 8, 9, 10, Plate C, the second. The sinking in of one-half the blastula into the other part is not effected rapidly, as frequently happens, reducing at once the cavity of the body to a simple slit, but is effected, on the contrary, in a very slow manner. It is during this slow process of invagination that the egg assumes an elongate form, as shown in fig. 7. It is toward the end of the process of invagination that the elongate form is most decided. Afterward, by degrees, the egg recovers its round form. Figure 9, which is an exterior view of the stage represented in section by fig. 8, shows the form already less elongated. Figure 10 shows a complete return to the round form. Figures 8, 9 show the archigastrula already well formed; nevertheless it is not until the following stage, fig. 10, that the form is completed. We have not only the constriction of the opening of the invagination which forms the mouth of the gastrula and the constriction of the cavity of the body to a simple slit, but there are other changes of great importance. The surface begins to have a general covering of fine vibratile cilia, and the embryo is swollen a little forward of the middle, so as to present at this portion a line (*c*) of the greatest width; this line separating the primitive uniform exodermic sac into two faces, the portion above the line being the oral face, and the portion below, the aboral face. The stage illustrated by fig. 11 shows another change equally equally important; the ciliary covering hitherto disseminated over all the surface begins to be concentrated on the oral face, the aboral face being without it. At the same time at the point of greatest width the exoderm begins to separate from the internal layer, which it has heretofore carpeted, in such a manner as to give rise to a sort of fold, formed as a thick bourrelet. This is developed more toward the aboral than toward the oral face, making the two faces hitherto unequal of the same dimensions. On account of the formation of this bourrelet the cavity of the body, heretofore a simple slit, begins to be enlarged at this point (*cc*); but at the same time that this local enlargement appears, it begins to disappear at another portion. All that part of the outer layer which formed the aboral face, in effect commences to disappear at this stage and already presents vague traces of a welding with the inferior part of the endoderm (fig. 11, *m*, Plate C), and the cavity of the body as it enlarges laterally begins to recede and disappear at the base of the embryo. Figure 12, Plate C, shows the same modifications much more accentuated. The annular bourrelet is developed in such a manner as to form the most voluminous part of the entire embryo and has quitted its exactly intermediary position, approaching more and more to the aboral pole, to which it is now much nearer than to the oral pole, and the face in which is situated the mouth, from being the smaller, is now much the larger face of the embryo. In this progressive enlargement of the exterior the annular fold which constitutes the bourrelet carries with it the entire layer, which is now strongly separated from the endoderm except at the aboral face, where it is welded with the endoderm. The cavity of the body, previously continuous, is thus reduced to its superior portion, which in turn is divided into two distinct parts, the part which borders the oral face (*cć*) and which forms the general cavity, properly speaking, and the part comprised in the bourrelet (*cm*), which later forms the cavity of the mantle. On the aboral face it is no longer visible except as a scarcely perceptible line, which in a confused manner delimits the exoderm from the inferior portion of the endoderm. On all the rest of this face it is seen that the two primitive layers are thickened in giving birth to a thick white mass of a histological structure difficult to determine. The cavity of the body is seen in the middle of this mass very indistinctly, and in the stage represented by fig. 13 it has entirely disappeared.

We have seen that since its first appearance, the median swelling and later the bourrelet, at first situated near the oral pole, afterward moves toward the opposite extremity, and finally is situated much nearer to the aboral pole. This process still continuing, the bourrelet is found situated at the extreme limit of the aboral face, necessarily by the continuation of this process, it comes to project beyond the aboral face in the form of a mantle (fig. 13, Plate C). The position of the bourrelet at the extreme limit of the aboral face modifies very much the general aspect of the embryo. It is no longer composed of two equivalent faces separated by the bourrelet, but now takes on the form of a hat, of which the crown is formed by the oral face, while the rims are formed by the bourrelet, which makes a strong projection around the aboral face. The embryo has at this time very much the structure described by SMITT as the structure of the embryo of *Tubularia serpens* and CRISIA, and agrees very well with the description of that author, of an embryo of the form of a flat hat, with large rims, analogous in form to the embryo of ALCYONIUM, described by HINCKS. "1. It is composed of a convex and a flat face, the latter surrounded by a projection and showing by transparence at the center, an internal organ formed by a round swelling of the outer layer, which is an opening to the center of a cavity." The two organs which SMITT describes as the rudiments of the tentacular crown, and the adhesive organ, are probably the annular bourrelet, the evolution of which has been described, and the digestive tube.

At this stage the buccal opening, situated at the middle of the oral face, is very distinct, and all this face, as well as the superior part of the bourrelet, is provided with a continuous covering of long vibratile cilia. The cavity of the bourrelet (*cm*) and the general cavity (*cc*) are still in direct communication as in the preceding stage.

All the rest of the development of the embryo consists of a general shrinking of the form, with an elongation toward the inferior part, whilst the bourrelet strongly projects beyond the aboral face. In consequence of the general shrinkage, which takes place rapidly, the embryo quickly changes from the discoidal to the elongate form represented in fig. 14, Plate C. At the same time the different organisms undergo modifications corresponding to the change in form.

The solid aboral face, hitherto almost flat, commences to project, the projection becoming more prominent as the shrinkage proceeds, and eventually forming a round or somewhat elongate mass (fig. 14, Plate C). While this round mass is forming, the bourrelet projects more and more as a sort of mantle, and finally the mass is almost entirely enveloped by the mantle, leaving only a simple opening, which forms the communication with the interior of the cavity circumscribed by the mantle. The figures 12 and 13, Plate C, show its formation in optical sections. In this transformation the two primitive portions of the embryo become more and more separated. In the stage represented by fig. 14, Plate C, the two extremities are enlarged and the middle constricted, forming two visceral masses of the body. The general cavity of the body (*cc*) and the mantle cavity are reduced to mere slits, and are not as heretofore in direct communication with each other, but their ends are close together at the constricted portion of the body, without being connected. Externally the free larva, at this stage, presents an elongate form (fig. 15, Plate C), with the posterior extremity much the larger, occupied by the mesodermic mass and covered by the mantle. The anterior part is less swelled and contains the intestine. The two portions are separated by the constricted portion before mentioned. The two visceral masses are visible by the transparence of the body as two dark spots at the extremities of the free larva. Each pole is occupied by an opening. The first, situated at the superior pole, is the buccal opening. It is capable of contracting in such a manner as to be reduced to a simple point, and frequently it is so small that it is almost impossible to distinguish it; in this case there are always present, in that part of the skin covering the intestine, radiating striæ, which are probably plications produced by the contractions of the buccal opening. At the opposite pole there is another opening capable of expanding and contracting itself, and at the bottom of which the aboral mass is visible. As at the opposite pole there are radiating lines, but finer and situated more closely together.

METAMORPHOSIS.

After the embryo has become fixed the first stage observed is that represented in Plate D, fig. 16, and is composed of an internal mass, *a*, and an external layer, *b*, which are separated from each other by a fatty layer, *c;* the first constituting a pyriform mass; the second, soft and transparent; the third is composed of fatty globules closely enveloping the central mass, and in turn enveloped by the external layer. The form of the entire embryo is determined by that of the internal mass and is necessarily pyriform. At this stage it does not present in its interior any cavity but apparently forms a solid flat mass, composed of thin concentric layers, *a*, *b*, *c*, in direct contact with each other. In the following stage (Plate D, fig. 17) the external layer has expanded into a round cell, which is separated from the internal mass, and forms at this time a discoidal plate. The wall, at first formed of an uniform transparent membrane, is now differentiated into three parts: the external layer, *d*, which completely invests the embryo; an interior layer, *a*, which has preserved the essential structure of *a*, fig 16, and at this stage consists of a somewhat thick, obscurely cellular layer, and is called the endocyst. Between the endocyst and the peripheral zone, *d*, there is already visible a calcareous deposit, in the form of an opaque ring. The cavity of the body situated between the endocyst and internal mass, before this, compressed in a small compass, as shown in fig. 16, Plate D, by the enlargement of the external layer into a round sac, becomes very spacious, and the fatty globules, heretofore generally adhering to the external layer, for the most part detach themselves and drop into the spacious cavity. Finally, the internal mass which has preserved its pyriform aspect, commences to show two small papillæ, which are the rudiments of the tentacles. Even at this early stage we are able to see, with certainty, that the internal mass forms the rudiments of the polyp, of which the inflated portion gives rise to the tentacular crown, while the more slender portion is the beginning of the alimentary canal. The differentiation of the parts of the zoœcium proceed in a very gradual manner and, as illustrated in fig. 17, are still vague, but in the stage represented by fig. 18, Plate D, the parts previously vaguely indicated are seen distinctly separated. The rudiment of the polyp is clearly seen, divided into the tentacular crown and the beginning of the alimentary canal. Moreover, the fatty globules are definitely separated from the outer envelope, and are irregularly disseminated in the cavity of the body. Another important change which takes place at this stage, is the appearance, a little in front of the center, and just at the anterior part of the polyp, of a round swelling of the endocyst. The disc first appears in the form of a round swelling, sessile on the walls of the body, but is soon elevated above the level by the circular uprising of the walls of the endocyst, which is rapidly effected and gives rise to a tubular conduit, terminated above by a disc, which is pierced by an opening. This uprising is not uniform but is much more rapid forward than behind, so that the disc first occupies a horizontal position and is parallel with the superior portion of the endocyst, but gradually, from the unequal development of the sides of the tube, it assumes first an oblique and then a vertical position.

The tube is at first very slender, but rapidly changes to the form represented in fig. 19, Plate D; but in this stage it is yet entirely membranous, and presents very distinctly a cellular structure. Fig. 19 shows the polyp more distinctly; a tentacular crown already well formed, as well as the rectum and the stomach distinct from each other. It occupies all the space between the tube *g*, into which is prolonged the tentacular sheath and the bottom of the cell, and apparently divides the cavity of the last into two symmetrical parts, in each of which the fatty-globules unite in two coherent masses. The endocyst is still visible, but becomes less distinct by the thickening, already considerable, of the calcareous ectocyst.

In the following stages (figs. 20, 21) the terminal disc is completed, also the terminal opening which forms the mouth of the cell; also the tube *h*, which is a little elongated, is covered, without sensibly increasing the diameter, by a calcareous layer, continuous with the primitive ectocyst, which it soon equals in thickness. Figure 20 shows the continuation of the growth of the polyp, the tentacles begin to elongate themselves into the tube, which begins to lose its very regular form.

The two symmetrical masses of fatty globules, which are seen in the preceding stage (fig. 19) assembled to the right and left of the polyp, are at this stage condensed in two compact masses, occupying a much smaller space. The arrangement of the globules are the same as in the Cheilostomata at a corre sponding stage, except that in those forms they are condensed in one mass instead of two, as in this form. Passing by the intermediate stages (fig. 21) shows us the polyp completely formed, with a pigmented stomach (hepatic follicles?). Figure 22 shows us the last stage in which the polyp is observed before the completion of the cell.

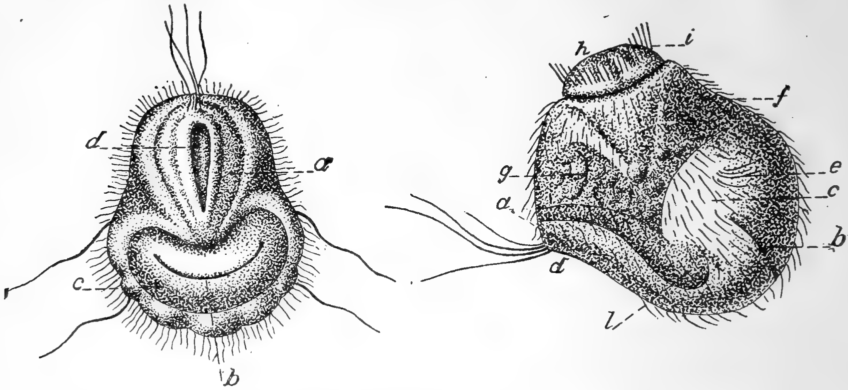
Figure 23 shows us a completed cell, and fig. 24 a group of cells, of which the cells marked *l* were formed by the budding of the cell, whose growth we have been studying.

In Plate E, figs. 1, 2, show the free embryo, front and back view of Mollia.

a, Ciliary plume. *b*, Mouth of gastrula. *c*, Oculiform points. *d*, Obscure portion of the body, comprised between the two branches of the stomach (intestine of Repiachoff?).

Figures 3 and 4 show the changes toward the formation of a cell. *p*, The polyp. *f*, Fatty globules disseminated in the period following fixation. *e*, Endocyst. *e′*, Ectocyst. *z*, The peripheral zone. In fig. 5 the calcareous ectocyst has acquired its normal thickness, while the peripheral zone has disappeared, as we have already seen in Tubulipora. The primitive cell is now completely formed and has always on the right or left a lateral cell. Figure 6 represents a more advanced stage than fig. 5. The lateral cell 1, after increasing in size, buds and is now divided by a wall into two superimposed cells, 1 and 1′, both still incomplete. In fig. 7 the cell 1 has acquired its complete development, but has not given birth to another cell. The cell 1′, has increased in size and shows two new cells, 2 and 2′, budding from it, showing in this stage as two lateral swellings; 2′ is already divided from its parent cell by a wall. In fig. 8 we see that the rudimentary cells of the preceding figures have increased in growth, 1′ being completely formed and the others well advanced; moreover, we see that the cells 1, 2, 1′ and 2′ are spread out to the left in such a manner as to fill the space between them and the neighboring cells, a process resulting in three new cells, 3, 3′ and 3″. In fig. 9 we see that the cells numbered 3 have increased in size, while the cells numbered 2 are nearly or quite completed, whilst the cells numbered 3 have spread out in such a manner as to fill the interstices between them and the cells 1′, 2, 2′, giving birth to a new range of cells numbered 4, composed of more and more numerically, which in turn thicken and give birth to another range. This form of growth continues indefinitely, each range of rudimentary cells giving birth to a new range, while the cells of the preceding range acquire their complete character. The continuation of this mode of growth finally forms a discoidal mass, the primitive cell occupying the center, the mass growing in size by the increase of the cells occupying the border.

29a



Left-hand figure. *Bicellaria ciliata*, Free embryo, oral face.
Right-hand figure. *Canda repens.* Free embryo, profile view. *a*, Pharynx; *b*, Opening of the cavity; *c*, Stomach; *d*, Mouth of the gastrula; *e*, Flagellum; *g*, Aboral mesoderm; *l*, Intestine.

STATOBLASTS.

In the Hippocrepian forms, there is still another mode of reproduction. At certain seasons of the year peculiar bodies occur attached to the funiculus (fig. 18, *z*) or lying loose in the perigastric space, to which ALLMAN has given the name of statoblasts, figs. 30, 31. They are lenticular bodies, varying in different genera from orbicular to elongate oval, and enclosed in a horny shell, consisting of two concavo-convex discs, united at their margins by a ring, which is of a different structure from the discs.

The statoblasts have erroneously been described as an egg, but are considered by ALLMAN to be a form of bud. They are developed on the funiculus and may be seen on that organ in various stages of growth.

The following account of them is taken from ALLMAN'S "Fresh-Water Polyzoa."

"In LOPHOPUS I have succeeded in following them through their various stages of early development. Their first appearance here is in the form of little swellings on the funiculus, consisting of a mass of minute cells, surrounded by a dense layer, continuous with the surface of the funiculus. The swelling now increases in size and assumes a more regularly oval form, whilst its contents appear more uniformly granular, and are plainly to be seen to be composed of two masses in close apposition to each other [fig. 30, *a*]. We next find that the two

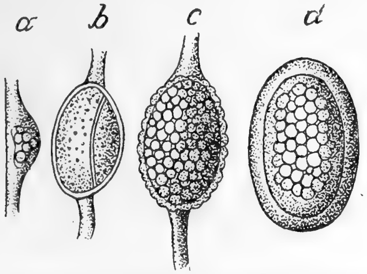


FIG. 30. Showing the development of a statoblast (after ALLMAN).

masses have lost their distinctness and fused together, and the whole contents now appear to be composed of minute cells, confined by common, external, transparent membrane, which is itself plainly cellular [*b*]. The cellular condition of its contents must not be confounded with true segmentation. The whole body now begins to assume a more lenticular form, and within the external envelope two other investments begin to show themselves. One of these, the more internal, extends over the whole of the cellular mass, but the other is confined to the margin of the lenticular mass, which it embraces in the form of a ring [*c*]. No manifest structure, beyond a simple granular one, can as yet be detected in these last formed envelopes; but the ring is soon seen to be composed of distinct cells [*d*], which present a bright central nucleus-like point, and a number of concentric layers, which remind us of the secondary deposits in certain vegetable cells. Up to this point the investments are all colorless and nearly transparent, but we now find that the internal envelope and annulus become more and more opaque, while the former assumes a deep brown color and the latter becomes yellow. They have both acquired a horny consistence, and the annulus is composed of large hexagonal cells filled with air. If now the whole be crushed under the microscope multitudes of cells will escape all filled with minute, strongly-refracting corpuscles, but any further observation of the progressive development of the contents, up to the opening of the statoblast and the escape of the young polyzoan, is henceforth, on account of the opacity of the covering, impossible. The statoblast having now its full form and breaking free from the funiculus, lies free in the perigastric space.

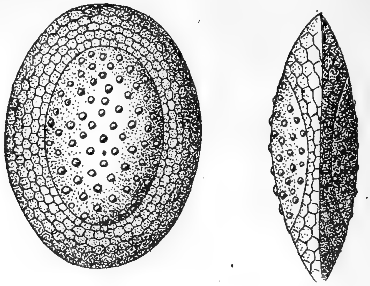


FIG. 31. A fully developed statoblast, frond and side view (after ALLMAN).

"When exposed to conditions favorable to its development, the two faces after a longer or shorter period separate from one another and a young polyzoan gradually emerges and floats away freely through the surrounding water. The surface of the young polyzoan thus become free is destitute of cilia except on the tentacles, and the motions of the young animal seem to be quite passive, except as they may be influenced by the cilia on the tentacles. At the period of its escape it possesses all the essential organization of the adult. The retractor muscles are well developed and the polypid is capable of regular exsertion and contraction, but the ectocyst is colorless and transparent and free from the earthy particles which in the greater number of species are afterward formed in it, and the little animal is still simple. It loses no time, however, in developing gemmæ, which soon change it to the compound form of the adult.

"The general structure of the statoblasts being now understood, the important question at once suggests itself, What is the true importance of these bodies? All that we have seen of them is manifestly in accordance with the nature of a bud. The invariable absence of a germinal vesicle and germinal spot, and their never exhibiting the phenomena of yelk cleavage, independently of the conclusive fact, that true ova and ovary occur elsewhere in the same individual, are quite decisive against their being eggs. We must then look upon them as *gemmæ* peculiarly encysted and destined to remain for a period in a quiescent or pupa-like state. It was for this reason, therefore, that I proposed for them the name of statoblasts — *Στατός βλάστη*."

NORTH AMERICAN PALAEOZOIC BRYOZOA.

CLASSIFICATION.

In determining the systematic position of the forms described in this paper, the form and manner of growth of the zoarium as a whole, as well as that of each cell, has been considered.

It is best not to give too much weight to microscopical characters, which not one student in ten can detect, to the neglect of more obvious characters, which can be observed by any student of ordinary scientific penetration. This is especially true of those forms which have undergone fossilization, and the consequent modification of microscopic characters.

It is a well-understood fact that one making a special study of a certain group or groups can see minute differences which can not be distinguished by others; not that they do not exist, but in order to distinguish them it needs constant and close study of that particular group; and it is apt to be the case that in the study of these minute differences more important points of agreement are overlooked.

In many forms, as STICTOPORA, the cells, from their manner of growth, need some support. In some species this support is provided for by a vesicular tissue between the cells; in others the space between the cells is filled up by an apparently, but not in reality, solid mass. As the structure in either case is simply for the support of the individual cells, if in other respects the zoarium and zoœcia are essentially the same, such difference in the supporting structure can make but little difference in systematic position of the two forms; certainly not a generic difference.

Though the MONTICULIPORIDÆ and allied forms are described here, there is but little doubt that all the forms which are here placed in the family AMPLEXOPORIDÆ and other allied forms are not Bryozoa. Any form which increases by fissiparity or by cœnenchymal gemmation, must of necessity be considered as a Coral.

In Miller's "North American Geology and Palæontology," 1889, the names of 1093 species of Bryozoa are given, occurring in the different geological formations of this country, as follows:

	Species.
Chazy	5
Trenton	79
Hudson River	141
Clinton	15
Niagara	95
Lower Helderberg	86
Corniferous	201
Hamilton	203
Chemung	2
Sub-Carboniferous	229
Carboniferous	34
Permian	3

But no significance can be attached to these figures, as the Bryozoa of some of the formations have been more thoroughly studied than those of others. For instance, though more forms have been described from the Lower Carboniferous than from the Hamilton Group, more than sixty additional species of the FENESTELLIDÆ alone from the Hamilton Group have been described in manuscript from the State of New York, and these occur in a comparatively small collection. It is safe to say that not one-half of the species of Bryozoa occurring in this country have yet been described.

Sub-kingdom **MOLLUSCOIDEA.**

Class BRYOZOA.

Order **Gymnolœmata.**

Sub-order **Chilostomata.**

Family **Fenestellidæ**, King, emend.

ANASTOMOPORA. ARCHIMEDES. ARCHIMEDIPORA. CYCLOPORINA. FENESTELLA. FENESTRALIA. FENESTRAPORA. FLABELLIPORA. FLABELLIPORELLA. HELICOPORA. HEMITRYPA. ISOTRYPA. LOCULIPORA. LYROPORA. LYROPORIDRA. LYROPORINA. LYROPORELLA. PHYLLOPORA. POLYPORA.

POLYPORELLA. PTILOPORA. PTILOPORELLA. PTILOPORINA. PINNAPORINA. PINNAPORELLA. RETEPORINA. SYNOCLADIA. TECTULIPORA. TECTULIPORELLA. UNITRYPA.

Family **Acanthocladiidae**, Zittel, emend.

ACANTHOCLADIA. GLAUCONOME. ICHTHYORACHIS. RAMIPORA.

Family **Thamniscidæ**, King.

CRISINELLA. DIPLOPORA. THAMNISCUS. THAMNICELLA.

Family **Arthrostylidæ**, Ulrich, emend.

ARTHROSTYLUS.

Family **Stictoporidæ**, Ulrich, emend.

CERAMELLA. EURYDICTYA. EVACTINOPORA. PACHYDICTYA. PHYLLODICTYA. PRISMOPORA. SCALARIPORA. SEMICPORA. STICTOCELLA. STICTOPORA. STICTOPORIDRA. STICTOPORELLA. TAENIODICTYA. TAENIOPORA.

Family **Intraporidæ**, nov. fam.

COSCINELLA. INTRAPORA. SEMIOPORA. STICTOPORELLA.

Family **Cystodictyidæ**, Ulrich, emend.

CYSTODICTYA. COSCINIUM. DICHOTRYPA. PHRACTOPORA. MEEKAPORA.

Family **Actinotrypidæ**, nov. fam.

ACTINOTRYPA.

Family **Rhinoporidæ**, Ulrich.

RHINOPORA.

Family **Ptilodictyidæ**, Zittel, emend.

GRAPTODICTYA. PHÆNOPORA. PTILODICTYA. PTILOTRYPA. STICTOPORINA. STICTOTRYPA.

Family **Acrogenidæ**, nov. fam.

ACROGENIA. DICRANOPORA. GONIOTRYPA.

Family **Clathroporidæ**, nov. fam.

CLATHROPORA.

Family **Thamnotrypidæ**, nov. fam.

THAMNOTRYPA.

Family **Arthroclemidæ**, nov. fam.

ARTHOCLEMA. HELOPORA. SEPTOPORA.

Family **Rhomboporidæ**, nov. fam.

BATOSTOMELLA. COELOCONUS. RHOMBOPORA.
TREMATELLA.

Family **Streblotrypidæ**, Ulrich emend.

CALLOTRYPA. STREBLOTRYPA.
BYTHOPORA.

Family **Rhabdosemonidæ**, Vine, emend.

ACANTHOCLEMA. NEMATAXIS.

Family **Bactroporidæ**, nov. fam.

BACTROPORA. NEMATOPORA.

Family **Chilotrypidæ**, nov. fam.

CHILOTRYPA.

Family **Phaceloporidæ**, Ulrich.

PHACELOPORA.

Family **Worthenoporidæ**, Ulrich.

WORTHENOPORA.

Suborder CYCLOSTOMATA.

Family **Fistuliporinidæ**, nov. fam.

CŒLOCAULIS. FISTULIPORIDRA. FISTULIPORINA.
PINACOTRYPA.

Family **Fistuliporidæ**, Ulrich emend.

Fistulipora. Lichenalia. Strotopora.

? Fistuliporella.

? Glossotrypa.

Family **Odontotrypidæ**, nov. fam.

Eridopora. Odontotrypa. Pileotrypa.

Selenopora.

Family **Ceramoporidæ**, Ulrich emend.

Ceramopora. Atactopora. Petigopora.

Family **Ceramoporellidæ**, nov. fam.

Ceramoporella. Chiloporella. Crepipora.

Diamesopora.

Family **Lichenoporidæ**.

Botryllopora. Sphagiopora. Scenellopora.

Family **Tubuliporidæ**, Busk.

Berenicea. Diastopora. Diastoporina.
Hernodia. Proboscina. Sagenella.
Stomatopora.

Family **Entalophoridæ**, Reuss.

Clonopora. Cystopora. Mitoclema.

Family **Reptaridæ**, nov. fam.

Reptaria. Hederella.

Suborder TREPOSTOMATA.

Family **Monticuliporidæ**, Nicholson emend.

Homotrypa. Monticulipora. Peronopora.

Family **Amplexoporidæ**, Ulrich emend.

Amplexopora. DeKayia. Heterotrypa.

Leptotrypa. Monotrypa. Monotrypella.

Petalotrypa. Ptychonema. Stenopora.

Family **Prasoporidæ.**

ASPIDOPORA. ATACTOPORELLA. HOMOTRYPELLA. PRASOPORA.

Family **Calloporidæ,** Ulrich emend.

BATOSTOMA. CALLOPORA. DEKAYELLA. DIPLOTRYPA. ? IDIOTRYPA.

Suborder CTENOSTOMATA.

ASCODICTYUM. RHAPOLONARIA. VINELLA.

UNCLASSIFIED.

CYCLOPORA. PROUTELLA.

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In the list of species, the name of each species is followed by a number and letter. The number refers to the work in which the species was first described, the letter to the formation in which the species occurs, as follows:

C. CHAZY.
D. TRENTON.
E. HUDSON RIVER.
F. CLINTON.
G. NIAGARA.
H. LOWER HELDERBERG.
K. CORNIFEROUS.
L. HAMILTON.
N. CHEMUNG.
O. LOWER CARBONIFEROUS.
P. CARBONIFEROUS.
R. PERMIAN.

GENERA AND SPECIES OF AMERICAN PALAEOZOIC BRYOZOA.

In the list of works containing accounts of genera and species, each work is preceded by a number. The number following each name refers to those numbers. The letter refers to the geological formation. (See above.)

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Descriptions of Families and Genera.

Family Fenestellidæ, King.

All the members of this family are reticulate, funnel or fan shaped, and are composed of slightly diverging bifurcating branches, either rigid and connected by cross bars (dissepiments) which are formed by opposite projections from adjacent branches, uniting midway between the branches, or sinuous and connected at intervals by anastomosis; in both cases the frond being perforated by symmetrically disposed quadrate or oval spaces (fenestrules). The cells are short utricular and arranged in two or more series, on one side of the branch only. The cell apertures are usually circular, surrounded by an elevation (peristome). The noncelluliferous face of the frond is composed of a more or less thick stratum of calcareous fibrous tissue, which is perforated by minute tubuli, rectangularly to the surface, and in some forms by larger thick walled tubes, the use of which is not known. The surface is usually striated and ornamented by granules, nodes or spinules. These features in aged fronds are usually obscured or obliterated by a calcareous deposit; the difference in appearance between the older and more recent portions of the frond being very marked.

The following genera are included in this family: ANASTOMOPORA, ARCHIMEDES, ARCHIMEDIPORA, CYCLOPORINA, FENESTELLA and its groups, FENESTRALIA, FENESTRAPORA, FLABELLIPORINA, HELICOPORA, HEMITRYPA, ISOTRYPA, LOCULIPORA, LYROPORA, LYROPORIDRA, LYROPORINA, LYROPORELLA, PHYLLOPORA, POLYPORA, POLYPORELLA, PTILOPORA, PTILOPORELLA, PTILOPORINA, PINNAPORELLA, PINNAPORINA, RETEPORELLA, RETEPORINA, SYNOCLADIA, SEMICOSCINIUM, TECTULIPORA, TECTULIPORELLA and UNITRYPA.

Several of these genera have been placed by authors under other families or subfamilies but they are so intimately connected and the change from one form to another, through intermediate forms, is so gradual (as shown in the article on the "Genera of Fenestellidæ" in the Annual Report of the State Geologist for 1893) that a separation into different families does not seem admissible. Thus FENESTELLA and POLYPORA have been placed in different families, yet both forms very gradually merge into the genus POLYPORELLA. A full discussion of the different genera will be found in the paper above referred to.

All the forms have a general resemblance to FENESTELLA and are separated from it by the number and disposition of the cell apertures, difference in the structure beyond the celluliferous face, mode of growth, etc.

FENESTELLA, Miller.

Type, *Fenestella antiqua*, Miller.

(Plate 2, figs. 1-17.)

This genus was first proposed in manuscript by J. S. MILLER of Bristol, England, but the first published description of it was given by W. LONSDALE in Murchison's Silurian System, Pt. II, p. 677. 1839.

DIAGNOSIS. A ramose, calcareous bryozoum, forming cup shaped or funnel shaped expansions; branches bifurcating and connected by apparently solid dissepiments; cell apertures occurring on one side of the branches; arranged in two parallel rows, which are separated by a carina or row of nodes. Reverse side consisting of a stratum of fibroid, calcareous tissue, which is traversed by numerous minute tubuli, at right angles to the surface. For illustrations of this genus, see Plate 2.

The species of this genus have been placed in the following groups based upon the character of the carina.

Group α, for forms with low, smooth carina.

Group β, for the forms with a range of nodes between the cell apertures, or a low, nodose carina.

Group γ, for forms with very prominent, equal, thin carinæ.

Group δ, for forms having carinæ expanded midway of their height, then contracting, the expanded portion having nodes on its margins.

Group ε, for forms with prominent carinæ, summits expanded, margins smooth.

Group ζ, for forms with prominent carinæ, expanded at the summit, margins nodose.

Group η, for forms with prominent, moderately thin carinæ, having conspicuous lateral projections at the summit. (*Fenestella perplexa.*)

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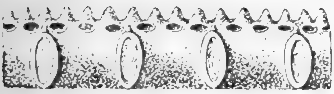

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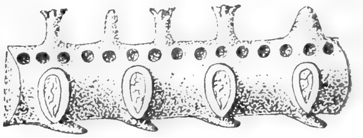

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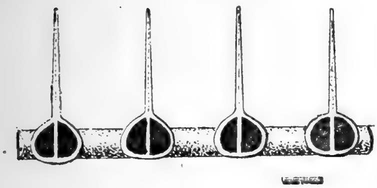

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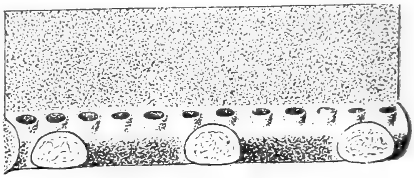

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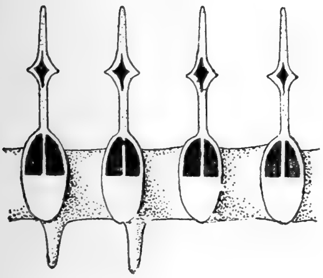

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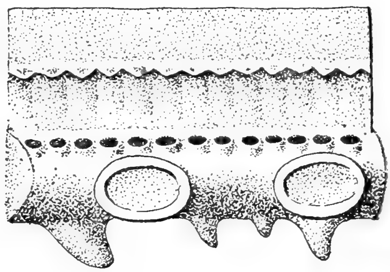

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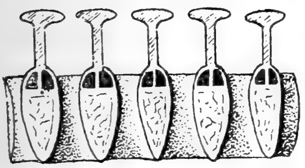

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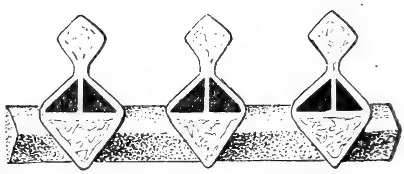

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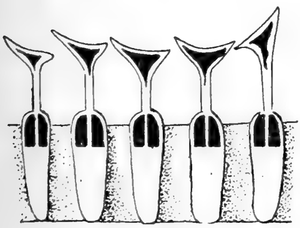

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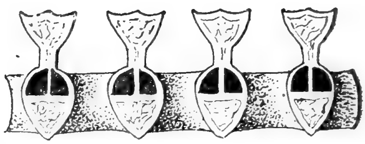

Figs. 32, 33, Group β. Figs. 34, 35, Group γ. Figs. 36, 37, Group δ. Figs. 38–41, Group ε.

POLYPORELLA, Simpson.

(Rep. of State Geologist for 1893, p. 700. 1894.)

Type, *Polyporella fistulata*, Hall (sp.).

(Plate 1, figs. 9, 10.)

Zoarium having the same general aspect as FENESTELLA. Cell apertures, on the narrower portion of the branches, disposed in two parallel rows, with or without a dividing ridge; on the wider portions in three and occasionally four rows.

This genus is intermediate between FENESTELLA and POLYPORA and was constituted to include those forms which might with propriety be included in either genus.

POLYPORA, McCoy.

(Carb. Foss. of Ireland, p. 206. 1845.)

Type, *Polypora dendroides*, McCoy.

(Plate 1, figs. 13-15.)

Bryozoum having the same manner of growth and general aspect as FENESTELLA, but having the cell apertures disposed in three or more ranges, entirely covering the celluliferous face of the branches, which are without a median keel or carina.

FLABELLIPORELLA, Simpson.

(Ann. Rept. State Geologist of N. Y. for 1893, p. 703. 1894.)

Type, *Flabelliporella lilœa*, Hall (sp.).

Zoarium consisting of ramose flabellate or fan-shaped expansions. Branches slender, bifurcating, connected by dissepiments. Celluliferous on one face only; cell apertures disposed in three or more longitudinal series.

A fragment of this genus is similar to one of POLYPORA. The forms are separated from that genus by the flabellate mode of growth.

FENESTRALIA, Prout.

(Trans. Acad. Sci., St. Louis. 1858.)

Type, *Fenestralia St. Ludovici*, Prout.

"Corallum flabelliform, bifurcating frequently and rapidly expanding into a broad frond, folded upon itself longitudinally near the top.

"*Longitudinal rays or interstices* (branches) large, round near the base, more angular toward the middle of the frond; midrib indistinct near the base, very prominent and well marked when slightly weathered.

"*Dissepiments* short, strong and enlarged at their junction with the longitudinal rays.

"*Fenestrules*, long, oval, or elliptical, rarely quadrangular, two to two and a half in two lines measured longitudinally ; four in two lines transversely.

"*Cells* in two rows on either side of the midrib, most generally opposite to the two rows, and opposite on the two sides of the midrib, five to each fenestrule, or twenty inclusive of the two rows on either side.

"*Reverse*, fenestrules quadrangular from the want of expansion in the junction of the dissepiments; rays and dissepiments rounded, minutely tubular, striate."

This species differs from FENESTELLA in its flabellate mode of growth, and in having two rows of cell apertures on each side of a median carina. It differs from FLABELLIPORINA, in having a median keel and it having uniformly four rows of cell apertures.

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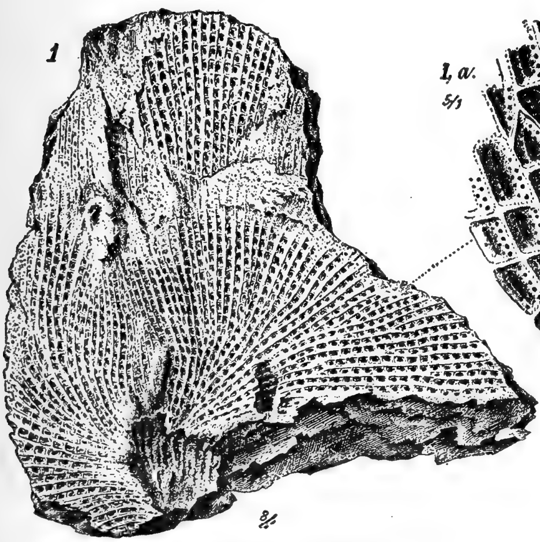

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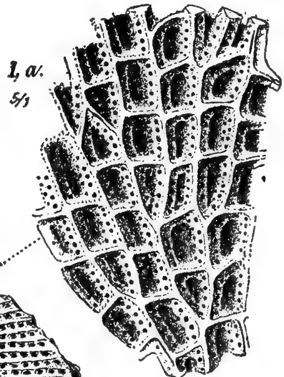

FIG. 42. *Fenestralia St. Ludovici.* Frond natural size. FIG. 43. A portion enlarged.

RETEPORELLA, Simpson.

(Ann. Rept. of State Geologist of N. Y. for 1893.)

Type, *Reteporella undulata.*

(Plate 1, figs. 1–5.)

Bryozoum consisting of infundibuliform or cup-shaped expansions, celluliferous on one face only ; branches sinuous or zig-zag, anastomosing at short and regular intervals in such a manner as to give rise to a regularly disposed system of fenestrules; cell apertures disposed in from three to seven longitudinal rows; branches without a median keel.

Many of the forms included in this genus have been described under the name RETEPORA, owing to a misapprehension of the characters of that genus. By some authors it is considered a synonym of PHYLLOPORA, but the original figures of that genus show that the branches are connected by celluliferous dissepiments, not by anastomosis.

The genus most nearly resembles POLYPORA in its general appearance, but it differs from that genus in the anastomosis of the branches.

RETEPORINA, D'Orbigny.

(Prodrome de Pal. t. i., p. 101.)

Type, *Reteporina prisca*, Goldfuss (sp.).

(Plate 1, figs. 6–8.)

"Ce sont des POLYPORA dont les cellules placés sur deux lignes parallèles, rapprochés, régulières, longitudinales, non séparées par une côte, sont a la partie supérieure des branches largement anastomosées de manière à ne laisser entre elles que des oscules oblongs, reguliérs, placés par lignes divergentes."

This genus differs from RETEPORELLA in having only two rows of cell apertures.

The original diagnosis states that the rows of apertures are not separated by a ridge, but as we have seen in FENESTELLA, the presence or absence of a carina, all other characters being the same, is not of generic importance.

CYCLOPORINA, Simpson.

(Ann. Rept. State Geologist for 1893.)

Type, *Cycloporina hemicycla*, Hall (sp).

(Plate 3, figs. 1–5.)

Bryozoum having the same general aspect as RETEPORINA; at irregular intervals, but invariably over a dissepiment, there are semi-circular, lateral projections from the carina, which extend about half the distance to the adjacent carina. Frequently the projections from adjacent carinæ unite and form solid connections of the two carinæ.

The carinæ of this genus vary in the same manner as do those of FENESTELLA, and from these variations the species are divided into several groups, corresponding to, and designated by the same letters as the groups of FENESTELLA.

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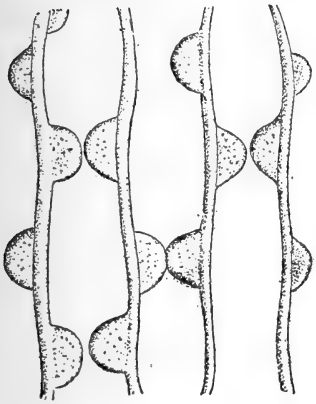

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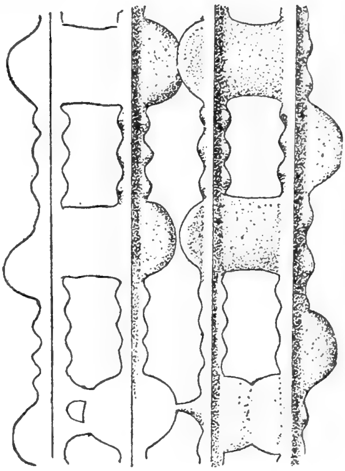

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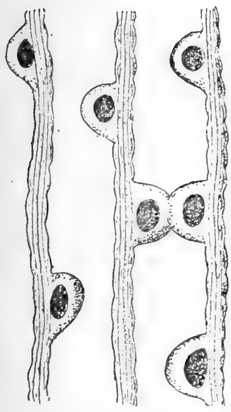

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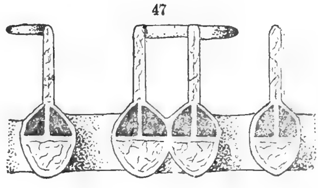

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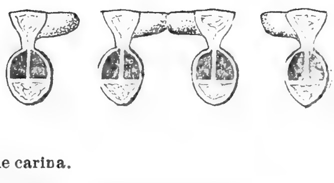

FIGS. 44–50. CYCLOPORINA, showing various forms of the carina.

FIGS. 44, 45, 46. Showing the carinæ of the species of this genus; viewed from above.

FIGS. 47. Illustrating the carinæ of group γ.

FIG. 48. Illustrating carinæ of group ε.

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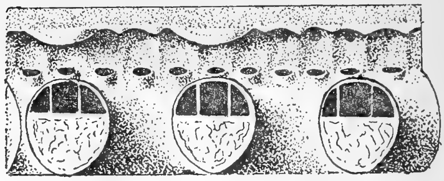

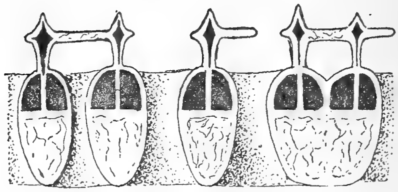

FIGS. 49, 50. Illustrating carinæ of group δ.

FENESTRAPORA, Hall.

(Rept. N. Y. State Geologist, p. 36, Pl. 2, fig. 17. 1885.)

Type, *Fenestrapora biperforata*, Hall.

(Plate 3, figs. 6–12.)

Bryozoum having the same general aspect as FENESTELLA. On the noncelluliferous face there are numerous triangular or circular pores or apertures of the larger tubuli. On the celluliferous face the cell apertures are disposed in two ranges, separated by a prominent carina, which has a row of small pores along the middle of its expanded summit.

PTILOPORELLA, Hall.

(Pal. N. Y., Vol. VI, p. 171. 1887.)

Type, *Ptiloporella laticrescens*, Hall.

(Plate 4, figs. 1–6.)

Bryozoum ramose, forming infundibuliform expansions; branches of two sizes, the smaller or secondary branches proceeding laterally from the larger or primary ones, either from one or both sides. As the frond expands other large branches proceed laterally from the primary ones, this process continuing during the growth of the frond; cell apertures arranged in two parallel rows, separated by a carina, the carinæ of the primary branches being much more prominent than those of the secondary branches.

PTILOPORINA, Hall.

(Pal. N. Y., Vol. VI, p. 172, Pl. 43, figs. 7–9.)

Type, *Ptiloporina sinistralis*, Hall.

(Plate 4, figs. 8–12.)

Bryozoum having the same manner of growth and general appearance as PTILOPORELLA, but differing from that genus in having three or more ranges of cell apertures, not separated by a carina. This genus bears the same relation to PTILOPORELLA that POLYPORA does to FENESTELLA.

PINNAPORINA, Simpson.

(Ann. Rept. of N. Y. State Geologist for 1893. 1894.)

Type, *Pinnaporina pinnata*, Hall (sp.).

(Plate 4, fig. 7.)

In general appearance and disposition of cell apertures this genus resembles PTILOPORINA, but differs from that genus in having a flabellate mode of growth. It differs from PINNAPORELLA in having three or more ranges of cell apertures not separated by a carina.

HEMITRYPA, Phillips.

(Pal. Foss. Cornwall, Devon. and West Somerset, p. 27, 1841.)

Type, *Hemitrypa oculata*, Phillips.

(Plate 5, figs. 1–11.)

Bryozoum having the same general appearance and manner of growth as FENESTELLA; cell apertures arranged in two parallel rows separated by a carina; carina prominent, expanded above and having lateral processes (scalæ), which, meeting midway between the carinæ, form an intermediate ridge or pseudocarina. The spaces between the scalæ or fenestrules usually correspond in number to the cell apertures.

This form differs from UNITRYPA in having simple lateral projections, instead of thin oblique plates, and in the formation of a pseudocarina.

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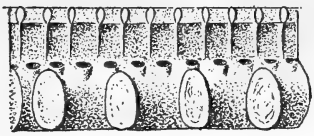

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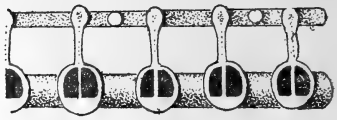

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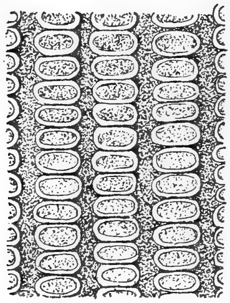

FIGS. 51-53. *Hemitrypa columellata.*
FIG. 51. A transverse section of a frond, x18.
FIG. 52. A side view of a portion of a branch and its carina, x18.
FIG. 53. Showing the tubular appearance of a transverse section of the carinæ and scalæ.

UNITRYPA, Hall.

(Rep. of N. Y. State Geologist for 1884, p. 36. 1885.)

Type, *Unitrypa lata*, Hall.

(Plate 5, figs. 15-19; Pl. 6, figs. 1-6.)

Fronds having the general appearance and mode of growth of FENESTELLA. The cell apertures are arranged in two parallel rows, separated by a carina; carina prominent, thickened above and connected by thin oblique plates (scalæ). Frequently the scalæ are abruptly bent at about half their height, and always present an imbricated appearance.

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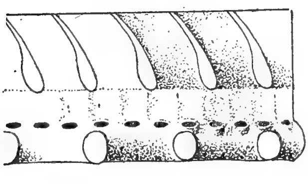

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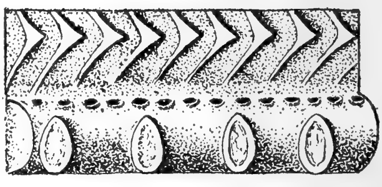

FIG. 54. *Unitrypa fastigata.* An enlargement showing the side view of a branch, with its carina, and section of the scalæ. The scalæ are oblique toward the base of the frond, a mode of growth of rare occurrence.
FIG. 55. *U. lata.* A side view of a branch and its carina, and a section of the scalæ, x18.

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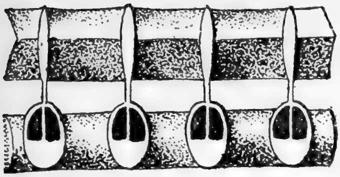

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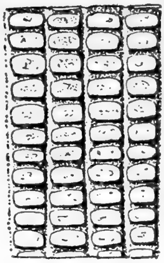

FIG. 56. A transverse section of a portion of the frond, x18.
FIG. 57. An impression in the rock made by the summits of the carinæ and scalæ.

SEMICOSCINIUM, Prout.

(Trans. Acad. Sci. St. Louis. 1858.)

Type, *Semicoscinium rhomboideum*, Prout.

This genus is probably a synonym for UNITRYPA, but as the original specimens can not be referred to and different opinions are entertained of it by authors the name UNITRYPA must stand.

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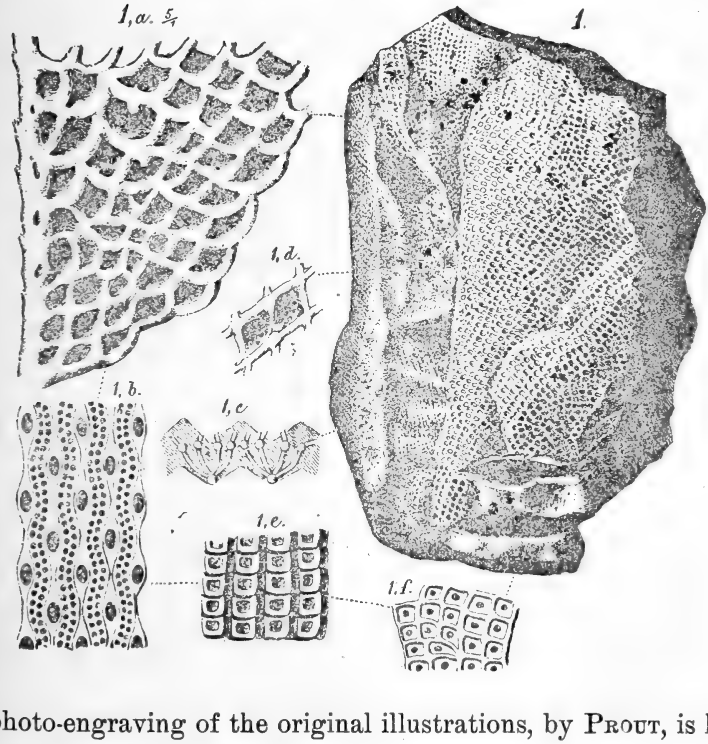

A photo-engraving of the original illustrations, by PROUT, is here given.

ISOTRYPA, Hall.

(Report of N. Y. State Geologist for 1884, p. 37. 1885.)

Type, *Isotrypa conjunctiva*, Hall.

(Plate 6, figs. 7–12.)

Bryozoum having the same general appearance as FENESTELLA; cell apertures arranged in two parallel rows separated by a carina; carinæ prominent, expanded at the summit; summits connected by round or oval, comparatively distant lateral bars. On the noncelluliferous face a conspicuous pore occurs on or near each dissepiment.

This genus differs from UNITRYPA not only in having conspicuous pores on the noncelluliferous face, but also in the character of the lateral processes. In UNITRYPA the scalæ consist of thin, oblique or bent, imbricating plates, which usually extend on the sides of the carinæ for at least one-half their height, each scala being formed of two lamellæ, coalescing at the summit. The carinæ of this genus are not of equal thickness, and when broken the base of the thicker portion alone remains attached to the branches, closely resembling a row of elongate nodes, in this respect being similar to HEMITRYPA.

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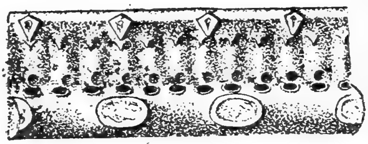

FIG. 59. *Isotrypa conjunctiva*. A side view of a portion of a branch and its carinæ; also showing a section of the dissepiments and scalæ, x18.

TECTULIPORELLA, Simpson.

(Ann. Rept. of N. Y. State Geologist for 1893.)

Type, *Tectuliporella consimilis*, Hall.

(Plate 6, figs. 13–15.)

This genus resembles ISOTRYPA in general appearance and manner of growth, but the summits of the carinæ and connecting bars are much stronger and are scarcely distinguishable from the noncelluliferous face of the frond. It differs, also, from ISOTRYPA in being without pores on the noncelluliferous face of the frond, and on the sides of the carinæ, above the cell apertures.

TECTULIPORA, Hall.

(Ann. Rep. State Museum Nat. Hist. 1887.)

Type, *Tectulipora loculata*, Hall.

(Plate 7, figs. 1–5.)

Bryozoum having the general aspect of TECTULIPORELLA; cell apertures arranged in two parallel rows; branches and dissepiments carinated; the carinæ of the dissepiments coalescing with those of the branches; carinæ prominent; summits expanded, frequently having a width nearly or quite equal to the branches and dissepiments below. The summits of the carinæ are angular or carinated, sometimes with a row of nodes along the middle, this portion of the frond having a strong resemblance to the noncelluliferous face of some Fenestelloid forms. This genus differs from LOCULIPORA in having the cell apertures arranged in two parallel rows; the dissepiments being noncelluliferous.

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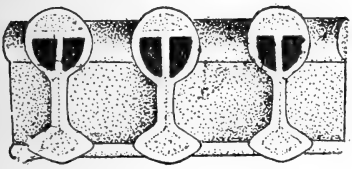

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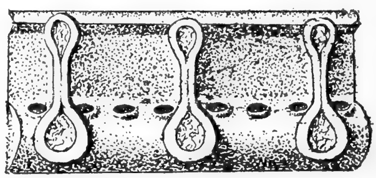

FIG. 60. *Tectulipora loculata*. A transverse sction of the branches and carinæ, showing a side view of dissepimental and its carinæ, x18.

FIG. 61. A transverse section of three dissepiments and their carinæ and a side view of a portion of a branch and its carina, x18.

LOCULIPORA, Rominger, mss.

(First published in Pal. N. Y., Vol. VI, p. xxiii. 1887.)

Type, *Loculipora biperforata*, Hall.

(Plate 7, figs. 6–12.)

Bryozoum infundibuliform, branches sinuous or zig-zag, anastomosing or connected by very short dissepiments, which are of about the same width as the branches. The noncelluliferous face usually presents more of an anastomosed appearance than the celluliferous; cell apertures disposed in oval order entirely surrounding the fenestrule; branches and dissepiments carinated; carinæ coalescing; summits much expanded, angular and slightly carinated; width of the summits usually about equal to the branches and dissepiments below. So close is the resemblance of this portion of the frond to the noncelluliferous face, that it is almost impossible to distinguish them. This genus is the only one, so far observed, in which the cell apertures are not arranged in parallel rows. It differs from TECTULIPORA, which it most closely resembles, in the sinuosity and frequent anastomosis of the branches, and in the oval arrangement of the cell apertures.

PHYLLOPORA, King.

(Ann. and Mag. Nat. Hist., 2d Series, Vol. 111, p. 389. 1849.)

Type, *Phyllopora Ehrenbergi*, King.

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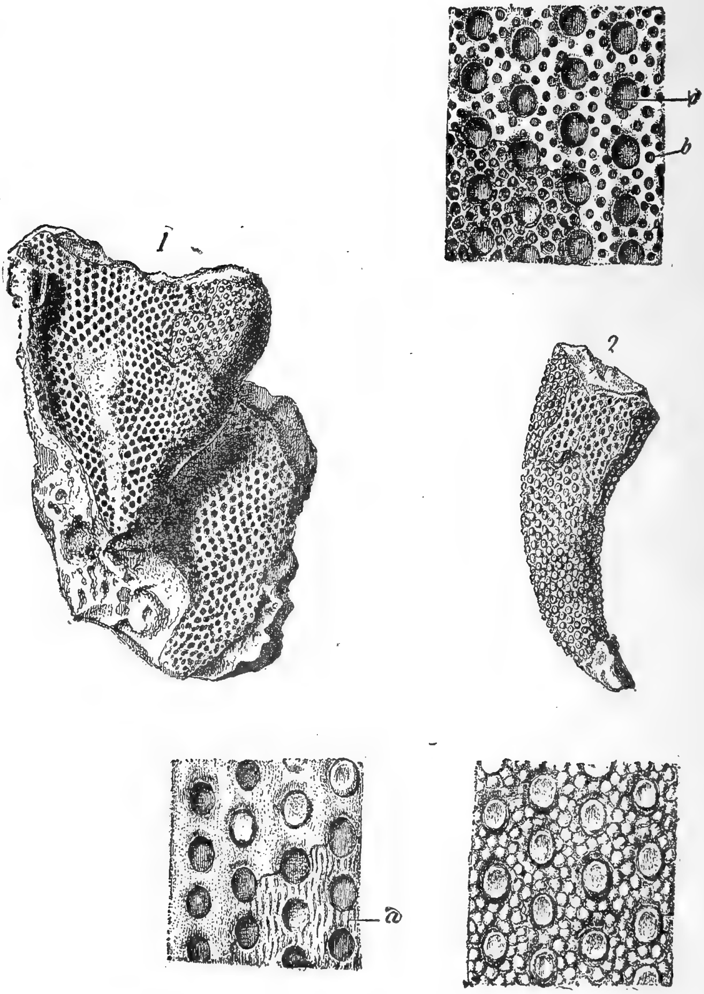

FIG. 62. *Phyllopora Ehrenbergi*, 1, 2, Fronds natural size; *upper figure*, celluliferous face; *lower left-hand figure*, noncelluliferous face; *lower right-hand figure*, showing filling of cells, the surface being worn away.

Original diagnosis. "A Fenestellidia consisting of infundibuliform, folded, perforated fronds or foliaceous expansions; cellules on the whole of the outer or under surface of the fronds, and planted more or less approximately to a position at right angles to the plane of the capillary tubular basal plate; cellule apertures with plain margins and parallel to the surface of the fronds."

The original illustrations, a photo-engraving of which is given below, show this genus to be a Fenestelloid form, the branches of which are connected by celluliferous dissepiments, in this respect differing from the genera hitherto described.

A discussion of this genus will be found in the Annual Report of the N. Y. State Geologist for 1893.

SYNOCLADIA, King.

(Ann. and Mag. Nat. Hist., 2d Series, Vol. 111, p. 389. 1849.)

Type, *Synocladia virgulacea*, Phillips (sp.).

Bryozoum infundibuliform, branches bifurcating, having at regular intervals lateral projections, obliquely ascending, coalescing with an opposite series from adjacent branches, and forming

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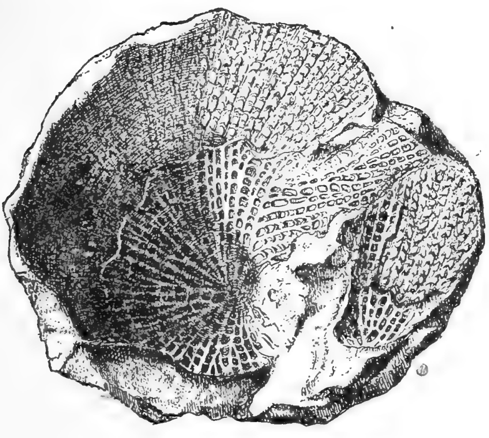

FIG. 63. *Synocladia virgulacea.* Frond, natural size.

arcuate or angular dissepiments. In some specimens many of the lateral projections are not oblique, in which case they have the same appearance as the ordinary forms of FENESTELLA. Usually there are three or more ranges of cell apertures on the branches and two on the dissepiments.

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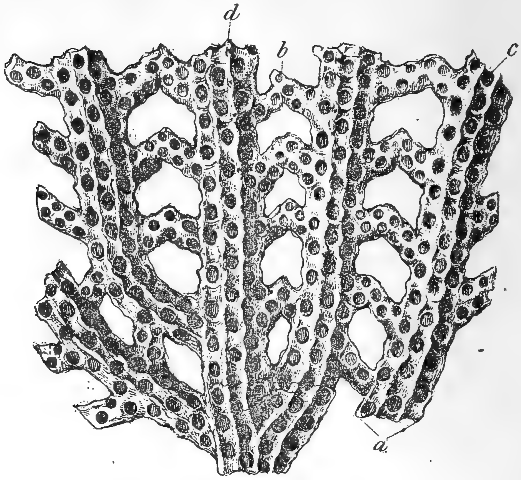

FIG. 64. A portion of the celluliferous face enlarged.

SEPTOPORA, Prout.

(Trans. Acad. Sci. St. Louis, Vol. I, p. 448. 1859.)

Type, *Septopora Cestriensis*, Prout.

Bryozoum infundibuliform, having the general aspect of FENESTELLA. On the celluliferous face the cell apertures are arranged in two longitudinal parallel rows, separated by a carina; dissepiments arcuate, angular or straight, and celluliferous.

PROUT in his original description says: "I have established this genus upon the character of the dissepiments, which are more celluliferous than the longitudinal rays (branches). Though in its general features it resembles FENESTELLA, it differs in a marked degree by its celluliferous dissepiments."

This genus differs from SYNOCLADIA in having only two ranges of cell apertures, separated by a carina, having the same relation to that genus that FENESTELLA does to POLYPORA.

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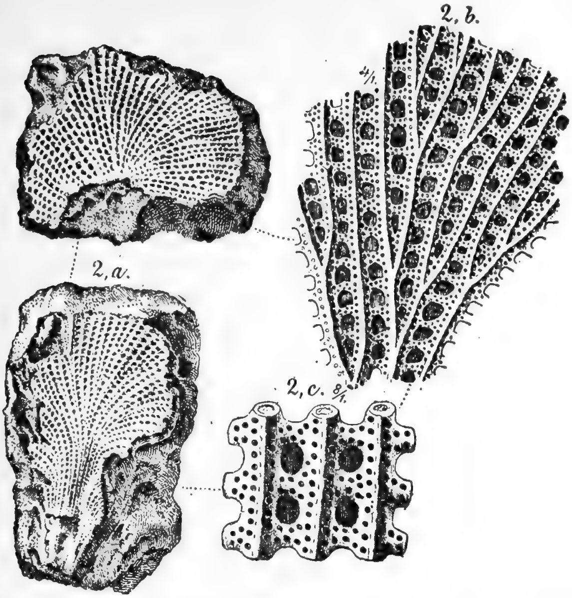

FIG. 65. *Septopora Cestriensis*, 2*a*, Fronds natural size; 2*b*, A portion of the frond e. x4; 2*c* A small portion x8.

LYROPORA, Hall.

(Proc. Amer. Ass. Ad. Sci., Vol. X, p. 179. 1857.)

Type, *Lyropora lyra*, Hall.

"Bryozoum consisting of reticulated, foliated expansions, margined on either side by strong, stony supports, which diverge from the base curving upwards and outwards."

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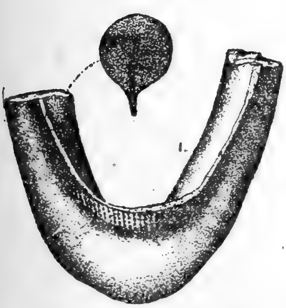

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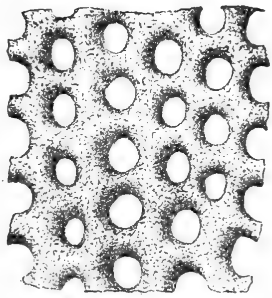

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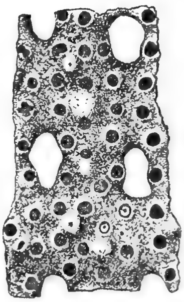

FIG. 66. *Lyropora ranosculum*. The thickened margin, natural size and transverse section of same.
FIG. 67. Noncelluliferous face of a frond, x9.
FIG. 68. Celluliferous face, x18.

The structure between the thickened margins has the same appearance as POLYPORA, being composed of bifurcating branches, connected by noncelluliferous dissepiments; cell apertures in three or more ranges, with no separating carina.

LYROPORELLA, Simpson.

(Ann. Rep. of N. Y. State Geologist for 1893. 1894.)

Type, *Lyroporella quincuncialis*, Hall (sp.).

Bryozoum having the same manner of growth and general appearance as LYROPORA, but having on the narrower portion of

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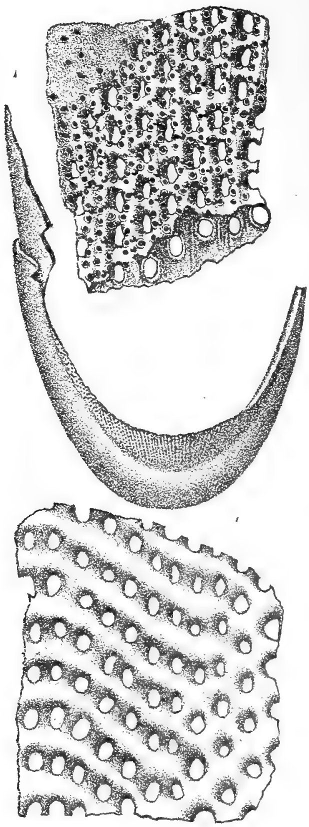

FIG. 69. *Lyroporella quincuncialis*. *Middle figure;* the thickened margin of the frond, natural size. *Lower figure*. Noncelluliferous face of a frond, x9.
Upper figure. Celluliferous face of a frond, x9.

the branches only two ranges of cell apertures, frequently separated by a carina, and on the wider portion of the branches three and occasionally more ranges without a dividing ridge. This genus has the same relation to LYROPORA that POLYPORELLA has to POLYPORA.

LYROPORIDRA, nov. gen.

Type, *Lyroporidra subquadrans*, Hall (sp.).

(Plate 9, fig. 19.)

This genus has the same general appearance and mode of growth as LYROPORA, but on the celluliferous face the cell apertures are arranged in four parallel rows, two rows on each side of a median carina or row of nodes.

This genus bears the same relation to LYROPORA that FENESTRALIA does to POLYPORA.

ANASTOMOPORA, nov. gen.

Type, *Anastomopora cinctuta*, Hall (sp.).

(Plate 9, figs. 20-23.)

This genus has a general resemblance to LYROPORA, but the branches are sinuous and anastomosing; cell apertures disposed in three or more ranges, without separating carina.

This genus bears the same relation to LYROPORA that RETEPORELLA does to POLYPORA, and is separated from it by the fact that the branches are connected by anastomosis, not by dissepiments.

HELICOPORA, Claypole.

(Quar. Jour. Geol. Soc., p. 30. 1883.)

Type, *Helicopora latispiralis*, Claypole.

Original diagnosis. "Polyzoary expanded, fenestrate and spiral. formed of slender, bifurcating rays, poriferous on one face, connected by nonporiferous bars, forming an open network; cells arranged in two rows along the rays, one on each side of a median keel; axis none, or consisting only of the thickened inner border of the polyzoary; not straight, but forming a spiral, rounded, nonporiferous or slightly poriferous inner margin."

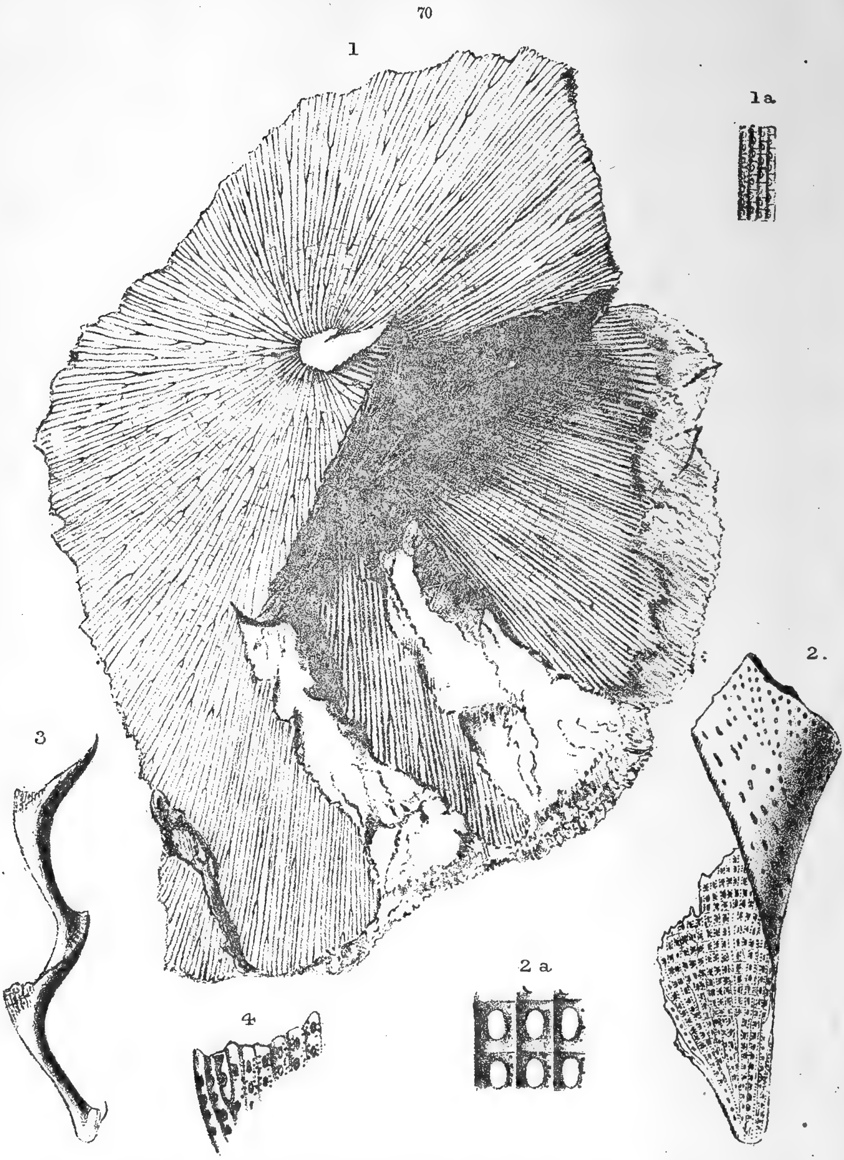

FIG. 70. A photo-engraving of CLAYPOLE'S original illustration. Fig. 1, *Helicopora latispiralis*. Lower face, showing four whorls of the spiral, nat. size; 2, *H. Ulrichi*, x8; 2a, A small portion, x8; 3, *H. archimediformis*, nat. size; 4, Enlarged view of the celluliferous part of fig. 3, x4.

ARCHIMEDES, Le Sueur.

(Amer. Jour. Sci., Vol. 43, p. 19. 1842.)

Type, *Archimedes Owenana*, Hall (sp.).

The forms in this genus do not differ in their essential structure from FENESTELLA; their mode of growth, however, is quite distinct; the expansion acquiring a solid central axis, around which it revolves in an ascending spiral form, spreading equally on every side. On the celluliferous face, the cell apertures are arranged in two parallel rows, separated by a carina or row of nodes.

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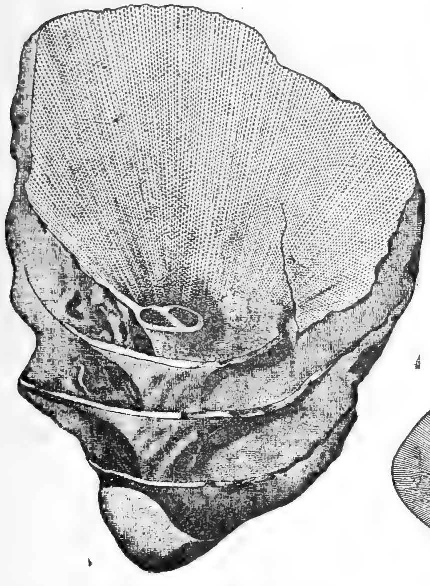

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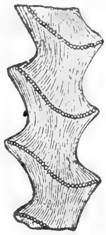


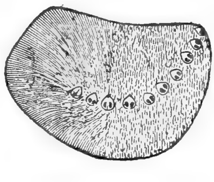


FIG. 71. *Archimedes Wortheni*, frond natural size.
FIG. 72. A longitudinal section of the central axis.
Lower fig. A transverse section of the central axis, x2.

PTILOPORA, McCoy.

(Syn. Carb. Foss. Ireland, p. 200.)

Type, *Ptilopora flustriformis*, McCoy.

(Plate 8, figs. 1–7.)

Flabelliform, attached by roots, from which a strong midrib arises, giving origin on each side to thin equidistant branches, which are connected by regularly disposed dissepiments; celluliferous on one face only; cell apertures disposed in two longitudinal, parallel rows, separated by a carina or row of nodes.

RECAPITULATION OF FAMILY FENESTELLIDÆ

Branches connected by dissepiments:

INFUNDIBULIFORM.

Cells in two ranges, separated by carinæ or row of nodes	FENESTELLA.
Cell apertures in two or three ranges, branches carinated or not	POLYPORELLA.
Cell apertures in three or more ranges, no carina	POLYPORA.
Cell apertures in four ranges, median carina	FENESTRALIA.
Cell apertures in two ranges, carina prominent, poriferous; reverse face poriferous	FENESTRAPORA.
Cell apertures in two ranges; carinæ with prominent, semicircular projections...	CYCLOPORINA.
Cell apertures in two ranges; carinæ prominent, connected by scalæ, which meet midway, forming pseudo-carinæ..	HEMITRYPA.
Cell apertures in two ranges; carinæ prominent, connected by oblique, thin plates............................	UNITRYPA.
Cell apertures in two ranges; carinæ connected by bars; reverse face poriferous	ISOTRYPA.
Cell apertures in two ranges; carinæ connected by bars; reverse face non-poriferous	TECTULIPORELLA.
Cell apertures in two ranges; branches and dissepiments carinated; carinæ very prominent, expanded at summit, and coalescing	TECTULIPORA.
Cells arranged in oval order, around fenestrules; branches and dissepiments carinated; carinæ prominent, expanded at summit, and coalescing............	LOCULIPORA.
Cells in (?) two ranges; dissepiments celluliferous.........	PHYLLOPORA.

Cell apertures in two ranges; branches carinated; dissepiments celluliferous and arcuate .... SEPTOPORA.
Cell apertures in more than two ranges; dissepiments arcuate and celluliferous . SYNOCLADIA.

FLABELLATE.

Cells in two ranges; median carina ..... FLABELLIPORINA.
Cell apertures in more than two ranges; no median carina .... FLABELLIPORELLA.

Forms having large primary branches, smaller lateral branches:

INFUNDIBULIFORM.

Cell apertures in two ranges; median carina .... PTILOPORELLA.
Cell apertures in more than two ranges; no median carina..................... PTILOPORINA.

FLABELLATE.

Cells in two ranges; median carina ..... PINNAPORELLA.
Cell apertures in more than two ranges; no median carina .... PINNAPORINA.

Branches at nearly right angles:

Cell apertures in two ranges; median carina .... PTILOPORA.

Branches connected by anastomosis:

INFUNDIBULIFORM.

Cells in two ranges; median carina ..... RETEPORINA.
Cells in more than two ranges; no median carina .... RETEPORELLA.

Base and lateral margins greatly thickened. Branches connected by dissepiments :

FOLIACEOUS.

Cell apertures in two ranges; median carina .... LYROPORINA.
Cell apertures in two and three ranges; with or without carina .... LYROPORELLA.
Cell apertures in more than two ranges; no median carina .... LYROPORA.
Cell apertures in four ranges; median nodes or carina .... LYROPORIDRA.

Branches connected by anastomosis :

Cell apertures in more than two ranges; no median carina..................... ANASTOMOPORA.

Forms with central axis; growth spiral :

Cells in two ranges; median carina ..... ARCHIMEDES.
Cells in more than two ranges; no median carina .... ARCHIMEDIPORA.

Growth spiral; no central axis :

Cells in two ranges; median carina ..... HELICOPORA.

Family Acanthocladiidæ.

The forms included in this family have a flattened stipe, from which proceed numerous short lateral branchlets and occasionally a larger branch having the same manner of growth as the main stipe; celluliferous on one side only; branchlets not connected by dissepiments. The following genera are included in this family: ACANTHOCLADIA, GLAUCONOME, ICHTHYORACHIS and RAMIPORA.

ACANTHOCLADIA, King.

(Ann. and Mag. Nat. Hist, 2d series, Vol. 111, p. 389. 1849.)

Type, *Acanthocladia anceps*, King.

Original diagnosis. "A Thamniscidia; stems symmetrically and bilaterally branched; more or less on one plane; rarely bifurcating; branches short, simple; occasionally elongated and becoming bilaterally branched; stems and branches celluliferous on the side overlooking the imaginary axis of the coral; cellules imbricated and arranged in longitudinal series; series of cellules separated from each other by a dividing ridge; gemmuliferous vesicles (?) on the dividing ridge."

The following figures are photo-engravings from KING's original illustrations:

73

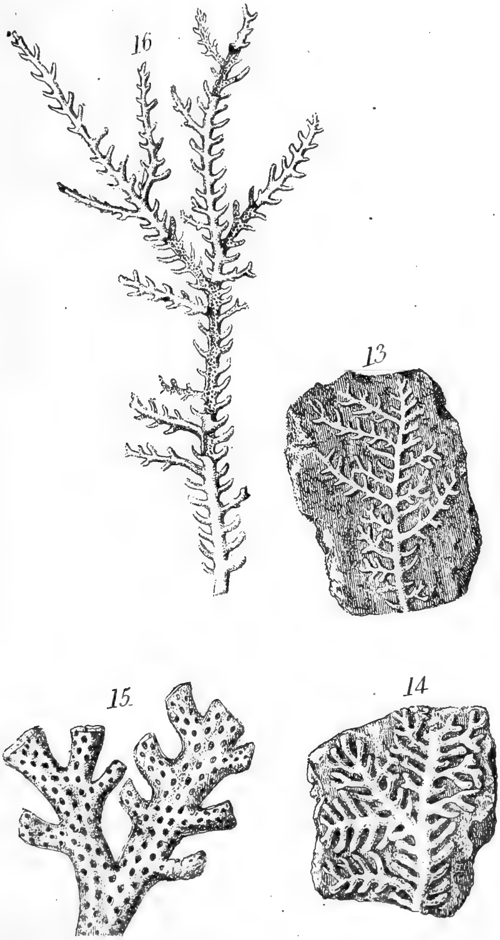


FIG. 73. *Acanthocladia anceps.* 13, A specimen slightly enlarged; 14, A specimen x2; 15, An enlargement to show the cell apertures; 16, A specimen, nat. size.

GLAUCONOME, Goldfuss.

(Petrefacta Germanica, Vol. I, p. 100, 1826; emended by Lonsdale in Murchison's Silurian System, p. 677, 1839.)

Type, *Glauconome disticha*, Goldfuss.

(Plate 8, figs. 8–15.)

Zoarium consisting of a main stem or rachis, from which proceed simple lateral branches, at regular intervals, and occasionally branches having the same manner of growth as the primary rachis; celluliferous on one face; cell apertures disposed in two longitudinal, parallel rows; usually separated by a carina.

ICHTHYORACHIS, McCoy.

(Carb. Foss. of Ireland, p. 205. 1844.)

Type, *Ichthyorachis Newenhami*, McCoy.

(Plate 8, figs. 16–21.)

Zoarium plumose, consisting of a rachis with short lateral branches or pinnules; celluliferous on one face. On the rachis the cell apertures are disposed in five or more rows, laterally in oblique ascending order; usually three ranges on the branches.

Family **Thamniscidæ**, King, emend.

The following genera are included in this family: THAMNISCUS, THAMNOCELLA, CRISINELLA and DIPLOPORA.

THAMNISCUS, King.

(Ann. and Mag. Nat. Hist., 2d Series, Vol. III, p. 309. 1849.)

Type, *Thamniscus dubius*, King.

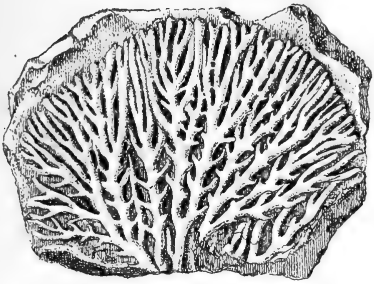
(Plate 9, figs. 14–18.)

Zoarium fruticose, giving forth lateral branches or bifurcating, on one plane; branches numerous, frequently of clavate appearance; not connected by dissepiments; celluliferous on one face; cell apertures in quincunx order or irregularly disposed.

KING's diagnosis. "The typical Thamniscidia; stems frequently and irregularly bifurcating, more or less on one plane; celluliferous on the side overlooking the imaginary axis of the coral; cellules imbricated and arranged in quincunx; gemmuliferous vesicles overlying the cell apertures."

Figs. 74 and 75 are photo-engravings from KING's original illustrations.

74



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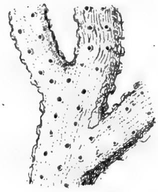

FIG. 74. *Thamniscus dubius*, natural size.
FIG. 75. Celluliferous face of same, enlarged.

THAMNOCELLA, nov. gen.

Type, *Thamnocella Cisseis*, Hall (sp.).

(Plate 9, figs. 4–12.)

Zoarium ramose, sometimes fruticose; giving off lateral branches or bifurcating; branches of equal size, and, compared with THAMNISCUS infrequent; cells numerous; arranged in quincunx order, forming oblique transverse rows.

This genus differs from THAMNISCUS in the infrequency of the branches, and in the fact that the branches are of uniform size; from some forms of DIPLOPORA in having numerous cell apertures, that genus having but two ranges.

DIPLOPORA, Young and Young.

(Proc. Nat. Hist. Soc. Glasgow. 1875.)

Type, *Diplopora marginalis*, Young and Young.

Very slender straight stems, throwing off a few lateral branches of equal dimensions (or bifurcating); celluliferous face with two ranges of cell apertures, and moderately developed median keel; noncelluliferous face striated.

FIG. 76. *Diplopora bifurcata*, natural size.
FIG. 77. A frond, x9.

CRISINELLA, Hall.

(Rep. of N. Y. State Geologist for 1883, pl. 26.)

Type, *Crisinella scrobiculata*, Hall (sp.).

(Plate 9, figs. 1-3.)

Zoarium ramose, solid; celluliferous on one face; cell apertures disposed in oblique ascending rows from the middle to the margin of the branch; peristomes prominent.

Family **Arthrostylidæ**, Ulrich, emend.

This family contains at present only the genus ARTHROSTYLUS.

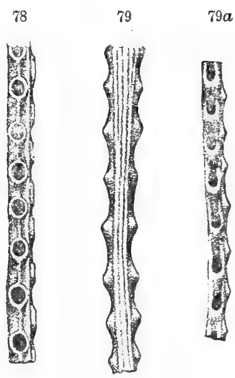

FIG. 78. *Arthrostylus conjunctus*. Lateral view of a portion of a segment, x18.
FIG. 79. Noncelluliferous face, x18.
FIG. 79*a*. Lateral view of another species.

ARTHROSTYLUS, Ulrich.

(Amer. Geologist, Vol. I, p. 230. 1888.)

Type, *Arthrostylus tenuis*, Ulrich.

Zoarium somewhat fruticose; composed of numerous, slender, equal segments, joined to each other by terminal articulation; celluliferous on one face only; opposite face longitudinally striated; cell apertures disposed in three or more longitudinal rows, separated by ridges.

Family **Stictoporidæ**, Ulrich, emend.

The forms included in this family are very similar in their mode of growth to Cystodictyidæ, but differ from the forms in that family in the absence of pseudo-septa and lunaria, the difference in the skeleton making a corresponding difference in the living organism. The following genera are included in this family: CERAMELLA, EURYDICTYA, EUSPILOPORA, EVACTINOPORA, PACHYDICTYA, PHYLLODICTYA, PRISMOPORA, SCALARIPORA, SEMIOPORA, STICTOCELLA, STICTOPORA, STICTOPORIDRA, STICTOPORELLA, TAENIODICTYA, TAENIOPORA and (??) ACTINOTRYPA.

CERAMELLA, Hall.

(Pal. N. Y., Vol. VI, p. xix. 1887.)

Type, *Ceramella scidacea*, Hall.

(Plate 14, figs. 2–6.)

Zoarium consisting of thin, foliaceous expansions, arising from a spreading base; celluliferous on each face; cells tubular, oblique; cell apertures oval or circular, disposed in quincunx order; surface marked by sterile maculae, which are usually depressed below the general surface of the branch.

EURYDICTYA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 309. 1890.)

Type, *Eurydictya montifera*, Ulrich.

" Broad, simple or irregularly divided bifoliate expansions without nonporiferous parallel margins; surface with more or less conspicuous, small, solid maculæ or monticules; zoœcial structure very much as in SULCOPORA, the difference being of small importance and due to zoarial habit."

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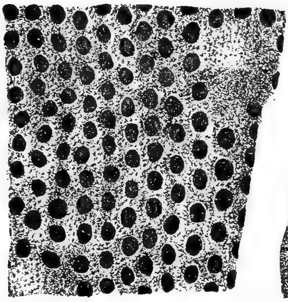

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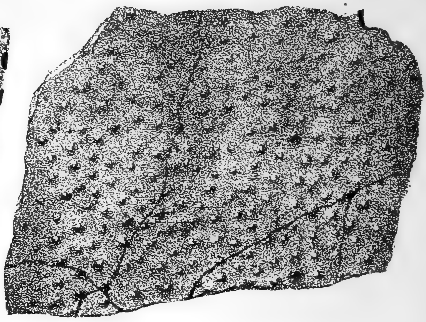

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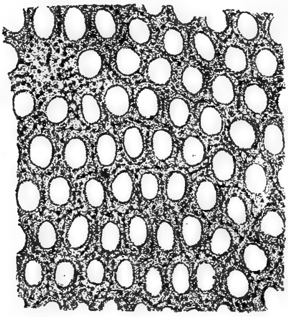

FIG. 80. *Eurydicta montifera.* A portion of the frond, natural size.
FIG. 81. Surface enlarged.
FIG. 82. A transverse section of the cells enlarged.

EUSPILOPORA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 389. 1890.)

Type, *Euspilopora serrata*, Ulrich.

(See Plate 10, fig. 20.)

"Zoarium consisting of small, flattened, irregularly dividing branches; zoœcial apertures subcircular or elliptical; arranged in four or more rows over the central portion of the branches, between slightly elevated longitudinal ridges, having numerous small nodes. At brief intervals, occurring alternately on each side of the branch, there are several short rows of apertures, directed obliquely upward and outward from the central rows, extending nearly to the sharp margins. Between these lateral rows the margin of the frond is more or less indented." (Ulrich)

The type species closely resembles *Stictopora palmipes*, which, though showing some variation from the ordinary forms of Stictopora, has not been considered distinct from that genus, though it may be.

Euspilopora Barrisi is identical with *Stictopora crassa* and does not have the characters which have been used to separate Euspilopora from Stictopora.

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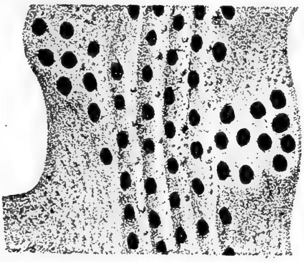

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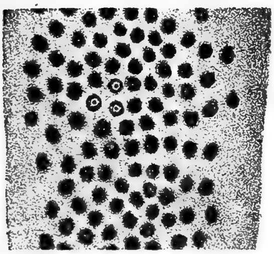

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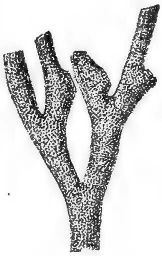

Fig. 83. *Euspilopora serrata*, natural size.
Fig. 84. Surface, x10.
Fig. 85. *E. barrisi*, natural size.
Fig. 86. A portion, x10.

Evactinopora, Meek and Worthen.

(Proc. Acad. Nat. Sci. Phila., p. 165. 1865.)

Type, *Evactinopora radiata*, Meek and Worthen.

"Zoaria consisting of four or more vertical leaves, which radiate from an imaginary axis so as to present in a transverse section a star shaped or cruciform outline; leaves thin, double;

celluliferous on both faces; * * * zoœcia with subcircular apertures; interspaces apparently solid at the surface; occupied by vesicular tissue internally. As growth proceeded, a gradually increasing deposit of minutely perforated calcareous laminæ covered the lower and older portions of the zoarium." (MEEK AND WORTHEN.)

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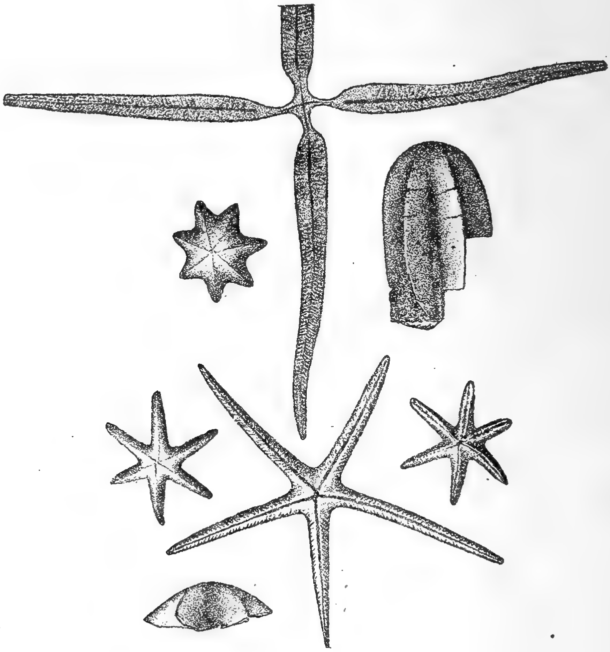

FIG. 87. *Evactinopora*, illustrating various forms of this genus.

PACHYDICTYA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 152. 1882.)

Type, *Pachydictya robusta*, Ulrich

"Zoaria varying from paralleled, margined, narrow branches, to large undulating expansions. The edges are acute and have a noncelluliferous border; * * * zoœcia rising rather abruptly from the mesial lamina, near which they have very thin walls; are broad elliptical or subquadrate in outline, arranged in longitudinal series, and partially separated from each other by small vesicles. Toward the surface their walls are thickened, ring like, and usually completely isolated and the interspaces solid." (ULRICH.)

PHYLLODICTYA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 153. 1882.)

Type, *Phyllodictya frondosa*, Ulrich.

"Zoaria leaf-like or consisting of irregular, broad branches. Zoœcia tubular, the prostrate portion long, apertures circular, slightly oblique, with the posterior portion elevated; interspaces wide, solid, traversed vertically by numerous minute tubuli." (ULRICH.)

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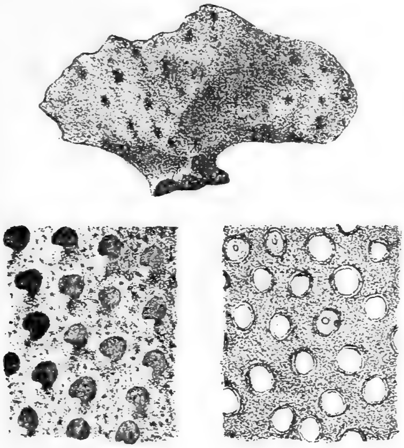

FIG. 88. *Phyllodictya frondosa.*
Upper fig., natural size.
Lower left hand fig., a portion of the surface x18.
Lower right hand fig., a transverse section of the cell tubes, x18.

PRISMOPORA, Hall.

(Bryozoans of the Upper Helderberg Group, p. 17. 1881.)

Type, *Prismopora triquetra*, Hall.

(Plate 12, figs. 9–15.)

Zoarium ramose; consisting of triangular branches, bifurcating or sometimes trifurcating; frequently forming irregular groups; branches with the sides equal or unequal, concave; celluliferous on each face; cells tubular, arising from the mesial plates, which extend from the center of the branch to each angle; margins of the branches solid; intercellular tissue vesiculose.

SCALARIPORA, Hall.

(Trans. Albany Institute, Vol. X, p. 159. 1881.)

Type, *Scalaripora scalariformis*, Hall.

(Plate 12, figs. 16-22.)

Zoarium consisting of groups of triangular prismatic branches, celluliferous on each face; sides of branches concave and crossed by transverse, elevated, celluliferous scalæ; cells tubular, arising from the radiating mesothecæ of the branches and from the mesotheca of the scalæ; margins of the branches and scalæ non-celluliferous.

STICTOCELLA, nov. gen.

(Plate 10, figs. 6, 7.)

Type, *Stictocella sinuosa*, Hall (sp.).

Zoarium consisting of flattened bifurcating branches, celluliferous on each face; cell apertures oval, irregularly disposed; peristomes equally elevated; interapertural space occupied by short irregular ridges, which are frequently covered by minute nodes, giving to the surface of some of the species a granular appearance.

This species differs from STICTOPORA in the irregular disposition of the cell apertures, and in the presence of the irregular ridges between the cell apertures.

STICTOPORINA, nov. gen.

(Plate 10, fig. 8.)

Type, *Stictoporina subcarinata*, Hall (sp.).

Zoarium consisting of flattened bifurcating branches, celluliferous on each face; cell apertures arranged in longitudinal parallel rows, circular; peristomes prominent; apertures of the two central rows the smallest, gradually enlarging to the outer row; margins of branches solid; transverse section of the branches lenticular; central rows of apertures separated by a ridge, sometimes the adjacent two rows are also separated by a carina.

This form has some resemblance to TÆNIOPORA (and is erroneously given by MILLER as a synonym), but differs from that genus in its more decidedly bifurcating mode of growth, and in the form of its transverse section. In this genus a section is lenticular, the most gently rounded near the base, while in

TÆNIOPORA the sides of the branches are angular, and near the base the branches are always triangular.

TÆNIODICTYA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 528, pl. 67, figs. 1, 1b.)

Type, *Tæniodictya ramulosa*, Ulrich.

"Zoarium growing from a basal expansion, into dichotomously divided narrow branches or broad fronds; * * * apertures elliptical or subcircular, surrounded by a sloping area. Interspaces ridge like." (ULRICH.)

This genus very closely resembles and is probably identical with STICTOPORA.

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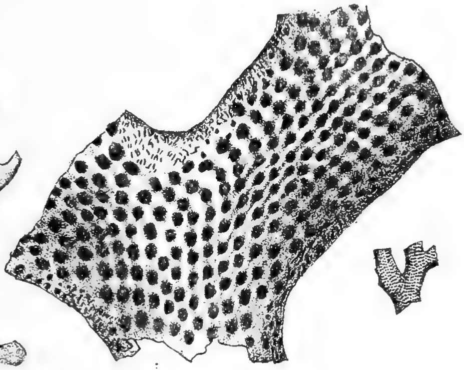

FIG. 89. *Tæniodictya ramulosa*, natural size.
FIG. 90. Surface of same, x9.

TÆNIOPORA, Nicholson.

(Geol. Mag., N. S., London, Vol. I, p. 120. 1874.)

Type, *Tæniopora exigua*, Nicholson.

(Plate 11, figs. 12–16; Plate 12, figs. 1–6.)

Zoarium ramose, flattened, proceeding from a spreading base, or from rootlets attached to foreign bodies; branches triangular or flattened. The branches of the lower portion of the frond are usually triangular, though this condition may occur on all portions of the frond; sides concave, equal or nearly so; from each angle proceed depressed, quadrangular branches, which both bifurcate and ramify laterally, continuing growth in the same manner as the parent branches; margins flat, smooth; cells tubular, cylindrical, gradually enlarging to the aperture.

In the triangular branches they proceed from laminæ, which extend from the center to each angle of the branch; in the flattened branches they proceed from the mesotheca, and are recumbent for about one-half their length, then abruptly turning and generally opening directly outward; intercellular tissue vesicular; cell apertures disposed in parallel longitudinal rows, and frequently in oblique ascending rows from the middle of the branch; apertures of the central rows the smallest, gradually enlarging to the marginal rows.

There is usually a prominent carina along the middle of the flattened branches.

Family **Intraporidæ**, nov. fam.

The forms included in this family have essentially the same manner of growth as the Stictoporidæ, but differ from the members of that family in having the interapertural space occupied by the cavities of vesicles.

The following genera are included in the family; **COSCINELLA, INTRAPORA, SEMIOPORA AND STICTOPORELLA.**

COSCINELLA, Hall.

(Pal. N. Y., Vol. VI, p. 19, pl. 64, figs. 9–12. 1887.)

Type, *Coscinella elegantula*, Hall.

(Plate 14, figs. 7–12.)

Zoarium consisting of an explanate frond, celluliferous on each face, with perforations or fenestrules at somewhat regular distances from each other; the whole having the appearance of being composed of sinuous anastomosing branches; base spreading, adhering to cyathophylloid corals or other bodies; mesotheca very thin, marked by arching undulations of growth, and also by longitudinal striations caused by the recumbent portions of the cell tubes; cells tubular, cylindrical; for one-half their length resting upon the mesotheca, then abruptly bending and continuing at right angles to their former course, opening directly outward; intercellular tissue composed of minute tubuli, with very closely disposed septa, or of vesicles so disposed that they have the appearance of septate tubuli; cell apertures circular; closely and irregularly disposed. The interapertural surface, and a space about .75 mm. wide around each fenestrule are occupied by minute angular pits.

INTRAPORA, Hall.

(Trans. Albany Institute, p. 157. 1881.)

Type, *Intrapora puteolata*, Hall.

(Plate 11, figs. 1-9.)

Zoarium consisting of a flattened, dichotomously branching or bifurcating frond, arising from a spreading base; cells tubular for one-half the length, parallel with the mesotheca, then turning abruptly outward; apertures oval, irregularly and very closely disposed; very frequently in contact; peristomes strong, slightly and equally elevated. The interapertural space is occupied by minute angular pits, generally a single series between adjacent apertures; intercellular space irregularly vesiculose.

SEMIOPORA, Hall.

(Trans. Albany Institute, Vol. X, p. 193. 1881.)

Type, *Semiopora bistigmata*, Hall.

(Plate 11, figs. 10-11.)

Zoarium consisting of a flattened dichotomously branched frond, proceeding from a spreading base attached to foreign bodies; branches narrow, not expanding before bifurcation; non-celluliferous marginal space very narrow; transverse section abruptly narrowing and very thin toward the margin; obscurely subangular near the middle; cells tubular, oblique, gradually enlarging to the aperture. The intercellular tissue is composed of irregularly disposed vesicles; cell apertures oval, sometimes nearly circular; regularly disposed in parallel longitudinal rows; the apertures of the marginal rows being larger than the others. Between adjacent cell apertures in a longitudinal direction are two minute pits side by side. In the course of growth these pits form minute tubuli between the cell tubes.

STICTOPORELLA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 152. 1882.)

Type, *Stictoporella interstincta*, Ulrich.

The type species of this genus belongs to INTRAPORA; other forms, as *S. cribrosa*, are members of the genus COSCINELLA.

Compare these figures with those of *Intrapora puteolata* and *Coscinella elegantula.*

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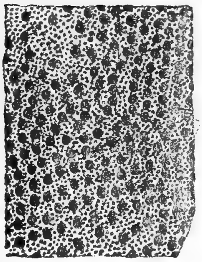

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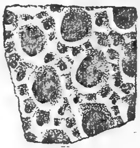

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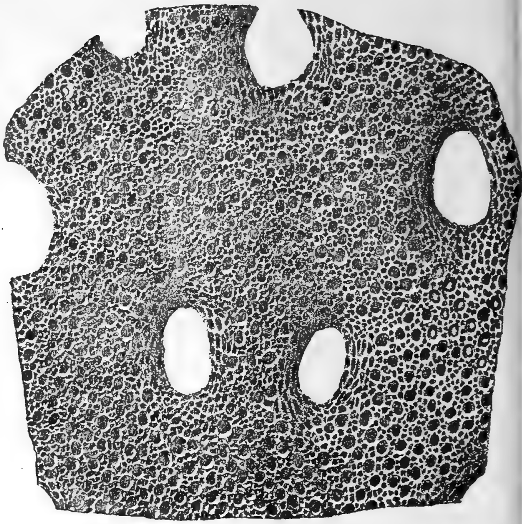

FIG. 91. *Stictoporella basalis*, a portion of the frond, x9.
FIG. 92. A still further enlargement, x25.
FIG. 93. *Stictoporella cribrosa*, x6.

Family **Cystodictyidæ**, Ulrich, emend.

The forms in this family have the same general appearance and manner of growth as the forms included in the STICTOPORIDÆ, but differ from those forms in having two septa, situated close together, in the cell tube, which form a lunarium at the aperture. The following genera are included in this family: CYSTODICTYA, COSCINIUM, COSCINOTRYPA, DICHOTRYPA, MEEKAPORA and PHRACTOPORA.

CYSTODICTYA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 152. 1882.)

Type, *Cystodictya ocellata*, Ulrich.

(Plate 10, figs. 11-20.)

This genus has the same general appearance and mode of growth as STICTOPORA, but differs from that genus in having two pseudosepta in the cell tube and a lunarium at the aperture.

Cystodictya Gilberti, though not the type species, shows the characteristic features of the genus much more clearly than any other.

Coscinium, Keyserling.

(Geognost. Beobacht., p. 192. 1846.)

Type, *Coscinium Cyclops*, Keyserling.

(Plate 13, figs. 8–12; pl. XIV, fig. 1.)

Original diagnosis. "Lobed expansions in the form of a leaf, consisting of two mutually applied strata, whose free planes exhibit free pores quincuncially arranged so that on a cross fracture of the leaf are seen the tubular oblique cells, biserially distributed on either side, quite the same as in Eschara; but here the foliaceous expansions are perforated by a regular series of holes as in *Adonea cribriformis*, from which it varies, however, in the want of an articulated stipe. Our genus coincides also with Eschara in the character of the intercellular substance, which is permeated by capillary tubules. This substance fills up with age; the holes likewise, which are then distinguished as spaces without cells."

The fronds of this genus very closely resemble those of Coscinella, but differ in the absence of interapertural pits, and in the presence of pseudosepta and lunaria.

Coscinotrypa, Hall.

(Report of N. Y. State Geologist for 1885; advance sheets Expl. of Plate XXIX. 1886.)

Type, *Coscinotrypa cribriformis*, Hall.

(Plate 13, figs. 1–7.)

Zoarium consisting of explanate fronds, celluliferous on both faces, with perforations or fenestrules at varying distances from each other. At irregular intervals the surface is raised into angular folds or plications, which continue growth in the same manner as and at right angles to the parent frond. These in turn give rise to similar elevations, the frond forming a very irregular mass; cell apertures arched and triangular, usually irregularly disposed, but sometimes alternating and subimbricating. The apertures adjacent to the fenestrules radiate from them; cells with two closely disposed, parallel pseudosepta, which form a lunarium at the cell aperture, which consists of strong crescentic denticulations. The fenestrules, in size and distance from each other, are extremely variable.

MEEKAPORA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 183. 1890.)

Type, *Meekapora eximia*, Ulrich.

Original diagnosis. "Bifoliate, sometimes branching; the median laminæ thin, flexuous; cells arranged with their oblique

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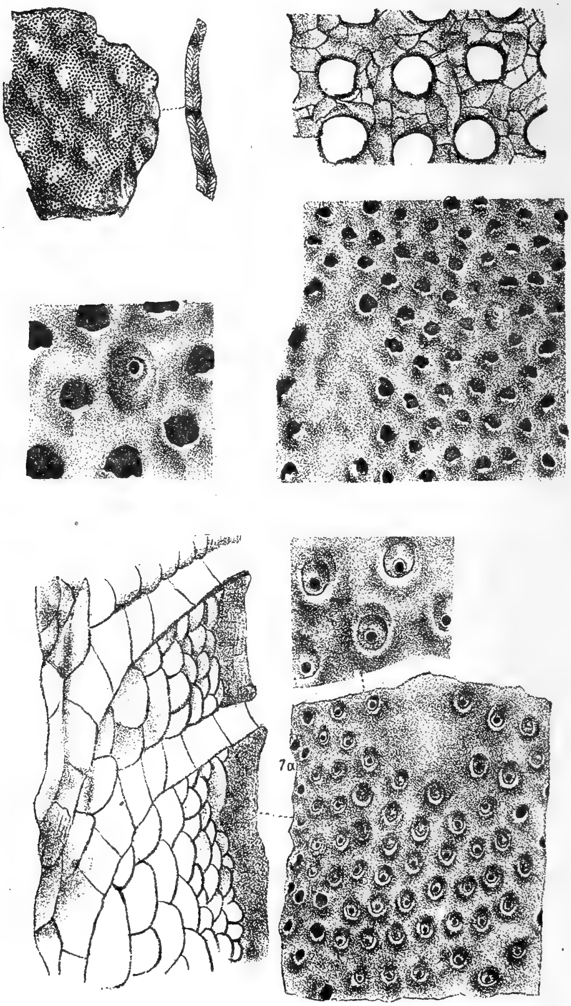

FIG. 94. Upper left-hand fig., *Meekapora eximia*, a frond, and vertical section, natural size.
Upper right-hand fig., transverse section, x18.
Middle figs., surface x9 and x16.
Lower right-hand figs., *M. clausa*. Surface, x9 and x18.
Lower left-hand fig, vertical section, x18,

apertures directed toward the distal margin of the expansion; lunarium moderate or obsolete; cell tubes oblique, the anterior walls thinned and flexuous; diaphragms numerous, often recurved; oœcium a large oval cell, showing a convex space with a small apical perforation." (Ulrich.)

PHRACTOPORA, Hall.

(Trans. Albany Inst., abstract, p. 12. 1881.)

Glyptotrypa, Ulrich.

Type, *Phractopora cristata*, Hall.

(Plate 24, figs. 11–14.)

Zoarium consisting of explanate fronds, having the surface raised at irregular intervals into prominent crests, which are celluliferous on each face; cells tubular, arising from a mesotheca, celluliferous on each face, with lunaria, which are frequently indistinct. The apertures are generally disposed in diagonally intersecting rows; intercellular structure, near the base, irregularly vesiculose, and having the appearance of septate tubuli above.

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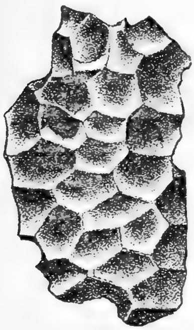

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FIG. 95. *Phractopora sagenella*, natural size.
FIG. 96. *Phractopora michelini*, natural size.

Family **Actinotrypidæ.**

ACTINOTRYPA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 386. 1890.)

Type, *Actinotrypa peculiaris*, Ulrich.

"Zoaria very much as in DICHOTRYPA. Zoœcial apertures showing the ends of from eight to ten vertical septa-like ridges, which extend down the inner side of the vestibule, nearly or quite to the primitive apertures." (ULRICH.)

The structure of the cell tubes precludes placing this genus under either STICTOPORIDÆ or CYSTODICTYIDÆ.

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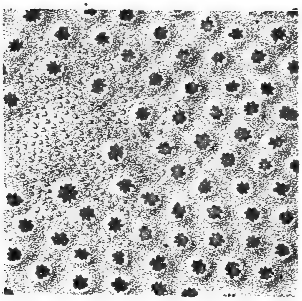

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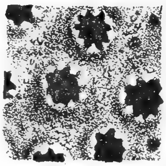

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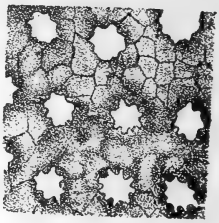

FIG. 97. *Actinotrypa peculiaris*, portion of the surface, x9.
FIG. 98. A still further enlargement, x18.
FIG. 99. A transverse section, showing the structure of the zoarium a short distance from the surface.

Family **Rhinoporidæ**, Ulrich, emend.

RHINOPORA, Hall.

(Pal. N. Y., Vol. II, p. 170. 1852.)

Type, *Rhinopora verrucosa*, Hall.

Zoarium consisting of lamellate or subpalmate fronds, which are celluliferous on both sides. The outer edges are thickened and celluliferous, and the entire surface on both sides is uniformly tuberculous. The tubercles (monticules) are usually smooth and solid at their summits, rarely celluliferous; surface also exhibiting slender, rounding, bifurcating ridges, which, when the zoarium is a little worn, appear as shallow grooves; cell apertures nearly circular, occupying the summits of prominent papillæ, arranged in more or less regular intersecting lines; interapertural space smooth; intercellular space occupied by mesopores.

Family **Ptilodictyidæ**, Zittel, emend.

The genus PTILODICTYA includes those forms which are pointed below, articulating into a spreading base; unbranched; straight or curved; but other genera are included in this family whose structure and mode of growth is the same as that of PTILODICTYA, except that they are bifurcating.

The following genera are included in this family: GRAPTODICTYA, PHÆNOPORA, PTILODICTYA, STICTOPORINA and STICTOTRYPA.

GRAPTODICTYA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 165. 1892.)

Type, *Graptodictya perelegans*, Ulrich.

" Zoarium arising from a pointed articulated base into continuous dichotomously divided narrow branches; zoœcia with subcircular apertures surrounded by a low peristome; subpolygonal in outline; interspaces depressed, generally linear; sometimes with one or two fine, tortuous, elevated lines; vertically linear in longitudinal sections, but with the lines interrupted." (ULRICH.)

PHAENOPORA, Hall.

(Pal. N. Y., Vol. II, p. 46. 1852.)

Type, *Phænopora explanata*, Hall.

(Plate 15, figs. 8-10.)

Bryozoan forming thin, broad or ensiform expansions, celluliferous on each face; cell apertures oval, separated by ridges, and having two minute pits between the ends of adjacent apertures.

This genus has a very close resemblance to the typical forms of PTILODICTYA, but is separated from them by the presence of interapertural pits, which is a constant feature.

PTILODICTYA, Lonsdale.

(Murch. Silurian System, p. 676. 1839.)

Type, *Ptilodictya lanceolata*, Lonsdale.

(Plate 15, figs. 4-7.)

Bryozoum consisting of a radially striated basal expansion, attached to foreign bodies, and which has at the center of the upper surface a socket for articulation with the subsolid extremity of the erect and conjoined frond; frond commonly lanceolate or falciform unbranching; margins of frond acute, noncelluliferous, smooth or striated; disposition of cell apertures variable; in the typical forms plumose, with longitudinal rows in the middle of the frond, and oblique lateral rows diverging from those on each side. Other species have longitudinal rows separated by ridges, and still others have the apertures arranged in diagonally intersecting rows.

PTILOTRYPA, Ulrich.

(Geol. Sur Ill., Vol. VIII, p. 193. 1890.)

Type, *Ptilotrypa obliquata*, Ulrich.

Original diagnosis. "Bifoliate, forming large ramose expansions. Zoœcial tubes and apertures very oblique. At the upper extrem-

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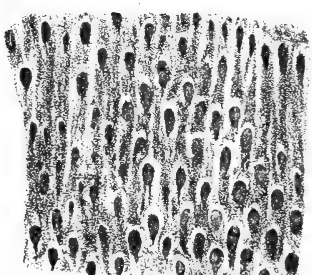

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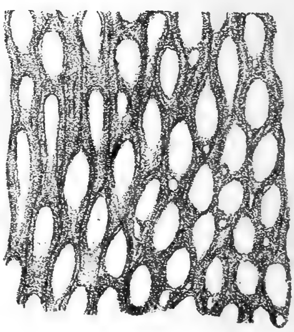


FIG. 100. *Ptilotrypa obliquata*, natural size.
FIG. 101. Vertical section, natural size.
FIG. 102. A portion of the surface enlarged.
FIG. 103. Tangential section, showing usual characters and accessory pores.

ity of the acutely oval aperture, there is a small cell, which is best seen in a tangential section; surface with irregular longitudinally channeled spots." (ULRICH)

STICTOPORINA, Hall.

(Pal. N. Y., Vol. VI, p. 20. 1887.)

Type, *Stictoporina claviformis*, Hall.

(Plate 10, figs. 1, 2.)

Zoarium obtusely pointed at the base, enlarging above and becoming flattened; bifurcations few; cells tubular, arising from a mesotheca; apertures oval, disposed in diagonally intersecting rows; interapertural space elevated, angular, enclosing the apertures in rhomboidal or polygonal areas.

Family Clathroporidæ.

The forms of this family are similar to those of PTILODICTYIDÆ in the form and arrangement of the cell apertures, but they consist of fenestrate fronds, arising directly from a spreading base.

CLATHROPORA, Hall.

(Pal. N. Y., Vol. II, p. 169. 1852.)

Type, *Clathropora frondosa*, Hall.

Original diagnosis. "Ramose or reticulate corals; uniformly poriferous on both sides of the reticulate fronds and all sides and branches of the stems of the ramose forms; apertures of cells more or less quadrangular; regularly arranged in series parallel to the direction of the stems or obliquely in quincunx order."

Two forms which can not be placed in the same genus were embraced in this description. The forms which have been considered for the past forty years as CLATHROPORA have the same general appearance and manner of growth as COSCINIUM, but the cell structure resembles that of PTILODICTYA. *Clathropora frondosa* must then be considered as the type of the genus.

104.

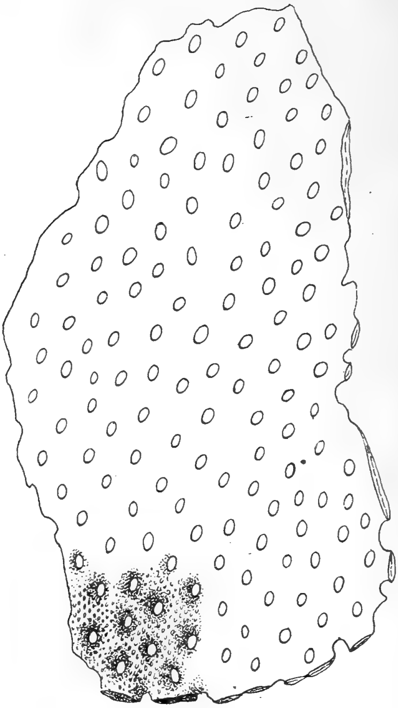


FIG. 104. *Clathropora frondosa*, natural size.

Family Acrogenidæ.

This family includes segmented forms, celluliferous on each face, segments narrow, very gradually increasing in width; mar gins noncelluliferous. It includes the genera ACROGENIA and DICRANOPORA.

ACROGENIA, Hall.

(Rept. of State Geologist, p. 51. 1884.)

Type, *Acrogenia prolifera*, Hall.

(Plate 15, figs. 11–20.)

Zoarium segmented, arising from cylindrical rootlets. Two segments proceed from the truncated termination of the preceding one; base of each segment obconical; terete above and strongly striated, gradually becoming flattened and celluliferous; apertures in rows separated by ridges; central ranges of apertures the smaller; apertures with comparatively prominent lunaria.

DICRANOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 166, pls. 6, 7.)

Type, *Dicranopora internodia*, Ulrich.

Zoarium comprised of bifurcating segments; bifurcations short; extremities truncate; a bifurcating segment arising from each preceding truncated extremity; margins subparallel; cell apertures usually arranged in parallel longitudinal rows, separated by ridges; the apertures of the outer rows being larger than the others; margins of segments noncelluliferous.

This genus bears some resemblance to ACROGENIA, but differs from that genus in the fact that each two segments proceed from the bifurcations of the preceding segment instead of from the truncated extremity of a simple segment.

GONIOTRYPA, Ulrich.

(Micro. Pal. of Canada, Pl. 2, p. 14; Pl. 9. 1889.)

Type, *Goniotrypa bilateralis*, Ulrich.

"Like DICRANOPORA in all respects, save that there is a prominent median ridge on each of the two faces of the double-leaved segment." (ULRICH).

Family **Thamnotrypidæ**.

This family includes at present only the genus THAMNOTRYPA, a form which can not well be included in any of the existing families.

THAMNOTRYPA, Hall.

(Pal. N. Y., Vol. VI, p. 101, Pl. 33, figs. 9, 10.)

Type, *Thamnotrypa divaricata*, Hall.

(Plate 12, figs. 7, 8.)

Zoarium consisting of a very narrow stipe, from which proceed, rectangularly, lateral branches; celluliferous on each face; cell apertures oval; usually disposed in two parallel longitudinal rows, separated by a prominent ridge. Sometimes three rows occur and occasionally four rows for a short distance on the stipe. On the lateral branches there are never more than two rows.

Family Arthroclemidæ.

Zoarium articulated, ramose; consisting of numerous subcylindrical segments; cells subtubular, more or less oblique; radially arranged around a central axis, opening on all sides of the segments. The family includes the following genera: ARTHROCLEMA, HELOPORA and (?) SCEPTROPORA.

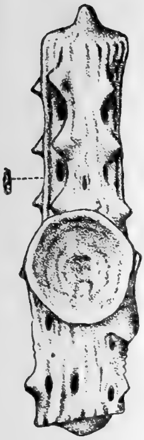
ARTHROCLEMA, Billings.

(Pal. Foss., Vol. I, p. 54. 1862.)

Type, *Arthroclema pulchella*, Billings.

Zoarium jointed, composed of numerous subcylindrical segments; celluliferous on all sides; arranged in a pinnate manner; articulation both terminal and lateral. The segments are of three kinds, primary, secondary and tertiary. The primary segments form the strong central stem, of which each segment has normally one or two sockets on opposite sides, for articulation with the secondary segments, which usually articulate in like manner, terminally with each other and laterally with still more slender tertiary segments; cells subtubular, apertures ovate, oblique, the lower border more or less prominent; disposed in longitudinal rows separated by ridges.

106



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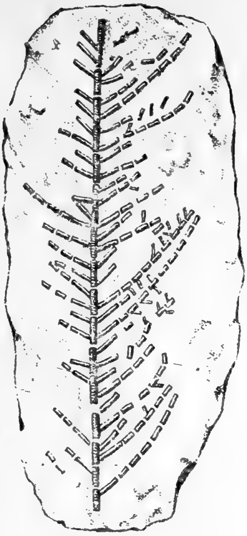

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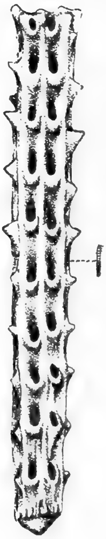

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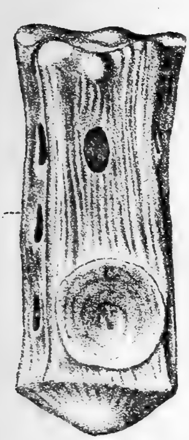

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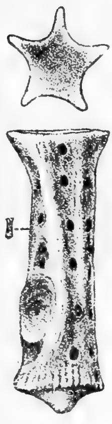


112

FIG. 105. *Arthroclema Billingsi*, natural size.

FIG. 106. *A. cornutum*, one of the primary segments, showing lateral sockets.

FIG 107. *A. cornutum*, four primary segments, natural size, and three x7, showing the articulating sockets near the base of each.

FIG. 108. Five of the secondary segments, natural size, and x7.

FIG. 109. *A. striatum*, lateral view of a large and strongly striated primary segment, x18.

FIG. 110. A secondary segment, x18, and end view of the preceding, x18.

FIG. 111. *A. armatum*, a complete segment of the secondary set, x18.

FIG. 112. *A. cornutum*, a primary segment, x18.

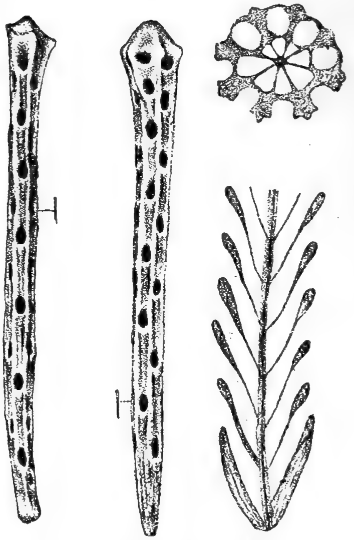
HELOPORA, Hall.

(Pal. N. Y., Vol. II, p. 44. 1852.)

Type, *Helopora fragilis*, Hall.

Zoarium consisting of numerous, subequal, small cylindrical segments, articulating terminally; celluliferous on all sides; cell tubes somewhat oblique, rectangular to the surface, or geniculate; cell apertures oval; arranged in a diagonally intersecting series or in longitudinal series separated by ridges.

113 114 115



FIGS. 113, 114. *Helopora Harrisi;* two segments, natural size and x18.
FIG. 115. Vertical section, and transverse section, x50.

SCEPTROPORA, Ulrich.

(American Geologist, Vol. I, p. 228. 1888.)

Type, *Sceptropora facula*, Ulrich.

Segments club shaped; the lower half striated; noncelluliferous; the extremity bulbous; upper half expanded; the center of the top with a large socket; cells tubular, arranged between vertical lines; apertures ovate.

116

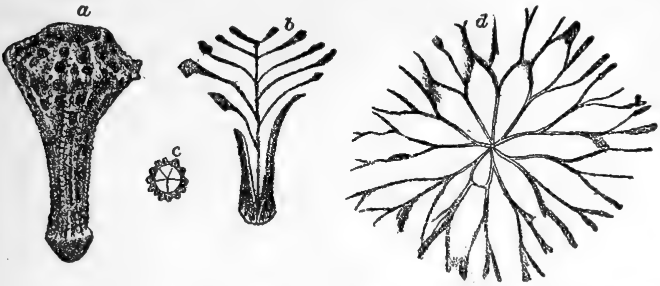


FIG. 116. *Sceptropora facula*, *a*, Segment of the average size and appearance; *b*, A vertical section, showing tubular cells, and central axis; *c*, Transverse section of a lower half of a segment; *d*. Transverse section of the expanded portion of a very large segment. All x18.

Family **Rhomboporidæ**, nov. fam.

Zoarium ramose solid; apertures more or less regularly arranged, oval or circular, placed at the bottom of a sloping area, rhombic or hexagonal in outline, or between straight or flexuous longitudinal ridges; mesopores wanting.

The following genera are included in this family: CŒLOCONUS, RHOMBOPORA and TREMATELLA.

CŒLOCONUS, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 402. 1890.)

Type, *Cœloconus rhombicus*, Ulrich.

"Zoarium simple, hollow, expanded gradually from the stri-

117 118

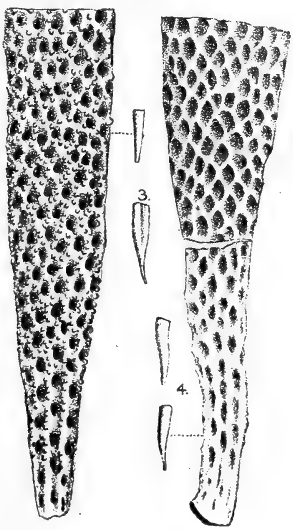


FIG. 117. *Cœloconus granosus*, natural size and x18.
FIG. 118. *C. rhombicus*, natural size and x18.

ated and subacute basal extremity; substance thin; external characters of zooecia as in RHOMBOPORA; primitive portion short; hemisepta well developed." (ULRICH.)

RHOMBOPORA, Meek.

(Pal. Eastern Nebraska, p. 141.)

Type, *Rhombopora lepidodendroidea*, Meek.

(Plate 19, figs. 10-13.)

Zoarium ramose, solid; cells cylindrical, radiating from an imaginary axis; tabulate; cell apertures disposed in straight longitudinal rows or in diagonally intersecting rows. In the former case the rows are generally separated by prominent ridges; in the latter the interapertural surface consists of rhombodial or polygonal elevations surrounding the apertures. Usually nodes or short spines occur between the cell apertures. The intercellular space near the surface is occupied by tubuli formed by the growth of the interapertural nodes.

TREMATELLA, Hall.

(Rep. of N. Y. State Geologist for 1886, advance sheets.)

Type, *Trematella annulata*, Hall.

(Plate 19, figs. 6-9.)

The internal character is similar to that of RHOMBOPORA, but the cells are more closely disposed and the intercellular space is generally solid; but sometimes the spiniform tubuli occur. The apertures are more closely arranged in a somewhat quincunx order, surrounded by polygonal elevations. The monticules are elongated laterally and are so disposed as to give to the branches an annulated appearance. This peculiar disposition of the monticules has been observed in all the species of the genus.

Family **Streblotrypidæ**, Ulrich, emend.

The forms included in this family are very similar to the RHOMBOPORIDÆ, but they have in the peripheral portion intercellular tubuli and interapertural polygonal pits.

STREBLOTRYPA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 103. 1890.)

Type, *Streblotrypa Nickelsi*, Ulrich.

(Plate 19, figs. 14, 15.)

The internal and external characters of this genus are very similar to those of RHOMBOPORA, but between the ends of the cell apertures are one or more angular pits, and in the peripheral intercellular space mesopores instead of "spiniform tubuli."

CALLOTRYPA, Hall.

(Pal. N. Y., Vol. VI, p. 24. 1887.)

Type, *Callotrypa macropora*, Hall.

(Plate 18, figs. 8–14.)

Zoarium ramose solid; cells arising from an imaginary axis at the center of the branch; cell apertures oval, irregularly disposed; peristomes equally elevated; interapertural space occupied by angular pits; sometimes there are also more or less prominent spines; peripheral intercellular space occupied by mesopores and spiniform tubuli.

The internal structure of this species is almost identical with STREBLOTRYPA, but it differs from that genus in having the cell apertures irregularly disposed and entirely surrounded by the mesopore apertures.

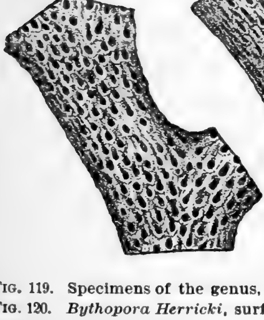
BYTHOPORA, Miller and Dyer.

(Cont. to Pal., No. 2, p. 6. 1879.)

Type, *Bythopora fruticosa*, Miller and Dyer.

"Dendroid, branches small, sometimes anastomosing; smooth; cell apertures longer than wide; separated by impressed lines."

121



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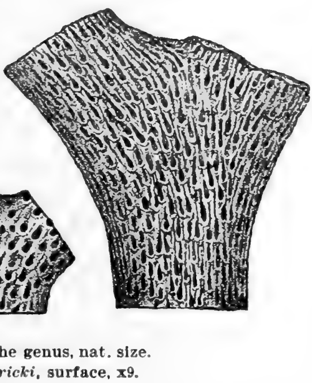

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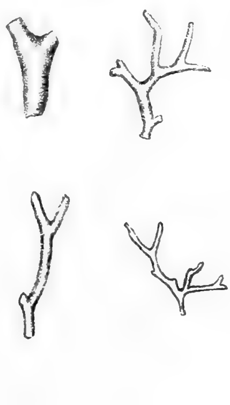

FIG. 119. Specimens of the genus, nat. size.
FIG. 120. *Bythopora Herricki*, surface, x9.
FIG. 121. *B. alcicornis*, x9.

Family **Rhabdosemonidæ**, Vine.

This family includes forms whose external characters are similar to those of RHOMBOPORIDÆ, but the cells arise from a filiform axis at the center of the branch. It includes the following genera: ACANTHOCLEMA, NEMATAXIS and (?) TROPIDOPORA.

ACANTHOCLEMA, Hall.

(Pal. N. Y., Vol. VI, p. 72. 1887.)

Type, *Acanthoclema alternatum*, Hall.

(Plate 16, figs. 6–12.)

Zoarium ramose, branches slender, cells cylindrical, arising from a filiform axis at the center of the branch; cell apertures oval, arranged in longitudinal parallel rows, separated by ridges or in diagonally intersecting rows; each aperture enclosed by a polygonal elevation. Nodes or conical spines usually occur between the cell apertures. When the interapertural space is spinulose the intercellular space is occupied by tubuli formed by the growth of the hollow spines. When the spines are absent the intercellular space is solid. The external characters of this genus and RHOMBOPORA are so similar that a knowledge of the internal characters is necessary to distinguish the genera.

NEMATAXIS, Hall.

(Pal. N. Y., Vol. VI, p. 74. 1887.)

Type, *Nemataxis fibrosa*, Hall.

(Plate 16, figs. 15–18.)

Zoarium ramose; cells cylindrical, arising from a central filiform axis, diverging at an angle of forty-five degrees until within a short distance of the surface, when they abruptly turn outward; the former portion of the cells in contact, the latter slightly separated; interspace apparently solid; cell apertures oval, arranged in parallel longitudinal rows, separated by a ridge; peristomes very thin, slightly elevated On the surface, at intervals, there are monticules destitute of cell apertures, which extend across the branch and give to it an annulated appearance. Frequently a solid calcareous growth extending over the branches obliterates all traces of the cell apertures.

TROPIDOPORA, Hall.

(Report of N. Y. State Geologist for 1886, Expl. pl. 25. 1886.)

Type, *Tropidopora nana*, Hall.

(Plate 16, figs. 1, 2.)

Zoarium minute, ramose; cell apertures arranged in irregular longitudinal rows, separated by sinuous ridges; peristomes very thin, slightly elevated.

It has been impossible to determine the internal character of this genus, but the external characters are so different from other Trematoporoid forms, that there here seems a necessity for a new genus.

Family Bactroporidæ.

BACTROPORA, Hall.

(Pal. N. Y., Vol. VI, p. 193. 1887.)

Type, *Bactropora granistriata*, Hall.

(Plate 16, figs, 13, 14.)

Zoarium simple, unbranched, lower extremity pointed, striated; external and internal characters very similar to RHOMBOPORA, but it can not be placed in the family RHOMBOPORIDÆ, on account of its simple form and pointed, striated base.

NEMATOPORA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 401. 1890.)

Type, *Nematopora quadrata*, Ulrich.

"Zoarium ramose, very slender; continuous above the pointed basal extremity; cells subtubular, short; arranged in a radial

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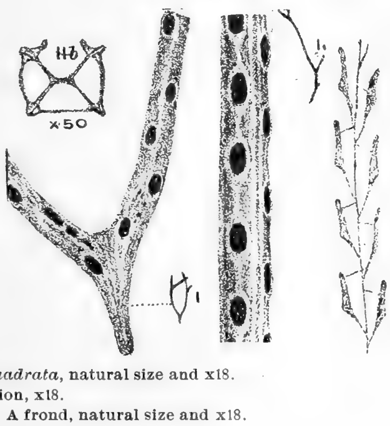


FIG. 122. *Nematopora quadrata*, natural size and x18.
FIG. 123. A vertical section, x18.
FIG. 124. *N. delicatula*. A frond, natural size and x18.
FIG. 125. A transverse section, x50.

manner around a very minute axial tube; apertures elongate oval, with a very thin, equally elevated peristome; disposed in longitudinal series, separated by smooth or granulose ridges."

Family **Chilotrypidæ**.

CHILOTRYPA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. VII, p. 49. 1884.)

Type, *Chilotrypa hispida*, Ulrich.

(Plate 21, figs. 1, 2.)

Zoarium ramose, branches cylindrical; cells tubular, arising from a small axial tube and curving to the surface; apertures oval, oblique to the surface, the lower portion of the peristome being the most strongly elevated; frequently arranged in diagonally intersecting rows; interapertural space solid; intercellular space vesiculose; vesicles comparatively large and irregularly disposed.

Family **Fistuliporinidæ**.

The forms comprised in this family consist of explanate fronds, free or incrusting, globular or semiglobular masses, occasionally ramose, with hollow branches; cells tubular, cylindrical, arising from a base consisting of a wrinkled epitheca; cell walls smooth, entire; intercellular space occupied by vesicular tissue, or tabulate mesopores, serving as a support to the slender cell tubes.

Some of the forms have hitherto been included in the family FISTULIPORIDÆ, but they differ from the forms properly included in that family by the entire absence of pseudosepta, a difference in the cell structure which must be accompanied by a corresponding difference in the structure of the animal. The following genera are included in this family: CŒLOCAULIS, FISTULIPORINA, LICHENOTRYPA, PINACOTRYPA.

CŒLOCAULIS, Hall.

(Pal. N. Y., Vol. VI, p. 23. 1887.)

Type, *Cœlocaulis venusta*, Hall.

(Plate 21, figs. 3-5.)

Zoarium ramose, hollow, inner surface a thin epitheca with transverse wrinkles, and fine longitudinal striations; cells tubular, arising from the epitheca, and parallel with it for a short distance, then turning abruptly outward; apertures circular or oval, sometimes irregularly disposed, at other times in a more or less regular quincunx order; peristomes thin, distinctly and equally elevated, usually smooth, but sometimes with numerous minute nodes or spinules; intercellular space occupied by irregularly disposed vesicles, or by regularly superimposed vesicles, resembling tabulate mesopores; interapertural space occupied by minute angular pits. This genus has been considered by one or more authors as a synonym of CHILOTRYPA, but the structure is radically different. In that genus the cells arise from a small, irregularly contracting and expanding tube, and the posterior portion of the peristome is much the thickest, strongly elevated and hood-like. Compare the figures of the two genera.

FISTULIPORINA, nov. gen.

(Plate 21, figs. 11–15.)

Type, *Fistuliporina serrulata*.

Zoarium usually consisting of free or incrusting explanate fronds, or of masses formed by the accretion of successive layers of growth; cells tubular, cylindrical, rectangular or oblique to the surface; intercellular space, near the base, occupied by irregularly disposed vesicles; above by regularly superimposed vesicles, or by tabulate tubuli (mesopores); cell apertures circular or oval; irregularly disposed; peristomes equally developed, often prominent; often granulose or spinulose; interapertural space occupied by angular pits, and frequently, in addition, by more or less prominent conical nodes or spines. This genus differs from FISTULIPORA in the form of the cell tube, and in the absence of pseudosepta and lunaria.

PINACOTRYPA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 384. 1890.)

Type, *Pinacotrypa elegans*, Ulrich.

"Thin, contorted expansions, with a wrinkled epitheca below; cells with subcircular apertures, and well-developed granose peristomes, thin walls, and, so far as observed, no lunarium; intercellular spaces wide, occupied by a single series of very large angular mesopores, which never present the appearance of vesicular tissue; tabulæ horizontal, few in the cell tubes, numerous in the mesopores."

Family Favicellidæ.

This family includes those forms having the cell apertures in a depressed vestibular area, enclosed by angular elevations, and comprised of two groups, in one of which the interapertural surface is solid, in the other occupied by angular pits. It includes the genera FAVICELLA and LICHENOTRYPA.

FAVICELLA, Hall.

(Pal. N. Y., Vol. VI, p. xviii. 1887.)

Type, *Favicella inclusa*, Hall.

(Plate 24, figs. 15–17.)

Zoarium consisting of thin, lamellate expansions, free, or incrusting other objects; cells tubular, cylindrical; for nearly one-half their length parallel and in contact with the epitheca; then somewhat abruptly bending, continuing almost rectangularly to the former portion, and opening directly outward; intercellular space occupied by vesicles, usually regularly superimposed, and having the appearance of tabulate mesopores about two-thirds the diameter of the cell tubes, with closely disposed tabulæ; cell apertures circular, irregularly disposed; peristomes thin, equally elevated. Midway between the cell apertures are comparatively strong, angular ridges, which coalesce and inclose the apertures in pentagonal or hexagonal vestibular areas. The surface between the angular ridges and cell apertures is occupied by minute angular pits, of much less diameter than the vesicles. On the surface at intervals are monticules occupied by pits or vesicles at the center; the cell apertures immediately surrounding them being larger than those on other portions of the frond.

LICHENOTRYPA, Ulrich.

(Cont. Amer. Pal., p. 23. 1886.)

Type, *Lichenotrypa longispina*, Hall, (sp.).

(Plate 23, fig. 7.)

Zoarium consisting of thin laminate expansions incrusting other objects. In the earlier stages of growth (which may be observed near the margin of the frond), the cell tubes are very short, the apertures oval, closely and irregularly disposed; peristomes prominent, the posterior portion strongly elevated; interapertural space smooth, flat or slightly concave. As the growth continues the posterior portion of the peristomes becomes more elevated, and those of adjacent apertures are united by thin irregular connecting walls, which traverse the interapertural spaces, and gradually form an elevated and very irregular net-work, which at numerous points is further elevated into strong spines. The apertures of some of the cell tubes occupy one side of the bottom of the large depressions; while others have grown with the net-work, and are on a level with numerous, irregularly distributed, angular and smaller cells, probably corresponding to the vesicular tissue of the immature type.

Family **Selenoporidæ**.

This family includes the forms similar to LICHENA IA, but having the cell apertures enclosed in a vestibular area formed by the coalescence of thin prominent plications.

SELENOPORA, Hall.

(Pal. N. Y., Vol. VI, p. xvii. 1887.)

Type, *Selenopora circincta*, Hall.

(Plate 24, figs. 4–7.)

Zoarium forming incrusting expansions. Cells tubular, oblique to the surface, pseudo-septate; frequently alternating and imbricating; apertures circular or slightly oval; anterior portion of peristome slight or entirely wanting; posterior portion strongly elevated, denticulated, projecting over and partially concealing the aperture. The posterior portion of the peristomes are connected by prominent oblique walls, which traverse the surface between the apertures, uniting and forming polygonal vestibular areas; the cell apertures being situated on the posterior portion of the floor of the area; surface with flat circular maculæ destitute of cell apertures. The cell apertures adjacent to these maculæ, and radiating from them, are larger and more oblique than those on other portions of the frond; intercellular structure the same as in FISTULIPORA. It is distinguished from the ODONTO-

TRYPIDÆ by the cell apertures being situated in vestibular areas; from FAVICELLIDÆ by the presence of pseudosepta and lunaria.

Family **Fistuliporidæ**, Waagen, emend.

The forms comprised in this family usually consist of explanate fronds, free or incrusting, globular or subglobular masses, or sometimes of irregular masses. Cells tubular with two pseudosepta and a lunarium at the aperture; intercellular space occupied by vesicles or tabulate mesopores; near the base invariably by vesicles, which probably serve to support the slender cell tubes.

The general appearance of these forms is very similar to the FISTULIPORINIDÆ, but they may very easily be distinguished by the presence of pseudosepta and lunaria. "The peculiar horseshoe shaped sinus along one side of the autopores (cell tubes) formed by the pseudosepta has been considered with much probability, as corresponding in the living animal with a ciliated groove ("siphonoglyphe") such as is found in the œsophagus of the Alcyonarians.

"It is but fair to state here, that several authors consider FISTULIPORA and allied genera to be cœlenterate corals of the order ALCYONARIA, and to increase by cœnenchymal gemmation; that the cell tubes are occupied by autozooids and the vesicles or mesopores by siphonozooids.

"In cœnenchymal gemmation a number of these cœnenchymal tubes apparently unite to form together a new autozooid, so that several reduced individuals become blended together into a single perfect one. * * * Now with this transformation a great change in size certainly goes hand in hand, and the new autozooid certainly requires much more room than did the siphonozooid. It might then be imagined that in reality that only one of the siphonozooids inhabiting the cœnenchymal tube is transformed into an autozooid, but to make room for the new individual, thus formed, the surrounding siphonozooids die, and that the first sign of the beginning of the decay is just the thickening of the outer walls, which are destined to form together the outer wall of the new autozooid." (Waagen, Palæontographica Indica, Vol. I, Ser. XIII, pp. 905, 906.)

If this view is correct, the vesicles (cœnenchymal tubes) should be smaller than the autopore, but in reality they are frequently larger, as in *Lichenalia cultellata*, where the diameter is from two to four times that of an autopore; and it seems almost a rule that the smaller the autopores, the larger the vesicles proportionally.

The forms of FISTULIPORA so gradually pass into other genera of undoubted BRYOZOA, that sometimes it is difficult to distinguish the genera apart, especially from fragments. *Fistulipora cellata* and *Intropora puteolata* have the cells and intercellular tissue so similar, that it is only possible to distinguish the two genera by their mode of growth; the one consisting of lamellate incrustations, and the other of bifoliate, dichotomously divided, flattened branches, with noncelluliferous margins.

FISTULIPORA, McCoy.

(Ann. and Mag. Nat. Hist, 2d Series, Vol. 111, p. 130. 1849.)

Type, *Fistulipora incrustans*, Phillips (sp.).

(Plate 22, figs. 11–13.)

Zoarium incrusting or massive, under surface of explanate forms consisting of a wrinkled epitheca; cells tubular, tabulate; with two more or less prominent pseudosepta along one side, giving a bilobed or trilobate form to a section of the cell; intercellular space, near the base, occupied by irregularly disposed vesicles; above by vesicles or tabulated mesopores; sometimes the vesicles are so regularly superimposed that they resemble the tabulate mesopores; cell apertures irregularly and generally closely disposed, bilobate or trilobate in outline, and having on the septate side a prominent lunarium; interapertural space occupied by mesopore apertures or vesicular cavities; surface usually with monticules or maculæ, the centers of which are generally occupied only by angular pits, the cell apertures immediately surrounding them being larger than those on other portions of the frond.

LICHENALIA, Hall.

(Pal. N. Y., Vol. II, p. 171. 1852.)

Syn., *Dybowskiella*. Type, *Lichenalia concentrica*, Hall.

(Plate 22, figs. 8-10; Pl. 23, figs. 1-6.)

Zoarium having the same general appearance and manner of growth as FISTULIPORA, but the interapertural surface is solid.

Notwithstanding statements to the contrary, it is a fact that the same species has invariably a cellulose interapertural surface or a solid one. Both characters do not occur on the same species.

FISTULIPORELLA, nov. gen.

Type, *Fistuliporella constricta*, Hall (sp.).

(Plate 22, figs. 5-7.)

Zoarium laminar or massive from the superposition of successive layers of growth; cells tubular; pseudoseptate; apertures subcircular, enclosed in a sloping, polygonal, vestibular area. On the interapertural surface, in addition to the vesicular cavities, are small oval apertures, with equally elevated peristomes; intercellular space vesiculose.

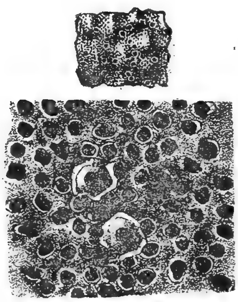
STROTOPORA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 383. 1890.)

Type, *Strotopora faveolata*, Ulrich.

"Ramose, branches large, irregular, solid or hollow; large, abruptly spreading cells, which are supposed to represent oœcia, are distributed among the ordinary cell apertures. When well preserved they appear on the surface as strongly convex nodes, with an opening on one side. In all other respects they are like FISTULIPORA."

126.



127.

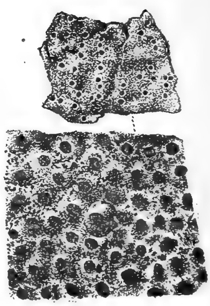


FIG. 126. *Strotopora faveolata.* Fragment, natural size and a portion of the surface of the same, x9.

FIG. 127. *Strotopora dermata.* A flattened fragment, natural size and a portion of the same, x9.

Family Odontotrypidæ.

The forms included in this family are usually very thin, incrusting expansions, but sometimes ramose, branches hollow; zoarium thin; cells short, oblique, pseudoseptate; intercellular space vesiculose; interapertural space solid.

ERIDOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 137. 1882.)

Type, *Eridopora macrostoma*, Ulrich.

Original diagnosis. "Zoarium thin, incrusting. Cell apertures subtriangular or ovate, and more or less oblique, with the margin strongly elevated on one side, or the peristome may extend unequally all around the aperture; it being always more prominent on one side than the other. Cell apertures surrounded by from one to three series of smaller, angular, interstitial cells, which, when the zoarium is well preserved, is covered by a membrane. Intercellular space occupied by vesicular tissue."

128.

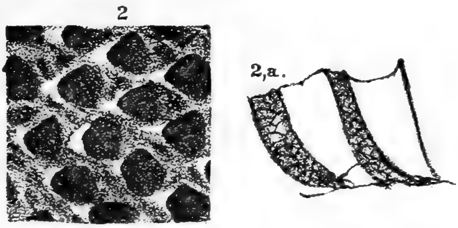


FIG. 128. *Eridopora macrostoma*. 2. Enlargement of a portion of the surface. 2*a*. Vertical section.

ODONTOTRYPA, Hall.

(Report of N. Y. State Geologist for 1885; advance sheets, explanation plate 30, figs. 24–27. 1886.)

Type, *Odontotrypa alveata*, Hall.

(Plate 24, figs. 1-3.)

Zoarium consisting of very thin expansions incrusting other objects; cells oblique, frequently imbricating; pseudoseptate; apertures oblique to the surface, trilobate, irregularly and very closely disposed; peristomes thin, anterior portion slightly elevated; posterior portion more strongly elevated, and having two prominent denticulations, producing a crescentic projection; intercellular space vesiculose; surface with elongate depressed maculæ, destitute of cell apertures.

PILEOTRYPA, Hall.

(Pal. N. Y., Vol. VI, p. xvi. 1887.)

Type, *Pileotrypa denticulata*, Hall.

(Plate 23, figs. 8–15.)

Zoarium usually consisting of thin incrusting expansions, but one form having the same characters is ramose, branches hollow. Cell tubes very oblique, frequently imbricating, pseudoseptate; cell apertures trilobate, irregularly disposed, or alternating and imbricating; anterior portion of the peristome slightly elevated; posterior portion strongly elevated, projecting over and partially concealing the aperture; denticulate; on some parts of the frond the upper portion of the cell tubes are frequently exposed for a third or more of their entire length; intercellular space occupied by irregularly disposed vesicles on tabulate mesopores; surface with frequent monticules the centers of which are destitute of apertures; from this space the cell apertures radiate in every direction; interapertural space solid.

GLOSSOTRYPA, Hall.

(Pal. N. Y., Vol. VI, p. xvii. 1887.)

Type, *Glossotrypa paliformis*, Hall.

(Plate 24, figs. 8-10.)

Zoarium tubular, cylindrical, hollow; diameter of tube 2 mm.; thickness of zoarium .40 mm. Cells tubular, with frequent narrow projections, (semi diaphragms) from the cell walls, extending partially across the tube; two pseudosepta on one side; cell apertures paliform, very closely disposed, frequently in diagonally intersecting rows; the surface presenting a reticulated appearance; apertures with denticulated lunarium; interapertural space elevated, forming ridges; frequently a prominent node at the intersection of the ridges; sometimes a depression or pit; surface with monticules which are laterally in contact, giving to the frond an annulated appearance; intercellular space vesiculose.

Family Ceramoporidæ, Ulrich.

The forms in this family are usually incrusting lamellate expansions, but sometimes free; cell apertures arched or triangular, usually imbricating; no pseudosepta.

The following genera are included in the family: ATACTOPORA, CERAMOPORA and PETIGOPORA.

ATACTOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. II, p. 119. 1879.)

Type, *Atactopora hirsuta*, Ulrich.

"Zoarium consisting of very thin expansions incrusting other objects; cell tubes short, very oblique, frequently alternating and imbricating; cell apertures oblique to the surface, oval but appearing petaloid from the numerous nodes, which occur not only between the apertures, but also on the cell walls near the aperture; surface with numerous small monticules, the centers of which are destitute of cell apertures."

CERAMOPORA, Hall.

(Pal. N. Y., Vol. II, p. 168. 1852.)

Type, *Ceramopora imbricata*, Hall.

(Plate 20, figs. 10-15.)

Zoarium consisting of flattened discoidal or lamellate incrusting expansions; cells radiating from one or more centers; cell apertures arched or triangular, frequently alternating and imbricating; mesopores few or entirely wanting; interapertural surface solid.

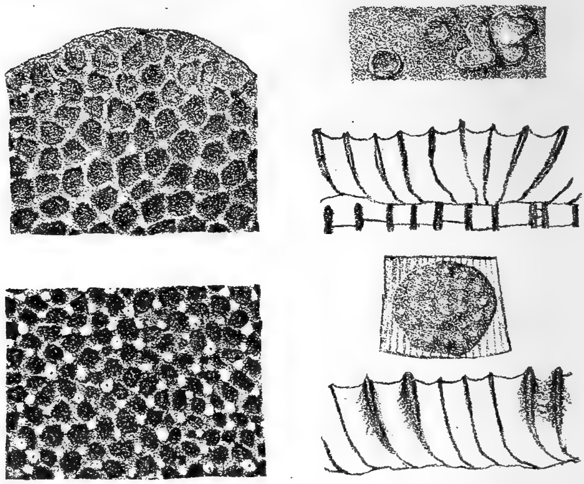
PETIGOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 155. 1882.)

Type, *Petigopora gregaria*, Ulrich.

Zoarium consisting of small circular or lamellate expansions incrusting other objects; cell tubes rectangular or oblique to the surface; walls very thin; cell apertures oval or circular, sometimes polygonal; very frequently oblique to the surface, alternating and imbricating, with frequent comparatively large spines at the angles formed by the junction of the cell walls; surface with monticules having apertures larger than those on other portions of the frond, the cell walls usually extending above the surrounding surface.

129



Upper right-hand figs. *Petigopora gregaria*, a frond natural size and vertical section enlarged.
Upper left-hand fig. Surface of same enlarged.
Lower right-hand figs. *P. asperula*, natural size and vertrical section enlarged.
Lower left-hand fig. Surface enlarged.

Family **Ceramoporellidæ.**

CERAMOPORELLA, Ulrich.

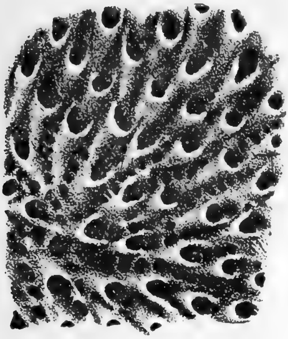
(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 156. 1882.)

Type, *Ceramoporella distincta*, Ulrich.

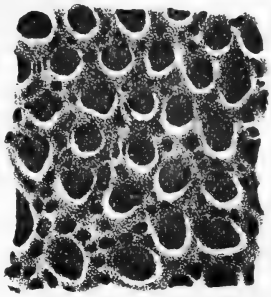
Zoarium incrusting, becoming massive by the superimposition of numerous thin layers; cell tubes short; walls thin; apertures more or less oblique; posterior portion of peristome strongly elevated, cucullate, denticulate; mesopores abundant, often completely isolating the cell tubes; surface with maculæ destitute of cell apertures, from which the cell apertures frequently radiate in all directions.

This genus may be distinguished from CERAMOPORA by the numerous mesopores.

130



131



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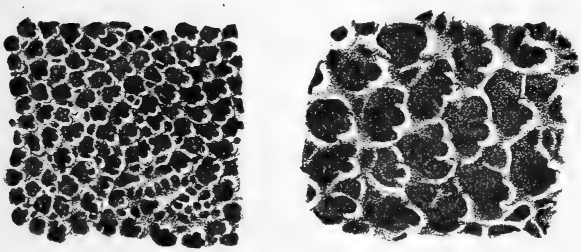


FIG. 130. *Ceramoporella distincta*. Surface x18.
FIG. 131. *C. interporasa*. x18.
FIG. 132. *C. inclusa*. Surface x9 and x18.

CHILOPORELIA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 157. 1882.)

Type, *Chiloporella flabellata*, Ulrich.

Original diagnosis. "Zoaria rising up into flabellate fronds from a greatly expanded heavy crust; cell tubes long, very thin-walled; large and of irregular shape in the axial region; walls much thickened near the surface; apertures ovate; the lunarium conspicuously elevated; mesopores numerous; diaphragms few, generally absent."

(?) Synonym for FISTULIPORA.

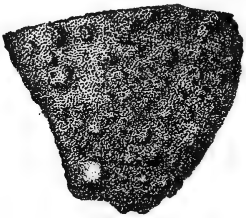
CREPIPORA, Ulrich.

(Geol. Sur. Ill., Vol. VII, p. 404. 1890.)

Type, *Crepipora simulans*, Ulrich.

Incrusting, lamellate or massive from the superimposition of successive layers of growth; cells slightly oblique; pseudoseptal; apertures rhomboidal or pyriform; lunarium prominent; surface exhibiting at irregular intervals minutely porous or subsolid elevations or depressions; mesopores usually restricted to the maculæ.

133



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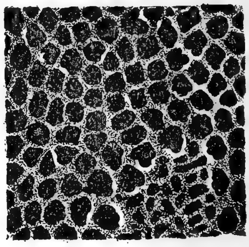

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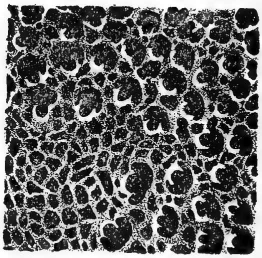

FIG. 133. *Crepipora simulans*. A frond, natural size.
FIG. 134. A portion of the surface, x12.
FIG. 135. *C. impressa*. A frond, natural size.
FIG. 136. A portion of the surface, x12.

DIAMESOPORA, Hall.

(Pal. N. Y., Vol. II, p. 158. 1852.)

Type, *Diamesopora dichotoma*, Hall.

(Plate 16, figs. 3–5.)

Zoarium ramose, hollow; thickness of frond about .33 mm. Inner surface composed of an epitheca, marked by strong concentric undulations of growth, fine concentric striations and fine longitudinal striæ, caused by the recumbent portion of the cell tubes; cells tubular, cylindrical, arising from the epitheca, and for about one-half their length parallel with it, then abruptly turning outward and opening obliquely to the surface; apertures oval, more or less regularly alternating and imbricating; posterior portion of the peristome strongly elevated and cucullate, projecting over and partially concealing the apertures, with two minute denticulations; surface with frequent maculæ destitute of cell apertures, the maculæ immediately adjacent to them being larger than the others and radiating.

THE MONTICULIPOROIDS.

The systematic position of many of the forms which have been included in the families MONTICULIPORIDÆ and FISTULIPORIDÆ has been the subject of much discussion, and authors are not now agreed whether they should be placed with the BRYOZOA or the Corals. Although in this work they have been placed with the Bryozoa, undoubtedly further study and investigation will show that some of the forms at least must be associated with the corals.

Prof. H. A. NICHOLSON has made a close study of these forms, and in his Manual of Palæontology, Vol. I, p. 352, he sums up the matter as follows:

"It must be admitted, however, that the zoölogical affinities of the Monticuliporoids is still a matter of uncertainty; in many of their features, both structural and developmental, they show marked relationship with the ACTINOZOA generally and with the ALCYONARIA in particular, while in others they approach the POLYZOA, and it must in the meanwhile remain a matter of individual opinion whether the Monticuliporoids should be considered as a very peculiar group of corals or an equally peculiar group of POLYZOA. * * * Leaving the external form of the skeleton entirely out of consideration, the general features which favor the reference of the Monticuliporoids to the Cœlenterates is as follows:

1. The common dimorphism of the colony in the Monticuliporoids finds its best parallel in HELIOPORA and HELIOLITES, the cœlenterate nature of which is undoubted. In particular the structural relationship between FISTULIPORA and HELIOLITES or PLASMOPORA are exceedingly close, the skeleton in both consisting

of large sparsely-tabulated tubes (autopores) separated by smaller closely-tabulated tubes (mesopores), and the former of these possessing radial structure of the nature of septa or pseudosepta.

2. The Monticuliporoids increase by fission as well as by gemmation, whereas the recent BRYOZOA appear to be uniformly characterized by a gemmiparous mode of development, which varies in its precise detail in the various groups. Moreover the gemmation of Monticuliporoids is intermural, and is precisely similar to that which obtains among the FAVOSITIDÆ.

3. Cœnenchymal gemmation occurs in the FISTULIPORIDÆ, this mode of growth being otherwise characteristic of HELIOPORA and the HELIOLITIDÆ.

4. The walls of the tubes in the Monticuliporoids are imperforate, while in the calcareous Bryozoa the skeleton seems to be almost always (probably always) perforate, and the cavities of contiguous cells are usually placed in direct communication by means of connecting foramina or tubes.

5. The abundant development of tabulæ in the Monticulporoids is a feature in which the organisms resemble a large number of undoubted corals.

6. Certain Monticuliporoids possess in their autopores radial folds or plications which may be compared with the pseudosepta of HELIOPORA; while others (*Monticulipora mammulata*) possess radially disposed calcareous spines, which are closely similar to the septal spines of FAVOSITES, of SYRINGOPORA and of certain species of HELIOLITES.

On the other hand there are the following considerations which would point to a relation between the Monticuliporoids and the Bryozoa, or which, at any rate, would more or less diminish the importance of some of the features above mentioned as showing Cœlenterate affinities of these organisms.

1 The polyzoary of HETEROPORA (which is undoubtedly a Bryozoan*) consists of large tubes scattered among small ones, though there does not seem to be any essential difference in the structure of these respectively.

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*Waagen says: "It may suffice to have proved that the systematic position of HETEROPORA is by no means certain. * * * If HETEROPORA, from a careful study of its animals, should ever be proved to be a Bryozoan, then also the FAVOSITIDÆ would have to be removed to the BRYOZOA."

2. Tabulæ are by no means confined to the Cœlenterates, precisely similar structures, so far as appearances go, being present in undoubted BRYOZOA (*e. g.* in HETEROPORA, LOMOPORA, FASCICULARIA, ALVEOLARIA, etc.)

3. Radial structures in the form of rows of spines are present in a number of BRYOZOA (*e. g.* HETEROPORA, DISCOPORELLA, etc.)

4. There are various BRYOZOA, such as RHOMBOPORA, CERIOPORA, and some of the Fenestelloids which possess structures very similar to the "acanthopores" of many Monticuliporoids. Structures possessing in some degree the same aspect, are found in the recent RETEPORIDÆ, where they serve to carry the avicularia.

5. Portions of the skeleton of *Fistulipora incrustans* have been shown by JOHN YOUNG, to become thickened and to exhibit a finely tubular structure, similar to that seen in the skeleton of FENESTELLIDÆ.

6. According to LINDSTROM, certain of the Monticuliporoids pass through early stages of development in which the skeleton is a distinctly Bryozoan type;* as an example of this we may take the base of the singular *Cellopora heterosole*, the base, and therefore, the first formed portion of which exhibits Bryozoan characters, while the main mass of the skeleton is of the ordinary Monticuliporoid type.

7. Lastly certain extinct forms, the Bryozoan nature of which seems unquestionable, are hardly distinguishable, as regards minute structure, from other forms which have always been regarded as Monticuliporoids. Thus an extremely close structural resemblance obtains between *Ceriopora interporosa* on the one hand and *Batostomella* (*Monticulipora*) *tumida* on the other.

WILLIAM WAAGEN (Palæontologia Indica, Vol. I, Series XIII, p. 854), has the following to say in regard to the family, MONTI-

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*Probably LINDSTRÖM was mistaken in his observations, being deceived by the superimposition of different forms,the incrustation of one form by another being of common occurrence. Two cases of metamorphosis are treated in detail, one of *Monticulipora* (*Diamulites*) *petropolitana*, which begins as a CERAMOPORA, and during its growth several times reverts to that form, but M. (D.) *petropolitana*, has unmistakably an intermural gemmation, which would preclude its being a Bryozoan. The other case is still more extraordinary, that of *M. ostiolato*. LINDSTRÖM says, that in its earliest stage it is a DISCOPORELLA, then a FISTULIPORA, then a THECOSTEGITES, finally becoming a MONTICULIPORA. FISTULIPORA has according to WAAGEN a coenenchymal gemmation, THECOSGITES a stolonal gemmation and MONTICULIPORA an intermural gemmation.

CULIPORIDÆ. "The family which has given us the greatest trouble in working out its affinities and its internal structure is MONTICULIPORIDÆ, not only because there had to be taken into consideration two opposite opinions of long standing, one supported by LINDSTRÖM and ROMINGER, regarding these fossils as Bryozoa, and another, supported strongly by NICHOLSON, taking them to be corals, but also, because the family as circumscribed by NICHOLSON could not be retained as made to include forms of ALCYONARIA as well as those belonging to HEXACORALLA.

"The first point, therefore, is to show the affinity of the MONTICULIPORIDÆ to the corals, in opposition to the view which considers them as Bryozoa. In our endeavors to decide this question, great difficulties were encountered on account of the fact that no decisive characters have so far been made out, by which the stony abodes of certain corals, and those of the *Bryozoa cyclostomata* could be distinguished. Both consist of minute cells, more or less tubular, often with horizontal partitions or tabulæ; and even organs comparable externally to radial septa are not entirely absent in some Bryozoa; from all of which it appears that in fossil forms neither the general habitus of the colonies nor the internal character of the single cells can be made use of for the distinction of the MONTICULIPORIDÆ and the Bryozoa. Yet after careful study we detected certain distinctive characters in the mode of propagation which are so radically different as to affect the shape and structure of the colonies; the structure of the walls of the cells is also different in the MONTICULIPORIDÆ and in the Bryozoa.

"In all these considerations we must exclude, however, the genus HETEROPORA. In its structure it can not be denied this genus exhibits a certain affinity to the MONTICULIPORIDÆ, but there are also so many discrepancies that its real relations must probably be looked for in other quarters.

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"If we turn now to the modes of propagation occurring in different groups of animals, we find that in Bryozoa there is only one such mode observable and that is gemmation. In the corals, on the contrary, two such modes have long since been made known—*fissiparity and gemmation.* Whilst, however, gemmation takes place in the Bryozoa only in a single manner, by protruding one of the walls of the mother cells and then partitioning off the protruded part, there are many different ways in which gemmation has been observed to occur in corals. With regard to the gemmation of Bryozoa very excellent observations have been published by BARROIS (Recherches sur l'embryologie des Bryozoaires, Lille, 1877) NITSCHE, CLAPARÉDE, etc. The mode of gemmation of corals, on the other hand, has been studied in detail by KOCH, whose chief work on the subject has been published in the Palæontographica. (III Series, Vol. V.)

"The difference between the animals inhabiting the colonies of Bryozoa and those that build up the colonies of corals are extremely striking in many respects, and must find their expression also in the mode in which the colonies are built up. The animals of the Bryozoa are, in the first place, much less long-lived than those of the corals, as they show, for by far the largest part of their existence, a so-called latent vitality. Each animal of a colony of Bryozoa produces only one or two gems*, only exceptionally more, more or less simultaneously, and mostly while it is yet in a rather juvenile stage, after which it stops its functions in this direction. The animal of a colony of corals never stops producing gems, but develops them at all times of its life and at different levels. This difference alone is the cause of a quite different growth of the colonies of the two classes of animals. Whilst in the Bryozoa gems are produced only in the peripheral parts of the colony, as for instance in BERENICEA or in arborescent forms only at the apex of the branches, as in ENTALOPHORA, in the corals gems are produced all over the colony in great numbers if the animals are well fed, etc., and in smaller numbers if the contrary is the case. * * * * * From all that we can gather in regard to the gemmation of recent Bryozoa, it appears that besides having the gemmation restricted to a very short period in a single animal's life, the production of gems is restricted to one side of the animal. It is always on the side opposite the aperture of the cell. This can be very easily made out in the CHEILOSTOMATA, where the aperture is always more or less lateral; but also in the CYCLOSTOMATA, where

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* A word used by the author to express the product of gemmation.

the aperture is terminal, the apex always bends to one side, opposite to the side on which the gems are produced. We will call the gem-producing side the dorsal one. In creeping colonies this dorsal side is always turned downwards; in arborescent forms it is turned inward, toward the axis of the stem. If thus a creeping colony changes into an arborescent one, the animals must turn around to a certain extent to bring their dorsal sides into a fitting position, but that is all the change that takes place in such a case.

"In the corals, on the contrary, gemmation takes place, indiscriminately, on all sides of the animal, and, therefore, no lineal descent of the animals is observable.

"In the MONTICULIPORIDÆ propagation takes place in a way which deviates very far from the modes described in the Bryozoa. As in corals two essentially different modes of propagation are observable — gemmation and fissiparity. The first of these is the more common one, and, therefore, we shall consider it first in the MONTICULIPORIDÆ. If we turn to Prof. KOCH's extremely important paper on the propagation of corals, we find he does not retain the old opinion as to the essential difference between fissiparity and gemmation, and from a biological point of view such an opinion may not be entirely justifiable, but from a practical point of view it appears to us as of great importance.

* * * * * * * * *

"The four modes of gemmation are classed by KOCH in the following manner:

"A. Internal gemmation.

"*a.* Tabular gemmation; the young coralites are produced by means of singularly transformed tabulæ.

"This mode of gemmation chiefly occurs in the RUGOSA or TETRACORALLA.

"B. External gemmation.

"*a.* Intermural gemmation; the young corallites are produced by the splitting of the primary mural plate (or primordial wall) of two or more adjoining corallites.

"*b.* Cœnenchymal gemmation; young corallites are produced by the fusion of several interstitial tubes.

"*c.* Stolonal gemmation; young corallites are produced by the budding of one of the stolons.

"The last of these modes is entirely restricted to the Alcyonaria; the second seems chiefly so, while the first has been observed up to the present time in Favositidæ and some Hexacoralla.

"If we regard the Monticuliporidæ as a whole as they have been circumscribed by Nicholson, we find in the forms thus comprised under the name that two of the above distinguished modes of gemmation are observable, the intermural and the cœnenchymal gemmations. According to the occurrence of the two modes of gemmation two different groups of forms can be distinguished within Nicholson's Monticuliporidæ, of one of which the genus Monticulipora, whilst of the other the genus Fistulipora may be considered the types. We take the two groups as forming two different families, for the one of which we retain the name Monticuliporidæ, whilst for the other we create the name Fistuliporidæ. The latter family must, however, be removed to the Alcyonaria, a mode of proceeding which will be justified later on.

"In the Monticuliporidæ, in this restricted sense, there remains only one method of propagation, the intermural one, which is chiefly characterized by the circumstance that the young animal formed by gemmation has no part in common with the mother animal, so that it is impossible to say from which of the surrounding animals the new one took its origin. It looks as if the new animal were only filling up a void space between several old animals. * * *

"This gemmation is certainly very far different from the mode of gemmation of Bryozoa as described above. The most radical difference always consists in the circumstance that in the Bryozoa the fully developed animals do not produce gems, but only the quite young ones, which are themselves still more or less in the state of buds. After this the next important difference is, that in Bryozoa the mother animal can always be made out, which is not the case in Monticulipora.

"On the other hand the gemmation of Monticulipora is absolutely identical with that occurring in the Favositidæ.

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"If thus the mode of increase of the colonies of the Monticulipora seems not to be in favor of the supposition of these organisms being Bryozoa, there are yet other points which also oppose such a supposition. One of these is the structure of the walls in the MONTICULIPORIDÆ and in the Bryozoa. There are many forms of Bryozoa which deposit carbonate of lime in the ectocyst of their body more or less abundantly. This deposit takes place in the median layer of the ectocyst only, whilst the outer and inner layers remain of a horny nature, which probably is the cause that in thin sections the calcareous walls of single individuals appear separated from each other by dark lines. If we now consider more in detail the structure of the calcareous substance of which the walls of the cells are built, we find that it is composed of very thin fibers placed vertically to the surface of the wall, so that in sections cutting the single cells transversely, a concentric arrangement of the fibers can never be observed. These fibers leave interstices between them at intervals, producing numerous capillary tubes, by which the walls of the Bryozoa seem always to be pierced in great numbers, if otherwise sufficiently well preserved. Every work on recent or fossil Bryozoa shows this.

"Of all this there is not a trace in the MONTICULIPORIDÆ.

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"The animals of a colony of corals undergo constantly a certain process of renovation. The animal deposits large masses of sclerenchyma behind itself and thus slowly ascends within the tube, sometimes chambering off the dead and useless parts of the corallum by diaphragms or tabulæ; the animals are all self-feeding, performing all their vital functions during their whole life-time, at the same time constantly producing new gems. The structure of the wall is in accordance with these peculiarities, the reversedly conical layers of sclerenchyma by which the wall of the MONTICULIPORIDÆ is built up indicate the ascending movement of the animal within its tube.

"The circumstance that the greater part of the animals of the colony of Bryoza is in a state of latent life, the functions of taking and digesting food being performed by only a few individuals at the top of the branches in arborescent forms, brings with it the other peculiarity, that all the animals of a colony are in intimate connection and communication with each other; this communication seems to be brought about partly by the capillary tubes mentioned above; for the most part, however, it is affected by large openings in the walls of the lodges, by which a free communication of all the animals of a colony is established. If the MONTICULIPORIDÆ were Bryozoa such openings must exist, and they must have been observed in some case or other, but nothing of the kind has ever been detected.

"From all this it appears that the MONTICULIPORIDÆ are not Bryozoa, and as they show the greatest affinity to FAVOSITIDÆ, it is very probable that they must be considered as corals and placed among the HEXACORELLA."

Family **Monticuliporidæ**, Nicholson, emend.

Zoaria massive, discoidal, lamellar or ramose. Cells polygonal in contact their entire length, increasing by intermural gemmation or by fissiparity. Cells tabulated and invariably with "cystiphragms" near the surface. The following genera are included in this family: HOMOTRYPA and MONTICULIPORA.

HOMOTRYPA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 240. 1882).

Type, *Homotrypa curvata*, Ulrich.

Zoarium ramose to subfrondescent; cells tubular polygonal, arising from an imaginary axis at the center of the frond, gradually diverging till near the surface, where they turn abruptly outward. The tube walls are very thin till they reach the peripheral region, where they become thickened. The thin walled portion of the cells have straight diaphragms, usually infrequent. In the peripheral portion of the zoarium the cells are provided with a series of cystoid diaphragms or cystiphragms, the space between their flexuous inner wall and the opposite wall of the cell being crossed by an equal number of straight diaphragms; mesopores wanting, but the numerous gemmæ or young cells have sometimes the appearance of mesopores; surface usually with maculæ or monticules, the centers of which are occupied by very small cells, while the cells immediately adjacent to them are larger than on other portions of the frond. Internally the smaller cells of the maculæ or monticules are without cystiphragms.

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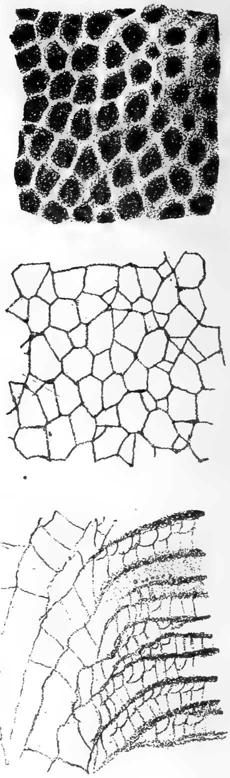

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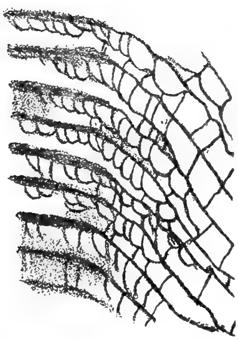

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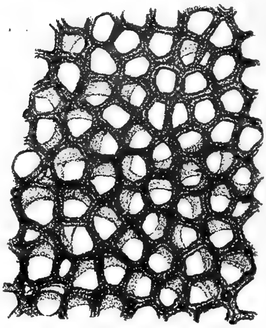

FIG. 137. *Homotrypa curvata*, natural size.

FIG. 138. *Upper fig.*, surface, x18; *Middle fig.*, transverse section x18; *Lower fig.*, vertical section x18.

FIG. 139. *Homotrypa callosa*. Vertical section x18.

FIG. 140 Transverse section x18.

MONTICULIPORA, D'Orbigny.

(Prod. 2, p. 279. 1847.)

Type, *Monticulipora mamillosa*, D'Orbigny.

(Plate 17, figs. 1–3.)

Zoarium massive, lobate, laminar, incrusting and sometimes irregularly frondescent. Cells tubular, polygonal, arising from an imaginary axis at the center of the frond, gradually diverging until near the surface when they more abruptly turn outward, at the same time becoming slightly thickened. Immediately above the point of gemmation the young cell or tube is crossed by numerous straight diaphragms, giving to it the appearance of a mesopore, subsequently the tabulæ become less crowded and the tube assumes the character of an ordinary cell. In addition to the diaphragm numerous cystiphragms are developed in the greater number of cells; surface with numerous conical monticules closely and subregularly disposed in intersecting rows.

This genus is distinguished from HOMOTRYPA by the much greater number of diaphragms and cystiphragms in the thin walled portion of the cell tubes, and the absence of the thickening of the cell walls in the peripheral region of the frond that is characteristic of HOMOTRYPA.

Family **Amplexoporidæ**, Ulrich, emend.

This family includes the forms which have a general resemblance to the Monticuliporidæ, and essentially the same mode of growth, but the cell tubes are without cystiphragms. The following genera are included in the family: AMPLEXOPORA, DEKAYIA, MONOTRYPA, MONOTRYPELLA, LEPTOTRYPA, PETALOTRYPA and STENOPORA.

AMPLEXOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 154. 1882.)

Type, *Amplexopora cingulata*, Ulrich.

(Plate 17, figs. 6, 7.)

Zoarium ramose or massive; cells polygonal, forming prismatic tubes, which arise from an imaginary axis at the center of the frond, gradually diverging till within a short distance of the surface, when they turn more abruptly outward. In the axial region the cell walls are very thin, and the diaphragms are comparatively distant. In the peripheral region the walls are much thickened and the diaphragms are much more numerous; surface with slightly elevated monticules, having cell apertures a little larger than those on other portions of the frond.

DEKAYIA, Edwards and Haime.

(Mon. de Pol. Foss. de Terr. Pal, p. 127. 1851.)

Type, *Dekayia aspera*, Edwards and Haime.

Zoarium ramose, branches cylindrical or flattened; cells tubular, polygonal, arising from an imaginary axis at the center of the branch, gradually diverging until near the surface, when they abruptly turn outward. In the axial region the walls are very thin, and the diaphragms are very infrequent or entirely wanting. In the peripheral region the cell walls are much thickened and the diaphragms are of moderately frequent occurrence, the walls becoming moniliform. The cell apertures are polygonal and have numerous spines (acanthopores) at the angles; surface with numerous maculæ, the cell apertures of which are larger than those on other portions of the frond.

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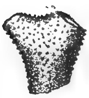

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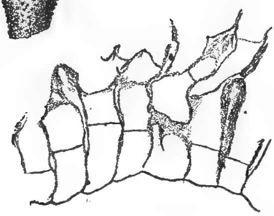

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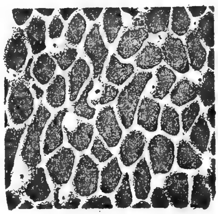

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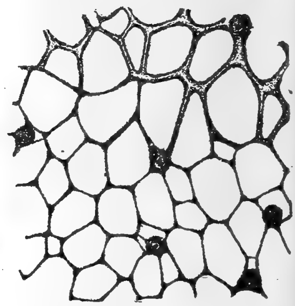

FIG. 141. *Dekayia devonica*, natural size.
FIG. 142. Vertical section, x18.
FIG. 143. Surface, x18.
FIG. 144. Transverse section, x36.

HETEROTRYPA, Nicholson.

(Pal. Tab. Corals, p. 291. 1879.)

Type, *Heterotrypa mammulata*, Nicholson.

Zoarium consisting of large lobate or frondescent expansions; cells tubular, polygonal, arising from an imaginary axis, gradu-

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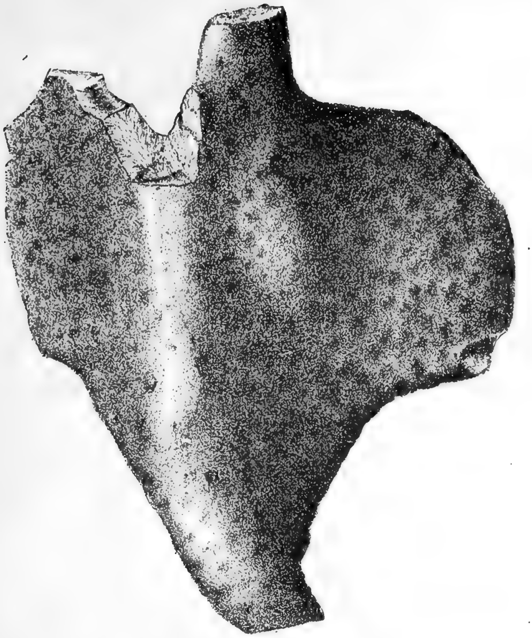

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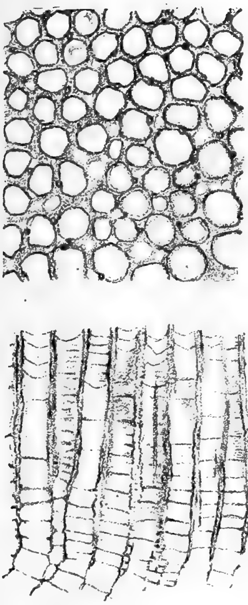

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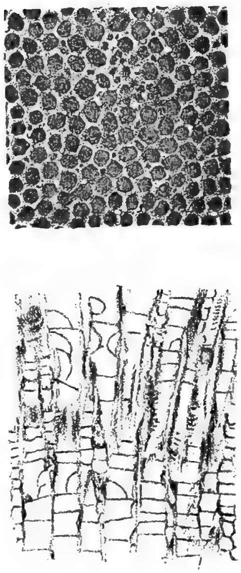

FIG. 145. *Heterotrypa prolifica*, natural size.
FIG. 146. Surface and transverse section x18.
FIG. 147. *H. singularis*. Transverse and vertical section x18.

ally diverging for about two-thirds of their length, then abruptly turning outward, the walls, previously very thin, becoming much thickened. In the axial portion of the cells the diaphragms are very infrequent or entirely wanting. In the peripheral portion they are closely disposed; surface with numerous monticules subregularly disposed in intersecting rows, occupied by cell apertures larger than those on other portions of the frond.

Numerous species have been placed in this genus, but with one exception they are not cogeneric with the type species. The mesopores spoken of by various authors are not mesopores, but young cells, there being no mesopores in the type species.

LEPTOTRYPA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. VI, p. 158. 1883.)

Type, *Leptotrypa minima*, Ulrich.

"Zoarium varying from thin incrustations to free forms of discoidal, spiral or elongate-spiral shape; irregular massive specimens also occur; cells polygonal, with thin walls and a variable number of delicate diaphragms; cell walls appreciably thickened in the peripheral region; spines or acanthopores small, more or less numerous, but usually restricted to the angles of junction between the cell tubes."

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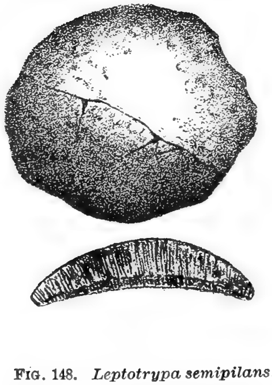

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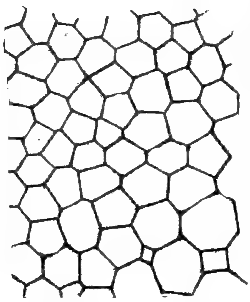

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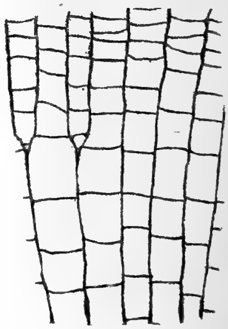

FIG. 148. *Leptotrypa semipilans*. A frond and vertical section, natural size.
FIG. 149. Vertical section of same, x18.
FIG. 150. Transverse section, x18.

MONOTRYPA, Nicholson.

(Pal. Tab. Corals, p. 320. 1879.)

Type, *Monotrypa undulata*, Nicholson.

Zoarium irregularly massive, discoidal, subglobose or hemispheric. Cell tubes polygonal, prismatic, and very thin throughout their entire length, and often undulating or wrinkled transversely; diaphragms remote or entirely wanting, except near the surface.

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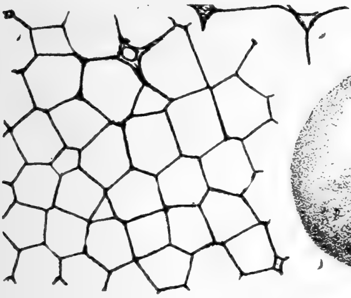

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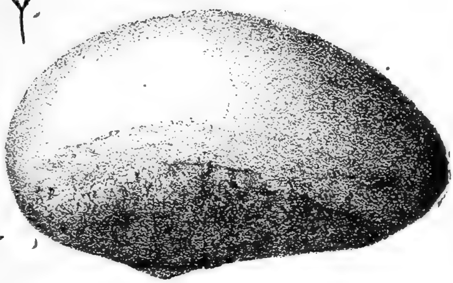

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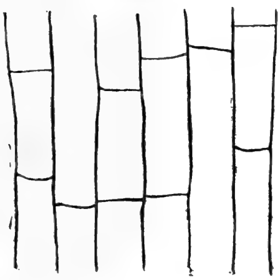

FIG. 151. *Monotrypa rectimuralis*, natural size.
FIG. 152. Transverse section, x18.
FIG. 153. Vertical section, x18.

MONOTRYPELLA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 173. 1882.)

Type, *Monotrypella æqualis*, Ulrich.

Zoarium ramose, branches cylindrical or flattened; cells tubular, polygonal, arising from the center of the branch, and more or less regularly curving to the surface. For the greater portion of the length of the cell tubes, their walls are very thin, and diaphragms remote or entirely wanting. Near the surface the walls become thickened and the diaphragms are numerous; surface with frequent maculæ of cell apertures larger than those on other portions of the frond.

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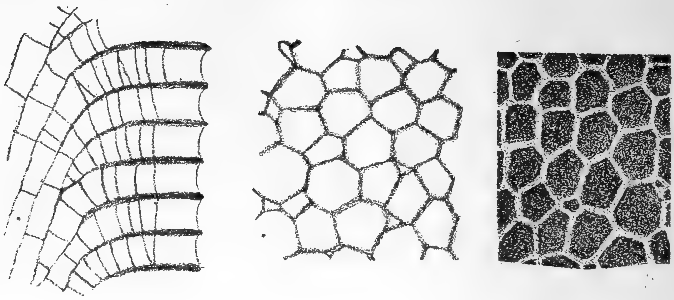

FIG. 154. *Monotrypella æqualis* surface, x18.
FIG. 155. Transverse section of same, x18.
FIG. 156. Vertical section, x18.

PETALOTRYPA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 377. 1890.)

Type, *Petalotrypa compressa*, Ulrich.

Zoarium bifoliate, consisting of irregular compressed branches or simple fronds; celluliferous on both sides; cell tubes prismatic, arising from a strongly flexuous mesotheca; apertures polygonal.

This genus may be distinguished from the other forms of this family by its bifoliate mode of growth, and the presence of a mesotheca.

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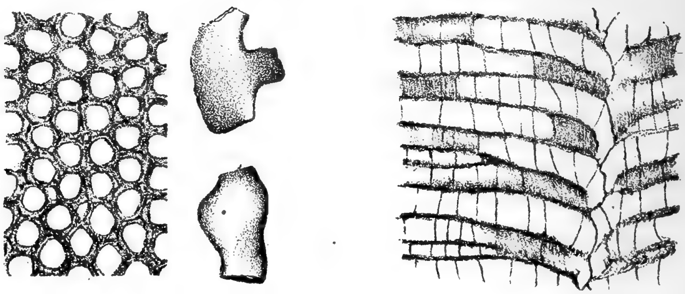

FIG. 157. *Petalotrypa compressa*, zoarium natural size.
FIG. 158. Transverse section of same, x18.
FIG. 159. Vertical section, x18.

PTYCHONEMA, Hall.

(Pal. N. Y., Vol. VI, p. 14, Pl. IX, figs. 12–17.)

(Plate 17, fig. 9.)

Type, *Ptychonema tabulatum*, Hall.

Zoarium forming spheroidal or hemispheric masses or ramose; cells polygonal; walls very thin, strongly and regularly corrugated, not wrinkled; the corrugations forming nodes at the angles; diaphragms entirely wanting in the typical species.

This genus may be distinguished by the strong and regular corrugations of the cell walls, a feature which must not be confounded with the transverse wrinkling of the cell walls of some other forms.

Both MONOTRYPA and PTYCHONEMA are undoubtedly cœlenterate corals.

STENOPORA, Lonsdale.

(Appendix to Darwin's Volcanic Islands, p. 161. 1844.)

Type, *Stenopora ovata*, Lonsdale.

I have not seen a specimen of this genus, but WAAGEN'S diagnosis is as follows:

"Zoarium incrusting, arborescent; foliaceous or hemispherical; fixed by its base to foreign bodies; composed of tubular cells, which are nearly vertical at the center of the zoarium, and radiate thence on all sides toward the surface. The cells are polygonal in the center of the zoarium, with thin walls, and very closely packed together; in their radiating peripheral part they become cylindrical, and their walls show regular transverse annular thickenings, which occur in the same manner and at equal distances in a great number of adjoining tubes. These thickenings alternate on the inside of the cells with periodical contractions of the walls; a vertical section of the walls being moniliform. There are other thickenings which extend longitudinally in the walls as in the MONTICULIPORIDÆ. They are the thickenings which precede gemmation, and project on the surface of the fronds as little spines between the single cell apertures. The cell apertures are partly quite open, partly quite closed by a kind of hemispheric lid. They are of unequal size. Tabulæ are present at very irregular distances. Mural pores and distinct well-developed septa are absent."

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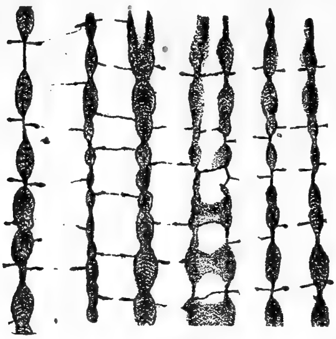

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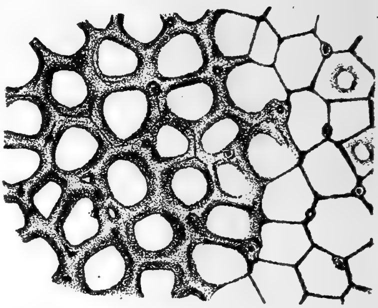

FIG. 160. *Stenopora intercalaris.* Surface and transverse section, x18.
FIG. 161. Vertical section of same, x18.

Family **Prasoporidæ.**

This family includes the forms having cells with diaphragms and cystiphragms, as in the MONTICULIPORIDÆ, but in addition there are mesopores, that feature separating the family from MONTICULIPORIDÆ. It includes the following genera: **ASPIDOPORA, ATACTOPORELLA, HOMOTRYPELLA** and **PRASOPORA.**

ASPIDOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 155. 1882.)

Type, *Aspidopora areolata,* Ulrich.

Zoarium consisting of thin lamellar expansions, or of more massive expansions formed by the superimposition of successive

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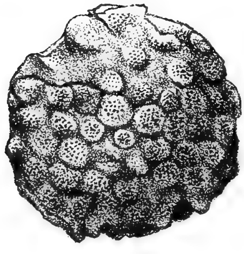

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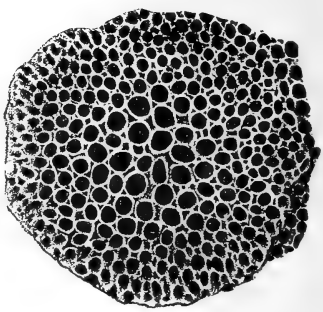

FIG. 162. *Aspidopora elegantula,* natural size.
FIG. 163. One of the areas, x9.
FIG. 164. A vertical section, x18.

layers of growth; rarely parasitic, generally free with a radiately and concentrically striated epitheca on the lower side; typically composed according to age of from one to many subequal parts, each part gently convex, with the cell apertures increasing in size from their margins to their centers; cell tubes with very infrequent diaphragms and more numerous cystiphragms; mesopores numerous, closely tabulate; surface with spiniform nodes.

ATACTOPORELLA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. VI, p. 247. 1883.)

Type, *Atactoporella typicalis*, Ulrich.

Zoarium generally forming thin crusts over foreign bodies, rarely lobate or subramose; surface with monticules and very closely resembling some forms of CERAMOPORELLA.

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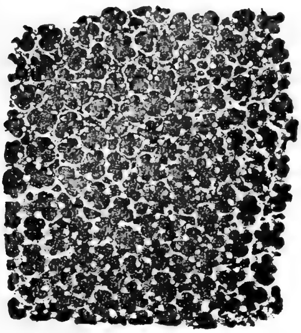

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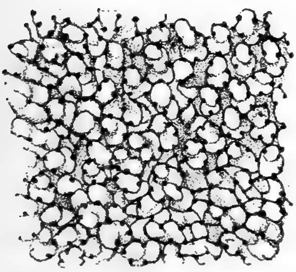

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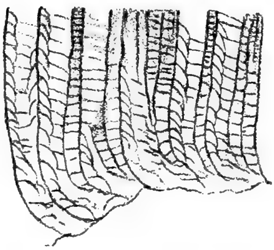

FIG. 165. *Atactoporella typicalis*, surface, x18.
FIG. 166. Transverse section, x18.
FIG. 167. Vertical section, x18.

Cells with very thin inflected walls; apertures oval, but the numerous nodes at their margins give to them an irregular petaloid appearance; cells with cystiphragms and occasional diaphragms; nodes very numerous, encroaching more or less on the cell cavity.

HOMOTRYPELLA, Ulrich.

(14th Rept. Geol. Sur. Minn., p. 83. 1886.)

Type, *Homotrypella instabilis*, Ulrich.

Zoarium somewhat irregularly ramose, sometimes palmate or frondescent; surface with maculæ, consisting of clusters of mesopores; cell apertures subcircular; mesopores abundant frequently isolating the cell tubes, closely tabulate; cell tubes with diaphragms and cystiphragms, the latter being chiefly developed in the median portion of the cell tubes; usually absent just below the surface and never occurring in the axial region; surface with numerous small nodes or granules.

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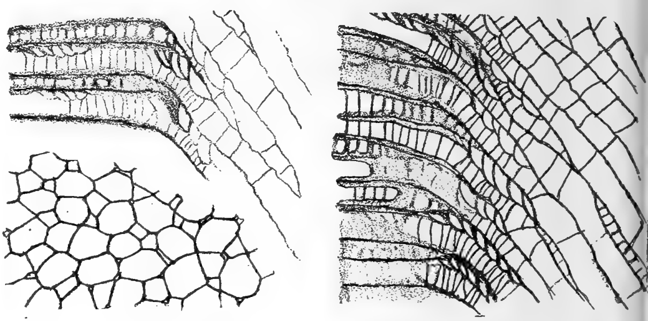

FIG. 168. *Homotrypella instabilis.* Fronds natural size.
FIGS. 169. Vertical and transverse sections, x18.

PRASOPORA, Nicholson and Etheridge.

(Ann. and Mag. Nat. Hist., 4th Series, Vol. XX, p. 38. 1877.)

Type, *Prasopora gravæ*, Nicholson and Etheridge.

Zoarium forming conical, hemispherical or irregular masses, the under side of the conical forms usually being concave and covered with a concentrically wrinkled epitheca; cells tubular, prismatic, becoming cylindrical as they approach the surface; walls thin, with both diaphragms and cystiphragms; mesopores few or numerous, sometimes completely isolating the cell tubes. In some species there are numerous spiniform nodes; surface with frequent maculæ of large cell apertures, or with monticules, the centers of which are destitute of cell apertures, and occupied by mesopore apertures.

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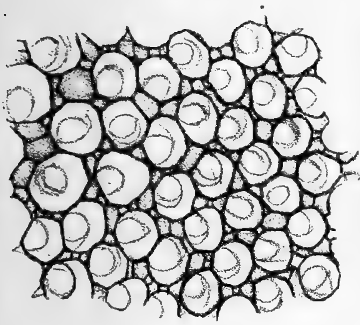

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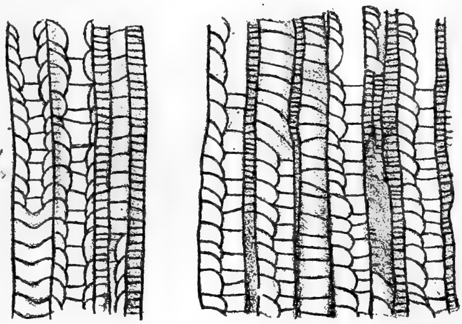

FIG. 170. *Prasopora conica*. Lateral, basal and sectional view of a specimen, natural size.
FIGS. 171, 172. *P. simulatrix*. Transverse and vertical sections, x18.

DIANULITES, Eichwald.

(Zool. special. Vol. I, p. 180. Dybowsky, Chætetes d. ost-balt. Siluriform., p. 14. 1877. Syn. *Diplotrypa*, Nicholson. Pal. Tab. Cor., p. 312. 1879.)

Type, *Dianulites petropolitana*, Eichwald.

I have been unable to obtain an authentic specimen of the type species, but judging from the published descriptions, its affinities are with the forms included in the family AMPLEXOPORIDÆ.

Most of the forms described under the name DIPLOTRYPA are not congeneric with the type species.

Family **Calloporidæ**, Ulrich, emend.

The forms included in this family are usually ramose, cells tubular, cylindrical, tabulate; mesopores more or less abundant, closely tabulate; interapertural space with pits (mesopore apertures).

The following genera are included in this family: BATOSTOMA, CALLOPORA, DEKAYELLA, NICHOLSONELLA and TREMATOPORA.

BATOSTOMA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 154. 1882.)

Type, *Batostoma implicatum*, Ulrich.

Zoarium ramose; cells tubular, arising from the center of the branch and curving outward; cell walls in the axial region very thin, becoming thicker in the peripheral region; cell apertures circular; peristomes equally elevated; interapertural surface with numerous pits (mesopore apertures), occasionally there are ornamental nodes or spines on the surface.

This genus in all probability is synonymous with CALLOPORA.

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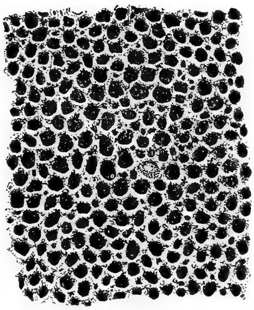

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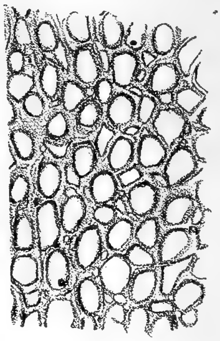

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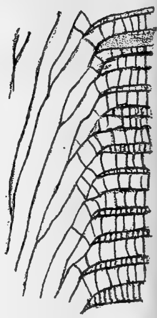

FIG. 173. *Batostoma Minnesotense*, zoarium, natural size.
FIG. 174. *B. Winchelli*. Surface x18.
FIGS. 175, 176. *B. varium*. Vertical section and transverse sections, x9.

CALLOPORA, Hall.

(Pal. N. Y., Vol. II, p. 144. 1852.)

Type, *Callopora elegantula*, Hall.

(Plate 18, figs. 1-7.)

Zoarium ramose, smooth or tuberculated; cells cylindrical, arising from an imaginary axis, gradually curving to the surface; diaphragms few or numerous; intercellular space occupied by tabulate mesopores; tabulæ very closely disposed, much more so than in the cell tubes; apertures circular; when perfect, closed by an operculum; closely and irregularly disposed, frequently nearly or quite in contact; interapertural space occupied by angular pits (mesopore apertures). The principal difference between this genus and TREMATOPORA is the presence of interapertural pits.

DEKAYELLA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 155. 1882.)

Type, *Dekayella obscura*, Ulrich.

Zoarium ramose, cells tubular, polygonal, arising from the center of the branch and curving outward; diaphragms distant;

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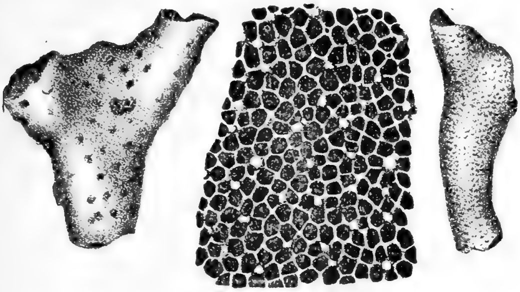

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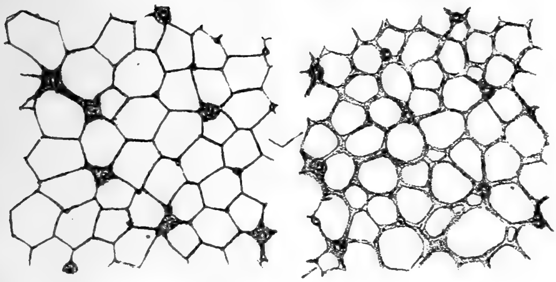

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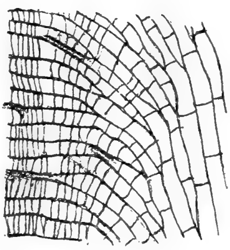

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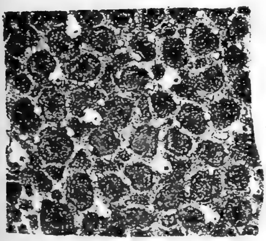

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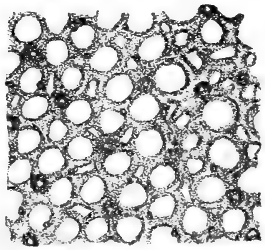

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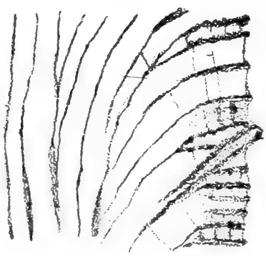


FIG. 177. *Dekayella prænuntia.* Natural size ,and surface, x9.
FIG. 178. Transverse sections of the same, x18.
FIG. 179. Vertical section, x9.
FIG. 180. *D. obscura*, surface, x18.
FIG. 181. Transverse section, x9.
FIG. 182. Vertical section, x9.

walls of cells in axial region very thin, becoming much thickened and sometimes slightly moniliform in the peripheral region.

This genus has been placed in this family because the author of the genus says that mesopores occur, but in a large number of sections of the type species that I have examined, the "mesopores" have much more the appearance of young cells. The genus should probably be placed in the family AMPLEXOPORIDÆ.

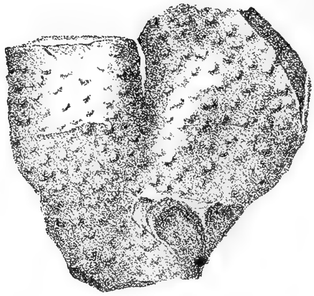
NICHOLSONELLA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 374.)

Type, *Nicholsonella ponderosa*, Ulrich.

Zoaria consisting of irregular, intertwining flattened branches or fronds. Cells tubular with a few diaphragms in the peripheral

183



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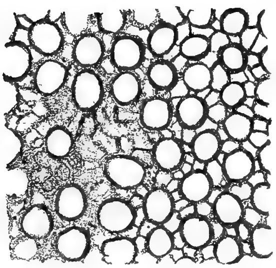

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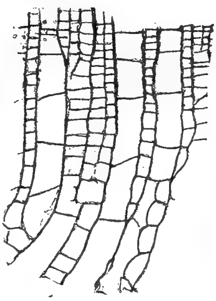

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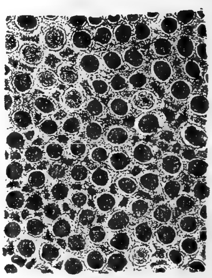


FIG. 183. *Nicholsonella cumulata*. Natural size.
FIG. 184. Surface of the same, x12.
FIG. 185. Transverse section, x18.
FIG. 186. Vertical section, x18.

region; apertures circular, with a faint granular peristome; intercellular space occupied by numerous angular mesopores or tubuli, that more or less completely isolate the cell tubes; walls of both the cell tubes and mesopores thin; mesopores with thick and numerous tabulæ or diaphragms.

TREMATOPORA, Hall.

(Pal. N. Y., Vol. II, p. 149. 1852.)

Type, *Trematopora tuberculosa*, Hall.

(Plate 19, figs. 1-5.)

Zoarium ramose, branches solid; surface with or without monticules; cells cylindrical, walls thin; apertures circular or oval, irregularly disposed; peristomes equally elevated; mesopores with numerous tabulæ; interapertural space solid. Frequently spinules occur between the cell apertures or on the peristomes.

This genus in its manner of growth is very similar to CALLOPORA, but differs from that genus in having a solid surface between the cell apertures. The solid surface is a persistent feature in all the species of this genus.

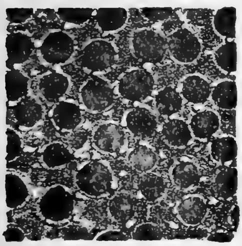
IDIOTRYPA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. VI, p. 272. 1883.)

Type, *Idiotrypa parasitica*, Ulrich.

Original diagnosis. Zoaria parasitically adhering to foreign objects; cells of two kinds, the true zoœcia being subcircular, with a slightly elevated thin peristome, and more or less completely separated from each other by a series of large angular interstitial cells. The two sets of cells are not distinguishable from each other in vertical sections, both being crossed by thick horizontal diaphragms occurring at short and regular intervals so as to divide the zoarium into so many equal layers.

187



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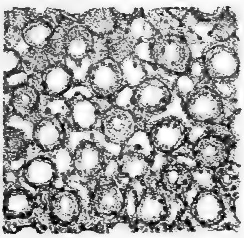

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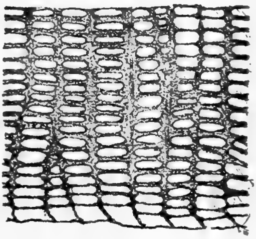

FIG. 187. *Idiotrypa parasitica*. Surface x18.
FIG. 188. Transverse section. x18.
FIG. 189. Vertical section of same, x18.

HEMIPHRAGMA, Ulrich.

(Report of the Geological and Nat. Hist. Survey. Minn., p. 299. 1893.)

"Zoaria like BATOSTOMA save in this, that the diaphragms in the peripheral part of the zoœcial tubes are incomplete." Ulrich.

190

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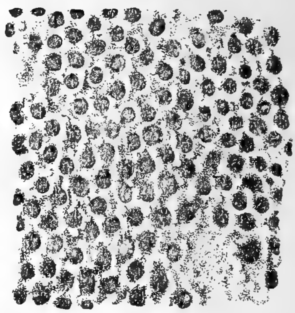

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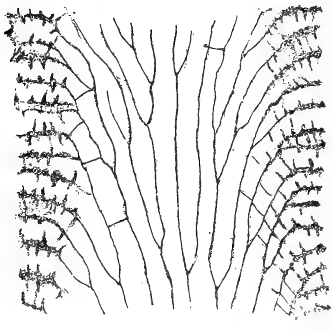

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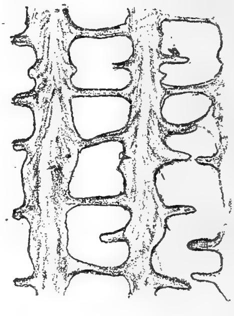

FIG. 190. *Hemiphragma irrasum.* Specimens, natural size.
FIG. 191. Surface, x9.
FIG. 192. Vertical section, x9.
FIG. 193. Cell walls, x35.

Family **Botrylloporidæ**, Miller.

BOTRYLLOPORA, Nicholson.

(Geol. Mag. N. S., Vol. I, p. 160. 1874.)

Type, *Botryllopora socialis*, Nicholson.

(Plate 20, figs. 16, 17.)

Zoarium consisting of small discoidal bodies, occurring singly or in groups, connected by vesicular tissue; adherent to foreign bodies by their under surface, which consists of a concentrically wrinkled epitheca. Nearly all the specimens observed are parasitic on Cyathophylloid or Favositoid corals, sometimes occurring in groups of from seventy-five to a hundred zoaria.

Zoarium convex with a depressed central area, which is somewhat variable in size.

Cells tubular, rectangular to the surface, disposed in double radiating rows, extending above the surface and forming prominent ridges; adjacent ridges generally separated by a space about equal to the width of a ridge, but sometimes more closely disposed. Alternate ridges extend from the depressed central space to the margin, the others commencing at about one-half the distance to the margin; cell apertures circular, in contact, often inosculating, having the appearance of being immersed; intercellular space vesiculose; vesicles comparatively large and irregularly disposed. The concave central space, that between the ridges and between the zoaria is vesicular, the vesicles between the ridges being much smaller than those occupying the central space. Between the zoaria some of the vesicles are of the same size as those between the ridges, others are much larger, circular or polygonal from mutual pressure.

SCENELLOPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., p. 150. 1882.)

Type, *Scenellopora radiata*, Ulrich.

Zoarium obconical the under side with an epitheca; the upper slightly concave and celluliferous; cell apertures occupying the center of ridges which radiate from a subsolid and depressed center; intermediate space smooth, without cells.

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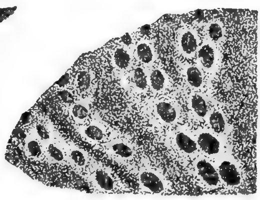

FIG. 194. *Scenellopora radiata*. Profile and top view, natural size.
FIG. 195. A portion of the noncelluliferous surface, x8.

SPHRAGIOPORA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 398. 1890.)

Type, *Sphragiopora parasitica*, Ulrich.

Zoarium a small discoidal body attached to other objects; upper surface flat or a little concave; cell apertures disposed in an irregularly radial manner from the center, on the summits of from six to nine more or less elevated ridges; at first they form only single rows, but at the outer margin the arrangement is biserial.

196

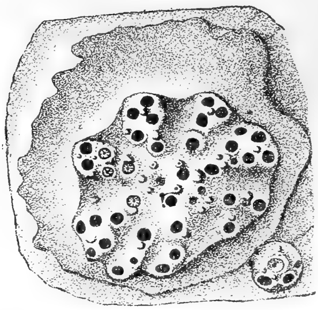

FIG. 196. *Sphragiopora parasitica*. A frond, x18.

Family **Tubuliporidæ**, Busk.

The forms included in this family are composed of simple cylindrical tubes, with inoperculated aperture. The following genera are included in the family: BERENICEA, DIASTOPORINA, HERNODIA, PROBOSCINA, SAGENELLA and STOMATOPORA.

BERENICEA, Lamoureux.

(Exp. Meth. des genres d. pol., 80. 1821.)

Type, *Berenicea diluviana*, Lamoureaux.

"Incrusting, composed of a very thin foliaceous base, from which proceed, gradually enlarging, distantly separated tubular cells; apertures circular or oval, situated near the broad anterior end; cells disposed in an obscurely radiate arrangement." BERE-

NICEA is a recent genus and I very much doubt if any Palæozoic forms are properly placed here.

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FIG. 197. *Berenicea Minnesotensis.* Two specimens, natural size.
FIG. 198. A portion of the surface, x25.

DIASTOPORINA, Ulrich.

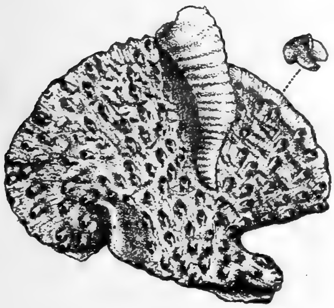
(Jour. Cin. Soc. Nat. Hist., Vol. XII, p. 177. 1890.)

Type, *Diastoporina flabellata*, Ulrich.

"Zoarium bifoliate, in general resembling DIASTOPORA; cells subtubular, prostrate, immersed; apertures constricted, subcircular, not prominent; interspaces finely punctate and striate longitudinally."

Probably a synonym of DIASTOPORA.

199



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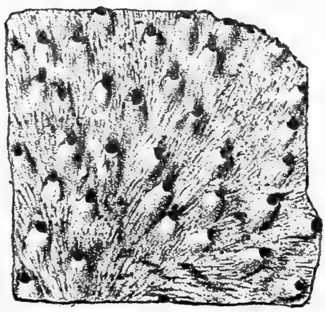


FIG. 199. *Diastoporina flabellata*, natural size and enlarged.
FIG. 200. A still further enlargement of the surface.

HERNODIA, Hall.

(Rep. State Geologist, N. Y., p. 58. 1884.)

Type, *Hernodia humifusa*, Hall.

(Plate 25, figs. 1, 2.)

Zoarium parasitic, procumbent, consisting of tubular, annulated cells, enlarging to near the aperture; increasing by lateral gemmation, the buds continuing growth in the same manner as the parent tube so that comparatively large surfaces are often covered.

PROBOSCINA, Audouin.

(Desc. de l'Egypte; Pol., p. 236. 1826.)

Zoarium adnate, branching dichotomously or inosculating, in the latter case forming an irregular large meshed net-work.

201

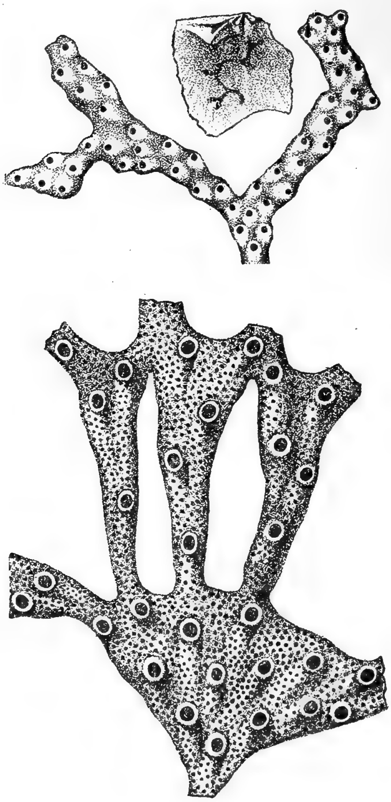


FIG. 201. *Proboscina tumulosa*, natural size and x9. Lower fig. *P. frondosa*. A frond, x18.

Cell tubes as in STOMATOPORA, excepting that they are more or less immersed and not uniserial, being arranged in two or more contiguous rows.

SAGENELLA, Hall.

(Pal. N. Y., Vol. II, p. 172. 1852.)

Type, *Sagenella membranacea*, Hall.

(Plate 20, fig. 4.)

Zoarium a thin membraniform expansion, growing upon the surface of other organic bodies cells subcylindrical, flattened for the greater part of their length, and continuing nearly parallel with the plane of the epitheca; arranged in a more or less regular diverging or radiating order, with intercalated ranges presenting a subimbricated appearance, turning abruptly and opening directly outward, cell apertures circular.

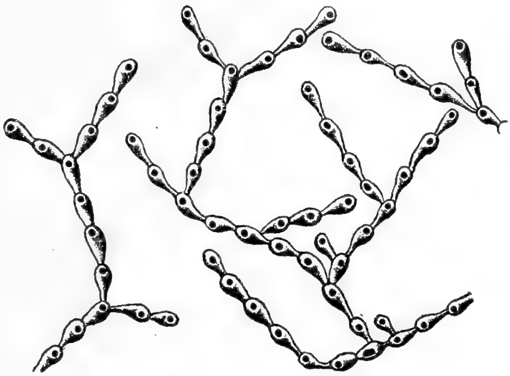
STOMATOPORA, Bronn.

(System d. Urwelt; Pflanzenthiere. 1825.)

Type, *Stomatopora dichotoma*, Bronn.

Zoarium adnate, cells subtubular, club shaped or ovate, not

203 204 202



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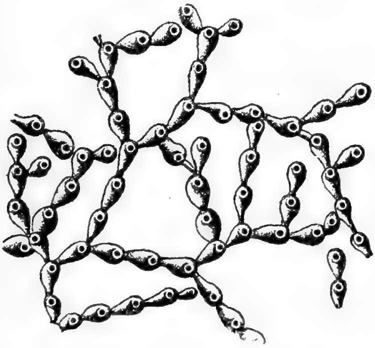

FIG. 202. *Stomatopora inflata*. Enlargement of different colonies, x9.
FIG. 203. Three cells, x 18.
FIG. 204. Vertical section of one of the cells, x18.

immersed; arranged in a single branching series; apertures subterminal, circular, more or less elevated, opening directly outward.

The shape of the cells and mode of increase is the same as in PROBOSCINA, differing from that genus only in having the cells arranged in a single series, in PROBOSCINA the cells being arranged in two or more series and more or less immersed.

Family **Entalophoridæ**, Reuss.

CLONOPORA, Hall.

(Bryozoans of the Upper Helderberg group, p. 20. 1881.)

Type, *Clonopora semireducta*, Hall.

(Plate 25, figs. 6, 7.)

Zoarium ramose; branches consisting of an aggregation of elongate, cylindrical, tubular cells, which at more or less regular intervals become entirely free, and turn abruptly outward in an umbelliform expansion or in alternation; cell apertures expanded.

CYSTOPORA, Hall.

(Trans. Albany Inst., Vol. X, p. 161. 1881.)

Type, *Cystopora geniculata*, Hall.

(Plate 25, figs. 3–5.)

Zoarium consisting of an aggregation of ampullate, tubular cells; the greatest diameter of the cell tube being at about two-thirds of its length; near the anterior end turning abruptly outward and much constricted at the aperture; cell tubes exposed for more than half their length, alternating, imbricating, arranged in spiral rows around the branch.

MITOCLEMA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 150. 1882.)

Type, *Mitoclema cinctosum*, Ulrich.

Zoarium ramose, slender; transverse section subcircular; cells tubular; very long; gradually diverging in all directions from an imaginary axis; apertures prominent, circular, arranged in a transverse series or spirally around the stem; walls thin.

206 205

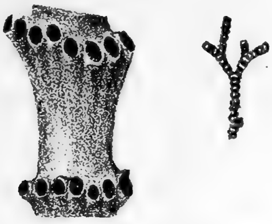

FIG. 205. *Mitoclema cinctosum*, natural size.
FIG. 206. A portion of the same, x18.

Family **Reptaridæ.**

This family includes those adnate forms, having a central axis and bilateral tubular cells. The following genera are included in the family: HEDERELLA and REPTARIA.

HEDERELLA, Hall.

(Trans. Albany Institute, Vol. X, p. 194. 1881.)

Type, *Hederella Canadensis*, Billings.

(Plate 25, figs. 10–13.)

Zoarium parasitic, procumbent, attached its entire length; usually occurring on corals or Brachiopoda. Zoarium consisting of a primary, cylindrical, tubular axis, which has bilateral tubular cells at frequent intervals and occasionally cells having the same manner of growth as the primary axis. This manner of growth is indefinitely continued so that comparatively large surfaces are covered by the fronds; cells subcylindrical with transverse annulations and striations, and also fine longitudinal striations; cell tubes in contact with the axis for a portion or the whole of their length.

REPTARIA, Rolle.

(Leonhard and Bronn, Neues Jahrbuch, p. 180. 1851.)

Type, *Reptaria stolonifera*, Rolle.

(Plate 25, figs. 8, 9.)

Zoarium adnate, consisting of a rachis, from which proceed, laterally, simple cell tubes, and, at irregular intervals, tubes which have the same manner of growth as the primary rachis. This mode of growth is continued indefinitely, the zoarium frequently covering a comparatively large area.

Cell tubes subcylindrical, slightly sinuous, especially near the base; the attached portion flat, the free portion convex. For a short distance the cells are nearly parallel with the rachis, then diverge at an angle of thirty-five or forty degrees; near the aperture turning directly outward, so that the aperture is at right angles to the main portion of the cell tube; margins of the cell tubes in contact, but not coalescing; the end of each succeeding cell tube projecting beyond the preceding one, giving a serrate appearance to the margin of the frond; cell tubes annulated.

Family Phaceloporidæ, Ulrich.

This family at present includes one genus, PHACELOPORA.

PHACELOPORA, Ulrich.

(Geol. Sur. Ill., p. 388. 1890.)

Type, *Phacelopora pertenuis*, Ulrich.

Zoarium articulated, segments short, conical, consisting of two or more equal conical cell tubes, with slightly contracted circular apertures.

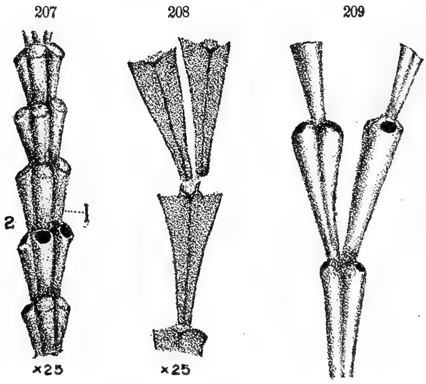

FIG. 207. *Phacelopora pertenuis*. Natural size, and x 25.

FIG. 208. A vertical section of the same, x 25.

FIG. 209. *P. constricta*. A portion of a frond, x 25.

CYCLOPORA, Prout.

(Trans. St. Louis Acad. Sci., Vol. I, p. 574. 1860.)

Type, *Cyclopora fungia,* Prout.

Zoaria consisting of lamellar or discoidal expansions; incrusting or free; under surface an epitheca, concentrically wrinkled and radially striated by the recumbent portion of the cell tubes. Cells tubular, at first prostrate, then curving somewhat abruptly and continuing rectangularly to the surface; apertures subcircular or somewhat truncated posteriorly; more or less regularly disposed. When regularly disposed there is an oblong depression between adjacent apertures; when irregularly disposed, this space may be divided into two smaller ones; or it may appear that the apertures are separated by unequal and irregularly situated depressions. With growth these interspaces are developed into tabulate mesopores.

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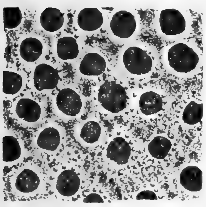

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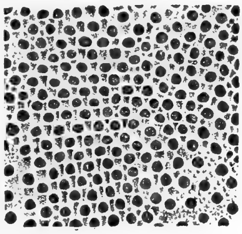

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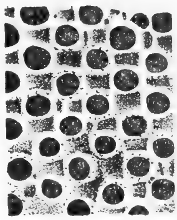

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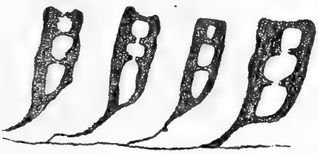


FIG. 210. *Cyclopora fungia.* A portion of the surface, x 9.
FIG. 211. Surface, x 18.
FIG. 212. An enlargement showing a portion of one of the maculæ.
FIG. 213. A vertical section, x 28.

PROUTELLA, Ulrich.

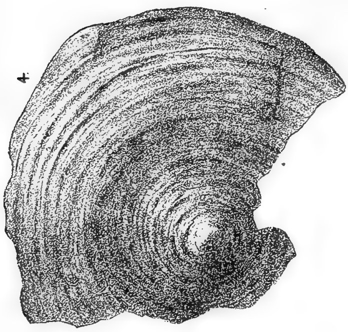
(Geol. Sur. Ill., p. 403. 1890.)

Type, *Proutella discoidea,* Ulrich.

"Zoarium discoidal, thin, free; the lower surface convex and with a concentrically wrinkled epitheca. Cells subtubular;

walls thin; apertures broadly elliptical, surrounded by a narrow sloping area, hexagonal in outline. When perfect there is a depressed calcareous plate that closes nearly two-thirds of the aperture, the orifice left being subtriangular in form. With age, successive layers are developed directly over the first, so that they gradually form a cell tube, seemingly having the cavity intersected by incomplete diaphragms, which appear to have their origin on the posterior wall, and extend out half way across."

214



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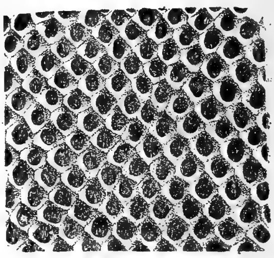

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FIG. 214. *Proutella discoidea.* Under surface, natural size.
FIG. 215. Upper surface of a fragment, natural size.
FIG. 216. A portion of the snrface, x 9.

Family Worthenoporidæ, Ulrich.

This family includes at present only the genus WORTHENOPORA.

WORTHENOPORA, Ulrich.

(Geol. Sur. Ill., Vol. VIII, p. 403. 1890.)

Type, *Worthenopora spinosa*, Ulrich.

"Zoarium bifoliate, branching or palmate. Cells very regularly arranged, subtubular, with the apertures semielliptical. On the surface the line of junction between the cells is marked by a longitudinal, elevated ridge. The truncate posterior margin of the aperture is raised into a less strong transverse bar. The elongate, triangular depressed front appears perfectly plain."

The condition in which the three following genera occur render their classification difficult: ASCODICTYON, RHOPALONARIA and VINELLA.

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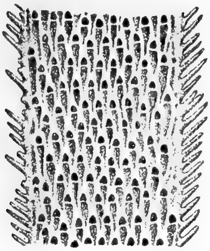

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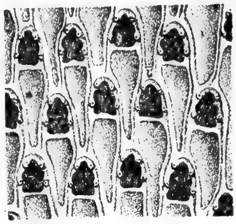

FIG. 217. *Worthenopora spinosa*, natural size.
FIG. 218. Surface, x9.
FIG. 219. A portion of the surface, x28.

ASCODICTYON, Vine.

(Ann. and Mag. Nat Hist., 4th Series, Vol. XIX, p. 463. 1877.)

Type, *Ascodictyon fusiforme.*

"Zoœcia consisting of radially arranged fusiform or bulbous cells, or filiform threads with periodic swellings."

220

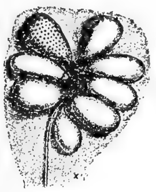

FIG. 220. *Ascodictyon stellatum.* A group of vesicles, x18.

RHOPALONARIA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. II, p. 26. 1879.)

Type, *Rhopalonaria venosa*, Ulrich.

Cells slender, fusiform, arranged in a single anastomosing

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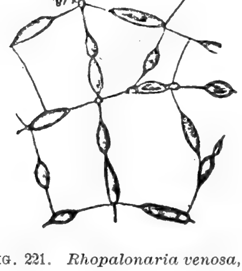


FIG. 221. *Rhopalonaria venosa*, x18.

series; cell mouths small, near one end of the cells. The animal had the power of excavating the substance of the body upon which it grew.

VINELLA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. XII, p. 173. 1890.)

Type, *Vinella repens*, Ulrich.

"Zoarium attached to foreign bodies; consisting of exceedingly slender, ramifying, thread-like tubular stolons, arranged in a more or less distinctly radiating manner; surface of tubes sometimes faintly lined longitudinally; a row of widely separated small pores along the center of the surface of the tubes; cells unknown. The cells must have been deciduous and developed by budding from the creeping stolons from the points now represented by the pores."

222

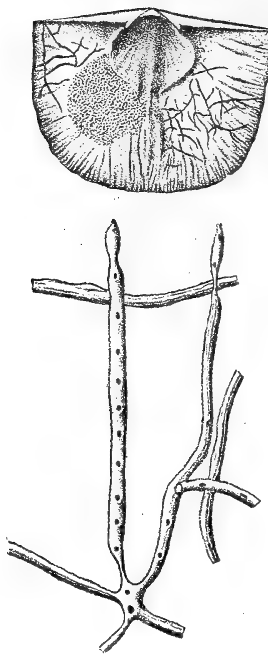


FIG. 222. *Vinella repens*, natural size, and a portion of the colony, x18.

ADDENDUM.

STICTOPORA, Hall.

(Pal. N. Y., Vol. I, p. 73. 1847.)

Type, *Stictopora elegantula*, Hall.

(Plate 10, figs. 9, 10, 20.)

Zoarium attached by a spreading base to foreign objects; ramose; branches thin, transverse section lenticular; composed of two layers of cells separated by a mesotheca; cell apertures circular or oval, surrounded by a peristome; rows of cells frequently separated by narrow ridges; margins noncelluliferous; interapertural space vesiculose or apparently solid.

This genus differs from CYSTODICTYA principally in the absence of pseudo septa and lunaria.

ARTHROPORA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 152. 1882.)

Type, *Arthropora Shafferi*, Ulrich.

"Zoarium jointed; segments short, with several branches projecting from each edge, some of which may or may not be tipped for articulation with succeeding segments; cell mouths sub-circular, separated by interstitial pits or sulci."

RHINIDICTYA, Ulrich.

(Jour. Cin. Soc. Nat. Hist., Vol. V, p. 152. 1882.)

Type, *Rhinidictya Nicholsoni*, Ulrich.

(Plate 10, figs. 3–5.)

"Zoarium narrow, branching at long intervals; cells surrounded by a close series of spiniform tubuli."

Very similar to STICTOPORA.

PTILOCELLA, nov. gen.

Type, *Ptilocella parallela*, Hall (sp.).

(Plate 15, figs. 1–3.)

Zoarium ensiform; in its pointed, striated base resembling PTILODICTYA, but the cell apertures are circular, arranged in parallel longitudinal rows, which are separated by ridges as in STICTOPORA; margin of frond noncelluliferous, striated.

FISTULIPORIDRA, nov. gen.

Type, *Fistuliporidra tesselata*, Hall (sp.).

(Plate 22, figs. 1–3.)

The manner of growth and internal structure is the same as in FISTULIPORINA, but the cell apertures are surrounded by angular elevations, enclosing the apertures in a polygonal vestibular area, the surface presenting a very different appearance from that of FISTULIPORINA.

FISTULICELLA, nov. gen.

Type, *Fistulicella plana*, Hall (sp.).

(Plate 22, fig. 4.)

The manner of growth and general appearance is the same as that of LICHENALIA, but the cells are circular and without pseudo septa or lunaria.

INDEX TO GENERA.

EXPLANATIONS OF PLATES.

PLATE A.

PALLUDICELLA EHRENBERGI.

Fig. 1. A very much enlarged drawing of a cell seen in section, with the polypide exserted, and exhibiting anatomical details.

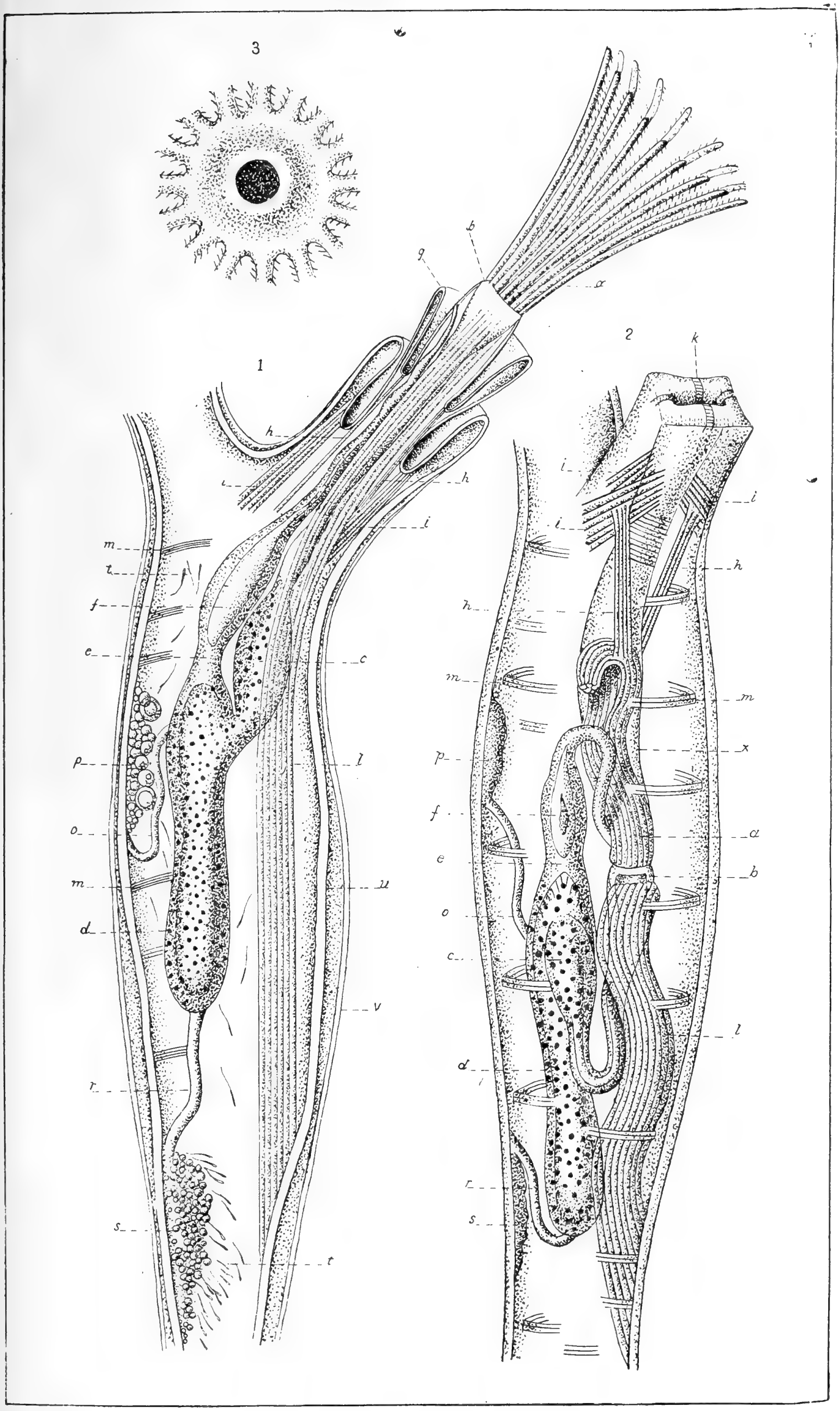
Fig. 2. Showing a section of a cell with the polypide retracted.

Fig. 3. Lophophore viewed upon the upper surface, with the mouth and roots of tentaculæ (after ALLMAN).

Explanation of lettering.

a, Tentacles.
b, Lophopore.
c, Cardiac cavity of stomach.
d, Pyloric cavity of stomach.
e, Pylorus.
f, Intestine.
g, Anus.
h, Posterior parieto-vaginal muscles.
i, Anterior parieto-vaginal muscles.
k, Muscles closing the orifice.
l, Retractor muscles of polypid.
m, Parietal muscles.
o, Superior funiculus.
p, Ovary.
r, Funiculus.
s, Testes.
t, Spermatozoa.
u, Endocyst.
v, Ectocyst.

PLATE A.



ANATOMY OF THE BRYOZOA.

PLATE B.

Bowerbankia densa.

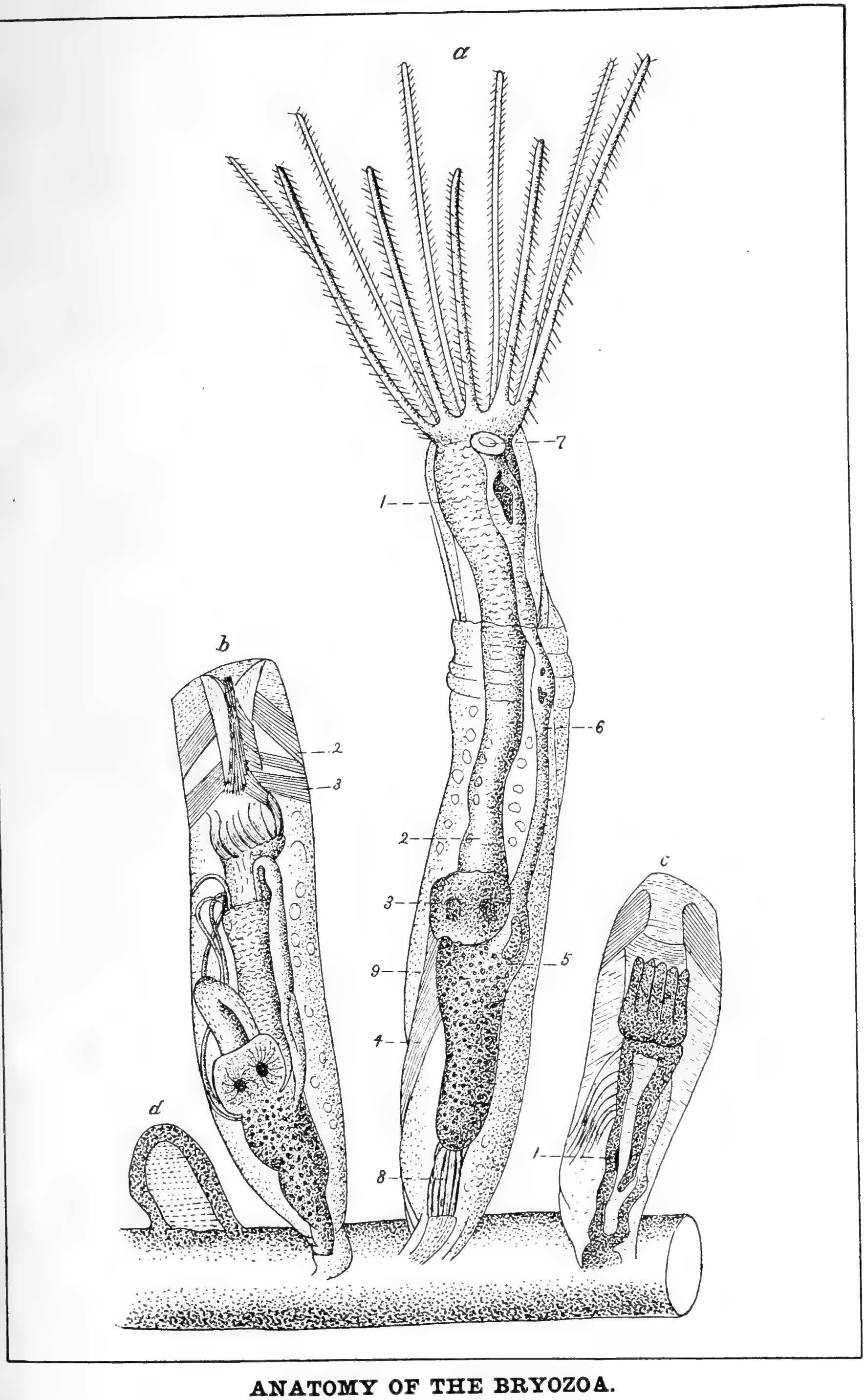
Fig. *a.* Showing the animal fully expanded.
1 Pharynx ; 2 Cardia ; 3 Gizzard ; 4 Stomach ; 5 Pylorus ; 6 Intestine ; 7 Anus ; 8, 9 Muscles.

Fig. *b.* The animal completely retracted.
2, 3 Opercular retractor muscles.

Fig. *c.* An immature animal.

Fig. *d.* One of the buds in its earliest state (after Farre).

PLATE B.



ANATOMY OF THE BRYOZOA.

PLATE C.

Embryology of PHALANGELLA FLABELLATA.

Explanation of lettering.

a, Cavity of the body.
b, Digestive cavity.
c, Mouth of the gastrula.
d, Exoderm.
e, Endoderm.
f, Oral face.
i, Aboral mesoderm.
k, Aboral face.
l, Cavity of the mantle.
m, Mantle.
n, Tentacles.
o, Endocyst.
p, Polypide.
r, Rectum.
x, Crown.
z, "Zone anhiste."

Fig. 1. Cell greatly enlarged.

Fig. 2. Cell divided in two, still adhering to the endocyst.

Fig. 3. Morula.

Figs. 4, 5. Beginning and enlargement of the cavity of segmentation.

Fig. 6. Blastula.

Figs. 7, 8, 9. Gastrula in different stages of formation, fig. 8 being a vertical section.

Fig. 10. A section, showing the appearance of the median swelling, which represents the crown.

Figs. 11, 12. Development of the median swelling, which at first (fig. 10) is near the oral face, approaching the middle (fig. 11), and afterwards nearing the aboral face (fig. 12). The same figures show the formation of the mesoderm *i*, between the aboral face and the posterior walls of the intestine.

Fig. 13. Showing a more developed state.

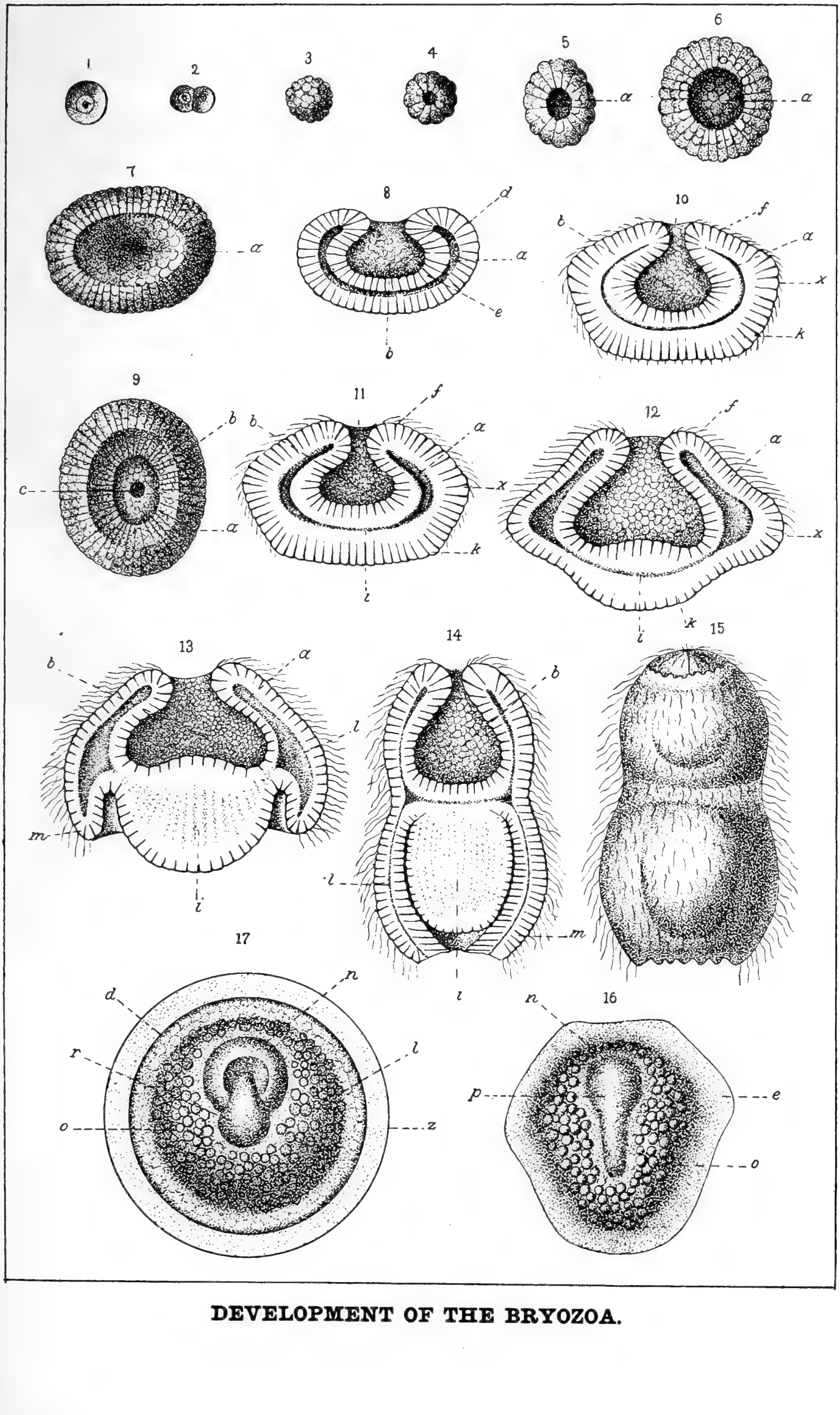
Fig. 14. A free embryo, vertical section.

Fig. 15. An exterior view of the same.

Fig. 16. First stage of fixation, composed of an internal pyriform mass, and an external layer spread over, and following all the contours of the internal mass. Between the two are shown the fatty globules.

Fig. 17. The external layer has separated from the internal mass, and has formed a discoidal sac, in which is easily distinguished the endocyst (*e*), the ectocyst (*n*), and the "zone anhiste" (*z*). Internally are shown the fatty globules and the pyriform mass, which now begins to show the rudiments of a polypide.

PLATE C.



DEVELOPMENT OF THE BRYOZOA.

PLATE D.

Continuation of embryology of Phalangella flabellata.

Explanation of lettering.

d, Ectocyst.
e, Endocyst.
n, Tentacles.
o, Fatty globules.
r, Rectum.
v, Terminal disc of tentacular tube.
w, Stomach.
z, "Zone anhiste."

Fig. 18. A more advanced stage; a little beyond the center is a discoidal plate, formed by the tubular uprising of the surface.

Fig. 19. The uprising of the surface under the disc *v* has formed a long tube (tentacular tube); the disc has changed from a horizontal position to a vertical on account of the unequal increase of the two faces of the tube, and has the beginning of an opening (opening of the cell). The rudimentary polyp begins to acquire a definite structure.

Fig. 20. The ectocyst is greatly thickened, and has formed on the tentacular tube. The fatty globules are condensed in two masses *o*.

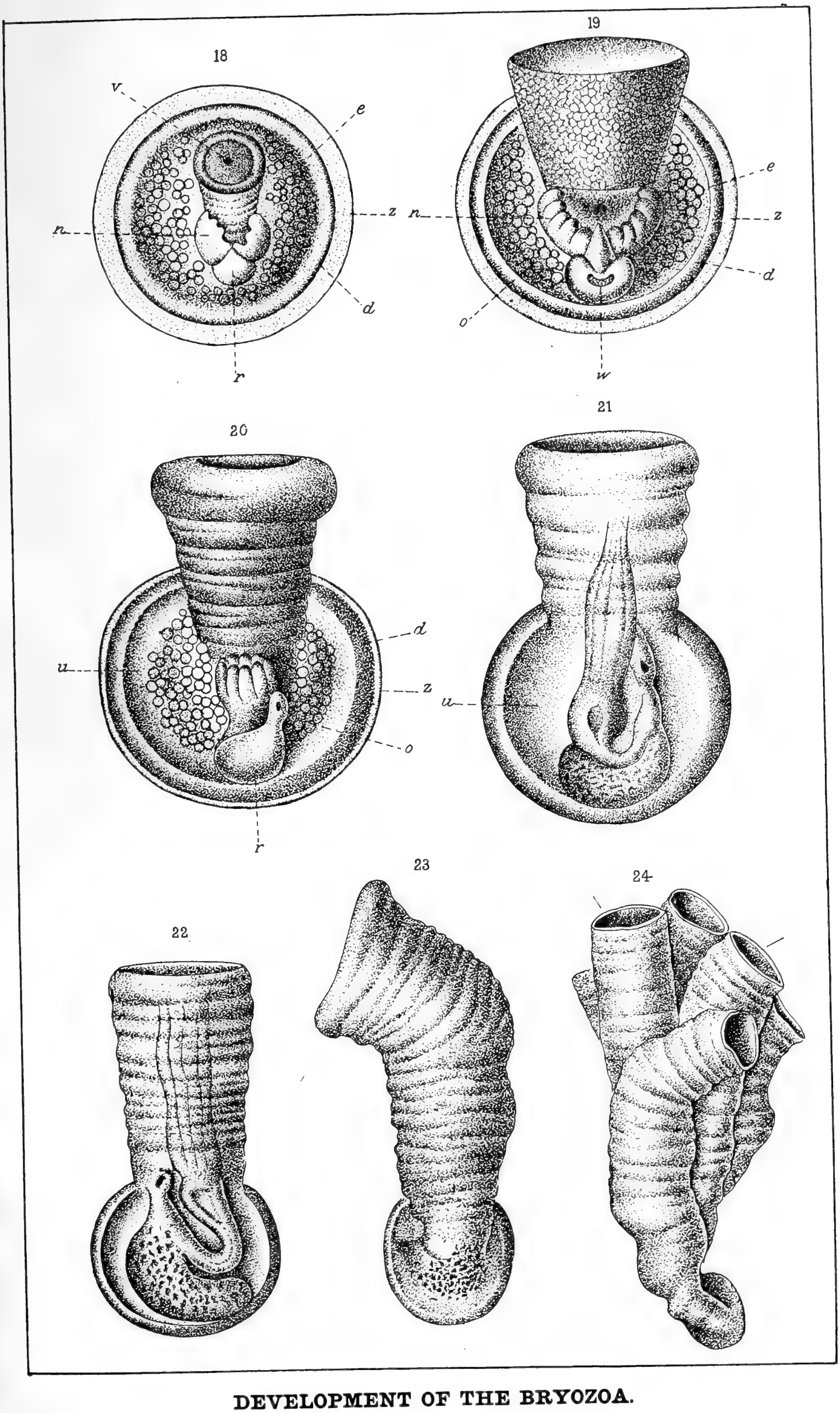
Fig. 21. The polyp has reached the complete state, and the "zone anhiste" has disappeared.

Fig. 22. The primitive cell and tentacular tube more developed.

Fig. 23. A profile view of a cell.

Fig. 24. Showing the manner of increase of the cells.

PLATE D.



DEVELOPMENT OF THE BRYOZOA.

PLATE E.

Mollia granifera.

Explanation of lettering.

a, Ciliary plume.
b, Mouth of the gastrula.
c, Oculiform points.
d, Obscure portion of the cavity of the body comprised between the two branches of the stomach.
e, Endocyst.
e^1, Ectocyst.
f, Fatty globules.
l, "Zone anhiste."
p, Polyp.

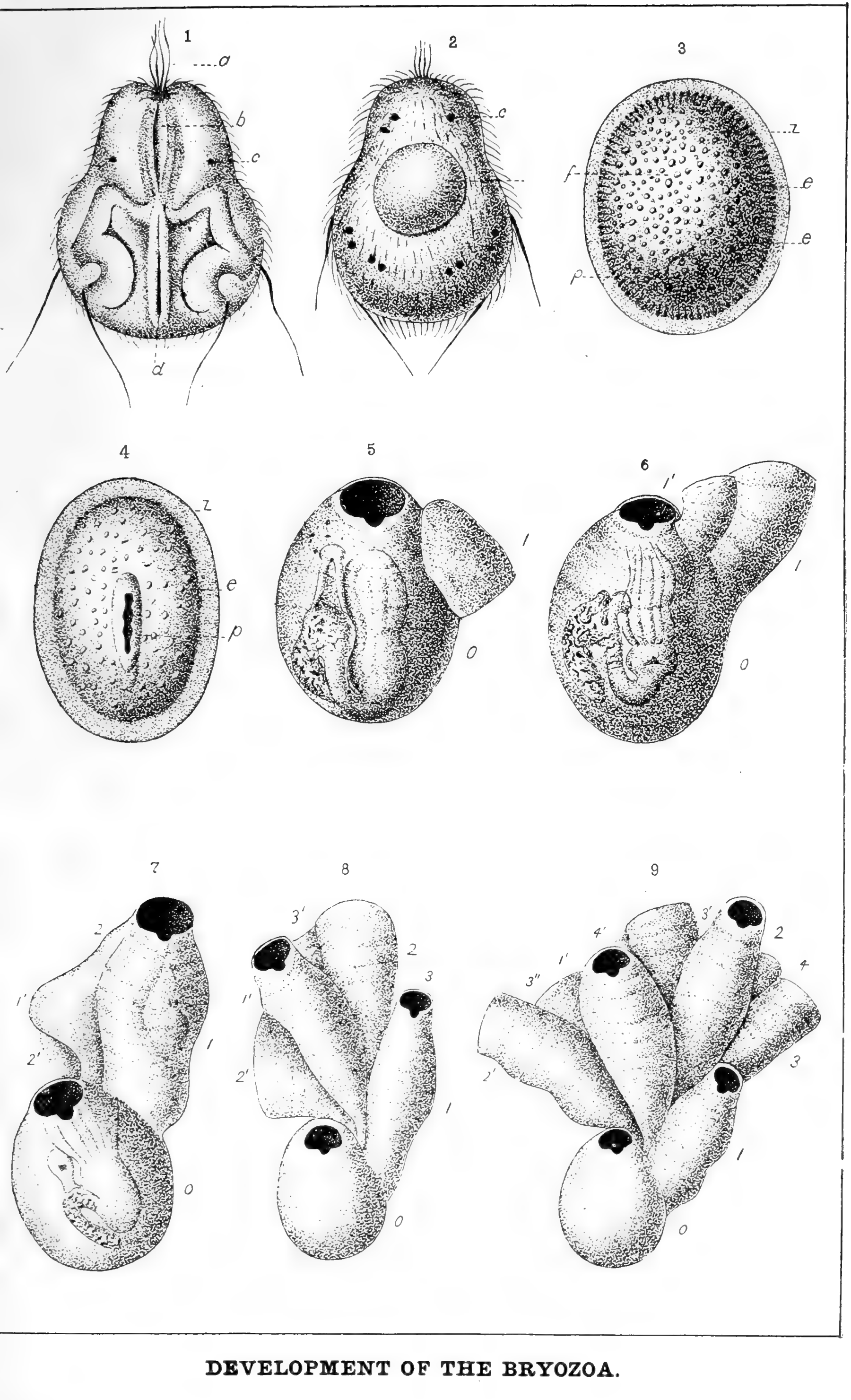
Figs. 1, 2. The oral and aboral face of a free embryo. x150.

Fig. 3. The first stage of metamorphosis, showing the beginning of the calcareous incrustation; the rudimentary polyp already exists; the fatty globules are less abundant. x125.

Fig. 4. The same more advanced. x125.

Figs. 5–9. Showing the manner of the growth and increase in number of the cells, page 473.

PLATE E.



DEVELOPMENT OF THE BRYOZOA.

PLATE I.

RETEPORELLA.

(Page 503.)

RETEPORELLA UNDULATA, Hall.

Figs. 1, 2. Natural size.
Fig. 3. Celluliferous face. x6.
Upper Helderberg group. *Falls of the Ohio.*

RETEPORELLA ADNATA, Hall (sp.).

Fig. 4. Noncelluliferous face. x6.
Fig. 5. Celluliferous face. x6.
Upper Helderberg group. *Falls of the Ohio.*

RETEPORINA.

(Page 504.)

RETEPORINA STRIATA, Hall.

Fig. 6. Noncelluliferous face. x6.
Fig. 7. Celluliferous face. x6.
Hamilton group. *New York.*

RETEPORINA PERUNDULATA, Hall.

Fig. 8. Noncelluliferous face. x6.
Upper Helderberg group. *Falls of the Ohio.*

POLYPORELLA.

(Page 502.)

POLYPORELLA FISTULATA, Hall (sp.).

Fig. 9. Transverse section. x6.
Fig. 10. Celluliferous face. x6.
Hamilton group. *New York.*

POLYPORA.

(Page 502.)

POLYPORA ASPECTANS, Hall.

Fig. 12. Transverse section. x6.
Fig. 13. Celluliferous face. x6.
Upper Helderberg group. *Falls of the Ohio.*

POLYPORA STRIATOPORA, Hall.

Fig. 11. Natural size.
Fig. 14. Celluliferous face. x6.
Fig. 15. Noncelluliferous face. x6.
Upper Helderberg group. *Falls of the Ohio.*

BRYOZOA.

Generic Illustrations.

Report State Geologist, 1894. Plate 1.

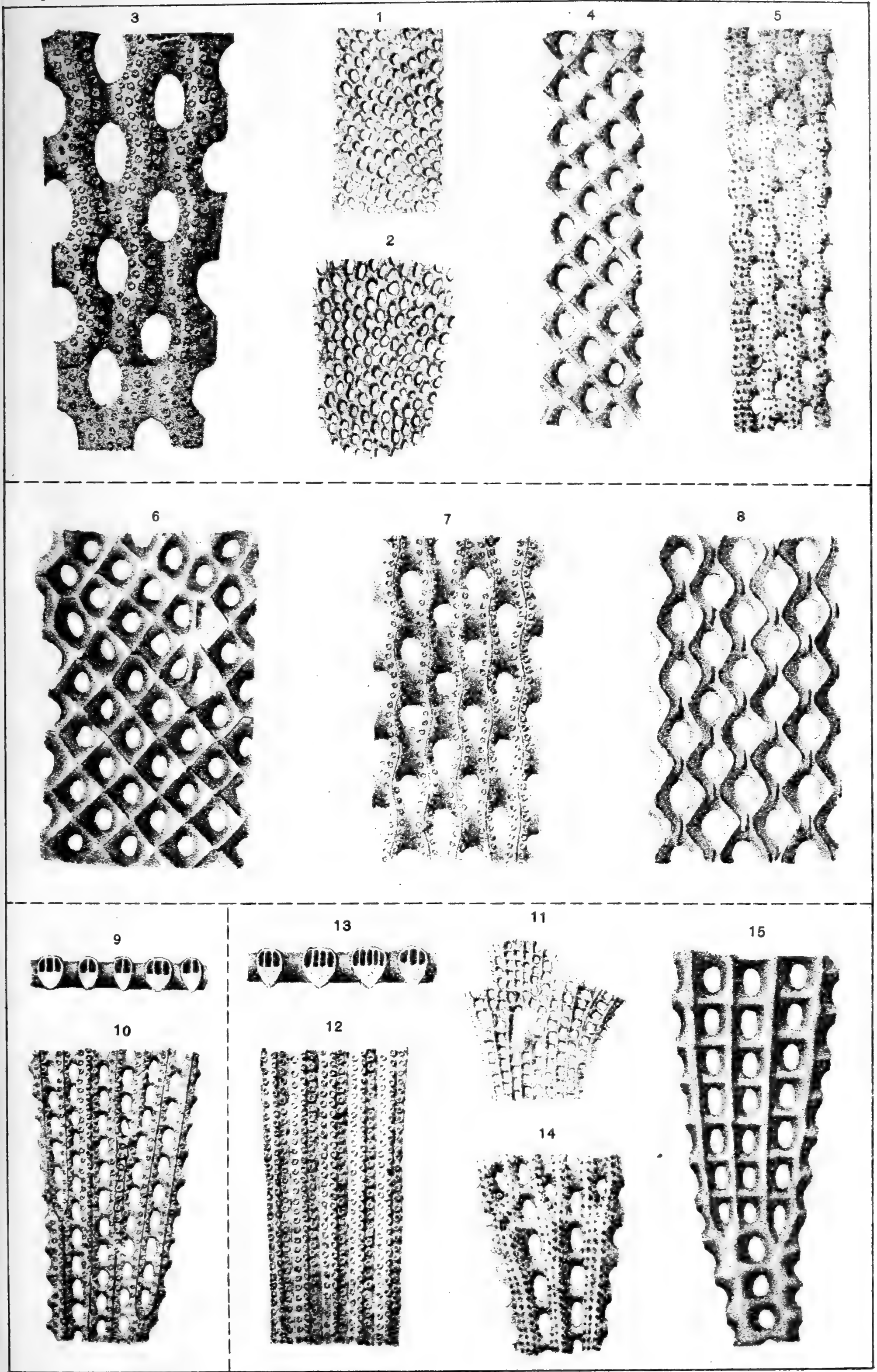


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PLATE II.

FENESTELLA.

(Page 500.)

Fig. 1. Celluliferous face, showing low, smooth carina. x6. Group α.

Fig. 2. Celluliferous face of a form showing a row of nodes between the rows of apertures. x6. Group β.

Fig. 3. Celluliferous face, with prominent carinæ expanded at the summit. x6. Group ε.

Fig. 4. Transverse section of a form belonging to group α.

Fig. 5. Oblique view of a portion of the celluliferous face of *F. stellata*, showing the very prominent stellate nodes. x6.

Fig. 6. A transverse section of a branch showing conical nodes. x6.

Fig. 7. Side view of a branch of *F. exornata*, showing the prominent, thin carina. x6.

Fig. 8. End view of branches of the same species. x6.

Fig. 9. Side view of a branch of *F. latijunctura*, showing the characteristics of the carinæ of Group δ.

Fig. 10. End view of branches of the same species. x6.

Figs. 11, 12. End view of branches of *F. bi-imbricata* and *F. laticarina*, showing the characteristics of Group ε. x6.

Fig. 13. An enlargement from the celluliferous face of a specimen, showing the characters of the carinæ of Group ζ.

Figs. 14–17. Fragments of specimens, natural size.

Fig. 18. An enlargement of the base of a frond of *F. variapora*.

BRYOZOA.

Generic Illustrations.

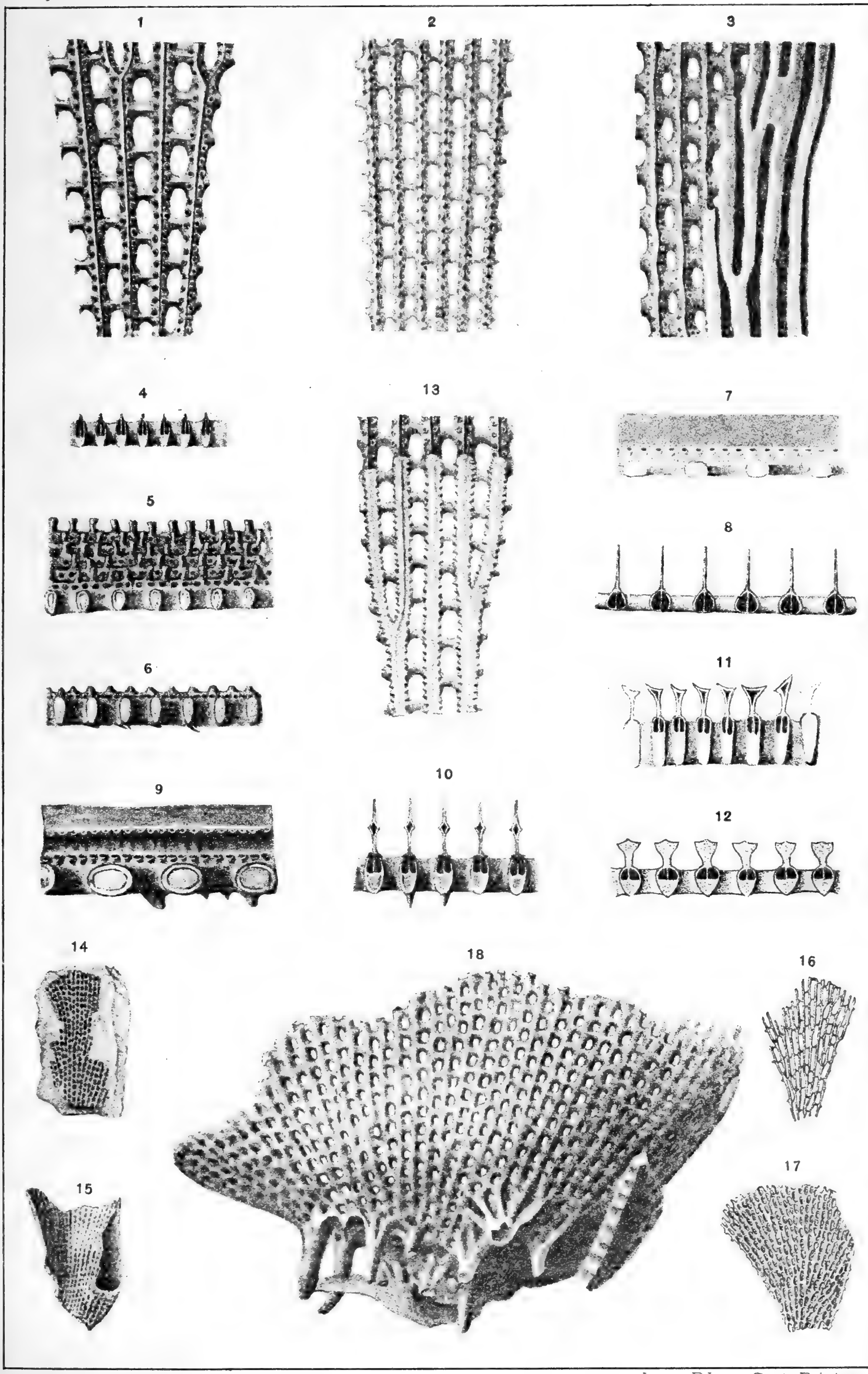

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PLATE III.

CYCLOPORINA.

(Page 504.)

CYCLOPORINA HEMICYCLA, Hall (sp.).

Fig. 1. Noncelluliferous face. x6.

Fig. 2. Celluliferous face. x6.

Fig. 5. Side view of a branch. x6.
Hamilton group. *New York.*

CYCLOPORINA SEMIROTUNDA, Hall (sp.).

Fig. 3. Noncelluliferous face. x6.

Fig. 4. Celluliferous face. x6.
Hamilton group. *New York.*

FENESTRAPORA.

(Page 506.)

FENESTRAPORA LARGIOR, Hall (sp.).

Fig. 6. Noncelluliferous face. x18.
Hamilton group. *Moscow, N. Y.*

FENESTRAPORA BIPERFORATA, Hall.

Fig. 7. An enlargement from the celluliferous face, showing the triangular pores. x18.

Fig. 8. An enlargement from the noncelluliferous face. x18.

Fig. 9. An enlargement from the celluliferous face, showing the cell apertures and the poriferous summits of the carinæ. x6.

Fig. 10. A still further enlargement of the poriferous summits of the carinæ. x18.

Fig. 11. Side view of a branch. x6.

Fig. 12. End view of branches. x6.
Hamilton group. *Moscow, N. Y.*

BRYOZOA.

Generic Illustrations.

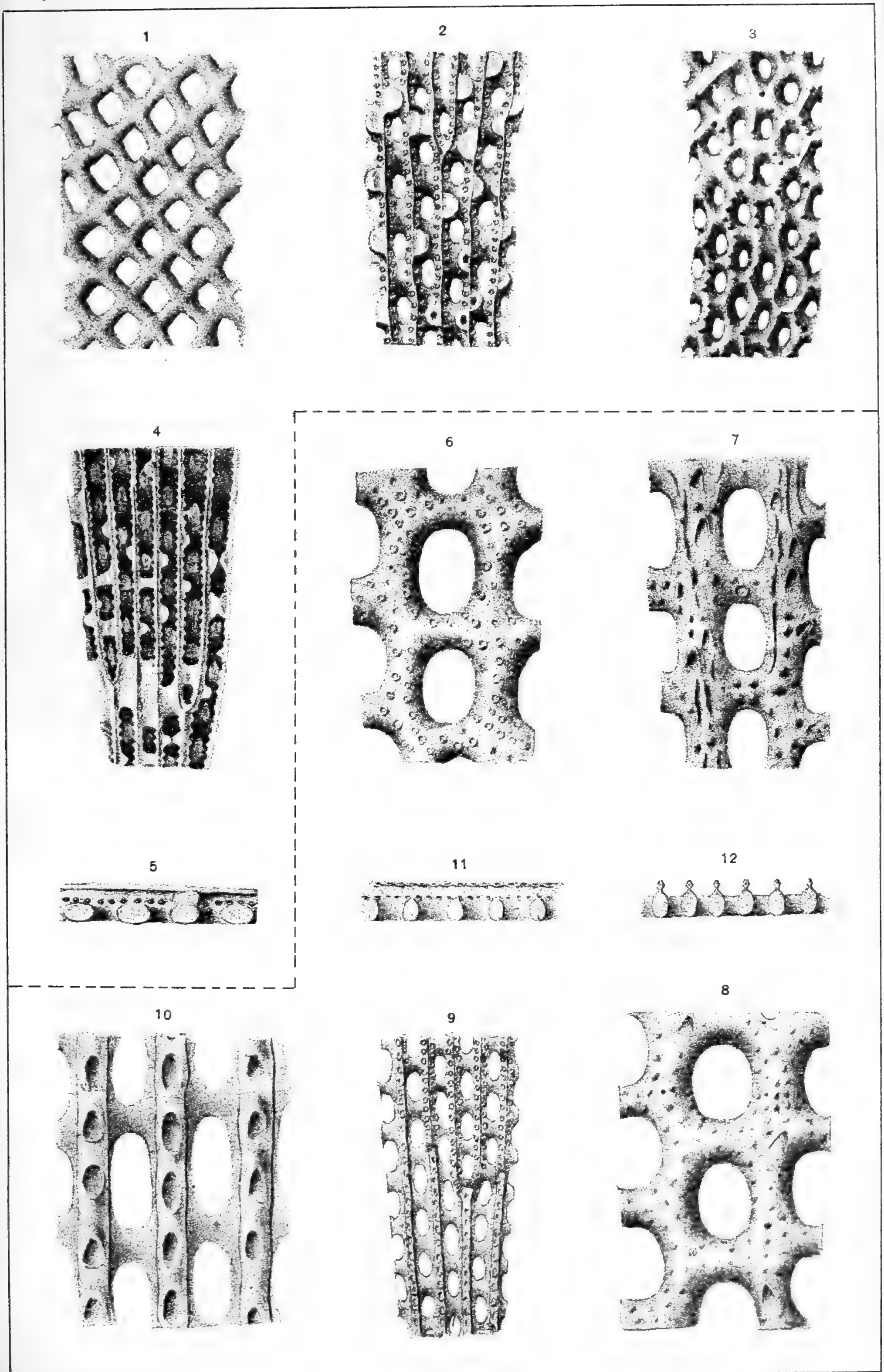

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PLATE IV.

PTILOPORELLA.

(Page 506.)

PTILOPORELLA INEQUALIS, Hall.

Fig. 1. A fragment of a specimen, natural size.
Fig. 2. An enlargement of a portion of the preceding figure. x6.
Upper Helderberg group. *Walpole, Ontario.*

PTILOPORELLA LATICRESCENS, Hall.

Fig. 3. A fragment, natural size.
Fig. 4. A transverse section of the branches. 6x.
Fig. 5. An enlargement from the noncelluliferous face of a frond, showing two of the primary branches. x6.
Fig. 6. An enlargement from the celluliferous face of Fig. 3, showing the form and arrangement of the cell apertures.
Upper Helderberg group. *Walpole, Ontario.*

PINNAPORINA.

(Page 507.)

PINNAPORINA PINNATA, Hall (sp.).

Fig. 7. A fragment of a frond, natural size.

PTILOPORINA.

(Page 507.)

PTILOPORINA CONICA, Hall.

Fig. 8. A fragment, natural size.
Upper Helderberg group. *Schoharie, N. Y.*

PTILOPORINA SINISTRALIS.

Fig. 9. A frond, natural size, showing all of the secondary branches proceeding from the sinistral side of the primary or larger branches.
Fig. 10. An enlargement of a portion of the same frond. x6.
Upper Helderberg group. *Walpole, Ontario.*

PTILOPORINA DISPARILIS.

Fig. 11. A fragment, natural size.
Fig. 12. An enlargement from the celluliferous face, showing from two to five ranges of cell apertures. x6.
Upper Helderberg group. *Walpole, Ontario.*

BRYOZOA.

Generic Illustrations.

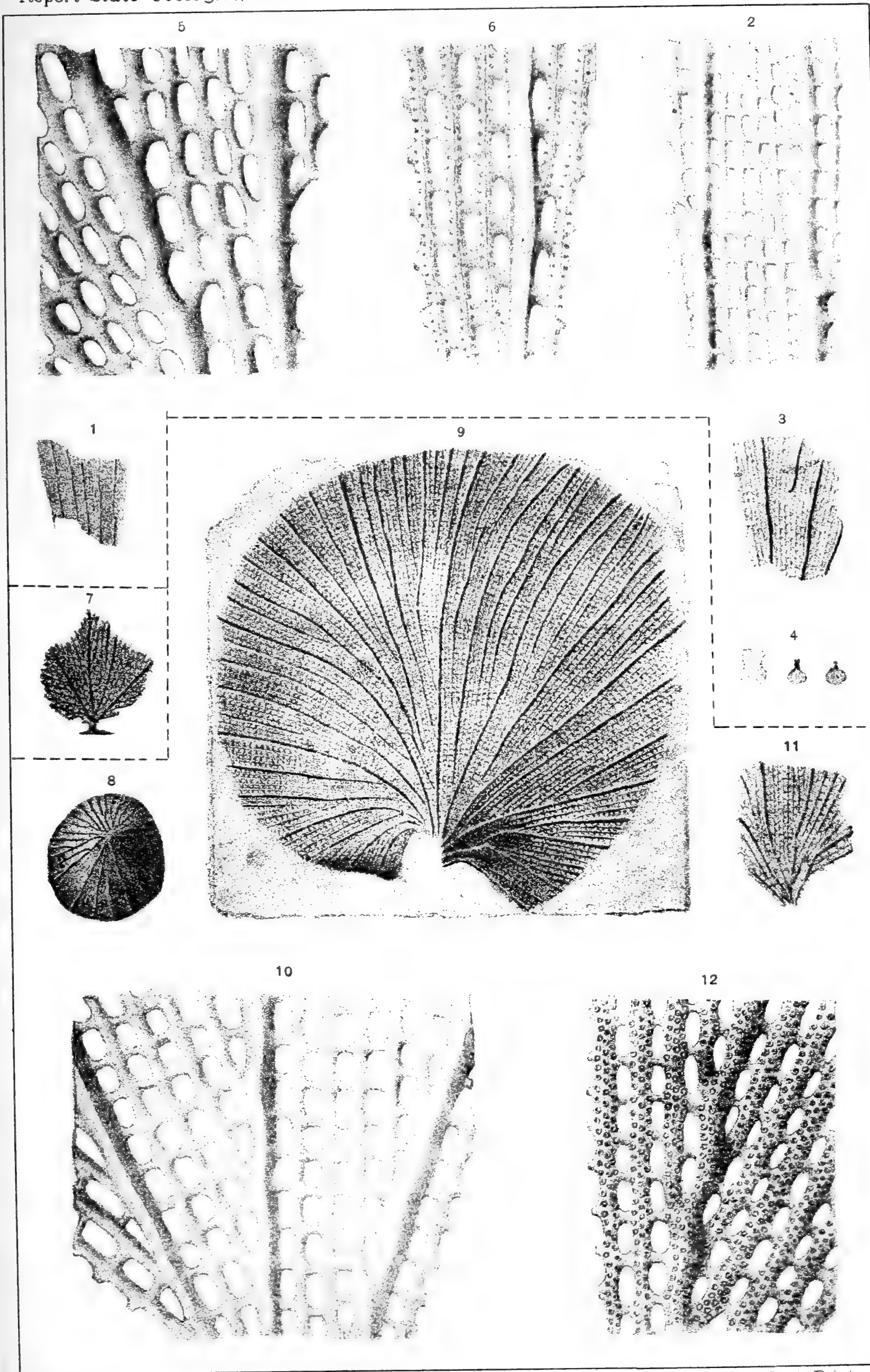

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PLATE V.

HEMITRYPA.

(Page 507.)

HEMITRYPA CRIBROSA, Hall.

Fig. 1. An enlargement of the base of a specimen. x6.

Fig. 2. A still further enlargement of the same specimen. x18.
Upper Helderberg group. *Falls of the Ohio*.

HEMITRYPA COLUMELLATA, Hall.

Fig. 3. A fragment, natural size.

Fig. 4. An enlargement from the noncelluliferons face of the frond. x6.

Fig. 5. An enlargement from the celluliferous face of a frond. The upper portion of the figure shows the superimposed hemitrypic structure. x6.

Fig. 6. A side view of a portion of a branch and carina. x6.

Fig. 7. End view of branches and carinæ. x6.

Fig. 8. Side view of a branch showing the cell apertures and the columellar appearance of the broken carina.

Fig. 9. Noncelluliferous face. x6.

Fig. 10. An impression in the rock of the celluliferous face. x6.

Fig. 11. Pseudo-carinæ and connecting scalæ. x6.
Upper Helderberg group. *Walpole, Ontario*.

UNITRYPA.

(Page 508.)

UNITRYPA CONNEXA, Hall.

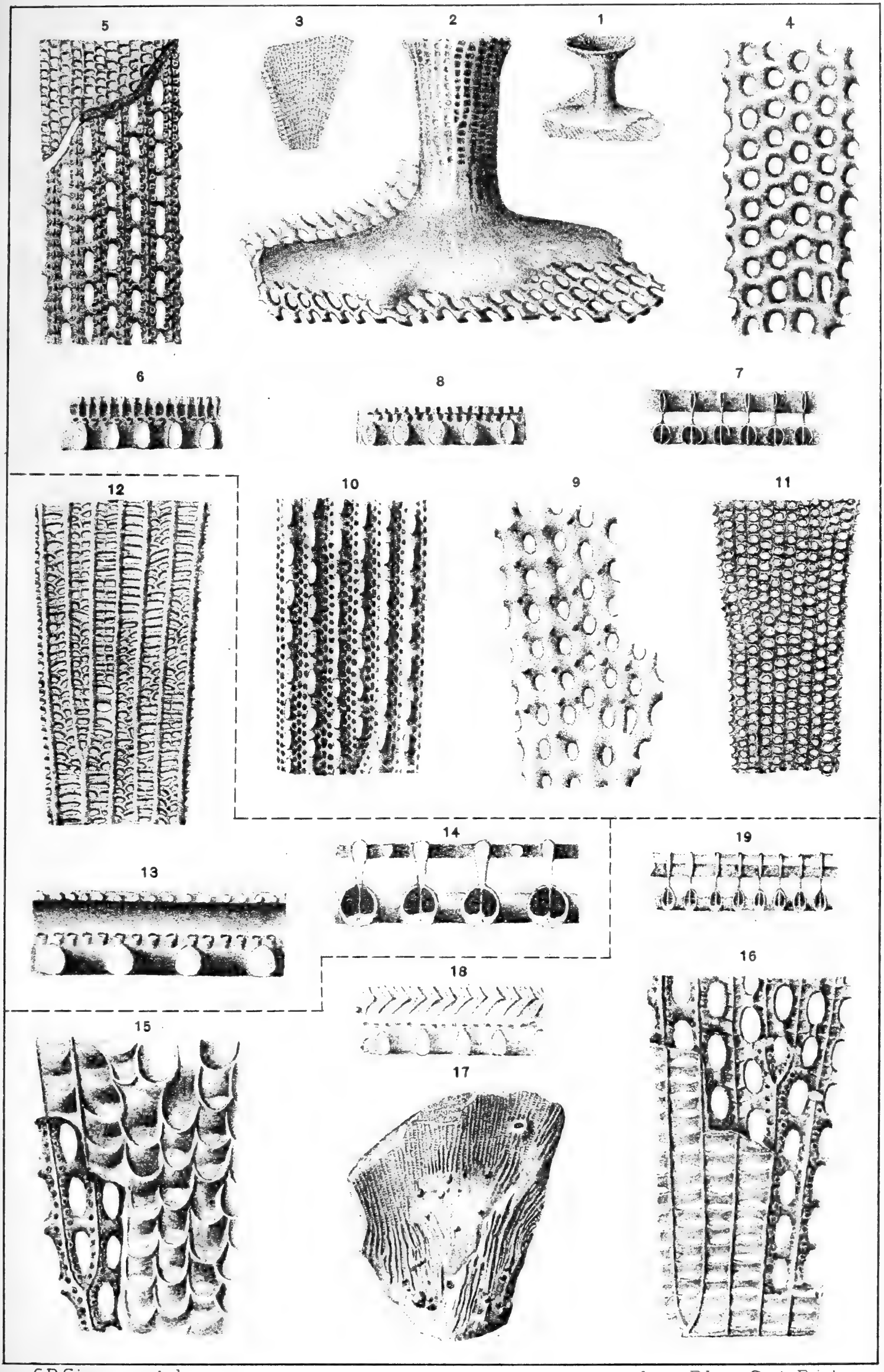
Fig. 12. An enlargement of the summits of the carinæ and connecting scalæ. On portions of the figure the scalæ are of unitrypic character, while on other portions they are hemitrypic. This species could, with equal propriety, be included in either UNITRYPA or HEMITRYPA.

Fig. 13. Side view of a portion of a branch and its carinæ. x6.

Fig. 14. Transverse section of branches and carinæ. x6.
Upper Helderberg group.

BRYOZOA.

Generic Illustrations.



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UNITRYPA ACCLIVIS, Hall.

Fig. 15. An enlargement. The lower left-hand corner shows the celluliferous face of the branches; the other portion showing the irregular summits of the carinæ and the connecting scalæ.

Upper Helderberg group. *Falls of the Ohio*.

UNITRYPA LATA.

Fig. 16. An enlargement, showing the summits of the carinæ and connecting scalæ, the celluliferous face of the branches, and also the interior of the branches.

Fig. 17. A fragment of a frond, showing the unitrypic face, natural size.

Fig. 18. A side view of a portion of a branch and its carina. x6.

Fig. 19. A transverse section of branches and their carinæ. x6.

PLATE VI.

UNITRYPA.

(Page 508.)

UNITRYPA FASTIGATA, Hall.

Fig. 1. A fragment of a frond, showing the noncelluliferous face, natural size.

Fig. 2. A fragment of a frond, showing the unitrypic characters, natural size.

Fig. 3. A transverse section of branches and their carinæ.

Fig. 4. A side view of a branch, showing the form of the scalæ. x6.

Fig. 5. An enlargement from the noncelluliferous face of the frond. x6.

Fig. 6. An enlargement, showing the summits of the carinæ and their connecting scalæ. x6.

Upper Helderberg group.

ISOTRYPA.

(Page 510.)

ISOTRYPA CONJUNCTIVA, Hall.

Fig. 7. A transverse section of branches and their carinæ. x6.

Fig. 8. A side view of a portion of a branch and its carina. x6.

Fig. 9. A side view of the upper portion of a branch, showing the columellar appearance of the broken carinæ; in this respect closely resembling a HEMITRYPA.

Fig. 10. An enlargement from the noncelluliferous face of a frond, showing the conspicuous pores on or near the dissepiments.

Fig. 11. An enlargement from the celluliferous face of a frond. x6.

Fig. 12. An enlargement, showing the summits of the carinæ and their connecting bars. x6.

Upper Helderberg group. *Walpole, Ontario.*

TECTULIPORELLA.

(Page 510.)

TECTULIPORELLA CONSIMILIS, Hall (sp.).

Fig. 13. An enlargement. The left-hand portion of the figure shows the summits of the carinæ and connecting bars; the central, the celluliferous face of the branches; the right-hand portion the interior of the branches. x6.

Fig. 14. An enlargement, showing the celluliferous face of the branches. x6.

Fig. 15. An enlargement, showing the summits of the carinæ and their connecting bars. x6.

Upper Helderberg group.

BRYOZOA.

Generic Illustrations.

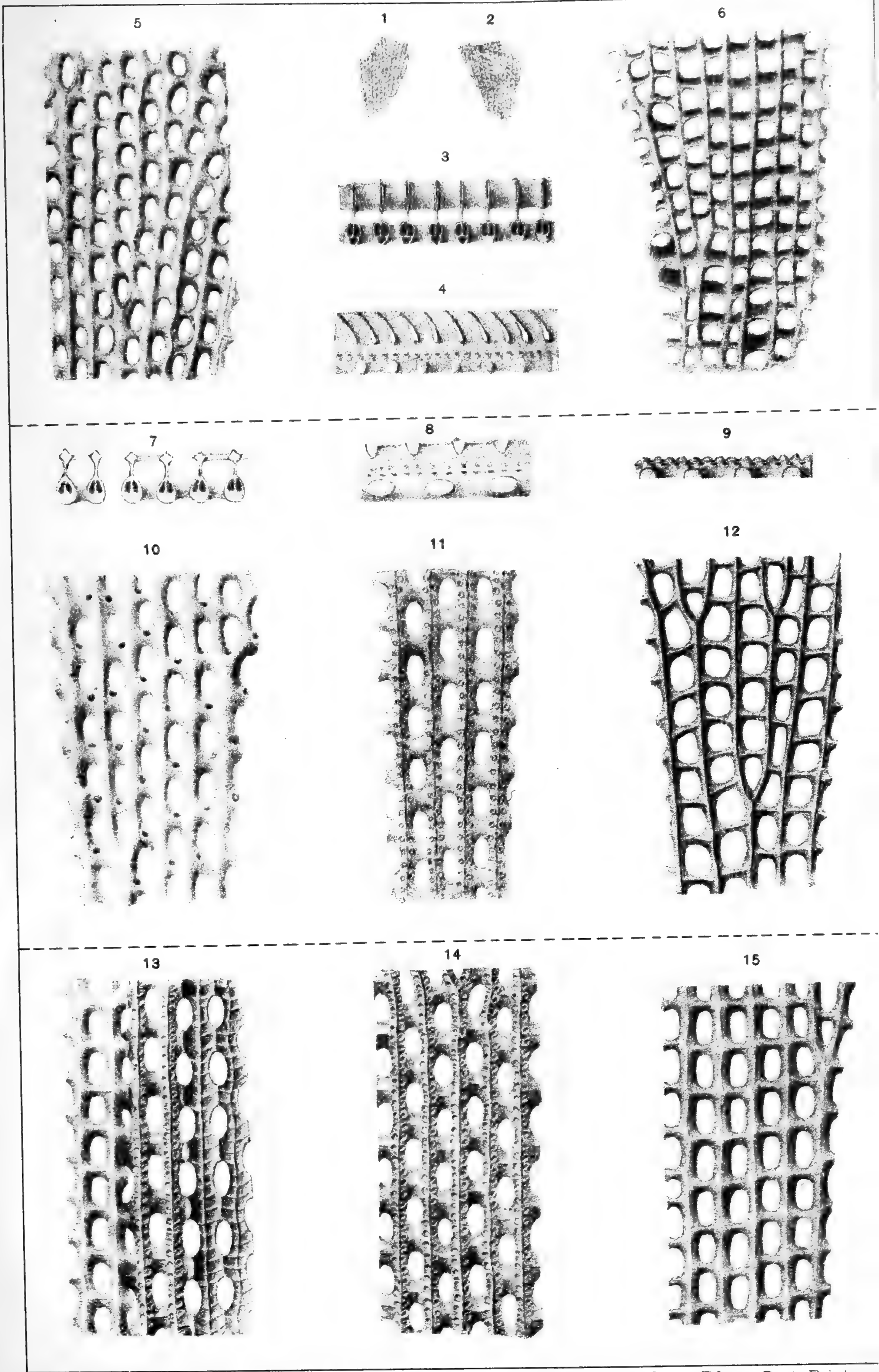

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PLATE VII.

TECTULIPORA.

(Page 511.)

TECTULIPORA BIPERFORATA.

Fig. 1. A transverse section of branches and carinæ. x18.

Fig. 2. A side view of a branch, showing sections of the dissepiments and their carinæ. x18.

Fig. 3. An enlargement from the noncelluliferous face of a frond. x18.

Fig. 4. An enlargement from the celluliferous face of a frond. x18.

Fig. 5. An enlargement, showing the summits of the carinæ of the branches and dissepiments. x18.

Upper Helderberg group. *Walpole, Ontario.*

LOCULIPORA.

(Page 511.)

LOCULIPORA PERFORATA, Hall.

Fig. 6. A side view of a branch, showing a section of the dissepiments and their carinæ. x6.

Fig. 7. A transverse section of three of the branches and their carinæ. x18.

Fig. 8. An enlargement from the noncelluliferous face of a frond. x6.

Fig. 9. An enlargement of the summits of the carinæ of the branches and dissepiments. x6.

Fig. 10. An enlargement. The lower portion of the figure shows the celluliferous face of the branches; the upper portion the summits of the carinæ. x6.

Fig. 11. An enlargement from the celluliferous face of a frond. x6.

Fig. 12. A portion of a frond, natural size.

Lower Helderberg group. *Albany county, N. Y.*

BRYOZOA.

Generic Illustrations.

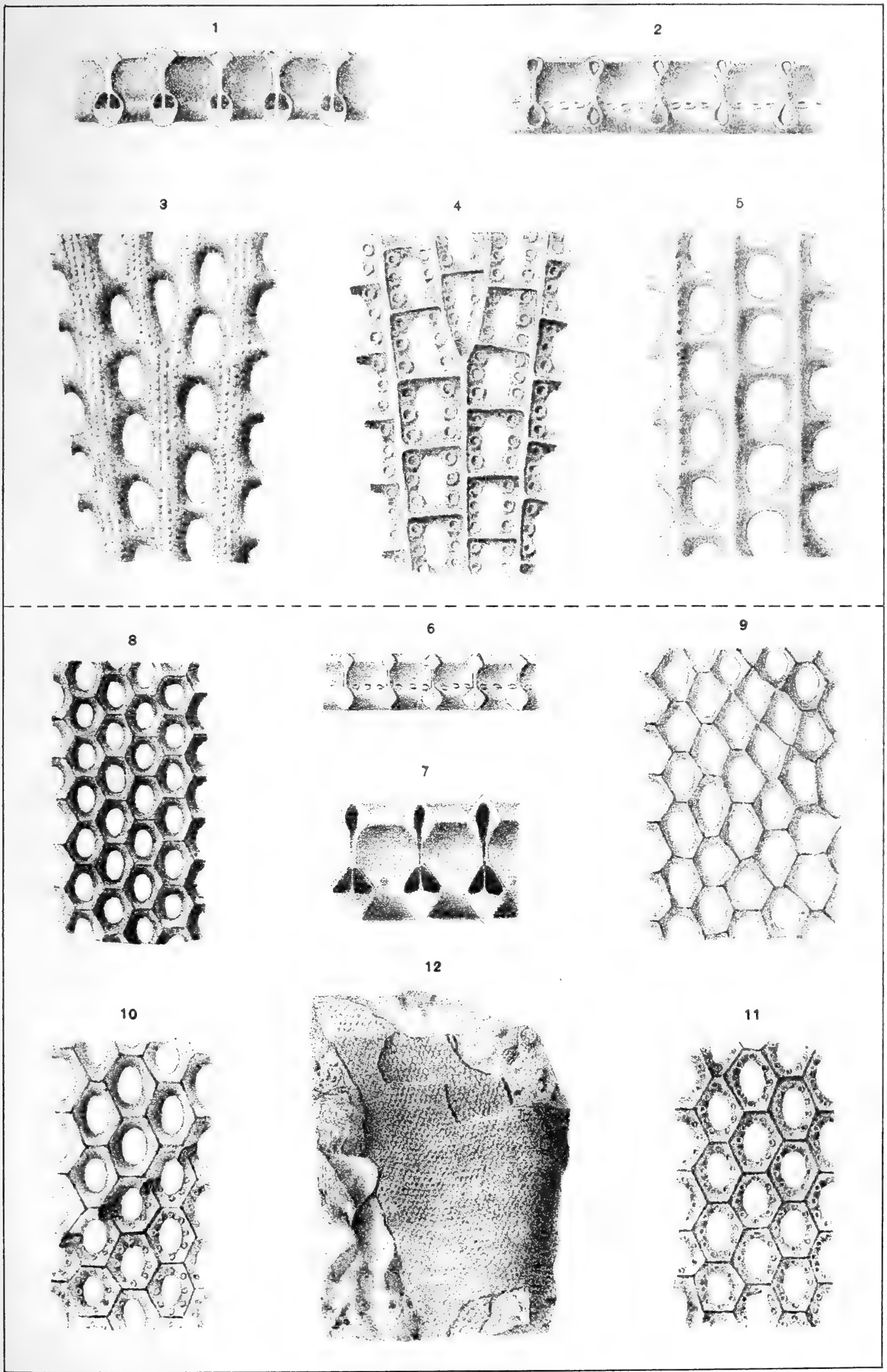

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PLATE VIII.

PTILOPORINA.

(Page 507.)

PTILOPORINA PINNATA, Hall.

Fig. 1. An enlargement of the noncelluliferous face. This figure is inserted here for comparison with PTILOPORA.

PTILOPORA.

(Page 519.)

PTILOPORA STRIATA, Hall.

Fig. 2. Noncelluliferous face. x6.
Fig. 3. Celluliferous face. x6.
Hamilton group. *Moscow, Livingston county, N. Y.*

PTILOPORA INFREQUENS, Hall.

Fig. 4. A fragment, natural size.
Fig. 6. The same specimen. x6.
Fig. 7. Noncelluliferous face of a fragment. x6.
Hamilton group. *Western New York.*

PTILOPORA NODOSA, Hall.

Fig. 5. The celluliferous face of a fragment. x6.
Hamilton group. *Near Alden, N. Y.*

GLAUCONOME.

(Page 524.)

GLAUCONOME SINUOSA, Hall.

Figs. 8, 9. Fragments, natural size.
Fig. 10. The celluliferous face. x6.
Upper Helderberg group. *Near Leroy, N. Y.*

GLAUCONOME TENUISTRIATA, Hall.

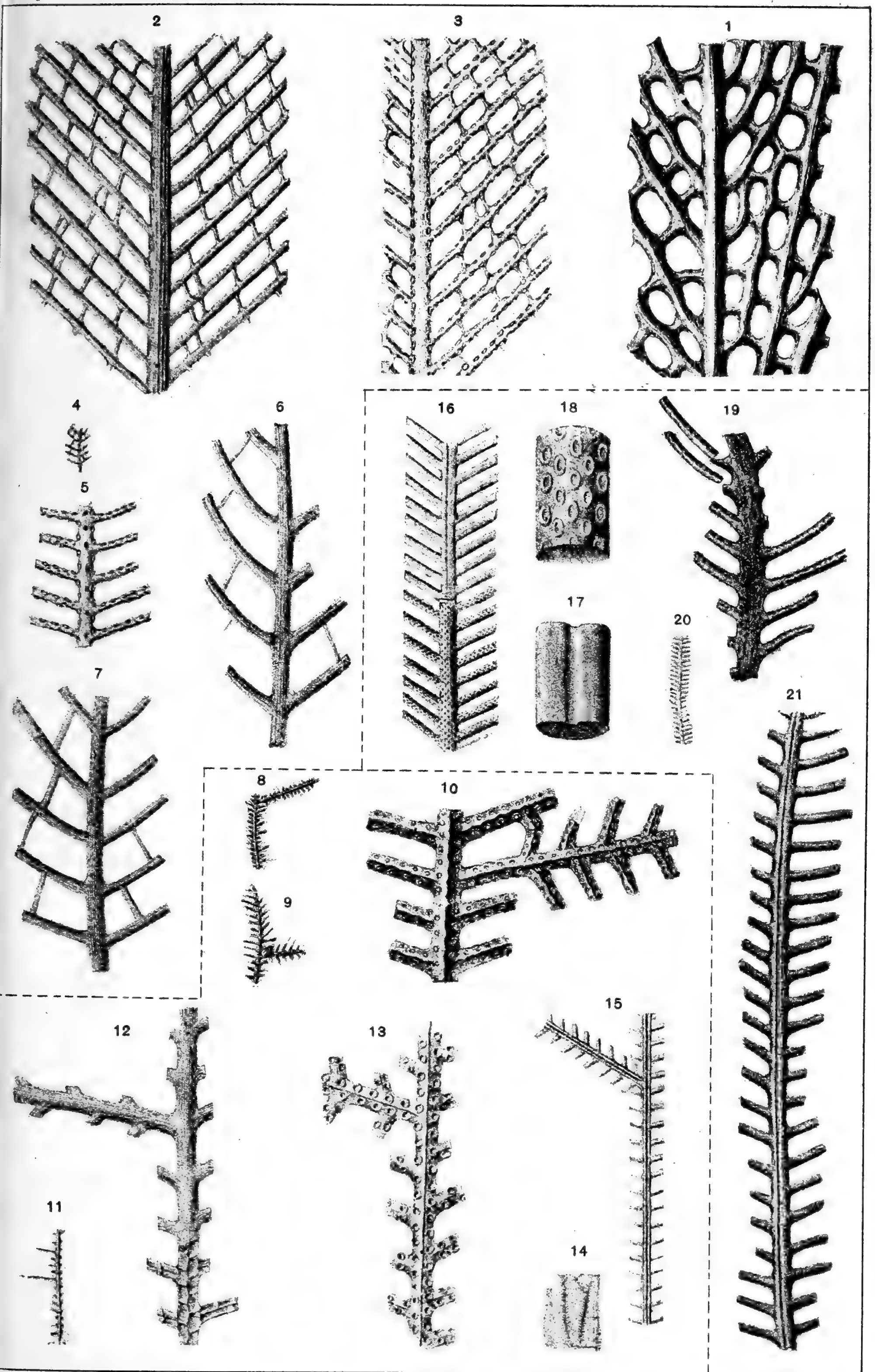
Fig. 11. A fragment, natural size.
Fig. 12. The noncelluliferous face. x6.
Fig. 13. The celluliferous face. x6.
Upper Helderberg group. *Near Buffalo, N. Y.*

GLAUCONOME CARINATA, Hall.

Fig. 14. Fragments, natural size.
Fig. 15. The noncelluliferous face. x6.
Hamilton group. *Full Brook, four miles east of Canandaigua Lake, N. Y.*

BRYOZOA.

Generic Illustrations.



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ICHTHYORACHIS.

(Page. 524)

ICHTHYORACHIS NEWENHAMI, McCoy.

Figs. 16–18. Copies of McCOY's original illustrations.

ICHTHYORACHIS NEREIS, Hall.

Fig. 19. The celluliferous face. x6.

Fig. 20. A fragment, natural size.

Fig. 21. The noncelluliferous face of a specimen. x6.
Lower Helderberg group. *Schoharie, N. Y.*

PLATE IX.

CRISINELLA.

(Page 526.)

CRISINELLA SCROBICULATA, Hall.

Fig. 1. A portion of a frond, natural size.
Fig. 2. Noncelluliferous face. x6.
Fig. 3. Celluliferous face. x6.
Upper Helderberg group.

THAMNICELLA.

(Page 525.)

THAMNICELLA NYSA, Hall.

Fig. 4. A fragment, natural size.
Fig. 5. The same. x6.
Lower Helderberg group. *Clarksville, N. Y.*

THAMNICELLA ASCUTA, Hall.

Fig. 6. A fragment, natural size.
Fig. 7. A portion of the celluliferous face. x9.
Fig. 8. A portion of the noncelluliferous face. x9.

THAMNICELLA CISSEIS, Hall.

Fig. 9. A frond, natural size.
Figs. 10, 11. A portion of the noncelluliferous face. x6.
Fig. 12. A portion of the celluliferous face. x6.
Fig. 13. A group of Bryozoa, among which are several specimens of this species.
Lower Helderberg group. *Clarksville, N. Y.*

THAMNISCUS.

(Page 524.)

THAMNISCUS VARIOLATA, Hall.

Fig. 14. A fragment of the noncelluliferous face of a frond. x3.

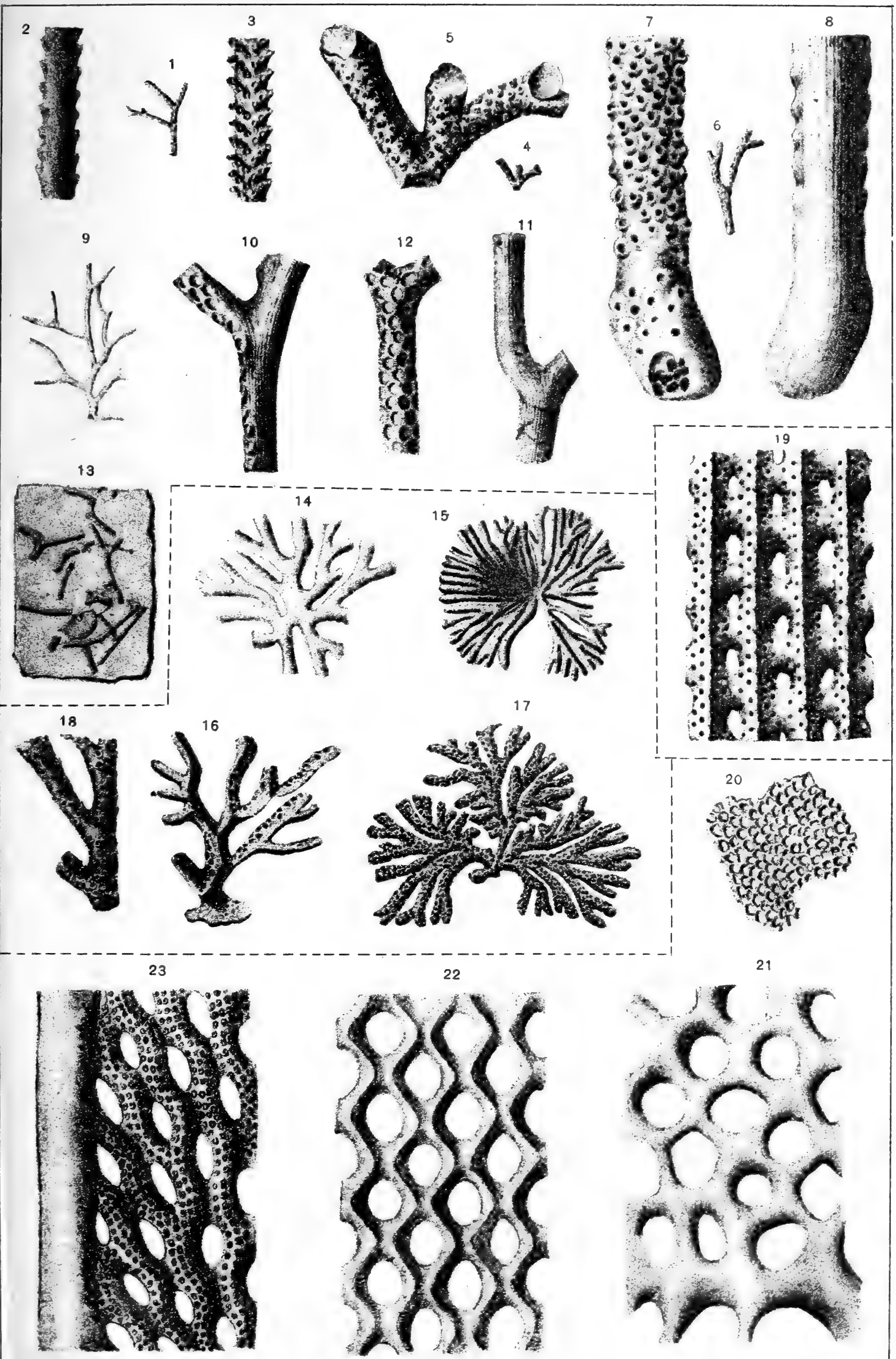
THAMNISCUS NIAGARENSIS, Hall.

Fig. 15. A frond, natural size.
Fig. 16. A portion of the celluliferous face. x2.
Fig. 17. A portion of the celluliferous face of another specimen, showing angular, carinated branches.
Niagara group. *Waldron, Indiana.*

BRYOZOA.

Generic Illustrations.

Report State Geologist, 1894. Plate 9.



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THAMNISCUS NANUS, Hall.

Fig. 18. A portion of the celluliferous face. x6.
Upper Helderberg group. *Falls of the Ohio.*

LYROPORIDRA.

(Page 517.)

LYROPORIDRA SUBQUADRANS, Ulrich (sp.).

Fig. 19. An enlargement of a portion of the celluliferous face of a frond, showing the disposition of the cell apertures.
Lower Carboniferous.

ANASTOMOPORA.

(Page 517.)

ANASTOMOPORA CINCTUTA, Hall (sp.).

Fig. 20. A fragment of a frond, natural size.

Fig. 21. An enlargement of a portion of the noncelluliferous face, showing irregular anastomosis. x6.

Fig. 22. An enlargement of the noncelluliferous face, showing regularly anastomosing branches. x6.

Fig. 23. An enlargement from the celluliferous face, showing the disposition of the cell apertures and the thickened margin of the frond.
Hamilton group.

PLATE X.

STICTOPORINA.

(Page 543.)

STICTOPORINA CLAVIFORMIS, Hall.

Fig. 1. A frond, natural size.
Fig. 2. The same. x6.
Hamilton group. *Bellona, N. Y.*

RHINIDICTYA.

RHINIDICTYA GRANULOSA, Hall.

Fig. 3. A segment, natural size.
Fig. 4. The same. x6.
Fig. 5. A still further enlargement of a portion of the surface, showing more distinctly the cell apertures and surface ornamentation.
Lower Helderberg group. *Catskill Creek, N. Y.*

STICTOCELLA.

(Page 532.)

STICTOCELLA INTERSTRIATA, Hall.

Fig. 6. A frond, natural size.
Fig. 7. A portion enlarged, showing the disposition of the cell apertures, the interapertural striations and the spinuliform projections in the cell tubes.
Hamilton group. *Alden, N. Y.*

STICTOPORINA.

(Page 532.)

STICTOPORINA SUBCARINATA, Hall.

Fig. 8. An enlargement of a portion of a branch. x6. The natural size of the frond is illustrated in fig. 6, pl. xii.
Hamilton group. *Bellona, N. Y.*

STICTOPORA.

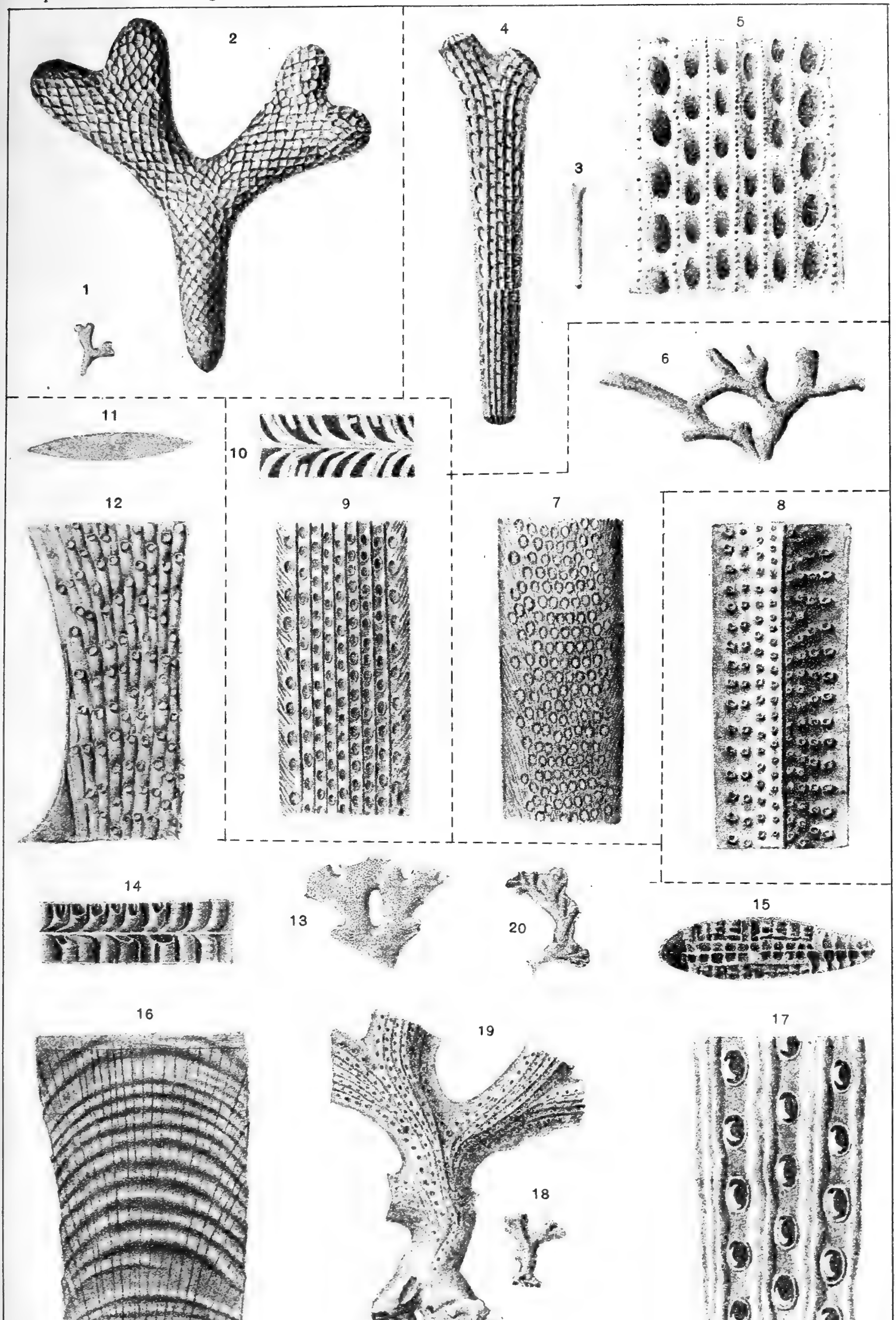
(Page 605.)

STICTOPORA CRESCENS, Hall.

Fig. 9. A portion of a frond. x6.
Fig. 10. A vertical section showing the form of the cell tubes, and the intercellular vesicular tissue. x6.
Upper Helderberg group. *Ontario.*

BRYOZOA.

Generic Illustrations.



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Stictopora palmipes, Hall.

Fig. 20. A frond, natural size.
Hamilton group. *New York.*

CYSTODICTYA.

(Page 536.)

Cystodictya incisurata, Hall.

Fig. 11. A transverse section of a branch. x6.
Hamilton group. *New York.*

Cystodictya gilberti, Meek.

Fig. 12. A portion of a frond from which the surface has been worn away, showing the cell tubes. x6.
Fig. 13. A fragment of a frond, natural size.
Fig. 14. A natural vertical section showing the cell tubes, and in some of them the septæ. x6.
Fig. 15. A natural transverse section. x6.
Fig. 16. An enlargement of the mesotheca, showing the transverse arching lines of growth and the longitudinal lines formed by the recumbent portion of the cell tubes. x6.
Fig. 17. An enlargement showing the cell apertures with denticulated projections. x6.
Upper Helderberg group. *Falls of the Ohio.*

Cystodictya ovatipora, Hall.

Fig. 18. A portion of a frond, natural size.
Fig. 19. The same. x6.
Upper Helderberg group. *Falls of the Ohio.*

PLATE XI.

INTRAPORA.

(Page 535.)

INTRAPORA PUTEOLATA, Hall.

Figs. 1–5. Fragments of fronds, natural size, showing variations in form.

Fig. 6. A portion of a frond. x6.

Fig. 7. A still further enlargement from the preceding figure. x18.

Fig. 8. An enlargement from another specimen having circular apertures and fewer interapertural pits. x18.

Fig. 9. A transverse specimen of one-half of a specimen. x6.

Upper Helderberg group. *Falls of the Ohio.*

SEMIOPORA.

(Page 535.)

SEMIOPORA BISTIGMATA, Hall.

Fig. 10. A frond, natural size.

Fig. 11. A portion of the preceding. x6.

Hamilton group. *New York.*

TÆNIOPORA.

(Page 533.)

TÆNIOPORA EXIGUA, Nicholson.

Fig. 12. A portion of the concave face. x6.

Fig. 13. A portion of the angular face. x6.

Fig. 14. The mesotheca worn away, showing the under portion of the cell tubes. x6.

Fig. 15. A transverse section of a branch. x6.

Fig. 16. A side view of the cell tubes, showing their form and mode of growth.

Hamilton group. *Various localities in New York.*

BRYOZOA.

Generic Illustrations.

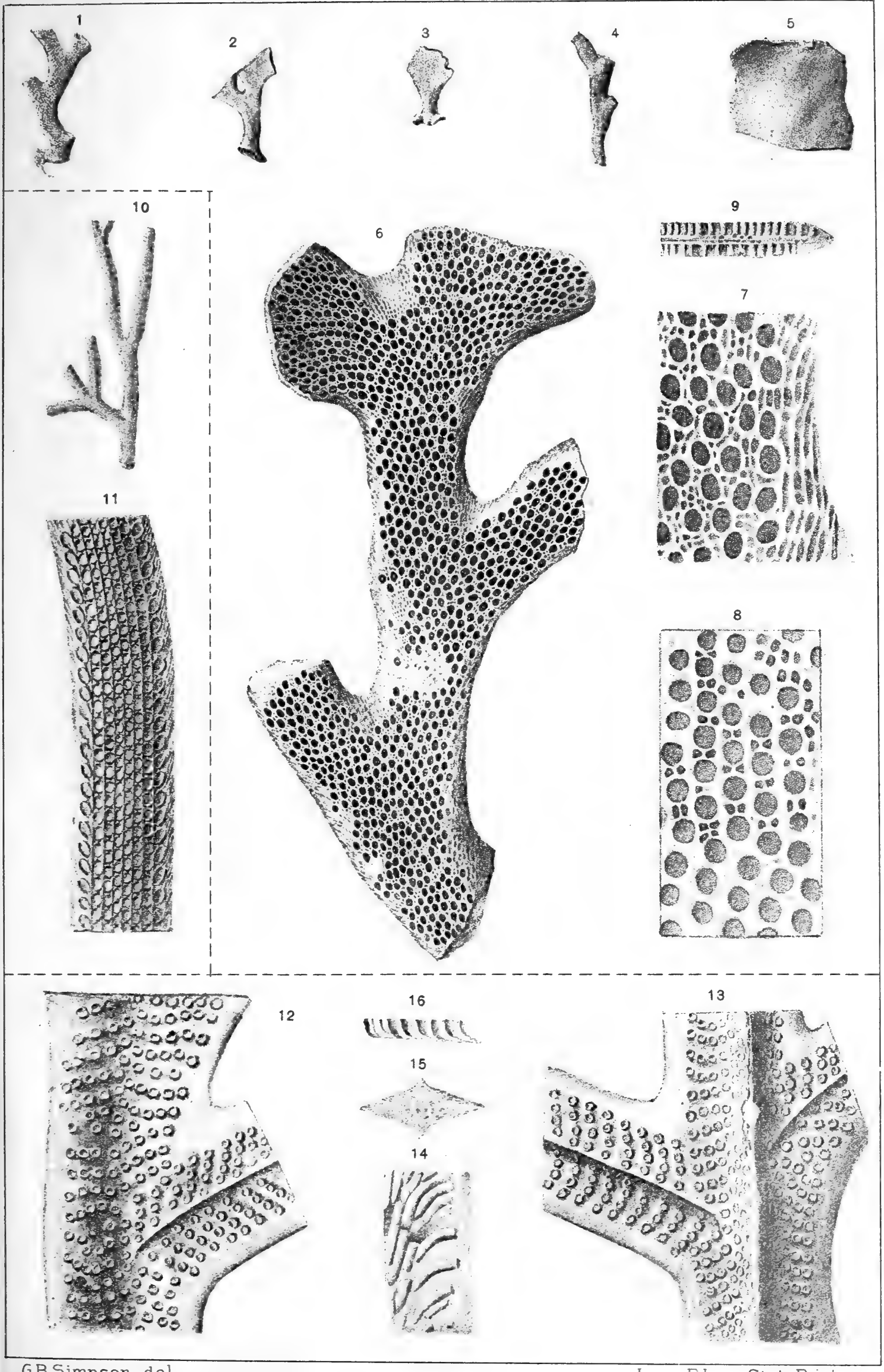

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PLATE XII.

TÆNIOPORA.

(Page 533.)

TÆNIOPORA EXIGUA, Hall.

Figs. 1, 2. Portions of fronds, natural size.

Fig. 3. A transverse section of the triangular main branch of fig. 1, x6. Compare this figure with fig. 15, *Prismopora triquetra.*

Fig. 4. An enlargement of a portion of a frond. x6.

Fig. 5. An enlargement from a specimen having only two ranges of cell apertures on each side of the carinæ. x6.

Hamilton group. *New York.*

STICTOPORINA.

(Page 532.)

STICTOPORINA SUBCARINATA.

Fig. 6. This figure is inserted here for comparison with figs. 1 and 2.

Hamilton group. *New York.*

THAMNOTRYPA.

(Page 546.)

THAMNOTRYPA DIVARICATA, Hall.

Fig. 7. A frond, natural size.

Fig. 8. A portion of the same. 6x.

Upper Helderberg group. *Near Buffalo, N. Y.*

PRISMOPORA.

(Page 531.)

PRISMOPORA TRIQUETRA, Hall.

Figs. 9, 10. Two specimens, natural size.

Fig. 11. A portion of one face of a branch. x6.

Fig. 12. An enlargement, showing the denticulated cell apertures. x18.

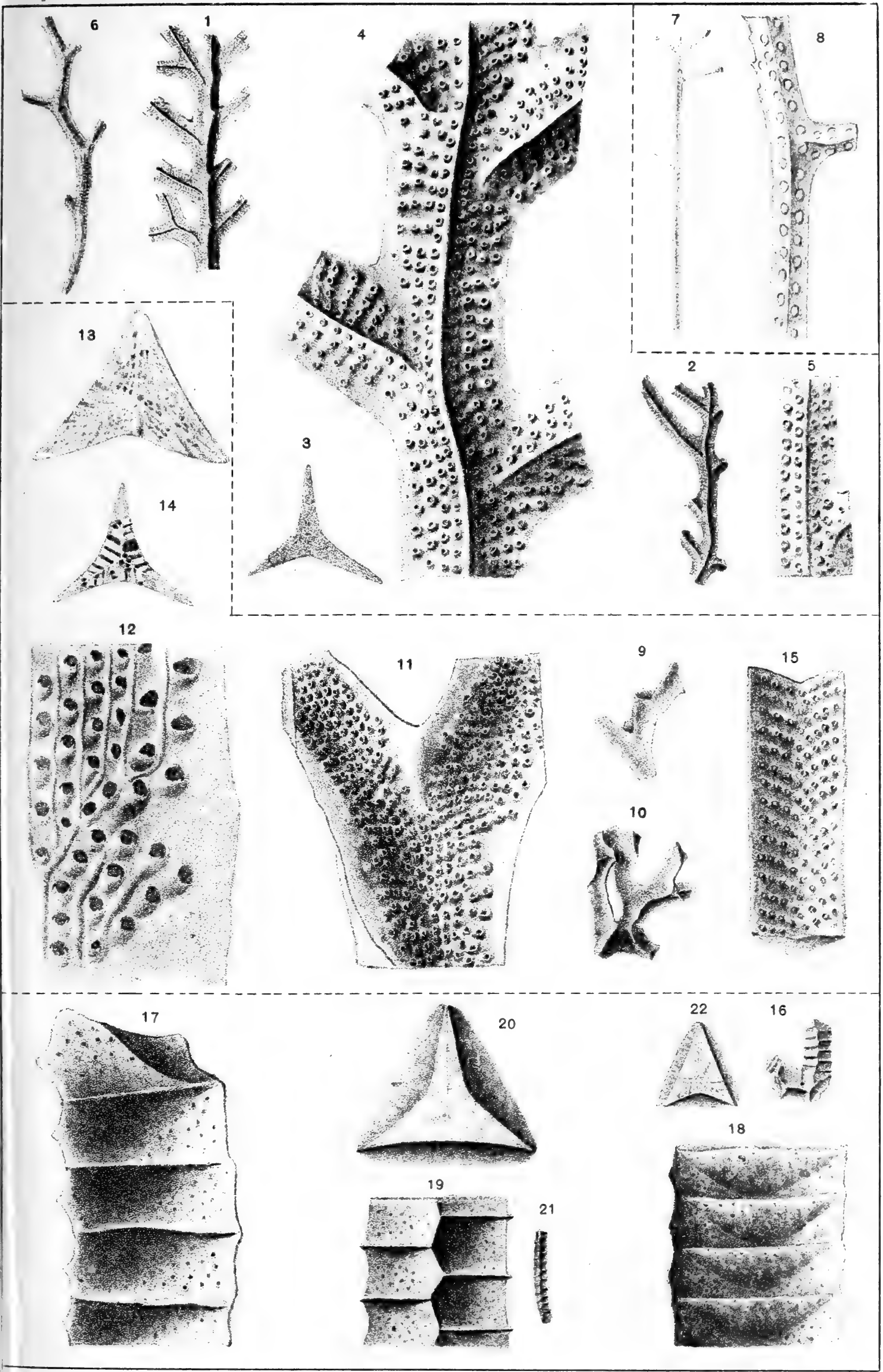
Fig. 13. A transverse section, showing the mesotheca and intercellular vesiculose tissue. x6.

Fig. 14. A natural transverse section showing mesotheca and cell tubes. x6.

Upper Helderberg group. *Falls of the Ohio.*

BRYOZOA.

Generic Illustrations.



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PRISMOPORA SUBTRIQUETRA, Hall.

Fig. 15. A portion of one of the faces of a branch. x6.
Upper Helderberg group. *Falls of the Ohio.*

SCALARIPORA.

(Page 532.)

SCALARIPORA SCALARIFORMIS, Hall.

Fig. 16. A specimen, natural size.
Fig. 17. An enlargement of the concave face of a branch. x6.
Fig. 18. An oblique view of the same, showing the form of the scalæ. x6.
Fig. 19. An enlargement of the two narrower faces of a frond. x6.
Fig. 20. A transverse section, showing the radiating mesothecæ, the cell tubes and the form of the scalæ. x6.
Upper Helderberg group. *Falls of the Ohio.*

SCALARIPORA SUBCONCAVA, Hall.

Fig. 21. A fragment, natural size.
Fig. 22. A transverse section. x6.
Upper Helderberg group. *Falls of the Ohio.*

PLATE XIII.

COSCINOTRYPA.

(Page 537.)

COSCINOTRYPA CRIBRIFORMIS, Hall.

Figs. 1–4. Fragments, natural size.

Fig. 5. A portion of a frond. x6.

Fig. 6. An enlargement from another specimen, showing the denticulated cell apertures. x6.

Fig. 7. A transverse section, showing one of the elevations, a feature characteristic of this genus, natural size.

Upper Helderberg group. *Falls of the Ohio.*

COSCINIUM.

(Page 537.)

COSCINIUM STRIATUM, Hall.

Fig. 8. A specimen, natural size.

Fig. 9. An enlargement of a portion of fig. 8.

Fig. 10. A still further enlargement, showing the denticulated cell apertures. x18.

Fig. 11. A transverse section of the portion of the frond between the fenestrules. x6.

Fig. 12. One of the cell apertures. x72.

Hamilton group. *Widder, Ontario.*

BRYOZOA.

Generic Illustrations.

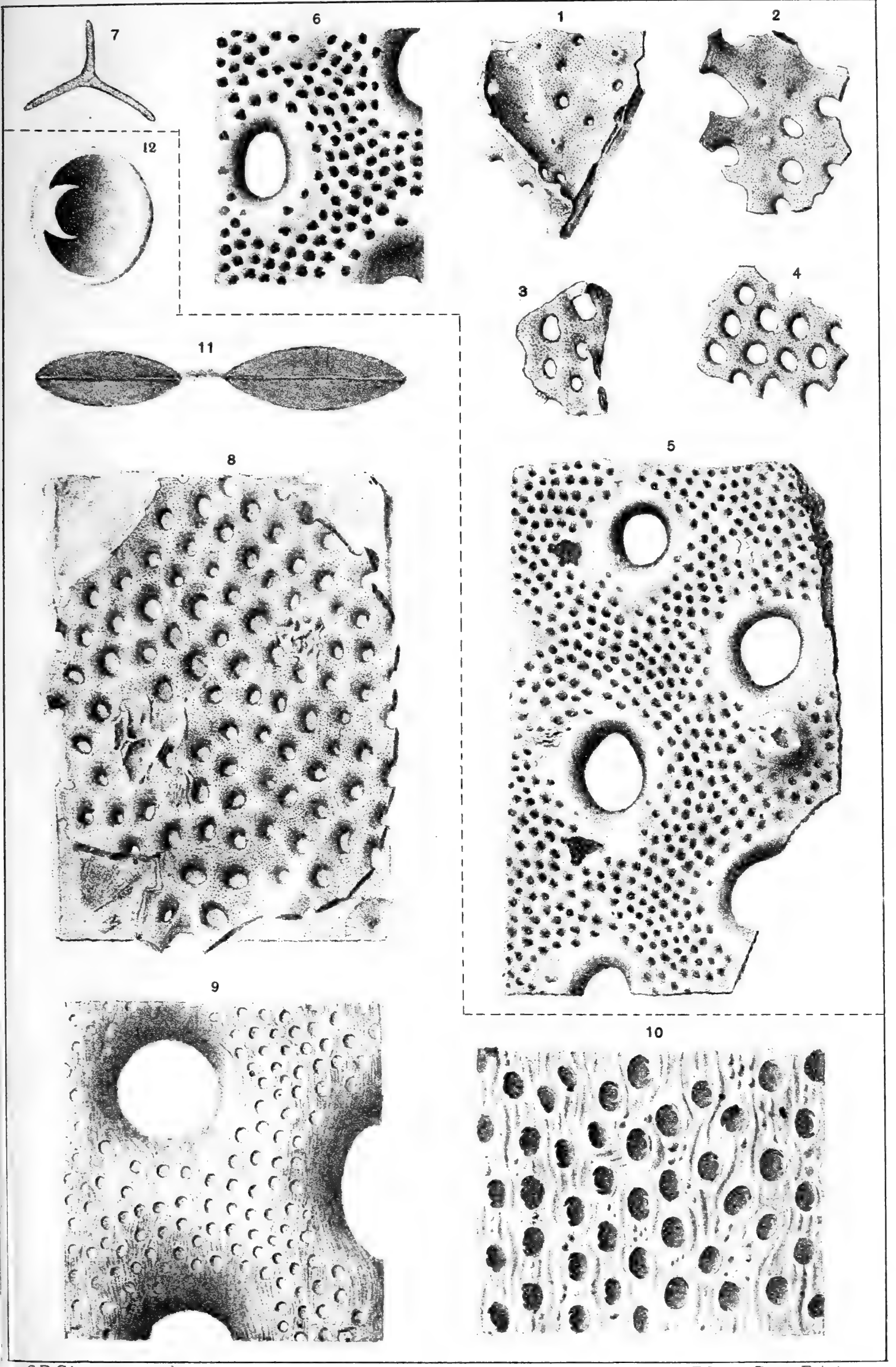

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PLATE XIV.

COSCINIUM.

(Page 537.)

Coscinium striaturum, Hall.

Fig. 1. A specimen, natural size.
Upper Helderberg group. *Stafford, N. Y.*

CERAMELLA.

(Page 527.)

Ceramella scidacea, Hall.

Fig. 2. A weathered specimen, natural size.
Fig. 3. An enlargement from the preceding. x6.
Fig. 4. A fragment of a well-preserved specimen, natural size.
Fig. 5. An enlargement from the preceding. x6.
Fig. 6. A vertical section, showing the form of the cell tubes and their manner of growth. x6.
Hamilton group. *New York.*

COSCINELLA.

(Page 534.)

Coscinella elegantula, Hall.

Fig. 7. A frond, natural size.
Fig. 8. A portion of the preceding figure. x6.
Fig. 9. A transverse section of the portion of the frond between adjacent cell apertures. x6.
Fig. 10. A vertical section, showing the form and manner of growth of the cell tubes and the intercellular vesiculose tissue. x6.
Fig. 11. An enlargement of the mesotheca. x6.
Fig. 12. An enlargement of one of the cell apertures. x72.
Hamilton group. *Widder, Ontario.*

BRYOZOA.

Generic Illustrations.

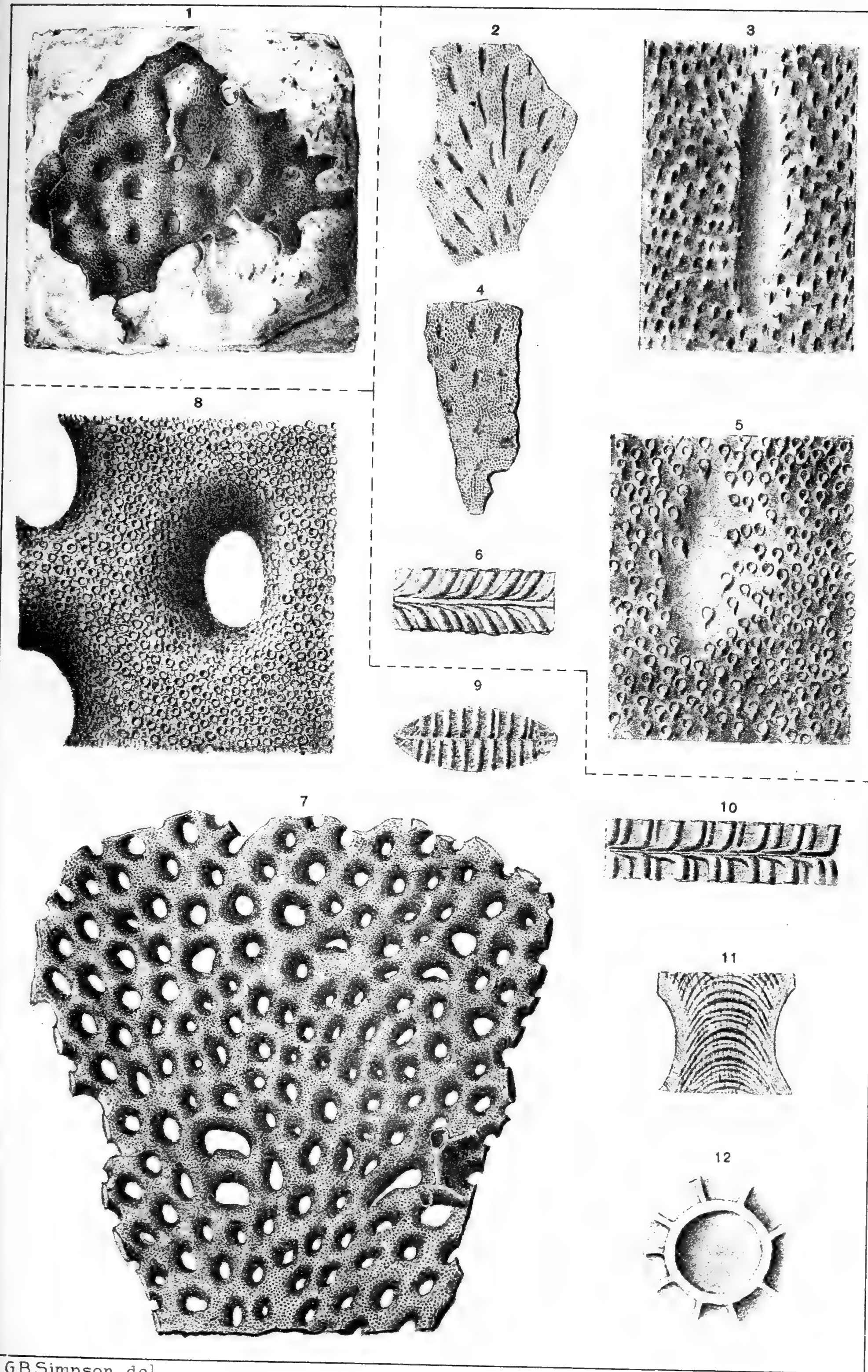

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PLATE XV.

PTILOCELLA.

PTILOCELLA PARALLELA, Hall.

Fig. 1. A specimen, natural size.
Fig. 2. A portion of the preceding. x6.
Fig. 3. A transverse section of a frond. x6.
Hamilton group. *Ontario county, N. Y.*

PTILODICTYA.

(Page 541.)

PTILODICTYA PLUMEA, Hall.

Fig. 4. A specimen, natural size.
Fig. 5. An enlargement of a portion of the surface. x6.
Fig. 6. An enlargement of the base of Fig. 4. x6.
Hamilton group. *West Hamburgh, N. Y.*

PTILODICTYA RETIFORMIS, Hall.

Fig. 7. An enlargement of the surface, showing the form and disposition of the cell apertures and the vestibular areas. x6.
Hamilton group. *Alden, N. Y.*

PHÆNOPORA.

(Page 541.)

PHÆNOPORA LIRATA, Hall.

Fig. 8. A portion of a specimen. x6.
Lower Helderberg group. *Clarksville, N. Y.*

PHÆNOPORA TENUIS, Hall.

Fig. 9. A specimen, natural size.
Fig. 10. An enlargement of the preceding. x6.
Lower Helderberg group. *Albany county, N. Y.*

ACROGENIA.

(Page 544.)

ACROGENIA PROLIFERA, Hall.

Figs. 11, 12. Segments, natural size.
Fig. 13. A perfect specimen, natural size.
Fig. 14. An enlargement of the roots of the preceding specimen. x6.

BRYOZOA.

Generic Illustrations.

Report State Geologist, 1894. Plate 15.

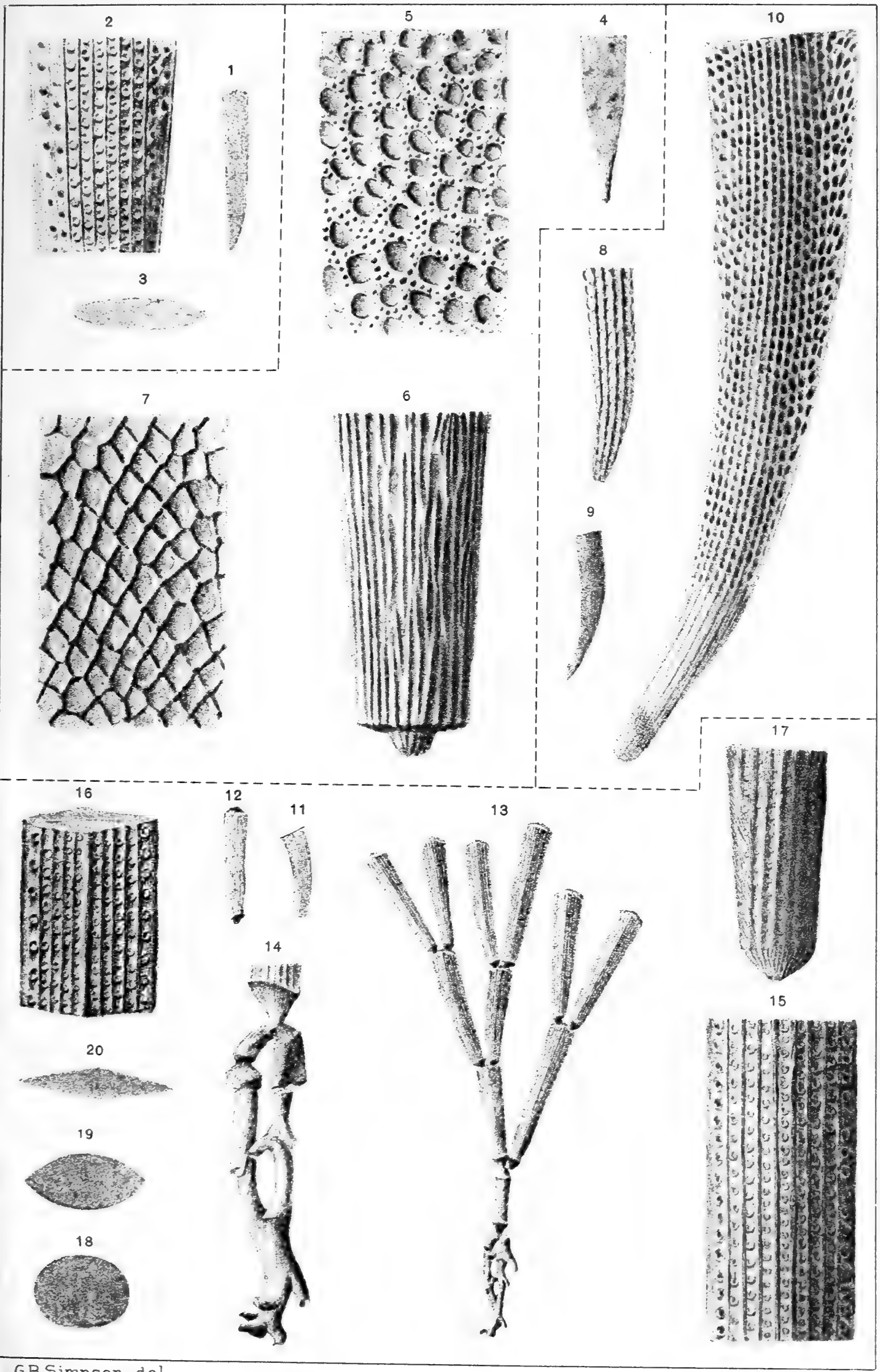

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Fig. 15. An enlargement from the central portion of a segment. x6.
Fig. 16. An enlargement from another segment, showing angular form and median carination. x6.
Fig. 17. An enlargement from the base of a segment. x6.
Figs. 18–20. Transverse sections from different portions of a segment. x6.

Hamilton group. *New York.*

PLATE XVI.

TROPIDOPORA.

(Page 553.)

Tropidopora nana, Hall.

Fig. 1. A fragment, natural size, with Aulopora.

Fig. 2. A portion of the preceding specimen. x18.
Upper Helderberg group. *Onondaga Valley, N. Y.*

DIAMESOPORA.

(Page 566.)

Diamesopora camerata, Hall.

Fig. 3. Several fragments of this species, natural size.

Fig. 4. A portion of a branch x6, showing the appearance and arrangement of the cell apertures and one of the maculæ.

Fig. 5. A section showing the cell tubes and epitheca. x6.
Upper Helderberg group. *Caledonia, N. Y.*

ACANTHOCLEMA.

(Page 552).

Acanthoclema alternatum, Hall.

Fig. 6. A specimen, natural size.

Fig. 7. A portion of the preceding specimen. x6.
Upper Helderberg group. *Onondaga Valley, N, Y.*

Acanthoclema scutulatum, Hall.

Fig. 9. A portion of a branch. x6.

Fig. 10. An enlargement showing the usual appearance and arrangement of the cell apertures. x18.

Fig. 11. An enlargement of a specimen having a pit at the base of each cell aperture in addition to the usual node.

Fig. 12. A vertical section. x18.
Hamilton group. *Canandaigua Lake, N. Y.*

BACTROPORA.

(Page 553).

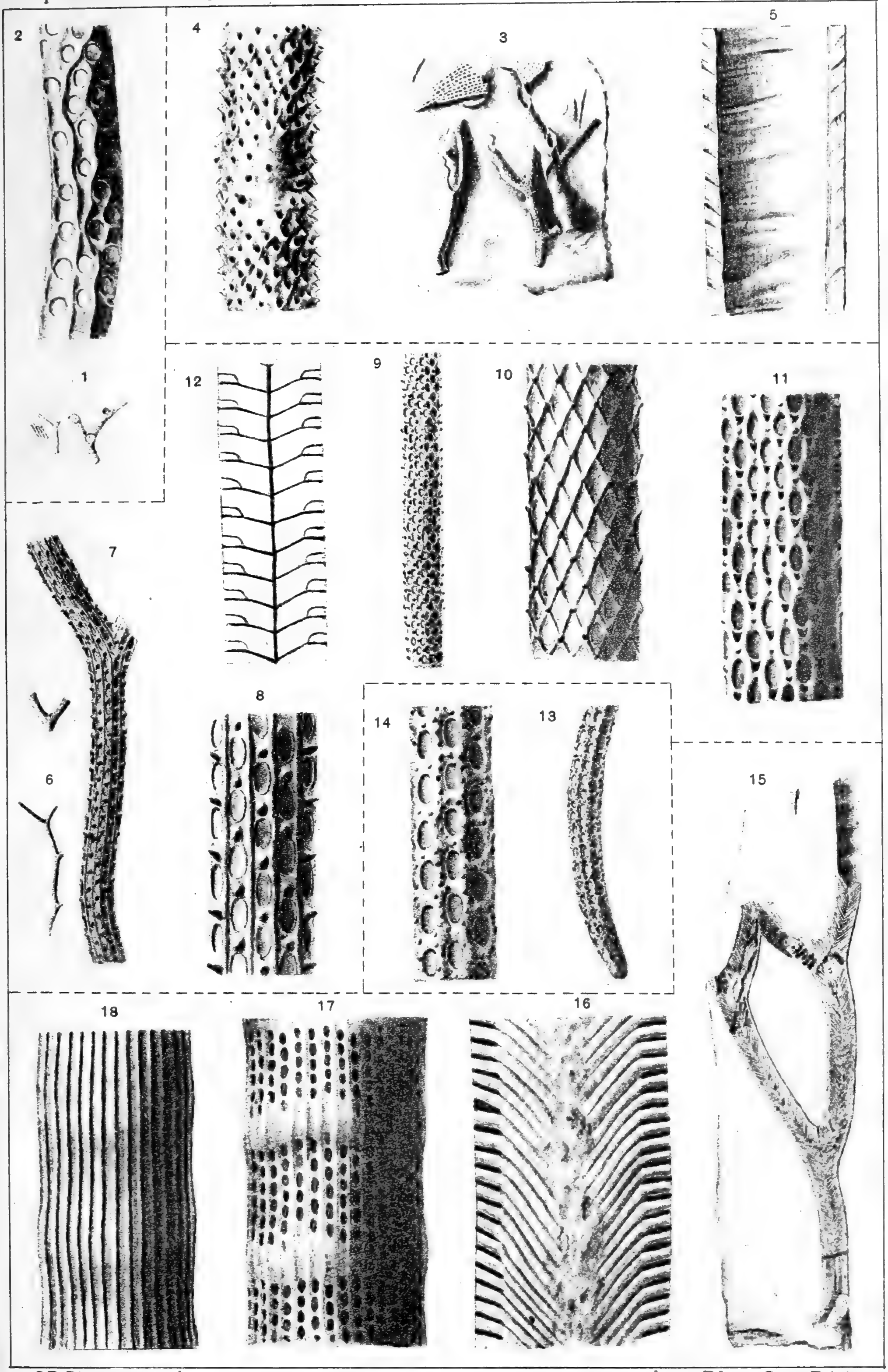
Bactropora curvata, Hall.

Fig. 13. A specimen. x6.

Fig. 14. A portion of the preceding specimen. x18.
Hamilton group. *Erie county, N. Y.*

BRYOZOA.

Generic Illustrations.



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NEMATAXIS.

(Page 552).

NEMATAXIS FIBROSUS, Hall.

Fig. 15. A specimen imbedded in the rock and fractured so as to show the internal structure, natural size.

Fig. 16. A part of the same. x6.

Fig. 17. A portion of a specimen showing the oval cell apertures disposed in regular longitudinal rows and maculæ destitute of cell apertures.

Fig. 18. A portion of a specimen having the cell apertures obliterated by a calcareous deposit.

Hamilton group. *Erie county, N. Y.*

PLATE XVII.

MONTICULIPORA.

(Page 577.)

MONTICULIPORA MAMMILLOSA, Hall.

Fig. 1. Zoarium, natural size.
Fig. 2. A vertical section. x6.
Fig. 3. A transverse section. x6.

These two sections show the generic characters.

Hudson River group. *Near Cincinnati, Ohio.*

PRASOPORA.

(Page 586).

Figs. 4, 5. A vertical and transverse section. x6.
Illustrating the characters of the genus.

AMPLEXOPORA.

(Page 577.)

Figs. 6, 7. A transverse and vertical section; illustrating the internal structure of the genus.

MONOTRYPELLA.

(Page 581.)

Fig. 8. An enlargement of the surface. x6.
Lower Helderberg group. *Near Schoharie, N. Y.*

PTYCHONEMA.

(Page 583.)

PTYCHONEMA TABULATUM, Hall.

Fig. 9. An enlargement of a portion, showing the peculiar corrugations of the cell tubes. x6.

Lower Helderberg group. *Near Schoharie, N. Y.*

BRYOZOA.

Generic Illustrations.

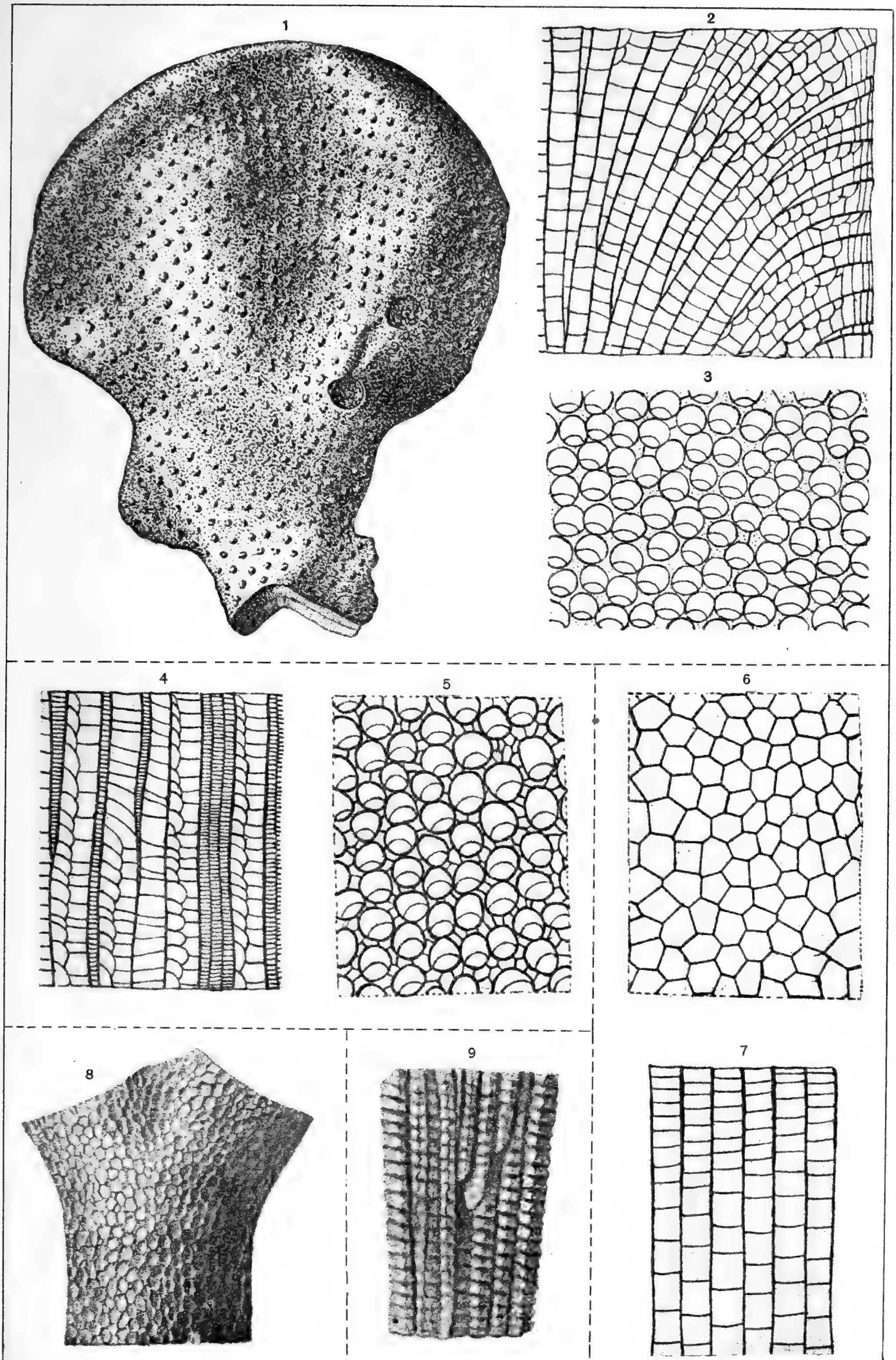

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PLATE XVIII.

CALLOPORA.

(Page 588.)

CALLOPORA ELEGANTULA, Hall.

Figs. 1, 2. Specimens, natural size.

Fig. 3. A fragment of a specimen fractured so as to show the cell tubes. x6.

Fig. 4. An enlargement of the surface, showing the form and arrangement of the cell apertures and interapertural openings. Several of the apertures on the lower portion of the figure have opercula.

Fig. 5. An enlargement of one of the apertures, showing the operculum. x100.

Figs. 6, 7. These sections show the tabulated cell tubes and the tabulated mesopores. x18.

Niagara group. *Lockport, N. Y.*

CALLOTRYPA.

(Page 551.)

CALLOTRYPA UNISPINA, Hall.

Fig. 8. A specimen, natural size.

Fig. 9. An enlargement showing the form and arrangement of the cell apertures and interapertural pits, and the prominent node at the base of each aperture. x18.

Fig. 10. An enlargement of one of the cell apertures and its accompanying node. x54.

Fig. 11. A thin vertical section, showing the internal structure. x18.

Lower Helderberg group. *New York.*

CALLOTRYPA MACROPORA, Hall.

Figs. 12, 13. Groups of Bryozoa, among which are several of this species.

Fig. 14. A portion of a branch. x18.

Lower Helderberg group. *New York.*

BRYOZOA.

Generic Illustrations.

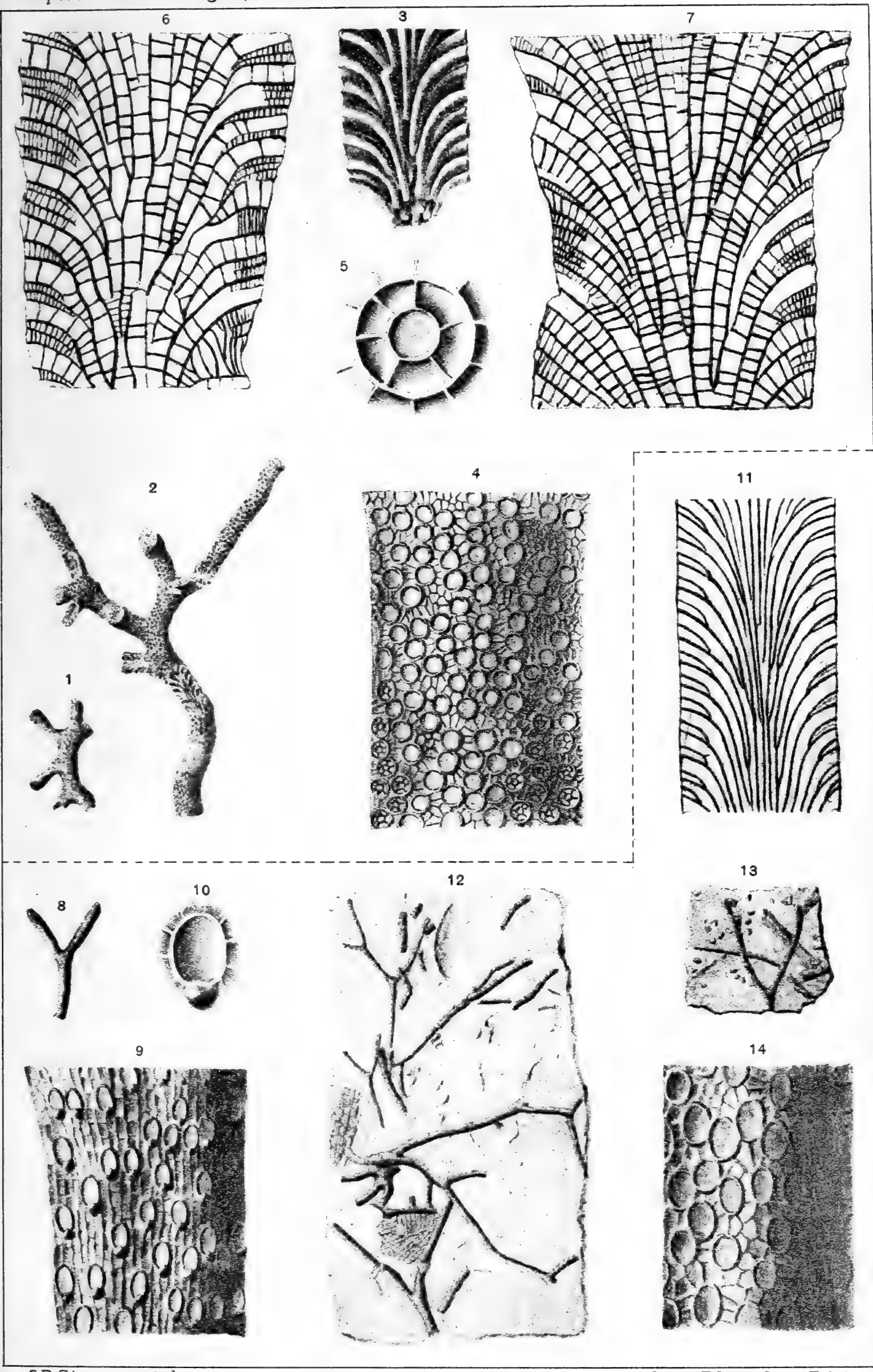

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PLATE XIX.

TREMATOPORA.

(Page 591.)

TREMATOPORA TUBERCULOSA, Hall.

Figs. 1, 2, 3. Fragments of this species, natural size.

Fig. 4. A portion of a branch showing the form and arrangement of the cell apertures, and the monticules destitute of cell apertures. x18.

Fig. 5. An enlargement of a thin section showing the cell tubes and the tabulated mesopores. x18.

Niagara group. *Lockport, N. Y.*

TREMATELLA.

(Page 550.)

TREMATELLA ANNULATA, Hall.

Figs. 6, 7. Specimens, natural size.

Fig. 8. A portion of a branch. x6.

Fig. 9. An enlargement of a thin section showing the internal structure.

Upper Helderberg group. *Falls of the Ohio.*

RHOMBOPORA.

(Page 550.)

RHOMBOPORA REGULARIS, Hall.

Fig. 10. A group of specimens, natural size.

Fig. 11. A portion of a branch. x18.

Upper Helderberg group. *Falls of the Ohio.*

RHOMBOPORA TRANSVERSA, Hall.

Fig. 12. A portion of a branch of this species. x6.

Fig. 13. An enlargement of a thin section showing the internal structure. x6.

Hamilton group. *Hamburgh, N. Y.*

STREBLOTRYPA.

(Page 551.)

STREBLOTRYPA HAMILTONENSE, Hall.

Fig. 14. An enlargement showing the regular arrangement of the cell apertures, the interapertural pits, and the sinuous ridges. x6.

Fig. 15. An enlargement from a specimen having unusually large cell apertures, and without the prominent longitudinal ridges.

Hamilton group. *West Williams, Ontario.*

BRYOZOA.

Generic Illustrations.

Report State Geologist, 1894. Plate 19.

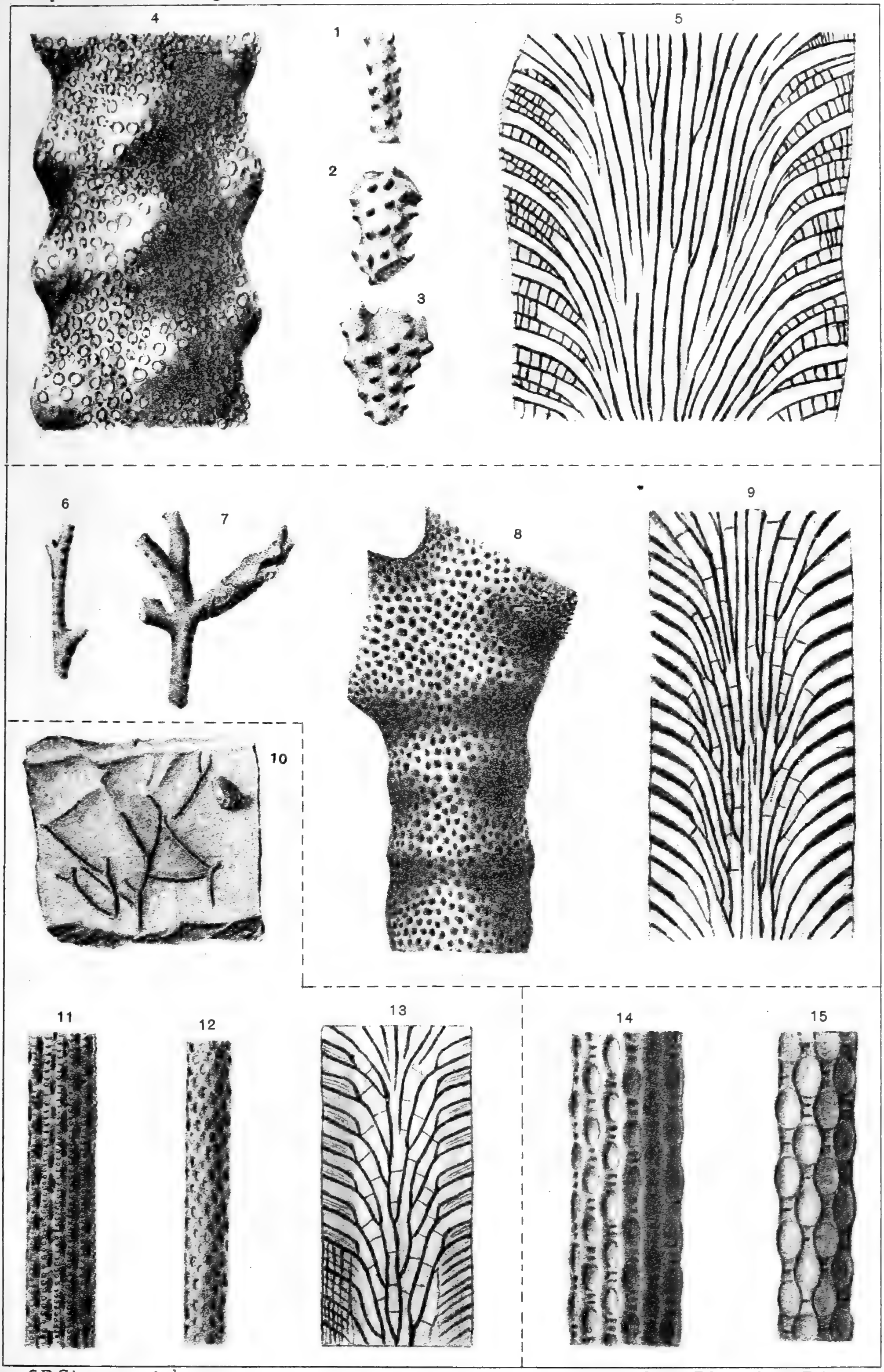

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PLATE XX.

PALESCHARA.

PALESCHARA INCRUSTANS, Hall.

Fig. 1. A zoarium incrusting *Streptelasma strictum*, natural size.

Fig. 2. An enlargement from the preceding, showing form and arrangement of the cells. x6.

Lower Helderberg group. *Near Clarksville, N. Y.*

PALESCHARA RADIATA, Hall.

Fig. 3. An enlargement, showing the form and arrangement of the cells. x6.

Lower Helderberg group. *Near Clarksville, N. Y.*

SAGENELLA.

(Page 597.)

SAGENELLA ELEGANS, Hall.

Fig. 4. An enlargement, showing the form of the cells. x6.

Niagara group.

CERAMOPORA.

(Page 563.)

CERAMOPORA MACULATA, Hall.

Figs. 5, 6, 7. The under side of three specimens, natural size.

Fig. 8. The upper surface of a specimen, natural size.

Fig. 9. An enlargement from the preceding figure, showing the form and arrangement of the cell apertures. x6.

Niagara group.

CERAMOPORA LABECULOIDEA, Hall.

Fig. 10. An enlargement of a zoarium. x6.

Lower Helderberg group. *Near Clarksville, N. Y.*

CERAMOPORA LABECULA, Hall.

Fig. 11. A fragment of a FENESTELLA, upon which are two separate colonies of this species. x6.

Niagara group.

CERAMOPORA PARVICELLA, Hall.

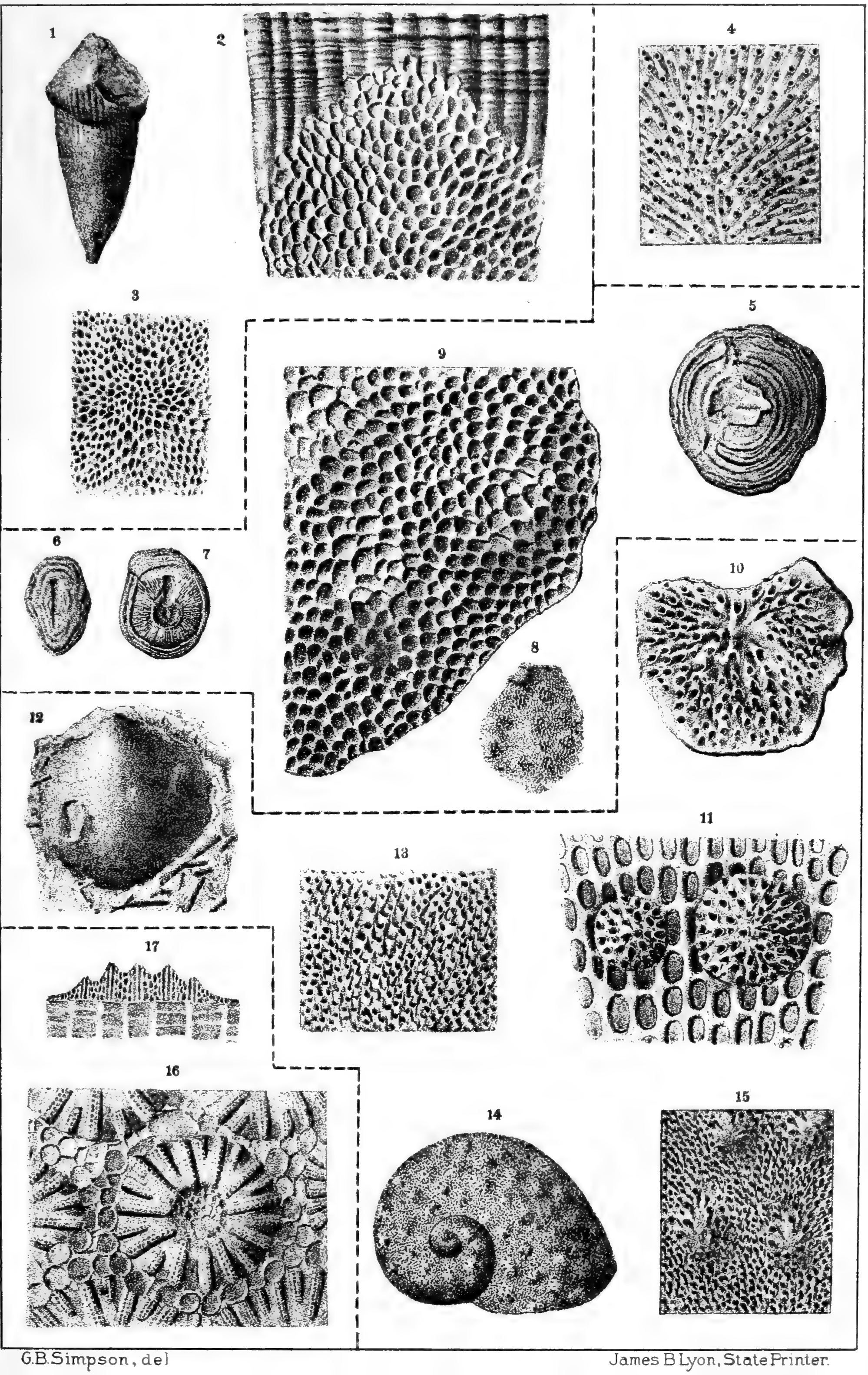
Fig. 12. A zoarium incrusting a MERISTELLA, natural size.

Fig. 13. An enlargement from the surface of the preceding, showing the form and arrangement of the cell apertures.

Lower Helderberg group. *Near Clarksville, N. Y.*

BRYOZOA.

Generic Illustrations.



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CERAMOPORA.

(Page 563.)

CERAMOPORA CONFLUENS, Hall.

Fig. 14. A zoarium entirely incrusting a specimen of *Platyostoma niagarense,* natural size.

Fig. 15. An enlargement, showing the character of the cells and the monticules. x6.

Niagara group. *Waldron, Indiana.*

BOTRYLLOPORA.

(Page 592.)

BOTRYLLOPORA SOCIALIS, Nicholson.

Fig. 16. An enlargement of a portion of a colony of this species. x6.

Fig. 17. An enlargement of a thin section showing the cell tubes and the intercellular vesicle. x6.

Hamilton group. *New York.*

PLATE XXI.

CHILOTRYPA.

(Page 554.)

CHILOTRYPA OSTIOLATA, Hall.

Fig. 1. Fragments of zoaria, natural size.

Fig. 2. An enlargement of a thin section showing the axial tube, the cell tubes and the intercellular vesicles. x9.

Niagara group. *Lockport, N. Y.*

CŒLOCAULIS.

(Page 554.)

CŒLOCAULIS VENUSTA, Hall.

Fig. 3. A fragment, natural size.

Fig. 4. An enlargement of the preceding. x6.

Fig. 5. An enlargement of a specimen fractured so as to show the cells, the intercellular vesicles and the epitheca. x9.

Lower Helderberg group. *Near Clarksville, N. Y.*

FISTULIPORINA.

(Page 555.)

FISTULIPORINA MICROPORA, Hall.

Fig. 6. An enlargement showing the manner of growth of the frond, the form and arrangement of the cell apertures and mesopores.

Hamilton group. *Erie county, N. Y.*

Figs. 7–10. Enlargements showing the internal structure of the following species:

Fig. 9. *F. stellata;* Fig. 10. *F. variopora.*

FISTULIPORINA DIGITATA, Hall.

Fig. 11. An enlargement of a frond incrusting a Cyathophylloid coral, showing the manner of growth and the form and arrangement of the cell apertures and mesopores. x6.

Hamilton group. *West Hamburgh, N. Y.*

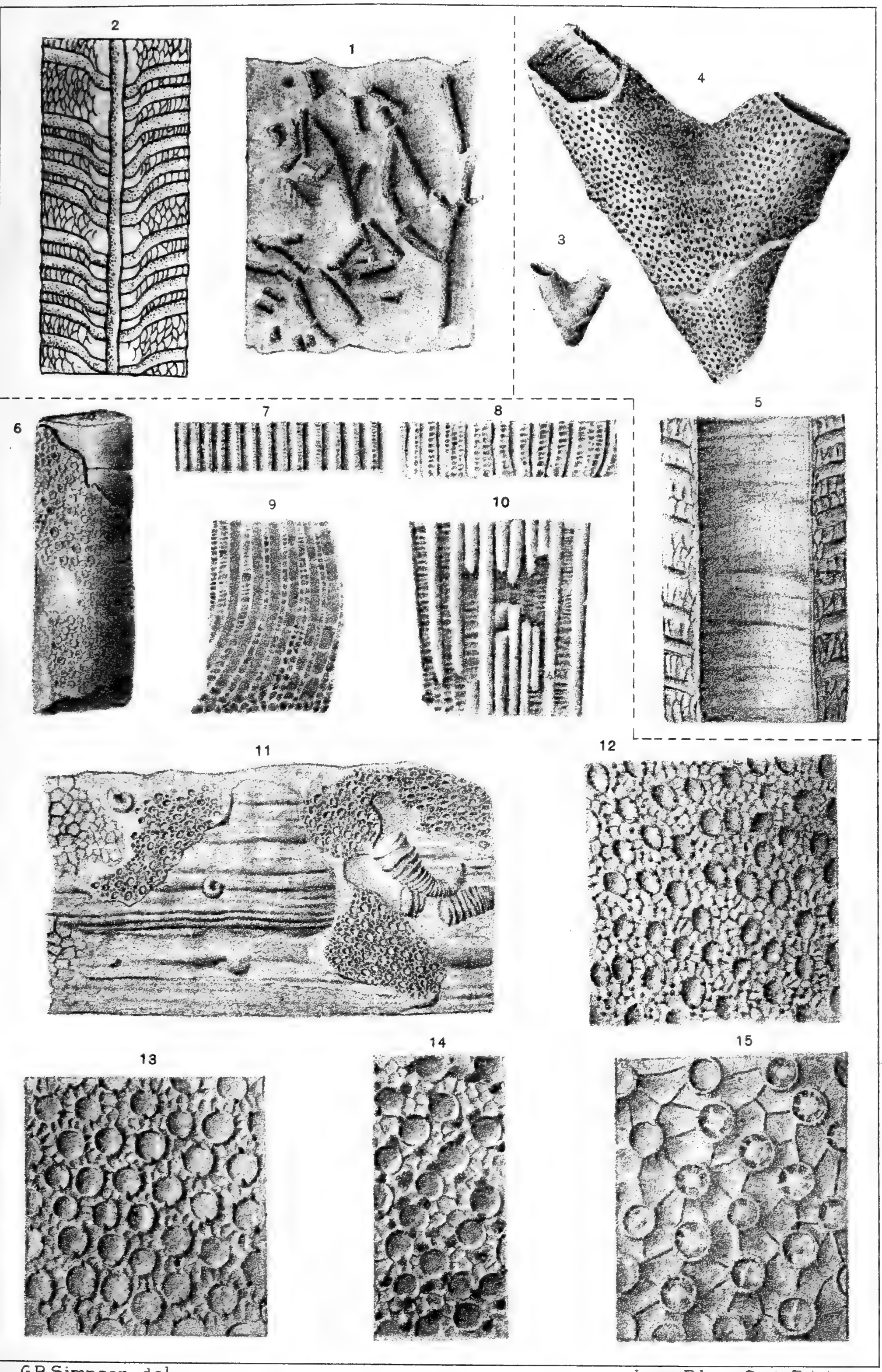
FISTULIPORINA MULTICULEATA, Hall.

Fig. 12. An enlargement showing the form and disposition of the cell apertures and the numerous nodes on the peristomes and walls of mesopores. x18.

Hamilton group. *Darien Center, N. Y.*

BRYOZOA.

Generic Illustrations.



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FISTULIPORINA CONFERTIPORA, Hall.

Fig. 13. An enlargement showing the circular cell apertures and nodose peristomes.
Lower Helderberg group. *Near Clarksville, N. Y.*

FISTULIPORINA PONDEROSA, Hall.

Fig. 14. An enlargement, showing the circular cell apertures, the mesopores and the prominent, conical, interapertural nodes. x18.
Lower Helderberg group. *Near Clarksville, N. Y.*

FISTULIPORINA SERRULATA, Hall.

Fig. 15. An enlargement, showing the cell apertures and mesopores, the serrulated peristomes and the characters of the opercula.
Hamilton group. *West Bloomfield, N. Y.*

PLATE XXII.

FISTULIPORIDRA.

(Page 606.)

FISTULIPORIDRA TESSELATA, Hall.

Fig. 1. An enlargement, showing the circular cell apertures and the polygonal vestibular areas. x18.

Fig. 2. An enlargement of a transverse section, showing the internal structure, the same as in FISTULIPORINA.

Fig. 3. An enlargement of a vertical section, showing the cell tubes and the intercellular structure. x6.

Hamilton group. *Western New York.*

FISTULICELLA.

(Page 606.)

FISTULICELLA PLANA, Hall.

Fig. 4. An enlargement of the surface. x12.

FISTULIPORELLA.

(Page 560.)

FISTULIPORELLA CONSTRICTA, Hall.

Fig. 5. An enlargement of the surface showing the denticulated cell apertures, the interapertural pores and the vestibular polygonal areas. x18.

Fig. 6. An enlargement of a tranverse section. x18.

Fig. 7. An enlargement of a vertical section, showing the cell tubes and the intercellular structure. x6.

Hamilton group. *Western New York.*

LICHENALIA.

(Page 559.)

The following figures are given to show the character of the cell apertures :

Figs. 8, 9. *Lichenalia colliculata.*

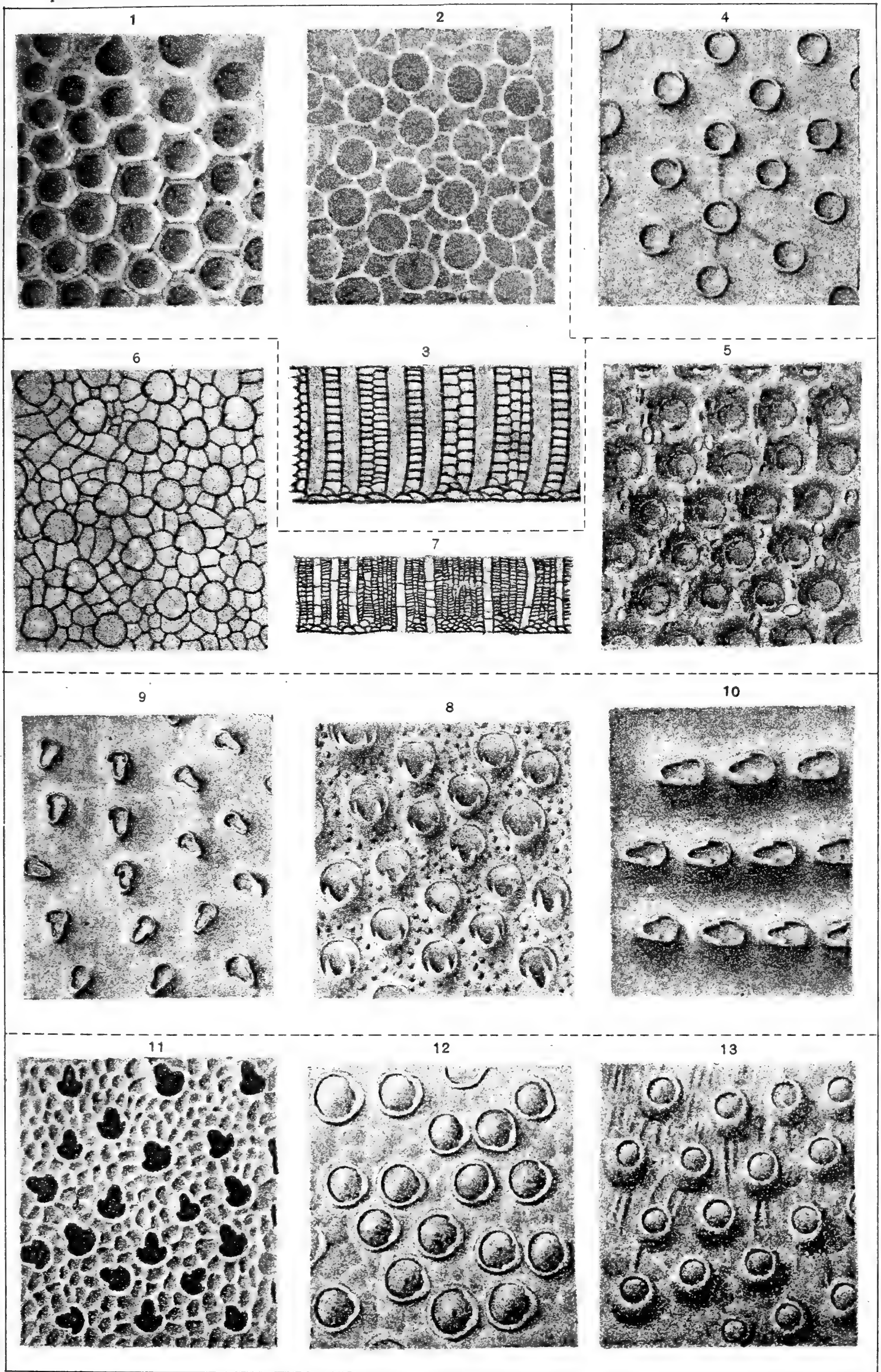
Fig. 10. *Lichenalia interaspera.*

Hamilton group. *New York.*

BRYOZOA.

Generic Illustrations.

Report State Geologist, 1894. Plate 22.



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FISTULIPORA.

(Page 559.)

The following figures are given to show the character of the cell apertures:

Fig. 11. *Fistulipora triloba.*
Lower Helderberg group. *New York.*

Fig. 12. *Fistulipora pustulosa.*

Fig. 13. *Fistulipora operculata.*
Hamilton group. *New York.*

PLATE XXIII.

LICHENALIA.

(Page 559.)

LICHENALIA SUBSTELLATA, Hall.

Fig. 1. A frond, natural size.
Upper Helderberg group. *Falls of the Ohio.*

LICHENALIA OVATA, Hall.

Fig. 2. A frond, natural size.
Upper Helderberg group. *Falls of the Ohio.*

LICHENALIA VESICULATA, Hall.

Fig. 3. A frond incrusting a Cyathophylloid coral, natural size.
Hamilton group. *Western New York.*

LICHENALIA SUBTRIGONA, Hall.

Fig. 4. An enlargement of a vertical section, showing the internal structure of the family FISTULIPORIDÆ. x6.
Hamilton group. *West Williams, Ontario.*

LICHENALIA LUNATA, Hall.

Fig. 5. An enlargement of the surface, showing the form and arrangement of the denticulated cell apertures and monticules. x6.

Fig. 6. A specimen fractured so as to show the internal structure. The pseudo-septa and tabulæ of the cell tubes showing very plainly. x6.
Upper Helderberg group. *Falls of the Ohio.*

LICHENOTRYPA.

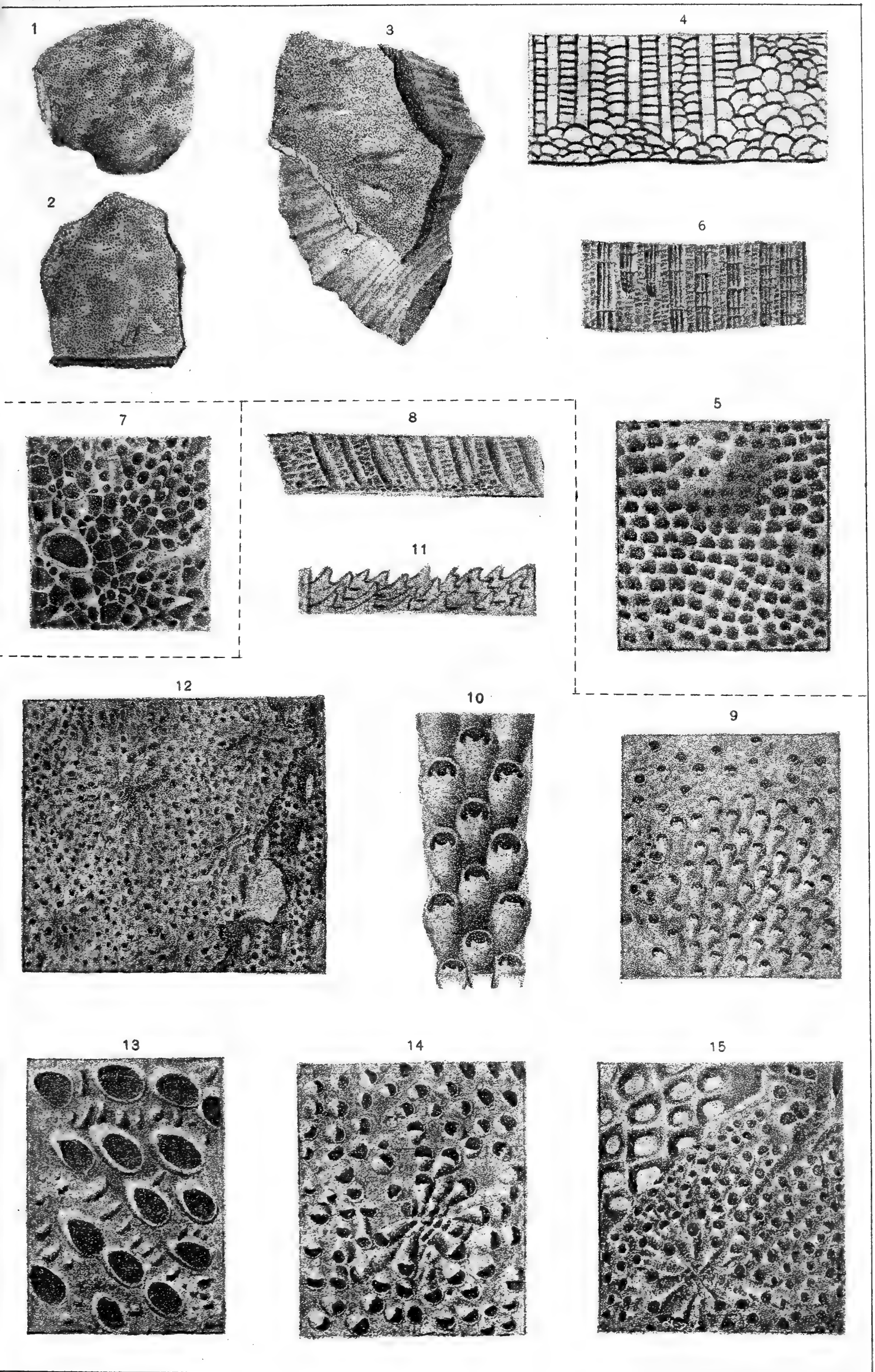
(Page 556.)

LICHENOTRYPA LONGISPINA, Hall.

Fig. 7. An enlargement, showing the form and arrangement of the cell apertures, the interapertural elevations and the spines at the angles. x6.
Upper Helderberg group. *Falls of the Ohio.*

BRYOZOA.

Generic Illustrations.



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PILEOTRYPA.

(Page 562.)

PILEOTRYPA CLIVULATA, Hall.

Fig. 8. An enlargement of a vertical section, showing the oblique cell tubes and intercellular vesicles.
Upper Helderberg group. *Falls of the Ohio.*

PILEOTRYPA PYRIFORMIS, Hall.

Fig. 9. An enlargement of the surface. x6.
Fig. 10. A still further enlargement, showing more distinctly the character of the cell apertures. x18.
Fig. 11. An oblique view of a portion of the surface. x6.
Upper Helderberg group. *Falls of the Ohio.*

PILEOTRYPA DENTICULATA, Hall.

Fig. 12. An enlargement of the surface, showing the form and arrangement of the cell apertures and the maculæ of larger cells. x6.
Upper Helderberg group. *Falls of the Ohio.*

PILEOTRYPA GRANIFERA, Hall.

Fig. 13. An enlargement of the surface. x18.
Upper Helderberg group. *Falls of the Ohio.*

PILEOTRYPA BISTRIATA, Hall.

Fig. 14. An enlargement of the surface, showing the form and arrangement of the cell apertures, and one of the maculæ. x6.
Upper Helderberg group. *Falls of the Ohio.*

PILEOTRYPA GEOMETRICA, Hall.

Fig. 15. An enlargement, showing the form and arrangement of the cell apertures and one of the maculæ. x6.
Upper Helderberg group. *Falls of the Ohio.*

PLATE XXIV.

ODONTOTRYPA.

(Page 561.)

ODONTOTRYPA ALVEATA, Hall.

Fig. 1. A frond, natural size, incrusting a FENESTELLA.

Fig. 2. An enlargement of a portion of the surface, showing the form and arrangement of the cell apertures and one of the maculæ. x6.

Fig. 3. A still further enlargement. x18.

Upper Helderberg group. *Falls of the Ohio.*

SELENOPORA.

(Page 557.)

SELENOPORA CIRCINCTA, Hall.

Fig. 4. A frond incrusting a FENESTELLA, natural size.

Fig. 5. An enlargement of the surface, showing the form and arrangement of the cell apertures and one of the maculæ. x6.

Fig. 6. A still further enlargement, showing more distinctly the denticulated cell apertures and the interapertural elevations. x18.

Upper Helderberg group. *Falls of the Ohio.*

SELENOPORA COMPLEXATA, Hall.

Fig. 7. An enlargement of the surface.

Upper Helderberg group. *Falls of the Ohio.*

GLOSSOTRYPA.

(Page 562.)

GLOSSOTRYPA PALIFORMIS, Hall.

Fig. 8. Fragment, natural size.

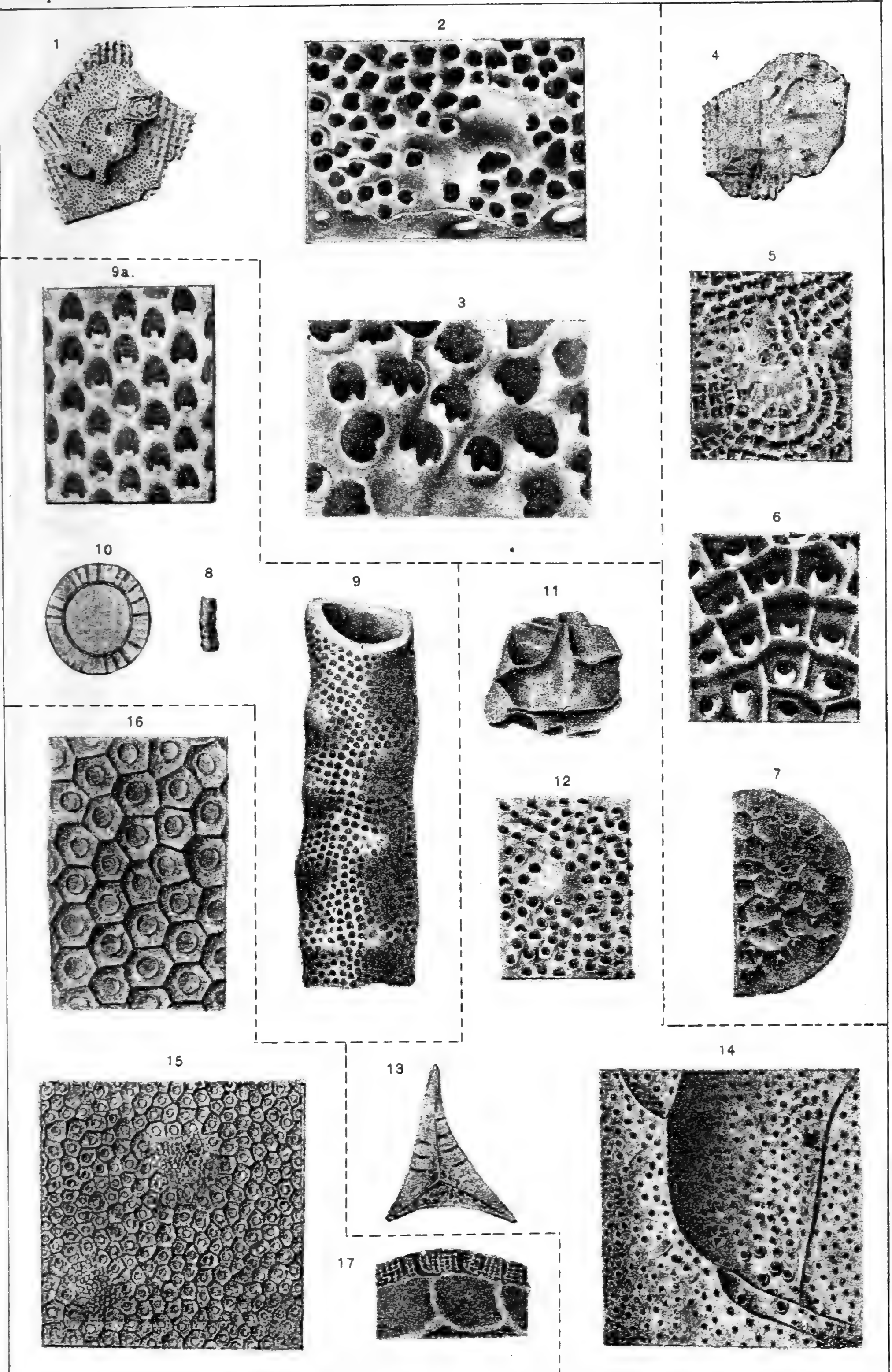
Fig. 9. The same. x6.

Fig. 10. Section showing cell tubes and thickness of zoarium. x6.

Upper Helderberg group. *Falls of the Ohio.*

BRYOZOA.

Generic Illustrations.



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PHRACTOPORA.

(Page 539.)

PHRACTOPORA CRISTATA, Hall.

Fig. 11. Zoarium, natural size.
Fig. 12. A portion of the surface. x6.
Fig. 13. Vertical section. x6.
Upper Helderberg group. *Falls of the Ohio.*

PHRACTOPORA LINEATA, Hall.

Fig. 14. Surface x6.
Hamilton group. *York, N. Y.*

FAVICELLA.

(Page 556.)

FAVICELLA INCLUSA, Hall.

Fig. 15. A portion of the surface. x6.
Fig. 16. A still further enlargement, showing more distinctly the surface characters. x18.
Fig. 17. A vertical section, showing internal structure. x6.
Hamilton group. *York, N. Y.*

PLATE XXV.

HERNODIA.

(Page 596.)

HERNODIA HUMIFUSA, Hall.

Fig. 1. A colony incrusting *Gomphoceras abruptum*, natural size.
Fig. 2. An enlargement from the preceding, showing more distinctly the form of the cells and their mode of growth. x6.
Hamilton group. *Cazenovia, N. Y.*

CYSTOPORA.

(Page 598.)

CYSTOPORA GENICULATA, Hall.

Fig. 3. A fragment, natural size.
Fig. 4. An enlargement, showing the ampulliform cell tubes and the constricted apertures. x6.
Fig. 5. A still further enlargement, showing more distinctly the features illustrated in fig. 4. x18.
Upper Helderberg group. *Manlius, N. Y.*

CLONOPORA.

(Page 598.)

CLONOPORA INCURVA, Hall.

Fig. 6. An enlargement, showing the form and arrangement of the cell tubes. x6.
Upper Helderberg group. *Manlius, N. Y.*

CLONOPORA SEMIREDUCTUS, Hall.

Fig. 7. An enlargement, showing the form of the cell tubes and their mode of growth. x6.
Upper Helderberg group. *Falls of the Ohio.*

REPTARIA.

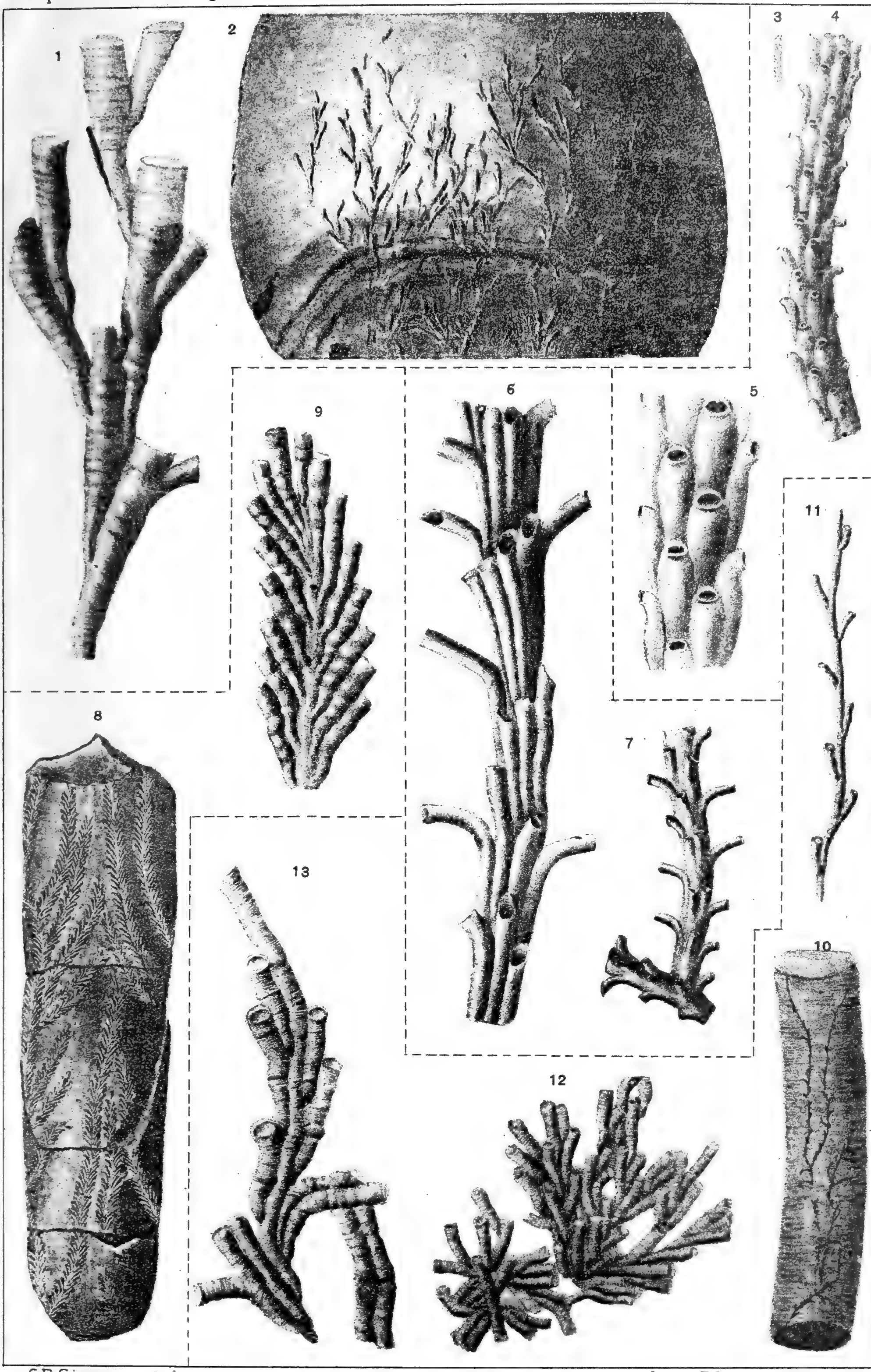
(Page 599.)

REPTARIA STOLONIFERA, Rolle.

Fig. 8. Colonies incrusting *Orthoceras constrictum*, natural size.
Fig. 9. An enlargement, showing more distinctly the form of the cells and their mode of growth. x6.
Hamilton group. *Cazenovia, N. Y.*

BRYOZOA.

Generic Illustrations.



HEDERELLA.

(Page 599.)

HEDERELLA CIRRHOSA, Hall.

Fig. 10. A colony, natural size.
Fig. 11. A portion of the preceding. x6.
Hamilton group. *York, N. Y.*

HEDERELLA CANADENSIS, Billings.

Fig. 12. An enlargement of a colony, showing an unusually compact growth. x6.
Fig. 13. An enlargement showing more distinctly the form of the cel apertures. x12.
Hamilton group. *New York.*